Implications of Fish Stocking at Waldo Lake, Oregon
by Jessica Bliss

Nearly a century of fish stocking at Waldo Lake, Oregon, has had a visible effect on the lake's limnological properties. The renowned ultraoligotrophic waters of Waldo Lake witnessed an increase in nutrient concentrations, a decrease in zooplankton diversity, and reduced clarity as a result of the introduction of over 20 million fish between 1912 and 1990. Human use of the area has increased considerably over the last 49 years, requiring adjustments to the way Waldo Lake is managed. The termination of fish stocking at Waldo in 1991 suggests a shift in management priorities: recreation in this case did not take precedence over science or conservation. Independent research regarding the lake's unique characteristics complements considerable public interest in maintaining the lake's pristine quality. The combination of these two factors is the primary reason for the continued ban on fish stocking at Waldo Lake.

I. Background: Basic Biology and Settler Use of Waldo Lake

Waldo Lake, the headwaters of the North Fork of the Willamette River, is located approximately 110 km east of Eugene, Oregon, on the north side of State Highway 58. Waldo stretches 9.6 kilometers in length and 2.65 kilometers in width, giving it a total surface area of roughly 26 sq. km and making it the second largest lake in the Oregon Cascades. Its maximum depth (128 m), located at its southern basin, is considerably greater than its mean depth (39 m). Its elevation (1,650 meters above median sea level) and water clarity (Secchi-disk reading 40.5m) classify Waldo Lake as an ultraoligotrophic high-mountain lake (Bronmark 175, Larson 2000: 6). The lake and its

watershed are within the Waldo Lake Wilderness Area, and included in the Oregon Scenic Waterway system (qtd. in Larson 2000: 4).

Early hypotheses about Waldo's geologic history suspected volcanic or glacial-caused basin depression. Although the area was certainly glaciated, it appears that the lake resides in a tectonic basin characteristic of the Central Oregon Cascade Range's fault-block subsidence formations. Intermittent streams, unchanneled runoff, groundwater seepage, and direct precipitation provide the bulk of the lake's water source; its small watershed area produces virtually no permanent surface drainage. Total annual precipitation is just less than 2 meters; combined with an annual evaporation loss of 1 meter, Waldo receives about one meter of precipitation-source input each year. An additional meter of water is contributed by annual snowmelt. The North Fork discharges an average of 24,420 acre-feet per year, which translates into an annual surface elevation variation of less than one meter (Larson 1995: 6).

Roughly 80 percent of the Waldo Lake watershed is forested, namely with mountain hemlock, western hemlock, lodgepole pine, western white pine, Douglas fir, noble fir, true fir, and Engelmann spruce. Mountain hemlock, true fir, and lodgepole pine dominate the immediate area surrounding the lake. Soils are organically poor, highly permeable, and less than 2 meters deep: basalt bedrock is visible at many places around the lake (Larson 2000: 5, personal observation 2003).

Acclaimed for its intense blue color and transparency, Waldo Lake is a marvel to limnologists, biologists, geologists, and the public alike. Its water is incomparably dilute, chemically similar to distilled tap water (Todd). The combined effects of having a small watershed area (barely twice that of the lake's total area), organically poor soils, and a

heavily forested boundary result in a very low amount of nutrient flow into the lake. As a consequence of having low nutrient levels, phosphorous in particular, appositely low rates of phytoplankton production typify Waldo Lake (Bronmark 177). This feature has changed in the last sixty years, as human access and use of the lake has increased.

Waldo Lake was effectively isolated from human activity until the late 1800s, when it appeared on a map prepared by the Surveyor-General of Oregon dated August 24, 1863 (Larson 1995). The U.S. Forest Service granted permission to A.R. Black for the construction of a canal on the lake's natural outlet in 1905; Black later sold the rights to the project to F.N. Ray and Simon Klovdahl in 1908. Ray and Klovdahl intended to monopolize water rights to the entire Willamette Valley using their newly formed Waldo Lake Irrigation and Power Company. Projecting to supply enough water to irrigate 100,000 acres of farmland and to generate 40,000 "horsepowers" of energy, Ray and Klovdahl would've had a significant effect impact on the economic, social, and ecological status of the Willamette Valley had they succeeded. Financial and logistic difficulties led to the demise of the project in 1914, but not before the Klovdahl Tunnel was constructed on the lake's southwestern edge. The tunnel has since been deemed a Natural Historic Place, and stands as a reminder of the first entrepreneurs set on manipulating the lake's natural processes (Claeyssens 21).

