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2005 Diamond Lake Submersed Aquatic Vegetation Survey

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2005 Diamond Lake Submersed Aquatic Vegetation Survey

Prepared for:
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Introduction

Diamond Lake is a large natural lake having a surface area of some 3214 acres (1300.7 hectares) and a maximum depth of 52 feet (15.8 meters) (Johnson et al, 1985) (Figure 1). It is located within the Umpqua National Forest in the Southern Cascade Mountains of Oregon, at an elevation of over 5000 feet (>1524 meters). Diamond Lake is a high-use waterbody that supports angling, public campgrounds, recreational boating, swimming, and water skiing. The human activity associated with the lake has been a significant contributor to the economy of southern Oregon since the early part of the twentieth century (USFS, 2004).

Historically Diamond Lake was fishless but since 1910 the lake has been managed as a popular trophy trout fishery. The unauthorized introduction of the tui chub (*Gila bicolor*) into the lake in the 1930s caused disruption of the food web and a decline in the fishery. In 1954, the Oregon Game Commission constructed a canal near the Lake Creek outlet, lowered the lake level, and treated Diamond Lake with rotenone, to eradicate tui chub. The lake was restocked with trout following the successful rotenone treatment and a fishery was maintained for several decades. In 1992, tui chub were re-introduced, through accidental introduction or intentional illegal stocking, and again caused a decline in the trout fishery (USFS, 2004).

Originally mesotrophic, Diamond Lake productivity increased over the last century to a eutrophic state (Eilers et al. 2001), and is currently included on the Oregon Department of Environmental Quality (ODEQ) 303(d) list of water quality limited water bodies for pH and algae (ODEQ 2002). The lake had severe blooms of the cyanobacteria (blue-green algae) *Anabaena flos-aquae*, which produce neurotoxins, in

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the summers of 2001, 2002, and 2003. *Microcystis aeruginosa*, another toxin producing cyanobacterium species, was also present in the 2003 bloom. Diamond Lake was closed to some public uses (wading, swimming, water skiing, and boating) during portions of all three summers due to public health and safety concerns (USFS, 2004).

Algae blooms and declining trout fishery have been attributed to alteration of the food web by the tui chubs. The chubs spawn early and consume the zooplankton in the lake, which reduces grazing pressure on phytoplankton. Since the lake is nitrogen limited, nitrogen-fixing cyanobacteria dominate the phytoplankton community. Therefore, the chubs reduce the quality of the trout fishery by reducing food available for trout and impact water quality by facilitating cyanobacteria blooms, which can be toxic.

In response to the impact of the tui chub on Diamond Lake the US Forest Service and Oregon Department of Fish and Wildlife are collaborating in a tui chub eradication effort. The eradication plan includes a 2.4-m (8 ft) drawdown of the lake in the winter and spring of 2006 and a rotenone treatment of remaining lake volume in 2006 to kill any remaining fish. The US Forest Service prepared an EIS for the drawdown and rotenone treatment.

Potential impacts of the drawdown on littoral aquatic plant communities were identified in the EIS. The US Forest Service conducted a qualitative survey to develop a species list for the lake (R. Helliwell, US Forest Service, Pers. Comm., September 2005) (Appendix A). The survey described here provides a quantitative, pretreatment measure of cover and biomass of aquatic plants in Diamond Lake. Follow-up sampling, using similar methods, will permit assessment of changes in the plant community following drawdown and refilling of the lake.

Methods

The littoral zone of Diamond Lake was sampled in August 2005. The littoral zone was defined as that portion of the lake less than six meters deep based upon hydroacoustic delineation of the maximum depth of macrophyte colonization conducted previously (Eilers and Gubala, 2003). One hundred sampling points were selected at random from a 10 x 10 m grid overlaid on the littoral zone using ArcGIS (Figure 1). A beacon-corrected Corvallis Microtechnologies Alto G12 GPS unit capable of sub-meter

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real-time accuracy was used for locating the points in the field. Because the projection used in the GIS layer did not match the coordinates in the field, some of the pre-selected sampling points were on shore. Additional sampling points were added randomly in the field to substitute for these points. In addition, some sampling was done at depths deeper than six meters to assess the accuracy of the hydroacoustic determination of the maximum depth of colonization.

