

Spread the Word...NOT the Tui Chub

Restoring Diamond Lake's Water Quality and Trout Fishery Through Invasive Species Removal and Education

The introduction of rainbow trout to the naturally fishless Diamond Lake attracted both wanted and unwanted visitors, resulting in significant changes to the health of the lake and lake-based recreational tourism. As Oregon Fish and Game officials stocked the lake with rainbow trout in the early 1900s, Diamond Lake grew in popularity as a fishing destination. Unfortunately, fishing enthusiasts brought an invasive fish species, the tui chub, to use as live trout bait. (Live bait is illegal in Oregon.) Over time, the exploding tui chub population not only took its toll on the rainbow trout fishery, but also on the overall water quality of the lake. The tui chub fed on larger herbivorous zooplankton—the microscopic organisms in the lake responsible for controlling algae growth—throwing the lake's nutrient cycling processes off balance. As a result, Diamond Lake suffered from excessive growth of toxic algae blooms that increased pH levels and reduced dissolved oxygen (DO) levels. Diamond Lake could no longer support its aquatic life designated use and was often closed for recreation during summer months due to potential health risks.

The Oregon Department of Environmental Quality (ODEQ) initiated the development of a TMDL to help Diamond Lake restore its aquatic life designated use. The TMDL analysis predicted that removing the tui chub from Diamond Lake would restore the lake's nutrient cycling processes and support the aquatic life designated use. Based on the TMDL recommendations, multiple stakeholders from the federal, state, and local levels collaborated to develop and implement a plan to remove the tui chub and restore the trout fishery. The biology and chemistry of Diamond Lake have shown significant improvement due to the removal of the tui chub. As a result, Diamond Lake is now both fishable and swimmable. Currently, Diamond Lake is meeting Oregon's water quality standards and ODEQ expects to remove Diamond Lake from the state's list of impaired waters in the next assessment cycle in 2010.

How are TMDLs at work in Diamond Lake?

Through the technical analysis, the Diamond Lake pH and DO TMDL provided stakeholders with a clearer understanding of the external and internal loads of nutrients affecting the levels of pH, DO, and algal blooms in the lake. The findings of the analysis, conducted using a computer model tailored to Diamond Lake, illustrated the relative contributions of nutrients from streams flowing into the lake and human activity in the watershed (i.e., external loads) versus the lake's nutrient cycling processes (i.e., internal sources). The final TMDL report provided

TMDL at a Glance

Diamond Lake TMDLs- pH and Dissolved Oxygen

(approved April 2007)

www.deq.state.or.us/wq/tmdls/umpqua.htm

Factors causing impairment

Aesthetics, fishing, and water contact recreation designated uses impaired due to elevated pH levels and reduced dissolved oxygen levels from excessive algal blooms

Sources contributing to impairment

Introduction of the tui chub, an invasive fish species, resulting in the removal of native aquatic organisms that typically control algae growth

Restoration options

Tui chub removal and educational efforts to prevent introduction of invasive species

Stakeholder involvement

Umpqua National Forest, Oregon Department of Fish and Wildlife, Oregon Department of Environmental Quality, Partners for Umpqua Watersheds, Oregon Wildlife Heritage Foundation, Oregon Division of State Lands, Oregon Department of Agriculture, Douglas County, PacifiCorp, watershed residents, local businesses, and several other state and federal agencies

Status of waterbody

Restoration of aquatic life designated use after removal of tui chub; anticipated attainment of other water quality standards with potential delisting by 2010

Benefits to stakeholders

Improved water quality, recreational opportunities (fishing, boating, and swimming), and lake aesthetics, as well as increased tourism

What is a total maximum daily load (TMDL)?