The Forest Service took jurisdiction over the Waldo Lake area in 1934; investigations of the lake's limnological properties began shortly thereafter. Fish-stocking practices had occurred somewhat sporadically since 1889, and continued with increasing regularity and intensity until 1990. (Further discussion of fish management issues will follow). Access to the lake improved drastically in 1966, when roads and

lakeside camping facilities were established and expanded. A 13-mile-long paved road between Highway 58 and Waldo opened in 1969; since then, the number of visitors to the area has increased from a few hundred in 1967 to 170,000 in 1994 (Willamette National Forest 2004).

II. Fish Stocking History

Private citizens enacted all fish management for Waldo Lake until the early 1900's, when the Oregon Fish and Game Commission (now the Oregon Department of Fish and Wildlife, ODFW) took over. The first documented fish release into Waldo took place on September 19, 1889, when Judge John Breckenridge Waldo translocated one hundred "small trout" from Crescent Lake (Ziller 144). ODFW began regular fish stocking in 1912.

The ODFW stocked Waldo with rainbow trout, brook trout, kokanee salmon, and cutthroat trout until 1990. Opossum shrimp (mysids) were also released as an additional food source for fish between 1965 and 1967 (Ziller 146, Larson 2000: 9). See Table 1 for a complete listing and timeline of fish releases.

Table 1. ODFW Fish Releases in Waldo Lake

Release Type	Total Number Released	Years
Rainbow trout	7,375,010	1913-1968
Brook trout	10,285,189	1939-1990
Kokanee salmon	1,503,378	1963-1971
Cutthroat trout	425,792	1976-1987
Opossum shrimp	519,000	1965-1967

In 1990, the Eugene-based Waldo Wilderness Council (WWC) accused the ODFW of violating the Clean Water Act of 1972, charging that ODFW needed a National Pollution Discharge Elimination System Permit to release fish into Waldo Lake.

ODFW agreed to abstain from stocking of any kind for five years until a permit could be obtained. The Oregon Department of Environmental Quality (ODEQ) declined to issue such a permit, stating "the existing water quality and water quality values shall be maintained and protected, and classified as 'Outstanding Resource Water of Oregon'" (Larson 1995: 19, WWC). No fish stocking has occurred at Waldo Lake since 1990.

III. Eutrophication of Waldo Through the Lens of Planktonic Species Abundance

Waldo Lake is among the most chemically dilute lakes in the world, and the most-studied ultraoligotrophic lake in the United States. Nitrogen and phosphorous levels suggest high levels of removal or retention in the watershed, leading to low ionic concentrations in the lake itself. An estimated 75-90% of the total nitrogen and phosphorous are removed by watershed or in-lake processes (Nelson 62). Phosphorous concentrations are typically what categorize a lake as oligotrophic, however, other standards may assist in the classification (Bronmark 37). Low planktonic abundance and high water transparency (indicated by the depth at which a white Secchi disk disappears) are two additional methods that have assisted in Waldo's classification as oligotrophic.

Waldo Lake has taken a turn towards eutrophication over the last few decades. Eutrophication, a term to describe the amplified abundance of nutrients, is observable to the human eye in the form of increased primary production and planktonic species density. As nutrient levels increase, so too does phytoplankton primary production. This has variable effects on the production of certain zooplankton species, which, combined with phytoplankton production, reduces clarity and visibility of water. The relationship between this process and fish stocking has been examined in several oligotrophic lakes, most prominently Lake Tahoe, CA, and Flathead Lake, MT (qtd. Larson 2000:14).

In the absence of large populations of planktivorous fish, Waldo's aquatic community was dominated by large zooplankton species, namely *Daphnia rosea*, *Diaphanosoma leuchtenbergianum,* and *Alona sp*. These cladocerans fed on the lake's dominate phytoplankter, *Glenodinium neglectum*, which comprises over 90% of Waldo's total phytoplankton (Salinas 73). When a large zooplankton species is the dominant planktonic herbivore, such as *Daphnia sp.*, freshwater bodies are characteristically oligotrophic (Brooks 239).