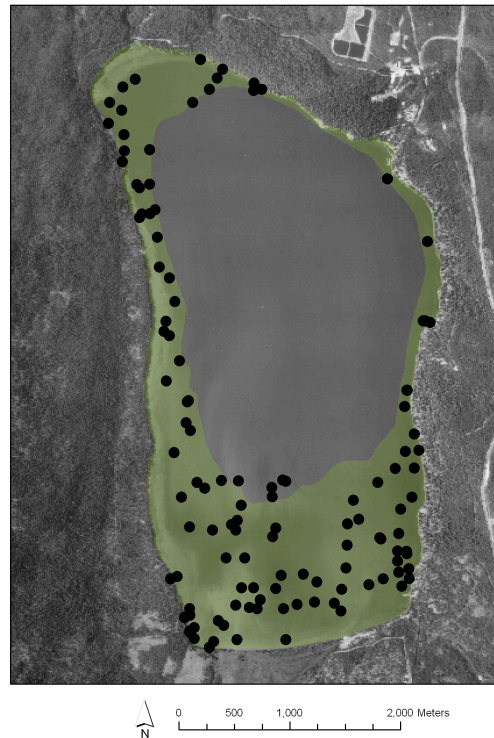


Figure 1. Diamond Lake map showing sampling points and littoral zone < 6 m deep.

At each sampling location a thatch rake affixed to a rigid aluminum pole was lowered into the water until the rake touched the sediment. Sample depth was determined by a scale on the pole. Plants were retrieved by twisting the rake, which entangled the plants in the rake tines. The sampling area was 0.114 m².

All sampling methods are biased in some manner. The rake sampling method used here likely under-sampled small, narrow-leaved species. Also, because plant stems are often intertwined, this sampling method included some plant material from an area larger than the rake sampling area. The magnitude of this bias varied by species, with *Ceratophyllum demersum* biomass estimates likely subject to the greatest bias because of

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its dense, intertwined stems and unrooted growth form. Presumably, the sampling bias will be consistent from year-to-year, which will allow comparison of biomass and cover before and after drawdown.

Plants collected by the rake were separated, identified to species, and fresh weight (nearest 0.5 g) of each species was measured using an Ohaus Model LS2000 electronic scale and/or an Intercomp CS200 hanging digital scale. Plants with a fresh weight less than the detection limit of the scale (0.5 g) were recorded as 0.5 gram. Filamentous algae were separated and weighed but were not identified.

Point sampling data is described by a binomial distribution, as the plant is either present or absent at each sampling location (Middleton, 1998; Newman et al, 1998; Nichols, 1984). The presence/absence data provides an estimate of the frequency of occurrence in the lake. This estimate is a statistical probability (p) that the randomly selected sample location will contain that species. The estimate of p is the number of sites where the species is found (X) divided by the total number of locations sampled (n):

$$p = \frac{X}{n}.$$

The probability that the species will not be present is $1-p$, or q . Based on the binomial distribution, if p or q are not very close to 0 or 1 a normal distribution can be assumed if two criteria are met – the product of n and p and the product of n and q must be greater than or equal to 5 (DeVoe and Peck, 1986; Brown et al, 2001). Error associated with the frequency estimate (δ) was calculated using Equation 1 with a confidence level of 95 %, i.e., the error reported is based on 95 % certainty that the true frequency is within the error estimate (Zar, 1999; Brown et al, 2001).

$$\delta = Z_{\alpha/2} \sqrt{\frac{pq}{n}} \quad \text{Equation 1}$$

Results and Conclusions

The maximum depth of colonization measured in the field was 6.8 m. Therefore, sampling points at depths greater than 6.8 m were excluded from estimates of cover and biomass. A total of 119 sampling points were included in the cover and biomass analyses.

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Six flowering plant species and two macro-algae were collected (Table 1, Appendix B-Table 2). The *Myriophyllum* specimens could not be positively identified to the species level because flowers were not present; however, they were most likely *M. verticillatum*, which was previously identified in Diamond Lake (Helliwell 2005). A *Nuphar* species, again without flowers, was collected in the *Nuphar polysepala*/*Typha latifolia* community on the northwest shoreline of the lake that was tentatively identified as *N. microphylla*. This species has not been recorded previously in the western USA (*Flora of North America*, www.eflora.org).

