Aquatic Resource Report for the Diamond Lake Restoration Project Environmental Impact Statement

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Report prepared by:

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Aquatic Resource Report for the Diamond Lake Restoration Project - Environmental Impact Statement

Methodology: Preparation of the following report and the EIS input included:

- On-site investigations of the proposed project area and surrounding areas to qualitatively assess the condition of the fisheries, aquatic habitat, & riparian resources, evaluate the effects of past, present and proposed management, and compare the existing conditions to desired future conditions.
- A literature review covering pertinent papers dealing with limnology, removal of exotic fish species, fish piscicides, zooplankton ecology, and aquatic insect ecology.
- Field review and discussions with the interdisciplinary team regarding past and proposed treatments at Diamond Lake.
- A review of pertinent sections of the NWFP FSEIS, S & Gs, and Umpqua National Forest Land and Resource Management Plan (LRMP)
- A review of the Diamond Lake and Lemolo Lake Watershed Analysis (USFS, 1998), the Middle North Umpqua Watershed Analysis (USFS, 1999).
- A review of NMFS' March 18, 1997 Biological Opinion on LRMP/RMP implementation.
- Aerial photography interpretation
- Contact and discussions with numerous experts in the fields of limnology, fisheries biology, and aquatic ecology.
- Close coordination and communication with other members of the aquatic subgroup of the Interdisciplinary Team in order to divide initial analysis and writing responsibilities, and synthesize the final results.

I. INTRODUCTION

The Forest Supervisor of the Umpqua National Forest finds there is a need for improvement of Diamond Lake's water quality and recreational fishery. Eradication or control of the existing tui chub[1] (*Gila bicolor*) population is considered essential for accomplishing these objectives[2].

Water Quality: Diamond Lake currently does not meet State water quality standards, LRMP Management Area goals, or support the "beneficial uses" of the lake. Diamond Lake is included in the Oregon Department of Environmental Quality's (ODEQ) 303(d)

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[1] Tui chub are fish in the minnow family that are not native to Diamond Lake.

[2] Approximately 95% of fish sampled in Diamond Lake in August 2002 were tui chub; this estimate does not include the large number of young-of-the-year tui chub less than 2 cm in length (Eilers and Gubala 2003). It is believed that the tui chub population is negatively impacting water quality at Diamond Lake through its impacts on the aquatic food chain. Diamond Lake has experienced a loss of large zooplankton species over the last decade (Eilers and Kann 2002). Tui chub eat zooplankton. Large zooplankton eat phytoplankton, such as the blue green "algae" *Anabaena flos-aquae* which "bloomed" at Diamond Lake in 2001,2002,& 2003. It is believed that the expanding tui chub population has "overgrazed" large zooplankton species in Diamond Lake and effectively eliminated the "biological control" that previously limited these algae populations (Eilers et al. 2001). This concept will be discussed in detail later in this document.

list of "water quality limited" water bodies for the parameters of pH[3] and algae (ODEQ 1998). The "beneficial uses" for Diamond Lake that are currently negatively impacted by these water quality exceedances include: resident fish and aquatic life, water contact recreation, aesthetics, and fishing (OAR 340-41-0282).

Annual monitoring data by ODEQ and others demonstrates that pH values exceeded standards[4] during the summer season every year from 1992-2002. Similarly, annual monitoring data from 1992-2002 indicate that State standards for algae[5] are not being met at Diamond Lake (JC Headwaters 2003). In the summers of 2001 2002, and 2003, Diamond Lake experienced severe blooms of the cyanobacteria (blue-green "algae") *Anabaena flos-aquae.* This type of algae produces a neurotoxin, that in high concentrations, is harmful to humans and other animals[6]. To protect public health and safety, the Umpqua National Forest, in cooperation with the Douglas County Health Department, closed Diamond Lake to some public uses (wading, swimming, water skiing, and boating) during portions of all three summers. Changes in lake ecology associated with overpopulation of the lake by tui chub are believed to be major contributing factors influencing the development of toxic algae blooms at Diamond Lake[7].

Diamond Lake is identified in the LRMP as a special management area (MA-2). As such, the lake is to be managed for concentrated developed recreation, favoring activities such as resort use, camping, picnicking, visitor information services, boating, fishing, interpretation and developed and dispersed winter sports (LRMP 1990, pgs. 110, 153). Summer-time lake closures which occurred during 2001 and 2002 due to degraded water quality are not compatible with MA-2 goals, are disappointing to some summer recreationists, and have negative economic impacts to some local businesses.

The desired condition for Diamond Lake is water quality that supports the beneficial uses of the lake and meets MA-2 goals. The existing water quality conditions do not meet State standards, do not support beneficial uses of the lake, and do not meet recreation management goals. Therefore, there is a need for improvement of water quality at Diamond Lake.

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[3] pH is a measure of acidity and alkalinity of a solution. A pH of 7.0 is a neutral solution. The pH of natural waters ranges between the extremes of 2 to 12 with 2 being the most acidic and 12 being the most alkaline or basic (Wetzel 1983) .

[4] The applicable water body specific pH standard for Cascades Lakes is 6.0 to 8.5 (OAR 340-41-0285(2)(d)(C)). Early water quality data indicate pH values exceeded this standard for most of the 1970's as well, probably due to the high densities of aquatic macrophytes (algae and aquatic plants) (JC Headwaters 2003).

[5] Development of fungi or other growths having a deleterious effect on stream bottoms, fish or other aquatic life, or which are injurious to health, recreation, or industry shall not be allowed (OAR 340-41-0285(2)(h)). A three-month (summer) average chlorophyll *a* value exceeding 0.01 mg/l (for natural lakes) shall be used to identify water bodies where phytoplankton (floating algae) may impair recognized beneficial uses (OAR 340-41-150(a)).

[6] Human health guidance levels derived from Yoo et al. (1995) and Chorus and Bartram (1999) indicate that when quantities of *Anabeana flos-aquae* contained in water samples reach 15,000 cells/ml it is appropriate to restrict public access for water contact recreation. In 2001, quantities of *Anabeana flos-aquae* reached approximately 600,000 cells/ml and 35,974 cells/ml in 2002.

[7] Eilers et al. (2001a,b) showed a strong correlation between historical changes in the lake and changes in the fisheries. In particular, the greatest increases in *Anabaena* akinetes (spore-like structures produced by this algae) were associated with increases in the tui chub population in both the 1940s/1950s and the 1990s.

The Diamond Lake recreational fishery does not currently meet State management objectives or LRMP Management Area goals. For several decades, Diamond Lake has supported a large and popular recreational trout fishery that is important to the local and regional economy. No natural trout reproduction occurs in the lake, so the Oregon Department of Fish and Wildlife (ODFW) traditionally maintained the fishery in a cost-effective manner, primarily by stocking the lake each year with about 400,000 fingerling rainbow trout.

Recreational Fishery: In recent years, the recreational fishery at Diamond Lake has declined dramatically from a high annual average harvest rate of about 270,000 trout averaging approximately 12 inches in size during the 1963-1978 time period to a 1999 low annual harvest rate of 5,000 trout averaging less than 10 inches in length (ODFW, Unpublished Creel Data). Failure of the formerly successful recreational fishery is attributed largely to changes in the ecology of the lake caused by overpopulation by tui chub (Eilers et al. 2001a; ODFW 2002).

The desired condition for the recreational fishery at Diamond Lake as described in applicable State regulations[8] is:

> Diamond Lake shall be managed for hatchery production under the basic yield alternative of Oregon's Trout Plan (OAR 635-500-0703), which in summary states that the natural productivity of a water-body will be used to grow trout to a harvestable size with or without the addition of fingerling or yearly hatchery trout (OAR 635-500-0115).

Specific fish stocking strategies and harvest goals associated with these regulations are generated through an adaptive management process[9]. Appropriate numeric goals for out-year stocking would be determined by ODFW using existing data and knowledge, ecological indices of lake health (i.e., zooplankton[10] and benthic invertebrate[11] populations), annual fish monitoring data and applicable nutrient loading allocations provided in ODEQ's pending TMDL publication.

LRMP MA-2 goals for the Diamond Lake fishery are general in nature and simply identify that fishing is a recreational activity that should be supported through management activities at the lake (LRMP 1990, pgs. 110, 153). Many members of the public have expressed dissatisfaction with the current recreational fishing opportunities at

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[8] Relevant Oregon Administrative Rules are reproduced in the glossary.
[9] An adaptive management process refers to the practice of implementing a management strategy, monitoring the results, and then adapting the strategy as needed before implementing again.
[10] Zooplankton are very small animals that are suspended in the water column . Freshwater zooplankton are dominated by four major groups: protozoa, rotifers, and two subclasses of Crustacea, the cladocerans and copepods (Mandaville 1997). The larger zooplankton (cladocerans and copepods) are important sources of food for many species of fish.
[11] Benthic invertebrates are invertebrate organisms such as worms, leeches, and snails that live in or on the sediments at the bottom of the lake (Mandaville 1997).

Diamond Lake (Personal observation, Sherri L. Chambers, 2003 Early Public Involvement Process).

The desired condition for Diamond Lake is an ecologically sustainable[12] recreational fishery that meets State standards and LRMP MA-2 goals. The existing fishery does not meet State standards and does not meet recreation management goals. Therefore, there is a need for improvement of the recreational fishery at Diamond Lake.

II. ALTERNATIVES

Detailed descriptions of each of the alternatives are contained in Chapter 2 of the EIS. For additional information regarding these alternatives, please refer to that document. For the purposes of this report, a brief description of each alternative is provided as a general reference for use when evaluating the environmental consequences of each alternative with regard to fish, zooplankton, benthic organism populations, and physical aquatic habitat.

Alternative 1 (No Action) –This alternative serves as the baseline for estimating environmental effects of the action alternatives. No canal reconstruction, lake draw down, mechanical fish harvest, chemical treatment, fish carcass removal, or lake refill would occur. No active measures to improve water quality at Diamond Lake would be implemented. Potentially harmful algae blooms and lake closures would be expected to continue.

ODFW would continue with the existing experimental fish stocking program (100,000 fish) in 2004 and 2005. In 2006, ODFW and the Oregon Fish and Wildlife Commission (OFWC) would revisit the Diamond Lake Fishery Management Plan to determine appropriate stocking. Based on current knowledge and budget, it is expected that ODFW would stock Diamond Lake with 24,000 legal sized rainbow trout on an annual basis in 2006 and beyond.

Alternative 2 (Proposed Action) - Proposed activities include: canal reconstruction, a fall/winter lake draw down, mechanical fish removal and utilization, a September rotenone (fish toxicant) treatment to eradicate tui chub, fish carcass removal and utilization, water management during lake refill period, monitoring, fish restocking, educational activities, and contingency measures for controlling tui chub if they are reintroduced to Diamond Lake in the future.

Alternative 3 (Put and Take Fishery) - Alternative 3 responds to the fish stocking issue. This alternative is designed to provide a "good"[13] recreational fishery that

[12] An ecologically sustainable fishery refers to the concept that fish stocking would be based on ecological indices such as phytoplankton, zooplankton, benthic invertebrate populations, and applicable nutrient loading factors.
[13] In general, a "good" recreational fishery represents a substantial improvement over the current fishery, but would not be expected to achieve the status of an "excellent" fishery such as existed at Diamond Lake during its previous peak period as a recreational fishery.

minimizes potential effects of fish on water quality in Diamond Lake. Alternative 3 is identical to the proposed action except that it would utilize a different fish stocking strategy to restock Diamond Lake following a rotenone treatment.

Alternative 4 (Mechanical/Biological) - Alternative 4 responds to the issues of fish stocking, non-target species, water quality, and wetland ecology. This alternative is designed to avoid effects of a chemical treatment and associated lake draw down on resources while still limiting/controlling the tui chub population to some degree. This alternative does not include a lake draw down so potential impacts to water quality and wetland ecology from a draw down are eliminated; and does not include a chemical treatment so potential impacts to non-target species and water quality from chemicals are eliminated. This alternative includes a modified fish stocking strategy designed to reduce the potential impacts of a recreational fishery on water quality in Diamond Lake.

This alternative includes all of the following components: annual mechanical harvest of tui chub using commercial fishing gear (seine nets, trawl nets, cast nets, gill nets, lampara[14] and beach seines, custom-built traps, or other types of commercial nets, seines, and traps), spawning disruption using electro-fishing boats in the shallow vegetated areas where the chub spawn, and predacious fish stocking in order to provide a biological control to tui chub populations.

Alternative 5 (Modified Rotenone and Fish Stocking) – Alternative 5 responds to the issue of increasing the effectiveness of a chemical treatment, and thereby, the likelihood of successfully removing all tui chub. Proposed activities are virtually identical to those in Alternative 2, and include: canal reconstruction, a fall/winter lake draw down, mechanical fish removal and utilization, a September rotenone (fish toxicant) treatment to eradicate tui chub, fish carcass removal and utilization, water management during lake refill period, monitoring, fish restocking, educational activities, and contingency measures for controlling tui chub if they are reintroduced to Diamond Lake in the future. This alternative differs primarily as a result of the rotenone formulation used. It would result in the use of a liquid rotenone formulation in areas with macrophyte growth, and the powdered form in the deeper, open water areas without substantial macrophytes.

