LAKE WISE

... a voice for quiet waters

NEWSLETTER FROM OREGON LAKES ASSOCIATION

MAY 2022

Theo Dreher, Newsletter Editor

IN THIS ISSUE

Celebrate Lake Appreciation Month with OLA at Suttle Lake on July 16

Join us at Cinder beach Day-Use Area to celebrate sockeye salmon reintroduction to the upper Deschutes River Basin and Suttle Lake, meet with US Forest Service personnel and other OLA members. Join an open-lake swim, check out on-going monitoring at Suttle Lake and enjoy the scenery.

Fall 2022 OLA Conference at Wallowa Lake Co-hosted with Nez Perce Tribe, October 14 &15

Reserve Friday 14 and Saturday 15 October for our joint conference with the Nez Perce Tribe. One day will be dedicated to celebrating sockeye salmon reintroduction and other issues focused on the Wallowa region. We will have the run of the lovely Wallowa Lake Lodge: please consider the Lodge and/or its cabins for accommodation. We'll also make remote attendance via Zoom available. Look for our Call for Abstracts for presentations to fill the second day of our conference as well as registration information.

July is Lake Appreciation Month:
Come celebrate with us at Suttle Lake on Saturday, July 16

Thank you, Governor Brown, for declaring July Lake Appreciation Month in Oregon!

STATE OF OREGON

PROCLAMATION

OFFICE OF THE GOVERNOR

WHEREAS: Lakes and reservoirs are among Oregon's most valuable natural resources; and

WHEREAS: Lakes and reservoirs provide drinking water, irrigation, energy, recreation, scenic beauty, and habitat for wildlife; and

WHEREAS: These beneficial uses have been of vital importance to Oregon's history, growth, and financial health; and

WHEREAS: Our lakes and reservoirs improve the quality of life for all Oregon residents, and their importance should not go unnoticed; and

WHEREAS: The State of Oregon recognizes the need to protect these lakes and reservoirs for future generations.

NOW, THEREFORE: I, Kate Brown, Governor of the State of Oregon, hereby proclaim **July 2022** to be

LAKES APPRECIATION MONTH

in Oregon and encourage all Oregonians to join in this observance.

IN WITNESS WHEREOF, I hereunto set my hand and cause the Great Seal of the State of Oregon to be affixed. Done at the Capitol in the City of Salem in the State of Oregon on this day, February 16, 2022.

Kate Brown

Kate Brown, Governor

Shemia Fagan

Shemia Fagan, Secretary of State

Come join us at Cinder Beach, Suttle Lake on July 16, 9 am to 4 pm

Cinder Beach Day-Use Area is at the east end of Suttle Lake, close to the turnoff from Hwy 20.

Organized by OLA Director Randy Jones

Our celebration at Suttle Lake will be in co-ordination with the Secchi Dip-In held by our parent organization, North American Lake Management Society (NALMS), to mark July each year as Lake Appreciation Month. The Secchhi Dip-In demonstrates how volunteer citizen-scientists/community volunteers can gather important monitoring information on lakes, rivers and wetlands.

9:00 Open water swim: an organized group swim off Cinder Beach suitable for beginning and intermediate swimmers (but wetsuit needed): try it yourself or watch others having fun, led by OLA Director Desiree Tullos

10:00-12:30 Informal talks from US Forest Service and Warm Springs Tribe on:

- the science of managing lake fisheries in the High Cascade Lakes
- reintroduction of sockeye salmon to the upper Deschutes River basin and Suttle Lake.

12:30-1:30 Enjoy your picnic lunch alongside a lovely mountain lake and amid discussions and tales about such lakes *OR* enjoy lunch with a beverage at the adjacent Lodge at Suttle Lake.

1:30-4:00 Visit exhibits, including:

- Portland General Electric, demonstrating its massive investments in basin riparian enhancement, instream flows, and anadromous fish reintroduction as a function of its relicensing efforts at the Pelton/Round Butte dam complex.
- OLA with microscopes to view phytoplankton, with info on harmful algal blooms and our Lake Abert advocacy
- Long-term monitoring data from a buoy near the east end of the lake, showing the results of a time-series, multiple-data acquisition partnership.
- How to use a Secchi disc and other ways in which citizens or volunteers can monitor a lake
- Want to get out on the water? Boat access will be available to get out and grab a sediment sample, take a Secchi disk measurement, or observe Suttle Lake bathymetry.