Plant biomass and cover were patchy. Highest submersed plant biomass occurred in the 3 to 6 m depth strata. (Figure 2 and Figure 3). *Myriophyllum* sp. and *Elodea canadensis* dominated at depths less than 3 m and *Ceratophyllum demersum* dominated at depths greater than 3 m (Figure 3). *C. demersum* biomass was much higher than that of other species, and was generally concentrated near the bottom of the water column in the deeper strata and not visible from the surface. *Potamogeton praelongus* biomass increased with depth and *Potamogeton pusillus* biomass decreased with depth. *Nitella* and filamentous algae occurred only at sampling locations greater than 3 m deep.

Potamogeton richardsonii was collected in only one sample and thus confidence estimates on its frequency did not meet the normality assumption. All other species were collected at high enough frequency that normality assumptions were met. *C. demersum*, *E. canadensis* and *Potamogeton praelongus* occurred most frequently (≈ 0.4) in the Diamond Lake submersed plant samples (Figure 4). Thirty-one percent of the sample locations were unvegetated.

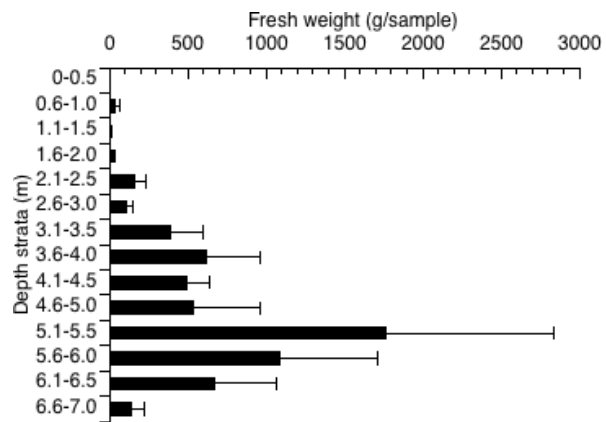


Figure 2. Depth distribution of total biomass (± 1 SE) of submersed aquatic plants in Diamond Lake in August 2005.