[14] A lampara net is a type of open water seine with tapered ends and a relatively deep, loosely hung center section. The net is set in a circle around the fish school and the two ends are brought together capturing the fish in the middle (Nielsen and Johnson 1989)

III. AQUATIC ENVIRONMENT

AQUATIC BIOLOGY

<u>Relationship to Issues</u>: Understanding the existing condition of Diamond Lake in the context of aquatic biology (algae, aquatic macrophytes, phytoplankton, zooplankton, insects and their interactions) is relevant to the issues of fish stocking, non-target species, and water quality

Zooplankton – Affected Environment

As discussed in the *phytoplankton* section of this document, plankton are defined as generally microscopic plants and animals that float or drift in great numbers in fresh or salt water (Webster's, 1988). Zooplankton are tiny animals living within the water column of a given body of water. The truly planktonic animals (in freshwater lakes) are dominated by three major groups: the rotifers, and two subclasses of the Crustacea, the Cladocera and Copepoda (Wetzel, 1983) (see figure x below). Zooplankton feed upon plant materials (phytoplankton, plant detritus[15], filamentous algae) and other zooplankton, and are in turn fed upon by larger insects and fish. As a result, zooplankton populations are of critical importance to water quality, fish, and wildlife populations in many lake systems.

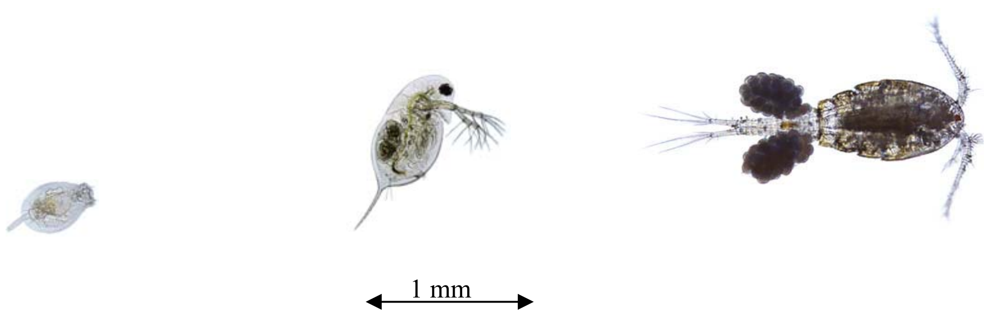

Figure X. Representative examples (and relative sizes) of the three major groups of zooplankton in freshwaters – from left to right - rotifers, cladocerans, and copepods.

<u>Diamond Lake:</u> Based on recent sediment cores[16] taken from the bottom of Diamond Lake (Eilers, 2001a), zooplankton populations are believed to have shifted over time. Prior to the introduction of fish into Diamond Lake around 1910, zooplankton populations were likely very abundant (Eilers, 2001a). Literature and data suggests that

[15] Plant detritus is composed of tiny, loose particles of living and dead plant matter.

[16] Sediment cores taken from lake bottoms consist of cylindrical samples of the bottom materials that have been deposited there over time. These cores possess compounds that allow scientists to date when material was deposited at any given layer in the core sample. Zooplankton and benthic organism body parts, as well as algae cell walls and spores are often preserved in these sediment layers. As a result, lake managers are able to use sediment core data to determine when changes in zooplankton, benthic organism, and algae populations occurred in the past.

pre-fish zooplankton populations in Diamond Lake were dominated by large copepods prior to fish introductions. In support of this theory, Liss et al. (1995) found that other fishless lakes in the Cascades were commonly dominated by large copepods. At some point after fish were stocked in Diamond Lake, the zooplankton community shifted from one formerly dominated by copepods to one dominated by large-bodied[17] cladocerans (also known as daphnia, or water fleas).

Currently, populations of zooplankton in Diamond Lake are now dominated by smaller-bodied animals, like small cladocerans (largely Bosmina species) and numerous rotifers (Vogel 2002, as cited in Salinas). The majority of these species are less than 0.75 mm (0.029 inches) in length (Vogel, personal communication, 2003). This dominance by smaller-bodied zooplankton is likely a direct result of heavy predation on larger-bodied zooplankton by tui chub. O'Brien (1979) found that ". . . the presence of planktivorous fish[18] in large numbers has unequivocally resulted in the elimination or reduction of large-sized species of zooplankton." Numerous other studies (Galbraith, 1967; O'Brien, 1979; Post and McQueen, 1987; Northcote, 1988) have also shown that large populations of plankton eating fish, like the tui chub in Diamond Lake, often result in a zooplankton population structure that is dominated by smaller-bodied individuals. The importance of zooplankton body size is discussed in more detail below.

Importance of Zooplankton to Fish Populations*:* In addition to tui chub, smaller rainbow trout and other salmonids will also feed on larger-bodied forms of zooplankton. Numerous studies (Galbraith, 1967; Baldwin et al, 2000) indicate that salmonids prey upon zooplankton 1.3 mm (0.051 inches) in size or larger. Below this size threshold, zooplankton are generally too small to be heavily utilized by salmonids as a food source. As trout grow, studies have shown that they shift from an exclusively zooplankton diet to one with a much larger component of aquatic insects and other benthic organisms (Luecke, 1986). In cutthroat trout for instance, this shift occurred when the fish attained a size of around 7 cm (or around 2 ¾ inches). In Diamond Lake, the majority of the rainbow trout were stocked as 3 inch (7.6 cm) fingerlings between 1962 and 1990. Although no stomach content data are available for these fish, it is likely that they switched from an exclusively zooplankton diet to one with a larger portion of aquatic insects and benthic organisms[19] shortly after being stocked in the lake.

In most lake ecosystems, salmonids do not generally reach the high densities quickly achieved by minnows like the tui chub. In Diamond Lake, there is very little successful trout reproduction that occurs (see fisheries section). As a result, the majority of the trout biomass in the lake at any given time is closely correlated to the number and size of fish stocked in previous years. Diamond Lake stocking records indicate that an average of around 400,000 fingerling rainbow trout, roughly 3 inches (7.6 cm) in length, were stocked annually from 1962 to 1990. When this number is compared to the current population estimate for tui chub in this same rough size range, approximately 24 million

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[17] Large-bodied zooplankton are those >1.0 mm in length, Medium-bodied are those between 0.75-1.0 mm, and Small-bodied zooplankton are those <0.75 mm (Allen Vogel, personal communication, 2003).
[18] Planktivorous fish are those that prey upon plankton.
[19] Benthic organisms are those that live on or near the bottom of a given waterbody.

(Loomis and Eilers, personal communication), the relative difference in potential impact on the zooplankton population is apparent.

In a study by Bird (1975) tui chub in East Lake (located near La Pine, OR) showed a preference for zooplankton, with 39% of the total food organisms consumed being cladocerans (daphnia). In addition, the same study documented that three of the four food items eaten in greatest quantities by the tui chub (cladocerans, amphipods[20], and dipterans[21]) were also the most preferred food items of trout in East Lake, Oregon. Therefore, there was considerable diet overlap between the two species. Assuming 3 inch trout and 3 inch chub consume zooplankton at approximately the same rate and amount in Diamond Lake, the average population of 7.6 million tui chub in this same size range (see Fish Section) could have a 19 times greater impact on zooplankton populations than the 400,000 rainbow trout fingerlings that had been stocked annually in Diamond Lake for 30 years prior to the discovery of tui chub. In addition, there are also an estimated average of 94.5 million tui chub in younger age classes (young of the year, 1 and 2 year old fish), ranging in size from 6 to 65 mm (¼ to 2½ inches) in length. These smaller fish also feed heavily upon zooplankton (Bird, 1975), and are likely exacerbating impacts to zooplankton populations in the lake.

While trout fingerlings and similar sized tui chub are in direct competition for large-bodied zooplankton, tui chub are likely consuming smaller zooplankton as well. In a study by Schneidervin (1987) in lakes where both trout and minnows were present, results indicated that the minnows preyed heavily upon small, medium, and large bodied zooplankton, effectively removing this potential trout food source before it had a chance to grow to a large enough size for trout to eat. Figure x below (courtesy of J. Eilers) represents an empirical model[22] of the likely relationship between fish and zooplankton size that has occurred in Diamond Lake over the past 90+ years.

[20] Amphipods, also known as scuds, are small shrimp-like crustaceans living on or near a lake or stream bottom.
[21] Dipterans are an insect group that include common flies, midges, and mosquitoes.
[22] An empirical model is one that relies upon or is gained from experiment or observation (Webster, 1988).

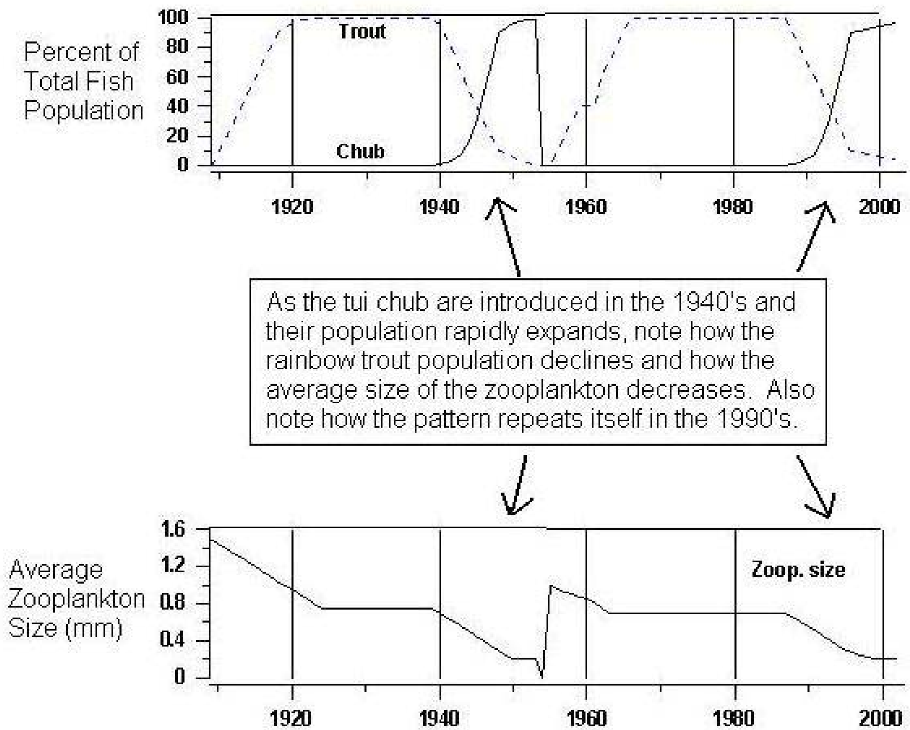

Figure x: An empirical model of the relationship between zooplankton and fish in Diamond Lake

Importance of Zooplankton to Water Quality: Zooplankton can influence water quality in a lake by feeding upon the phytoplankton populations found there. These tiny animals are essentially removing plant particles from the water column to use as food. As a result, zooplankton can have a dramatic effect on water clarity. In general, larger zooplankton individuals are able to capture and utilize larger food particles. As reported by Wetzel (1983), numerous studies have shown that when large-bodied zooplankton are removed from a lake or pond, water transparency decreased as algae populations were able to grow relatively unchecked. The lack of large-bodied zooplankton in Diamond Lake is likely one of the many contributing factors responsible for decreasing water clarity and the unusually large blooms of blue-green algae seen in recent years in the lake.

Another important aspect of the zooplankton's relative contribution to lake water quality is the type of food they tend to feed on. Certain zooplankton feed on a wide variety of algae of different sizes and shapes. Other zooplankton are highly selective in the algal types ingested, and circumstantial evidence suggests that algae releasing toxic organic compounds, such as blue-green algae, are selected against (i.e. not eaten as readily) by zooplankton, regardless of food size and shape. The majority of studies regarding zooplankton feeding rates on toxic blue-green algae indicate that most species of zooplankton reduce their feeding rates when they are feeding in waters with high concentrations of toxin-producing algae (Wetzel, 1983).

As mentioned in the **Phytoplankton** section of this document, in Diamond Lake, different species of phytoplankton exist in many different sizes and forms. In particular, the blue-green algae *Anabaena flos-aquae* often form large strands that are difficult for smaller-bodied zooplankton to utilize as food. In addition, this algae has been known to produce toxins in the lake in certain years. Therefore, the combination of a zooplankton population dominated by smaller-bodied individuals and an algae population dominated by large, toxin producing species may be serving to reduce the overall extent and effect of zooplankton grazing on phytoplankton in Diamond Lake.

In Diamond Lake, it is apparent that blue-green algae populations vary in terms of population size, species abundance, and whether those species produce toxins in any given year (see Phytoplankton section). A complete understanding of these variables in the lake has not been attained, and will continue to be a source of uncertainty regarding future trends of blue-green algae growth. Regardless of the zooplankton relationship with blue-green algae blooms in Diamond Lake, the literature is consistent in that it recognizes that smaller-bodied zooplankton are not as readily able to consume larger-sized colonies of phytoplankton, such as the blue-green algae, *Anabaena flos-aquae*. As a result, the potential for the existing zooplankton populations in Diamond Lake to effectively graze upon large blooms of blue-green algae has been greatly reduced. This reduction in grazing potential is primarily a result of the tui chub induced shift from a larger-bodied zooplankton population, to one dominated by smaller-bodied organisms.

As mentioned above, zooplankton are critically important to water quality and fish populations in lake systems. For more information regarding the relationships between zooplankton, water quality, and fish populations in Diamond Lake, refer to the ***Water Quality*** and ***Fish*** sections of this document.

