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

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)

[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.

[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

Relationship to Issues: 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.

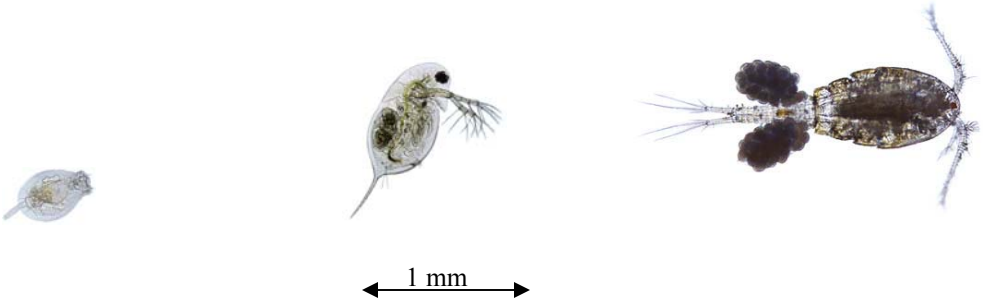

Figure X. Representative examples (and relative sizes) of the three major groups of zooplankton in freshwaters – from left to right - rotifers, cladocerans, and copepods.

Diamond Lake: 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 pre-fish zooplankton populations in Diamond Lake were dominated by large copepods

[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.

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

[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).

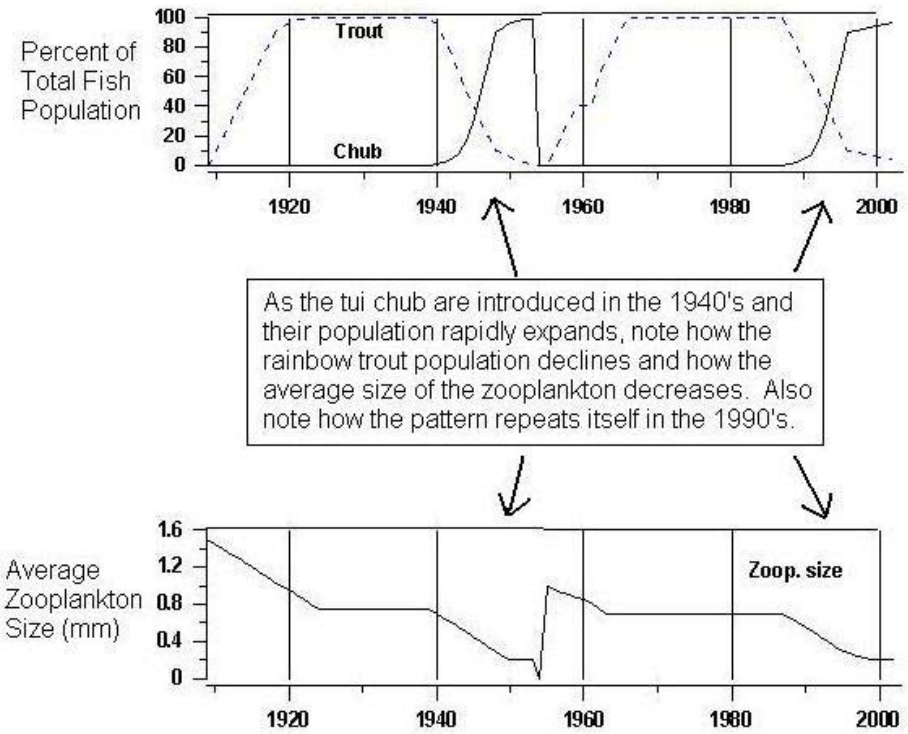

Figure x: An empirical model of the relationship between zooplankton and fish in Diamond Lake

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

[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) and Alternative 3 (Put and Take Fishery), 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) 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 and 3, 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 and 3, 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 50,000-150,000 fingerlings, and 10,000 legal sized rainbow for the first year following chemical treatment). 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 this alternative, 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 and 3, if monitoring 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 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 85-95% 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 4 to 6 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 and 3 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 and 3) do 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

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

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, Alternative 2 represents a short-term contribution to the cumulative effect of management on zooplankton, with a predicted long-term beneficial impact. Future fish stocking strategies under this alternative 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 Alternative 2 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. 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, the likely cumulative impact of Alt. 4 would 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, Alternative 4 represents a primarily neutral or potentially limited positive contribution to the cumulative effects of management activities on future zooplankton populations.

Connected Actions: Under Alternatives 2 and 3, 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.

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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.

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 and 3 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 and 3 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 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 and 3 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 descrived activities mentioned in table xx, would be the continued contribution 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 and 3, 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				
Element	**Alternative 1 - No Action**	**Alternative 2 - Rotenone**	**Alternative 3 - Put and Take Fishery**	**Alternative 4 – Mechanical & Biological**
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. High long-term negative impacts to zooplankton body size due to high predation by tui chub.
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.

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:

Based on the above discussion, Alternative 1 would result in continued suppression of zooplankton populations in the short and long-term, and would prevent attainment of Aquatic Conservation Strategy Objective 9[28]. Alternatives 2 and 3 would result in

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

dramatic immediate decreases in zooplankton populations due to the addition of rotenone. However, these population declines would be short-term, and not expected to last for more than a few months. The three 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 and 3) 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 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. Also in the long-term, Alternatives 2 and 3, 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].

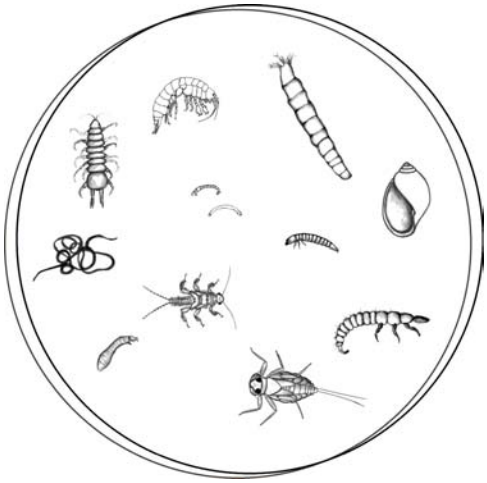
In summary, from a zooplankton standpoint, the relative ACS ranking of each alternative would be as follows (from best to worst):

Alternative 3 – Most effective at moving toward attainment of ACS objectives
Alternative 2 – 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 – Retards attainment of ACS objectives

[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.

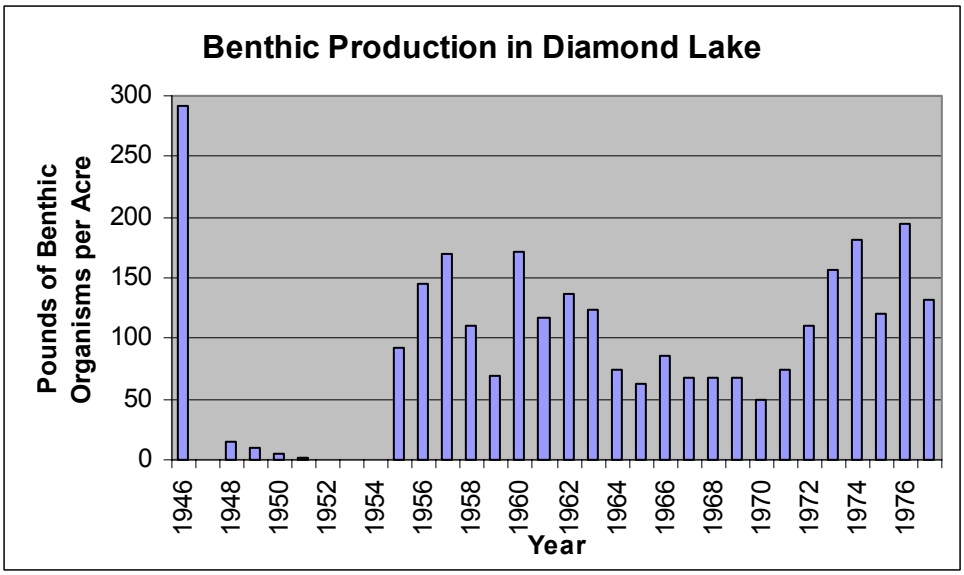


Figure x: Benthic production in Diamond Lake from 1946 to 1977.

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) and Alternative 3 (Put and Take Fishery) 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 and 3) 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 and 3) 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 quality*** section). The benthic community around the remainder of the lake would likely

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

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 and 3 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 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 Alternative 2 would differ slightly from those of Alternative 3. While each alternative proposes the complete removal of tui chub, Alternative 2 proposes 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 150,000 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 and 3, 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.

Alternative 2 would result in a long-term cumulative improvement 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, Alternative 2 represents a short-term contribution to the cumulative effect of management on benthic organisms, with a predicted long-term beneficial impact. Future fish stocking strategies under this alternative 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 Alternative 2 in that its potential contribution to cumulative effects is further reduced by stocking with fish not expected to prey heavily on benthic organisms.

Alternative 4 represents the alternative with the greatest amount of uncertainty regarding affects to the aquatic community. This alternative would attempt to remove roughly 85-95% of the reproductive age chub from Diamond Lake on an annual basis for 6 years. 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. The process of adjusting salmonid stocking regimes in response to perceived changes in aquatic invertebrate indices may have little effect in terms of stabilizing those populations. Based upon past history, tui chub are able to out-compete trout for available food resources in Diamond Lake. The continued presence of a variable tui chub population is likely to result in continued suppression of benthic organism populations.

Given the long-term delay before impacts to benthic organisms would potentially subside and the risk that improvements may not even occur, Alternative 4 is expected to result in continued cumulative effects to benthic organisms. These cumulative effects would occur for at least six years and likely would continue indefinitely into the future.

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 and 3 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 and 3, 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 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 and 3 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 and 3 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 and 3 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 and 3 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**	**Alternative 3 - Put and Take Fishery**	**Alternative 4 – Mechanical & Biological**
Benthic Organism Production	Benthic organism production would continue to be 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 by high predation from tui chub, and poor water quality conditions.
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 poor water quality conditions.

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

Conclusions: 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 would prevent attainment of Aquatic Conservation Strategy Objective 9. Benthic populations downstream in Lake Creek, Lemolo Reservoir, and the North Umpqua River would likely remain unchanged. Alternatives 2 and 3 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 not expected to last for more than a few months. The three 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 and 3) 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.