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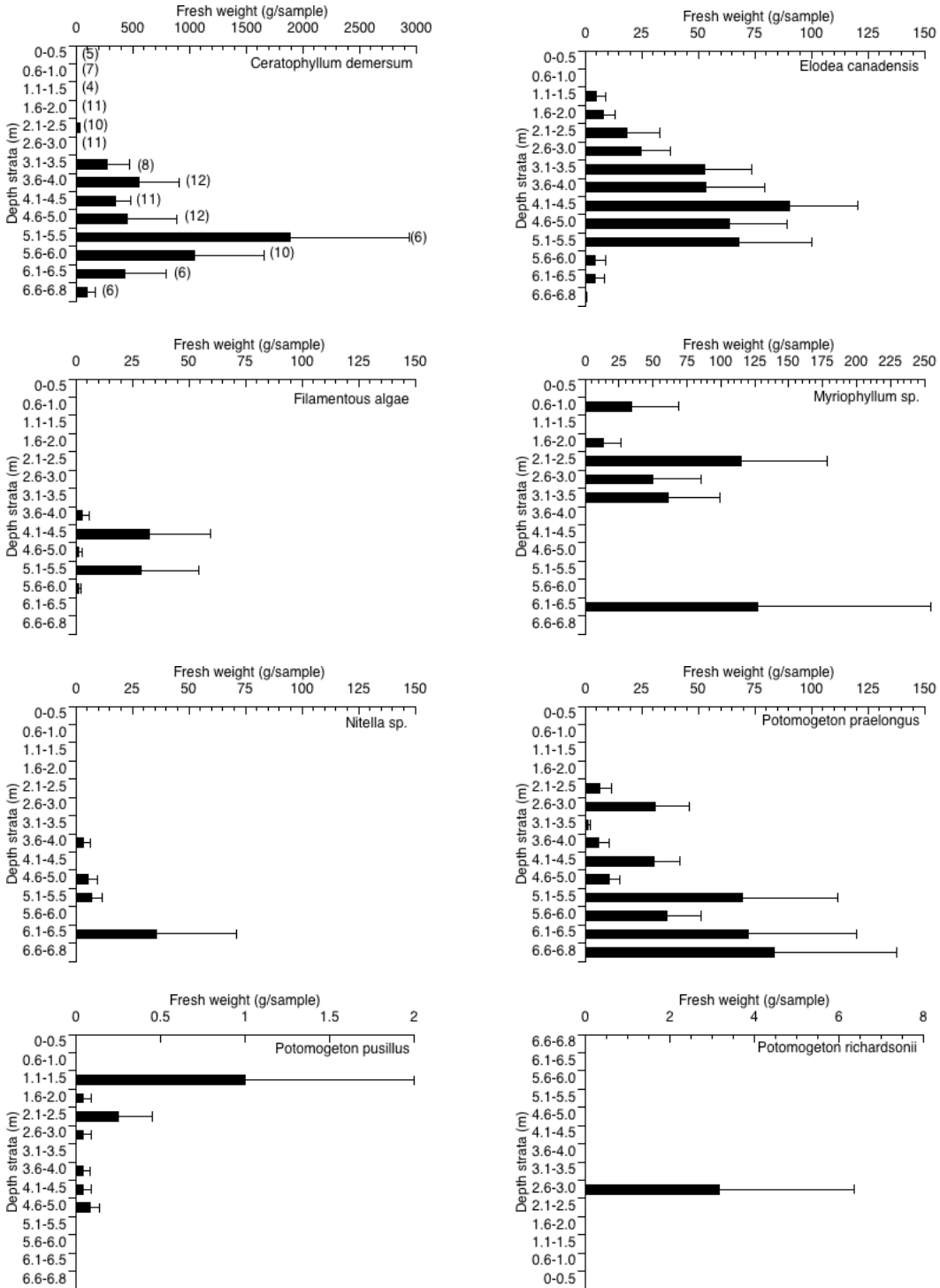


Figure 3. Depth distribution of biomass (± 1 SE) of submersed aquatic plant species in Diamond Lake in August 2005. (#) indicates number of samples collected in strata. Note differences in biomass scales.

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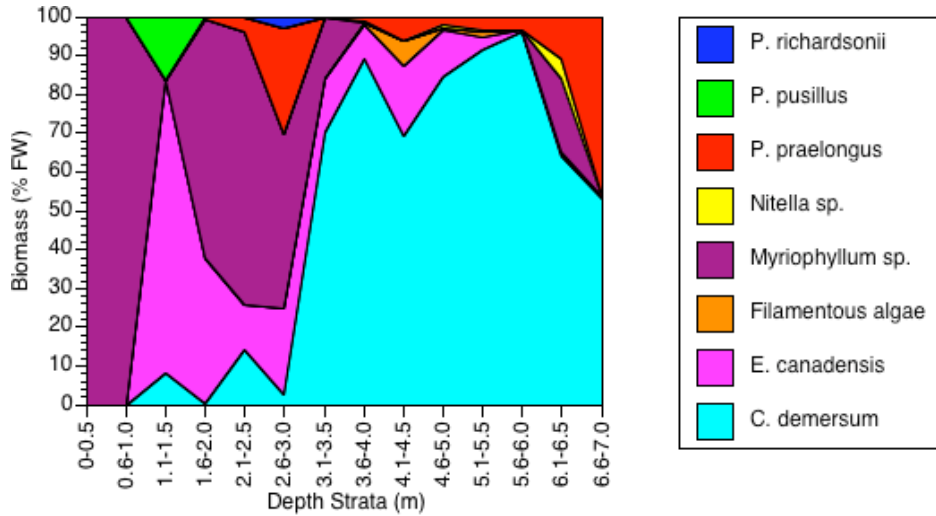


Figure 4. Composition of submersed aquatic plant community (% of biomass) in 0.5 m depth intervals in Diamond Lake in August 2005.

