

Photo: Cora Cook

Native and Non-Native Fishes in the Goose Lake Basin, Oregon: Comprehensive Findings from the 2022-2024 Field Seasons

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For:
Oregon Department of Fish and Wildlife, U.S. Fish and Wildlife Service, Lake County Umbrella Watershed Council, & other interested stakeholders

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Executive Summary

- We comprehensively sampled a total of 42 unique sites from 2022 to 2024, all of which were previously sampled by ODFW in 2007.
    - Includes 17 sites in Thomas-Bauers, 14 sites in Drews, 6 sites in Dry, and 5 sites in Eastside watersheds.
    - At each site, we electrofished, recorded habitat data, and downloaded water temperature data. In 2024, we also collected diet samples from 88 redband trout at 23 sites, 30 trout otoliths, and macroinvertebrates from 21 sites, which are still being processed.
- We collected eDNA across study years to expand fish data coverage and compare eDNA with traditional electrofishing. eDNA was sampled at electrofishing sites after fish sampling in 2022 and concurrently in 2023. Additionally, we sampled a series of "eDNA-only" sites, including 35 in 2022, 56 in 2023, and 10 in 2024. Initial findings from 2023 eDNA samples show high fidelity with electrofishing results with some additional detections of native fish species.
- Fish community trends from 2007 and 2022 to 2024:
    - Lower elevation sites in the Thomas Creek sub-basin contained speckled dace, pit roach, Tui chub, fathead minnow, and lamprey.
    - Higher elevation sites in the Thomas Creek sub-basin contained mostly specked dace in the Thomas Creek tributaries and redband trout in the Cottonwood Creek tributaries.
    - Burned sites in the Thomas Creek sub-basin contained mostly redband trout and lamprey.
    - Low elevation Drews Creek sites mostly supported specked dace, and communities varied widely between 2007, 2022, 2023, and 2024.
    - High elevation Drews Creek sites mostly contained redband trout and lamprey.
    - Dry Creek had the highest species diversity of any stratum and supported a wide variety of redband trout, lamprey, and minnow species.
    - We only observed redband trout at the Eastside sites in the Warner Mountains.
- We finished hand digitizing Basin watercourses, and a stream spatial network object was created from the modified data.
- We successfully compiled and archived spatial data from multiple publicly available sources, including NAIP and Landsat imagery, DEMs, and various classification maps. Key datasets include hydrologic shapefiles, land cover classifications, and climate model outputs such as NorWEST stream temperature predictions. Additionally, we have quantified surface water availability trends for key reservoirs using remote sensing metrics.
- We are continuing to make progress towards completing several tasks, including assessing land use and vegetation cover changes, evaluating hydrogeomorphic changes, and analyzing thermal regimes and desiccation risk across sites. We are also quantifying the frequency and duration of lethal and sub-lethal temperature events to identify potential thermal refugia. Additionally, we are comparing fish abundance and distribution data from 2022–2024 to 2007 data, examining relationships between fish communities and environmental drivers, and evaluating the effects of wildfire by comparing thermal regimes and fish communities at burned and unburned sites in the Thomas Creek watershed.

1. Background

The Goose Lake Basin is one of several Great Basin systems that has been heavily impacted by drought and other environmental stressors in recent years. The Basin is an endorheic desert valley that runs north-to-south on the border of Oregon and California. Four major watersheds (HUC10; Thomas Creek, Drews Creek, Dry Creek, and Willow Creek) and many smaller tributaries drain into Goose Lake, a slightly alkaline system that has historically dried up during severe drought years and drains into the Pit River to the south during very high flow years. The Goose Lake Basin is a region of concern for state and federal agencies because it is home to endemic fish species like the Goose Lake redband trout (adfluvial and fluvial life history strategies), Goose Lake lamprey, Goose Lake tui chub, and Goose Lake sucker. These endemics coexist with a variety of native and non-native species, including the recently delisted Modoc sucker. Consequently, the Thomas Creek-Goose Lake, Dry Valley, and Warner Mountains regions have been listed as "Conservation Opportunity Areas" in the Oregon Conservation Strategy—the overarching state strategy for conserving fish and wildlife. The Conservation Strategy, along with several local and regional planning documents, has explicitly identified the maintenance, enhancement, and restoration of riparian and wetland habitats in the Goose Lake Basin as a priority conservation need.

Sampling efforts conducted by the U.S. Geological Survey (USGS) and Oregon State University (OSU) in 2022 marked the first year that comprehensive data were collected in the Goose Lake Basin in more than a decade. Prior to this, the Basin was opportunistically sampled for redband trout and other native species by the Oregon and California Departments of Fish and Wildlife, and the most recent comprehensive fish sampling efforts were conducted by Oregon Department of Fish and Wildlife (ODFW) in 2007. Water quality data for the Basin was also sparse because USGS stream gauges were removed in the 1970s and 80s (although four Oregon Water Resources Department gauges are still operational on Cottonwood and Drews Creeks). We rectified this data gap by installing more than 30 water temperature loggers throughout the Basin during the 2022 field season, which can also be used to track dewatering events. Groups like the Lake County Umbrella Watershed Council, Lakeview Soil and Water Conservation District, and Goose Lake Fishes Working Group have conducted or are planning to conduct several restoration and fish passage projects. Monitoring data from 2022–2024 will directly support these agencies' fish and habitat conservation efforts as well as conservation efforts led by ODFW and the U.S. Fish and Wildlife Service (USFWS). Here we present comprehensive monitoring data from our 2022, 2023, and 2024 field seasons, including fish abundance and water quality trends.

2. Study Objectives

The goal of this project is to collect up-to-date, comprehensive monitoring data for the Oregon portion of the Goose Lake Basin. Information on fish habitat use and habitat quality will allow our partners and stakeholders to make informed habitat maintenance, enhancement, and restoration decisions for a productive and resilient watershed. Specific objectives (as funded by the Oregon Watershed Enhancement Board; OWEB) include:

1) Assess current and historical habitat conditions in the Goose Lake Basin using remotely sensed data
2) Monitor stream temperature for watercourses in the Thomas Creek, Drews Creek, Dry Creek, and Willow Creek sub-basins
3) Obtain contemporary information on native and non-native fish abundance, distribution, and habitat use
4) Obtain baseline data to monitor the effects of the Cougar Peak/Patton Meadow wildfires on fish and their habitat

Table 2-1 Overview of progress to completing study objectives and summary of initial findings

Task	Status
Objective 1: Assess current and historical habitat conditions in the Goose Lake Basin using remotely sensed data	
1-1: Compile a database of multi-band satellite and aerial imagery for the Goose Lake Basin.	COMPLETE: We have obtained multi-band NAIP and Landsat imagery for the Goose Lake Basin as well as LIDAR and other relevant remotely sensed data sets.
1-2: Update existing spatial data for watercourses, wetlands, lakes, and other waterbodies.	COMPLETE: We have validated and modified the NHDPlus hydrography dataset for the Basin as needed. Node that more accurate NHDPlus HR data are now available for the Basin.
1-3: Quantify land use change through time for the Thomas Creek, Drews Creek, Dry Creek, and Willow Creek sub-basins.	IN PROGRESS: We have obtained a time series of RCMAP imagery to quantify land use change through time.
1-4: Quantify change in vegetation cover and density for the Thomas Creek, Drews Creek, Dry Creek, and Willow Creek sub-basins and stream-adjacent habitats.	IN PROGRESS: See above. We have also developed a habitat classification procedure using NAIP imagery to classify vegetation types and measure canopy cover over monitored stream segments.
1-5: Evaluate changes in hydrogeomorphology for important hydrologic features.	IN PROGRESS: We are using Landsat imagery to assess and quantify water levels of major lakes and reservoirs in the Goose Lake Basin through time.
Objective 2: Monitor stream temperature for watercourses in the Thomas Creek, Drews Creek, Dry Creek, and Willow Creek sub-basins	
2-1: Write a sampling and analysis plan (SAP) to outline how water quality data will be collected, QA/QCed, analyzed, and shared according to ODEQ water quality monitoring and reporting requirements.	COMPLETE (This is an OWEB funding requirement): The SAP is completed and has been approved by Oregon DEQ.
2-2: Install a network of water temperature loggers at high- and low-elevation sites in each sub-basin.	COMPLETE: HOBO OnSet® continuous temperature loggers have been installed in 35 stream segments (plus an additional air temperature monitoring location). Lost and malfunctioning loggers have been replaced as needed, and duplicate deployment beginning in fall 2024 will allow for data redundancy and help prevent data loss.

2-3: Compare thermal regimes and desiccation probability among sites, and relate thermal regimes to relevant environmental variables.	IN PROGRESS: We have assessed probability of stream drying for each site over the 3-year study period.
2-4: Quantify frequency and duration of lethal and sub-lethal temperature events at each site, and use established temperature-habitat relationships to identify potential thermal refugia.	IN PROGRESS: We have assessed data from the 2023 and 2024 water years in relation to optimal thermal ranges for redband trout.
Objective 3: Obtain contemporary information on native and non-native fish abundance, distribution, and habitat use	
3-1: Conduct electrofishing and eDNA sampling efforts at high- and low-elevation sites in each sub-basin.	COMPLETE: In 2022, a total of 36 sites were sampled using electrofishing and 35 additional sites were sampled for eDNA. In 2023, 33 sites were sampled using electrofishing and 56 additional sites were sampled for eDNA. In 2024, 33 sites were sampled using electrofishing and 10 additional sites were sampled for eDNA.
3-2: Compare findings from electrofishing and eDNA sampling to determine effectiveness of eDNA metabarcoding for monitoring fish distribution and relative abundance in the Goose Lake Basin and other Great Basin systems.	COMPLETE: We have compared findings from 2022 and 2023 electrofishing efforts and eDNA samples using two eDNA primers: MiFish and Meta. Initial findings suggest that eDNA is more sensitive than electrofishing for detecting the presence of local fish species. There are subtle differences in the primers' ability to detect certain species. For example, the Meta primer is better at detecting lamprey, while MiFish appears to be more sensitive for some minnows.
3-3: Compare fish abundance and distribution data from 2022–2024 to 2007 data.	IN PROGRESS: An initial comparison of 2007 and 2022–2024 monitoring data indicates that communities are largely similar, but that observed abundances of some species (e.g., redband trout) have declined substantially.
3-4: Analyze fish abundance, distribution, and community structure, and their relationship to environmental drivers.	IN PROGRESS: Initial findings suggest a strong elevational gradient, whereby invasive species tend to occur more at lower elevation and lower gradient sites, while redband trout and lamprey appear at higher elevation and higher gradient sites.
Objective 4: Obtain baseline data to monitor the effects of the Cougar Peak/Patton Meadow wildfires on fish and their habitat	
4-1: Examine post-fire vegetation change using remotely sensed imagery for major fires that have occurred over the past few decades, including the Cougar Peak/Patton Meadow wildfires.	IN PROGRESS: We have obtained a time series of RCMAP imagery to quantify vegetation change through time.
4-2: Compare thermal regimes among burned and unburned sites in the Thomas Creek watershed using continuous water logger data.	IN PROGRESS: We have started analyzing three years of water temperature data from continuous data loggers.

4-3: Compare fish abundance, distribution, and community structure among burned and unburned sites in the Thomas Creek watershed.	IN PROGRESS: Fish communities appear to differ between burned and unburned areas in the Thomas Creek watershed, but it is as of yet unclear whether this is driven by changes in habitat due to fire or drought. Monitoring data from 2023 (a wetter year) and quantifications of habitat change will help us elucidate these relationships.

3. Methods and Preliminary Findings

3.1 Study area and sampling site selection

Sampling efforts took place in the Oregon portion of the Goose Lake Basin. In 2007, ODFW visited 144 sites over 655 stream km of available summer habitat (Fig. 3-1). Roughly 330 points were generated using a spatially-balanced, Generalized Random Tessellation Stratified design (GRTS), and of those points, the 144 sampled sites were selected based on accessibility, site characteristics (e.g., depth, temperature), and time limitations.

During the 2022 field season, we visited 36 sites that were randomly selected from sites sampled in 2007. These sites were stratified by HUC10, elevation, and burn status (Drews-Low, Drews-High, Thomas-Low, Thomas-High, Thomas-Burned, Dry, and Eastside [Willow Creek]). Here we collected a full suite of monitoring data, including electrofishing, eDNA samples, and water temperature loggers. In 2023, we dropped 6 sites due to a lack of fish detections, spatial overlap, or accessibility limitations (Drews 09, Drews 25, Drews 26, Dry 21, Nongame 49, West Goose 28). Two sites were not sampled because we were unable to obtain landowner permissions (West 03, West 13). Five new sites were resampled from the 2007 sampling regime (Drews 12, Drews 21, Dry 05, Nongame 17, Nongame 65) for a total of 33 monitoring sites in 2023 (Fig. 3-1). Water loggers were installed at the newly added sites throughout the summer. In 2024, we collected electrofishing, and water temperature logger data. We dropped 3 sites due to lack of fish detections or accessibility limitations (West 03, West 13, and Nongame 23). One new site was resampled from the 2007 sampling regime (Thomas-Bauers 09) for a total of 33 monitoring sites in 2024 (Fig. 3-1).

We also used GRTS to generate a suite of about 250 "eDNA-only" sites. We collected eDNA samples at 35 of these sites in 2022, 56 of them in 2023, and 10 of them in 2024. We used GPS to log locations that were dry upon arrival or were otherwise inaccessible.