Zooplankton reproduction and resilience: The reproductive rates and life histories of zooplankton are extremely diverse. Water temperature and food supply are critically important to the rate of zooplankton population development. In general, as water temperature and suitable food supplies increase, the rate of population development also increases (Wetzel, 1983). Environmental stress in the form of decreasing water temperature, shortened day-length, reduced food availability, lack of dissolved oxygen, and increases in predation often trigger zooplankton populations to produce resting eggs[23]. Certain types of resting eggs are typically encased in a heavy cell wall, and are resistant to freezing, drying, and other environmental stresses. In some cases, these resting eggs may float and form large accumulations along windward shorelines, where they may become entangled and transported by birds to other water bodies (Wetzel, 1983). In many cases, these eggs will not hatch until conditions are more favorable (sometimes months or years later).

[23] The production of resting eggs is an adaptation that zooplankton have developed to allow their populations to persist in spite of future environmental uncertainties. These eggs can be produced asexually (by an individual female) or by fertilization between a male and a female.

As a result of the life history traits mentioned above, many species of zooplankton are highly resilient in spite of environmental extremes. Some species can repopulate nearby water bodies through transport by waterfowl, and others can even rebound quickly after the complete drying of small lakes or ponds. In Diamond Lake, it is likely that the existing stresses on zooplankton populations induced by high predation from tui chub, a large proportion of less palatable blue-green algae (ie. less food), and poor water quality conditions have served to increase the development of resting eggs. Theoretically, if the existing environmental stresses in Diamond Lake are removed or reduced, zooplankton populations are likely to rebound strongly. While no specific zooplankton data is available for Diamond Lake immediately following the rotenone treatment in 1954, the highly successful results of fingerling stocking following this treatment tend to support the theory above.

Tributary Streams and Lake Creek: In stream systems, such as Short Creek, Silent Creek, and Lake Creek, zooplankton communities are much smaller relative to lakes. Experiments in streams found that zooplankton prefer low flow areas such as backwaters, pools and the benthic (bottom) boundary layer (Richardson 1992). Very little information is available regarding zooplankton in the streams adjacent to Diamond Lake. Both Richardson (1991) and Shiozawa (1986) found that zooplankton are more abundant in streams where the climate and the stream type promote the formation of pools and the water in the pools is warmed. As mentioned in the Aquatic Habitat Section, habitat surveys in Short, Silent, and Lake Creeks indicated a lack of large quantities of deeper pool habitat. In addition, water temperatures in Short and Silent Creeks are consistently very cold. Therefore, zooplankton populations in these streams are likely to be relatively small, and not a major component of the aquatic organisms living there.

An exception to this general lack of zooplankton occurs in the upper section of Lake Creek, near Diamond Lake. In this area, relatively large numbers of zooplankton are typically carried into Lake Creek by the outflowing waters of Diamond Lake. It is not likely that these lake-adapted zooplankton species would persist for long periods of time in this turbulent stream environment. In addition, the filter feeding component of the aquatic insect community in this area is relatively large, and has presumably adapted to utilize the abundant food resource of zooplankton provided by the lake.

Lemolo Reservoir: Limited information is available regarding the zooplankton population in Lemolo Reservoir. Samples taken in 1992 indicated that the population consisted mainly of cladocerans, copepods, and rotifers. Total zooplankton densities were considered to be quite low, however the species composition was characteristic of a mesotrophic[24] lake with moderate amounts of organic material (A. Vogel, as cited in PacifiCorp, 1995). A likely factor causing the low densities was reduced food quality due to the dominance of blue-green algae. The large cladocerans *Daphnia galeata mendotae* and *D. pulicaria* were relatively abundant. Their presence in moderately high numbers was indicative of low planktivory by the fish community (Pacificorp, 1995). In

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[24] A mesotrophic lake is one with a moderate level of biological productivity. A mesotrophic lake is capable of producing and supporting moderate populations of living organisms.

support of this, Mills and Schiavone (1982) found that generally, in lakes where predation is successfully controlling planktivore density, the mean body lengths of crustacean zooplankton are greater that 1.0 mm (0.039 inches).

Although tui chub are also present in Lemolo Reservoir, they do not reach the high densities seen in Diamond Lake (see Fish section). Therefore, in Lemolo Reservoir, tui chub apparently do not impact zooplankton populations to the extent seen in Diamond Lake.

North Umpqua River (from Lemolo Reservoir to Rock Creek): As mentioned in the Tributary Streams section, zooplankton are not thought to be a major component of invertebrate populations in stream systems. In the free-flowing sections of this river below Lemolo Reservoir, the consistenly cold water is likely one of the key factors limiting stream-adapted zooplankton populations.

In the larger reservoirs below Lemolo, such as Toketee Reservoir and Soda Springs Reservoir, it is likely that zooplankton populations represent a larger component of the overall aquatic invertebrate populations found in those areas. However, no specific information could be found regarding zooplankton populations in those respective water bodies. Based on this lack of information, it is assumed that zooplankton populations in these reservoirs are somewhat similar to the populations seen in Lemolo Reservoir.

ENVIRONMENTAL EFFECTS ON ZOOPLANKTON

Effects of Rotenone on Zooplankton: Based on laboratory bioassays performed on various zooplankton, it is expected that at least 50% of the cladocerans and copepods would die from exposure to the rotenone concentrations commonly used in fisheries work (0.5 ppm and up) (Bradbury, 1986). The action alternatives that propose to use rotenone in Diamond Lake (Alts. 2 & 3) would result in concentrations of 2 ppm of the Pro-Noxfish formulation. Kiser (as cited in Bradbury, 1986) found that the greatest reduction in total zooplankton counts came between 15 minutes and one hour after treatment began. During this time, mid-water zooplankton numbers dropped by 70%. In 16 of 19 studies reviewed by Bradbury (1986), zooplankton numbers were reduced by 95-100% shortly after rotenone treatment.

Although zooplankton populations are drastically reduced immediately following rotenone treatment, these communities do recover in almost all cases. Even in those lakes where not a single living plankter appeared in the post-rotenone samples, enough escaped or survived treatment to eventually repopulate the lake (Bradbury, 1986). Some zooplankton escape treatment in densely weeded areas where rotenone is quickly detoxified (Almquist 1959, Kiser et al 1963 – as cited in Bradbury, 1986). Others may survive simply by virtue of their tolerance to rotenone. Certain zooplankton may survive by means of tough resting eggs which are unaffected by rotenone (Bandow 1980; Anderson 1970; Kiser et al 1963 – as cited in Bradbury, 1986).

There is normally a period of 2 to 12 weeks following rotenone treatment during which there are no crustacean zooplankton in the open water. Rotifers, although reduced in number, were never absent in the studies reviewed. Following this period, zooplankton populations rebuild quickly. Zooplankton communities in most lakes eventually return to their pre-rotenone levels of abundance and diversity. During the period where no fish are present, the zooplankton community structure often shifts to one dominated by larger-sized cladocerans (daphnia). This complete recovery takes between two and twelve months after rotenone treatment (Bradbury 1986).

Direct Effects – Diamond Lake: Alternative 1 (No Action) and Alternative 4 (Mechanical/Biological) are not likely to have any direct effects on zooplankton populations in Diamond Lake. Under these alternatives, there are no alterations of lake water levels and no additions of chemicals to the system, which would be the primary source of a direct effect on zooplankton. Stocking of trout under these alternatives is not expected to directly impact zooplankton populations due to the fact that they are currently being heavily impacted by tui chub. As mentioned above, due to the heavy predation on zooplankton by tui chub, there are virtually no zooplankters in the lake of a large enough size to be utilized by salmonids.

Alternative 2 (Proposed Action), Alternative 3 (Put and Take Fishery), and Alternative 5 would each be likely to directly affect zooplankton populations. In each case, the primary impact would be a result of lake draw-down and chemical additions to the lake. The actions of canal reconstruction and wetland expansion are not expected to measurably impact zooplankton populations due to the relatively small size and short-term nature of these actions (2-3 weeks). The drawdown portion of the project (Alts 2, 3, and 5) would result in an approximate 30% reduction in total water volume in the lake. As this water is draw down, a portion of the existing zooplankton population would be carried downstream with it, thereby removing a portion of zooplankton biomass from the lake. Of more importance, the direct effect of rotenone addition to Diamond Lake would result in a relatively quick decline in mid-water zooplankton numbers, with populations being severely reduced. Kiser (as cited in Bradbury, 1986) found that the greatest reduction in total zooplankton counts came between 15 minutes and one hour after treatment began. As mentioned above in the Affected Environment section, in 16 of 19 studies reviewed by Bradbury (1986), zooplankton numbers were reduced by 95-100% shortly after rotenone treatment.

Indirect Effects – Diamond Lake: Under Alternative 1, zooplankton populations would continue to be preyed upon by the large population of tui chub. This would result in the continued suppression of average zooplankton body size and overall species diversity.

All action alternatives are likely to have varying levels of indirect effects on zooplankton populations. Following the drawdown and chemical treatments associated with Alternatives 2, 3, and 5, zooplankton populations would rebound strongly during the brief period without fish in the lake, but in succeeding years would be primarily influenced by the fish stocking strategies used. After the complete eradication of all fish from Diamond Lake and the period of time allowed for recovery of the base aquatic ecosystem (i.e.

zooplankton, aquatic insects, etc.), zooplankton populations would be expected to return to a state similar to that predicted prior to fish introductions in the lake (i.e. large proportion of large-bodied cladocerans and copepods). In addition, under Alternatives 2, 3, and 5, zooplankton population recovery would be further enhanced in the spring months due to the presence of ample nutrients resulting from natural sources, as well as nutrients derived from remaining decaying aquatic organisms (zooplankton and benthic organisms) and fish carcasses that were missed during carcass recovery efforts.

In the absence of fish predation, populations would recover in terms of total numbers, general species diversity, and a dramatic increase in the average size of zooplankton. (Bradbury 1986; CDFG 1994). Once salmonids are stocked back into the lake, they would again become the primary predator on zooplankton. Salmonid stocking under Alternative 2 would be conservative at first, with relatively small numbers of fish stocked (estimated to be approximately 100,000 fingerlings, and 10,000 legal sized rainbow for the first year following chemical treatment). Initial salmonid stocking under Alternative 5 would also be conservative, with an estimated stocking of 50,000-100,000 fingerlings, 10,000-25,000 catchable-size predacious trout. Close monitoring of zooplankton numbers and size indices would be carried out annually to ensure that the stocked fish are not overgrazing zooplankton populations. Under these alternatives, zooplankton populations would likely mimic the pattern expressed in the empirical model above (figure x), experiencing a slight decrease in the average size of individual zooplankters, but not the dramatic shift in community size and structure that is believed to have contributed to recent blooms of blue-green algae, and corresponding water quality problems in the lake.

Under Alternative 3, zooplankton populations are not expected to be dramatically influenced by the large numbers of catchable-sized fish stocked in the lake. The fish proposed for use in this alternative would be domesticated rainbow trout from the Washington State Trout Lodge stock (a mix of Kamloops and other rainbow stocks). Trout from this broodstock would not reproduce successfully in Diamond Lake, would not prey significantly on available food organisms, and the majority would not survive through the winter (D. Loomis, ODFW, personal communication). Therefore, in the absence of any substantial predation on zooplankton, it is likely that zooplankton populations would experience a dramatic recovery in terms of species diversity, numbers, and average size.

Under Alternatives 2, 3, and 5, if monitoring prior to restocking with fish reveals a slow recovery of zooplankton numbers and diversity, the following mitigation is recommended: Active recolonization would be facilitated by adding zooplanktors.

Under Alternative 4, zooplankton populations would be influenced primarily by the remaining portion of the tui chub population, and to a much lesser extent, the larger salmonids that are stocked. The effect on zooplankton populations is highly dependent upon the proportion of the existing tui chub population removed in each of the successive years of proposed mechanical chub harvest. Assuming mechanical harvest is successful in reducing the numbers of reproductive age chub by 90-95% annually, it is likely that zooplankton populations would respond positively, with a gradual increase in the relative proportion of cladocerans and an increase in the average size of individual zooplankters. This improvement would be slow at first, due to the continued presence of millions of younger tui chub in the 0, 1, and 2 year age classes that would not be initially impacted by the mechanical removal methods. Over a 5 to 7 year period, as these young fish grow to the sizes targeted for removal, and overall reproduction rates (and juvenile fish numbers) are reduced as a result of these continued mechanical removal efforts, their predation impact on zooplankton is also likely to lessen accordingly.

The extent of potential improvements associated with alternative 4 is difficult to predict however. Past efforts utilizing commercial fishing gear to remove tui chub in Diamond Lake were not considered to be effective. Only small numbers of chub were captured relative to the amount of effort expended. However, it should be noted that these efforts were not carried out during the peak of the chub spawning season, when the fish would be most concentrated and most vulnerable to mechanical removal.

Similar mechanical removal efforts have been conducted annually in Lava Lake (near Sunriver, Oregon) for the last several years. During this time, intensive netting of tui chub has taken place each summer in this 368 acre lake in an effort to control chub populations, and improve water quality and the recreational trout fishery. Tui chub only spawn in a small portion of the lake (roughly 5% of the area) where macrophytes are present. Overall, these efforts have not been considered to be very successful, as Lava Lake continues to suffer from depressed trout populations, and blooms of blue-green algae (Ted Fies, Personal Communication, 2003). This lake was recently listed on the State's 303(d) list of impaired water bodies as a result of low levels of dissolved oxygen.