After 4:00 Consider dinner at The Lodge at Suttle Lake next door.

phytoxigene™

CyanoDTec

Molecular (DNA) based technology (Real Time PCR) that detects and quantifies the presence of Cyanobacteria, blue green algae, and their toxin producing genes in aquatic environments.

2022 OLA Graduate Scholarship Recipient: Kathryn Queen

Kathryn (Katey) is an MS student at the Institute of Watershed Studies at Western Washington University working under the supervision of Prof. Angela Strecker. She is interested in high montane lakes, which are important features scattered across the Cascade Range. Being considered as sentinels of climate change, high montane lakes are likely to see restructuring of their biological communities with profound effects at all trophic levels. Katey will vary inputs of leaf litter and humic substances to learn about the influence of terrestrial inputs on lake zooplankton and physicochemical status. The young ponds formed after the Mt. St. Helens eruption present a unique study site for such experiments.

Congratulations, Katey! We look forward to hearing about your research at a future OLA conference.

Lake Abert Conservation

Lake Abert Conservation Committee, Trish Carroll (chair), Ron Larson,
Tammy Wood, Amy Simpson, Theo Dreher

Recognizing the acute ecological problem presented by the fact that Lake Abert has been all but dry since summer 2021, *The Oregonian/OregonLive* published an article on 16 January, 2022: *Oregon's Lake Abert is in 'deep trouble.' The state shut down its effort to figure out why*, written by Rob Davis. Some of us were interviewed for this article, and Ron Larson's photography was featured.

The *Oregonian* article criticized the inactivity of state agencies with responsibilities to manage water and wildlife in Oregon for not working to protect Lake Abert and its critical role in supporting migratory birds. Those birds rely on the hypersaline lake's masses of brine shrimp and alkali flies to fuel their migration. State agencies have not sought ways to protect water flows and keep the lake from going dry, thereby providing opportunities for new demands on limited Chewaucan Basin water, such as for PacifiCorp's proposed pumped storage hydroelectric generation scheme. More troubling, *The Oregonian's* reporting uncovered apparently deliberate actions within state agencies to stop research into Chewaucan hydrology, particularly into the effect of Rivers End Reservoir on water flows into Lake Abert. This reservoir was built on private land in 1994 with financial support from Oregon Department of Fish and Wildlife (ODFW) and US Fish and Wildlife Service, in support of wetland habitat in its immediate surrounds. However, after it was discovered that dam construction had disturbed a Northern Paiute burial ground, oversight intended to protect waterflows to Lake Abert were abandoned. Intended legal requirements to mitigate impacts to the lake during reduced inflows have never been applied to Rivers End Reservoir operations.

The Oregonian article led to a flurry of concerns from the Governor's office and legislators, reported upon in a follow-up article. The House Interim Committee on Agriculture, Land Use and Water (Rep. Ken Helm, chair, Reps. Susan McLain and Mark Owens, vice-chairs) asked ODFW, ODEQ (Environmental Quality) and OWRD (Water Resources) to present information on Lake Abert and the Chewaucan watershed in a 21 February, 2022, Oregon House hearing. OLA has worked with partners, Oregon Natural Desert Association (ONDA), WaterWatch of Oregon, and National Audubon Society Saline Lakes Initiative to advance discussions about protecting Lake Abert. This group sent a letter to the Governor's Office outlining steps we would like to see taken to protect Lake Abert, after which the Office coordinated a meeting with our group and the state agencies listed above.

Aerial photos of Lake Abert in April 2021 (left) and July 2021 (right). The pink color of the lake in July was due to the presence of hypersaline-adapted microbes that proliferated when the lake became more saline. Photos by Ron Larson.

The renewed attention on Lake Abert also led to the formation of the Chewaucan Watershed Collaborative, which is comprised of local residents and landowners. Rep. Owens organized a field trip for this group with the state agencies to Lake Abert, and the Collaborative has begun an outreach to conservation organizations. Trish Carroll and Theo Dreher represented OLA in a very congenial "get-to-know-you-and-your-thinking" meeting with the co-chairs of the Collaborative, Colleen Withers and Tess Baker, on May 14 in Bend. Meetings with our partners are following, and we hope that such discussions can lead to amicable and constructive changes that will help Lake Abert, while respecting the livelihoods of those living in the Chewaucan Basin.