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 – 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 – Retards attainment of ACS objectives

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

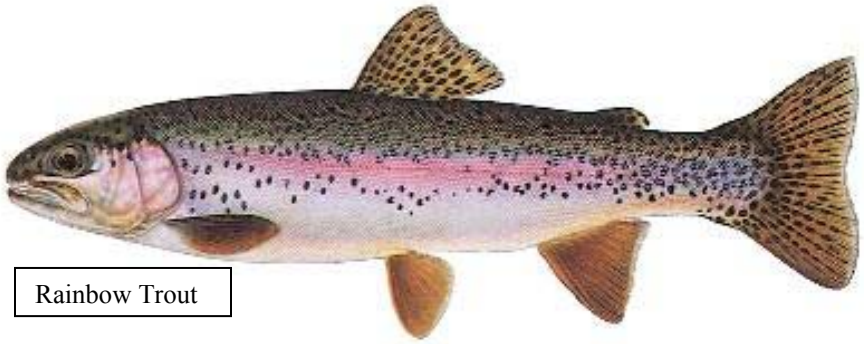
Historically, all waters above Toketee Falls, including Diamond Lake and its tributaries, were believed to be naturally fishless (USDA, 1998). It is likely that numerous large waterfalls on the upper North Umpqua River (i.e. Lemolo Falls, Toketee Falls, and others) would have blocked the upstream migration 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 federally listed 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 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.

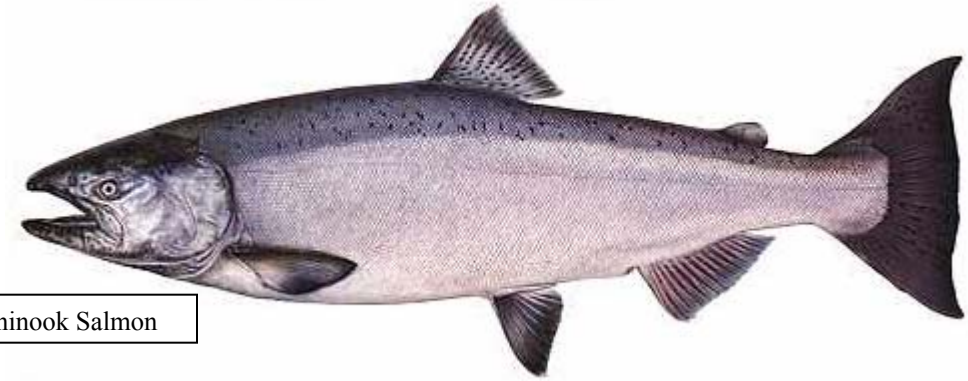
[32] Resulting from volcanic ejection.
[33] Sensitive species are managed by the Forest Service to prevent the likelihood that these species would need to be listed under the Endangered Species Act.

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

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 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.

[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.

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 of Diamond Lake and into Lake Creek.

The existing fish population in Lake Creek is believed to have migrated upstream from Lemolo Reservoir, and downstream, from Diamond Lake. Lake Creek is capable of supporting successful spawning, and the existing salmonid populations are generally self-sustaining, with contributions from the other areas mentioned above.

No fish stocking is known to take place in this stream. No estimates of fish population size have been conducted in the eleven mile length of Lake Creek between Diamond Lake and Lemolo Reservoir. However, there is a modest recreational trout fishery that occurs at either end of this stream, near the respective lake or reservoir water bodies (Loomis, personal communication).

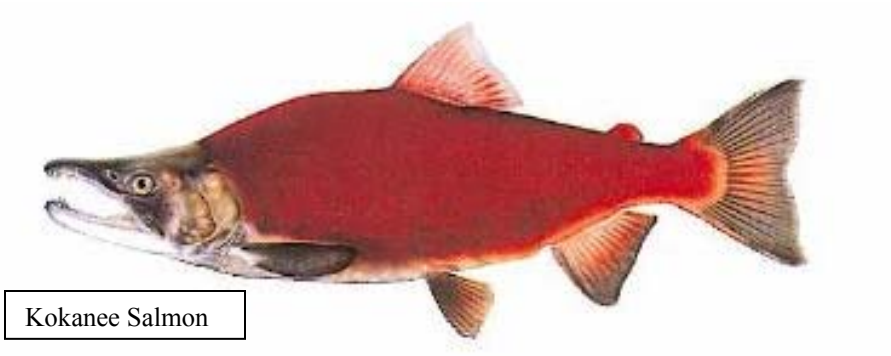
While no population estimate of tui chub in Lake Creek has been made, data collected in 2003 from a fish trap located in Lake Creek near Diamond Lake indicates that large numbers of tui chub enter this system in late spring and early summer. Almost 7,000 tui chub were caught in this trap over the spring and summer months. Since this trap only captures a portion of the fish moving past it each day, this figure only represents a partial count of chub that out-migrated from Diamond Lake into Lake Creek. Throughout the summer months, chub were observed occupying habitats in slow moving pools and backwater areas of Lake Creek. However, based on the chub's preference for slow water habitat, it is likely that the majority of these fish moved through the system, and into Lemolo Reservoir. Those chub that remain in Lake Creek are likely washed downstream during the high, cold flows that routinely occur during the spring snowmelt runoff period. The occurrence of large numbers of tui chub leaving Diamond Lake has been observed since 1994 (Loomis, personal communication).

It should be noted that a 6 foot waterfall (human constructed) is located in Lake Creek approximately 1,000 feet downstream from Diamond Lake. This structure likely prevents upstream migration by all fish species inhabiting Lake Creek. This migration barrier was likely constructed as part of the 1954 rotenone treatment in order to prevent tui chub and brown trout from re-entering Diamond Lake. Based on its height, it is highly unlikely that tui chub could ever make it over the falls. This constructed barrier, which is still in stable condition, apparently functions as planned in 1954 and is expected to continue to block upstream tui chub passage in the future.

Lemolo Reservoir: Lemolo Reservoir was created in 1954 when Lemolo Dam was constructed, damming the North Umpqua River at the confluence of Lake Creek and Poole Creek. Fish management in Lemolo Lake began shortly afterward in 1955. Lemolo Reservoir currently supports populations of rainbow trout, kokanee salmon, brook trout, brown trout, and tui chub (see photos). The kokanee population mainly occurs in Lemolo Lake, entering Lake Creek and the upper North Umpqua River only to spawn.

Brook Trout

Brown Trout



Kokanee Salmon

From 1955 to 1972, various trout were stocked in the lake, until brown trout became the dominant species (DEA, 1998). Today, the majority of the fish population in Lemolo Lake is self sustaining, with naturally spawning populations of brown trout, kokanee salmon, and brook trout. Some limited annual stocking of catchable-sized rainbow trout does occur in Lemolo in order to provide a fishery in the late summer months, when brown trout are typically harder to catch (Loomis, personal communication). Tui chub are also present in the lake, but their population does not seem to be expanding like it is in Diamond Lake (Loomis, Personal Communication). As mentioned above, golden shiner were formerly only known to occur locally in Diamond Lake (USDA, 1998). However, it is likely that some golden shiner are present in Lemolo Reservoir based upon the discovery of shiner migrating out of Diamond Lake.

Today Lemolo Lake is primarily managed for brown trout and kokanee salmon, with 10,500 angler trips recorded in 1997 (DEA, 1998). Studies of brown trout in Lemolo Lake in 1992 revealed that populations were healthy, attaining a length of 8 inches (20.3 cm) by age 2, and 12 inches (30.5 cm) by age 3 (FERC, 1994). The North Umpqua Hydroelectric Project also conducted a creel survey on Lemolo Lake in 1992. Data collected during this survey indicated that angling peaked from April to July, with an estimated 7,500 bank and 19,100 boat anglers. From the survey, the overall catch rate was approximately 0.47 fish per angler hour, and it was estimated that 9,020 legal-sized trout were caught (FERC, 1994).

The tui chub population in Lemolo Reservoir has not expanded as rapidly as the population in Diamond Lake. It is likely that there are several reasons for the apparent inability of the tui chub to dominate Lemolo Reservoir. With an average depth of around 29 feet (8.8 meters), Lemolo Reservoir is deeper than Diamond Lake (22.5 ft. average

depth, or 6.9 meters), and doesn't contain the large littoral areas that are common at Diamond Lake. In addition, Lemolo Reservoir is routinely lowered in the winter, exposing the limited shallow areas to harsh winter conditions. As a result, Lemolo Reservoir does not contain an abundance of aquatic macrophytes, which are essential to the successful reproduction of tui chub. In addition, the relative amount of warmer surface waters in Lemolo is substantially less than that seen in Diamond Lake. In Lemolo, warmer surface water temperatures usually extended to depths of 9.8 to 16.4 feet (3 to 5 meters) (USDA 1998), whereas in Diamond Lake, warmer surface water temperatures usually extend to depths of around 26.2 feet (8 meters). This relative lack of extensive warm surface waters in Lemolo may also be a potential limiting factor on chub populations. From a predator standpoint, there is a healthy population of brown trout in Lemolo Reservoir, which may be preying on the tui chub. All of these factors are apparently leading to a relatively stable tui chub population in Lemolo Reservoir.

North Umpqua River (From Lemolo Reservoir to Rock Creek): The portion of the North Umpqua River between Soda Springs Dam and Lemolo Dam is dominated by resident trout. Rainbow trout, brown trout, and brook trout are the primary species living in this section of the river. The majority of this area is characterized by swift flowing segments of river, divided by several reservoirs created for hydropower use. In addition to the larger reservoirs, there are several canal systems and forebays (water holding areas) that also support populations of resident trout. Soda Springs Dam is a complete barrier to upstream fish passage, and consequently, represents the upper extent of anadromous fish in the North Umpqua system.

From Soda Springs Dam, downstream to the confluence with Rock Creek, (a distance of 33.8 miles) the North Umpqua River is classified as a Wild and Scenic River. One of the Outstandingly Remarkable Values (ORV's) that led to this designation is the fishery. This segment of the North Umpqua River supports populations of summer and winter steelhead trout (*Oncorhynchus mykiss*), spring Chinook salmon, coho salmon, resident and migratory cutthroat trout, resident rainbow trout, brown trout, Pacific lamprey (*Lampetra tridentata*), several sculpin (*Cottus* spp), speckled dace (*Rhinichthys osculus*), Umpqua dace (*Rhinichthys evermanni*), and redside shiner (*Richardsonius balteatus balteatus*). Other species, such as brook trout and tui chub have been encountered occasionally. However, these fish are believed to be moving through the area from upstream populations due to their small numbers and sporadic presence. It is not likely that tui chub could establish a reproducing population segment in this portion of the North Umpqua River due the consistently cold water and abundance of fast-water habitat found here.

ENVIRONMENTAL EFFECTS ON FISH

Effects of Rotenone on Fish: 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). The high susceptibility of fish to rotenone is mostly due to its efficient entry through the gills. Once in the bloodstream, rotenone is quickly carried to vital

organs (such as the brain), where it inhibits cellular respiration (Oberg, 1964 – as cited in Bradbury).

