HYDROLOGY AND CHANGE IN GOLD LAKE BOG

Willamette National Forest, Oregon

By Phillip Goodling

1. Introduction

Gold Lake Bog Research Natural Area is a 656-acre high-elevation wetland system that is home to the largest breeding population of the federally threatened **Oregon Spotted Frog** (*Rana pretiosa*) west of the Cascade crest in Oregon (Fig. 1). The Research Natural Area (RNA) contains a variety of **groundwater dependent ecosystems**, which include "ponds, sedge-dominated fens, sedge-dominated marshes, willow and birch swamps, and seasonally dry grasslands" that are fed by **limnocrene** (pool-forming) springs, by **rheocrene** (downhill-flowing) springs, and by Salt Creek (USDA FS, 2013).

In 2011, the Oregon Spotted Frog Site Management Plan was established to assess the threat of "**alteration of hydrologic regimes; drought; climate change effects; [and] vegetation changes such as succession**" on the RNA, and to monitor water levels and temperature within the RNA (USDA FS, 2011) Futher impetus for this work was to collect water quality data for locations that serve as loafing and feeding sites for Oregon Spotted Frogs and to characterize groundwater-dependent ecosystems within the RNA.

Previous work at this site includes peat coring to collect paleoclimate and paleoflora data (Sea and Whitlock, 1995), investigations on successional encroachment by Christy (2003) and by Doerr (2010), and research by GeoCorps America interns Kelli Parsons (2013) and Julie Scott (2014).

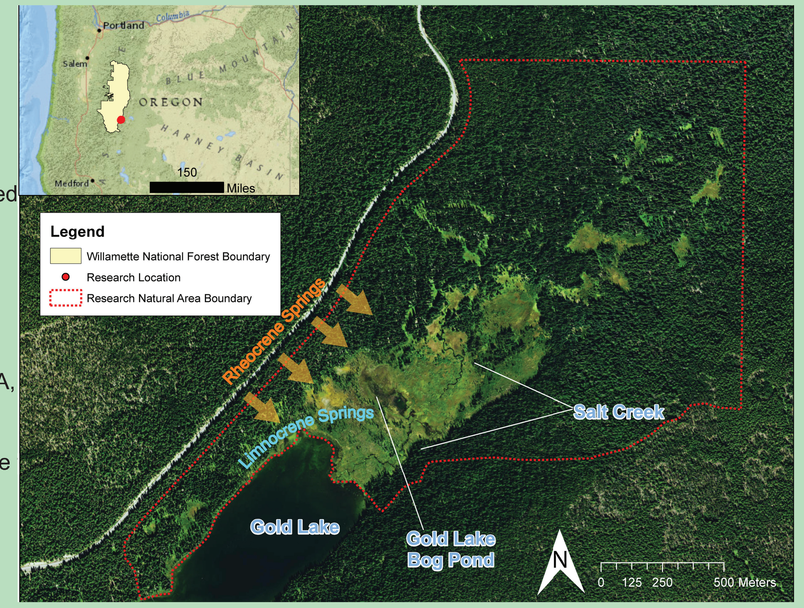


Figure 1- Gold Lake Bog Research Natural Area is located on the southwest edge of Willamette National Forest in Oregon. It is fed by rheocrene and limnocrene springs, and by Salt Creek. The RNA contains a pond called Gold Lake Bog Pond. It drains into Gold Lake, via Salt Creek. The wetland is home to a large breeding population of Oregon Spotted Frog (see left).

2. Research Goals and Methods

a) How much does dissolved ion chemistry vary between water sources within Gold Lake Bog? How much does water level and water temperature vary on seasonal scales in the RNA?

• Twelve samples were collected and submitted to CCAL Water Analysis Laboratory at Oregon State University for **dissolved ion analysis** (Scott, 2014).

• Fourteen HOBO© Water Temp Pro temperature sensors were deployed across the RNA to collect **hourly temperature readings** (Scott, 2014).

• Seven Solinst© LevelLogger temperature and pressure sensors were deployed in seven shallow piezometers installed into the first five feet of peat to collect **daily temperature and pressure readings** (Scott, 2014). Barometric data from HJ Andrews Experimental forest and gaging data was used to convert pressure readings to a water elevation.

b) How is the hydrology of the RNA changing through time? How does that affect the ecosystem?