The OLA Lake Abert Conservation Committee has recently produced a short informational sheet on Lake Abert, with an accompanying annotated list of key references. This paper forms the last 4 pages of this issue of LakeWise.

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Harmful Algae Blooms (HABs) Corner

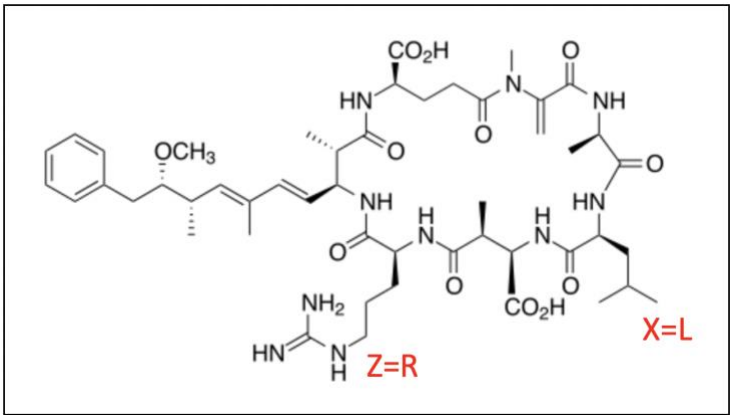
Contributed by Theo Dreher, President, OLA, Professor Emeritus of Microbiology, Oregon State University

New research assessing microcystin toxicity following oral dosing differs from previous results

Chernoff and colleagues at the EPA recently published a couple of articles in the journal *Toxins* reporting on the effects of various microcystin congeners (chemical variants) in mice after oral exposure. Unless direct skin absorption proves to be a significant exposure route, oral dosing is the most realistic comparison to real-world exposure, which would normally occur by water ingestion. These are the first exposure studies using oral dosing.

Chernoff, N. et al., The Comparative Toxicity of 10 Microcystin Congeners Administered Orally to Mice: Clinical Effects and Organ Toxicity, *Toxins* 2020, *12*(6), 403; **https://doi.org/10.3390/toxins12060403**

Chernoff, N. et al., Dose–Response Study of Microcystin Congeners MCLA, MCLR, MCLY, MCRR, and MCYR Administered Orally to Mice, *Toxins* 2021, *13*(2), 86; https://doi.org/10.3390/toxins13020086



Structure of microcystin-LR, with leucine (L) in the X position and arginine (R) in the Z position. There are over 200 variants (congeners) with different amino acids at X and Z and/or changes at other positions.

The new results show that marked differences can exist in the toxicities (via the oral route) between different congeners. Microcystin LA (MC-LA), MC-LR, and MC-LY were toxic at the lowest doses tested. MC-YR induced less severe toxicity, while MC-RR was toxic only at considerably higher levels. The congeners MC-LF, MC-LW, MC-RR, and MC-WR induced few symptoms of toxicity, though the toxicities of these congeners were not tested at higher doses.

These studies are important, because they show a wide range of toxicity associated with oral exposure to different microcystin congeners. Significantly, the toxicity spectrum differs from that deduced after intraperitoneal injection of microcystin, or from in vitro cell exposure or biochemical inhibition assays. All forms of exposure provide useful experimental information, but oral exposure is probably the closest to real-world exposure and therefore of high public health interest.

The range of toxicities associated with different congeners suggests that public health agencies should keep track of which congeners are present in HABs, to allow the best decisions to be made for public health protection.

Congener	NOAEL (mg/kg)	LOAEL (mg/kg)
MCLA	1	3
MCLR	3	5
MCLY	3	5
MCRR	9	22
MCYR	5	7

New toxicity estimates from oral feeding of mice. NOAEL, NO Adverse Effect Level; LOAEL, Lowest Adverse Effect Level.