It is a study or analysis that calculates the maximum amount of a pollutant that a waterbody can receive and still meet water quality standards. The TMDL establishes a pollutant budget and then allocates portions of the overall budget to the pollutant's sources. For more information on TMDLs, visit EPA's website at www.epa.gov/owow/tmdl.

an explanation of how changes to the biological community found in Diamond Lake due to the tui chub population changed how efficiently the lake cycled nutrients, resulting in excessive algal blooms. The model used in the TMDL analysis estimated the percentage of tui chub that stakeholders would need to remove from the lake to improve the lake's nutrient cycling and restore water quality. In addition, the TMDL analysis revealed that changes in trout stocking densities would also be necessary to attain water quality standards.

Who were the participating stakeholders and key partners?

Development of TMDLs in the state of Oregon is the responsibility of the Oregon Department of Environmental Quality (ODEQ). To develop the pH and DO TMDLs for Diamond Lake, ODEQ worked with key stakeholders and partners at the federal, state, and local levels. TMDL implementation, unlike TMDL development, is in the hands of other stakeholders and partners, depending on the actions recommended by the TMDL. In the case of Diamond Lake, the U.S. Forest Service staff from the Umpqua National Forest and the Oregon Department of Fish and Wildlife (ODFW) led the effort to remove the tui chub from Diamond Lake. Local stakeholders that participated in implementation activities, as well as participated in TMDL development, included watershed residents, city and county agencies and officials, members of local watershed groups and environmental organizations, as well as businesses with a local presence. Key state partners, in addition to ODEQ and ODFW, included the Oregon Division of State Lands, Oregon Department of Agriculture, and the Oregon Department of Forestry. The U.S. Environmental Protection Agency (EPA) is a key federal partner involved in both reviewing and approving the pH and DO TMDL for Diamond Lake, as well as a funding partner providing resources to support implementation.

How did stakeholders participate in the TMDL process?

The overall TMDL process includes the following elements: section 303(d) listing decisions, TMDL development, and TMDL implementation. Each element of the TMDL process provided stakeholders with an opportunity to express concerns and share information about the water quality problems in the Diamond Lake with ODEQ and other key partners. A description of each element of the TMDL process is provided below.

Section 303(d) Listing Decisions

If a waterbody does not meet water quality standards (i.e., numeric or narrative criteria) for one or more pollutants, it goes on a state's 303(d) list. Impaired waterbodies on this list require a TMDL for each pollutant contributing to the impairment. Stakeholders have the opportunity to provide input during the 303(d) listing process. The Umpqua National Forest, administered by the U.S. Forest Service, is the designated land management agency for the properties surrounding Diamond Lake. Staff from the Umpqua National Forest support water quality studies on Diamond Lake. Data collected through these studies indicated water quality demonstrated that Diamond Lake was not meeting water quality standards. ODEQ placed Diamond Lake on Oregon's 303(d) list in 1998 due to high pH and chlorophyll a levels associated with excessive algal blooms during summer months. Diamond Lake also appeared on the 303(d) list in 2004 for the same listings, as well as low DO.

TMDL Development

In 2005, ODEQ initiated the development of the Diamond Lake TMDL to address the resident fish and aquatic life beneficial use impairments caused by excessive algal blooms, increased pH, and low DO levels that do not meet water quality standards. The Diamond Lake TMDL was a component of the overall TMDL development process for the Umpqua Basin.

One of the first steps in developing a TMDL is identifying an appropriate numeric target associated with water quality standards—specifically, the water quality criteria component of water quality standards. Diamond Lake did not meet the numeric water quality criteria for pH and DO. In addition, Diamond Lake did not meet the narrative water quality criteria for aquatic weeds and algae. As a result, ODEQ listed Diamond Lake for all three parameters. Through the TMDL analysis, ODEQ had to identify a numeric target that would take into account attainment of all three parameters. ODEQ discovered through the TMDL development process that Diamond Lake would naturally exceed the pH and aquatic weed water quality standards due to extended periods of above average air temperatures and below average wind velocities. Therefore, ODEQ had to take these factors into account when identifying an appropriate numeric target for the TMDL. ODEQ selected a numeric target of 4,000 kg/yr of cyanobacteria (blue-green algae) biomass for the TMDL. The final TMDL report states that this target provides for the attainment of the pH, aquatic weed, and DO water quality criteria.