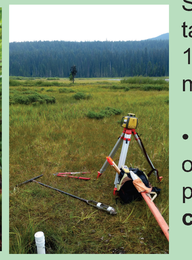
• Following the methods of Drexler et al. (2012), a 65-year record of aerial photography was collected, georeferenced, and the boundary between solid tree vegetation and groundwater-dependent low-lying sedge was drawn in ArcMap 10.1 to **evaluate change in fen area** over time.

• Modeled climate data was downloaded for Gold Lake Bog to assess whether statistically significant changes in climate is expected for the RNA over the 65-year record (PRISM Climate Group, 2015).

c) How much variation in groundwater depth is there within the RNA? Is this a dominant control on species of vegetation in sections of the RNA?

• Using the US Forest Service Groundwater-Dependent Ecosystems Level I Inventory Field Guide (2012) method, a hand auger was used to bore a 3ft-9ft hole at 72 location throughout the RNA and allowed to recharge for at least 24 hours before a **depth to water reading was recorded** using an electric water level tape. A Topcon Auto-laser level was used to record the surface elevation of each point relative to an arbitrary datum. Surface elevation, depth to water, and water table elevation were interpolated in ArcMap 10.1 using the Natural Neighbor interpolation method with a grid size of 5ft.

• During the above survey, dominant species of vegetation was recorded to evaluate a previously- created **map of vegetative species** (Bailey, unpublished).



3. Results

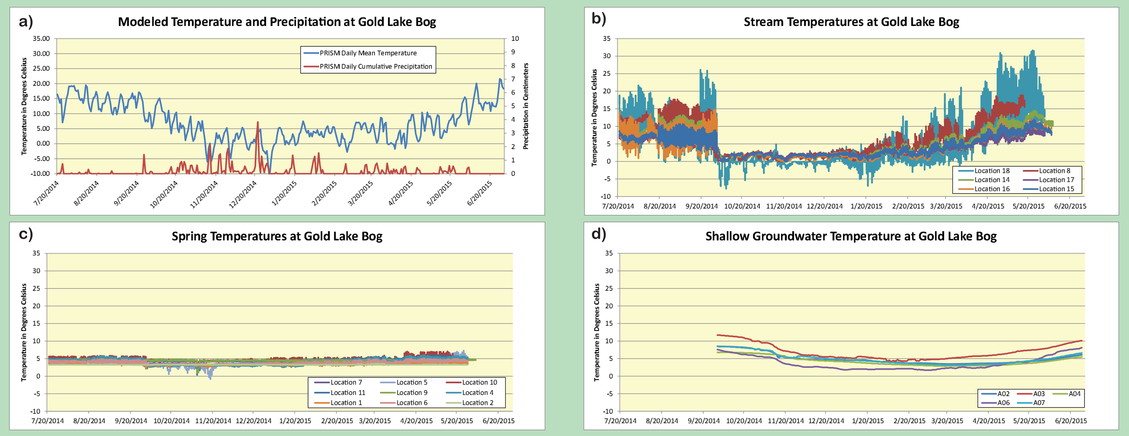


Figure 2. Water temperature variation by water body type. a) Daily mean air temperature and daily cumulative precipitation (modeled by PRISM). b) Stream temperatures (Salt Creek and Ray Creek) flowing into Gold Lake Bog. c) Rheocrene and limnocrene springs in the southwestern portion of the RNA. d) Temperature recorded at five shallow pvc piezometers (total depth = 5ft). Stream temperatures display the greatest seasonal variation, followed by shallow groundwater, and finally, springs. Note: Axes for all four graphs are identical.

