Aquatic Macrophytes

AFFECTED ENVIRONMENT

As is typical of shallow, soft-bottomed lakes, Diamond Lake has a broad zone of aquatic macrophytes, which are aquatic plants that include large (non-microscopic) algae, mosses, liverworts, ferns, and fern-like plants that are adapted to an aquatic environment. Macrophytes in Diamond Lake are concentrated on the broad, gently sloping bottoms along the south and northwest shore, with fewer populations along the western shore and in the cove by the Lodge (see Figure X). Most of the eastern shoreline is too rocky and steep to support macrophytes. Light penetration into the lake limits macrophytes to a depth of about 19.7 feet (6 m)(Eilers & Gubala 2003). Total macrophyte cover was estimated at 30-50% of the lake's bottom in a 1979 study (Lauer et al.) which is supported by hydroacoustic[1] sampling in 2002 (Eilers & Gubala 2003). Macrophytes are commonly grouped by their life-forms, which play different ecological roles within the lake. These life forms include: emergent species, floating leaved rooted species, submersed rooted species, and submersed free-floating species.

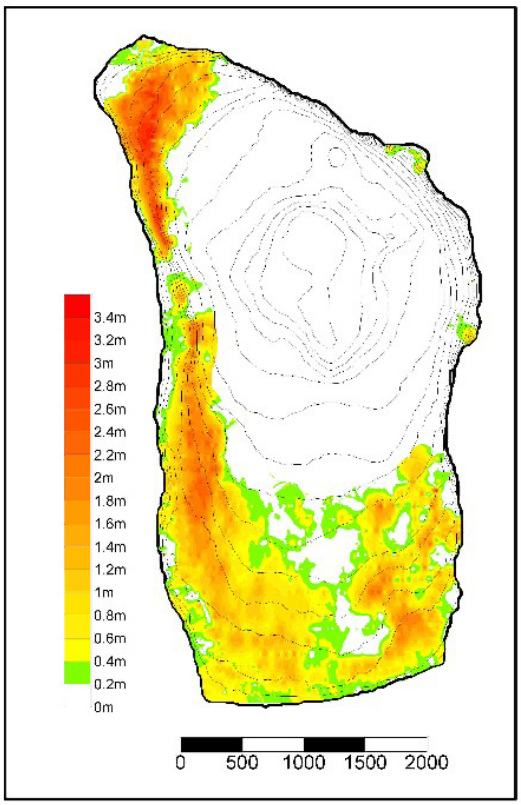

Figure X. Distribution of aquatic macrophytes in Diamond Lake based upon hydroacoustic sampling in 2002 (Eilers and Gubala 2003).

[1]Hydroacoustic sampling utilizes high frequency sound waves to identify bottom features, fish, aquatic vegetation, and zooplankton within waterbodies.

Emergent Species: These plants are rooted in shallow water, but have stalks that grow up out of the water. Diamond Lake has a loosely defined community of emergent species in the northwest corner of the lake. There is a large assemblage of the emergent species common cattail (*Typha latifolia*) and hardstem bulrush (*Scirpus acutus*) along the shoreline north of the Thielsen View Campground. Interspersed within this community is yellow pond-lily (*Nuphar lutea* ssp. *polysepala*), which is a rooted plant with floating leaves. The only other emergent species that occurs within the lake itself are several small patches of common spike-rush (*Eleochaeris palustris*) and a single patch of inflated sedge(*Carex vesicaria*). All of the emergent species in the lake are rhizomatous[2], so they tend to occur in dense patches.

One species that was consistently located in shallow water during the macrophyte inventory in 2002 (Helliwell et al. 2003) is what appears to be an aquatic, juvenile form of water bulrush, which should be an emergent species. For some reason, it evidently remains in a juvenile state without ever producing adult leaves or reproductive structures. It is possible that water bulrush (*Scirpus subterminalis*) is a remnant from the former shoreline community at Diamond Lake.

Floating Leaved Rooted Species: The other rooted species with free-floating leaves in the lake is water smartweed (*Polygonum amphibium*). There are scattered plants of this species near the outlet of the lake.

Submersed Rooted Species: Species that are rooted in the bottom of the lake, but have submersed leaves make up the overwhelming bulk of the macrophyte biomass within the lake. The principle submersed rooted species include: white-stalked pondweed (*Potamogeton praelongus*), water-milfoil (*Myriophyllum verticillatum*), and Canadian waterweed (*Elodea canadensis*). Helliwell et al. (2003) found water-milfoil to be the most commonly encountered macrophyte in the lake during an inventory of the shallow depths (<6.5 feet or 2 m) in 2002. However, white-stalked pondweed extends to much greater depths and almost certainly is the most abundant macrophyte in the lake. It is also the tallest with plants in excess of 13 feet (4 m) observed (Helliwell et al. 2003). Canadian waterweed is perhaps the most broadly distributed of the submersed species. It was observed growing at depths less than 3.3 feet (1 m), but is also reported to be associated with white-stalked pondweed between depths of 6.6 - 13.1 feet (2-4 m) (Lauer et al. 1979). Lauer et al. (1979) also reported stonewort, a large, coarse algae with whorled branches, growing at the deepest vegetated areas of the lake at 13.1 – 19.7 feet (4-6 m).