A treatment of 2 mg/L formulated rotenone (100 μg/L rotenone) is anticipated to remain toxic long enough to kill most, if not all, of the fish species present in target waters. (CDFG, 1994). Fish eggs are resistant to rotenone treatments because of an impervious chorion[35] (CDFG, 1994).

In Diamond Lake, approximately 260,000 pounds of powdered rotenone, and roughly 375 gallons of the liquid formulation Noxfish would be used. The powdered form of rotenone is comprised only of ground plant roots, and therefore only contains rotenone and rotenolone compounds. The chemicals associated with liquid Noxfish include rotenone, and other inert ingredients that act as emulsifiers and solvents. The four primary inert ingredients include xylene, trichloroethylene, naphthalene, and 2-methylnaphthalene. These inert ingredients make up roughly 85-90% of the liquid formulation, and are considered to be volatile or semi-volatile organic compounds that are expected to evaporate within several weeks. These chemical compounds do not contribute to the lethality of the formulation, but are important to ensure the solubility and dispersion of rotenone in the water (CDFG, 1994).

Note: Although fish stocking usually occurs as one of the last action items associated with each alternative, the action of stocking fish is considered to be a direct effect in this analysis.

Direct, Indirect, and Cumulative Effects – Short and Silent Creeks: With the lack of a lake drawdown and no chemical treatment, Alternatives 1 and 4 would have no direct, indirect or cumulative effects on Short or Silent Creeks.

The effects of Alternatives 2 and 3 would be extremely limited as well. The direct effect of the rotenone drip stations proposed for Short and Silent Creeks (located within the actual lake perimeter) would be to render the downstream waters toxic to fish. Any fish present downstream of these sites would likely move down into Diamond Lake upon contact with rotenone treated waters. Based upon the overall lack of fish presence in Short and Silent Creeks, it is unlikely that any fish would be killed or displaced in these areas.

No indirect or cumulative effects to fish populations in Short or Silent Creeks would result from the rotenone treatment. Upon cessation of the rotenone drip stations, rotenone and the other formulation constituents would be quickly flushed downstream and out of these respective stream systems. It is uncommon to find rotenone in stream sediments (CDFG, 1994). The VOC's (volatile organic compounds) do not accumulate in the sediment, and only naphthalene and the methyl napthalenes temporarily (less than 8 weeks) accumulate in the sediments (Finlayson, 2000). Rotenone dissipates in flowing waters relatively quickly (less than 24 hours) due to dilution and increased rates of hydrolysis (Finlayson et al, 2000). Based on the continuation of the drip stations for 17

[35] The chorion is the outer membrane of an egg or embryo.

days in these two streams, an estimated total of 375 gallons of liquid rotenone (Noxfish formulation) would be utilized. All of the chemicals associated with these drip stations would break down and/or evaporate relatively quickly, or be transported to Diamond Lake, where they would evaporate over a short period of time.

Direct Effects – Diamond Lake: The no-action alternative (Alternative 1) would result in status quo management of the fisheries at Diamond Lake. No physical or chemical treatments would occur in the lake. A direct effect of this alternative would be that the Oregon Department of Fish and Wildlife would continue with the existing experimental fish stocking program (~100,000 fish/year) in 2004 and 2005.

Alternative 2 (Proposed Action) would have a direct impact on current fish populations in Diamond Lake as a result of the canal reconstruction, lake draw-down, mechanical removal of tui chub (netting), the addition of rotenone, and the addition of salmonids back into the lake. Canal reconstruction would result in minor short-term (2-3 week) disturbance and displacement of fish as sediments are removed from the canal and placed in the northwest corner of the lake to expand the existing wetlands. The draw-down portion of the proposed action would result in lowering the lake level by 8 feet (2.4 meters). This would result in a 10% reduction in total surface area and a 30% reduction in water volume, and would expose a large percentage of the near-shore zone that supports abundant growth of aquatic vegetation. As the lake is drawn down, tui chub would be forced out of this preferred habitat into interior portions of the lake. In addition, during the draw-down it is likely that numerous tui chub would enter the Lake Creek system, and be transported to downstream areas. In order to minimize tui chub movement out of Diamond Lake, the following mitigation is recommended: A trap will be installed to minimize fish movement out of Diamond Lake during the drawdown portion of the project. This trap could consist of stationary trap nets in combination with block nets or weirs.

The mechanical removal of tui chub utilizing trap nets and other commercial fishing techniques would likely reduce chub population numbers to some unknown extent. These activities are proposed for a duration of up to one month. Based upon past chub removal efforts utilizing these techniques, and the fact that a large percentage of the existing chub biomass is comprised of fish too small to be effectively netted, this effort would likely result in a low to moderate reduction in total fish biomass in Diamond Lake.

Based upon the results of the rotenone treatment in 1954, the addition of rotenone in the fall would result in the eradication of all fish living in Diamond Lake, Short Creek, and the lower mile of Silent Creek. While the original rotenone treatment in 1954 was apparently successful in removing all tui chub from the lake, it should be noted that some of the literature reviewed indicates that it is rare to kill all fish with a single rotenone treatment (Bradbury 1986).

In the spring following rotenone treatment, a relatively small number of trout would be stocked into Diamond Lake. Based on preliminary estimates by ODFW biologists, a range of 50,000 to 150,000 Oak Springs rainbow trout fingerlings, and roughly 10,000

legal-sized Eagle Lake rainbow trout would be stocked. These fish would provide a small recreational fishery while still allowing for recovery of zooplankton and benthic invertebrate populations (the biological indicators).

The direct effects of Alternative 3 (Put and Take Fishery) would be similar to those of Alternative 2. Both alternatives include canal reconstruction, lake draw-down, mechanical removal of tui chub (netting), the addition of rotenone, and the addition of salmonids back into the lake. Alternative 3 differs from the other action alternatives as a result of the proposed fish stocking regime. Under this alternative up to 400,000 domesticated, put-and-take rainbow trout would be stocked throughout the fishing season in Diamond Lake annually. This would likely provide a large recreational fishery similar to that seen in the 1970's and 1980's.

The direct effects of Alternative 4 differ substantially from those of the other action alternatives. Alternative 4 does not include the actions of canal reconstruction, lake drawdown, chemical treatment, and lake refill. As a result, none of the direct effects associated with those treatment components would apply to Alternative 4. This alternative would result in the direct mechanical removal of a substantial portion of the tui chub biomass from the lake in each of six consecutive years. Mechanical removal methods would have a goal of removing 85-95% of the spawning population of tui chub. Immediately following mechanical chub removal efforts, up to 250,000 predatory salmonids would be stocked in the lake. These fish would be larger-sized Eagle Lake rainbow trout capable of feeding on the remaining tui chub prey base, and would provide a moderate recreational fishery. The extent and effectiveness of chub predation by these fish is unknown.

Although the numbers of fish stocked in Alternatives 3 and 4 are somewhat similar, the recreational fishery under Alternative 4 is expected to be slightly smaller than that under Alternative 3. This difference would be a result of special angler harvest regulations implemented under Alternative 4 that may limit the harvest of large fish in an effort to maintain the predatory controls on the tui chub population.

Indirect Effects – Diamond Lake: An indirect effect of Alternative 1 would be the continued maintenance of large populations of tui chub, and small populations of salmonids added during the experimental stocking program employed by the ODFW. 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. In addition, continued high levels of algal productivity would likely result in anoxic conditions throughout much of the lake during the spring and summer months, and could result in fish kills under certain environmental conditions. When these large algae blooms produce toxins, it is also possible that fish kills could occur as a result of these toxins (Christoffersen, 1996).

The indirect effects of Alternative 2 would be focused mainly in Diamond Lake, Lake Creek, and Lemolo Reservoir. In Diamond Lake, a relatively small number of trout would be stocked in the lake once biological indices indicate it is ecologically acceptable

to do so (as mentioned above). Indirectly, this alternative would result in high growth and survival rates of these stocked fish. These fish are likely to thrive due to the recently recovered prey base of large-bodied zooplankton and other benthic organisms. As a result, a small recreational fishery would likely return to Diamond Lake within a few years. The average fish caught would be of excellent size and body condition due to the abundant forage base and the presence of multiple age classes of trout (resulting in the potential for larger fish being available to the angler).

The indirect effects of Alternative 3 would be similar to those of Alternative 2. The primary difference with this alternative would be the size of the recreational fishery, as well as the condition of the fish caught. Under this scenario, up to 400,000 domesticated rainbow trout would be stocked in the lake throughout the angling season. Based on past experience with this stock, these fish would not be expected to take advantage of the available food resources. As a result, fish will gradually start to lose body condition and size over time until they are caught, or die with the onset of harsher winter conditions. Stocking at these levels would likely provide a large recreational fishery at Diamond Lake. The average fish caught would be of modest size and body condition, and would mimic the average size of fish that were originally stocked. Very few of these fish would be expected to survive through the winter, or attain larger sizes.

Alternative 4 would have a different suite of indirect effects than the other action alternatives due to the lack of a lake draw-down, no chemical treatment, and no period of Lake Creek de-watering. Under this alternative, up to 250,000 larger sized, predatory trout would be stocked in the lake. It is anticipated that these larger fish would take advantage of the abundant tui chub food source, and grow to relatively large sizes. Stocking of these large trout would likely result in a moderate recreational fishery returning to the lake, with the potential for anglers to catch trophy sized fish. The potential use of angler harvest restrictions in order to limit the removal of large predatory fish (to maintain a predatory control on the chub) may reduce the desirability of this fishery.

The addition of larger-sized piscivorous trout (Eagle Lake rainbow trout, or brown trout, or Kamloops rainbow trout) may result in a reduction in tui chub numbers as a result of predation. However, preliminary stomach content data from Eagle Lake rainbow trout recently stocked in Diamond Lake indicates that very few tui chub are being consumed by these fish (Loomis, personal communication). Based on information contained in a report by the Oregon State Game Commission (Locke 1947), large brown trout were likely present in Diamond Lake when tui chub were first introduced. These trout were apparently not able to prevent the rapid expansion of the tui chub population. Therefore, the addition of piscivorous fish may result in a further reduction in tui chub numbers, but the extent of that reduction is unknown.

The successful mechanical removal of a large portion of the spawning tui chub population in Diamond Lake on a yearly basis (over a span of 6 years) would reduce the annual spawning success of the chub population in the short-term and lead to relatively small numbers of juvenile tui chub produced each year (millions instead of billions).

Assuming an average population of 7.6 million reproductive chub in Diamond Lake at the time of treatment, the successful removal of 90% of the spawning tui chub population in the first year of mechanical treatment would result in roughly 760,000 reproductive chub remaining in the lake. Assuming all of these remaining chub were in the 2.4-3.7 inch range (6.0-9.4 cm) and that 50% were female, they would be capable of producing roughly 127,300,000 eggs. For more information on tui chub population and egg production estimates associated with Alternative's 1 and 4, refer to Appendix X, Population Model Predictions for Tui Chub Removal at Diamond Lake (ODFW, 2004).