Cumulative Effects – Diamond Lake: The 1954 rotenone treatment and past, present, and future fish stocking strategies are the primary management activities that contribute to a potential cumulative effect on zooplankton populations (see Cumulative Effects tables for details). However, as described above with the existing suppressed population, the relative contributions of these management activities to future zooplankton populations are considered to be minor. Under Alternative 1, zooplankton populations would continue on their present course as a result of the large population of tui chub. Actual numbers and species diversity of zooplankton would likely vary on an annual basis – corresponding to environmental changes or other factors associated with interspecific competition[25]. Under this alternative, zooplankton populations would remain dominated by small-bodied cladocerans and rotifers into the future. Past, ongoing, and reasonably foreseeable management activities would have no meaningful contribution to a cumulative effect on zooplankton populations in Diamond Lake.

The cumulative effects of Alternatives 2, 3, and 5 would be substantially different than those of Alternative 1. As discussed in the indirect effects section, the long-term effects on zooplankton populations depend largely upon the fish stocking strategies used. The chemicals contained in the rotenone formulations proposed for use (Alts 2, 3, and 5) do

[25] Interspecific competition is the natural process of similar organisms competing with one another for available food and habitat resources.

not persist in the environment for long periods of time, and would not be expected to impact zooplankton in future years (Bradbury, 1986; Finlayson et al, 2000). In numerous studies of zooplankton populations in lakes following rotenone treatment, most of these populations were considered to be completely recovered (to pre-treatment conditions) in less than one year (Bradbury, 1986; Finlayson personal communication, 2003). Of the studies reviewed, the lakes that required more than one year for zooplankton recovery to occur were oligotrophic[26] alpine systems, unlike Diamond Lake.

Thus, Alternatives 2, 3, and 5 represent a short-term contribution to the cumulative effect of management on zooplankton, with a predicted long-term beneficial impact. It is also acknowledged that under Alternatives 2, 3, and 5, at some unknown point in the future, if tui chub remain or are reintroduced and contingency plans fail, adverse impacts to zooplankton similar to current problems would be expected to recur. Future fish stocking strategies under these alternatives would have increased cumulative impacts on zooplanktors, but due to the proposed monitoring and adaptive management, consequences of these impacts to this aquatic resource are considered to be minor. Alternative 3 only differs from Alternatives 2 and 5 in that its potential contribution to cumulative effects is further reduced by stocking with fish not expected to prey heavily on zooplankton.

The cumulative effect of Alternative 4 is more difficult to predict based on the uncertainty associated with mechanical methods of chub removal, and the need to consistently remove a large proportion of the spawning chub population for at least 6 consecutive years in order for this alternative to be successful. In addition, mechanical removal at some unknown intensity level would likely be required indefinitely following the initial 6 years of high intensity mechanical removal in order to maintain reduced chub populations. As mentioned in the indirect effects discussion, predation pressure from tui chub would likely decline gradually if mechanical removal methods are successful. However, if mechanical methods are discontinued after 6 years, or are not successful during any of these years, there is a chance that tui chub populations would rapidly expand again. Based on the inability of predacious fish (ie. Brown trout) to control the tui chub in the 1950's after partial chub removal efforts (see Fish section), it is unlikely that piscivorous fish (Eagle Lake rainbow or brown trout) would be able to control chub populations in this instance.

Based upon past experiences from the early 1950's, and more recent experiences with mechanical removal efforts in Lava Lake, the likely cumulative impact of Alt. 4 could be similar to that of Alt 1. As demonstrated in the past, the high fecundity[27] of tui chub virtually ensures their rapid future population expansion in Diamond Lake (see Fish section). Thus, under this scenario, Alternative 4 represents a limited positive contribution to the cumulative effects of management activities on future zooplankton populations. However, it should be noted that the likelihood of achieving or maintaining improvements in zooplankton populations in the long-term under this alternative could be increased with annual implementation of the described contingency plan over time.

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[26] Oligotrophic systems are those that are low in nutrient inputs, and have low productivity.
[27] Fecundity is a measure of reproductive potential.

Connected Actions: Under Alternatives 2, 3, and 5, the Diamond Lake Resort has requested a permit to remove accumulated sediment and trash, and repair docks at the Resort marina. In addition, the Resort would also conduct similar work to remove old dock structures and moorage material from areas near the South Shore Store and Pizza Parlor. This work would be accomplished using heavy equipment, when these areas are dry following the lake drawdown. The affected area would be approximately 2/3 of an acre, and would remove approximately 750-1,000 cubic yards of material. All material removed would be hauled to an approved disposal site. As a result of the small size and lack of in-water work, no direct, indirect or cumulative impacts to zooplankton populations would result from this action.

Direct, Indirect, and Cumulative Effects on Zooplankton – Tributary Streams and Lake Creek: As mentioned previously, zooplankton in stream ecosystems are not considered to be a major component of the invertebrate populations living in those streams. Therefore, Alternatives 1 and 4 would not result in any detectable short-term effects to zooplankton populations in the tributaries to Diamond Lake, or Lake Creek. These alternatives may result in artificially small zooplankton populations in Lake Creek in the long-term as a result of elevated predation pressure on zooplankton by the continued presence of tui chub in pools and slow water areas.

Alternatives 2, 3, and 5 would likely result in direct short-term decreases in stream zooplankton populations, followed by short-term increases. In Short and Silent Creeks the decreases would come as a direct result of rotenone drip stations, which would kill the relatively small populations of zooplankton found in those systems below the chemical drip stations. However, it should be noted that these drip stations would be located at sites on the streams located within the actual full-pool perimeter of Diamond Lake, since the lake would be lowered by 8 feet at the time of treatment. In Lake Creek, the decreases would be an indirect result of the lake drawdown, which would result in above average high flows for an extended duration, followed by a short period of channel dewatering in the upper 6 miles of Lake Creek. Following this, slight short-term increases in zooplankton may occur in Lake Creek as an indirect result of increased quantities of pool habitat induced by the high flows during drawdown. This increase would likely last for several years until habitat conditions gradually returned to pre-drawdown conditions.

The long-term cumulative effects of Alternatives 2, 3, and 5 would be an eventual stabilization of zooplankton populations in Lake Creek as flow and habitat conditions return to their natural state. This stabilization may be followed by slight population increases. In the absence of tui chub in Lake Creek, it is likely that stream-adapted zooplankton populations would increase due to an overall decrease in predation pressure from these fish.

Direct, Indirect, and Cumulative Effects on Zooplankton – Lemolo Reservoir: None of the actions proposed in the alternatives are located in Lemolo Reservoir. As a result, there are not likely to be any direct effects to zooplankton populations in Lemolo Reservoir from any of the alternatives.

From an indirect standpoint, Alternatives 1 and 4, which would result in continued tui chub presence in Diamond Lake, would result in the continued contribution of varying levels of nutrient enriched waters to Lemolo Reservoir via Lake Creek. This would likely result in increased algal production in the warmer surface waters of Lemolo Reservoir (Eilers, 2001b). Depending upon the dominant phytoplankton species, increases in algal production may be followed by increases in zooplankton populations as well.

Alternatives 2, 3, and 5 would result in reductions in the amount of nitrogen enriched water entering Lemolo Reservoir via Lake Creek (see **Water Quality** section). As a result, algal productivity would likely be reduced slightly from current conditions, and zooplankton populations may decrease slightly as their primary food resource decreases.

The cumulative effects of Alternatives 1 and 4, in combination with the previously described activities mentioned in table xx, would be the continued contribution of varying levels of nitrogen enriched waters to Lemolo Reservoir, potentially leading to small increases in zooplankton populations in that system. The relative increase is difficult to predict due to other controlling factors, such as the species of phytoplankton dominating the reservoir, the extent of fish predation on zooplankton populations, the extent of fish stocking, and other environmental conditions. If Alternative 4 is successful in reducing chub populations in Diamond Lake in the long-term, the relative nutrient contribution to Lemolo would be expected to be somewhat smaller than that seen in Alternative 1.

The cumulative effects of Alternatives 2, 3, and 5, in combination with other activities mentioned in table xx, would be a reduction in the amount of nitrogen in the waters entering Lemolo Reservoir via Lake Creek. This may result in slight decreases in phytoplankton production and consequently, small reductions in zooplankton populations as well. The relative decrease is difficult to predict due to other controlling factors, such as the species of phytoplankton dominating the reservoir, the extent of fish predation on zooplankton populations, the extent of fish stocking, and other environmental conditions.

Direct, Indirect, and Cumulative Effects on Zooplankton – North Umpqua River (From Lemolo Reservoir to Rock Creek): Zooplankton populations in these areas are likely small, and influenced primarily by cold water, and other physical habitat limitations. In addition, the reservoirs associated with the hydropower system in the upper North Umpqua River are considered to be nutrient sinks (Eilers, 2001b). Therefore, the majority of the nutrients entering those systems are quickly utilized by local biological activity, and not transferred to downstream areas. As a result, none of the alternatives are likely to result in any detectable direct, indirect, or cumulative effects on zooplankton populations in the North Umpqua system below Lemolo Reservoir.

Summary of Alternative Effects on Zooplankton Populations in the Diamond Lake Analysis Area					
Factor	**Alternative 1 - No Action**	**Alternative 2*– Rotenone with Put, Grow, and Take Fishery**	**Alternative 3*– Rotenone with Put and Take Fishery**	**Alternative 4** – Mechanical & Biological**	**Alternative 5*- Modified Rotenone and Fish Stocking**
Average Zooplankton body size	Continued high short and long-term negative impacts to zooplankton body size due to high predation by tui chub.	High short-term negative impacts to zooplankton due to rotenone treatment. Moderate to High mid and long-term beneficial impacts to zooplankton size due to lack of intense tui chub predation, and only low to moderate predation by trout fingerlings.	High short-term negative impacts to zooplankton due to rotenone treatment. High mid and long-term beneficial impacts to zooplankton size due to lack of intense tui chub predation, and low or no predation by stocked domesticated trout.	Continued moderate to high short-term negative impacts to zooplankton size due to continued moderate to high predation levels. Potentially moderate to high long-term negative impacts to zooplankton body size due to high predation by tui chub.	High short-term negative impacts to zooplankton due to rotenone treatment. Moderate to High mid and long-term beneficial impacts to zooplankton size due to lack of intense tui chub predation, and only low to moderate predation by trout fingerlings.
Zooplankton species diversity	Species diversity relatively low compared to pre tui chub conditions. Zooplankton population continues to be dominated by small rotifers and small cladocerans.	Species diversity increases over time. Large daphnia and copepods increase in numbers, and replace rotifers as the dominant zooplankton.	Species diversity increases over time. Large daphnia and copepods increase in numbers, and replace rotifers as the dominant zooplankton.	Species diversity relatively low compared to pre tui chub conditions. Zooplankton population continues to be dominated by small rotifers and small daphnia.	Species diversity increases over time. Large daphnia and copepods increase in numbers, and replace rotifers as the dominant zooplankton.

Edible Zooplankton Trends	Continued high short and long-term negative impacts to numbers of edible zooplankton due to high predation by tui chub	High short-term negative impacts to zooplankton due to rotenone treatment. Moderate to High mid and long-term beneficial impacts to edible zooplankton numbers due to lack of intense tui chub predation, and only low to moderate predation by trout fingerlings	High short-term negative impacts to zooplankton due to rotenone treatment. High mid and long-term beneficial impacts to edible zooplankton numbers due to lack of intense tui chub predation, and low or no predation by stocked domesticated trout.	Continued moderate to high short-term negative impacts to edible zooplankton numbers due to continued moderate to high predation levels. Potentially moderate to high long-term negative impacts to edible zooplankton numbers due to moderate/high predation by tui chub.	High short-term negative impacts to edible zooplankton numbers due to rotenone treatment. Moderate to High mid and long-term beneficial impacts to edible zooplankton numbers due to lack of intense tui chub predation, and only low to moderate predation by trout fingerlings.

*** It is also acknowledged that under Alternatives 2, 3, and 5, at some unknown point in the future, if tui chub remain or if/when they are reintroduced and contingency plans fail, adverse impacts adverse to zooplankton similar to current problems would be expected to recur. Under this scenario, the likelihood of sustaining improvements in zooplankton populations in the long-term may be increased with annual implementation of the described contingency plan.**

*** * The likelihood of achieving or maintaining improvements in zooplankton populations in the long-term under this alternative may be increased with annual implementation of the described contingency plan.**

Table x: Summary of Alternative Effects on Zooplankton Populations.

Aquatic Conservation Strategy (ACS): Each of the alternatives will be evaluated with regard to attaining ACS objectives. As listed on page B-9 of the ROD for the Northwest Forest Plan (1994), the ACS was developed to restore and maintain the ecological health of watersheds and aquatic ecosystems contained within them on public lands. The ACS must strive to maintain and restore ecosystem health at watershed and landscape scales to protect habitat for fish and other riparian-dependent species and resources and restore currently degraded habitats. Complying with the ACS objectives means that an agency must manage the riparian-dependent resources to maintain the existing condition or implement actions to restore conditions. Improvement relates to restoring biological and physical processes within their ranges of natural variability.