When a freshwater body is stocked with a considerable population of planktivorous fish, such as kokanee salmon and various mysid species, large zooplankters are easily preyed on and tend to disappear. Smaller zooplankton species, such as *Bosmina longinostris* and various rotifers, flourish. This tends to characterize the system as eutrophic. The transparency of water when planktonic herbivores are small is considerably less than when the herbivores are large: Secchi-disk visibility in water with large zooplankton is 3.5 times greater than with small zooplankton (Brooks 240).

Of the four limnological studies of Waldo conducted in the late 1960's, two concluded that the lake was "totally devoid" of plankton. The other two retrieved fewer than 1 large zooplankton individual per cubic meter, and neither of these observed a measurable number of small planktonic species. Between 1986 and 1998, large cladocerans (*Daphnia sp*.) became scarce, and were gradually replaced by smaller cladocerans (*Bosmina l.*). By 1991, 55 small zooplankton individuals per cubic meter were gathered (Larson 2000: 15).

Vogel and Li (123) aligned the zooplankton collection data with fish stocking schedules to reveal a suspicious tendency. In 1969, when zooplankton density was at its

lowest, Waldo Lake still maintained low phytoplankton primary production. Kokanee salmon and mysid introductions continued through the early 1970's, and took their toll on the *Daphnia sp*. population. Smaller cladocerans gained a consequent advantage, their populations expanded, and the volume of their excrement has been enough to increase nitrogen and phosphorous levels to a record-high level. Accordingly, primary production of Waldo Lake has increased and led to a trend towards eutrophication.

It is therefore understood that the ecological communities of Waldo Lake have changed substantially during the period of research from 1969 to 1998. The ratio of large to small zooplankton species has shrunk, the overall abundance of zooplankton has increased, and the overall diversity of zooplankton species has diminished (Larson 2000: 15). Although this alteration to the structure and abundance of Waldo's aquatic community was most likely not the primary impetus for prohibiting fish stocking on the lake, it has certainly played a role in demonstrating the potential and realized effects that humans may have on an environment.

IV. The Current State of Waldo: Analysis and Recommendations

There is no reason to suspect that fish stocking will ever resume at Waldo Lake (Swanson, Scott). The grounds for this are multi-fold; however, it can be estimated that the public has played a major role in determining the lake's fate. Whereas increased public demand for lake access led to the 135 km of trail and 205 developed campsites in the area, public interest in maintaining the lake's pristine qualities has also directed management activities (Willamette National Forest 2001). The desire to reduce human impact on the Waldo Lake Wilderness Area is ironically coupled with a desire to increase accessibility, calling for some complicated restrictions.

According to the Willamette National Forest Land and Resource Management Plan, the Waldo Lake area was classified under the Recreation Opportunity Spectrum (ROS) as "Roaded Natural" until 2001. This classification was intended to change to "Semi-primitive Nonmotorized," due to claims from the public that non-electric motorized boats were contaminating the lake (Iwamoto). It has since been shown that the contamination is indiscernible; however, the reclassification will most likely still occur within the next three years, citing noise pollution as sufficient justification (Maben).

Although non-electric motorized boats may not affect the biological communities within Waldo Lake in a way comparable to fish stocking, public interest and involvement in preserving the unique character of the lake is admirable. A survey of 243 lake-users in 2001 revealed that boat motors and water quality were the top two concerns for lake management issues (Willamette National Forest 2001). While the science of eutrophication may not be clear to the majority of lake-users, the desire to return the lake to its natural, pristine state is widespread.

Given the public's genuine desire to reduce human impact on the Waldo Lake Wilderness Area, the current obligations of scientists familiar with Waldo's limnology are education and research. There is very little, if any, outreach education or information readily available to lake visitors. Improving lake user comprehension of Waldo Lake's ecologic properties will increase the chance that the area will indeed recover from a century of high-speed human activity. In addition to education, further research and monitoring of water quality, eutrophication, and ecology within the lake is needed to fully assess the continued impact of fish stocking on ultraoligotrophic waters. The public demand for this information is high, a fact made obvious by the presence and concern of

ever-increasing lake users. The responsibility of conducting and publishing research about Waldo Lake's unique character lies squarely on scientists' shoulders; in this way, the public may continue to enjoy and respect Waldo Lake for years to come.