New research on cylindrospermopsin and microcystin present in recent HABs in Oregon lakes

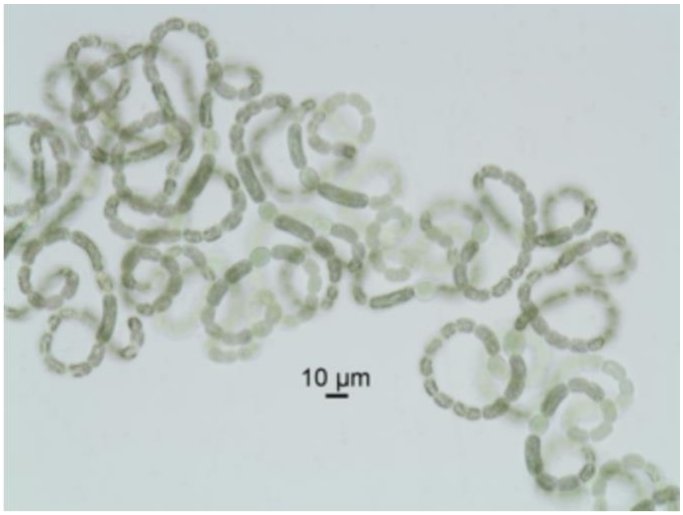
The Dreher lab at Oregon State University has published a study combining genetic and chemical analysis of cyanotoxin occurrences in Oregon Lakes, including Detroit Reservoir, Odell Lake and Lake Billy Chinook.

Dreher, T.W., Foss, A.J., Davis, E.W. II and Mueller, R.S. 7-epi-cylindrospermopsin and microcystin producers among diverse *Anabaena/Dolichospermum/Aphanizomenon* CyanoHABs in Oregon, USA. *Harmful Algae*, 2022, 116, 102241 https://doi.org/10.1016/j.hal.2022.102241

In this paper, we've shown that the cylindrospermopsin variant produced in Detroit Reservoir is actually 7-epi-cylindrospermopsin, which has similar toxicity to cylindrospermopsin itself. The responsible cyanobacterium is *Dolichospermum* sp. DET69, which usually peaks around Memorial Day, but probably persists at low levels through the summer. The form of microcystin detected in Detroit Reservoir was the rather uncommon congener [Dha^{7}]MC-HtyR, which is produced by *Dolichospermum* sp. DET73. This strain has been present during the summer, but also around Memorial Day. These two *Dolichospermum* strains likely account for the occurrences of cylindrospermopsin and microcystin throughout the bloom season, though further studies should be done to see if there are any other significant toxin producers in the lake.

Detroit Dam and Reservoir (Wikipedia)

A different strain of *Dolichospermum*, found both in Odell Lake and Lake Billy Chinook, produces predominantly the MC-LR microcystin congener. *Dolichospermum* strains are common in Oregon lakes, and several, such as those found in Upper Klamath Lake, Diamond Lake, Blue River Reservoir and Dexter Reservoir, are not producers of cyanotoxins. All of these strains are genetically distinct from one another, and they don't even all fall into the same species. *Aphanizomenon flos-aquae* (AFA) strains in Oregon are also widespread, and they genetically overlap with *Dolichospermum*. None of the AFA strains studied have possessed cyanotoxin genes, and AFA, as in Upper Klamath Lake, is thus nontoxic.



Dolichospermum sp. DET69 from Detroit Reservoir, the producer of 7-epi-cylindrospermopsin

Oregon Lakes in the News: Waldo Lake & its history

A focus this year of the Archaeology Roadshow program presented by the Portland State University Anthropology Department has been *The Archaeology of Water*. Check the link for upcoming talks.

A talk on the history of Waldo Lake by historic preservation consultant Paul Claeyssens was scheduled for 18 May but has been postponed: check for rescheduling here. OLA was active in supporting the January 2021 designation of Waldo Lake as an Oregon Outstanding Water Resource, which authorizes DEQ to protect the lake.

Waldo Lake is named for Judge John Breckenridge Waldo, who enjoyed summers at the lake between 1880 and 1907, and later called for its preservation. Happily, this was ultimately successful, despite attempts and plans for development.