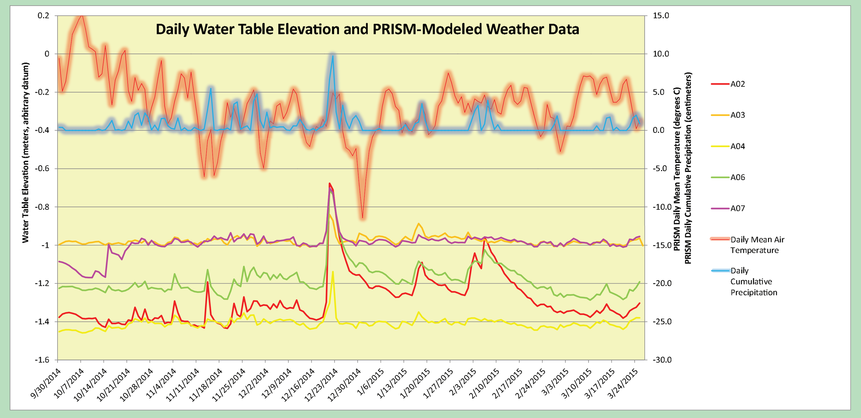


Figure 3. Daily recorded water table elevations (arbitrary datum) in 5 piezometers, plotted with daily mean air temperature and daily cumulative precipitation (modeled by PRISM). The largest cumulative daily precipitation produced a large response in all piezometers. Outside of this event, the water table elevation varies little over this six-month period. Piezometer A02, which is closest to Gold Lake Bog Pond, is most responsive to precipitation events.

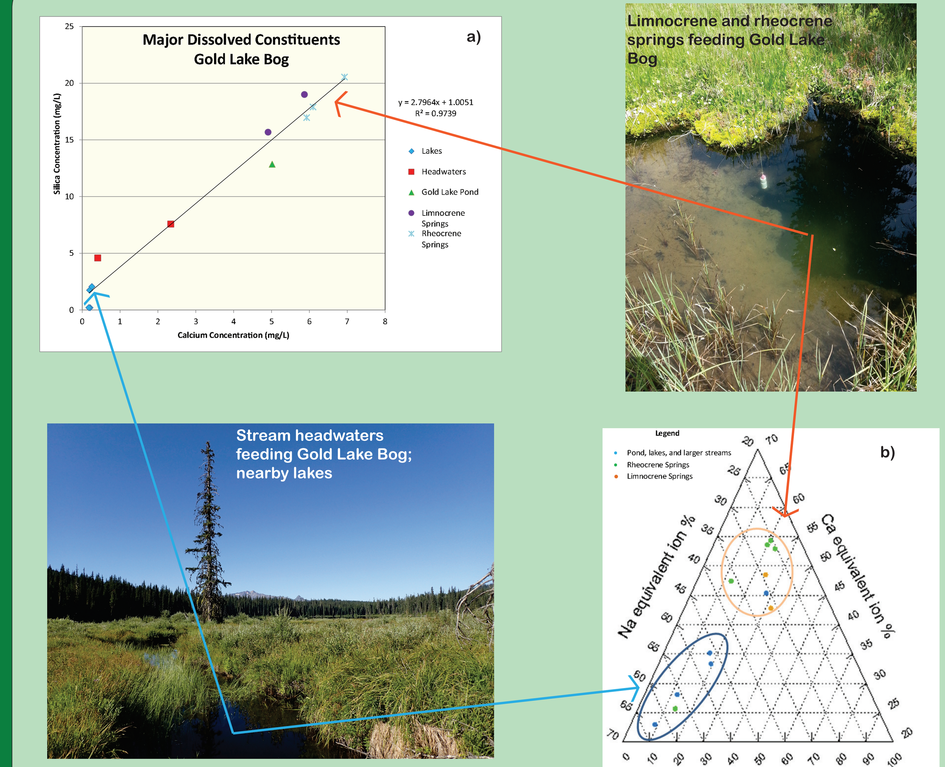


Figure 4. Dissolved ions in Gold Lake Bog water bodies. a) Dissolved calcium and silica show a linear positive correlation, which indicates that the likely source of these ions is likely the volcanic aquifer here. The lower concentration found in lakes and larger streams is closer to that of precipitation than the rheocrene springs and limnocrene springs.

b) Dissolved cations with the greatest range between all samples were plotted on a tri-linear plot. The ions were plotted as a percentage of total dissolved ion equivalents (corrected for ionic mass as described by Hem (1985)). Lakes and stream headwaters tend to have lower relative calcium and magnesium concentrations and higher relative sodium concentrations than the limnocrene and rheocrene springs that feed Gold Lake Bog. Note: groupings are not statistically drawn.