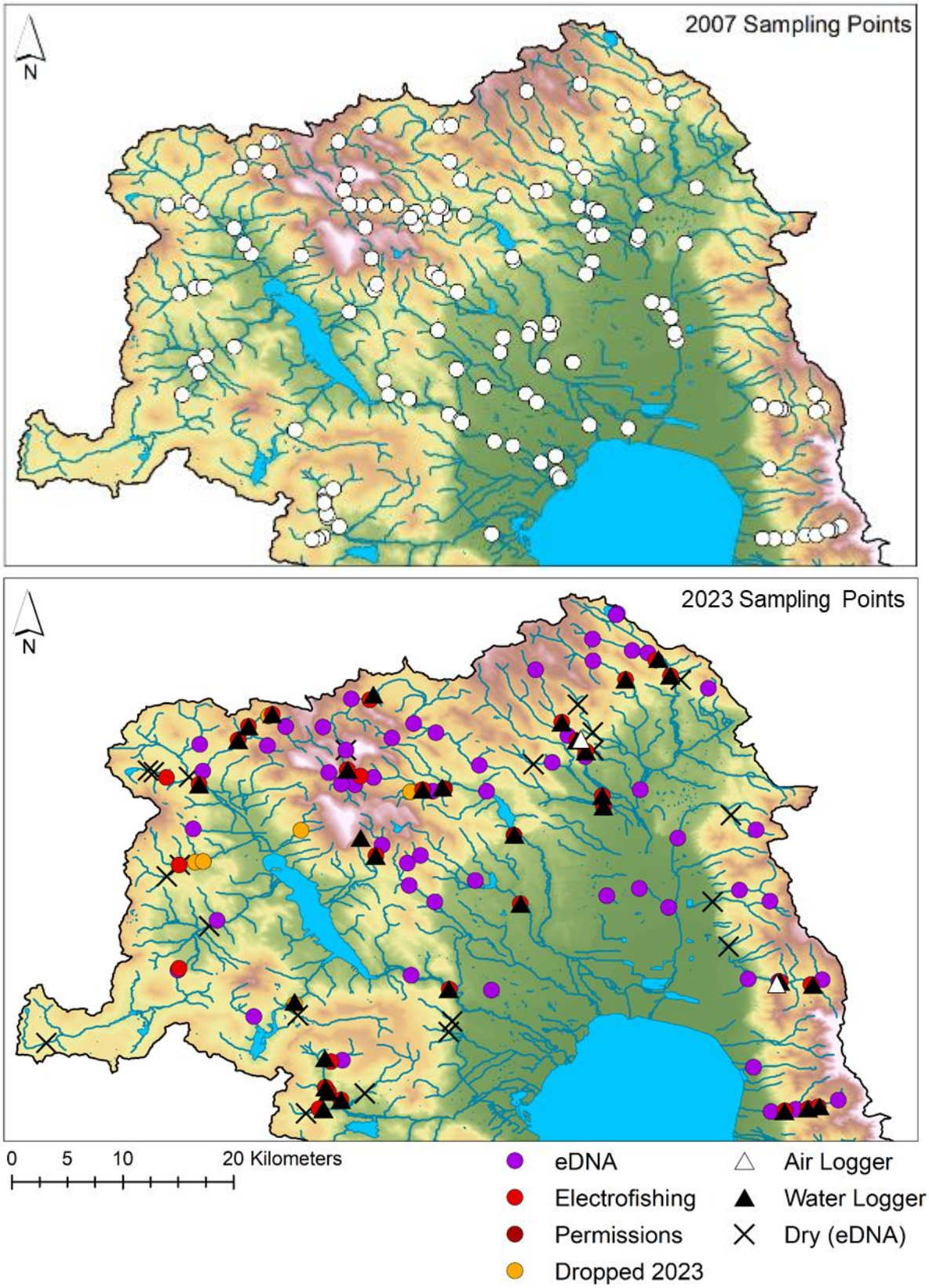

Figure 3-1 Sampling sites from 2007 ODFW field efforts (top) and 2023 field efforts (bottom)—which represent the most intensive sampling year.

3.2 Objective 1: Assess current and historical habitat conditions in the Goose Lake Basin using remotely sensed data

Task 1-1: Compile a database of remotely sensed data	Status: Complete
Task 1-2: Update existing spatial data for watercourses and waterbodies	Status: Complete
Task 1-3: Quantify land use change	Status: In Progress
Task 1-4: Quantify change in vegetation cover and density	Status: In Progress
Task 1-5: Evaluate hydrogeomorphologic change	Status: In Progress

Methods: We are using publicly available spatial and remote sensing data to accomplish Tasks 1-1 through 1-5 including National Agriculture Imagery Program (NAIP) imagery, Landsat imagery, and Digital Elevation Models (DEMs). Data from a variety of other freely available sources have also been included (e.g., National Land Cover Database [NLCD], National Hydrography Dataset [NHD], Oregon Department of Transportation, National Interagency Fire Center). We will conduct a change analysis of land use and vegetation cover data. Analyses will be conducted at the Basin scale or for stream-adjacent areas within a 100-m buffer of identified watercourses. To evaluate land use change (Task 1-3), we will use NLCD spatial datasets. To evaluate vegetation change (Task 1-4) and hydrogeomorphologic change (Tasks 1-2, 1-5), we will use NAIP imagery, Landsat imagery, and a 10-meter DEM. Parameters of interest may include: normalized difference vegetation index (NDVI), normalized difference water index (NDWI), elevation, slope, and soil and vegetation burn intensity.

To quantify hydrogeomorphologic change (Task 1-5), we have created updated shapefiles of watercourses and waterbodies in the Basin based on NHDPlus high resolution hydrologic data from USGS. NHDPlus data were hand-corrected to create a new, more accurate record of hydrologic features in the Basin. We accessed Landsat imagery in Google Earth Engine to quantify surface water availability through time for Goose Lake, Drews Reservoir, and Cottonwood Reservoir using two metrics: NDWI and Dynamic Surface Water Extent (DSWE).

Preliminary Findings: Thus far, we have successfully compiled spatial data from a variety of publicly-available sources. Data have been actively archived in a database similar to what's shown in Table 3-1, including information on the data type, date of collection, file type, file name and extension, file size, resolution (for raster data), projection/coordinate system, data source, website of origin, and relevant notes. Important raster data files include a 13 arc-second (approximately 10 m) USGS DEM with associated elevation, slope, hillshade, and aspect data, NAIP imagery, Landsat imagery, NLCD classification maps, and Oregon vegetation classification maps. Important shapefiles include state lines and municipal boundaries, watershed boundaries, NHD hydrology data, transportation networks from Oregon Department of Transportation, historical fire boundaries (NIFC), land ownership, restoration sites (OWEB), existing stream barriers (ODFW), and sampling locations. We have also compiled model output from climate simulations like NorWEST, which includes spatial stream networks for South-Central Oregon.

Table 3-1 Example of file database used to track spatial data for the Goose Lake Basin.

Category	Date	Spatial Layer	File Name	File Type	File Size
Aspect	3/13/2019	Raster	aspect	grid	251 MB
Barriers	9/10/2020	Geodatabase	Fish_Passage_Barriers	*.gdb	27 MB
Barriers	9/10/2020	Geodatabase	Priority_Barriers	*.gdb	6.12 MB
Barriers	9/10/2020	Shapefile	ODFW_Barriers_2020	*.shp	5.5 MB
Barriers	9/10/2020	Shapefile	ODFW_Barriers_Rem_2020	*.shp	5.5 MB
Barriers	9/10/2020	Shapefile	ODFW_Priority_2020	*.shp	5.5 MB
Boundaries	7/25/2022	Geodatabase	GovernmentUnits_National_GDB	*.gdb	6.30 GB
Boundaries	8/12/2022	Geodatabase	GOVTUNIT_California_State_GDB	*.gdb	137 MB
Boundaries	8/12/2022	Geodatabase	GOVTUNIT_Oregon_State_GDB	*.gdb	91 MB
DEM	3/13/2019	Raster	usgs_dem_a1	grid	891 MB
DEM	3/13/2019	Raster	usgs_dem_gl	grid	245 MB
Fire	2022	Shapefile	WFIGS_2020_2021	*.shp	96.1 MB
Fire	2022	Shapefile	Fire_2020_2021_18020001	*.shp	1.90 MB
Fire	2022	Shapefile	Historical_Fires_18020001	*.shp	1.50 MB
Hillshade	3/13/2019	Raster	Hillshade_45	grid	245 MB
Hydrology	6/9/2022	Shapefile(s)	NHD_18020001_HU8	folder	45 MB
Hydrology	9/9/2019	Geodatabase	NHDPLUS_H_1802_HU4_GDB	*.gdb	1.92 GB
…					

For NAIP 4-band ortho imagery, we downloaded 76 total tiles that encompass the Oregon portion of the Goose Lake HUC8 that were combined into a single mosaiced image for 2020, 2022, and 2024. We plan to do the same for the years 2005, 2009, 2011, 2012, 2014, 2016, and 2017. For Landsat 8/9 multi-band imagery, we have downloaded Collection 2 Level 2 data (bands 1-7, 10) for 1984–2024 as well as Collection 2 Level 3 DSWE products for 2020–2024 (Fig. 3-2). Products were only downloaded when cloud cover was light-to-absent (less than 25%). Bands were composited into a single, multi-band image.

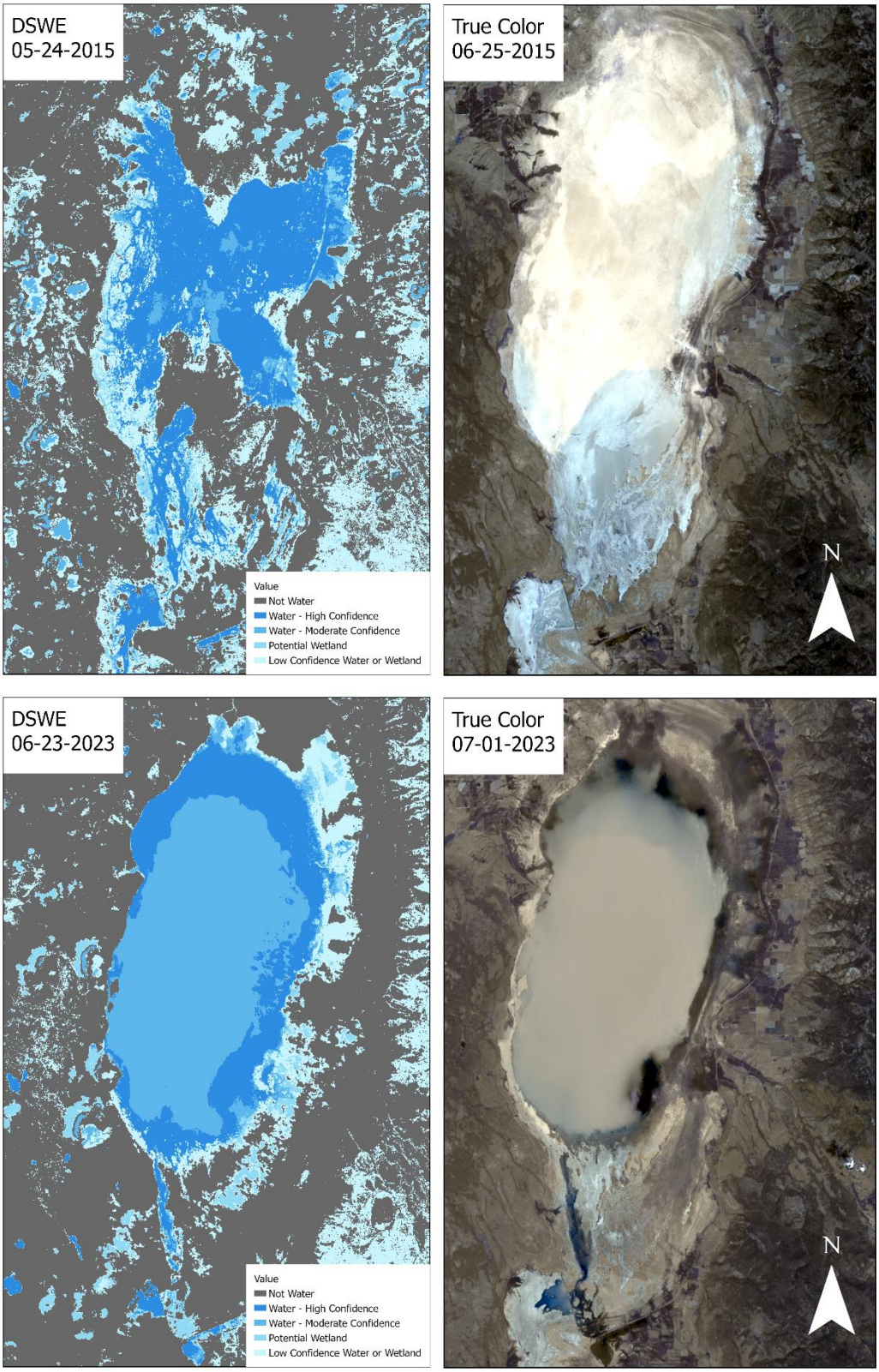

Figure 3-2 Landsat 8 multi-band (RGB) imagery and Dynamic Surface Water Extent (DSWE) products showing differences in the surface area of Goose Lake between 2015 and 2023.

Hand digitization of Basin watercourses was initiated by a GIS intern in Spring 2022 and completed by graduate student Jacob Dickey in 2023 (Fig. 3-3). A stream spatial network object was created from the modified data for future spatial analysis of water quality and fish distributions. Improvements to the process will continue through the duration of the project. Conducting this procedure at set intervals across multiple decades of available data will allow us to determine how stream and lake morphology has shifted through time for major watercourses. Of particular interest is Goose Lake itself, which has watered and dewatered numerous times in recent history. Using Landsat NDWI and DSWE, we generated an automated process in Google Earth Engine to calculate lake area through time (Fig. 3-4), which will provide us with the opportunity to determine how its probability of dewatering is related to climactic variables such as air temperature, precipitation, and snowfall. A similar digitization procedure was outlined in Moore 2016 for nearby Lake Abert (https://doi.org/10.1016/j.scitotenv.2016.02.161). In addition to water use and recreational activities, this information is highly valuable for the management of redband trout, which exhibits both adfluvial (lake rearing) and fluvial (stream rearing) life histories in the Basin.