Paul Claeyssens wrote a history of Waldo Lake in 2000: Waldo Lake History: Prehistoric Period to Present, *Lake and Reservoir Management*, 16:25-39 https://doi.org/10.1080/07438140009354220

The Oregon Lakes Association Mission

OLA, a non-profit organization founded in 1990, promotes understanding, protection and thoughtful management of lake and watershed ecosystems in Oregon. Serving entirely through volunteer efforts, the Oregon Lakes Association puts on an annual conference, publishes a tri-annual newsletter, sponsors Harmful Algal Bloom trainings, and works as an advocate for lakes in the legislative arena. For additional information on OLA, write to the address above, or visit our website

OLA and *Lake Wise* welcome submissions of materials that further our goals of education and thoughtful lake management in Oregon. OLA is grateful for corporate support that helps sustain the organization. Corporate members are offered the opportunity to describe their products and services to *Lake Wise* readers. These descriptions are not OLA endorsements and opinions appearing in *Lake Wise* are not OLA policy statements.

LakeWise
Oregon Lakes Association
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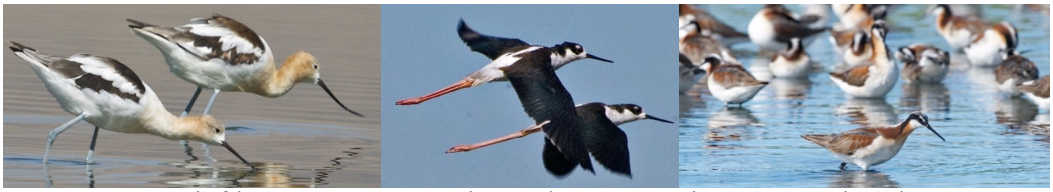
Lake Abert - A Critical Ecosystem Under Threat



American Avocets (left), Black-necked Stilts (middle), and Wilson's Phalaropes (right) are just three of the 80 waterbirds that frequent Lake Abert.

April 2022
OregonLakesAsssociation
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Introduction. Lake Abert is Oregon's only hypersaline lake and one of the state's most important waterbird lakes. Its defining characteristic is its abundant specialized biota of brine shrimp and alkali flies providing a critical food source for migratory waterbirds. The lake is recognized for its international importance for the conservation of American Avocets, Black-necked Stilts, threatened Snowy Plovers, Eared Grebes and Red-necked and Wilson's Phalaropes. In the Intermountain West, the habitat for migratory birds provided by Lake Abert is irreplaceable: only the distant Great Salt Lake and Mono Lake can provide comparable food resources. Refs: 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12.

Figure 1. In 2014, the lake was so salty that it was dominated by red microbes.

Hydrology. The Chewaucan River is Lake Abert's main water source. Historically, the river flowed through marshes before entering the lake, providing freshwater habitat also used by waterbirds. Since the late 1800's, river channelization, Rivers End Reservoir construction, and diversion for irrigation have drastically changed Chewaucan hydrology. Flood irrigation is used to benefit both agriculture and waterbirds, but this habitat benefits birds that have many other freshwater habitat options in eastern Oregon, while preventing water from sustaining the unique habitat of Lake Abert. Refs: 7, 8, 9, 11, 12.

Effects of Chewaucan River Flows on the Lake. Lake Abert was very low or dry during the exceptional drought years of low river flow during the 1930's Dust Bowl era. The only other recent desiccation events have both been in the last decade: 2014-16 & 2021 (Figs. 1, 2). This occurred despite Chewaucan River flows (esp. in 2014-16) not being as persistently low as in the 1930's (Figure 2), suggesting that water diversions have made the lake less resilient to low flows. Refs: 7, 8, 9, 11, 12.

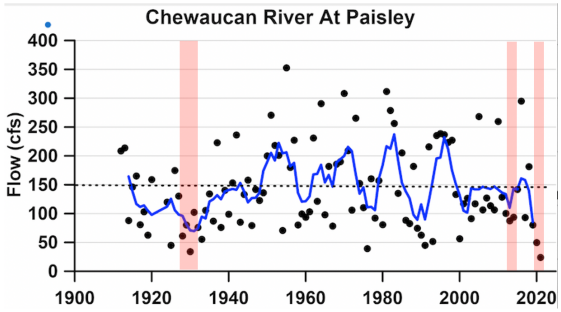

Figure 2. Chewaucan River flow, 5-yr-average (blue line); pink bars: Lake Abert nearly dry.