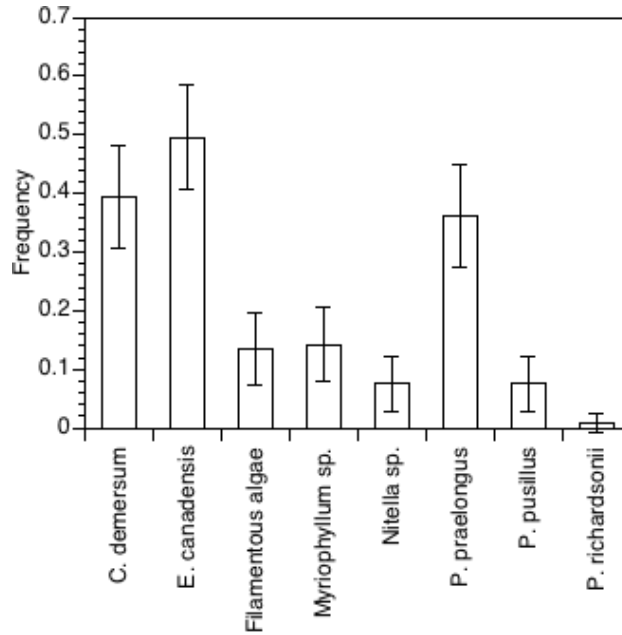


Figure 5. Frequency of occurrence of submersed aquatic plant species in Diamond Lake samples collected in August 2005 (\pm 95% confidence interval).

Variation in plant community composition with depth suggests that the drawdown could have a differential effect on plant species in the lake. *Myriophyllum sp.* and *E. canadensis* dominated the plant community in the drawdown zone and are likely to be most impacted by the drawdown. *C. demersum* and *Potamogeton praelongus* were most common at depths greater than 3 meters, where drawdown impacts should be minimal.

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Recolonization of the drawdown zone will occur from the seed bank and vegetative propagules that survive the drawdown. Plant fragments from the deeper water areas may also colonize the drawdown area. *C. demersum*, in particular, will likely spread into the drawdown area rather quickly. The time to re-establish the current plant community following drawdown is unknown, however, it is unlikely that any submersed plants will be eliminated from the lake by the drawdown. Drawdown impacts on floating leaf and emergent plants may be significant in the short term, however, vegetative and seed re-establishment is likely over the long term.

Post-drawdown sampling should follow sampling protocols used in pre-drawdown sampling to allow comparison of frequency and biomass estimates. Variation in biomass is high and it is unlikely that significant differences in mean biomass can be detected without substantially more sampling. Procedures used by Helliwell to develop the species list should also be implemented post-drawdown to document changes in the species list. The unidentified *Nuphar* species found in the emergent, *Nuphar polysepalum*/*Typha latifolia* community along the northwest shoreline should be monitored closely following drawdown and surveys in other lakes in the Cascades should be conducted to document the distribution of the plant and verify the tentative identification as *N. microphylla*. This species range is described as northeastern US and Canada, Europe, and north Asia (*Flora of North America*, www.efloras.org). If the identification is verified the Diamond Lake population would represent a substantial range expansion for the species.

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Appendix A. USFS comprehensive list of wetland and aquatic species in Diamond Lake, OR

(Compiled by R. Helliwell, USFS Botanist and Noxious Weed Coordinator)

Myriophyllum verticillatum
Potamogeton praelongus
Elodea canadensis
Ceratophyllum demersum
*Scirpus cf. subterminalis**
Isoetes echinospora
Potamogeton richardsonii
Potamogeton berchtoldii
Potamogeton crispus
Polygonum amphibium
Ranunculus aquatilis
Nuphar polysepalum
Scirpus acutus
Eleocharis palustris
Typha latifolia
Carex vesicaria
Chiloscyphus polyanthos (liverwort)
Fontinalis antipyretica (moss)

Appendix B. 2005 submersed vegetation sampling data from Diamond Lake, OR.

Biomass measurements are in grams.