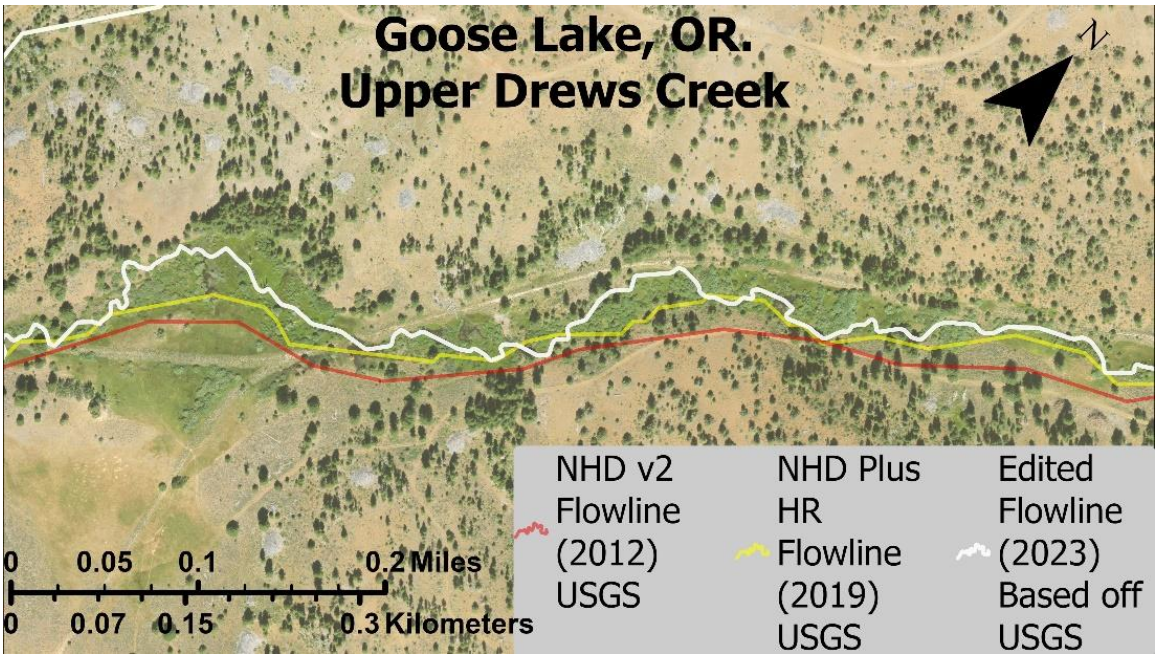

Figure 3-3 Section of upper Drews Creek with original NHD flow lines (red & yellow) and newly hand-digitized river segment (white).



Figure 3-4 Annual maximum and minimum surface area (km^2) through time for Goose Lake, Drews Reservoir, and Cottonwood Reservoir. Note that high turbidity in Goose Lake limited the utility of NDWI for estimating surface water availability in some years (1992–1997, 2011–2023).

3.3 Objective 2: Monitor stream temperature for watercourses in the Thomas Creek, Drews Creek, Dry Creek, and Willow Creek sub-basins

Task 2-1: Write SAP for water quality data	Status: Complete
Task 2-2: Install and maintain a network of water temperature loggers	Status: Complete
Task 2-3: Compare thermal regimes among sites	Status: In Progress
Task 2-4: Identify thermal refugia for cold-water fishes	Status: In Progress

Methods: We installed Hobo Onset® water and air temperature loggers at each site after concluding eDNA and electrofishing data collection to minimize eDNA contamination and disturbance to fish. All devices were programmed for one-hour logging intervals prior to deployment. Air loggers were anchored using 36-inch cable ties and water loggers were anchored using DUCKBILL® Earth Anchors Model 68. For water loggers, location for the anchor was chosen based upon adequate security, depth, and mixing. A sledgehammer and driving rod were used to drive the anchor as deep as possible into the substrate, leaving at least six inches of cable protruding. After reaching the desired secure depth, the driving rod was removed and the cable was pulled with enough pressure to rotate and anchor the duckbill into the substrate. The logger was inserted into a PVC solar shield, two 11-inch zip ties were threaded through the solar shield and data logger, and two zip ties were used to secure the solar shield and data logger to the anchor using the provided loop. Multiple photos were taken of the data logger location. A crew member stood next to the data logger in each photo for scale and reference, with unique features captured in the photo near the data logger (such as large boulders or snags). For air temperature loggers, the data logger was inserted into a PVC solar shield, two 11-inch zip ties were threaded through the solar shield and data logger, and two 36-inch cable ties were used to secure the solar shield and data logger to a tree near the bank of the study site. Reference photos were captured as described above.

Continuous water temperature data will be analyzed as a decomposed time series using univariate and multivariate statistical analyses. Variables of interest will include factors related to the magnitude, frequency, and variability of thermal events throughout the year. The amount of time water temperatures exceed thermal tolerance limits for cold-water fishes is of particular interest.

Preliminary Findings: HOBO OnSet® continuous temperature loggers were installed in 35 stream segments (plus 3 additional air temperature monitoring locations) and were successfully downloaded in August/October 2023 and October 2024 for a full range of dates between 6/2022 and 10/2024 for most sites. We did experience some data loss, with 9/38 loggers lost or compromised between deployment in 2022 and download in 2023 (Dry 09, Nongame 23, Thomas 12, Thomas 21, Thomas 26, West 03, West 13, West 27) and 6/36 loggers lost or compromised in 2024 (Eastside 14, Eastside 27, Drews 18, Drews 22, Thomas 23, and West 17). Lost and malfunctioning loggers were replaced, and duplicate deployment beginning in fall 2023 will allow for data redundancy and help prevent data loss.

We compared air and water temperature logger data to determine when a site dewatered, where water temperature values within 90% of daily recorded air temperature maximums indicated that a

site had likely gone dry or was in the process of drying out. Eight of the 37 water loggers for which high quality data were available indicated that dewatering occurred (Fig. 3-5). All of these were in low elevation or Dry Creek drainage sites: Nongame 83, Nongame 17, Drews 09, Drews 18, Drews 19, Dry 09, Dry 11, and Dry 21. For the five sites that went dry in 2022, it appeared that streamflow recommenced during the fall rains in November or December. For the two sites that went dry in 2023, loss of streamflow became apparent during July and resumed in September. Four sites went dry starting in July 2024: Nongame 17, Drews 19, Dry 09, and Dry 11.

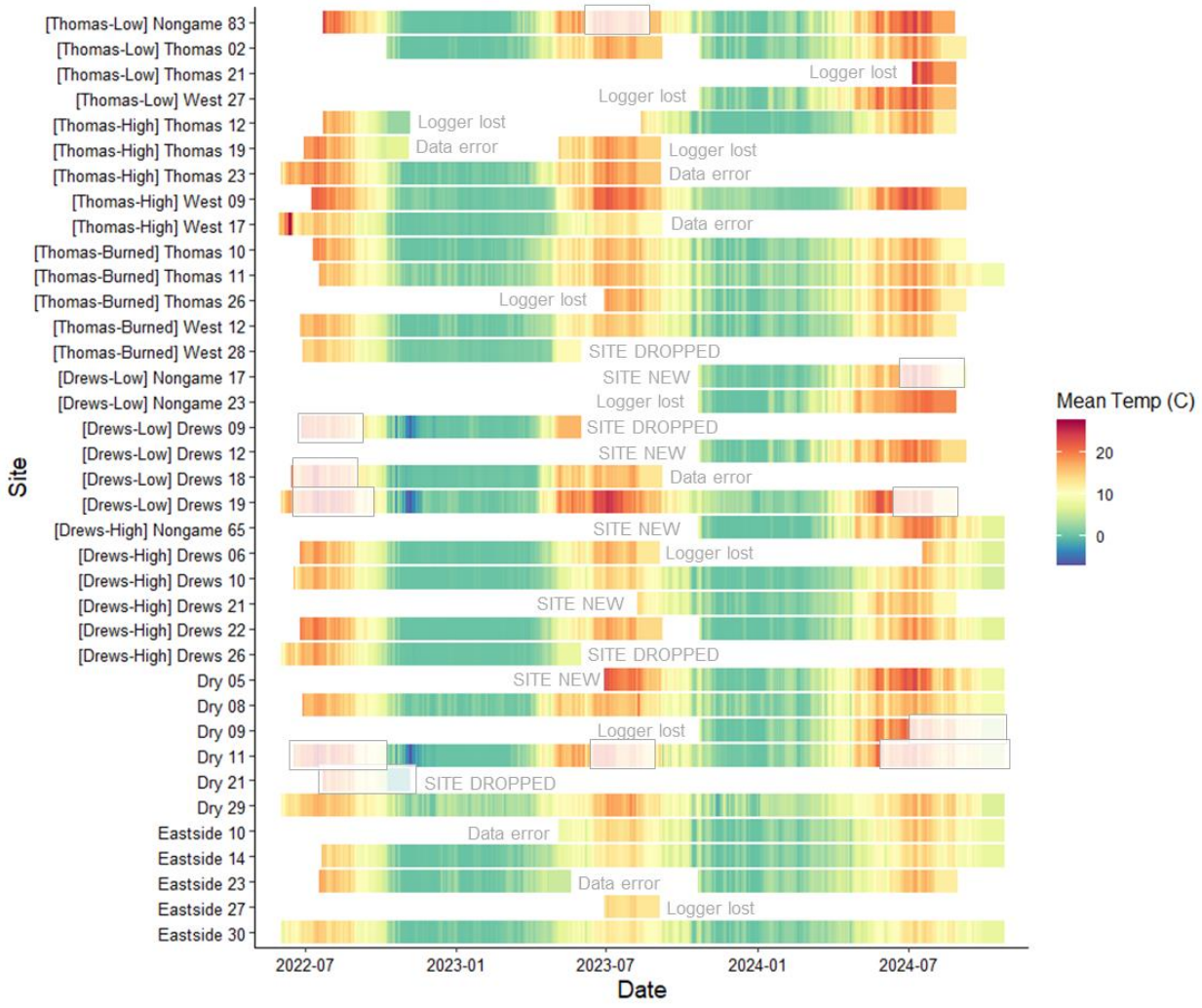

Figure 3-5 Water temperatures through time in the Goose Lake Basin. Periods of drying are indicated by the faded boxes.

Mean daily water temperatures across all sites monitored in the Basin ranged from freezing (0°C) in November through March to an average high of 18.07 ± 3.23°C on July 17, 2023. Temperature trends were variable among sites (Table 3-2). Low elevation sites in the Thomas Creek sub-basin were generally 1–4°C hotter than sites in the Thomas-High or Thomas-Burned strata, even though in some cases these sites were only 50–100 m different in elevation. Water temperatures in burned and unburned portions of the Thomas Creek sub-basin did not appear to differ substantially for the time period monitored.

We observed a similar trend in the Drews Creek sub-basin to an even more substantial degree. Sites in the Drews-Low stratum were the most likely to dewater, and in some cases were as much as 7–8°C hotter than sites in the Drews-High stratum. Dry Creek sites had similar temperature profiles and a similar likelihood of dewatering to Drews-Low sites. Conversely, Eastside (Willow Creek) sites maintained the coolest temperatures throughout the year. These sites exhibited temperatures of 12–14°C at the peak of summer when sites of similar elevation in the Thomas and Drews watersheds were averaging 16°C or greater. Lingering snowpack in the Warner Mountains likely modulated summer water temperatures, even later in the season.

Table 3-2 Average monthly water temperatures by stratum as recorded by continuous water temperature loggers. The "N" term refers to the number of loggers that were operational and not in dry stretches of stream.

	Thomas-Low		**Thomas-High**		**Thomas-Burned**	
Month	**Mean ± SD**	**N**	**Mean ± SD**	**N**	**Mean ± SD**	**N**
August 2022	20.09 ± 1.47	1	17.02 ± 1.98	5	15.57 ± 1.41	4
September 2022	14.59 ± 1.58	1	12.6 ± 2.56	5	11.8 ± 1.97	4
October 2022	7.52 ± 3.55	2	7.25 ± 2.47	5	6.97 ± 2.43	4
November 2022	0.65 ± 1.22	2	0.88 ± 1.15	3	1.02 ± 1.22	4
December 2022	-0.03 ± 0.03	2	0.73 ± 0.59	3	0.86 ± 0.89	4
January 2023	0.1 ± 0.34	2	0.61 ± 0.46	3	0.98 ± 0.89	4
February 2023	-0.04 ± 0.18	2	0.53 ± 0.33	3	0.84 ± 0.69	4
March 2023	0.64 ± 0.92	2	0.86 ± 0.4	3	1.25 ± 0.82	4
April 2023	4.4 ± 2.36	2	1.93 ± 2.02	3	2.86 ± 1.47	4
May 2023	11.94 ± 3.67	2	8.52 ± 4.24	3	8.38 ± 3.59	4
June 2023	14.87 ± 2.35	2	13.14 ± 2.72	4	12.66 ± 1.45	3
July 2023	17.09 ± 0.73	1	17.47 ± 3.1	4	16.15 ± 1.04	4
August 2023	18.01 ± 2.33	2	16.42 ± 2.72	4	15.28 ± 1.4	4
September 2023	13.73 ± 2.3	1	11.88 ± 2.8	5	11.02 ± 1.81	4
October 2023	8.62 ± 3.06	1	6.77 ± 3.03	2	7.29 ± 2.83	4
November 2023	3.17 ± 2.25	3	2.31 ± 1.73	2	3.21 ± 2.22	4
December 2023	1.46 ± 1.19	3	1.65 ± 1.6	2	1.87 ± 1.31	4
January 2024	0.87 ± 1.34	3	1.1 ± 1.06	2	1.4 ± 1.32	4
February 2024	2.73 ± 1.23	3	0.82 ± 0.48	2	2.4 ± 0.76	4
March 2024	3.71 ± 2.31	3	0.88 ± 0.64	2	2.93 ± 1.33	4
April 2024	8.19 ± 2.35	3	2.75 ± 1.21	2	5.53 ± 1.52	4
May 2024	12.46 ± 3.25	3	8.55 ± 3.26	2	9.86 ± 2.49	4
June 2024	17.29 ± 2.58	3	15.34 ± 3.18	2	14.23 ± 1.65	4
July 2024	20.24 ± 2.36	4	19.37 ± 2.49	2	16.67 ± 1.54	4
August 2024	18.77 ± 3.2	4	17.78 ± 2.26	2	15.11 ± 2.04	4
September 2024	-		-		12.19 ± 1.58	1
October 2024	-		-		10.09 ± 0.58	1