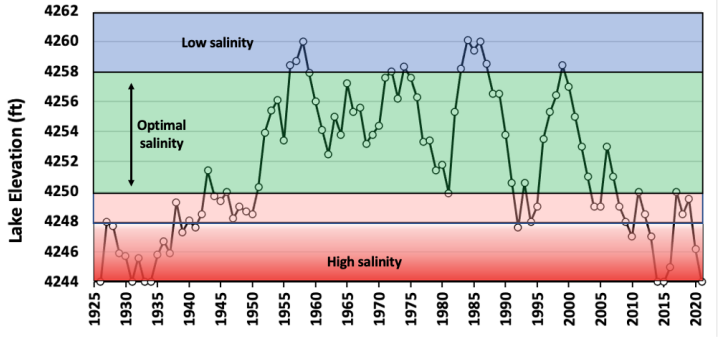

Figure 3. Changes in Lake Abert elevations and ecological salinity zones.

How Lake Abert's Hydrology Impacts the Ecology. The salinity of Lake Abert varies with its water level and that affects the biota (Fig. 3). At elevations of 4250-4258 ft, salinities are optimal for the biota (green in Fig. 3, 2.5-10% salinity). Below a level of ~4248 ft, salinity exceeds 15%, and the brine shrimp and alkali fly populations become progressively more stressed (red in Fig. 3). As water levels approach 4245 ft, it is so saline that only microbes are able to live in the lake. The lake was in the red zone in 2014-2016 and in 2020-2021, and consequently was unable to provide critical food for migratory birds. Refs: 3, 4, 5, 8, 9, 12.

Three aquatic species dominant the lake: left - *Ctenocladus* algae; middle - brine shrimp, and right – alkali flies cover shoreline.

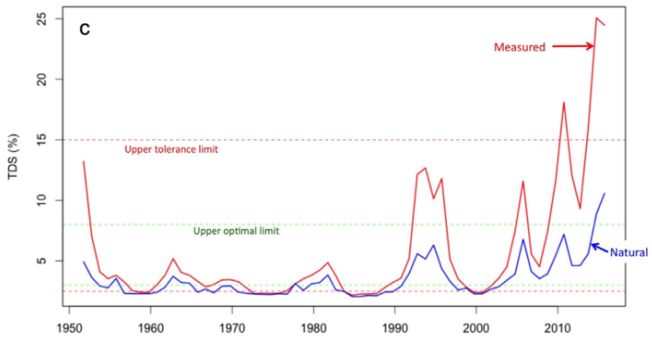

Figure 4. Estimated changes in Lake Abert salinity with/without water diversions. Source: Moore (2016).

Effects of Water Diversions on Lake Abert. The lake ecosystem is in trouble! The salinity has recently been in the red zone (Fig. 3). The cause of the low lake levels and high salinity has been debated. However, Moore (2016) determined that if the lake had received natural inflows with no diversions, salinities would not have reached harmful levels (Fig. 4: Moore 2016, *Science of the Total Environment* 554-555: 142-154). This emphasizes that climate change alone is not the cause of Lake Abert's recent decline. ***Our future water policy decisions can help prevent further desiccation cycles.*** Refs: 8, 9, 12.

Effects of Lake Abert's Water Levels on Birds. The numbers of birds present at one time at Lake Abert have exceeded 300,000. These numbers drop dramatically as the lake gets lower and salinity rises (Fig. 5). The abundance of waterbirds at the lake was especially small in 2014-2016 and 2020-2021, when water levels were very low. Even when the lake recovered in 2017-19, birds numbers did not fully rebound, indicating limited resiliency of the migratory bird population's use of Lake Abert. Preventing further desiccation events and permanent declines in bird numbers is URGENT. Refs: 8, 9, 12.

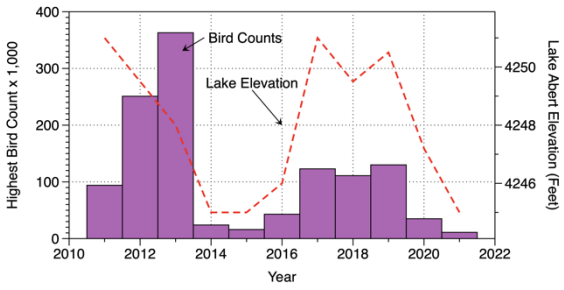

Figure 5. Highest bird counts at Lake Abert 2011-2021. Source: East Cascades Audubon Society.