Submersed Free-Floating Species: The only other common macrophytes in Diamond Lake are the submersed free-floating species coontail (*Ceratophyllum demersum*) and quillwort (*Isoetes echinospora*) which is a tiny submersed plant that is rooted in very shallow water. The former species is widely scattered, primarily amongst the water-milfoil, but is never abundant. The later species is a tiny, grass-like plant that is actually more closely related to ferns because it reproduces by spores from sacs at the base of the leaves. See Table X in the Aquatic Macrophyte report for a complete species list for Diamond Lake.

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[2] Rhizomatous plants have rhizomes which are horizontally creeping underground stems which bear roots and leaves and usually persist from season to season.

There is only one non-native macrophyte currently known to occur in Diamond Lake. Curly pondweed (*Potamogeton crispus*) was first reported by Salinas (1998) at the south shore dock. It was also discovered along the western shore during the 2002 inventory (Helliwell et al. 2003). This species is not well-established at present, but has been known to take over some lakes.

The Oregon State Game Commission Annual Report (OSGC 1953) noted that the white-stalked pondweed had all but disappeared in 1952. This coincided with the tui chub proliferation of that time and the pondweed was reported to have recovered by 1955 following lake draw down and rotenone treatment the previous year (OSGC 1956). Although this may simply be the direct result of light limitation from algal blooms, a reduction of this magnitude may involve more complex interactions. It is possible that this condition involved cascading trophic interactions[3] initiated by tui chub introduction and proliferation. The most significant[4] direct impact to the macrophytes may actually have been periphyton[5] increase resulting from reduction in grazing zooplankton (Jones & Sayer 2003, Martin et al. 1992).

McHugh (1972) considered the presence of large beds of aquatic plants in Diamond Lake to be a direct result of eutrophication, which he assumed to be caused by sewage and other man-caused inputs of contaminants. It now appears that the principle source of nutrient inputs is natural although the introduced fisheries, specifically tui chub, have resulted in increased productivity of the lake (Eilers et al. 2001b). The size and morphology of Diamond Lake suggests that even under a mesotrophic[6] nutrient regime there would be a significant macrophyte component to the lake. Macrophyte diversity reaches its peak in moderately productive systems and declines in highly eutrophic systems (Dodson et al. 2000). There is no quantitative means to assess how closely the current macrophyte communities resemble conditions prior to the 1950's. However, anecdotal observations over the last half century indicate significant alteration of macrophyte communities resulting from changes in water quality and the biotic composition of the lake.

Other than white-stemmed pondweed, the only other species recorded as occurring in the lake prior to 1979 are Canada waterweed and water-milfoil. Water-milfoil had previously been reported by McHugh in 1972 and is currently ubiquitous. It seems unlikely that the species could have disappeared completely from the lake only to reappear later, although invertebrate herbivores have been implicated in the decline of the invasive European milfoil (*Myriophyllum spicatum*)(Johnson et al. 1998). Moreover, it is likely that there have been significant shifts in species dominance over time resulting from changes in competition, herbivory, lake productivity, weather, and trophic interactions.

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[3] Cascading trophic interactions refers to effects that work their way through the aquatic foodchain; i.e. increases in tui chub leads to lower numbers of zooplankton which leads to increases in phytoplankton/periphyton which leads to decreases in macrophytes.
[4] It is also possible that direct feeding from crustaceans or mollusks may have contributed to the decline, but this is only rarely a significant cause of macrophyte reductions.
[5] Periphyton refers to algae, protozoa, fungi and bacteria that are attached to macrophytes.
[6] A mesotrophic nutrient regime refers to a "moderate level" of nutrients and biological productivity. A mesotrophic lake is capable of producing and supporting moderate populations of living organisms.

There are no known records available for historic emergent communities in Diamond Lake, but it should be noted that the level of the lake has been maintained at artificially high levels during the summer months by control of the outflow at Lake Creek, since at least the 1950's. It is also maintained at artificially constant levels, since the lake would naturally draw down slightly over the course of the summer. This has resulted in year-round inundation of shoreline areas that may previously have supported emergent rather than aquatic vegetation. Water level management has probably also resulted in unnaturally steep, stable banks that were augmented by planting of reed canary grass (*Phalaris arundinaceae*), a non-native species that was widely planted in riparian areas throughout North America for soil stabilization. It now represents the dominant shoreline species around the lake.