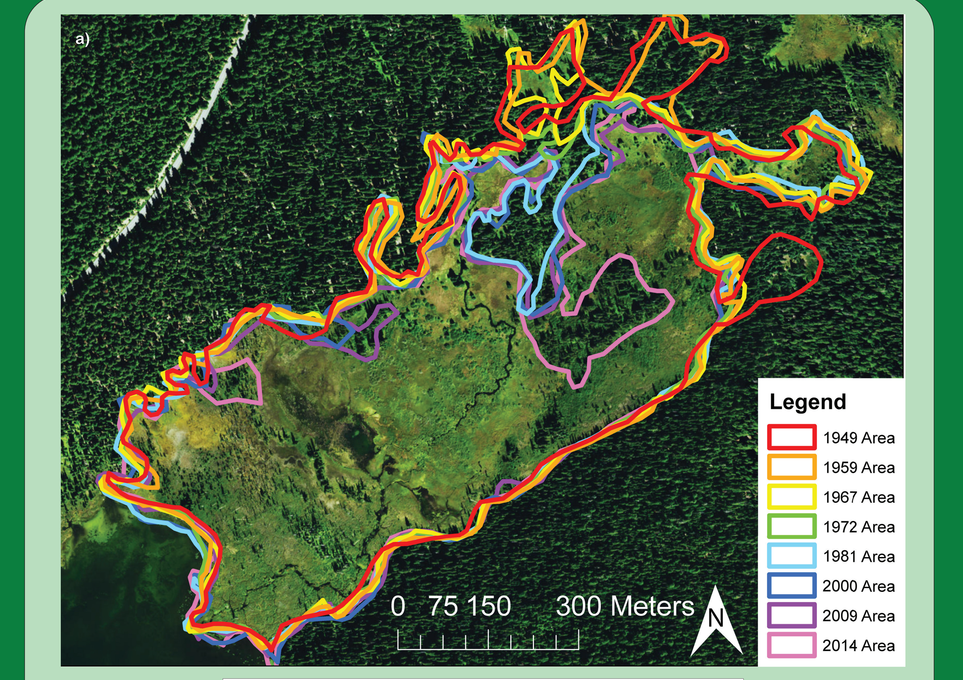


Figure 5. Delineation of fen area using aerial photography. **a)** The area of continuous low-lying sedge vegetation has decreased over 24.7 % over the past 65 years, due to the encroachment of upland tree species. The northern edge of Gold Lake Bog, which has rheocrene spring inputs, has experienced the greatest encroachment, while the southern boundary has stayed constant through time.