Growth of algal blooms results from the excessive levels of nutrients—nitrogen and phosphorus—and usually occurs during mid to late summer when factors such as temperature and lake conditions promote production. As a result, the TMDL analysis for Diamond Lake examined the various sources of nutrients to determine the relative significance. Understanding the sources of nutrients helped to understand the causes of water quality problems in the lake and identify potential implementation strategies. Sources of nutrients to Diamond Lake include both external and internal sources. External sources include natural sources (i.e., nutrients from streams), septic tanks, fish stocking, and fish bait. Of these external sources, the TMDL analysis showed nutrient loads from natural sources to be the most significant. However, the analysis revealed that external sources of nutrients were not the primary cause of Diamond Lake’s water quality problem. The problem stemmed from the internal loads of nutrients—the nutrients recycled within the lake. Modification of the lake’s biological communities by the invasive tui chub led to modification of the lake’s ability to efficiently recycle nutrients, causing excessive algal blooms.

Using computer models, ODEQ simulated conditions in Diamond Lake, including daily fluctuations in flow and water temperature, as well as biological interactions affecting nutrient cycling in the lake. Results from the modeling analysis estimated a current peak production of cyanobacteria biomass of 20,000 kg/year—five times greater than the numeric target established through the TMDL to achieve water quality standards for pH, algae, and DO.

The two sources of nutrients to Diamond Lake are external sources—streams, septic systems, fish stocking, and live bait—and internal loads. The TMDL report contains nitrogen and phosphorus load allocations for these sources. On the basis of the modeling analysis, achieving the numeric target for cyanobacteria in Diamond Lake would require limiting nutrient loads from streams to current levels and reducing nutrient inputs from fish bait, fish stocking and septic systems to 1975 levels. Internal nutrient loads would also require a reduction to 50 percent of the 1975 internal load. The analysis determined that achieving the load allocation for the internal loads would require a 90–100 percent reduction in the tui chub population, as well as a reduction in the stocked trout population. As a result, the TMDL report provides a secondary load allocation of zero tui chub and 440,000 trout per year to achieve the numeric target for cyanobacteria established to attain water quality standards for pH, algae, and DO in Diamond Lake.

During TMDL development for the Umpqua Basin (which includes Diamond Lake) in 2006, ODEQ asked the general public for comments on the proposed TMDL report, as well as the associated Water Quality Management Plan (WQMP). In addition to the

■ Stakeholders Say...

“Anyone working in recreation does it for the satisfaction, not for the money, but it is our livelihood. When your lake has a problem, you get involved to find a solution. Getting involved answered a lot of questions for us about the area. We found a solution that had a huge ripple effect both on the lake’s ecosystem and on our local economy.”

—Rick Rockholts, Manager
Diamond Lake Resort

60-day public comment period, ODEQ conducted four information sessions around the basin and held two formal public hearings. The TMDL report contains over 90 pages of public comments and responses from ODEQ.

TMDL Implementation

The final TMDL report acknowledges a multi-agency workgroup that developed a Diamond Lake Restoration Strategy, including a Final Environmental Impact Statement and a Record of Decision prepared by the Umpqua National Forest. As the designated land management agency, the Umpqua National Forest, is also the lead agency for implementing the Diamond Lake Restoration Strategy. The Diamond Lake Restoration Strategy presents implementation options to restore water quality in Diamond Lake, as well as enhance the recreational fishery. The implementation options contained in the Strategy focus on removal of the tui chub population, as recommended through the TMDL analysis.