ENVIRONMENTAL EFFECTS

Direct Effects:
Alternatives 2 and 3 would both involve short-term impacts to the macrophyte flora through lake draw down. The draw down itself would expose all macrophytes that are rooted within the top eight feet of the current lake level. This is about a third of the total rooting depth and probably less than a third of the total area covered by macrophytes (see Figure X). Because the macrophyte flora grows along a depth gradient, most of the species would be affected because more species occur in shallow water than in deep water. Of the rooted species, only white-stem pondweed and Canada waterweed currently appear to have significant biomass below eight feet. Free-floating species, such as coontail, are expected to simply float to the new habitat. Some species, particularly the abundant water-milfoil, would likely adapt to the new water level through colonization by stem fragments, rhizomes, seeds, and winter buds. The rooted submersed species would be beginning to senesce and die back naturally about the time the lake level would be dropped. Therefore, there would be little direct mortality to above ground biomass from desiccation during the draw down itself.

Other rooted species, including yellow pond lily, quillwort, and all of the emergent species would be drained and would have to survive the summer through stored reserves in their roots. There may be mortality to exposed plants due to freezing incurred by beginning the draw down prior to the onset of winter. The severity of the winter may be significant in survival of rooted macrophytes in exposed areas. Application of Rotenone in the 1950's was preceded by a draw down period from mid-July to September, rather than over the winter; therefore, macrophyte recovery at that time may not be a good predictor of present recovery.

The proposed application of rotenone under Alternatives 2 and 3 would have no discernable affect on the macrophyte flora because rotenone formulations are not toxic to plants (U.S. EPA as cited in CDFG 1994). There would likely be some damage to macrophyte beds from mechanical fish harvest proposed under Alternative 4. Since aquatic plants provide hiding cover for fish, especially small fish, the macrophyte beds would pose a challenge to efficient fish harvest. However, the proposal is to use gill nets rather than seines in the vicinity of the dense macrophyte beds, which would result in minimal damage to the plants. It is also possible that there may be damage to macrophytes resulting from carcass recovery in Alternatives 2 and 3. However, this

activity would occur when submersed rooted macrophytes would be dying back for the winter. There could be incidental collection of species which do not die back during the winter, but this is not expected to be significant.

Excavation of the canal and deposition of the spoils to augment an existing wetland under Alternatives 2 and 3 would also have short-term impacts to macrophytes. The existing canal has partially filled with sediments and has had some reestablishment of macrophytes within its confines. The limited numbers of plants within this man-made feature are considered insignificant relative to the populations beyond the canal. Deposition of the dredged material near the shoreline would bury submersed aquatic plants in that vicinity of the shoreline which are comprised principally of quillwort, Canadian waterweed, and water-milfoil. Emergent species with suitable root structures[7] would be planted in this area in order to increase the likelihood that sediments would stay in place once the silt fence is removed (see mitigation in Chapter 2 and planting prescription in the Botany report). Overall, the direct effect of this activity is considered to be minor to the macrophytes in the area.

Alternative 1 proposes no activity; therefore, there would be no direct effects to macrophytes from this alternative.

Indirect Effects:
Indirect effects to macrophytes under all of the alternatives would principally be from the trophic cascades, which are the feeding levels within the lake's food web. For example, the introduced tui chub and young rainbow trout feed upon zooplankton which in turn feed upon phytoplankton. The relationships with macrophytes are more complicated. Increases in phytoplankton compete with macrophytes, to a degree, for nutrients. Large numbers of phytoplankton also reduces light penetration into the lake which limits the depth to which submersed macrophytes can grow. Periphyton, which refers to algae together with protozoa, fungi and bacteria that are attached to macrophytes, may also increase indirectly because of large numbers of fish. Excessive periphyton growth suppresses macrophytes and generally results in a shift towards phytoplankton.

Alternative 1 has the potential to result in a crash of white-stem pondweed, and possibly other macrophytes, much as it occurred in the early 1950's (Loomis 2002). As long as tui chub populations remain high, there will be predation upon zooplankton, with cascading trophic effects that may result in alteration of the current macrophyte community (Jones & Sayer 2003, Lodge et al. 1994, Martin et al. 1992). On the other hand, past history is no guarantee that similar results would necessarily follow. The tui chub have been expanding in Diamond Lake since the early 1990's and severe blooms of *Anabaena flos-aquae* have occurred from 2000-2003, but it is noteworthy that the macrophyte community has not crashed in similar fashion to what evidently occurred in the early 1950s. Other than the hydroacoustic sampling of the lake in 2002, there is no repeatable, quantitative data on macrophytes that would allow for more in-depth analysis on community trends.