*As a supplement to this report, I've included the results of an informal survey completed by 20 University of Oregon students. Upon having a conversation with someone who spends a lot of time at the lake, I realized that the reasons for fish stocking might be poorly understood. The survey was meant to investigate students' comprehension of the motivations for the initiation and termination of fish stocking at Waldo Lake. The results of the survey can be found in the Appendix.

Appendix

The Survey:

The purpose of this survey is to assess public understanding of fish management at Waldo Lake, Oregon.

*Waldo Lake is located on the north side of State Highway 58. It has been determined to be one of the purest lakes in the world; its water has the chemical equivalence of distilled tap water.

* Fish stocking refers to the release of fish, either from a hatchery or alternate location, into a waterway. The Oregon Department of Fish and Wildlife began stocking Waldo lake with fish in 1912. Stocking ended in 1991.

1. Have you been to Waldo Lake? Y/N

2. What would you say is the **primary** reason that Waldo Lake would be stocked with fish? (choose one)
   A. For recreational purposes
   B. To replace populations of native fish that no longer exist
   C. To eliminate a non-native species in the lake
   D. To create a larger population of fish for future stocking elsewhere
   E. Because all lakes should have a fish population
   F. Other:

3. What would you say is a good reason to **continue** fish stocking at Waldo Lake? (choose two or less)
   A. For recreational purposes
   B. To replace populations of native fish that no longer exist
   C. To eliminate a non-native species in the lake
   D. To create a larger population of fish for future stocking elsewhere
   E. Because all lakes should have a fish population
   F. There is no good reason
   G. Other:

4. What would you say is a good reason to **stop** fish stocking at Waldo Lake?
   A. Fish stocking disrupts natural ecological processes
   B. The fish don't survive
   C. The expense of stocking the lake is too large
   D. Fish stocking may pollute the water
   E. There were not enough fishermen to make it profitable
   F. There is no good reason
   G. Other:

5. The Oregon Department of Fish and Wildlife has not stocked Waldo with fish since 1990. Why do you think they stopped this practice?
   A. Fish stocking disrupts natural ecological processes
   B. The fish don't survive
   C. The expense of stocking the lake is too large

D. Fish stocking may pollute the water
E. There were not enough fishermen to make it profitable
F. There is no good reason
G. Other:

6. Please briefly describe your experience(s) at Waldo Lake. What did you do while you were there? If you fished, please note if you caught anything and what it was.

Survey Results

1. All 20 subjects had been to Waldo Lake
2. Primary reason for stocking at Waldo Lake:
    20: For recreational purposes
3. Good reason to continue stocking:
    6: To replace populations of native fish that no longer exist
    1: Because all lakes should have a fish population
    15: There is no good reason
4. Good reason to stop stocking:
    16: Fish stocking disrupts natural ecological processes
    1: The fish don't survive
    3: The expense of stocking is too large
    11: Fish stocking may pollute the water
    1: There were not enough fishermen to make it profitable
5. Reason that ODFW stopped stocking:
    12: Fish stocking disrupts natural ecological processes
    4: The fish don't survive
    9: The expense of stocking is too large
    5: Fish stocking may pollute the water
    2: There were not enough fishermen to make it profitable
6. Activities performed while at Waldo Lake:
    6: Kayaked/Canoed
    13: Camped
    9: Swam
    10: Hiked
    1: Scuba diving
    1: Skied
    1: Fished (caught nothing)

Discussion

Given my small, isolated sample size, I don't claim to be able to interpret public comprehension of Waldo Lake fish management effectively. Nonetheless, I found it quite interesting to evaluate my peers' understanding of the issue. I confess that I was surprised with the results I received; most subjects had the basic understanding that fish stocking might have a negative impact on the lake's limnology.