A potential complicating factor associated with the partial removal of the chub population is that of a compensatory response[36]. As large numbers of tui chub are removed through mechanical harvest or predation, the formerly stunted population would then be exposed to increases in food and habitat availability. Remaining fish would likely respond positively to this increase in available resources, resulting in consequent increases in average length and weight of individual chub. Bird (1975) indicated that as tui chub length and weight increase, the number of eggs produced also increases. As an example, a 5 inch (12.7 cm) chub could produce an average of around 5,000 eggs per spawning cycle, while a 7 inch (17.8 cm) chub could produce an average of around 28,000 eggs per spawning cycle. Therefore, as large numbers of chub are removed from the lake, the remaining population would likely respond indirectly by increases in body size and number of eggs produced by each individual fish. It is unknown to what extent this potential increase in egg production may offset the population reductions achieved by mechanical and/or predatory removal of tui chub.

Connected Actions: Under Alternatives 2 and 3, 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 on fish populations would result from this action.

Cumulative Effects – Diamond Lake: Past, present, and future fish stocking strategies, as well as the 1954 rotenone treatment and a variety of fish-oriented facility developments (i.e. boat docks, boat launch ramps, etc) represent the primary management activities that contribute to cumulative effects on fishery resources in Diamond Lake. Considered in this context, Alternative 1 would result in a long-term continuation of tui chub as the dominant fish species in Diamond Lake. Tui chub populations would eventually reach some unknown maximum sustainable level. Once this point is reached, chub populations would vary from year to year due to density-induced food shortages, disease, or water-quality induced mortality. Salmonids would continue to be stocked on

[36] A compensatory response occurs when a given population adjusts (compensates) to changes in its environment.

a limited basis in order to maintain a recreational fishery in Diamond Lake. It is likely that most stocked salmonids would be caught in the recreational fishery, or would starve to death over time due to the lack of an exploitable prey base. Very few salmon or trout would survive over the winter due to the lack of a food source.

Alternatives 1 and 4 would result in the continued presence of tui chub in Diamond Lake. If recreational fishing results in the removal of a large portion of the predacious Eagle Lake rainbow trout population (under Alternative 4), this may inadvertently remove the majority of the predation control on the tui chub population, potentially allowing their populations to rapidly expand. In addition, if the predacious fish stocked into the lake do not prey upon the chub to the extent expected, it is likely that chub populations would quickly expand, eventually exceeding the capability of the piscivorous fish predation controls. If this occurred, conditions similar to those seen currently (i.e. poor water quality and trout survival) would reappear. Thus, it is uncertain whether Alternative 4 would result in a meaningful positive cumulative impact on the fishery beyond the six-year lifetime of the project. For more information on tui chub population and egg production estimates associated with Alternative's 1 and 4, refer to Appendix X, Population Model Predictions for Tui Chub Removal at Diamond Lake (ODFW, 2004).

Alternative 2 would likely result in the complete eradication of tui chub, and the reestablishment of the put-grow-and take fishery that formerly existed at the lake. Fish stocking levels would likely be modified annually over the first several years based on the monitoring of zooplankton and benthic invertebrate indices. Over the long-term, the number of fish stocked would likely stabilize as fisheries managers utilized the biological indicators to adapt stocking levels to maximize the attainment of water quality and recreational fishery goals. Based upon the numbers of fish stocked in the past, and the relative effects that stocking apparently had on water quality, it is likely that the future fish stocking levels would be somewhat similar to those seen in the past. Thus, Alternative 2 is expected to result in a positive cumulative impact on the fishery beyond the lifetime of the project.

Alternative 3 would also result in the complete eradication of tui chub, but the fishery would change to a put-and-take scenario. Up to 400,000 domesticated rainbow trout would be stocked annually. The majority of these fish would be caught each year, with very few expected to survive through the winter months. As a result, recreational fishery levels may be similar to those seen in the past, but there is also a chance that these levels would decrease due to the lack of opportunities to catch larger-sized fish, which may result in a less desireable fishing experience overall. Thus, a positive cumulative impact is expected under this alternative, but it may be somewhat less than that seen under Alternative 2.

Riparian Unit of Silent and Short Creeks and Diamond Lake and Forest Plan Riparian Prescriptions (C2-1 And C2-1V) under Alternatives 2 and 3:

Alternatives 2 and 3 would both apply rotenone to Silent and Short Creeks and to Diamond Lake, which would be in conflict with two riparian prescriptions in the Umpqua National Forest Land and Resource Management Plan (LRMP). These prescriptions state that pesticides will not be applied in such riparian units of fish bearing stream, lakes, and ponds. Therefore, a one-time, site-specific Forest Plan amendment would be necessary in order to implement either Alternative 2 or 3.

The rotenone application to Silent and Short Creeks under Alternatives 2 and 3 would occur within the channels that would flow through the drawn down lake bed, rather than in upstream areas where the creeks flow through a vegetated riparian area. As disclosed above in this section, the impacts from the rotenone would be a fish kill in these channels which are expected to contain very few fish. The impact to fish and the aquatic ecosystem of these streams would be of limited extent and duration, as the pesticide is not expected to persist in either in water or in sediments for any significant length of time. Moreover, the native populations of aquatic life killed by the rotenone are expected to return to a healthy state within about 1 year.

The impacts from the rotenone application within Diamond Lake would be a complete fish kill and a substantial kill of the other aquatic organisms in the lake such as zooplankton and benthic invertebrates. These biological impacts would be of limited extent and duration, as the pesticide is not expected to persist in either in the lake water or in lake sediments for any more than a few months. Moreover, the populations of native zooplankton and benthic invertebrates are expected to rebound rapidly, attaining species diversity and populations superior to the existing condition prior to treatment.

In the case of both Silent and Short Creek (located within the perimeter of the existing lake), and Diamond Lake itself, the short-term impacts of using the pesticide rotenone would be outweighed in both aquatic/riparian ecosystems by the long-term beneficial effects to these ecosystems. This is especially true in light of the existing condition of these ecosystems as a result of the tui chub infestation. Since riparian prescriptions C2-1 And C2-1V have the intent of meeting riparian, fisheries, and water quality objective of the Forest Plan, and since these Forest Plan objectives are highly compromised by the existing infestation of tui chub, this one-time use of rotenone is consistent with over-all Forest Plan objectives under the circumstances of the tui chub problem. Since the issuance of the Umpqua National Forest LRMP in 1990, the tui chub population has reached extreme levels, compromising water quality in the vicinity of the mouths of both stream and lake ecosystems as a whole.

Four factors need to be considered in order to include a non-significant Forest Plan Amendment in the Record of Decision for this project if either Alternative 2 or 3 was selected. First, the timing of the amendment would be well into the planning period of the existing LRMP. The next plan revision is estimated to begin in 2007, thus timing would not be a significant factor related to an amendment. Second, the affected area is small in relation to the Umpqua Nation Forest Plan area, and no rotenone would escape to any downstream areas elsewhere on the Forest. Thus, the location and size of the area involved in the potential amendment are not a significant factor. Third, since the tui chub

introduction, the anticipated Forest Plan levels of recreation services are depressed (see Recreation section in this Chapter). A Forest Plan amendment allowing the use of rotenone under either Alternative 2 or 3 would help attain the levels of good and services consistent with goals, objectives, and outputs anticipated in the Forest Plan. Therefore, such an amendment would not be significant. Finally, the change in these management prescriptions only applies to this specific circumstance at Diamond Lake and two inflowing streams of the lake. The proposed amendment would not change management of existing or future projects within the Diamond Lake Management Area, therefore the proposed amendment is not significant based on this factor. Considering these four factors together, the proposed Forest Plan amendment under either Alternative 2 or 3 would not represent a significant change to the Umpqua National Forest Land and Resource Management Plan.

Direct Effects - Lake Creek: Alternatives 1 and 4 are not likely to result in any direct effects to fish populations in Lake Creek, due to the lack of the lake drawdown and no period of Lake Creek de-watering.

Alternatives 2 and 3 would result in removal of the flashboards[37] at the outlet of the lake (beginning of Lake Creek) to initiate the lake drawdown portion of the action. Once the lake is lowered by approximately 2-3 feet (0.6 to 0.9 meter) by removal of these flashboards, water will no longer exit the lake via this route. At this point, water will be routed out of the Lake by use of the reconstructed canal, which is at a lower elevation, and capable of draining additional water out of the lake. At this time, the section of Lake Creek located between the lake and the canal outlet (roughly 1,200 feet, or 366 meters) would dry up due to a lack of surface flow. This occurrence would displace fish and eliminate aquatic habitat in this area. This portion of the Lake Creek channel would remain dry for a period of approximately 1½ years. Surface flows would most likely return to this stream segment in the spring following chemical treatment, when the lake level has risen by at least 5 feet (1.5 meters).

In the portion of Lake Creek below the canal confluence, the draw-down phase of the project would result in relatively high stream flows for a period of 4 to 6 months. This extended duration of bankfull flows during the fall, winter and spring months would likely require fish in Lake Creek to expend substantial amounts of energy to survive. As a result, fish mortality may be higher than the natural mortality rates seen under normal flow conditions.

Under Alternatives 2 and 3, immediately prior to chemical treatments in the lake, the headgates controlling flows in the canal (and Lake Creek) would be closed. This would result in the portion of Lake Creek below the confluence of the canal drying up for approximately 1-2 months until lake water was determined to be free of rotenone, and water releases were re-initiated again into the canal, and ultimately in the creek. Recent flow and groundwater investigations in Lake Creek (refer to groundwater hydrology

[37] There are several boards placed across a concrete channel located at the beginning of Lake Creek, the outlet stream of Diamond Lake. These boards serve the purpose of raising the surface water elevation of Diamond Lake by two feet.

section) indicate that there is very little accretion of flow in the upper 6 miles of Lake Creek, from tributary or groundwater sources. As a result, when surface flow is cut off from Lake Creek immediately prior to chemical treatment (and after) it is likely that this stream would virtually dry up in this 6 mile stretch. Below this segment, stream flow conditions would improve dramatically due to the flow added by Thielsen Creek.

During this period of no-flow in the upper 6 miles of Lake Creek, it is likely that a large portion of the fish in this area would perish as a result of channel dewatering. An unknown portion of the fish population would likely persist in the small residual pools that would remain in certain areas. These pools are not likely to completely dry up due to sub-gravel flow[38] and localized contributions of groundwater that were encountered during the flow investigations. Flow conditions should improve at stream mile 6 due to the stream flow added by Thielsen Creek, which would not be affected by the Diamond Lake Project.