Recovery of the macrophyte flora subsequent to rotenone treatment and refilling of the lake is difficult to assess under Alternatives 2 and 3. Because lake systems are

[7] Maintenance of the water level at full pool through the summer growing season limits the potential diversity of colonizers for this created wetland.

comprised of complex, connected, interdependent biota that can be highly dynamic, precise determination of the indirect consequences of biomanipulation are speculative[8]. There is anticipated to be rapid expansion of zooplankton populations under Alternative 2 and possibly even more so with Alternative 3 due to their differing fish stocking strategies. Specifically, this should result in recovery of large-bodied Daphnia which have the potential to reduce phytoplankton and decrease turbidity. This should provide excellent conditions for recovery of macrophytes by improving clarity of the water.

There is, however, the potential that there could be substantial damage to plants rooted in the draw down zone of the lake due to freezing over winter and/or desiccation during the summer. This wouldn't necessarily preclude recovery of the macrophytes in this zone, but it may slow the recovery rate if the area needs to be recolonized. There is also the potential that stress to deepwater-adapted species that would be subjected the previous summer to shallow water, would not recover as vigorously. If there is a significant lag in macrophyte recovery this could result in repartitioning of the nutrient balance within the lake to phytoplankton. However, since the dominant submersed macrophyte species in the lake would have much or most of their habitat remaining, this should provide sufficient means for revival of at least this portion of the macrophyte flora. Therefore, there is a reasonable expectation that something resembling the current macrophyte communities would reestablish under Alternatives 2 and 3 and possibly even extend to deeper depths, but there is considerable uncertainty surrounding in what manner and how quickly. Both Alternatives 2 and 3 are considered to be very similar in their indirect effects upon macrophytes. Alternative 3 may have a slightly greater likelihood of resulting in conditions favorable for macrophyte communities realizing their potential. However, it is likely that the draw down conditions (which are the same in both alternatives) would be far more significant to macrophyte conditions than fish-stocking strategies.

It is unknown how the single, non-native, weedy species would respond to the treatments in Alternatives 2 and 3. The two known locations of curly pondweed are within the proposed draw down zone and could succumb to harsh conditions that the draw down may result in. There is also the potential that it could respond more rapidly to the unstable conditions likely to ensue as the lake refills and the biota recovers.

Alternative 4 lacks the negative affects of the lake draw down while providing at least partial reduction of tui chub and whatever consequent affect this has on the rest of the lake's ecosystem. Because it is the least disruptive proposal over the short run, this alternative is most likely to retain the current macrophyte populations in something resembling their present condition for the foreseeable future. Long-term consequences to macrophyte assemblages under this alternative would be subject to the effects of the tui chub populations and distributions over time, along with the populations and distributions of the other organisms within the lake.

Cumulative Effects:

[8] Jones and Sayer (2003), in discussing alternative equilibrium states in lake systems declare that "[o]nce a change has been precipitated, restoring pre-change conditions is insufficient to reinstate the previous community".

Salinas (1998) noted an increase in nutrient inputs to the lake over time, particularly since the 1960's. Increased nutrient inputs typically result in an increase in phytoplankton, although the pathways and interactions between biota are exceedingly complex (Wetzel 2001). Submersed macrophytes decline at very high levels of nutrient loading, but are tolerant of a broad range of nutrient loads. Productivity of emergent macrophytes, on the other hand, would continue to increase with increased nutrients. Alternatives 2 and 3 would presumably result in a short-term increase in nutrients from decaying fish that would be partially mitigated through mechanical collection of carcasses. The nutrient increases are not expected to result in decline of macrophytes, but there is no quantitative data to base this assumption upon.

Other past and ongoing actions, primarily related to recreation, provide a slight increase in sedimentation. Suspended sediment in the water column reduces light penetration which in turn restricts photosynthesis in submersed macrophytes. Improvements to the campgrounds and especially paving of the Diamond Lake loop road has limited sediment inputs from these sources such that shoreline inputs represent the principle input to the lake. Nothing in any of the proposed alternatives would directly affect overall sedimentation rates over time. However, if the proposed draw down were to adversely impact macrophyte populations, the reduction in macrophytes, which buffer shorelines from wave erosion, would likely result in an increase in suspended sediments.

Conclusions:
Macrophyte populations have the potential to change under all of the alternatives (including the no-action alternative). The greatest potential for an abrupt change to macrophytes is from the draw down schedule proposed in Alternatives 2 and 3. The combination of exposing rooted species to freezing temperatures in the winter and drought during the summer could result in significant mortality to much of the macrophyte flora. However, because the majority of submersed macrophyte beds would remain aquatic throughout the draw down, it is reasonable to expect for rapid and substantial recovery of, at least the dominant submersed species. Because of the lack of empirical data on macrophytes in Diamond Lake and the complexity of lake ecosystems in general, there is considerable uncertainty about the fate of macrophyte diversity, distribution, and biomass over time. This is true of all alternatives, but particularly true of Alternatives 2 and 3 because the draw down schedule is anticipated to be the most significant variable for macrophyte conditions.

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