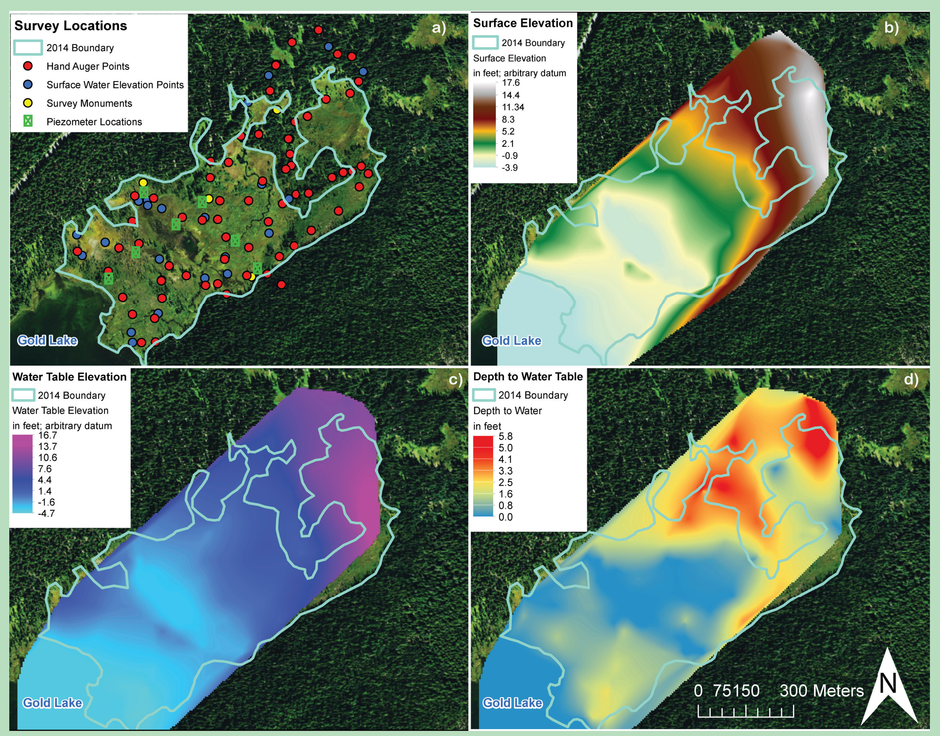


Figure 6. Survey locations used to collect surface and groundwater elevations. First, primary and secondary monuments were established (yellow symbols). **a)** At each location, the surface water elevation (blue symbols) or ground surface elevation (red symbols) were collected relative to the monuments in a series of 5 looped transects. A hand auger was used to core the peat and a 24-hour recharge water table elevation was determined. The survey was conducted over a 10-day period with no precipitation.

b) Elevation was found to slope to the southeast, with an elevation range of 21.5 feet from the highest point surveyed to the elevation of Gold Lake.

c) Water table elevation follows the surface topography in Gold Lake Bog, including a slight drainage divide between the pond in the middle of Gold Lake Bog and Gold Lake. A total elevation range of 21.4 feet was observed in the study area. Both surface water and auger hole-derived groundwater table elevations were included in the interpolation dataset.

d) The depth to the shallow groundwater table is at or near zero feet for much of Gold Lake Bog, despite a survey period in late summer (August 2015). A range in depth to groundwater of 5.8 feet was recorded in the study area, with the deepest water table in the area of greatest intrusion by upland tree species (shown in Figure 5).

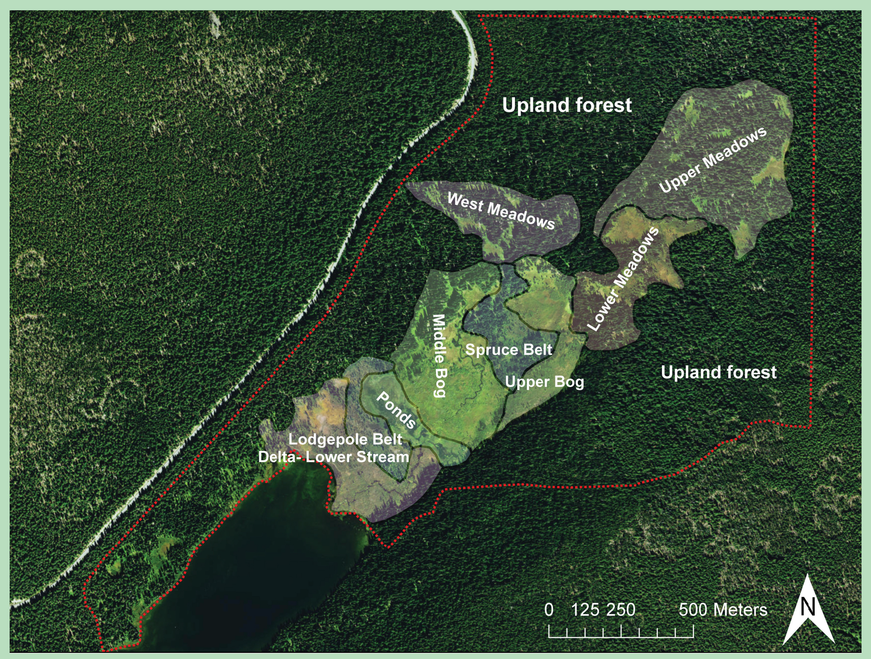


Figure 7. RNA subsections. Gold Lake Bog Research Natural Area was divided into 10 subsections by Bailey (unpublished) using indicator vegetation and hydrologic characteristics of each environment. These subsections were ground-truthed on a field visit with Bailey and using data collected during the 10-day groundwater table elevation survey. Detailed descriptions of each section have been compiled for future use by the National Forest Service. Oregon Spotted Frogs are primarily found in the Delta-Lower Stream, Lodgepole Belt, and Ponds subsections as well as in Gold Lake.

