Lake Abert, OR: A Terminal Lake Under Extreme Water Stress

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Western Intermountain Lakes are Dying

Water is life! Searching that phrase with Google brought 1.9 billion results, so there must be something to it. In fact that statement could not be truer than in the arid West. Take for example, Lake Abert in south-central Oregon. In most years the lake has attracted waterbirds in almost countless numbers. In fact, Lake Abert surpassed the Great Salt Lake as having the highest densities of shorebirds on a per area basis. Now, waterbirds and other species dependent on Lake Abert and other terminal lakes throughout much of the intermountain West are at risk from a drying climate and unsustainable water diversions, as is described in this edition of *LakeLine*.

Lake Abert Introduction

Lake Abert is located in the far northwest corner of the hydrographic Great Basin, in Lake County Oregon (Figure 1). In their winter 2011 *LakeLine* article, Larson and Larson described how Lake Abert, a salty and highly alkaline terminal (or endorheic) lake, is one of two lakes that are remnants of Lake Chewaucan, which existed during the Pleistocene epoch. Today, 10,000 years later, the future of Lake Abert is in doubt.

Lake Abert has a watershed of over 850 square miles. Because the watershed is in the rain shadow of the Cascade Mountain Range, the watershed produces little runoff in relationship to its size, and consequently annual water yield averages less than 150 acre-feet per square mile. Its main tributary, the Chewaucan River, drains about 650 square miles.

Lake Abert's hydrology is now dominated by brief periods of rising water levels during infrequent wet years, followed by longer periods of declining water levels due to dry conditions where evaporation exceeds inflows. Because annual evaporation rates from the lake average 40 inches (Phillips and Van Denburgh (1971), it takes only a few years of low inflows to shrink the lake.

History of Lake Abert Water Levels

Within recorded history, Lake Abert reached a maximum elevation of approximately 4,260.5 feet above mean sea level (msl) in 1958, following an unusually wet period (Phillips and Van Denburgh (1971). At that elevation, the lake covered 64 square miles, contained an estimated volume of 500,000 acre-feet, and had a maximum depth of about 15 feet. Decades earlier during the extended drought of the Dust Bowl era of the 1920s and 1930s, the lake was dry or nearly so for 6 years, and reached its lowest documented elevation of approximately 4,245 feet (msl). At that elevation, Lake Abert covered approximately 12 square miles, had an estimated volume of 3,000 acre-feet, and the maximum water depth was only about 2 feet.

Based on the dramatic changes in size, volume, and depth experienced by

Figure 1. Lake Abert looking north from near the south end of the lake (June 16, 2014). Salt deposits are visible along the shore due to the low lake levels and high salinity. The cause of the brown water is unknown but may be precipitated iron.

Lake Abert in the 20th century, it is clear that the lake is a sensitive indicator of hydrologic conditions. This sensitivity is based partially on the balance between precipitation rates in the watershed and evaporation from the lake. However, inflows to the lake are further reduced by upstream agricultural diversions, as well as a storage and evaporation from a private reservoir. Exactly what the impact of these hydrologic alterations is on the lake is unclear because the State of Oregon does not monitor agricultural diversions, nor does it currently measure water levels in the lake. Fortunately, concerned volunteers have monitored water levels, but this has become increasingly difficult because water levels are well below the lowest staff gage (Figure 2). One indication of the possible effect water diversions have on the lake is the fact that water rights from the Chewaucan River upstream from the lake equal a rate sum of over 350 cubic feet per second (cfs), according to data provided on the Oregon Department of Water Resources website. That diversion rate, if fully used, would exceed total flow in the river in most months during most years.

Figure 2. Lake Abert, March15, 2014. The lowest staff gage is on the boulder directly behind the person and water levels were below the gage. By mid-June 2014, the water level was several hundred feet beyond the gage.

Lake Abert Varying Water Chemistry

Not only does Lake Abert experience considerable hydrologic variability, its water chemistry is also changing. In 1963, the lake contained an estimated 13 million tons of dissolved solids and was described as the largest inland saline water body in the Pacific Northwest by Phillips and Van Denburgh (1971). Sodium, chloride, and carbonate are the major ions present in the lake (Van Denburgh 1975). The salinity, which is a measure of total dissolved solids, is inversely related to lake volume, with salinity increasing as lake volume decreases. For example, in 1958, when the lake was at its largest recorded volume, the salinity was 18 g/L (Phillips and Van Denburgh 1971), which is about half that of seawater, which averages about 35 g/L. This is in contrast to the dissolved solid concentration we recently measured in June 2014, when it reached 280 g/L. Once the lake reaches a salinity of between 50 and 100 g/L, it has serious adverse effects to algae, brine shrimp, and brine flies, the primary prey of the waterbirds (Boula 1985; Keister 1992; Herbst 1994; Herbst and Bradley 2004).

Recent Impacts from Drying Climate and Unsustained Water Diversions

In the past decade, Lake Abert has experienced only two years of high inflows – 2006 and 2011. Since 2000, water levels, water volume, and depth in the lake have declined. This has resulted in higher salinities, which has had dire consequences on its ecosystem. Most plants and animals that live in salt lakes have an optimum salinity that is similar to that of the ocean. If the salinity is less, freshwater-adapted species can invade and alter saline ecosystems. And, if the salinity gets too high, it causes osmotic stress, increased energy demands, and consequently productivity and biodiversity are reduced. Additional stress from high salinities can come from reduced concentrations of dissolved oxygen.