Conclusions and ACS Discussion:

Based on the above discussion, Alternative 1 would result in continued suppression of zooplankton populations in the short and long-term, and has the potential to retard attainment of Aquatic Conservation Strategy Objective 9[28] at a local, but not 5th field scale. Alternatives 2, 3, and 5 would result in dramatic and immediate decreases in zooplankton populations due to the addition of rotenone. However, these population declines would be localized (6th field scale) and short-term (not expected to last for more than a few months). The four action alternatives would result in varying levels of zooplankton population recovery in the long-term, and would not prevent attainment of ACS Objective 9. Based upon past history at Diamond Lake, alternatives that propose to completely remove tui chub (Alternatives 2, 3, and 5) are more likely to achieve desired zooplankton population recovery suitable to support stocked salmonids and contribute to improved water quality conditions. Alternative 4, which does not completely eradicate tui chub, may be the least effective of the action alternatives at movement toward ACS

[28] ACS Objective 9 – Maintain and restore habitat to support well-distributed populations of native plant, invertebrate, and vertebrate riparian-dependent species.

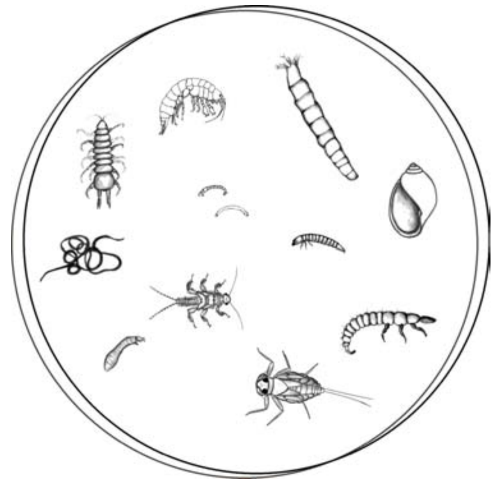
Objective 9, due to the potential for continued expansion of the remaining tui chub population, and uncertainty regarding the efficacy of mechanical and biological methods to remove chub over a multiple-year timeframe. The likelihood of achieving or maintaining improvements in zooplankton populations in the long-term under this alternative may be increased with annual implementation of the described contingency plan over time. Also in the long-term, Alternatives 2, 3, and 5, which result in the most robust populations of zooplankton (in terms of species diversity and size indices), are likely to provide the greatest contribution to water quality recovery and attainment of ACS objective 4[29]. It is also acknowledged that under Alternatives 2, 3, and 5, at some unknown point in the future, if tui chub remain or if/when they are reintroduced and contingency plans fail, adverse impacts similar to current zooplankton population reductions would be expected to recur. Under this scenario, the likelihood of sustaining improvements in zooplankton populations in the long-term may be increased with annual implementation of the described contingency plan.

In summary, from a zooplankton standpoint, the relative ACS ranking of each alternative would be as follows (from best to worst):

Alternative 3 – Most effective at moving toward attainment of ACS objectives
Alternative 2 & 5 – Effective at moving toward attainment of ACS objectives
Alternative 4 – Least effective of the action alternatives at moving toward attainment of ACS objectives
Alternative 1 – Potentially retards attainment of ACS objectives, but not at applicable 5th field scale

[29] ACS Objective 4 – Maintain and restore water quality necessary to support healthy riparian, aquatic, and wetland ecosystems. Water quality must remain within the range that maintains the biological, physical, and chemical integrity of the system and benefits survival, growth, reproduction, and migration of individuals composing aquatic and riparian communities.

Benthic Organisms – Affected Environment



Benthic organisms are those that live on or near the bottom of a lake or stream. In Diamond Lake, benthic organisms include aquatic insects like mosquito and midge larvae, mayfly larvae, caddisfly larvae, damselfly larvae, dragonfly larvae, and others. In addition, other bottom-dwelling invertebrates[30] such as leeches, snails, amphipods (or scuds), worms, and crayfish also form an important component of the benthic community. In many lakes, benthic organisms are of primary importance to fish and other aquatic animals using those systems.

Diamond Lake: No quantitative information regarding benthic organism community structure or overall numbers are available prior to the introduction of fish into Diamond Lake. However, insect body parts preserved in lake bottom sediment cores collected by Eilers in 2003 indicate that there was a large component of midge larvae (chironomids) present in the lake prior to fish introductions. During this pre-fish timeframe, sediment core samples contained approximately 460 midge heads per gram of sediment. Sediment layers evaluated from 2002 contained roughly 250 midge heads per gram of sediment (Eilers, 2003). These recent samples also indicate that the chironomid community has become more tolerant of decreasing water quality (Eilers, 2003b). This data suggests that there was a substantial decrease in midge population size and a shift in species diversity coincident with the introduction of fish, and especially the rapid expansion of the tui chub population.

In Diamond Lake, early sampling of benthic life at the bottom of the lake during a 1946 study indicated that benthic productivity appeared to be considerably above average when compared to other Oregon lakes (OSGC, 1947). This study reported an average standing crop of roughly 292 pounds of benthic organisms per acre of lake-bottom. Scuds, leeches, snails, and midge-larvae comprised a large percentage of this standing crop, and were also found in large numbers in areas with aquatic vegetation. This value declined rapidly as the chub population expanded in the late 1940's and early 1950's. Populations of benthic organisms appeared to rebound quickly following the rotenone treatment in 1954 (see figure x below).

[30] Animals without a spine or backbone.

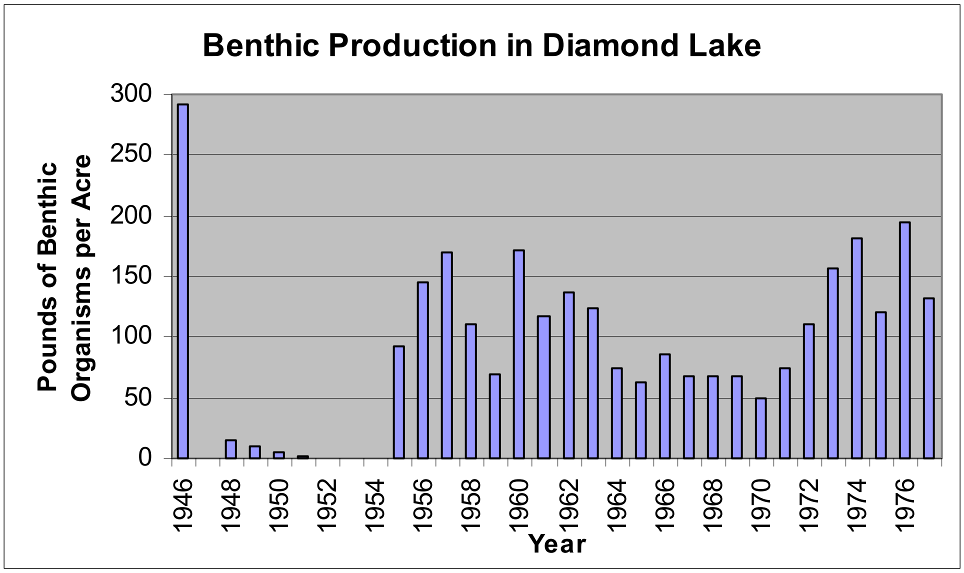


Figure x: Benthic production in Diamond Lake from 1946 to 1977.

Benthic samples were also collected from 1971-1977 by the U.S. Environmental Protection Agency (Lauer et al, 1979). These samples were collected utilizing different techniques, and are not directly comparable to the samples collected in 1946. However, this study did document that benthic populations in the lake were very diverse, and that populations in the deeper part of the lake were quite different from those in the near-shore areas.

No estimate of past crayfish abundance is available due to the fact that none of the past benthic samples reported capture of any crayfish in Diamond Lake. This may be a result of the crayfish's ability to move quickly, and avoid capture in the sampling equipment, or an indication that they weren't present in the lake in great abundance. Regardless, recent anecdotal evidence indicates that the current crayfish populations are quite large. In support of this, fish trapping efforts in Lake Creek (near Diamond Lake) also resulted in the capture of over 4,000 crayfish during the summer months. Since this was the first year of fish trapping efforts in Lake Creek, it is not known whether this is an annual occurrence or an isolated migration event. This outmigration may also coincide with the period when dissolved oxygen decreased to extremely low levels in the bottom waters of Diamond Lake, forcing the crayfish to find suitable habitat elsewhere.

Other anecdotal information from long-time residents and recreationists in the area indicates that large hatches of mosquitoes, flies, and midges were common throughout the spring and summer months prior to the introduction of tui chub. These individuals also indicate that large hatches of aquatic insects are virtually non-existent currently. Other insect life reported in the area included sporadic large hatches of damsel flies, dragon flies, caddis flies, and mayflies.

Currently, aquatic insect communities and other invertebrates in the lake are believed to be severely limited by millions of tui chub, directly through consumption and indirectly through impacts on water quality. Based on the recent bottom samples, scuds have been virtually eliminated from Diamond Lake. In the 1957-60 period, they represented over 60 percent of the organisms sampled, but by 2002, only 3 individuals were found in the 66 bottom samples collected. In addition, recent benthic samples indicated that the only invertebrates present in large numbers are those that are tolerant of extremely low dissolved oxygen levels (Eilers, 2003c). This is likely an indication that water quality near the bottom of the lake is poor, and currently not capable of supporting diverse assemblages of aquatic insects and other bottom dwelling organisms.

Tributary Streams and Lake Creek: No information could be found regarding aquatic insect populations in Short and Silent Creeks. Based on the very cold water originating from these streams, and the presence of large amounts of highly angular sands embedding the larger pumice substrates, it is not likely that these streams are highly productive in terms of aquatic insects.

In Lake Creek, the Umpqua National Forest has conducted aquatic insect monitoring at three sites on an intermittent basis from 1990 to 2001. In general, aquatic insect populations in Lake Creek appear to be moderately healthy and typical of lake outlet stream types. These insect communities appear to be somewhat limited by a lack of overall habitat complexity, and borderline warm water conditions (Wisseman, 2001). The lack of habitat complexity and the warm water conditions in Lake Creek are both naturally occurring situations, and not due to human-induced management actions upstream (see **Aquatic Habitat** and **Water Quality** sections).

The uppermost monitoring site in Lake Creek is located near Diamond Lake. The aquatic insect community at this site is substantially different than the two sites located further downstream. In this area, the insect community is dominated by filter feeders (i.e black fly larvae) and net spinners (i.e. certain caddisfly species), with overall densities being 2 to 3 times higher than those at the lower sites. These differences are likely the result of localized adaptations that have allowed the insect community to take full advantage of the large quantity of food resources coming out of Diamond Lake (i.e. live zooplankton, plant particles, etc.).

In addition, there is no evidence that the severe Anabaena bloom in 2001 affected aquatic insect communities in Lake Creek (Wisseman, 2001). This corresponds well with information reported by Eilers (personal communication, 2003) that indicates fairly rapid decreases in blue-green algae levels once water from Diamond Lake enters Lake Creek. This rapid decline in algae abundance is a result of algae cells being physically disrupted and ruptured as water in Lake Creek tumbles through several steep, boulder dominated sections (cascades).

Lemolo Reservoir: No benthic sampling data for Lemolo Reservoir could be located at the time of this report. Based upon the apparently low levels of planktivory suggested by limited zooplankton sampling, it is also assumed that predation levels on benthic organisms are relatively low as well. In addition, water quality in the deeper portions of Lemolo Reservoir is considered to be much better than in Diamond Lake (see Water

Quality section). These cooler bottom waters contain ample amounts of dissolved oxygen capable of supporting a diverse assemblage of benthic species. Therefore, until quantitative benthic population data becomes available, it is assumed that benthic organism populations in Lemolo Reservoir are relatively healthy.

North Umpqua River (From Lemolo Reservoir to Rock Creek): The Umpqua National Forest has conducted aquatic insect monitoring on an intermittent basis at several sites along the main stem of the North Umpqua River for several years. In general, from Lemolo Reservoir to the National Forest boundary (over 47 miles), these samples show a slight downward trend in insect population diversity and abundance.

It is not known whether this is a result of aquatic impacts from past land management actions, changes to nutrients and water quality induced by actions associated with the hydropower project, or simply a natural occurrence associated with increasing river size.

ENVIRONMENTAL EFFECTS ON BENTHIC ORGANISMS

Effects of Rotenone on Benthic Organisms: Regardless of the organism, rotenone's primary toxic action is at the cellular level, where it inhibits the cell's ability to utilize oxygen (Bradbury, 1986). As in fish, the high susceptibility of insects to rotenone is primarily due to easy entry via the gill-like tracheae and the cuticle, although rotenone can also enter effectively through the mid-gut (Tischler 1935; Fukami et al 1970 – as cited in Bradbury, 1986). Once in the bloodstream, rotenone is quickly carried to vital organs (such as the brain), where it inhibits cellular respiration (Oberg, 1964).

Some field studies indicate little or no changes in invertebrate populations following formulated rotenone treatments. Two year studies by Houf and Hughey (1973 – as cited in CDFG, 1994) and Houf (1974 – as cited in CDFG, 1994) found no short-term or long-term effects on population abundance, relative number of dominant species, or species diversity of either zooplankton or benthos in ponds following treatments of 0.5 to 2 mg/L formulated rotenone. Burress (1982 – as cited in CDFG, 1994) found that benthic communities were seriously reduced by a 2 mg/L formulated rotenone treatment, but recovered to higher than pre-treatment levels in 69 days. Other more recent studies (Mangum and Madrigal 1999) indicate that rotenone treatments in streams can result in a substantial loss of more sensitive species. Some of the sensitive species in those studies (primarily mayflies, caddisflies, and stoneflies) were still missing five years after the initial rotenone treatment.