Abbreviations: CEDE = *Ceratophyllum demersum*, ELCA = *Elodea Canadensis*, FIAL = Filamentous algae, MYsp = *Myriophyllum* species, NIsP = *Nitella* species, POPR = *Potamogeton praelongus*, POPU = *Potamogeton pusillus*, PORI = *Potamogeton richardsonii*

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Waypoint_ID	Lat (ddwgs84)	Lon (ddwgs84)	Depth(m)	CEDE	ELCA	FIAL	Mysp	Nlsp	POPR	POPU	PORI	Total Biomass
57	43.141636	-122.16334	0.25									
9	43.15323	-122.136123	0.5									
40	43.136022	-122.159113	0.5				0.5					0.5
104	43.13844522	-122.1618302	0.5									
109	43.13729128	-122.1612817	0.5									
108	43.13737933	-122.161225	0.75									
			freq	0	0	0.0	1.0	0.0	0.0	0.0	0.0	
			biomass	0	0	0.0	0.5					0.5
			% biomass	0	0	0.0	100.0					
39	43.136468	-122.158615	0.8				242.0					242.0
105	43.13852783	-122.161715	1									
100r	43.181957	-122.1535272	1									
10r	43.15188633	-122.135617	1									
3r	43.16229917	-122.1342094	1									
87r	43.17565783	-122.1682018	1									
			freq	0	0	0.0	1.0	0.0	0.0	0.0	0.0	
			biomass	0	0	0.0	242.0					242.0
			% biomass				100.0					
90	43.178782	-122.169723	1.2									
82	43.171103	-122.166383	1.3									
35	43.136589	-122.150621	1.5		0.5							0.5
103	43.13863883	-122.1612282	1.5		2	18				4.0		24.0
			freq	1	2	0.0	0.0	0.0	0.0	1.0	0.0	
			biomass	2	18.5					4.0		24.5
			% biomass	8.163265	75.5102					16.3		

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Waypoint_ID	Lat (ddwgs84)	Lon (ddwgs84)	Depth(m)	CEDE	ELCA	FIAL	Mysp	Nlsp	POPR	POPU	PORI	Total Biomass
41	43.139189	-122.161283	1.6									
38	43.136629	-122.156031	1.7			10	8.0					18.0
25	43.14225	-122.136893	1.75									
106	43.13676417	-122.1607877	1.75			0.5						0.5
76	43.16181	-122.163803	1.9									
56	43.14181	-122.1626	2			32	139.0		1.0			172.0
107	43.13762944	-122.1607568	2									
23r	43.14348767	-122.1370808	2									
29r	43.14084917	-122.1376475	2	0.5	47.7					0.5		48.7
4r	43.16242883	-122.1347629	2									
99r	43.18142767	-122.1526787	2									
			freq	1	4	0.0	2.0	0.0	1.0	1.0	0.0	
			biomass	0.5	90.2		147.0		1.0	0.5		239.2
			% biomass	0.20903	37.70903		61.5		0.4	0.2		
77	43.162618	-122.163546	2.1									
42	43.138175	-122.1581	2.2			11	286.0					297.0
75	43.161445	-122.163193	2.2									
88r	43.17652283	-122.1680013	2.25									
72r	43.14065289	-122.1443395	2.4	40						2.0		42.0
22	43.143692	-122.137119	2.5									
31	43.14146	-122.139732	2.5	68.55	0.5		569.3		0.5			638.8
32	43.13952	-122.14517	2.5	124.29	30.39				53.0	0.5		208.2
43	43.137811	-122.15749	2.5		144		294.0					438.0
80	43.167035	-122.164223	2.5						9.0			9.0
			freq	3	4	0.0	3.0	0.0	3.0	2.0	0.0	
			biomass	232.84	185.89		1149.3		62.5	2.5		1633.0
			% biomass	14.25886	11.38369		70.4		3.8	0.2		