	Drews-Low		Drews-High		Dry		Eastside	
Month	**Mean ± SD**	**N**	**Mean ± SD**	**N**	**Mean ± SD**	**N**	**Mean ± SD**	**N**
August 2022	-	0	16.22 ± 1.55	4	15.79 ± 0.91	2	14.59 ± 1.28	3
September 2022	-	0	11.57 ± 2.23	4	12.54 ± 1.64	2	11.22 ± 2.06	3
October 2022	-	0	5.99 ± 2.59	4	8.3 ± 2.23	2	6.09 ± 2.31	3
November 2022	1.9 ± 1.22	2	0.28 ± 0.65	4	0.93 ± 2.84	3	0.38 ± 0.73	3
December 2022	-1.42 ± 2.4	3	0.1 ± 0.09	4	1.06 ± 1.59	3	0.4 ± 0.59	3
January 2023	0.27 ± 0.77	3	0.14 ± 0.16	4	1.5 ± 1.7	3	0.78 ± 0.89	3
February 2023	0.54 ± 0.72	3	0.14 ± 0.12	4	1.46 ± 1.46	3	0.44 ± 0.36	3
March 2023	0.46 ± 0.49	3	0.22 ± 0.18	4	1.64 ± 1.45	3	1.16 ± 0.82	3
April 2023	0.47 ± 0.46	3	1.09 ± 0.93	4	4.82 ± 3.16	3	3.06 ± 1.19	3
May 2023	2.78 ± 3.11	3	6.26 ± 2.37	4	11.88 ± 3.15	3	6.36 ± 1.75	4
June 2023	12.87 ± 3.91	2	11.19 ± 1.76	3	14.07 ± 2.61	3	9 ± 1.28	3
July 2023	16.38 ± 2.84	2	15.81 ± 1.42	3	18.5 ± 2.6	3	12.88 ± 0.93	4
August 2023	19.65 ± 3.84	2	14.59 ± 1.89	4	16.86 ± 2.27		13.01 ± 1.21	3
September 2023	17.72 ± 2.07	1	9.44 ± 1.65	2	12.09 ± 2.14		9.27 ± 1.67	3
October 2023	13.96 ± 2.08	1	5.85 ± 2.59	2	7.81 ± 2.65		6.09 ± 2.83	4
November 2023	9.1 ± 2.56	4	1.97 ± 2.06	4	3.48 ± 2.41		2.22 ± 1.9	5
December 2023	3.43 ± 2.29	4	0.41 ± 0.71	4	1.59 ± 1.63		1.15 ± 0.92	5
January 2024	1.25 ± 1.35	4	0.28 ± 0.5	4	1.33 ± 1.53		1.07 ± 1.17	5
February 2024	0.96 ± 1.28	4	0.66 ± 0.63	4	2.98 ± 1.3		2.1 ± 0.81	5
March 2024	1.95 ± 1.28	4	1.29 ± 1.13	4	3.24 ± 1.79		2.33 ± 1.23	5
April 2024	2.99 ± 2.22	4	4.55 ± 1.96	4	8.02 ± 1.89		4.32 ± 1.05	5
May 2024	8.66 ± 2.79	4	8.86 ± 3.25	4	11.88 ± 2.95		6.48 ± 1.61	5
June 2024	13.04 ± 3.17	4	13.49 ± 2.17	4	16.5 ± 3.13		10.26 ± 1.51	5
July 2024	17.41 ± 2.47	4	16.62 ± 1.93	4	18.22 ± 2.74		13.97 ± 1.66	3
August 2024	19.35 ± 1.25	1	14.61 ± 2.69	5	15.18 ± 2.38		12.89 ± 2.05	3
September 2024	-		11.34 ± 2.07	4	12.61 ± 1.87		10.31 ± 1.56	3
October 2024	-		8.82 ± 1.48	4	10.28 ± 1.02		8.47 ± 0.43	3



Figure 3-6 Water temperature data classified by thermal tolerances for redband trout, including low (<12°C), optimal (12–19°C), optimal-high (19– 24°C), and high (>24°C). Time periods where minimum temperatures indicated freezing (<1°C), or where water logger data was indicative of stream drying are also highlighted.

Coldwater fishes display a range of thermal tolerances, above which they can experience metabolic consequences or mortality events. Rainbow trout (*Oncorhynchus mykiss*) are believed to have an upper thermal tolerance of roughly 16–19°C based on laboratory studies; however, the redband subspecies has evolved to withstand higher temperatures in aridlands environments. The critical thermal tolerance limit for redband trout (i.e., the temperature at which individuals become incapacitated) is estimated to be about 29.4°C, with evidence of stress occurring at temperatures above 24°C (Rodnick et al. 2004; https://doi.org/10.1111/j.0022-1112.2004.00292.x). Water temperature logger data indicate that most sites in the Goose Lake Basin sustained water temperatures within the optimal range for redband trout (Fig. 3-6). Streams were more likely to dewater than to reach lethal temperatures, posing potential issues with respect to habitat connectivity and availability.

In the Thomas Creek watershed, we did not observe substantial differences in spring 2023 (1.5 years post-burn) water temperature profiles between the High and Burned strata, but the Low stratum was generally warmer beginning in April. A comparison of water logger data from three sites in the Low,

High, and Burned strata demonstrates this trend (Fig. 3-7). While average water temperatures remained within optimal temperature limits for redband trout during the spring growing period, maximum temperatures frequently reached stress thresholds in June at the Thomas-Low site (Nongame 83).

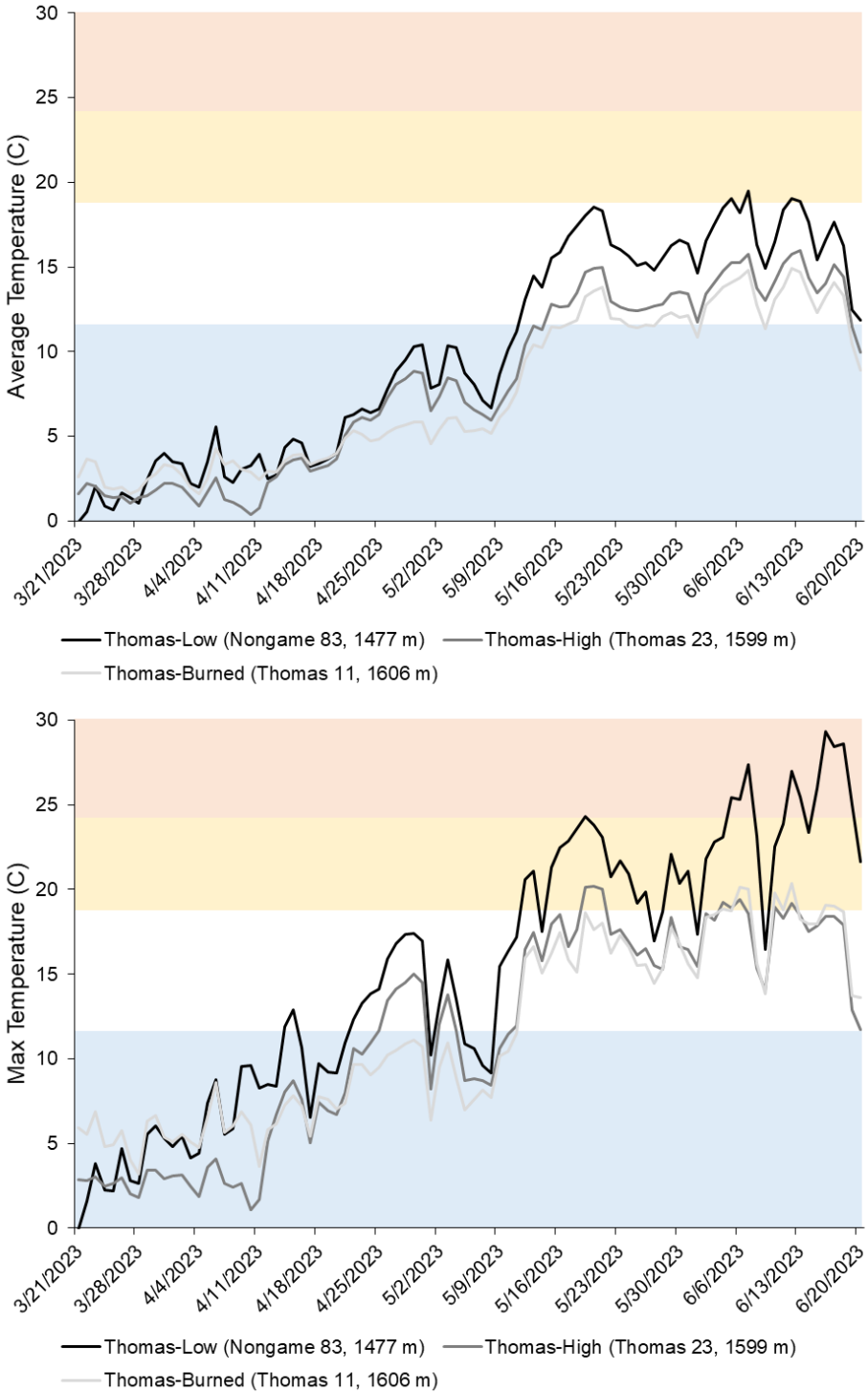

Figure 3-7 Spring 2023 average (top) and maximum (bottom) daily water temperature data for three water loggers installed in the Thomas-Low, Thomas-High, and Thomas-Burned strata. Colored bars indicate thermal tolerance ranges

for redband trout, including low (blue; <12°C), optimal (white; 12–19°C), optimal-high (yellow; 19–24°C), and high (orange; >24°C).

Little information is available for streamflow, but data are available from four Oregon Water Resources Department (OWRD) gauges—one on Cottonwood Creek above Cottonwood Reservoir (11339995), one on Cottonwood Creek along Highway 140 (11340695), one in Cottonwood Reservoir (11340000), and one in Drews Reservoir (11338500). We present ten water years of provisional data from gauge 11339995 in Figure 3-8 below. Data from 2024 indicate that mean daily stream flow (in cubic feet per second; cfs) was slightly higher than the ten-year average, reaching an early peak of 116 cfs at the end of January and a maximum estimated peak of 119 cfs at the end of April (compared to a ten-year average peak of 81 cfs).

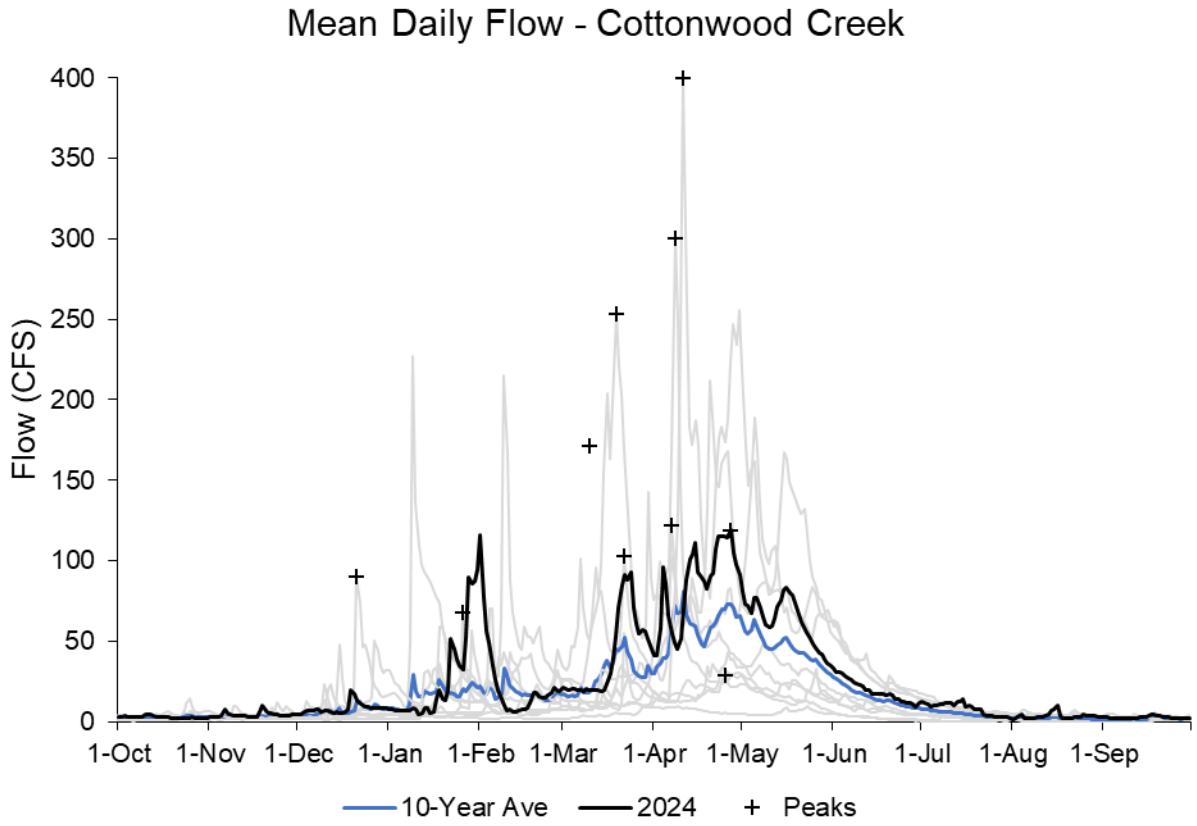

Figure 3-8 Mean daily flow (cubic feet per second) for the 2024 water year (black line) and 2015-2023 water years (light gray lines) compared against the ten-year average (blue line). Peak flows for each year are delineated with a black plus sign.