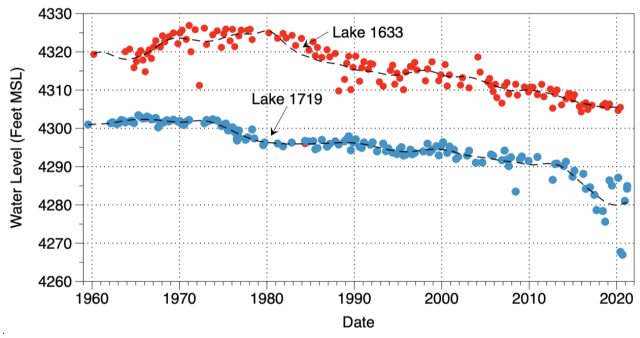

Figure 6. Decline in water levels in two Chewaucan Basin wells. Source: OWRD well-log website.

Management of the Lake Abert Area The Oregon Water Resources Department continues to issue water rights in the basin: however, if fully utilized, over 200,000 ac-ft per year would be diverted, more than the river's annual flow in 96% of the years from 1925-2021. That's clear evidence that the basin's water is over-appropriated. Unsustainable ground-water use has also occurred, resulting in steady aquifer depletion (Fig. 6). Due to the lake's ecological significance and the need to protect it from future water losses, the Bureau of Land Management listed Lake Abert as an "Area of Critical Environmental Concern" in 1996. ***But no action has been taken (State or Federal) to protect the lake.*** Ref: 2.

Conclusions and a Recommendation:

1. The hypersaline habitat of Lake Abert is rare and essential to hundreds of thousands of migratory waterbirds.
2. Water diversions, on top of climate change, have been responsible for the lake's recent desiccation.
3. There is urgency: Lake Abert has been almost dry twice in the last decade; bird populations there have suffered.
4. ***Actions are urgently needed to increase water flow into the lake,*** informed by a comprehensive analysis of Chewaucan Valley/Lake Abert hydrology and ecology. The possibilities include implementing planned Rivers End Reservoir permit conditions; establishing in-stream and in-lake water rights; compensating ranchers to reduce diversions or for other practices that return water to Lake Abert; purchasing and/or leasing water rights; reassessing the value of flood irrigation for wetland habitat and considering a switch to high efficiency irrigation.

References

1. *Boula, K.M. 1986. Foraging ecology of migrant water birds, Lake Abert, Oregon. M.S. Thesis, Oregon State University, Corvallis, OR. 99 pp.* This was the first study of waterbirds at the lake and found that avocets, Eared Grebes, gulls, Northern Shovelers, and Wilson's Phalaropes dominated. Alkali fly life stages predominated in the diet, but brine shrimp were important for shovelers.

2. *Bureau of Land Management. 1996. High Desert Management Framework Proposed Plan Amendment and Final Environmental Impact Statement for the Proposed Lake Abert Area of Special Environmental Concern (ACEC) in Lake County, Oregon.* The BLM recognized that Lake Abert was a rare and critically-important saline ecosystem and therefore determined it should be classified as an ACEC.

3. *Conte, F.P, and P.A. Conte. 1988. Abundance and spatial distribution of Artemia salina in Lake Abert, Oregon. Hydrobiologia 158:167-172.* This paper determined that brine shrimp were extremely abundant in the lake and estimated a lake-wide abundance of 3×10^{11} adults with a total biomass of 7×10^{6} kg.

4. *Herbst, D.B. 1988. Comparative population ecology of Ephydra hians Say (Diptera: Ephydridae) at Mono Lake (California) and Lake Abert (Oregon). Hydrobiologia 158:145-166.* Herbst research focused on the life history and ecology of alkali flies and found that salinity was a critical factor affecting its abundance. The reported observations were consistent with a hypothesis that proposes biotic interactions limit *E. hians* abundance at low salinity, and physiological stress limits abundance at high salinity.

5. *Herbst, D.B. 1994. Aquatic ecology of the littoral zone of Lake Abert: Defining critical lake levels and optimum salinity for biological health. Report prepared for the Oregon Department of Fish and Wildlife and the U.S. Bureau of Land Management, August 1994. 33 pp.* This report identified optimal salinities of 2.5-10 % were necessary to maintain productivity of the lake ecosystem and salinities above 10-15% would reduce productivity and hinder recovery. Lake levels of 4252-4256 would provide maximum for alkali flies.