I was particularly surprised that 100% of the subjects identified recreation as the primary reason for fish stocking. Given that few of the subjects are fishermen, I anticipated more diverse responses. It seems to be generally understood that stocking altered ecological balances within the lake, either via pollution or species disruption, and that this was the main reason for its termination.

There appears to be a dominant answer to most of the questions, all these "popular answers" are what I considered the "environmentalist choices" as I wrote the survey. Perhaps this is representative of the reputed liberal perspectives found on the UO campus; more likely, it is due to the fact that most of the people I surveyed are my friends, who spend a lot of time outdoors or in science class. I am pleased to say that all subjects expressed curiosity about the "true" answers.

As for the individual activities performed at the lake, I didn't expect to have only one subject who had attempted fishing. Aside from that, all of those surveyed seem to have participated in fairly typical activities. Certainly my favorite parts of the survey were the comments. Here are a few of the responses:

"I remember cold air, mosquitoes, and brushing my teeth at a sort of well"

"Although the water was pristine, we saw no fish or any other non-plant life"

" I love Waldo Lake, especially when there aren't any people there"

"My experiences at Waldo can only be described as ZEN"

I would like to improve this survey (the questions and answers could use some work), and disperse it to a much wider spectrum of people. It occurred to me that I could potentially use this idea for my thesis project. In that case, a discussion of the results would hopefully be much more insightful and complex. Stay tuned.

BIBLIOGRAPHY

Bronmark, Christer, and Hansson, Lars-Anders. The Biology of Lakes and Ponds. New York: Oxford University Press, 1998.

Brooks, John. Eutrophication: Causes, Consequences, Correctives. Washington D.C.: National Academy of Sciences, 1969.

Claeyssens, Paul G. Private Enterprise and Early Twentieth Century Water Resources Development on Oregon's Second Largest Lake: A Cultural Resource Evaluation of the Klovdahl Tunnel. Willamette National Forest, U.S. Forest Service, 1987.

Iwamoto, Robert I. Decision Notice and Finding of No Significant Impact: Managing Recreation Use on Waldo Lake: Environmental Assessment. Willamette National Forest, 2001. http://www.fs.fed.us/r6/willamette/manage/waldolake/planningdocs/waldo_dn.pdf

Larson, Douglas, and Salinas, John. "Waldo Lake Limnological Investigations: 1986-1995". Independently published,1995.

Larson, Douglas. "Waldo Lake, Oregon: Eutrophication of a Rare, Ultraoligotrophic, High-Mountain Lake." Lake and Reservoir Management 16 (2000): 2-13.

Maben, Scott. "Forest Service again considers ban on gas-powered boats at Waldo Lake." Register-Guard May 12, 2004.

Nelson, Peter. "Waldo Lake, Oregon, Chemical Composition: Major Ions, Buffering Capacity, and Nutrient Loading." Lake and Reservoir Management 16 (2000): 52-62.

Personal observation. October and November 2003.

Salinas, John, and Larson, Douglas. “Phytoplankton Primary Production and Light in Waldo Lake, Oregon. Lake and Reservoir Management 16 (2000):71-84.

Scott, Rick. “Re: Regarding Waldo.” Personal communication. May 9 2004.

Swanson, Rebecca. “Re: Regarding Waldo.” Personal communication. May 10 2004.

Todd, Dennis. Lecture, Clark Honors College, University of Oregon, April 15, 2004.

Vogel, Allan, and Li, Judith. “Recent Changes in the Zooplankton Assemblage of Waldo Lake, Oregon.” Lake and Reservoir Management 16 (2000):114-123.

Willamette National Forest. Content Analysis. 2001. Middle Fork Ranger District http://www.fs.fed.us/r6/willamette/manage/waldolake/planningdocs/analysis.pdf

Willamette National Forest. Waldo Lake Wilderness Area. May 20 2004. http://www.fs.fed.us/r6/willamette/index.html

Waldo Wilderness Council. Waldo Lake. May 15 2004. http://www.uoregon.edu/Nuwc/index2.html *website has various addresses listed

Ziller, Jeffrey, and Wade, Mark. “A History of Fish Management in Waldo Lake, Oregon.” Lake and Reservoir Management 16 (2000): 144-148.