3.4 Objective 3: Obtain contemporary information on native and non-native fish abundance, distribution, and habitat use

Task 3-1: Conduct electrofishing and eDNA sampling	Status: Complete
Task 3-2: Compare findings between electrofishing and eDNA data	Status: Complete
Task 3-3: Compare 2022-2024 data to 2007 data	Status: In Progress
Task 3-4: Analyze fish abundance, distribution, and environmental drivers	Status: In Progress

Methods: Sampling efforts from 2022 to 2024 consisted of updated surveys using both traditional (electrofishing) and novel (eDNA metabarcoding) methods. Fish species abundance in the watershed was assessed using three different methods: electrofishing to depletion, mark-recapture, and eDNA sampling. In 2022, we sampled 36 sites with traditional and novel sampling methods and 35 additional sites using only eDNA. In 2023, we sampled 33 "full-suite" sites and an additional 56 sites using eDNA. In 2024, we sampled 33 sites with traditional methods only and an additional 10 sites using eDNA.

During electrofishing efforts, we measured fish abundance and local habitat variables. Water temperature, dissolved oxygen, and conductivity data were noted using a YSI multimeter. Stream depth and width were recorded at 0m, 50m, and 100m intervals. Macrohabitat type and substrate composition were observed and reported at each transect location. Large wood (at least 10 cm in diameter and 3 m long) within the wetted channel was tallied. We deployed block nets across the stream width at the top and bottom of the 100 m reach, ensuring the bottom of the net was flush with the streambed using large rocks. The backpack electrofisher was set up downstream of the bottom block net. We used the quick set-up feature to get an initial setting and voltage adjustments were made as needed. Beginning at the downstream end of the reach, one shocker and two netters shocked while walking a zig zag motion to the upstream block net. Netters used their feet to gently disturb the substrate and used their nets to disturb reedy grasses. One crew member carried a bucket filled with stream water to contain shocked fish. We performed electrofishing to depletion with a minimum of two passes and a maximum of four passes (each pass including both an up- and downstream sweep).

At the conclusion of each pass, collected fish were moved to a bucket with fresh water and kept in a shady spot with a bubbler to provide oxygen. We anesthetized fish using MS-222 (except redband trout >200 mm) prior to processing. Fish were identified to species, counted, weighed, and measured to the nearest millimeter. We recorded length measurements as fork length for all species except lamprey and sculpin, for which we used total length. When large numbers of a species were captured at a site (>100), we measured a random subsample of individuals (n=25). Following processing, we allowed fish to fully recover in aerated water before releasing them near their location of capture. The process was repeated for a second pass and if a fifty percent reduction in fish catch was not achieved, two additional electrofishing passes were made. We also used mark-recapture to determine sampling efficacy at five sites. After allowing several hours for recovery, each site was resampled using electrofishing and the recapture rates of marked individuals were used to estimate abundance and validate the efficacy of electrofishing efforts. Additionally, stomach contents were sampled from 88 redband trout (≥ 135 mm fork length) across 23 sites using gastric lavage. Contents were stored in plastic bags filled with 95% ethanol for future prey item identification. Prey items will be identified to genus and measured by the Arismendi Lab at OSU in spring 2025. In addition, a subset of redband trout (n = 30) used for diet analysis were also euthanized for an age-structure analysis.

To better evaluate habitat conditions for stream-dwelling fish, we collected macroinvertebrate samples concurrently with fish sampling at 21 electrofishing sites, with the assumption that

macroinvertebrates serve as indicators of prey availability for fish, particularly salmonids. Sites were randomly selected using a stratified approach, with three sites sampled per stratum. Pilot data were collected in 2023 using a kick net. A random sample of 30 macroinvertebrates were selected per site and identified to order. In 2024, aggregate samples were collected at three transect locations (0 m, 50 m, and 100 m) per site. At each transect, one crew member positioned a 500-µm mesh D-net facing downstream, while another gently disturbed the substrate upstream of the net for 30 seconds to dislodge invertebrates. After sampling, the net was inverted over a 5-gallon bucket, and stream water was poured over the mesh to rinse the collected invertebrates into the bucket. The bucket's contents were subsequently poured over a 500-µm stainless steel mesh sieve, and all invertebrates ≥ 500 µm were retained. Samples were preserved in 95% ethanol and transported to OSU for analysis. They are currently being identified to the lowest taxonomic level, weighed, and measured.

For eDNA sample collection, we collected triplicate samples plus one (distilled water) control sample for each site. We sterilized all materials before entering the stream. Criteria for selecting water collection locations within the stream were based on habitat use of the target species, ideally from a riffle and in the thalweg. When filtering was conducted on-site, the sample was poured directly from a one-liter Nalgene bottle into a filter funnel. When taking grab samples for later filtering off-site, water was collected in three, sterile one-liter Nalgene bottles with one sample per bottle. The grab bottle was rinsed three times with water from the sample site, capped, and shook during each rinse. Rinse water was disposed of downstream of the sample location. We filled the grab bottle, avoiding stirring up sediment while collecting the sample. The cap was firmly placed on the bottle and the bottle was labeled with site name and sample number and placed in a cooler. We processed all off-site samples within 24 hours of collection. eDNA samples were processed by the Levi Lab at OSU.

We are using multivariate statistical techniques to evaluate changes in fish abundance and community structure among years and sites. We will also use multivariate statistical techniques to compare the 2024 macroinvertebrate data with redband trout diet samples to gauge prey resource availability for salmonids in the Goose Lake Basin, identify patterns in prey composition, assess the overlap between available macroinvertebrates and trout diets, and evaluate whether specific habitat conditions influence prey availability. Additionally, diet and otolith samples will be used to develop and validate a bioenergetics model for the Goose Lake redband trout. eDNA metabarcoding is being used to assess current population distributions and compare to contemporary and historical data. We have taken advantage of the Oregon Biodiversity Genome Project's assembly of mitochondrial genomes for all of Oregon's fishes and a new "Metameta" primer set. Analysis of eDNA output will be compared to the traditional survey data to assess its utility for system and basin-wide monitoring efforts.

Preliminary Findings: A summary examination of electrofishing data comparing 2007 to 2022 findings indicated that fish communities did not change substantially, but that numbers of native trout and minnows have declined over the last 15 years (Figures 3-9 through 3-15; note that 2007 values have not been standardized by sampling area). Preliminary findings indicate that fish communities were similar in 2023 and 2024 as well. In the Thomas Creek watershed, low elevation sites (1495 ± 36 m) were characterized by a mix of lamprey, trout, and native minnows, with

occurrences of non-native fathead minnows, and crappie in Thomas Creek. A newly sampled site in Thomas Creek had a high abundance of Modoc Suckers. High elevation sites (1759 ± 138 m) were characterized by speckled dace (in Thomas and Cox Creeks) and redband trout (in Cottonwood Creek), with some introduced brook trout below Cottonwood Meadow Lake and some juvenile and adult lamprey in Cox Creek. In the Cougar Peak burn zone, most of which was high elevation (1658 ± 67 m), redband trout and lamprey predominated. Redband trout abundances appeared to have declined substantially between 2007 and 2022–2024 at all sites while larval lamprey abundances increased in Upper Cottonwood and Camp Creeks. A seemingly isolated population of Pit sculpin at Thomas-Bauers 26 in Camp Creek was still present in 2022 but not in 2023 or 2024.

The Drews Creek watershed was punctuated by widespread declines in fish abundances. At lower elevation sites (1556 ± 46 m), sucker, Pit roach, speckled dace, and Tui chub were all highly abundant in Dent Creek and Dog Creek in 2007, but were absent in 2022; however, a sampled site on Hay Creek in 2023 and 2024 had very high numbers of native and non-native minnows. In upper Drews Creek (1735 ± 69 m), communities were characterized by lamprey and redband trout, with abundances lower during the 2022-2024 sampling years than in 2007. A seemingly isolated population of Pit sculpin at Drews 06 in upper Drews Creek was still present across all survey years (2022–2024).

The Dry Creek stratum (1563 ± 46 m) also appeared to experience widespread fish declines at some sites. In Falls Creek and upper Dry Creek, redband trout were absent or depressed. However, redband trout increased at two Dry Creek sites in 2024. In Dry Creek, previously robust populations of larval lamprey, sucker, Pit roach, speckled dace, and Tui chub were absent in 2022, although speckled dace were observed at Dry 21 when they were not observed in 2007. Pooling at these sites may have contributed to some differences. All native and non-native minnow populations increased in 2024. On the Eastside (1658 ± 48 m), the only species observed in Crane and Kelly Creeks was still redband trout, and fewer were observed across survey years (2022-24) compared to 2007.

Some sites, especially "Non-Game" sites, may have been sampled by additional, passive methods in 2007 such as minnow traps, fyke nets, or seine nets. We included only electrofishing data from 2007 in Figures 3-9 through 3-15. Challenges to electrofishing Non-Game sites meant that they were generally underrepresented across survey years (including "full suite" sampling efforts used in 2023). We attempted to compensate for this during the 2023 field season by sampling more Non-Game sites (and areas with similar habitat characteristics such as lower elevation and regular agricultural use) using eDNA.

Exploratory analyses of the 2023 macroinvertebrate pilot data revealed significant differences in macroinvertebrate community structure among strata (ANOSIM test: $R = 0.270$, $p = 0.013$). Terrestrial invertebrates, such as Plecoptera, Ephemeroptera, and Trichoptera, were predominantly found in the Eastside stratum, while low-elevation, disturbed sites were dominated by aquatic taxa such as Decapoda and Amphipoda (Fig. 3-16). Additionally, a Pearson's correlation test was conducted to evaluate the relationship between macroinvertebrates and redband trout abundance. The results indicated a positive linear correlation ($r = 0.52$) between redband trout and Plecoptera counts.

Redband trout diets were sampled across all seven strata, with most samples collected from higher-elevation sites in the Warner Mountains, followed by upper-elevation sites within the Thomas Creek burned zone. In contrast, the lowest number of suitable redband trout for diet sampling (≥ 135 mm fork length) was found at lower-elevation sites in Drews Creek. Both the redband trout diet samples and the 2024 macroinvertebrate data are still undergoing processing. Of the invertebrate samples processed so far (17 out of 21 sites), a total of 2,360 specimens have been identified, representing 21 unique orders. The most prevalent orders identified to date include Trichoptera (n = 533), Ephemeroptera (n = 522), and Diptera (n = 379).

Otoliths from redband trout were collected across six strata, with most samples originating from sites in the Warner Mountains. The otoliths were extracted from trout carcasses at Oregon State University in the fall of 2024 and are currently being processed into slides at the Marine and Anadromous Fisheries Ecology Lab in Newport, Oregon. Once prepared, the otoliths will be aged using Image-Pro software to analyze growth patterns.

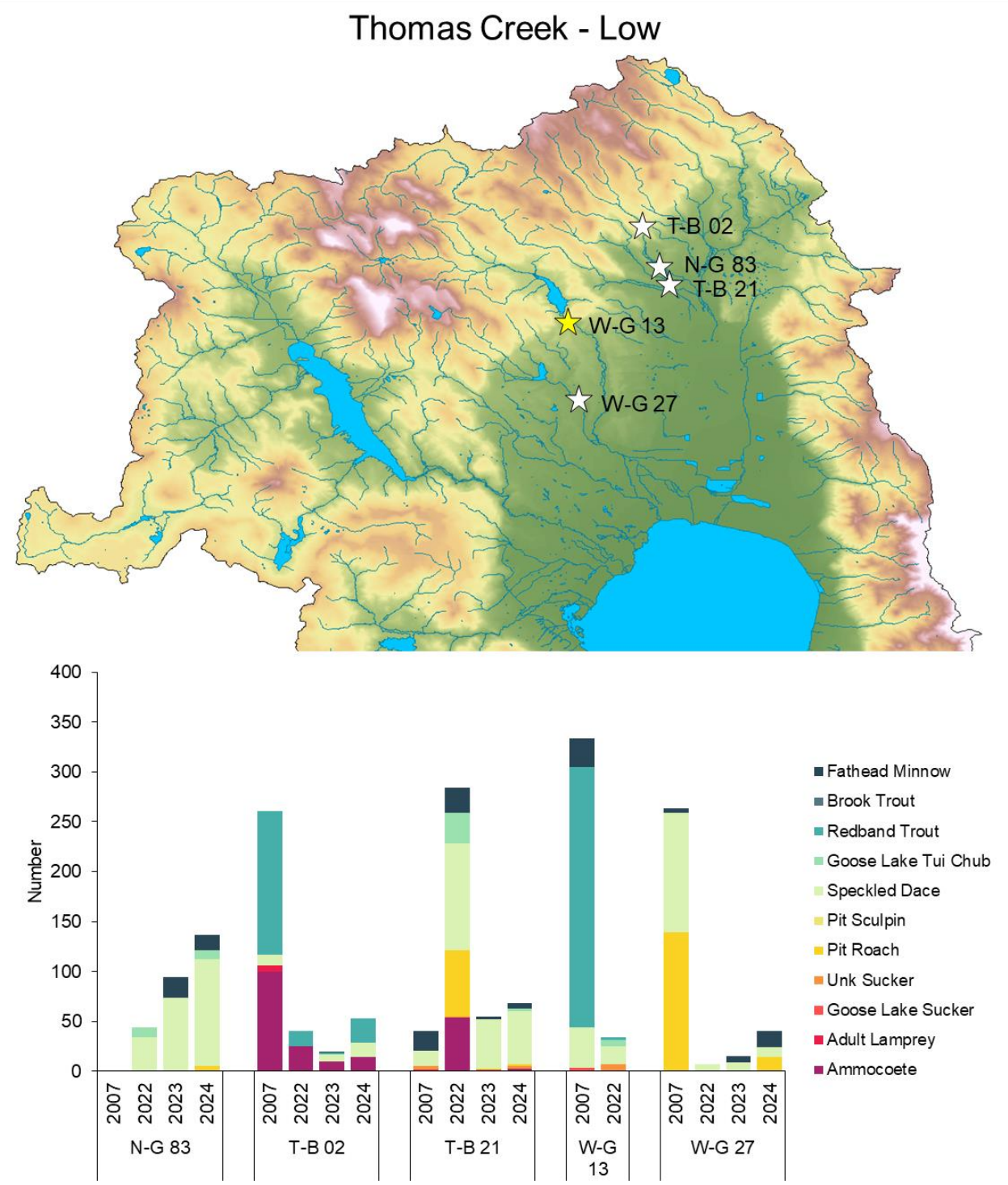

Figure 3-9 Map of sampling sites (top) and species abundances (bottom) for non-rare fish species in 2007 and 2022–2024 for the Thomas Creek – Low stratum. Yellow stars indicate sites for which access permissions could not be obtained in 2023 or 2024.