Indirect Effects – Lake Creek: Alternatives 1 and 4 would have a different suite of indirect effects than the other action alternatives due to the lack of a lake draw-down and no period of Lake Creek de-watering. Tui chub would continue to move out of Diamond Lake and into Lake Creek, where they may be competing with resident trout for food and habitat resources.

Alternatives 2 and 3 would result in an extended period of high flow along the entire length of Lake Creek during the drawdown, and an extended period of very low (or no) flow in the upper 6 miles of Lake Creek before and after chemical treatment. These fluctuations would likely result in a dramatic decline in trout populations within this stream. Fish populations would be expected to return to pretreatment levels within two to four years, as other trout move in to occupy available habitat from downstream areas, as well as Diamond Lake. The lack of habitat and food resource competition from tui chub in Lake Creek may also result in slight increases in trout populations in the long-term.

Cumulative Effects – Lake Creek: The previous rotenone treatment, past, present, and future water rights and fish stocking are the primary management activities that contribute to cumulative effects. In this context under Alternatives 1 and 4, fish populations in Lake Creek would be expected to remain relatively unchanged over time. Tui chub would continue to move out of Diamond Lake and into Lake Creek, where they may be competing with resident trout for food and habitat resources. However, it is unlikely that tui chub could out-compete trout in the majority of this fast water stream environment. Thus, cumulative impacts are considered to be minor.

Under Alternatives 2 and 3, there would likely be a short term reduction in trout populations, followed by a longer term recovery of these fish. No tui chub would be present to compete with resident trout. Physical habitat conditions may increase in quality for several years following treatment, but would return to pre-treatment levels

[38] Sub-gravel flow is the portion of water that actually flows through the substrates of a channel, rather than on top of them as the surface flow we most commonly recognize as a stream.

within a few years of the action (see **Aquatic Habitat** section). Thus, cumulative effects to the Lake Creek fishery are considered to be minor.

Direct, Indirect, and Cumulative Effects – Lemolo Reservoir: It is unlikely that any of the alternatives would result in direct effects to fish populations in Lemolo Reservoir.

Alternatives 1 and 4 would result in the continued contribution of nutrient enriched waters entering Lemolo Reservoir, potentially having an indirect and cumulative impact on trophic interactions in that system. The slight increases in zooplankton and benthic organism production may result in small beneficial impacts to trout and kokanee populations in Lemolo Reservoir, due to the increased availability of food resources. However, these benefits may be counteracted by the thousands of additional tui chub that would also move into Lemolo Reservoir annually from Diamond Lake.

Alternatives 2 and 3 would likely result in a dramatic reduction of nutrient enriched waters entering Lemolo Reservoir. Indirectly, this may result in slight decreases in zooplankton and benthic organism populations in that system, and consequent decreases in the amount of food resources available to trout and kokanee populations. It is also likely that the lake drawdown phase of these alternatives could result in a large pulse of tui chub being carried out of Diamond Lake and into Lemolo Reservoir. However, installation of a trap to prevent fish movement out of Diamond Lake (as described earlier) would minimize this potential impact. In the short-term, this would likely have a small to moderate indirect negative impact of these salmonid populations due to increased competition for food resources. Cumulatively however, no further outmigration of tui chub from Diamond Lake would be expected in future years due to their eradication with rotenone. The number of tui chub competing with trout and kokanee for food resources would gradually lessen, and eventually reach some stable level. This would likely result in small beneficial impacts to salmonid populations in the long-term. Cumulative effects under all alternatives are considered to be minor.

Direct, Indirect, and Cumulative Effects – North Umpqua River (From Lemolo Reservoir to Rock Creek): It is unlikely that any of the alternatives would result in direct or indirect effects to fish populations in the North Umpqua River below Lemolo Reservoir, due in large part to the relatively large distances from Diamond Lake to this portion of the North Umpqua River (Diamond Lake is located 11 and 33 miles upstream of Lemolo Lake and Soda Springs dam, respectively). In addition, the series of reservoirs in this portion of the North Umpqua River have a moderating influence, virtually eliminating potential impacts associated with flow increases during lake drawdown, as well as nutrient and sediment contributions to downstream areas. Numerous project design criteria were also developed to specifically eliminate the potential for negative aquatic impacts to occur.

Alternatives 1 and 4 would result in the continued contribution of nutrient enriched waters entering Lemolo Reservoir, and ultimately the North Umpqua system. In combination with other activities in the basin (i.e. recreation, timber harvest, fertilization, hydropower activities, and others in Table xx) this could result in a cumulative negative

impact on trophic interactions in that system (ie. shifts in aquatic insect functional feeding groups). Conversely, Alternatives 2 and 3 (in combination with the cumulative activities listed in table xx) would likely result in slight reductions of nutrient enriched waters entering Lemolo Reservoir and the North Umpqua system. This may ultimately lead to slight beneficial impacts to downstream populations of aquatic insects.

The extent of the potential negative or beneficial impacts to the trophic structures downstream (from all alternatives) is likely to be relatively small when considered in context with all of the other activities in the watershed (table xx). Therefore, it is highly unlikely that any of the alternatives would result in detectable impacts to fish species living in those areas.

Potential Cumulative Effects Common to All Alternatives: There is the possibility of introducing non-indigenous fish genetics into the indigenous fish populations in the Umpqua Basin living downstream as a result of stocking Eagle Lake rainbow trout and Kamloops rainbow trout. Even though all non-endemic fish proposed for stocking in the various alternatives would be artificially sterilized (triploid), the procedures used to obtain sterile fish are not 100% effective. In a report by the Idaho Fish and Game (Megargle and Teuscher, 2001), roughly 5-35% of rainbow and cutthroat trout strains sterilized utilizing heat shock techniques were found to be capable of successful reproduction. This report demonstrates that different strains of fish often have differing susceptibilities to heat, pressure, or chemical sterilization techniques. If a portion of the non-indigenous stocks of trout proposed for use in Diamond Lake are reproductively viable, there is a remote chance that these fish could interbreed with fish from the Umpqua basin.

This risk is considered to be relatively minor however, due to the improbability of this actually occurring. Spawning habitat in Diamond Lake, and Short and Silent Creeks, is marginal at best, and has not resulted in substantial trout production in the past. Furthermore, Eagle Lake rainbow trout are adapted to a closed lake environment and are not considered to be migratory in nature (Paul Chappel, Personal Communication, 2003). Non-sterilized Kamloops rainbow trout have been used in Diamond Lake for a number of years. To date, no self-sustaining spawning populations of these fish have been detected in the rivers, streams, or lakes within the analysis area.

Although Alternatives 1 and 4 would result in the continued presence of tui chub in Diamond Lake, Alternatives 2 and 3 would likely eradicate tui chub from the lake for an unknown period of time. Based on past history and the cumulative activities listed in table xx, such as future recreational fishing and boating, it is reasonably foreseeable to predict that tui chub may be reintroduced (accidentally or intentionally) at some point in the future. As pointed out in the Diamond Lake/Lemolo Lake Watershed Analysis "given that two introductions of tui chub have occurred, and that one introduction occurred approximately 30 years after the original trout stocking in 1910 and the other approximately 30 years after rotenone treatment in 1954, it seems reasonable to assume that this is an appropriate timeframe until the next reintroduction of a nuisance fish will once again require a major management intervention." If history is an accurate measure

of this likelihood, then the 30 year timeframe would be an appropriate estimate. If tui chub remain or are reintroduced, it is reasonable to assume that negative impacts to the recreational fishery would again occur.

Summary of Alternative Effects on Fish Populations in the Diamond Lake Analysis Area				
Element	**Alternative 1 - No Action**	**Alternative 2 -Rotenone**	**Alternative 3 - Put and Take Fishery**	**Alternative 4 – Mechanical & Biological**
Expected Tui Chub Populations	Tui chub populations would remain high, limited only by available food and habitat resources.	Based upon the past rotenone treatment, tui chub would likely be eradicated from Diamond Lake	Based upon the past rotenone treatment, tui chub would likely be eradicated from Diamond Lake	Tui chub populations may decrease slightly in the short-term as a result of commercial harvest, but would likely increase substantially over time as remaining fish compensate for this by increasing body size and egg production.
Trout body condition	Stocked legal-sized fish would continue to lose body mass due to lack of food resources	Stocked fingerlings would grow quickly due to utilization of the abundant food resources (i.e. zooplankton and benthic organisms).	Stocked legal-sized fish would continue to lose body mass due to their highly domesticated nature and lack of tendency to feed upon available food resources.	An unknown portion of the stocked larger-sized fish would likely gain body mass as they prey upon chub populations.
Recreational Fishery And Estimated Annual Angler Catch*	Recreational fishery would remain relatively small due to small numbers of legal-sized fish stocked and continued low desirability of fishery (induced by lake closures, algae blooms, and low potential for capture of large, high quality fish). Annual catch estimated to be 10,000 fish/year in long-term (2007 and beyond).	Recreational fishery would likely be relatively large over time as stocked fingerlings grow to large sizes. Numbers of fish stocked may vary based upon biological indices. Fishery would likely regain the former high desirability due to the potential to capture numerous large sized, high quality fish. Annual catch estimated to be between 100,000-200,000 fish/year in long-term.	Recreational fishery would likely be relatively large due to stocking of large numbers of legal-sized fish. Fishery may not regain the former high desirability due to presence of only one size-class of fish, and put-and-take nature of fishery. Annual catch estimated to be between 80,000-160,000 fish/year in long-term.	Recreational fishery would likely be moderate due to stocking of large numbers of larger-sized predacious trout. Fishery may not regain former high desirability due to angler harvest restrictions that limit the harvest of larger fish, and continued lake closures associated with toxic algae blooms. Annual catch estimated to be between 50,000-70,000 fish/year in long-term.
Fish Stocking Management Strategy	Experimental Fish Stocking Program in the short-term, followed by stocking of 24,000 legal-sized fish annually in the long-term (small put-and-take fishery).	Basic Yield Alternative, using ecological indices to determine appropriate numbers of fish to stock. (moderate to large put-grow-and-take fishery).	Intensive Use Alternative, large numbers of legal-sized fish would be stocked annually (large put-and-take fishery).	Featured Species or Trophy Fish Alternative, large numbers of legal or trophy sized fish would be stocked annually, with special angler harvest regulations (moderate put-and-take fishery, with potential for some catch-and-release size restrictions).