4. Discussion

Gold Lake Bog is highly dependent on groundwater in the form of flowing rheocrene springs, pool-form limnocrene springs, and a shallow peat aquifer to maintain consistent cold and wet conditions suited to the Oregon Spotted Frog. These inputs have a higher dissolved ionic load than the stream inputs, nearby lakes, and ionic precipitation ionic modeled in the area (Nelson, 2000). This suggests that the water from these three inputs has been stored in an aquifer for a longer period, and might be more resistant to temperature changes due to climate change.

In areas of the RNA that are least influenced by groundwater, environmental change has been significant and consistent since 1949. The area of groundwater-dependent ecosystem is decreasing, particularly in the areas named "Spruce Belt" and "Upper Bog."

One possible explanation for the observed changes in ecosystem is decreased groundwater supply to Gold Lake Bog due to decreased snow pack in the Cascade range (a result of anthropogenic global warming). Other potential causes are over-hunting of beaver, (which control water availability by damming) and fire suppression by humans (which may encourage unnatural succession). Areas of the RNA most important to the Oregon Spotted Frog and other sensitive cold water- dependent species remain relatively stable due to the continuing influence of springs.

References

Bailey, Timothy, Personal Communication, 2015.

Christy, J.A., 2003, Summary of vegetation studies, 1960-2002, Gold Lake Bog Research Natural Area. Unpublished Report on file with: Middle Fork Ranger District, Willamette National Forest, 46375 Highway 58, Westfir, OR, 97492.

Doerr, J., 2010, Monitoring Tree and Shrub Encroachment in the Gold Lake Bog Area. Unpublished Report on file with: Middle Fork Ranger District, Willamette National Forest, 46375 Highway 58, Westfir, OR, 97492.

Drexler, J. Z., Knifong, D., Tuil, J., Flint, E., and Flint, A., 2012, Fens as whole-ecosystems of groundwater recharge under climate change: Journal of Hydrology, v. 481, p. 22-34.

Hem, John D., 1985, Study and Interpretation of Chemical Characteristics of Natural Water, U.S. Geological Survey, Water Supply Paper 2254

HJ Andrews Experimental Forest Research Program, 2015, Meteorological data from benchmark stations at the Andrews Experimental Forest, 1957 to present, funded by the National Science Foundation's Long-Term Ecological Research Program (DEB 0823380), US Forest Service Pacific Northwest Research Station, and Oregon State University.

Nelson, Peter O., 2000, Waldo Lake, Oregon Chemical Composition: Major Ions, Buffering Capacity, and Nutrient Loading: Lake and Reservoir Management, v. 16:1-2, p. 52-62, DOI: 10.1080/07438140009354222

PRISM Climate Group, Oregon State University, http://prism.oregonstate.edu, created 6/17/2015

Scott, J., 2014, Gold Lake Bog Hydrological Survey. Unpublished Report on file with: Middle Fork Ranger District, Willamette National Forest, 46375 Highway 58, Westfir, OR, 97492.

Sea, Deborah S. and Whitlock, Cathy, 1995, Postglacial vegetation and climate of the cascade range , central Oregon: Quaternary Research, v.43, p. 370-381

US Department of Agriculture, Forest Service, 1965, Establishment Report, Gold Lake Bog Natural Area, On file with Middle Fork Ranger District, Willamette National Forest, 46375 Highway 58, Westfir, OR, 97492. 53p.

US Department of Agriculture, Forest Service, Willamette National Forest, 2010, Gold Lake Bog, Oregon spotted frog (Rana Pretiosa), site management plan, On file with Middle Fork Ranger District, Willamette National Forest, 46375 Highway 58, Westfir, OR, 97492. 53p.

US Department of Agriculture, Forest Service, 2012, Groundwater-Dependent Ecosystems: Level I Inventory Field Guide: Forest Service Gen. Tech. Report WO-86a, 191 p.

US Department of Agriculture, Forest Service, Willamette National Forest, 2013, Establishment Record Amendment Addition to the Gold Lake Bog Research Natural Area. On file with Supervisor's office, Willamette National Forest, 3106 Pierce Parkway, Suite D, Springfield OR, 97477. 47p.

Image Credits:

Oregon Spotted Frog- http://www.californiaherps.com/frogs/pages/r.pretiosa.html

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Photo: The author (center-left) with four Willamette National Forest district hydrologists and the Willamette National Forest soil scientist during a discussion of soil conservation best practices.