In both aquatic insects and fish, rotenone tolerance tends to vary inversely with oxygen requirements. Simply put, aquatic organisms that are tolerant of low dissolved oxygen are more resistant to the toxic effects of rotenone. A large portion of the aquatic insects and other benthic organisms currently living in Diamond Lake are tolerant of low dissolved oxygen or are able to burrow into the soft mud (Eilers, personal communication). As a result, these organisms may be able to survive a rotenone treatment. In addition, as noted above, the vast majority of invertebrates that would be considered as sensitive to the effects of rotenone have already been virtually eliminated from Diamond Lake by extensive predation, and poor water quality conditions.

Direct Effects - Diamond Lake: Alternative 1 (No Action) and Alternative 4 (Mechanical/Biological) are not likely to have any detectable direct effects on populations of benthic organisms in Diamond Lake. Under these alternatives, there are no alterations of lake water levels and no additions of chemicals to the system, which would be the primary source of a direct effect on the benthos[31]. The addition of fish also has the potential to directly impact benthic populations. However, in the presence of much larger tui chub populations and severely depressed populations of benthic organisms, these impacts would be non-detectable.

Alternative 2 (Proposed Action), Alternative 3 (Put and Take Fishery), and Alternative 5 (modified Rotenone and Fish Stocking) would each be likely to directly affect benthic populations to some extent. In each case, the impact would be a result of canal reconstruction, wetland expansion, lake drawdown, chemical additions to the lake, and stocking of fish. The canal reconstruction portion of the project would result in approximately 1,000 cubic yards of sand, silt, and aquatic plants being removed from the existing canal area within the perimeter of the lake. This material would be utilized to increase the size of an existing wetland in the northwest corner of the lake. Any benthic organisms living within the canal sediments, or in the area of wetland expansion would likely be killed. However, based upon the relative small size of the area disturbed, these impacts are expected to be minor and short-term.

The drawdown portion of the project (Alternatives 2, 3, and 5) would result in an approximate 30% reduction in total water volume in the lake. As this water is draw down, a portion of the lake bottom along the near-shore (littoral) zone would be dewatered, thereby temporarily reducing the amount of suitable habitat for benthic organisms. In addition, small areas of gravel may be added in several areas in order to create low-water roadbeds that would allow boats to be launched and chemicals to be loaded onto those boats. Of more importance to benthic populations, the direct effect of rotenone addition (Alternatives 2, 3, and 5) to Diamond Lake would result in a relatively quick decline in benthic organism numbers. According to Bradbury (1986), the immediate effect of rotenone on benthic organisms in lakes and ponds varies, but it does not affect them as drastically as it does plankton. In a review of 13 studies, Bradbury (1986) reported that immediate reduction in total numbers of benthic animals ranged from a low of 0% to a high of 71%, with a mean of 25%. It is important to note that the current benthic population in Diamond Lake is considered to be severely depressed and simplified as a result of predation and secondarily to poor water quality conditions that render much of the lake uninhabitable to many benthic organisms.

Indirect Effects – Diamond Lake: Alternative 1 would result in the continued suppression of benthic populations by the large population of tui chub. The benthic community in deeper parts of the lake would remain simplified, with only a few species capable of tolerating the low dissolved oxygen conditions found there (refer to the ***water***

[31] Benthos is defined as "the organisms living on sea or lake bottoms" (Webster, 1988).

quality section). The benthic community around the remainder of the lake would likely persist at extremely low levels, due to the intense predation on those populations by the tui chub.

The indirect effects of Alternative 4 may be similar to those of Alternative 1, with slight improvements to benthic species diversity and overall numbers. These improvements would be a result of the partial removal of a portion of the tui chub biomass, and the consequent reduction in overall predation levels on benthic populations. The chub targeted for removal under this alternative are the larger sized reproductive aged fish (from 3 to 10 inches in length). Based on this size range, these fish are also likely to be highly efficient and effective predators on benthic organisms. It is impossible to quantify this improvement, due to the potential for continued expansion of the remaining tui chub population, and uncertainty regarding the efficacy of mechanical methods to remove chub over a multiple-year timeframe.

Portions of the indirect effects of Alternatives 2, 3, and 5 would be identical to each other, and are considered to be beneficial effects. Following chemical treatment and complete removal of tui chub, the lake would be left fishless for a period of time. During this time, the lake would refill to full summer pool, and a large portion of the former benthic diversity and abundance that was present prior to the establishment of tui chub would return. The areas of exposed shoreline, including areas where gravel was added for low-water access, are likely to be quickly recolonized by recovering benthic populations. In addition, high levels of nutrients originating from decaying aquatic organisms (zooplankton and benthic organisms) and fish carcasses missed during carcass recovery efforts would also fuel a relatively rapid recovery. In numerous studies cited in Bradbury (1986), populations of benthic organisms returned relatively rapidly following removal of various fish species using rotenone. Based on benthic population recovery following rotenone treatment in Diamond Lake in 1954, it is estimated that virtually all of the major organism groups that were present in substantial numbers prior to tui chub establishment would again return to Diamond Lake following rotenone treatment. However, if monitoring (prior to restocking with fish) reveals that benthic population and species diversity recovery are not occurring naturally, the following mitigation is recommended: Active recolonization.

A portion of the indirect effects of Alternatives 2 and 5 would differ slightly from those of Alternative 3. While each alternative proposes the complete removal of tui chub, Alternatives 2 and 5 propose to restock the lake with rainbow trout fingerlings. The size and number of fish stocked would have an influence on benthic invertebrate populations. As mentioned in the affected environment section, juvenile salmonids often shift from a diet dominated by zooplankton to one with a larger component of aquatic invertebrates when trout reach a length of around 2¾ inches (7 cm). These fish would immediately begin to prey upon the available food resources (zooplankton and benthic organisms). Based upon past fingerling stocking and benthic production data in Diamond Lake, stocking of 50,000 to 100,000 fingerling rainbow trout would not be expected to dramatically affect those invertebrate populations. Over time, benthic invertebrate indices would be developed from extensive annual monitoring of those populations in order to help define a fish stocking regime that does not significantly impair benthic invertebrate populations.

Alternative 3 proposes to restock Diamond Lake with a large number of domesticated rainbow trout. These highly domesticated fish would not be expected to prey significantly on available food organisms like benthic invertebrates, and would not be expected to survive through the winter months. In the absence of substantial fish predation, populations of benthic invertebrates would be expected to recover to near pre-fish levels.

Connected Actions – Diamond Lake: Under Alternatives 2, 3, and 5, the Diamond Lake Resort has requested a permit to remove accumulated sediment and trash, and repair docks at the Resort marina. In addition, the Resort would also conduct similar work to remove old dock structures and moorage material from areas near the South Shore Store and Pizza Parlor. This work would be accomplished using heavy equipment, when these areas are dry following the lake drawdown. The affected area would be approximately 2/3 of an acre, and would remove approximately 750-1,000 cubic yards of material. All material removed would be hauled to an approved disposal site. As a result of the small size and lack of in-water work, no direct, indirect or cumulative impacts to benthic organisms would result from this action.

Cumulative Effects: The 1954 rotenone treatment and past, present, and future fish stocking strategies are the primary management activities that contribute to a potential cumulative effect on benthic populations (see Cumulative Effects tables for details). However, as described above with the existing suppressed populations, the relative contributions of these management activities to future benthic populations are considered to be minor. The cumulative effect of Alternative 1 would be the continued maintenance of severely truncated benthic invertebrate populations. Large populations of tui chub would continue to consume the majority of aquatic invertebrates produced in the lake. In addition, poor water quality conditions would continue, thereby further limiting the size and diversity of the benthic organism populations in the future.

Alternatives 2 and 5 would result in long-term cumulative improvements in benthic invertebrate species diversity and total abundance. The complete eradication of tui chub, followed by an ecologically oriented approach to trout stocking would likely result in a dramatic improvement in benthic populations when compared to the existing condition. Past evidence in Diamond Lake indicates that benthic populations rebounded strongly following the rotenone treatment in 1954 (see figure x). The lack of predation by tui chub, water quality improvements associated with chub removal, and a trout stocking regime that is developed around the biological indices mentioned above would all contribute to increased benthic organism population diversity and numbers.

Thus, Alternatives 2 and 5 represent a short-term contribution to the negative cumulative effect of management on benthic organisms, with predicted long-term beneficial impacts. Future fish stocking strategies under these alternatives would have increased cumulative impacts on benthic organisms, but due to the proposed monitoring and adaptive management, consequences of these impacts to this aquatic resource are considered to be minor.

Alternative 3 would likely result in the largest improvements to benthic organism populations. The combination of chub eradication and stocking with domesticated rainbow trout would essentially remove any significant fish predation on those organisms As a result, benthic invertebrate populations would be expected to flourish. The lack of predation coupled with water quality improvements associated with chub removal would lead to an invertebrate population that is somewhat similar to that believed to be present prior to the introduction of fish. The historic occurrence of large hatches of mayflies, caddisflies, midges, mosquitoes, dragonflies, and damselflies during the spring and summer months would likely return over time.

Thus, Alternative 3 only differs from Alternatives 2 and 5 in that its potential contribution to cumulative effects is further reduced by stocking with fish not expected to prey heavily on benthic organisms. It is also acknowledged that under Alternatives 2, 3, and 5, at some unknown point in the future, if tui chub remain or if/when they are reintroduced and contingency plans fail, adverse impacts to benthic organisms similar to current problems would be expected to recur. Under this scenario, the likelihood of sustaining improvements in benthic populations in the long-term may be increased with annual implementation of the described contingency plan.

Alternative 4 represents the alternative with the greatest amount of uncertainty regarding affects to the aquatic community. Following one year of experimentation with mechanical removal techniques, this alternative would attempt to remove 90-95% (or more) of the reproductive age chub from Diamond Lake on an annual basis for 6 years. In addition, mechanical removal at some unknown intensity level (estimated at one month/year for analysis purposes) would likely be required indefinitely following the initial 6 years of high intensity mechanical removal in order to maintain reduced chub populations.

If successful, the end result would be a much smaller population of tui chub that is considered manageable by stocking of piscivorous fish to control them. Assuming this alternative is successful at dramatically reducing tui chub populations, it is likely that benthic invertebrate populations would respond in a positive manner. There would be a decrease in benthic predation by tui chubs, along with an increase in benthic predation by salmonids. The total number of fish predicted in Diamond Lake following treatment is unknown, but is anticipated to be significantly less than the currently existing population of tui chub.

With the continued presence of tui chub, there is a risk that the process of adjusting salmonid stocking regimes in response to changes in aquatic invertebrate indices may have little effect in terms of stabilizing those indices. Since tui chub are able to out-compete trout for food in Diamond Lake, the continued presence of a variable tui chub population is likely to result in continued suppression of benthic organism populations in the lake. Given the long-term delay before impacts to benthic organisms would potentially subside and the risk that improvements may be relatively small and difficult to manage for (when compared to alternatives that result in eradication of chub, Alternative 4 is expected to result in continued cumulative effects to benthic organisms. These cumulative effects would be strongest during the first several years of intensive mechanical removal efforts, prior to when the chub population is substantially reduced. Following this period, cumulative effects would likely continue at some unknown level indefinitely into the future due to the continued presence of chub. The extent of the long term cumulative effects is dependent upon the overall success of mechanical removal and biological controls. If chub populations are significantly reduced, cumulative effects on benthic organisms would be reduced as well. If chub populations are not significantly reduced, cumulative effects on benthic organisms would continue to be high.

It should be noted that the likelihood of achieving or maintaining improvements in benthic invertebrate populations in the long-term under this alternative would be higher than seen in Alternative 1, and could be substantially increased with annual implementation of the described contingency plan over time.

Direct, Indirect, and Cumulative Effects – Tributary Streams and Lake Creek: Alternatives 1 and 4 would have no direct effect on benthic organism populations in tributary streams or Lake Creek. In addition, based upon macroinvertebrate sampling data, there are apparently no detectable impacts in Lake Creek resulting from existing water quality conditions in Diamond Lake. Therefore, no indirect or cumulative impacts to Lake Creek invertebrate communities would be expected under Alternatives 1 and 4 as a result of water quality. However, there is the possibility of small indirect and cumulative impacts to benthic populations resulting from tui chub predation as a result of these alternatives.

The direct effects of Alternatives 2, 3, and 5 would be a short-term, dramatic decline in benthic organisms below rotenone drip stations in Short and Silent Creeks. However, the rotenone drip stations would actually be located on these streams at sites within the lake perimeter, since the lake would be lowered by 8 feet at the time of treatment. In addition, benthic populations in Lake Creek would also experience a dramatic decline. This decline would result from the extended duration of high flows, followed by a period of no or extremely low flows in all or portions of Lake Creek. An indirect result of extended high flows in Lake Creek is an increase in habitat complexity and the amount of pool habitat in that stream. This would likely result in an increase in the diversity and abundance of benthic organisms as they take advantage of this new habitat.

From a cumulative perspective, this increase would only last for several years. As physical habitat in Lake Creek returns to the relatively simplified pre-drawdown conditions (ie. pools fill in), the benthic organism community size and structure is also likely to return to one representative of a stable, simple-habitat stream channel. As mentioned above, the 1954 rotenone treatment and associated activities, and fish stocking are the primary activities contributing to a cumulative effect. Based on the recovery of the benthos following the 1954 treatment and the long-term neutral impacts to habitat, cumulative impacts associated with these alternatives are expected to have minor consequences to benthic organisms in Lake Creek.