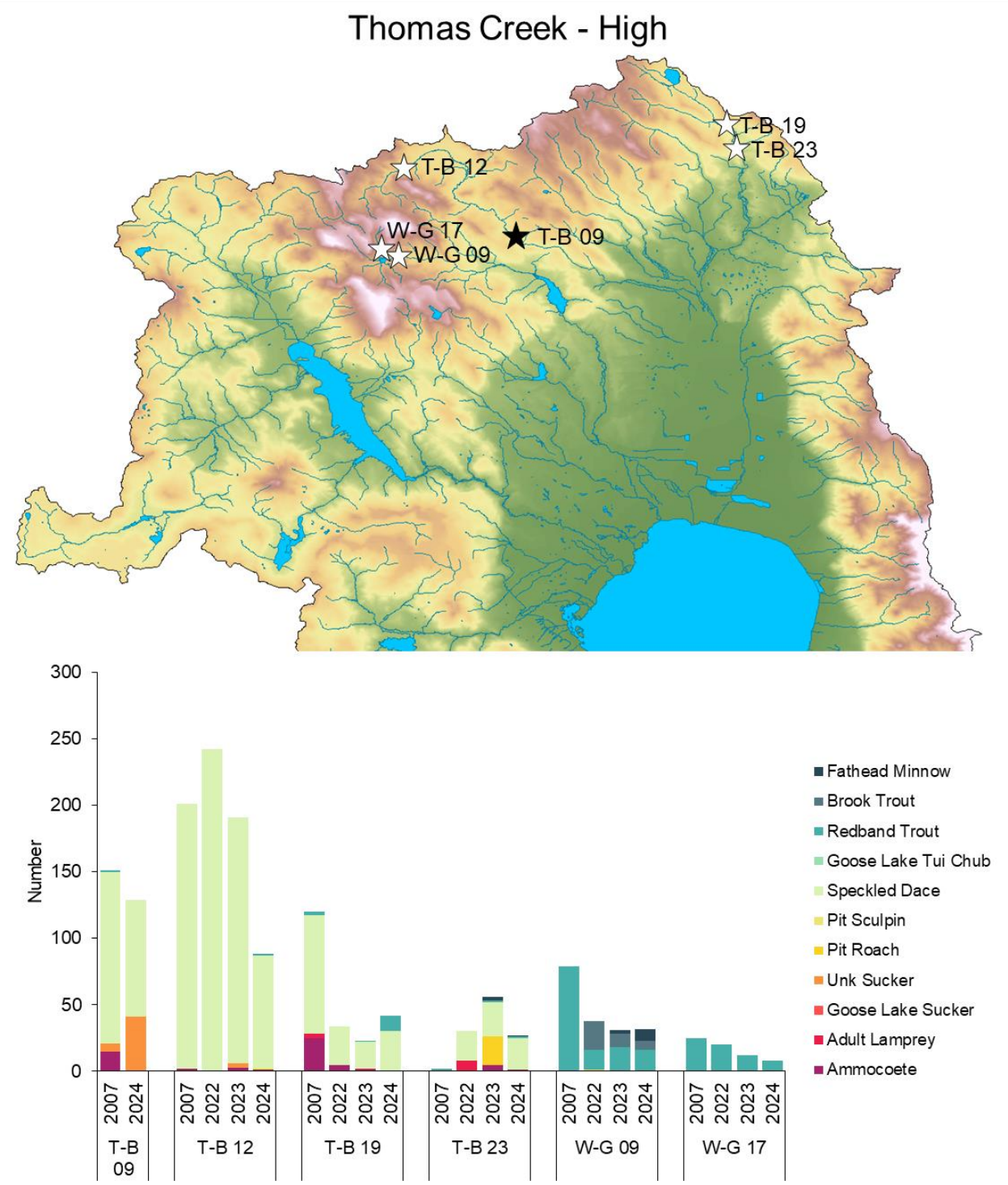

Figure 3-10 Map of sampling sites (top) and species abundances (bottom) for non-rare fish species in 2007 and 2022–2024 for the Thomas Creek – High stratum. Black stars indicate sites that were new in 2024.

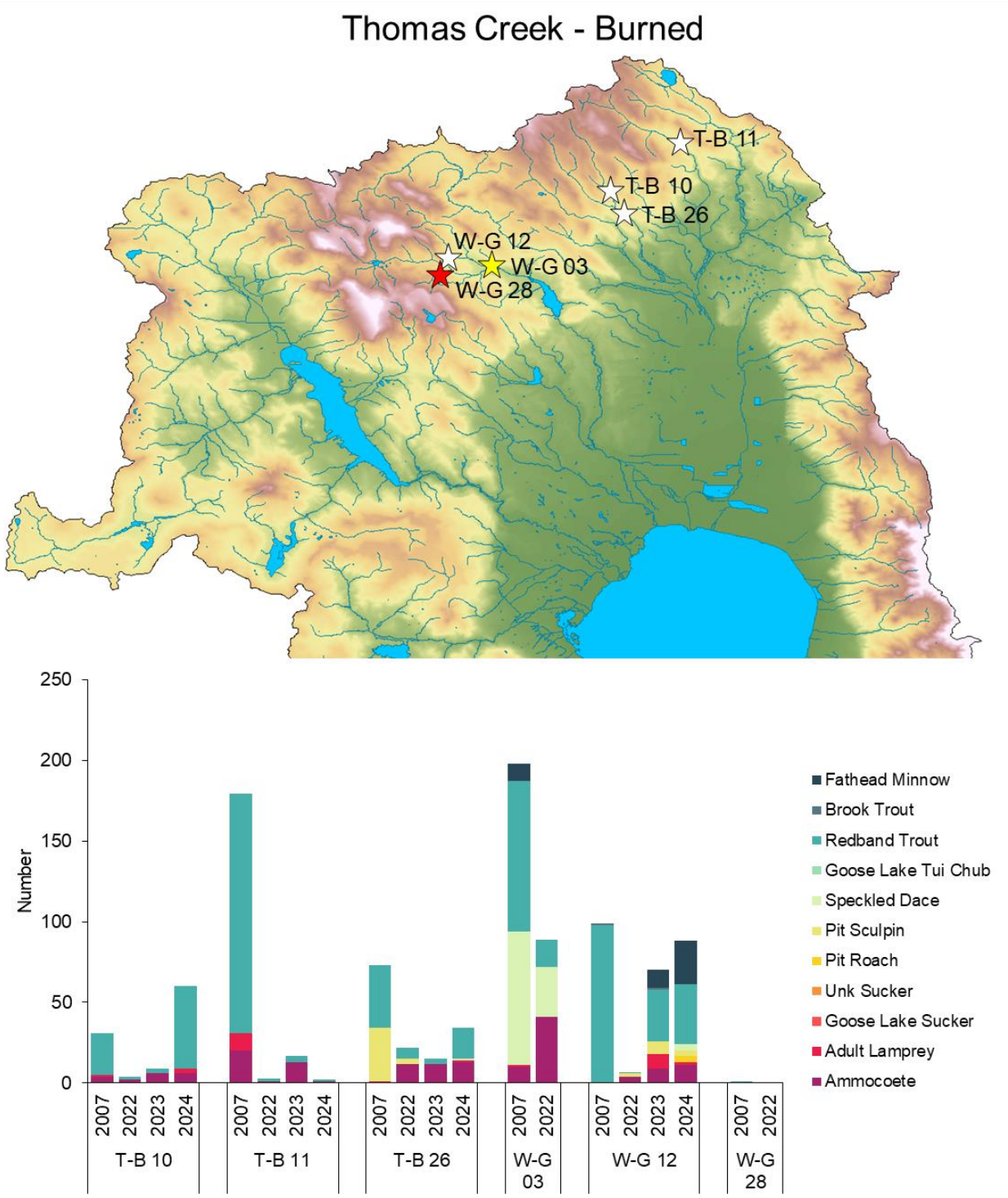

Figure 3-11 Map of sampling sites (top) and species abundances (bottom) for non-rare fish species in 2007 and 2022–2024 for the Thomas Creek – Burned stratum. Red stars indicate sites that were moved in 2023 due to access limitations and lack of fish. Yellow stars indicate sites for which access permissions could not be obtained in 2023 or 2024.

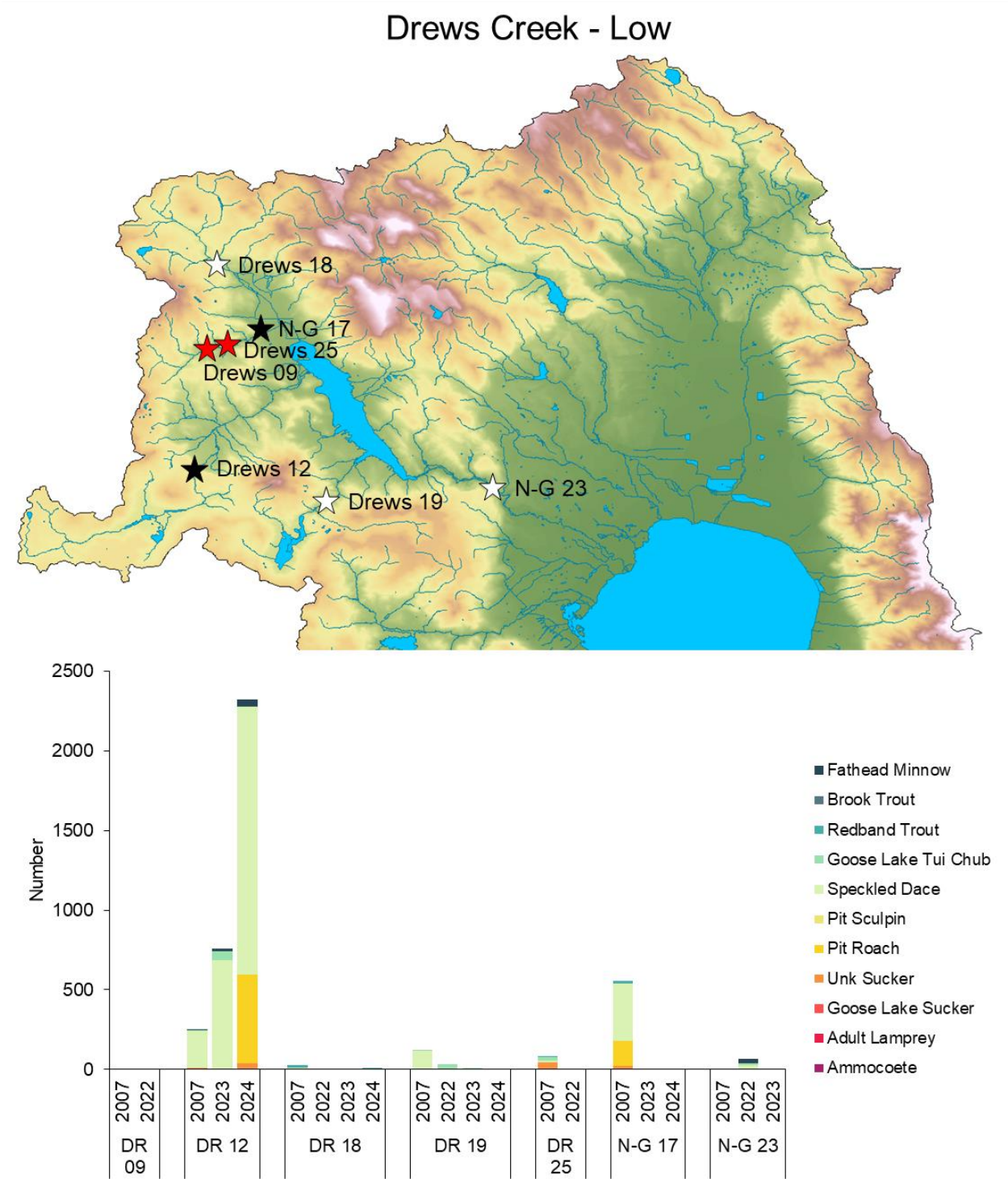

Figure 3-12 Map of sampling sites (top) and species abundances (bottom) for non-rare fish species in 2007 and 2022–2024 for the Drews Creek – Low stratum. Red stars indicate sites that were moved in 2023 due to duplicate sampling effort. Black stars indicate sites that were new in 2023.