6. *Jehl, J.R., Jr. 1999. Population Studies of Wilson's Phalaropes at Fall Staging Areas, 1980-1997: A Challenge for Monitoring Waterbirds. International Journal of Waterbird Biology 22(1):37-46.* Jehl determined that the great majority of Wilson's Phalaropes used three saline, Great Basin lakes: Great Salt Lake, Lake Abert, and Mono Lake, before their southward migration.

7. *Keister Jr., G.P. 1992. The ecology of Lake Abert: Analysis of further development. Special Report, Oregon Department of Fish and Wildlife, Salem, OR, April 1992. 34 pp.* This report determined that annual use by shorebirds equaled ~1.7 million use-days for shorebirds and 760,000 for waterfowl, thus showing its importance for these birds. The lake also provided nesting habitat for 40% of Oregon's inland Snowy Plovers. Hydrological modeling showed that diversion of >4,400 ac-ft/y will produce "significant adverse impacts to the lake ecosystem and provided operational alternatives for the River's End Reservoir to minimize effects to the lake.

8. *Larson, R., J. Eilers, K. Kreuz, W.T. Becher, S. DasSarma, and S. Dougill. 2016. Recent Desiccation-related Ecosystem Changes at Lake Abert, Oregon. Western North American Naturalist 76(4):389-404.* These authors found in 2014, Lake Abert, shrank to about 5% of its maximum size, and its salinity increased from 7.5 to 25%. This resulted in a major ecosystem shift from one dominated by invertebrates and waterbirds to one composed primarily of hypersaline-adapted microbes. The primary cause of the event appears to have been the combined effects of upstream water diversions and lower river flows that were exacerbated by a moderate decade-long drought and elevated evaporation rates.

9. *Moore J. 2016. Recent desiccation of Western Great Basin Saline Lakes: Lessons from Lake Abert, Oregon. U.S.A. Science of the Total Environment 554:142-154.* Addressing the 2014-16 lake desiccation episode, Moore found under natural conditions the lake would have higher volume and lower salinities because annual water withdrawals account for one-third of mean lake volume. Without withdrawals, the lake would have maintained

annual mean salinities mostly within the optimal range of brine shrimp and alkali fly growth. Even during the last two years of major drought, the lake would have maintained salinities well below measured values. Change in climate alone would not produce the recent low lake volumes and high salinities that have destroyed the brine shrimp and alkali fly populations and depleted shorebird use at Lake Abert.

10. *Oring, L.W., L. Neel, and K.E. Oring. 2009. Intermountain West Regional Shorebird Plan. U.S. Shorebird Conservation Plan. 55 p.* These authors found that up to 90% of the world's adult Wilson's Phalaropes molt/stage in the intermountain west hypersaline lakes prior to migrating to South America, and that Great Basin saline lakes stand out as being enormously important for both breeding and migrating shorebirds. Of particular importance are the large hypersaline lakes, e.g., Great Salt Lake, UT; Lake Abert, OR and Mono Lake, CA, and the salt lake/playa associated marshes of Utah, Oregon and Nevada.

11. *Phillips, K.N. and A.S. Van Denburgh. 1971. Hydrology and geochemistry of Abert, Summer, and Goose lakes, and other closed-basin lakes in south-central Oregon. Closed-Basin Investigations. U.S. Geological Survey Professional Paper 502-B. 86 pp.* This report described in great detail the hydrology the Lake Abert and developed a water balance of the lake showing that the Chewaucan River was the major source of water. The authors concluded that during droughts, water diversions likely had more of an impact on the lake than occurred as a result of the previous marshes.

12. *Senner, N.R., J.N. Moore, S.T. Seager, S. Dougill, and S.E. Senner. 2018. A salt lake under stress: Relationships among birds, water levels, and invertebrates at a Great Basin saline lake. Biological Conservation 220: 320-329.* These authors found that as the area of Lake Abert decreased and salinity increased during 2014-16, both invertebrate and waterbird numbers declined, with especially high salinities associated with the presence of few waterbirds and invertebrates. The findings reinforce physiological studies showing that both invertebrates and waterbirds can only tolerate a narrow range of salinities.