That problem was evident in Lake Abert in 2010 when salinities reached about 170 g/L. That summer, brine shrimp (*Artemia franciscana*) turned bright red from high levels of hemoglobin that they produced in response to reduced concentrations of dissolved oxygen. In August of that year the water turned red because dying brine shrimp were concentrated near shore in windrows. That year alkali or shore flies (*Ephydra hians*), which normally are present in vast numbers along the Lake Abert shoreline, were mostly confined to a few areas along the shore where freshwater seeps reduced the salinity. The numbers of migrating waterbirds (e.g., avocets, stilts, phalaropes, sandpipers, gulls, and ducks) was also much reduced from previous years, so it was evident that there was a cascading effect of high salinities that propagated through the food web.

In 2011, conditions improved due to higher inflows that reduced salinities to below 100 g/L, but in 2012, low inflows allowed salinities to increase and in October 2012 they reached 160 g/L. Of more concern were conditions in 2013 when the lake once again experienced a high-salinity-driven ecosystem collapse. Somehow brine shrimp hatched that spring, even though most of the lake was considered too salty to support these invertebrates. Apparently, inflows entering at the south end of the lake reduced salinities sufficiently for brine shrimp to hatch and they apparently survived the higher salinities that they experienced later as the lake mixed. Nevertheless, the shrimp remained small throughout the season, likely a result of osmotic stress and low primary productivity caused by the high salinity. By late July 2013, evaporation caused the salinity to reach 200 g/L, and finally in early August, the brine shrimp died and flies were scarce. Loss of the invertebrate food base evidently caused waterbirds to leave the lake prematurely, because in late July 2013 approximately 350,000 waterbirds, mostly Wilson's phalaropes, were present at the lake, but a month later numbers were less than 3,000 according to data collected by volunteers from the East Cascades Audubon Society and posted on their website (www.eBird.org).

Keith Kreuz, who with his wife Lynn, have harvested brine shrimp from the lake for 30 years, managed to capture a small amount of brine shrimp for his Oregon Desert Brine Shrimp Company, but by August, low harvests forced Keith to halt operations. By September of 2013, the salinity in the lake was nearly 250 g/L, and something happened that hadn't occurred in the lake in over 80 years, salt began precipitating from the saturated brine. Most of this was calcium carbonate ($CaCO_3$), which formed crusts of triangular white or translucent crystals up to half-inch in length over areas of the shoreline (Figure 3), and salt was present on the lake bottom and brine in the sediment.

Figure 3. Calcite crystals up to 0.5 inches long appeared along the shore of Lake Abert in September 2013.

2014 Observations

So far in 2014, the situation for the ecosystem at Lake Abert is even worse than it has been previously except for the extended Dust Bowl era drought. Inflows to the lake over the 2013-2014 winter and spring were minimal with lake elevations only increasing a few inches from the previous fall, and a wide band of alkali-encrusted shoreline was present at both ends of the lake (Figure 4). In the spring of 2014 there was no hatch of brine shrimp and adult alkali flies were confined to freshwater seeps. As a result, Keith and Lynn Kreuz were unable to harvest shrimp, which is the first time this has happened in three decades.

The most recent lake level measurement made in mid-June 2014 indicated that the lake was at 4246.2 feet (msl). The lake has not been that low since 1937.

Figure 4. South end of Lake Abert June 16, 2014, looking west and showing an extensive alkali-encrusted playa forming due to low water levels. The Chewaucan River enters the lake from the left. Flow into the lake was estimated to be less than 1 cubic foot per second.

At the end of July 2014, the lake had receded so far that we were unable to measure the elevation. What remained of the lake had tuned a vivid red color (Figure 5). We believe the red coloration is from salt-loving or "halophytic" bacteria that are also known as extremophiles, because they can survive under very harsh environmental conditions such as the high osmotic stress resulting from extreme salinities. *Halobacterium* is the likely species present in the lake. It has also been reported from the Great Salt Lake, Owens Lake, and the Dead Sea. *Halobacterium* has a red photosynthetic pigment called bacteriorhodopsin. If hydrologic conditions continue, Lake Abert will remain in an ecological state where it can only support halophytic bacteria like *Halobacterium*.

Some aspects of the current state of Lake Abert are not new, since it has likely undergone similar events multiple times in the past. Its biota is adapted to such events and will return once inflows resume and salinities decline. However, past events occurred before the hydrology was impacted by surface and groundwater depletions, and climate change may create a drier climate than has been seen in the recent past.

The current situation at Lake Abert is partially the result of a lack of concern by policy makes and managers charged with protection of natural resources. Lake Abert is a public trust resource that the State of Oregon has responsibility to protect. Finally, Oregon has adopted an "Integrated Water Resources Strategy" that requires the Oregon Department of Water Resources to create an integrated state water resource policy [ORS 536.220(2) (a)]. Lake Abert and adjacent terminal lakes, including Goose Lake and the Warner Lakes, may well be the litmus test of this strategy. We are hopeful, but not optimistic, that implementation of this plan will result in future water-use decisions that consider how Lake Abert and the species that depend on it will be affected. Lake Abert is a watery jewel in a parched landscape that has been a key feeding stopover site for migrating waterbirds. Its future is in our hands.

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Figure 5. South end of Lake Abert July 30, 2014, looking southwest. The lake has receded further from conditions in June 2014 and has taken on a red color believed to be from the halophytic bacterium Halobacterium.

Next Issue –
Winter 2014 *LakeLine*

In our next issue, we look at "Lakes in Winter."
When cold weather arrives,
how do fish, plants, and algae cope?
Does water chemistry change?
Find out next in the winter *LakeLine*.