Fish Species Mix Selected for Use	Continued experimentation with legal sized Eagle Lake rainbow trout, brown trout, and/or spring Chinook salmon in the short-term. Small numbers of legal sized Eagle Lake rainbow trout in long-term.	Fishwich or Oak Springs stock rainbow trout fingerlings, and smaller numbers of larger sized Eagle Lake rainbow trout, brown trout, or spring Chinook salmon.	Trout Lodge stock of rainbow trout, with smaller numbers of larger sized Eagle Lake rainbow trout, brown trout, or spring Chinook salmon.	Eagle Lake rainbow trout (Featured Species Alternative) Or Brown trout or Kamloops Trout (Trophy Fish Alternative)

*** Estimated annual angler catch values were developed by the Oregon Department of Fish and Wildlife, 2003.**

Table x: Summary of Alternative Effects on Fish Populations.

Conclusions: NOTE: *All general discussions pertaining to the recreational fishery in Diamond Lake are in relation to the 1990 OFWC management plan 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.* Based on the above discussion, Alternative 1 (no action) would result in the maintenance of large populations of tui chub, with a much smaller component of catchable-sized salmonids that are stocked annually in the lake to maintain a small recreational fishery. Alternatives 2 and 3 would likely result in the eradication of tui chub populations in Diamond Lake. In addition, each of these alternatives would provide a moderate to large recreational fishery in Diamond Lake.

In alternative 2, a mix of salmonids would be stocked, including relatively small numbers of fingerling rainbow trout (Fishwich or Oak Springs stock), and legal or trophy-sized predacious fish species (Eagle Lake rainbow trout, brown trout, or spring chinook salmon). In the absence of tui chub, these fish would be expected to thrive as they take advantage of the abundant prey items available to them (see zooplankton and benthic organism sections). Alternative 2 would result in multiple age classes of trout being present in Diamond Lake at any given time.

In Alternative 3, large numbers of domesticated rainbow trout would be stocked into the lake, providing a relatively large recreational fishery. These fish would not be expected to utilize available food sources to the extent seen in other strains of fish, and would not be expected to survive through the winter months. As a result, substantial numbers of trout would be present in the lake on a seasonal basis, and would be comprised of one general size and age range of fish.

Alternative 4 would result in the maintenance of a reduced population of tui chub, and a population of larger-sized predacious salmonids. Even though the numbers of fish stocked in Alternatives 3 and 4 are similar, Alternative 4 proposes to use special angler harvest regulations that limit the removal of large predatory trout in order maintain the predation control effect on chub populations. This reduced ability to catch and keep larger fish may decrease the desirability of the recreational fishery. Therefore, this alternative would likely provide a moderate fishery when compared to Alternative 3. There are many additional uncertainties associated with this alternative, including whether piscivorous salmonids would prey upon tui chub, whether these salmonids would be able to prevent the expansion of the remaining tui chub population, and whether mechanical chub removal methods would be able to successfully remove 85-95% of the spawning chub population.

ACS Consistency:
As discussed previously throughout this document, large populations of tui chub are directly or indirectly tied to the existing conditions of poor water quality, toxic algae blooms, and suppressed zooplankton and benthic invertebrate populations. Therefore, any alternative that would not improve these conditions would retard attainment of Aquatic Conservation Strategy objectives. Alternative 1, the no action alternative, would retard attainment of ACS objectives.

Each of the action alternatives has the potential to result in improved aquatic conditions in the long term. Therefore, each of these alternatives would be consistent with the ACS. The degree to which conditions are improved and the longevity of those improvements would likely vary by alternative. Therefore, some alternatives would better meet the long term intent of the ACS than others. Alternative 4 would result in a partial removal of the chub population, and stocking of up to 250,000 larger-sized predacious fish. It is unknown whether the mechanical and predatory controls on tui chub populations would be effective at keeping their populations at a relatively low level. Therefore, this alternative may not be as effective at improving aquatic conditions in the long-term as other alternatives that propose to completely eradicate tui chub.

Alternatives 2 and 3 would result in complete eradication of the tui chub, and restocking of rainbow trout. Alternative 2 would restock rainbow trout fingerlings under a put-grow-and take scenario. Fingerling stocking levels are expected to be relatively conservative (low) at first, and would be modified (increased or decreased) over time based upon biological indicators of aquatic health. Therefore, Alternative 2 would result in substantial improvements to water quality, zooplankton, and benthic organism populations in the long-term (due to the removal of the chub), but there would always be some level of predation pressure exerted on the aquatic organisms (due to the put-grow-and take fish stocking scenario).

Alternative 3 would restock up to 400,000 legal sized domesticated rainbow trout annually under a put-and-take scenario. Unlike the fingerling stockings, these highly domesticated fish are not expected to prey upon the available food sources of zooplankton and benthic organisms, and would not be expected to survive through the winter months. As a result, this alternative is likely to result in the largest improvement to water quality, zooplankton, and benthic organism populations in the long term (due to removal of the chub and lack of predation on the other aquatic organisms).

In summary, from water quality and aquatic 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 – 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 – Retards attainment of ACS objectives

PHYSICAL AQUATIC HABITAT – AFFECTED ENVIRONMENT

Diamond Lake:

Salmonid Spawning Habitat: Salmonid reproduction in Diamond Lake proper does occur, but it is believed to be limited (Locke, 1947; Loomis, personal communication, 2003). Rainbow trout have repeatedly been observed spawning on a gravel shoal area on the northeast shore of the lake, but few efforts have been made to investigate the relative success of this spawning. Locke (1947) placed fertilized trout eggs in wire screen baskets containing gravel, and then placed those baskets at varying depths along the gravel shoal in the northeast corner of the lake. He found live fry at each of the depths tested, and determined that successful spawning could occur in the lake.

Overall, there are very few areas in the littoral zone[39] that have gravel substrates suitable for salmonid spawning. In addition, the high productivity of the lake has resulted in bottom substrates that are covered by layers of silt and organic detritus. Even if the salmonid population in Diamond Lake was prone to margin spawning in lake environments, it is likely that the success of this spawning would be limited by the lack of habitat and the relatively poor quality of this habitat

Tui Chub Spawning Habitat: Diamond Lake provides ample habitat for successful tui chub reproduction. As cited in Bird (1975), Kimsey found that tui chub must spawn upon vegetation and away from the influence of the bottom muck in order for their eggs to survive. The littoral zone of Diamond Lake supports a robust population of emergent aquatic vegetation, especially at the southern and northwestern ends (Eilers, 2003). Of the 3,031 acres of surface area in Diamond Lake, roughly 35-40% support populations of emergent aquatic vegetation. In addition, the relatively warm waters of Diamond Lake are also conducive to successful chub spawning.

Rearing Habitat: Recent studies looking at sediments in Diamond Lake (Eilers, 2001a) suggest that the Lake has always been relatively productive in terms of nutrients and primary production, but that overall productivity has increased substantially following the introduction of fish. Sediment accumulation rates (SAR) have increased substantially since fish were introduced. The periods of greatest SAR increases coincide with the periods when tui chub populations were very large in the lake.

This naturally high productivity is one of the primary reasons why trout stocking in the lake has been so successful over the years. The high productivity results in large amounts of phytoplankton, which are actively grazed by zooplankton and aquatic insects, which in turn fueled a healthy, diverse population of larger zooplankton and aquatic insects. When fish were added into this pre-existing food web, they quickly took advantage of the abundant food source. Historically, the Oregon Department of Fish and Wildlife stocked the lake primarily with rainbow trout fry (1910 to 1961), and then rainbow trout fingerlings (1962-1999) averaging 3-4 inches in length. When trout were the dominant fish in the lake, Diamond Lake was renowned for its ability to produce large fish in only

[39] The littoral zone is the relatively shallow near-shore area.

one year. It was not uncommon for the 3-4 inch fish, typically stocked in June, to grow to lengths of 12-14 inches by the following June or July. This put-grow-and take fishery gained a large following, eventually providing one of the largest recreational fisheries in the state of Oregon (ODFW, 1996).

Juvenile tui chub generally utilize the same food resources as salmonids, primarily consuming zooplankton and aquatic insects. In studies of tui chub in East Lake, Bird (1975) found that "the four food items eaten in greatest quantities by the tui chub also contain the three most preferred food items of trout in East Lake." As a result of this diet overlap, tui chub were also able to thrive in habitat provided by Diamond Lake.

Current habitat conditions are not considered optimal for fish or other aquatic life. As mentioned in the **Water Quality** section, in the summer months Diamond Lake routinely experiences pH values in violation of State standards, depletion of dissolved oxygen in deeper portions of the lake, and large blooms of toxic blue-green algae. These conditions result in depressed populations of zooplankton and benthic organisms, which are the primary prey items for fish in the lake.

Tributaries to Diamond Lake:

Six named tributaries drain into Diamond Lake. Like Diamond Lake, all were historically fishless. Silent Creek and Short Creek are the only perennial streams believed to be capable of providing habitat for fish.

The 1947 Diamond Lake Study prepared by the Oregon State Game Commission reported that the mouths of Silent Creek and Short Creek were closed to angling until July 15th in order to protect spawning fish. During this time, trout would concentrate in these areas before and after spawning, and would be highly vulnerable to angling.

Silent Creek is a relatively short stream (approximately 1.8 miles long) with stable flows due to the spring fed nature of the headwaters. As a result, streambed substrates are stable in nature and result in easily detectable redds (gravel nests) when spawning activities occur in the stream. Recent spawning surveys conducted in Silent Creek during the spring of 2003 detected numerous redds (gravel nests) within the lower 0.7 mile stretch of stream channel. While no fish were seen during these surveys, the redds were relatively large, and were likely constructed by fish greater than 15 inches in length. No redds were observed in Short Creek during these surveys (C. Street, personal communication, 2003).

Although numerous redds were observed in Silent Creek, the relative success of this spawning activity is believed to be low. The vast majority of the sediments in this stream are comprised of fine, highly angular sands, and small pumice gravels. All redds observed contained large quantities of sand mixed in throughout their larger substrates. This situation is likely resulting in unusually high egg mortality as a result of limited intragravel flow of oxygenated water, and the highly abrasive nature of the sands within

the streambed. In addition, consistently cold water in Silent Creek would result in a prolonged incubation period for fish eggs within the gravel.

Small numbers of tui chub and rainbow trout 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. A habitat inventory was conducted in Silent Creek in 1997. This survey documented ample habitat complexity capable of supporting fish populations. However, during the entire survey only one fish was seen (a rainbow trout) by experienced snorkel surveyors looking for fish.

A copy of the Silent Creek stream survey report is located in the Analysis File for this project.

Lake Creek:

Lake Creek is the only outlet stream from Diamond Lake. It is approximately 11.6 miles in length, and drains into Lemolo Reservoir. As with Diamond Lake, very little information is available regarding Lake Creek prior to 1910. It is believed that this outlet stream to the lake was also naturally fishless due to a series of large waterfalls located lower in the North Umpqua subbasin (i.e. Toketee Falls, etc.). Currently, Lake Creek supports populations of rainbow trout, brook trout, brown trout, and tui chub.