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Waypoint_ID	Lat (ddwgs84)	Lon (ddwgs84)	Depth(m)	CEDE	ELCA	FIAL	Mysp	Nlsp	POPR	POPU	PORI	Total Biomass
83	43.171372	-122.166133	2.6						10.0			10.0
26	43.142889	-122.138114	2.75				367.8		5.3			373.1
27	43.141988	-122.138003	2.75		10.04		178.5		82.9			271.4
95r	43.18391217	-122.1594218	2.8									
96r	43.18310383	-122.1570107	2.8									
92	43.180492	-122.169577	2.9		37							37.0
74r	43.13886817	-122.1444682	2.9	0.5	55							55.5
44	43.139421	-122.156115	3		35			0.5	94.0		35.0	164.5
24r	43.1437145	-122.1381008	3		136.2					0.5		136.7
30r	43.14100494	-122.1413546	3	33.39					145.6			179.0
5r	43.16243783	-122.1349827	3									
			freq	2	5	0.0	2.0	1.0	5.0	1.0	1.0	
			biomass	33.89	273.24		546.4	0.5	337.8	0.5	35.0	1227.3
			% biomass	2.761436	22.26423		44.5	0.0	27.5	0.0	2.9	
21	43.145139	-122.137959	3.25	491.16	127.56							618.7
45	43.13923	-122.154642	3.25		43		9.0					52.0
46	43.139134	-122.153783	3.25	7								7.0
48	43.139112	-122.150832	3.25	32	115.5		0.5					148.0
14	43.148099	-122.136442	3.5	5.77	124.79							130.6
47	43.139852	-122.153404	3.5		6		286.0		0.5			292.5
53	43.140847	-122.154128	3.5	1630	3		174.5		0.5			1808.0
54	43.140857	-122.155481	3.5	0.5	1	0.5	16.0		8.0			26.0
			freq	6	7	1.0	5.0	0.0	3.0	0.0	0.0	
			biomass	2166.43	420.85	0.5	486.0		9.0			3082.8
			% biomass	70.27521	13.65164	0.0	15.8		0.3			

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Waypoint_ID	Lat (ddwgs84)	Lon (ddwgs84)	Depth(m)	CEDE	ELCA	FIAL	Mysp	Nlsp	POPR	POPU	PORI	Total Biomass
33	43.139627	-122.147382	3.6	61.01	30.12							91.1
93	43.181741	-122.168084	3.6									
73	43.157756	-122.163612	3.7	3					47.0			50.0
52	43.140739	-122.15167	3.8	3720	11		0.5		0.5			3732.0
89	43.177869	-122.168013	3.9		292.5			40.0				332.5
15	43.147118	-122.137685	4		85.86							85.9
20	43.144704	-122.139933	4		48.2							48.2
49	43.141246	-122.147113	4	285.5	167.5	34.0				0.5		487.5
28r	43.14147367	-122.136855	4	79.59								79.6
34r	43.13942833	-122.1493428	4	2487.92								2487.9
6r	43.15679017	-122.1368248	4									
71r	43.14237211	-122.1438565	4			3	2.0		26.0			31.0
			freq	6	7	2.0	1.0	1.0	3.0	1.0	0.0	
			biomass	6637.02	638.18	36.0	0.5	40.0	73.5	0.5		7425.7
			% biomass	89.37905	8.594207	0.5	0.0	0.5	1.0	0.0		
78	43.164232	-122.16254	4.1									
91	43.179851	-122.168232	4.1		6				76.0			82.0
94	43.182362	-122.166722	4.2		283.5				39.0			322.5
70r	43.14421633	-122.1437037	4.2	1278.5	28	17.0			25.0			1348.5
50	43.141887	-122.14858	4.25	93	41	301.0						435.0
51	43.141815	-122.151041	4.3	350	200				23.0			573.0
58	43.145852	-122.161192	4.3	72	75	12.0	3.0					162.0
55	43.143301	-122.157169	4.4	1070	190				0.5			1260.5
19	43.144795	-122.140055	4.5	771.8	18.58				19.6			810.0
81	43.169468	-122.164436	4.5	153	152	0.5			23.0			328.5
85r	43.17378467	-122.1666508	4.5			26.0			126.5	0.5		153.0
			freq	7	9	5.0	1.0	0.0	8.0	1.0	0.0	
			biomass	3788.3	994.08	356.5	3.0		332.6	0.5		5475.0
			% biomass	69.1932	18.15684	6.5	0.1		6.1	0.0		