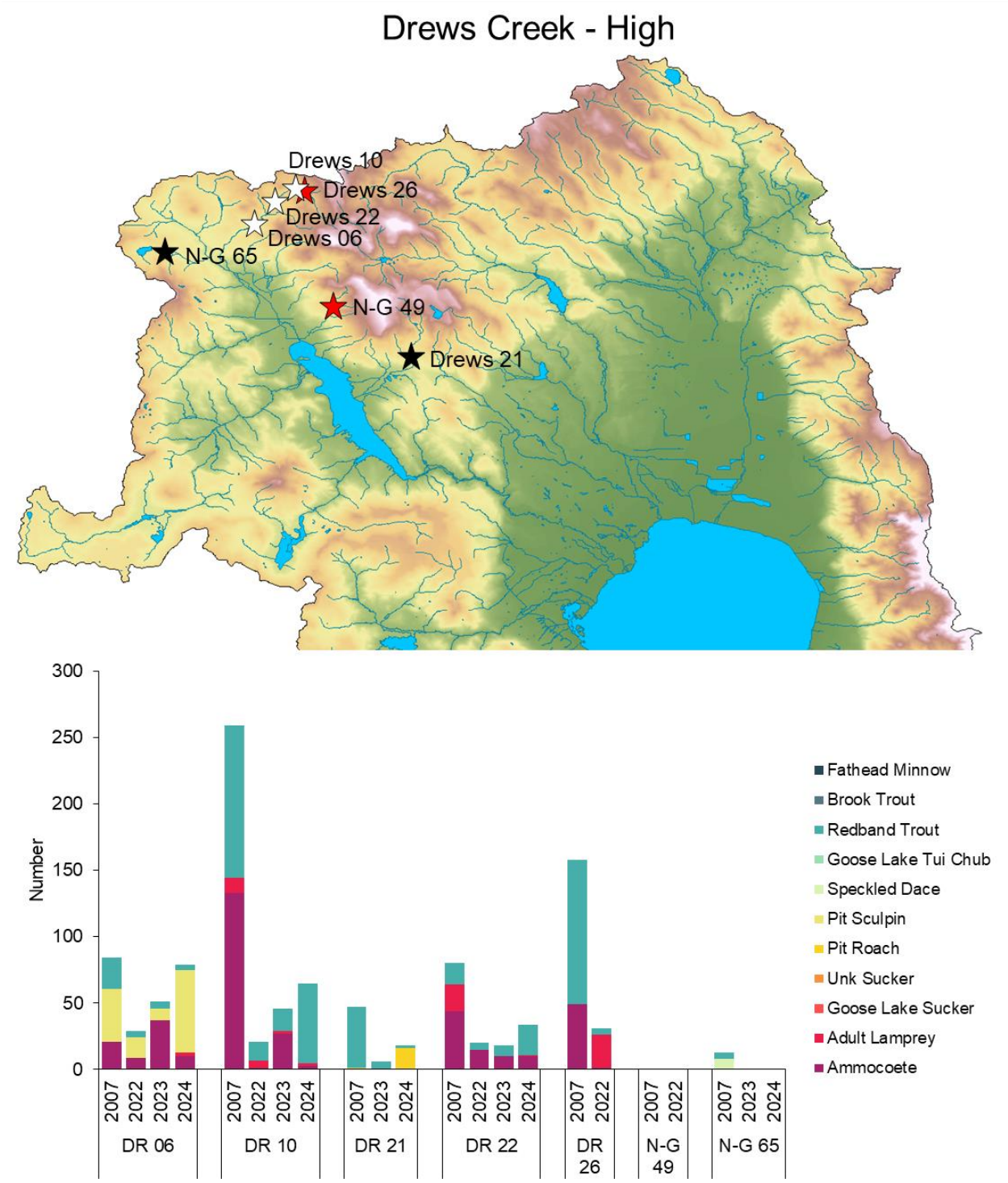

Figure 3-13 Map of sampling sites (top) and species abundances (bottom) for non-rare fish species in 2007 and 2022–2024 for the Drews Creek – High stratum. Red stars indicate sites that were moved in 2023 due to duplicate sampling effort. Black stars indicate sites that were new in 2023.

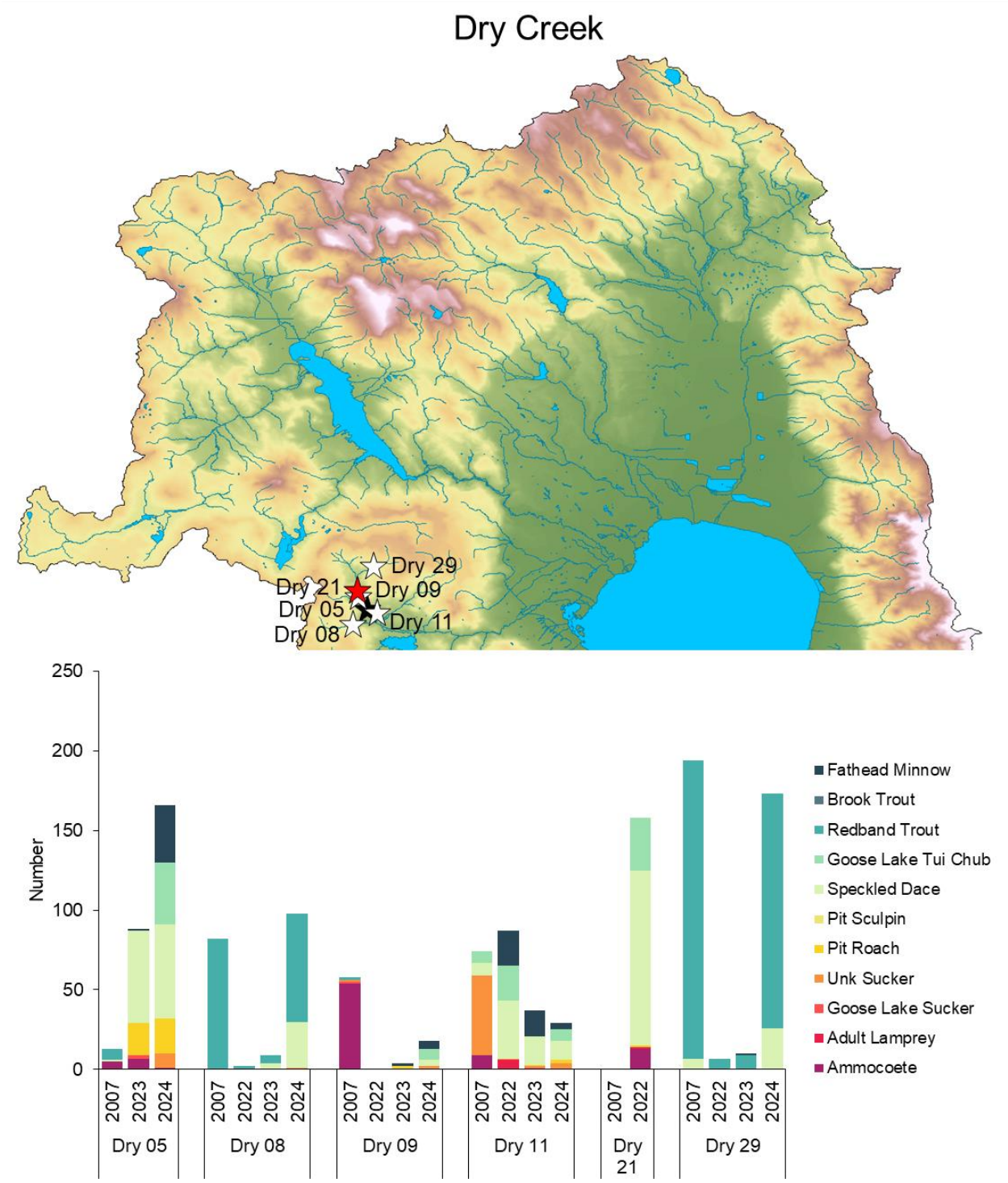

Figure 3-14 Map of sampling sites (top) and species abundances (bottom) for non-rare fish species in 2007 and 2022–2024 for the Dry Creek stratum. Red stars indicate sites that were moved in 2023 due to duplicate sampling effort. Black stars indicate sites that were new in 2023.

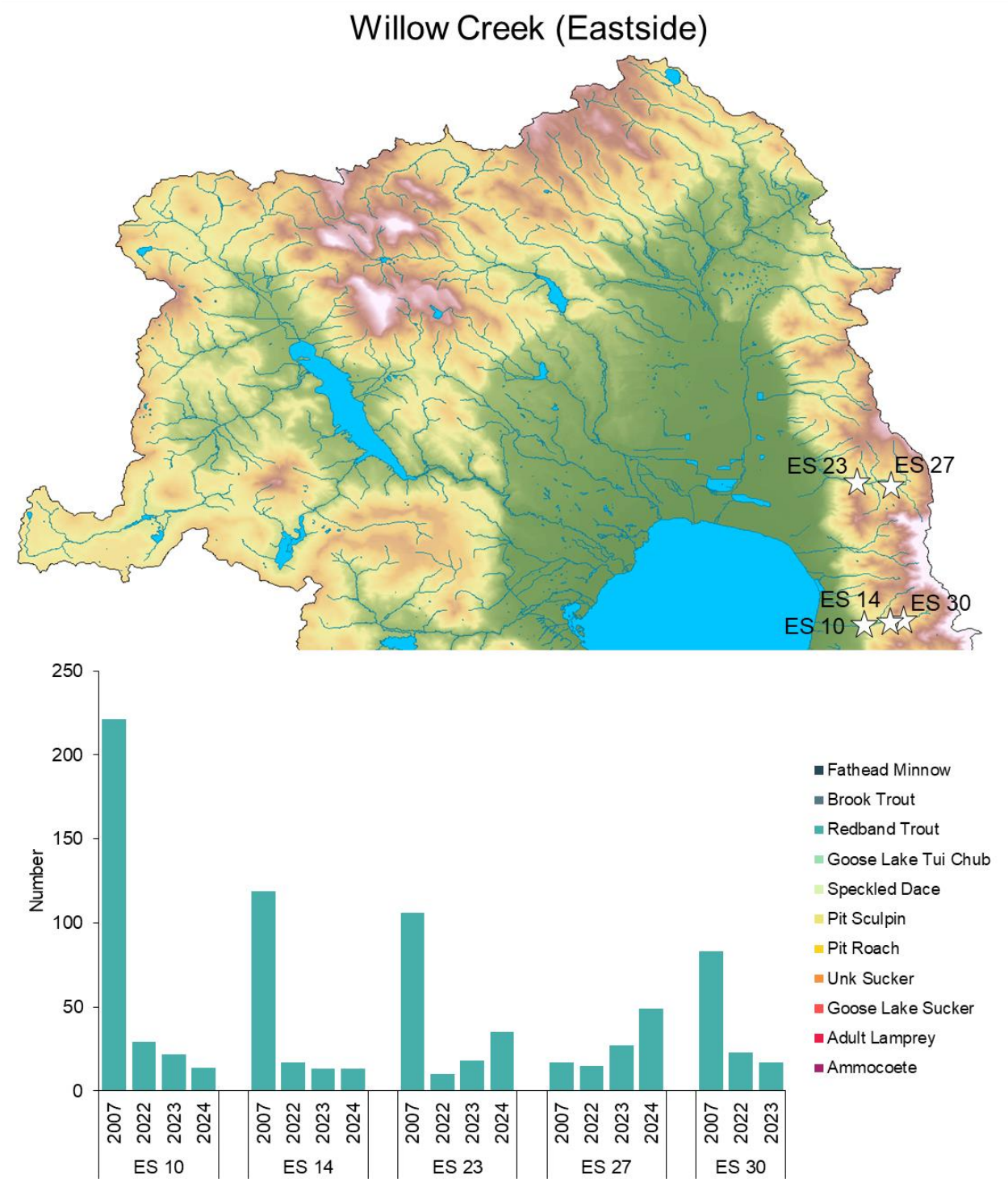

Figure 3-15 Map of sampling sites (top) and species abundances (bottom) for non-rare fish species in 2007 and 2022–2024 for the Eastside (Willow Creek) stratum.

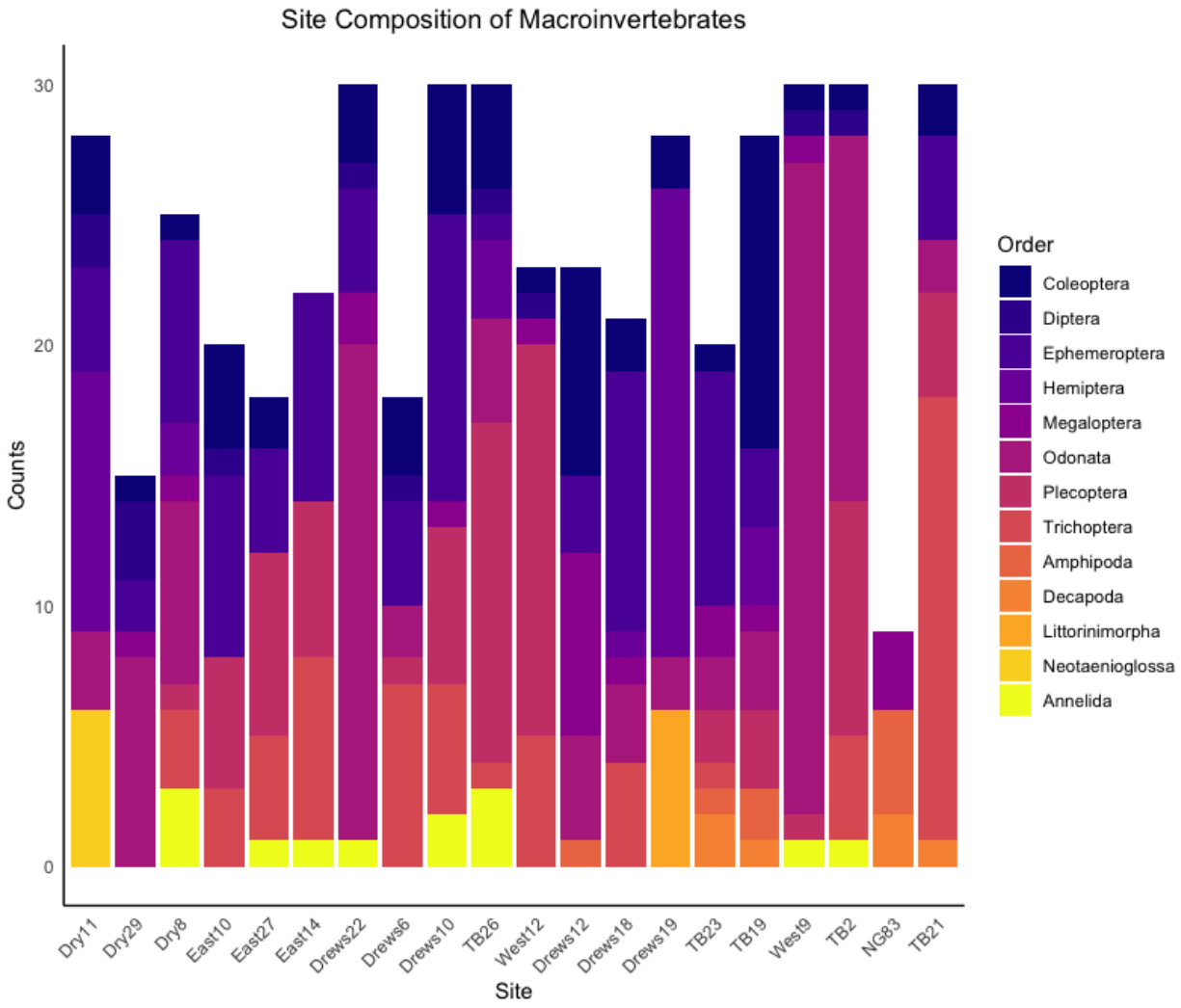

Figure 3-16 Stacked barplot displaying the number of macroinvertebrates collected in 2023 across 20 sites. Macroinvertebrates are categorized by Order and arranged by stratum.