Implementation partners, led by the Umpqua National Forest and the Oregon Department of Fish and Wildlife (ODFW), initiated a process to restore the biological balance of Lake Diamond through the eradication of the tui chub and phased restocking of trout. In 2005, partners began reducing the lake water level by 50 percent to remove excess nutrients and decrease the amount of the chemical rotenone needed to kill the tui chub population. Prior to applying rotenone, project partners removed live tui chub using nets. In the fall of 2006, partners added 100,000 pounds of rotenone to the lowered lake and then removed the tui chub carcasses. The process resulted in the removal of approximately 103,000 pounds of tui chub—a population of approximately 98 million—from Diamond Lake.

Trout restocking efforts by ODFW began in spring 2007 and have followed a conservative, phased approach as recommended by the TMDL. Goals for the restocking effort included avoiding high internal nutrient loading, minimizing pressure on zooplankton, and providing a fishery that would attract anglers back to Diamond Lake. In 2007, ODFW restocked Diamond Lake with approximately 184,000 fingerling and catchable-sized trout. The number of restocked trout grew to nearly 286,000 in 2008. Both years the number of restocked trout were well below the target of 440,000 fingerlings recommended in the TMDL. In 2009, ODFW plans to stock 300,000—350,000 fingerlings.

In addition to tui chub removal and trout restocking, the restoration project also includes an important educational component to prevent the reintroduction of invasive species to Lake Diamond by visiting recreational enthusiasts.

The ODFW states that the overall treatment project costs approximately \$6 million in federal, state, county, and private contributions. Financial support for implementation activities, including the water quality monitoring after the lake drawdown and the rotenone application, were provided in part from Clean Water Act section 319 grant monies. Approximately \$166,338 in section 319 funds and state matching funds supported implementation activities, as well as baseline monitoring for the TMDL analysis and database development. EPA also provided \$15,378 of TMDL program funding to support TMDL monitoring.

What is the current status of Diamond Lake as a result of the TMDL process?

Monitoring data collected in Diamond Lake after the removal of the tui chub demonstrate that the lake now supports its aquatic life designated use. To monitor the health of Diamond Lake after the removal of the tui chub, ODFW assessed the lake in 2007 and compiled the 2008 Lake Conditions Index Report. This report uses metrics related to water chemistry and biology to measure changes in the lake's condition. The 2008 report states that Diamond Lake's pH levels are near or below the 8.5 water quality criteria value and DO levels meet the water quality criteria appropriate for Diamond Lake on most days.

In addition, the 2008 report states that chlorophyll a values decreased from a high of 50 µg/L before the rotenone treatment to less than 10 µg/L (the numeric water quality criterion associated with aquatic weeds and algae) after treatment. Figure 1 illustrates the changes in chlorophyll a values in Diamond Lake before and after tui chub removal.

Stocked trout health has also improved since the eradication of the tui chub, according to ODFW assessment data. Before the removal of the tui chub, stocked trout had a growth rate and a survival rate of nearly zero. During the summer of 2007, stocked trout grew an average of two inches per month. ODFW states that trout growth rates are now similar to the growth rates observed in the 1970s and 1980s—the decades known as the *hey days* for fishing in Diamond Lake.

Data from two years after tui chub eradication and trout restocking have shown signs of water quality improvements in Diamond Lake. Benthic organisms, an important food source for mature trout, increased from less than 25 pounds per acre (lbs/ac) in 2004—2006 to 200.6 lbs/ac in 2007 and 168 lbs/ac in 2008. Before treatment of Diamond Lake in 2006, the bio-volume of cyanobacteria was 24,407 cells per milliliter (cells/ml), or 25.7 percent of the bio-volume. Two years after treatment of the lake, the bio-volume of cyanobacteria decreased to 49 cells/ml or 4.9 percent of the bio-volume. ODEQ will use this information and other required data inputs to run the model used in the TMDL analysis to determine how these decreases translate into annual cyanobacteria biomass (i.e., kg/yr) reductions—the numeric target established in the TMDL. The pH of Diamond Lake also decreased from 8.5 to less than 7.8 during this two year period.