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Waypoint_ID	Lat (ddwgs84)	Lon (ddwgs84)	Depth(m)	CEDE	ELCA	FIAL	Mysp	Nlsp	POPR	POPU	PORI	Total Biomass
2	43.168885	-122.134427	4.75		110.98							111.0
12	43.150438	-122.136163	4.75		7.77							7.8
18	43.146343	-122.142369	4.75	105	104							209.0
86	43.173534	-122.166349	4.8		315				37.0			352.0
79	43.166127	-122.163129	4.9		58			55.0	21.0			134.0
1	43.174051	-122.138783	5									
11	43.151796	-122.137128	5		35.66							35.7
59	43.145563	-122.158613	5	5245	10	16.0			1.0			5272.0
67	43.148289	-122.162019	5	29	71			7.0	32.0	0.5		139.5
36r	43.14327017	-122.1550697	5	16.31	51.97							68.3
7r	43.15681	-122.1368902	5									
84r	43.17140283	-122.1652102	5			0.5			37.0	0.5		38.0
			freq	4	9	2.0	0.0	2.0	5.0	2.0	0.0	
			biomass	5395.31	764.38	16.5		62.0	128.0	1.0		6367.2
			% biomass	84.73612	12.00498	0.3		1.0	2.0	0.0		
68	43.151897	-122.162831	5.2	30	74			21.0	7.0			132.0
69r	43.14597183	-122.143621	5.2	1755		154.0			7.0			1916.0
62	43.144974	-122.151981	5.4	370	183			21.0	152.0			726.0
13	43.150454	-122.138253	5.5	4.27								4.3
60	43.145998	-122.156517	5.5	6749	9	5.0			241.5			7004.5
61	43.145544	-122.156031	5.5	2400	142	15.0			10.0			2567.0
			freq	6	4	3.0	0.0	2.0	5.0	0.0	0.0	
			biomass	11308.27	408	174.0		42.0	417.5			12349.8
			% biomass	91.56664	3.303705	1.4		0.3	3.4			

2005 Diamond Lake Submersed Vegetation Samling data

Waypoint_ID	Lat (ddwgs84)	Lon (ddwgs84)	Depth(m)	CEDE	ELCA	FIAL	Mysp	Nlsp	POPR	POPU	PORI	Total Biomass
98	43.182385	-122.157615	5.7									
16	43.149298	-122.140237	5.75	31.39	0.5							31.9
63	43.145691	-122.151602	5.75	3160	43	4.0			116.0			3323.0
17	43.147878	-122.142963	5.8					0.5				0.5
97	43.181491	-122.158489	5.8									
64	43.149607	-122.157574	6	5765					11.0			5776.0
65	43.148991	-122.159427	6			0.5			104.5			105.0
66	43.149447	-122.160282	6	1440	2	8.0			42.0			1492.0
37r	43.1463445	-122.1558487	6	44	0.5				88.0			132.5
8r	43.15546983	-122.1371553	6									
			freq	5	4	3.0	0.0	1.0	5.0	0.0	0.0	
			biomass	10440.39	46	12.5		0.5	361.5			10860.9
			% biomass	96.12831	0.423538	0.1		0.0	3.3			
72	43.156117	-122.161174	6.1									
70	43.154318	-122.161445	6.25				763.0		279.5			1042.5
69	43.153685	-122.160962	6.4	356.5								356.5
85	43.173796	-122.165239	6.4		4				151.0			155.0
95	43.180424	-122.160349	6.5									
101	43.14758217	-122.1554183	6.5	2230	23.5			213.0	0.5			2467.0
			freq	2	2	0.0	1.0	1.0	3.0	0.0	0.0	
			biomass	2586.5	27.5		763.0	213.0	431.0			4021.0
			% biomass	64.32479	0.683909		19.0	5.3	10.7			
74	43.159366	-122.162114	6.7					0.5				0.5
84	43.171721	-122.164652	6.75									
102	43.14954583	-122.1556818	6.75	462	0.5				206.0			668.5
71	43.156028	-122.161299	6.8	20	2				296.0			318.0
111	43.14823133	-122.1519723	6.8	90								90.0
114	43.149475	-122.1504162	6.8	2								2.0
			freq	4	2	0.0	0.0	1.0	2.0			
			biomass	574	2.5			0.5	502.0			1079.0
			% biomass	53.19741	0.231696			0.0	46.5			
124			Tot. freq.	47	59	16.0	17.0	9.0	43.0	9.0	1.0	
			p	0.379032	0.475806	0.1	0.1	0.1	0.3	0.1	0.0	
			Error	0.085392	0.087904	0.1	0.1	0.0	0.1	0.0	0.0	