No extensive surveys of fish populations have been conducted in this stream, although anecdotal reports do indicate that there is a moderate recreational trout fishery during the spring and summer months. Presumably, brown trout and brook trout entered the Lake Creek system from Lemolo Reservoir. These fish species are commonly reported in Lemolo Reservoir, and the North Umpqua River upstream of Lemolo Reservoir. They have been able to migrate upstream within Lake Creek to a point approximately 1,000 feet (304.8 meters) downstream of Diamond Lake. A concrete weir that creates a complete barrier to upstream migration is the only obstacle that has prevented these fish from entering the Diamond Lake system. It is likely that rainbow trout and especially tui chub originally entered the Lake Creek system via Diamond Lake. However, both species are now present in Diamond Lake and Lemolo Reservoir, and can access the Lake Creek system from either direction.

Lake Creek was surveyed in 1996 using Region 6 USFS protocols. These surveys indicate that large wood is abundant throughout most of the stream, but there are few deep pools present. The presence of large quantities of wood, but lack of pool habitat is likely the result of the extremely stable stream flow patterns in Lake Creek. As a result, annual stream energy is relatively low, and Lake Creek is not able to scour and maintain large quantities of deep pool habitat. The Diamond Lake and Lemolo Watershed Analysis (1998) indicate that there was no evidence that past lake drawdown activities in 1954 destabilized streambanks or aquatic habitat in this system. Lake Creek is considered to be healthy and near its reference condition, with habitat attributes well within the range of natural variability for a stable, lake outlet stream system.

A copy of the stream survey report is located in the Analysis File for this project.

Lemolo Reservoir: Aquatic habitat in Lemolo is not as conducive to tui chub spawning and rearing as that seen in Diamond Lake. With an average depth of around 29 feet, Lemolo Reservoir is deeper than Diamond Lake (22.5 ft. average depth), and doesn't contain the large littoral areas that are common at Diamond Lake. In addition, Lemolo Reservoir is routinely lowered in the winter, exposing the limited shallow areas to harsh winter conditions. As a result, Lemolo Reservoir does not contain an abundance of aquatic macrophytes, which are essential to the successful reproduction of tui chub. In addition, the relative amount of warmer surface waters in Lemolo is substantially less than that seen in Diamond Lake. In Lemolo, warmer surface water temperatures usually extended to depths of 3 to 5 meters (USDA 1998), whereas in Diamond Lake, warmer surface water temperatures usually extend to depths of around 8 meters. This relative lack of extensive warm surface waters in Lemolo may also be a potential limiting factor on chub populations.

Temperature monitoring in 1992 showed strong vertical stratification, with temperatures of 68 to 72 F near the surface, and 52 F near the bottom. Temperatures were similar in 1993, with 64 F near the surface, and 48 F near the bottom at 50 feet (USDA, 1998).

The deeper portions of Lemolo Reservoir do not experience the severe oxygen depletion that is common in Diamond Lake during the summer months. As a result, fish, zooplankton, and benthic organisms are able to utilize these areas during summer months.

North Umpqua River (From Lemolo Reservoir to Rock Creek):

Downstream from Lemolo Reservoir, the North Umpqua River flows for roughly 16 miles before entering Toketee Reservoir. From Toketee Reservoir, the river flows for another 4.5 miles before entering Soda Springs Reservoir. From Soda Springs, the river flows for another 70 miles before entering the main stem Umpqua River.

From Soda Springs Dam, downstream to the confluence with Rock Creek, (a distance of 33.8 miles) the North Umpqua River is classified as a Wild and Scenic River. This segment of the North Umpqua River was designated a recreational river under the National Wild and Scenic Rivers Act of 1988. Roseburg BLM manages the lower 8.4 miles and the Forest Service manages the upper 25.4 miles. As defined by the Act, a National Wild and Scenic River must be undammed and must have at least one outstandingly remarkable value (ORV). The established ORV's for the North Umpqua Wild and Scenic River are: fisheries, water quality and quantity, recreation, scenic, and cultural. The underlying principles of the Act are to keep the designated River in a free flowing condition and to recognize the River's importance to our natural and cultural heritage.

The North Umpqua River between Soda Springs dam and the confluence with Steamboat Creek is confined and is largely characterized by boulder and bedrock morphology. Channel gradients are predominantly less than 1 percent, with 1 to 2 percent gradients

present in a portion of the reach between Soda Springs powerhouse and Boulder Creek. Large boulders and abundant bedrock outcrops create pools and provide channel complexity. From Steamboat Creek downstream to Rock Creek, many reaches contain bedrock ledges divided by a deep trough through which most bedload is carried and stored. More cobble and gravel bars can be found in this reach having a heterogeneous mix, with the median diameter in the cobble range.

Due to the inherent resiliency of the mainstem channel in this reach, the gross appearance (and resultant habitat elements) of the river is likely to be very similar today to what it was in reference conditions (North Umpqua WA, 2001). In brief, the North Umpqua River is considered to be healthy, supporting viable native fish populations and maintaining the outstandingly remarkable values of the river.

ENVIRONMENTAL EFFECTS ON PHYSICAL AQUATIC HABITAT

Direct Effects – Short and Silent Creeks: Under Alternatives 1 and 4, aquatic habitat conditions would likely be similar to those described in the Affected Environment section of this document. There would be no lake drawdown or refill periods that could potentially affect aquatic habitat conditions in Silent Creek or Short Creek.

A direct effect of Alternatives 2 and 3 would be the addition of liquid formulation rotenone to the lower portions of Silent Creek and Short Creek (within the actual lake perimeter) through the use of drip stations. These chemicals would result in toxic habitat conditions for all gilled animals for a period of roughly 17 days (the estimated duration of the rotenone drip stations). Following cessation of rotenone drip stations, aquatic habitat conditions would return to normal within a matter of hours, as the remaining rotenone and the other formulation constituents are flushed downstream into Diamond Lake. It is uncommon to find rotenone in stream sediments (CDFG, 1994). The VOC's (volatile organic compounds) do not accumulate in the sediment, and only naphthalene and the methyl napthalenes temporarily (less than 8 weeks) accumulate in the sediments (Finlayson, 2000). Rotenone dissipates in flowing waters relatively quickly (less than 24 hours) due to dilution and increased rates of hydrolysis (Finlayson et al, 2000). Based on the continuation of the drip stations for 17 days in these two streams, an estimated total of 375 gallons of liquid rotenone (Noxfish formulation) would be utilized. All of the chemicals associated with these drip stations would break down and/or evaporate relatively quickly, or be transported to Diamond Lake, where they would evaporate over a short period of time.

Indirect Effects – Short and Silent Creeks: Under Alternatives 1 and 4, aquatic habitat conditions would likely be similar to those described in the Affected Environment section of this document. There would be no lake drawdown or refill periods that could potentially indirectly affect aquatic habitat conditions in Silent Creek or Short Creek.

Following treatments described in Alternatives 2 and 3, aquatic habitat conditions in Silent Creek and Short Creek may change slightly. These changes would include stream channel down-cutting and incision through soft lake bottom sediments as the lake is

drawn down by 8 feet. Based upon review of recent aerial photos, evidence of this occurrence appears to be present from the first drawdown in the 1950's. On these photo's, the presence of a deeper, sinuous channel extending out into the lake is visible. This channel was likely formed during the 1954 drawdown of Diamond Lake.

Cumulative Effects - Short and Silent Creeks: The 1954 drawdown is the primary past management activity that impacted these creeks. There are no ongoing or reasonably foreseeable actions that contribute meaningfully to a cumulative effect on these aquatic habitats. Under Alternatives 1 and 4, aquatic habitat conditions would likely be similar to those described in the Affected Environment section of this document. There would be no actions associated with these alternatives that would contribute to cumulative impacts to aquatic habitat conditions in Silent Creek or Short Creek.

As mentioned above, Alternatives 2 and 3 may result in stream channel downcutting within the perimeter of the lake. Upstream of this point, there was no visible evidence of aquatic habitat change in these streams as a result of the 1950's treatment of Diamond Lake. Recent field review of channel and habitat conditions within the lower portions of these streams indicates that both channels contain adequate substrate and large woody material roughness to prevent significant channel downcutting and incision from migrating in an up-stream direction for more than 0.25 mile. Therefore, no cumulative change would be anticipated as a result of these alternatives.

Direct Effects – Diamond Lake: Under the No-Action alternative and Alternative 4, aquatic habitat conditions would likely remain similar to those described in the Affected Environment section of this document. There would be no lake drawdown or refill periods that could directly affect aquatic habitat conditions in Diamond Lake.

Following treatments described in Alternatives 2 and 3, aquatic habitat conditions in the lake would change dramatically in the short and long-term. In the short-term, the lake level would be lowered by 8 feet. This would result in a decrease of 10 % of the lake surface area, and a substantial dewatering of those littoral areas dominated by heavy macrophyte growth. Upon addition of 260,000 pounds of powdered rotenone, lake water would be toxic to all gilled animals for a period of approximately 2 to 21 days (CDFG, 1994).

Indirect Effects – Diamond Lake: Under the No-Action alternative, indirect effects on aquatic habitat quality would continue to occur in several areas. In Diamond Lake, the continued presence of a large tui chub population would continue to impact water quality (high pH, low DO, toxic algae blooms), rendering a large portion of the habitat uninhabitable to salmonids during the late spring and summer months.

Under Alternatives 2 and 3, it is likely that the physical parameters of pH and dissolved oxygen would improve slightly and stabilize as a result of changes to the food web brought on by the lack of tui chub. See the biological discussions for a more detailed explanation.

The indirect effects of Alternative 4 would be similar to those of Alternative 1. The continued presence of a variable tui chub population would continue to impact water quality, and also render much of the habitat uninhabitable to trout during late spring and early summer months. The extent of this impact is expected to be slightly lower than that seen in Alternative 1 due to the annual partial removal of a portion of the tui chub population.

Cumulative Effects - Diamond Lake: There are multiple past, present, and reasonably foreseeable management activities that could contribute to the cumulative effects on aquatic habitat in Diamond Lake. Primary contributors include: the 1954 rotenone treatment, water rights, fish stocking, and development of recreational facilities in and around the lake. As mentioned repeatedly, most of these activities contribute to the existing condition of the lake, however tui chub are the main negative influence on potential aquatic conditions in the foreseeable future. The cumulative effects of Alternatives 1 and 4 are likely to be similar. The continued presence of a variable tui chub population would likely result in highly impaired physical habitat quality. High pH levels, low dissolved oxygen content, and continued blooms of toxic algae would render much of the habitat in Diamond Lake unusable to fish.