How did local stakeholders benefit from the TMDL process?

Removal of the tui chub from Diamond Lake provided the lake's natural nutrient cycling processes to regain its balance. As a result, both water quality and the lake's biological communities showed improvement. It is anticipated that these improvements will lead to Diamond Lake's removal from the state's list of impaired waters in 2010.

In addition to water quality benefits, the restoration of Diamond Lake has benefitted stakeholders in several ways. Additional benefits that followed the restoration of Diamond Lake include:

- **Decreased human health risks.** Before treatment of Diamond Lake to remove the tui chub, state officials closed the lake for recreation during summer months when the toxic blue-green algae dominated the lake. Blue-green algae blooms produce toxins that are harmful to humans and animals. After implementation, blue-green algae went from the dominant algae type in Diamond Lake to only a small percentage of the algal community.
- **Revived tourism to boost local economy.** Diamond Lake is a vital component of the state and local economy because of its world-renowned angling opportunities. Diamond Lake recreational enthusiasts contribute approximately \$3.5 million to the local economy each year. For 13 years, poor fishing seasons plagued the lake, reducing the number of visitors to the Diamond Lake area. Restoring water quality and aquatic communities have helped to also restore Diamond Lake's reputation as a favorite destination for trout anglers. According to ODFW, there were 72,085 angler trips in 2007. These trips generated an estimated \$3.76 million in sales and \$2.57 million in labor income in the area (based on the 2006 value of the dollar). In addition to bringing in tourism dollars, improvements to the lake have also resulted in an increase in job opportunities. The Diamond Lake Resort, the third largest employer in the area, had a staff of 80 when tourism was suffering most and has since increased the staff by over 60 percent due to the boost in lake-based tourism.

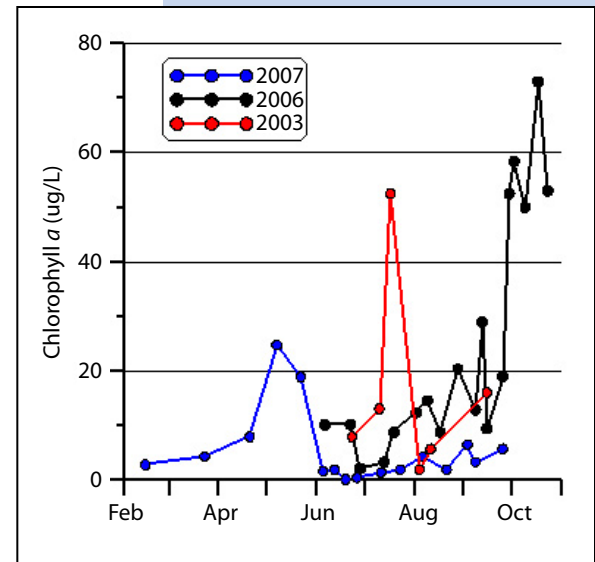


Figure 1. Reduction in algal blooms, as represented by chlorophyll a, before and after chub removal.

- **Improved aesthetics.** Significant reductions in nuisance algae occurred and the lake increased from a visible depth of 10 feet to almost 50 feet after implementation.
- **Increased educational awareness to prevent spread of invasive species.** Several agencies including ODEQ, ODFW, Oregon State Marine Board, and Umpqua National Forest have focused their efforts on education as a means to prevent the spread of invasive species. It is illegal to use live bait for fishing anywhere in Oregon. The educational effort for Diamond Lake reminds visitors of that law through educational brochures and signage around the lake. In addition, partners conducted a boater survey to better understand boaters' habits and perceptions relating to the spread of invasive species. Educational efforts remind boaters and recreational enthusiasts of the simple steps they can take, such as washing boats and fishing equipment, to avoid giving *aquatic hitchhikers* a free ride to Diamond Lake.



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For more information on the Oregon TMDL Program, visit www.deq.state.or.us/WQ/TMDLs/TMDLs.htm