Direct, Indirect, and Cumulative Effects – Lemolo Reservoir: None of the alternatives are likely to result in direct effects to benthic communities in Lemolo Lake. Under Alternatives 2, 3, and 5, this is primarily due to the fact that no chemicals would be added to Lemolo Lake, and the drawdown of Diamond Lake would occur gradually during the fall, winter, and early spring months during a period of low biological activity. Under Alternatives 1 and 4, none of the associated activities would be experienced as far downstream as Lemolo. Therefore, no direct effects would occur in Lemolo from any of the alternatives.

From an indirect and cumulative effects standpoint, Alternatives 1 and 4 may result in minor beneficial impacts to benthic communities in Lemolo Reservoir as a result of continued inputs of varying levels of nitrogen enriched waters coming out of Diamond Lake via Lake Creek. This nutrient enriched water is currently resulting in increased algal productivity in the warmer surface waters of Lemolo Reservoir, and would continue to do so over time. The combination of increased algal production and cool, well oxygenated waters near the bottom of the reservoir would likely result in the production and maintenance of moderate to large populations of benthic organisms (relative to the potential in Lemolo Reservoir in the absence of additional nutrients). The extent of these increases is difficult to quantify due to other controlling factors, such as the species of phytoplankton dominating the reservoir, the extent of fish predation on benthic populations, the extent of fish stocking, and other environmental conditions.

When considering Alternatives 2, 3, and 5 from an indirect and cumulative effects standpoint, they would likely result in a general long-term decrease in the amount of nitrogen enriched water coming out of Diamond Lake and effecting downstream environments such as Lemolo Reservoir. This reduction in nitrogen may result in small decreases in algal production, and consequently, reductions in benthic production as well. The extent of these reductions is difficult to quantify due to other controlling factors, such as the species of phytoplankton dominating the reservoir, the extent of fish predation on benthic populations, the extent of fish stocking, and other environmental conditions. The indirect effects of Alternative 2, 3, and 5 are small and not considered substantial enough to lead to a cumulative effect on aquatic invertebrates in Lemolo Lake.

Direct, Indirect, and Cumulative Effects – North Umpqua River (from Lemolo Reservoir to Rock Creek): None of the alternatives are likely to result in direct effects to benthic communities in the North Umpqua River below Lemolo Reservoir. This is primarily due to the fact that no chemicals would enter Lake Creek, Lemolo, or the North Umpqua River, and the drawdown of Diamond Lake would occur gradually during the fall, winter, and early spring months during a period of low biological activity. No direct effects would occur under Alternatives 1 and 4 because the activities associated with these would not be experienced as far downstream as this section of the North Umpqua River.

As mentioned above, indirectly and cumulatively, Alternatives 1 and 4 may result in slight beneficial impacts to benthic communities in the Lemolo Reservoir system. Indirect impacts to benthic populations in the North Umpqua River downstream of Lemolo Reservoir are unlikely, however, due to the rapid uptake of nutrients in Lemolo. The cumulative nutrient impacts potentially associated with these alternatives, timber harvest and other activities in the upper North Umpqua River area (e.g. fish stocking, fishing, fuels reduction projects, horse camping, and use of dispersed recreation sites) may be contributing to slight impacts to benthic communities downstream of Lemolo. These impacts are evident as shifts in benthic organism communities that have likely developed to take advantage of increased algal production in certain downstream areas (Anderson 1998). The extent of Diamond Lake's relative contribution to this situation has not been quantified.

As mentioned above, Alternatives 2, 3, and 5 would result in a general decrease in the amount of nitrogen enriched water coming out of Diamond Lake, and would indirectly result in decreases in algal and benthic organism productivity in Lemolo Reservoir. As seen with Alternatives 1 and 4, Alternatives 2, 3, and 5 are not likely to indirectly impact benthic populations in the North Umpqua River downstream of Lemolo Reservoir. From a cumulative impact standpoint, however, the long-term decrease in nitrogen inputs originating from Diamond Lake, in combination with other activities (table xx) may result in decreased algal production in downstream areas. Should this occur, benthic population feeding groups in these areas may shift slightly, moving back towards an assemblage more representative of the natural, nutrient-limited river system.

Summary of Alternative Effects on Benthic Organism Populations in the Diamond Lake Analysis Area					
Element	**Alternative 1 - No Action**	**Alternative 2*– Rotenone with Put, Grow, and Take Fishery**	**Alternative 3* – Rotenone with Put and Take Fishery**	**Alternative 4** – Mechanical & Biological**	**Alternative 5* – Modified Rotenone and Fish Stocking**
Benthic Organism Production	Benthic organism production would continue to be heavily suppressed by high predation from tui chub, and poor water quality conditions.	Benthic organism production would increase dramatically due to increasing water quality and relatively light predation from stocked fingerling trout.	Benthic organism production would increase dramatically due to increasing water quality and virtually no predation from highly domesticated stocked fish.	Benthic organism production would continue to be suppressed to an unkown extent by moderate/high predation from tui chub, and potentially poor water quality conditions.	Benthic organism production would increase dramatically due to increasing water quality and relatively light predation from stocked fingerling trout.
Benthic Organism Species Diversity	Benthic organism communities would remain simplified, and dominated by species that are tolerant of high predation and poor water quality conditions.	In the presence of improving water quality, and relatively light predation, benthic organism communities would likely regain their former complexity over time.	In the presence of improving water quality, and virtually no predation, benthic organism communities would likely regain their former complexity over time.	Benthic organism communities would remain simplified, and dominated by species that are tolerant of moderate/high predation and potentially poor water quality conditions.	In the presence of improving water quality, and relatively light predation, benthic organism communities would likely regain their former complexity over time.

*** It is also acknowledged that under Alternatives 2, 3, and 5, at some unknown point in the future, if tui chub remain or are reintroduced and contingency plans fail, adverse impacts to benthic organisms similar to current problems would be expected to recur. Under this scenario, the likelihood of sustaining improvements in benthic populations in the long-term may be increased with annual implementation of the described contingency plan.**

*** * The likelihood of achieving or maintaining improvements in benthic populations in the long-term under this alternative may be increased with annual implementation of the described contingency plan.**

Table x: Summary of Alternative Effects on Benthic Organism Populations.

Conclusions and ACS Discussions: Based on the above discussions, Alternative 1 (no action) would result in continued suppression of benthic organism populations in Diamond Lake in the short and long-term, and potentially retard attainment of Aquatic Conservation Strategy Objective 9 at the project area scale. However, benthic populations downstream in Lake Creek, Lemolo Reservoir, and the North Umpqua River would likely remain unchanged and thus the alternative would have a neutral effect regarding attainment of ACS objectives at the 5th field scale. Alternatives 2, 3, and 5 would likely result in immediate reductions in benthic organism populations due to the addition of rotenone. However, these population declines would be short-term and localized, and not expected to last for more than a few months. The four action alternatives would result in varying levels of benthic organism recovery in the short and long-term, and would not prevent attainment of ACS Objective 9. Based upon past history at Diamond Lake, alternatives that propose to completely remove tui chub (Alts 2, 3, and 5) are more likely to achieve desired benthic organism population recovery suitable to partially support stocked salmonids. Alternative 4, which does not completely eradicate tui chub, may be the least effective of the action alternatives at movement toward ACS objectives, due to the potential for continued expansion of the remaining tui chub population, and uncertainty regarding the efficacy of mechanical methods to remove chub over a multiple-year timeframe. Also in the long-term, alternatives that result in the most robust populations of benthic organisms (in terms of species diversity and abundance) are likely to provide the greatest contribution to aquatic ecosystem recovery. It is also acknowledged that under Alternatives 2, 3, and 5, at some unknown point in the future, if tui chub remain or are reintroduced and contingency plans fail, adverse impacts similar to current benthic population reductions would be expected to recur. Under this scenario, the likelihood of sustaining improvements in benthic populations in the long-term may be increased with annual implementation of the described contingency plan.

In summary, from a benthic organism standpoint, the relative ACS ranking of each alternative would be as follows (from best to worst):

Alternative 3 – Most effective at moving toward attainment of ACS objectives
Alternative 2 & 5 – Effective at moving toward attainment of ACS objectives
Alternative 4 – Least effective of the action alternatives at moving toward attainment of ACS objectives
Alternative 1 – Potentially retards attainment of ACS objectives, but not at applicable 5th field scale.

FISH

Relationship to Issues: Fish are relevant to the issues of fish stocking, non-target species, water quality, impacts on indigenous fish species, recreation, and economics.

Fish – Affected Environment

Historically, all waters above Toketee Falls, including Diamond Lake and its tributaries, were believed to be naturally fishless (USDA, 1998). It is likely that numerous large waterfalls on the upper North Umpqua River (i.e. Lemolo Falls, Toketee Falls, and others) would have blocked the upstream migration of fish from the lower areas of the basin. As reported in the Lemolo and Diamond Lake Watershed Analysis (USDA, 1998), if fish had made it upstream past Toketee and Lemolo Falls and successfully established populations, they would have had to endure several periods of glacial activity and periodic pyroclastic[32] ash flows from Mt. Mazama to have survived to current times. No record of fish in Diamond Lake or the surrounding streams prior to stocking with trout (circa 1910) by the Oregon Department of Fish and Wildlife has been found (ODFW, 1996).

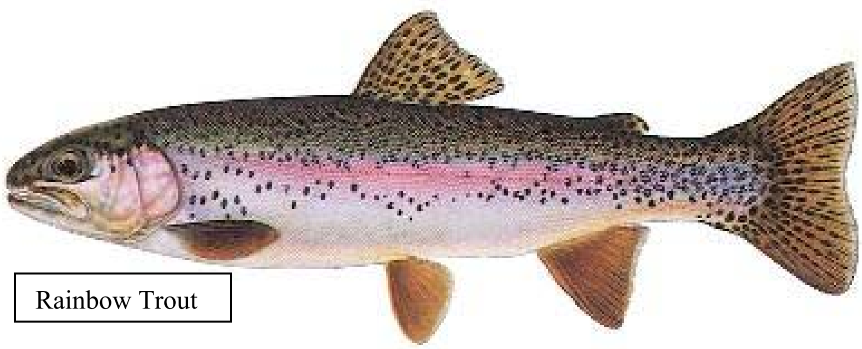
Oregon Coast coho salmon (*Oncorhynchus kisutch*), a formerly listed and currently proposed threatened species under the Endangered Species Act, are present in the North Umpqua River subbasin. The nearest habitat for coho salmon is located approximately 33 miles downstream from Diamond Lake, 23 miles downstream of Lemolo Reservoir, and 5 miles downstream of Toketee Reservoir, below Soda Springs dam. Umpqua River cutthroat trout (*Oncorhynchus clarki clarki)*, Oregon Coast Chinook salmon (*Oncorhynchus tshawytscha)*, and the Umpqua chub (*Oregonichthys kalawatseti*) are on

[32] Resulting from volcanic ejection.

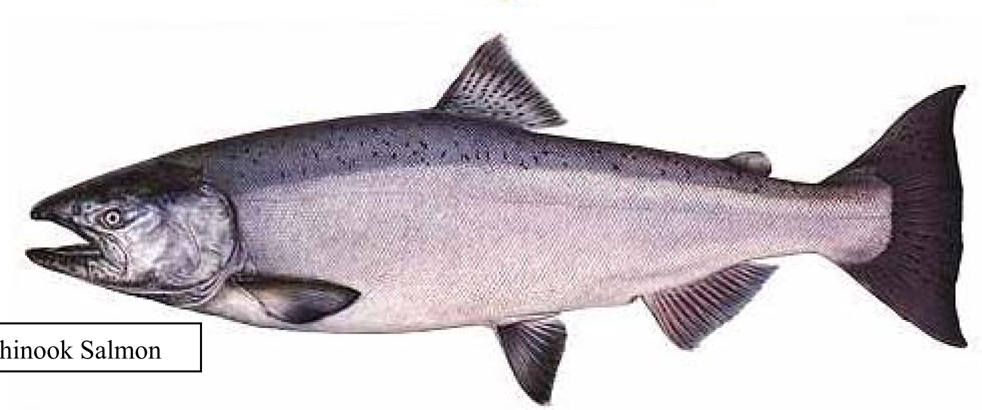
the USDA Forest Service Region 6 sensitive species list[33]. The nearest habitat for cutthroat trout and Chinook salmon is also located below Soda Springs dam. The nearest habitat for the Umpqua chub is located approximately 105 miles downstream, in the main stem Umpqua River.

Silent and Short Creeks: Of the six named tributaries to Diamond Lake, only Silent and Short Creeks (see Map X) are believed to be capable of supporting fish populations. The other streams are considered to be too small, or are intermittent, and would not be capable of supporting fish. Anecdotal observations have indicated that small numbers of tui chub and rainbow trout (*Oncorhynchus mykiss*) periodically enter the lower segment of Silent Creek from Diamond Lake. However, cold water temperatures (40°to 45°F) found year round likely limit the stream's use by fish. Results from a recent habitat inventory conducted in Silent Creek in 1997 support this assessment. During the entire 1.8 mile survey, only one fish (a rainbow trout) was seen by experienced snorkel surveyors looking for fish.