We have compared findings from 2023 electrofishing efforts and eDNA samples using two eDNA primers: MiFish (12S) and Metameta (16S). Initial findings suggest that eDNA is more sensitive than electrofishing for detecting the presence of local fish species. There are subtle differences in the primers' ability to detect certain species. For example, the Meta primer is better at detecting lamprey, while MiFish appears to be more sensitive for some minnows.

SITE	REDBAND TROUT	LAMPREY	SUCKER	PIT SCULPIN	TUI CHUB	SPECKLED DACE	PIT ROACH	BROOK TROUT	FATHEAD MINNOW
THOMAS_21		O	O		O	O	EF		O
NONGAME_83		EF			O	O			O
THOMAS_02	O	O				O			EF
THOMAS_26	O	O				O			
THOMAS_10	O	16S							
THOMAS_12	O	16S	O			O			12S - TRACE
THOMAS_11	O	16S							
THOMAS_23	O	O			12S - TRACE	O	EF		O
THOMAS_19	O	O				O			
WEST_27	O - TRACE		O		O	O			O
WEST_13 (NS)	O		O						O
WEST_12	O	O		O		O		12S	O
WEST_09	O							O	O
WEST_17	O								12S - TRACE
NONGAME_23	12S - TRACE		O		12S - TRACE	O			O
NONGAME_17		O				12S			
NONGAME_65	12S					O			
DREWS_19						EF			
DREWS_12			O		O	O	EF		O
DREWS_21	O				O	O			12S - TRACE
DREWS_18	O		O			O			
DREWS_06	O	16S		O					
DREWS_22	O	O				12S			
DREWS_10	O	16S							
DRY_05		16S	O		O	O	EF		EF/12S-TR
DRY_08	O					O			
DRY_09			O		O	O	EF		O
DRY_11		16S	O		O	O	EF		O
DRY_29	O					12S			O
EAST_10	O								
EAST_14	O					12S			
EAST_23	O					O			
EAST_27	O								
EAST_30	O								

Table 3-3 Comparison of fish species detected by electrofishing and eDNA in 2023 at each site. Green cells indicate a species was detected using both electrofishing and eDNA, blue cells indicate a species was detected by eDNA only, and red cells indicate a species was detected by electrofishing only. A circle specifies that both the 12S and 16S eDNA primers detected a species. Yellow perch, brown bullhead, smallmouth bass, crappie, and pumpkinseed were all detected by 12S and 16S primers at Drews 18.

3.5 Objective 4: Obtain baseline data to monitor the effects of the Cougar Peak/Patton Meadow wildfires on fish and their habitat

Task 4-1: Examine post-fire vegetation change — Status: In Progress

Task 4-2: Compare thermal regimes among burned and unburned sites — Status: In Progress

Task 4-3: Compare fish abundance and distribution among burned and unburned sites — Status: In Progress

Methods: For Objective 4, we will leverage the data collected in Objectives 1–3 including NDVI and soil and vegetation burn intensity spatial data; water temperature information from at least 15 logger sites in the Thomas Creek sub-basin; electrofishing data from at least 15 stream segments in the Thomas Creek sub-basin; and eDNA metabarcoding data from approximately 50 sites in the Thomas Creek sub-basin. Analyses will be limited to direct comparisons of data collected in the relevant burned and unburned areas. Stratified sampling throughout burned and unburned sites will allow us to make direct comparisons among thermal regimes (Task 4-2) and fish abundance and distribution (Task 4-3) using a before-after/control-impact study design.

Preliminary Findings: We have downloaded 2020 NAIP imagery (2022 pending) and Landsat Collection 2 Level 2 Landsat imagery for 2021, including time periods encompassing the Cougar Peak/Patton Meadow fire(s) (Fig. 3-17). These data sets will allow us to examine post-fire habitat change in affected areas of the Basin. Differences in fish communities (Figs. 3-9, 3-10, 3-11) are outlined above.



Figure 3-17 Landsat 8 multi-band (RGB) imagery showing Goose Lake portion of Fremont-Winema National Forest before and after the Cougar Peak/Patton meadow fire(s). Landsat Collection 2 Level 3 Burned Area (BA) Science Product shows area classified as "burned."

4. Challenges and Next Steps

We adapted our sampling protocols for the 2024 field season based on lessons learned from the 2023 field seasons. We ordered macroinvertebrate sampling equipment prior to the start of the field season to ensure sufficient data collection that occurred concurrently with fish sampling.

In 2022, drought conditions were a moderate hinderance to sampling efforts because they influenced our ability to electrofish (due to stagnant, shallow water and elevated temperatures) and collect eDNA samples. In 2023 and 2024, early season sampling was impacted by swiftly moving, deep water at some sites. With a better understanding of hydrologic conditions in the Basin, we were able to accurately time sample collection during the 2024 field season.

Although we received landowner permission to sample at West 03 and West 13, we were unable to access these sites due to feasibility issues. West 13 is located directly below the Cottonwood Creek reservoir and our ability to electrofish was hindered by swiftly moving, deep water. Site conditions at West 03 also did not meet the closure assumptions for sampling protocols, as a series of burned trees had fallen across the stream over the winter, creating a network of braided channels. Additionally, we were unable to sample Nongame 23 due to deep water.

We successfully installed 38 Hobo loggers during the 2022 field season. Loggers were downloaded and redeployed in October 2022; however, a problem with the Hobo logger software rendered many of the files inaccessible. We were able to successfully retrieve those data during May and October 2023. Unfortunately, 9 loggers were lost or malfunctioned. We replaced those loggers in November 2023 and deployed a subset of duplicate loggers to ensure redundancy. A total of 41 loggers are currently deployed across 35 unique locations, including 5 duplicates and 1 air logger. The loggers were downloaded in August and October of 2024. We will continue collecting temperature data through September 2025.

We supplemented existing survey protocols in 2024 by collecting redband trout diets, otoliths, and macroinvertebrate samples from a stratified random selection of survey sites. Invertebrates were preserved in 95% ethanol from 21 sites using D-nets. Diet samples were preserved in 95% ethanol from 23 sites using gastric lavage. Diet contents and macroinvertebrates will be weighed and identified using a light microscope. Findings will support an on-going analysis looking at prey availability and growth for the Goose Lake Basin redband trout.

In 2024, our team received funding from the Northwest Climate Adaptation Science Center. The grant has significantly enhanced our ongoing efforts by enabling a comprehensive assessment of water availability, habitat connectivity, and priority habitats using stable isotope "isoscapes." We are using hydrogen and oxygen isotopes to quantify the proportional contributions of snow, rain, and groundwater to seasonal stream flows, while applying Spatial Stream Network and Bayesian mixing models to partition water sources throughout stream networks and assess connectivity. We collected pilot water samples across the basin in May and November of 2024 and will repeat sampling efforts in 2025. The resulting data will help predict how climate-mediated stressors, such as limited water availability, might impact the distribution of native fish populations in the Goose Lake Basin.

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Appendix A: Field Photos



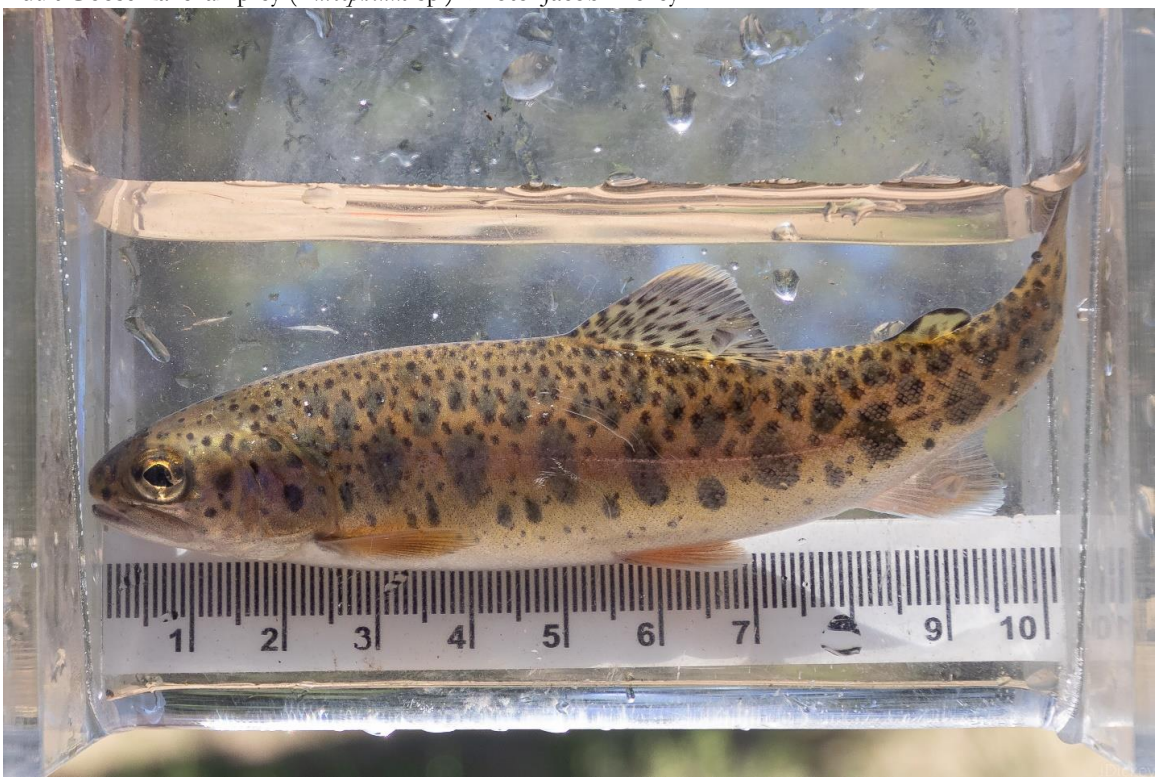
Pit sculpin (*Cottus pitensis*). Photo: Jacob Dickey



Goose Lake Tui Chub (*Siphateles bicolor thalassinus*). Photo: Katherine Carey



Adult Goose Lake lamprey (*Entosphenus* sp.). Photo: Jacob Dickey



Goose Lake redband trout (*Oncorhynchus mykiss newberrii*). Photo: Jacob Dickey



Diet sample collection of a redband trout (*Oncorhynchus mykiss newberrii*). Photo: Katherine Carey



Electrofishing in Drews–High stratum. Photo: Cora Cook



Aleah Dew and Roberto Ponce Velez identify a specimen. Photo: Jacob Dickey



Katherine Carey sorts through invertebrates. Photo: Jacob Dickey



Jacob Dickey collects an eDNA sample. Photo: Katherine Carey

Appendix B: Notes and Errata

Table B-1 Sites that were dropped for the 2024 field season

Site(s)	Stratum	Location	Reason
West-Goose 13	Thomas-Low	Cottonwood Creek, below Cottonwood Reservoir	Received landowner permission in 2024 but site conditions were not conducive for backpack electrofishing (deep, swiftly moving water). Collected eDNA and re-installed a water logger.
West-Goose 03	Thomas-Burned	Cottonwood Creek, above Cottonwood Reservoir	Received landowner permission in 2024 but site conditions did not meet the closure assumption for sampling (braided channel created from downed logs post-fire). Collected eDNA and re-installed a water logger.
Non-Game 23	Drews-Low	Drews Creek, below Drews Reservoir	No fish caught in 2023. Site conditions were not conducive for backpack electrofishing (deep water). Collected eDNA and maintained existing water logger.

Table B-2 Total fish observed by electrofishing in 2024 and at same sites in 2007. Non-native species are denoted with an "NN." 2007 totals do not include number of fish captured via passive sampling methods.

Species	N 2007	N 2024	% Change	2024 Mortalities
Lamprey ammocoete	419	88	-79 %	0
Goose Lake lamprey	1	0	-100 %	0
Pit-Klamath brook lamprey	9	0	-100 %	0
Lamprey (unknown adult)	44	14	-68 %	0
Goose Lake sucker	11	1	-91 %	0
Modoc sucker	0	68	NA	0
Sucker (unknown)	80	29	-64 %	0
Pit roach	298	625	110%	4
Pit sculpin	73	113	55%	0
Speckled dace	1172	2357	101%	26
Goose Lake Tui chub	14	72	414%	0
Redband trout	1651	750	-55%	6
Brook trout (NN)	1	7	600%	1
Brown bullhead (NN)	0	0	NA	0
Crappie (NN)	0	3	NA	0
Fathead minnow (NN)	26	178	585%	12
Pumpkinseed (NN)	0	0	NA	0
Yellow perch (NN)	0	6	NA	0