The long-term effects of Alternatives 2 and 3 would be beneficial and would likely include an improvement in dissolved oxygen content, water clarity, a decrease in pH, and a decrease in the frequency, duration, and intensity of toxic blooms of blue-green algae. These physical changes would be a cumulative result of changes to biological processes occurring in Diamond Lake, as well as improved fish stocking practices over time. See the biological discussions for a more detailed explanation.

Direct Effects - Lake Creek: Under Alternatives 1 and 4, physical aquatic habitat and streambank conditions in Lake Creek would remain unchanged, due to the lack of a lake drawdown component.

Alternatives 2 and 3 would result in removal of the flashboards at the outlet of the lake (beginning of Lake Creek) to initiate the lake drawdown portion of the action. Once the lake is lowered by approximately 2-3 feet by removal of these flashboards, water will no longer exit the lake via this route. At this point, water will be routed out of the Lake by use of the reconstructed canal, which is at a lower elevation, and capable of draining additional water out of the lake. At this time, the section of Lake Creek located between the lake and the canal outlet (roughly 1,200 feet) would dry up due to a lack of surface flow. This portion of the Lake Creek channel would remain dry for a period of approximately 1½ years. Surface flows would most likely return to this stream segment in the spring following chemical treatment, when the lake level has risen by at least 5 feet.

In the portion of Lake Creek below the canal confluence, the draw-down phase of the project would result in relatively high stream flows for a period of 4 to 6 months.

Under Alternatives 2 and 3, immediately prior to chemical treatments in the lake, the headgates controlling flows in the canal (and Lake Creek) would be closed. This would result in the portion of Lake Creek below the confluence of the canal drying up for approximately 1-2 months until lake water was determined to be free of rotenone, and water releases were re-initiated again into the canal, and ultimately in the creek. Recent flow and groundwater investigations in Lake Creek indicate that there is very little accretion of flow in the upper 6 miles of Lake Creek, from tributary or groundwater sources. As a result, when surface flow is cut off from Lake Creek immediately prior to chemical treatment (and after) it is likely that this stream would virtually dry up in this 6 mile stretch. Below this segment, stream flow conditions would improve dramatically due to the flow added by Thielsen Creek.

Indirect Effects – Lake Creek: Under Alternatives 1 and 4, physical aquatic habitat and streambank conditions in Lake Creek would remain unchanged, due to the lack of a lake drawdown component.

Under Alternatives 2 and 3, extended high flows associated with the drawdown would likely result in scouring and deepening of pools in areas with large wood concentrations and/or boulders, and along the outside bends of channel meanders. This change would likely be temporary in nature, with pool depths returning to pre-drawdown levels within several years of normal flow conditions after the drawdown.

Large wood amounts and stability would not be expected to change substantially as a result of the lake drawdown. The majority of the complex aquatic habitat in Lake Creek is in close association with stable large wood. The majority of this large wood appears to have originated from adjacent riparian stands, and is often found in the exact location where it originally fell (as a result of relatively stable flow patterns and low stream energy). Many of the stable large wood pieces have remained in place for decades or more, as evidenced by surrounding vegetation growth and/or channel features. Lake Creek is not prone to severe high flows or debris torrents. Therefore, the large wood found in this system is extremely stable when compared to other streams in western Oregon. Any pieces of wood that might be mobilized during drawdown activities would likely be captured and retained on the next wood accumulation or channel bend downstream.

Areas of stream bank erosion currently present in the Lake Creek channel may be exacerbated by the extended duration of bankfull flows. The majority of these naturally eroding areas are located downstream of Thielsen Creek. This increased erosion is likely to be temporary in nature, with erosion from these naturally unstable areas returning to pre-treatment levels within a 3 to 5 year period after the drawdown. The high level of channel complexity provided by ample quantities of large wood and boulders would result in deposition of a large portion of these sediments in gravel bars and other smaller depositional areas. As mentioned in the existing condition for Lake Creek, there was no evidence that past lake drawdown activities in 1954 destabilized streambanks or aquatic habitat in this system. The estimated stream flow of 180 cfs during the 1954 drawdown

(USDA, 1998) also indicates that streamflows during that time period were likely significantly higher than those proposed in this project (ie. 110 cfs).

Lake Creek is considered to be a healthy, functioning stream system, with habitat characteristics typical of smaller lake-outlet stream types. Cumulatively, when considering the reasonably foreseeable future activities likely to occur in this area (table x), physical habitat in this system is expected to remain healthy in the long-term.

Direct, Indirect, and Cumulative Effects – Lemolo Reservoir: There would be no direct effects to physical aquatic habitat in Lemolo Reservoir resulting from any of the alternatives. Indirectly and cumulatively, Alternatives 1 and 4 would likely result in continued delivery of nutrient enriched waters to Lemolo Reservoir. These nutrients would continue to contribute to increased productivity in the reservoir, and may lead to future negative impacts to dissolved oxygen and pH. As mentioned in Eilers report (2001b), Lake Creek currently contributes roughly 15% of the flow to Lemolo Reservoir, but contributes approximately 50% of the nitrogen to that system.

Alternatives 2 and 3, which would result in the eradication of the tui chub, would also likely result in a substantial reduction in the amount of nitrogen contributed to downstream areas. Indirectly and cumulatively, the lack of nutrient rich waters would result in slight decreases in productivity, as well as improvements to the parameters of dissolved oxygen and pH.

As mentioned above, the lake drawdown associated with Alternatives 2 and 3 is likely to result in localized increases in stream-bank erosion in Lake Creek. It is likely that a portion of the gravel and fine sediment generated from this erosion would be deposited in Lemolo Reservoir. Based upon preliminary analysis from the project Hydrologist and Geologist, it is unlikely that the amount of material deposited in Lemolo Reservoir would be large enough to form a noticeable depositional feature (fan, delta, bar, etc.). Based upon the large size of the reservoir, this small amount of material would be inconsequential to the aquatic habitat found there.

Direct, Indirect, and Cumulative Effects – North Umpqua (From Lemolo Reservoir to Rock Creek): There would be no direct, indirect, or cumulative effects to the physical habitats in the North Umpqua River below Lemolo Reservoir resulting from any of the alternatives.

Any potential effects of the drawdown and increased flows would be buffered by Lemolo Reservoir. Pacificorp is a partner in the project, and would work with the drawdown operation to avoid large changes in reservoir storage and release. Therefore, no effects to seasonal streamflow (or physical habitat conditions) below Lemolo Reservoir would be expected under Alternatives 2 and 3. As mentioned in the hydrologists report, the amount of additional flow generated by the proposed lake drawdown activities is small relative to the North Umpqua system, and is within the standard of measurement error for the streamflow gauging station located in the North Umpqua River near Copeland Creek.

Conclusions:
Based on the above discussion, Alternative 1 would continue to result in poor physical habitat conditions in Diamond Lake, and contribute to nutrient and water quality problems in Lake Creek and Lemolo Lake in the short and long-term. This would retard attainment of ACS objective 9.

The three action alternatives would have varying impacts on physical habitats within the project area. Based on past history at Diamond Lake and numerous literature reviews, Alternatives 2 and 3 which would completely remove tui chub are more likely to result in aquatic habitat quality improvements in Diamond Lake and Lemolo Lake. There would be short-term impacts to Short, Silent, and Lake Creeks under these alternatives, but the extent and duration of these impacts would be relatively minor. Physical habitat would likely return to pre-project conditions within a week in Short and Silent Creeks, and within a few years in Lake Creek. As a result, these alternatives would not retard or prevent attainment of ACS objective 9.

Although there would be no short-term impacts to aquatic habitat, Alternative 4, which does not completely eradicate tui chub, may be the least effective of the action alternatives at movement toward attainment of ACS objective 9, due to uncertainties regarding the efficacy of mechanical and biological population control methods. As a result, the extent and duration of improvements to aquatic habitat in Diamond Lake and Lemolo Lake under this alternative are uncertain. Based upon the failure of past efforts to partially control chub populations in Diamond Lake and elsewhere, it is likely that the effects of Alternative 4 would be similar to those of Alternative 1.

In summary, from a physical aquatic habitat 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 – 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 – Retards attainment of ACS objectives

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Appendix A. Biological Evaluation

Appendix B. Best Management Practices, Management Requirements, Mitigation Measures, and Monitoring

Mitigation Measures:

Zooplankton: Active recolonization would be facilitated by adding zooplanktors.

Benthic Organisms: Active recolonization

Fish: A trap will be installed to minimize tui chub movement out of Diamond Lake during the drawdown portion of the project. This trap could consist of stationary trap nets in combination with block nets or weirs.

Monitoring:

Pre and post project environmental monitoring is an effective way to evaluate the relative success or failure of a potential project. Unfortunately, there was very little monitoring associated with the rotenone treatment that occurred in Diamond Lake in 1954. Information pertaining to channel changes in Lake Creek associated with the drawdown, changes to zooplankton and aquatic insect diversity and abundance, changes in wildlife species diversity and abundance, nutrient inputs to downstream waters, etc. would have been extremely useful in evaluating the potential impacts (positive and negative) of this proposed action, and its alternatives.

With that in mind, it is imperative that a comprehensive monitoring plan be implemented in conjunction with any action alternative that may be selected. Where pertinent, the following list of potentially affected parameters would be monitored prior to any proposed treatment of Diamond Lake, and for several years following that treatment. In addition, parameters marked with an asterisk (*) are those that would be collected on an annual basis (indefinitely) to assist in determining and adjusting the appropriate fish stocking strategy.

- Representative channel cross-sections in Lake Creek (5 pinned and benchmarked reference sites) (2 people X 3 days to set up and/or collect data each year = 6 person days; 1 person X 2 days for data entry and reporting = 2 person days. Total time = 8 person days per year)
- Representative photo-points at cross-sections (5 sites) and potential erosional sites (3 identified sites) in Lake Creek (including pre project, during project implementation, and post project photo sets) (2 people X 2 days per photo set, X 3 photo sets = 12 person days; 1 person X 1 day for report preparation. Total time = 13 person days per year)

- Bank scour pins placed at potentially unstable stream banks in Lake Creek (3 identified sites) to evaluate relative erosion and sediment contribution to downstream areas. (2 people X 2 days to set up and/or collect data each year = 4 person days; 1 person X 1 day for data entry and reporting. Total time = 5 person days per year)
- * Monthly zooplankton samples to determine relative species abundance and size composition of the population. Would be sampled in May, June, July, August, September, and October.
- * Monthly benthic samples at representative sites to determine aquatic invertebrate biomass, species diversity, and relative abundance. Would be sampled in May, June, July, August, September, and October
- Stomach content data on various age class salmonids with the objective of figuring out which age-class of fish are actually having an impact on zooplankton, etc.