Diamond Lake: Currently, rainbow trout, spring chinook salmon, tui chub, and golden shiner (*Notemigonus crysoleucas*) are found in Diamond Lake (see photos below).

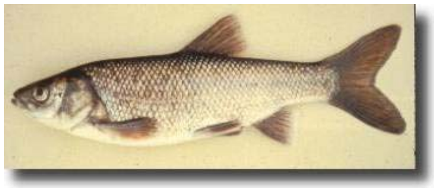


Rainbow Trout



Chinook Salmon

[33] Sensitive species are managed by the Forest Service to prevent the likelihood that these species would need to be listed under the Endangered Species Act.



Tui Chub

Golden Shiner

Past Management History (1910 to 1954): Rainbow trout of Spencer Creek origin (Klamath basin) were first put into Diamond Lake in 1910 (ODFW, 1996). Annual stocking efforts were necessary in order to sustain the fish population due to limited natural fish reproduction in the lake and its tributaries (USDA, 1998). This stocking was so successful that an egg-taking facility was established in 1919 by the Oregon Fish Commission. This station operated for 33 years, utilizing rainbow trout eggs to restock the lake and as a supply source for other hatcheries. Excellent trout fishing was reported by the early twenties, with six to eight pound trout common, and a reported record trout of 27½ pounds (Locke, 1947). Rainbow trout were stocked into Diamond Lake at increasing levels up until 1946, when the numbers of fish began to be reduced. Table 1 displays rainbow trout stocking data for Diamond Lake through 1954.

Diamond Lake Fish Stocking Data from 1910 through 1954			
Date	**Strain**	**Number Stocked**	**Size**
1910-1938	Spencer Creek	1.0 million (per year)	fry
1938-1945	Spencer Creek	2.0 million (per year)	fry
1946	Spencer Creek	4.0 million	fry
1947	Spencer Creek	3.3 million	fry
1948	Spencer Creek	2.0 million	fry
1949		None	
1950	Spencer Creek	49,000	Legal sized
1951	Spencer Creek	47,000	Legal sized
1952	Spencer Creek	49,000	Legal sized
1953	Spencer Creek	32,000	Legal sized
1954		None	

Table 1: Early stocking data for Diamond Lake (ODFW, 1996a)

Sometime in the 1940's tui chub, a minnow native to the Klamath basin, was introduced into Diamond Lake. Most local fisheries professionals believe these fish were introduced by an unwitting fisherman who had been using them as live bait, and dumped the remaining bait overboard at the end of the day. Based on the biology of the tui chub, and its presence in many other lakes within a one hour drive radius of Diamond Lake, it is also possible that these fish were accidentally transported to the lake as eggs attached to aquatic weeds, or perhaps larvae or small juveniles trapped in bilge water, or live wells (Frank Bird, personal communication). Regardless of the source, the tui chub population grew quickly while the rainbow trout population and angling pressure declined.

By 1946, the decline in angling success, decreasing size of rainbow trout, and drop in fishing pressure triggered a preliminary biological investigation of Diamond Lake. This study found populations of rainbow trout, brown trout (*Salmo trutta*), and tui chub present in the lake (Locke, 1947). It is important to note that brown trout were likely present in Diamond Lake at the time when tui chub were first introduced. Although these fish were not routinely taken in the recreational fishery, Locke (1947) reported that three overnight gillnet sets in October of 1946 resulted in the capture of five brown trout weighing from 1.5 to 7 pounds (0.7 to 3.2 Kgs). In comparison, 15 rainbow trout, ranging from 1.5 to 3.5 pounds (0.7 to 1.6 Kgs), were also caught in these same gillnet sets. An additional 30 brown trout were collected in Lake Creek above the falls through angling and use of poison. Brown trout are known to be voracious predators, often feeding primarily on other small fish if they are available. While there is no direct evidence to confirm that the brown trout in Diamond Lake preyed upon the tui chub, it is highly likely that the chub would have provided an ample food source for these aggressive fish. However, these trout were apparently not able to keep the rapidly expanding chub population in check.

By 1946, enormous schools of tui chub were beginning to show up in the shallow shoreline waters. Efforts to control the tui chub population included seining and partial chemical treatment in the shallow areas of the lake where they were observed to be spawning. These methods are believed to have eliminated over 68 million chub between 1946 and 1950, but the tui chub continued to flourish while rainbow trout populations continued to decline (ODFW, 1996). In 1954 the entire lake was treated with rotenone to eliminate all fish. The biologist coordinating the operation, John Dimick, estimated that 32 million tui chub were killed, or around 400 tons of fish.

One year after this treatment, a spring-spawning strain of rainbow trout originating from British Columbia, Canada (the Kamloops stock) was introduced into the lake. Although not native to Oregon, it was presumed that this “pure” stock (i.e. not mixed with other strains of rainbow) would perform better than stocks used previously in the lake (ODFW, 1996). However, stocking of Kamloops rainbow was discontinued after 1961 due to their relatively low fry-to-adult survival, and their poor body condition in the spring when the fishing season opened (during and immediately after the trout spawning season).

From 1962 through 1969 a mixed stock of rainbow trout was used in Diamond Lake. These trout originated from Oregon in the Willamette River, the Roaring River, and Oak Springs areas. Unlike the majority of other rainbow trout stocks that tend to spawn in the spring, these stocks were developed to spawn in the fall. As a result, juveniles of this fall spawning stock were able to attain a larger size than their spring-spawning counterparts by the time they were stocked in the various lake systems (Loomis, personal communication). Stocked as fingerlings in June, these fish had an exceptional survival rate, with approximately 70% surviving to a catchable size. A typical 3 inch (7.6 cm) fingerling stocked in June would grow to a 12 to 14 inch (30.5 to 35.6 cm) fish by the following summer. From 1962 to 1990, roughly 400,000 fingerlings (primarily Oak Springs strain) were stocked on an annual basis. Table x below displays fish stocking data from 1955-1990.

Diamond Lake Fish Stocking Data from 1955-1990			
Date	**Strain**	**Number Stocked**	**Size**
1955	Kamloops	530,000	Fry
1956	Kamloops	250,000	Fry
1957	Kamloops	300,000	Fry
1958	Kamloops	1,014,000	Fry
1959	Kamloops	1,000,000	Fry
1960	Kamloops	1,063,000	Fry
1961	Kamloops	1,175,000	Fry
1962-1969	Mixed Strain	400,000-500,000	Fingerlings
1970-1990	Oak Springs	300,000-400,000	Fingerlings

Recent Management History: In the recent past, Diamond Lake has been managed under a formal management plan that was adopted in 1990 by the Oregon Fish and Wildlife Commission. This management plan includes the objectives of 100,000 angler trips per year, harvest of 2.7 fish per angler trip (or 270,000 trout), with an average fish length of 12 inches (30.5 cm). It is important to note that these figures were developed from data collected during the peak of Diamond Lake's angling success (1963 to 1978).

In 1992, tui chub were discovered again in Diamond Lake. As tui chub populations expanded exponentially, the success of the fingerling rainbow trout stocking program at the lake began to decline substantially (ODFW, 1996). This situation closely paralleled the fishing declines seen in the early 1950's, when tui chub were first introduced into Diamond Lake.

Current Conditions: Based on hydroacoustic surveys[34] and trapnetting data over the last several years, the estimated yearly tui chub population from 1995 to 2003 has averaged around 7.6 million fish greater than 2½ inches (>6.4 cm) in length, with a range of 1.7 to 23.7 million (Loomis and Eilers, personal communication). Based upon life history and fecundity tables generated by Bird (1975) and population modeling by ODFW (2004), the large average population of spawning-age tui chub in Diamond Lake would be capable of producing approximately 6.9 billion eggs in a single year. In addition, during this same timeframe there are also an estimated average of 94.5 million tui chub in younger age classes present in Diamond Lake on an annual basis. These fish represent

[34] Hydroacoustic surveys utilize high frequency sound waves to identify bottom features, fish, aquatic vegetation, and zooplankton within waterbodies. These surveys are capable of estimating fish numbers and the relative sizes of fish.

young-of-the-year, 1 year, and 2 year old fish, ranging in size from ¼ to 2½ inches (6 to 65 mm) in length. As Bird (1975) indicated in his work with tui chub, the food preferences of tui chub and trout in lake environments are very similar. Therefore, tui chub and stocked rainbow trout are in direct competition for available food resources in Diamond Lake.

The population of tui chub in Diamond Lake is currently exhibiting characteristics of a stressed population. The number of larger chub greater than 6 inches (>15.2 cm) is declining, and the number of fish considered to be in the catch-able size range using nets (greater than 2.5 inches or 6.4 cm) has also declined recently. The age and size when sexual maturity is reached has also likely declined. In summary, this is an indication that population stressors have resulted in more fish spawning at younger ages and smaller sizes.

The actual number of chub present in any given year is dependant upon a number of factors, including food availability, competition, weather, water quality conditions, over-winter survival, and overall habitat limitations induced by the large size of the chub population as a whole. While the chub population in Diamond Lake is variable from year to year, there is virtually no chance that the entire population would crash naturally, thereby eliminating tui chub from the lake. As chub populations decline as a result of natural causes, previously utilized food and habitat resources become available, thereby increasing the growth and productivity of the remaining chub. As these remaining fish grow larger, they are also able to produce a greater number of eggs, ultimately leading to more tui chub. Therefore, due to the cyclic nature (i.e. rise and fall) of the population, tui chub are likely to persist in Diamond Lake indefinitely without some form of management intervention.

Based on the apparent inability of Diamond Lake to meet formal management plan basic yield fish numbers, ODFW is currently managing Diamond Lake using modified fish management guidelines. For the last several years, stocking of fingerling rainbow trout has been dramatically reduced due to their poor survival, and stocking of legal size rainbow trout and other experimental species has been initiated. While this strategy provides a small recreational fishery, it is viewed as a temporary measure due to the high cost. As shown in table x below, recent efforts to identify a salmonid that can successfully compete with or prey upon tui chub in Diamond Lake has led to an increasingly complicated experimental stocking program.

As an example: In 2003, Diamond Lake opened for trout fishing on April 26, and a total of nearly 100,000 legal-sized fish were stocked periodically throughout the fishing season. Of these fish, roughly 60,000 were catchable-sized hatchery spring chinook, approximately 24,000 were catchable-sized Eagle Lake rainbow trout (sterile triploid stock), and 15,000 were two-pound (0.9 Kg) Kamloops rainbow trout. In addition to catchable-sized fish, 50,000 Oak Springs rainbow trout fingerlings and 40,000 spring Chinook fingerlings were also stocked. This fish stocking cost approximately $184,000. Table x below displays recent fish stocking data associated with the experimental stocking program.

Diamond Lake Fish Stocking Data from 1991-2003			
Date	**Strain**	**Number Stocked**	**Size**
1991	Oak Springs rainbow	350,000	Fingerlings
1992	Oak Springs rainbow	425,000	Fingerlings
	Cape Cod rainbow	5,000	Legal sized
1993	Oak Springs rainbow	350,000	Fingerlings
	Cape Cod rainbow	14,000	Legal sized
1994	Oak Springs rainbow	425,000	Fingerlings
	Cape Cod rainbow	5,000	Legal sized
1995	Oak Springs rainbow	400,000	Fingerlings
	Cape Cod rainbow	7,500	Legal sized
	Williamson rainbow	12,000	Fingerlings
1996	Oak Springs rainbow	350,000	Fingerlings
	Cape Cod rainbow	10,000	Legal sized
1997	Oak Springs rainbow	350,000	Fingerlings
	Cape Cod rainbow	7,700	Legal sized
	Williamson rainbow	50,000	Fingerlings
1998	Oak Springs rainbow	345,000	Fingerlings
	Cape Cod rainbow	7,500	Legal sized
	Williamson rainbow	50,000	Fingerlings
1999	Oak Springs rainbow	380,000	Fingerlings
	Cape Cod rainbow	8,000	Legal sized
	Williamson rainbow	50,000	Fingerlings
	Kamloops rainbow	5,000	Trophy sized
2000	Oak Springs rainbow	60,000	Fingerlings
	Cape Cod rainbow	38,000	Legal sized
	Kamloops rainbow	15,000	Trophy sized
2001	Oak Springs rainbow	50,000	Fingerlings
	Cape Cod rainbow	31,000	Legal sized
	Kamloops rainbow	15,000	Trophy sized
2002	Oak Springs rainbow	50,000	Fingerlings
	Cape Cod rainbow	26,000	Legal sized
	Spring Chinook salmon	40,000	Fingerlings
	Spring Chinook salmon	24,000	Legal sized
	Kamloops rainbow	15,000	Trophy sized
2003	Oak Springs rainbow	50,000	Fingerlings
	Spring Chinook salmon	40,000	Fingerlings
	Spring Chinook salmon	60,000	Legal sized
	Kamloops rainbow	15,000	Trophy sized
	Eagle Lake rainbow	24,000	Legal sized

Table x: Recent fish stocking information for Diamond Lake

Lake Creek: Lake Creek currently supports populations of rainbow trout, brook trout (*Salvelinus fontinalis*), brown trout, and tui chub. There is also a small component of the kokanee population (*Oncorhynchus nerka kennerlyi*) from Lemolo Lake that enters the lower portion of Lake Creek in the fall to spawn. From a local standpoint, golden shiner were formerly only known to occur in Diamond Lake (USDA, 1998). However, fish trapping efforts in Lake Creek during 2003 documented 16 golden shiner migrating out