Diamond Lake water quality during 2007 and long term trends of Fish Stocking Index parameters

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by

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Summary

During the summer of 2007 Portland State University monitored the water quality and biological characteristics of Diamond Lake, Oregon. Data were entered into a Microsoft ACCESS database and graded for precision and accuracy quality according to Oregon Department of Environmental Quality standards. Parameters monitored included those identified in the Diamond Lake Fish Stocking Index (Eilers 2003; Eilers et al. 2008). The Fish Stocking Index (FSI) is a proposed series of water quality and fish health parameters that are sensitive to levels of zooplankivory and benthivory in the lake by both stocked trout and invasive Tui chub (*Gila bicolor*). Tui chub most recently invaded the lake circa 1990 and were eradicated in 2006.

We evaluated FSI parameters monitored in 2007 in relation to long term trends and sensitivity to Tui chub density and trout stocking. Fish health index parameters were not evaluated. Benthic macroinvertebrate biomass, large zooplankton density, and edible zooplankton recovered in 2007 after the eradication of Tui chub. In contrast, small zooplankton density declined in 2007 after steady increase over the course of the Tui chub population growth. Chlorophyll a concentrations, *Anabaena* density, and depth integrated primary productivity declined after increases from 2001 through 2006. Secchi disc transparency increased in 2007 to values not observed since the early 1990's. Surface water pH values decreased in 2007 to within water quality standards. Hypolimnetic dissolved oxygen concentrations remained low in 2007, possibly due to the biological oxygen demand of decomposing Tui chub carcasses. Continued monitoring of FSI parameter is recommended to prevent negative impacts of excessive trout stocking.

Introduction

The influence of zooplanktivorous fish on water quality have been observed in many lakes (Brett and Goldman 1996) including Diamond Lake, Oregon (Eilers et al. 2007; Turner et al. 2006). Sarnelle and Knapp (2005) suggest that the dominant mechanism behind these observations is that increased grazing pressure on large herbivorous zooplankton decreases grazing pressure on phytoplankton, which in turn leads to higher phytoplankton biomass and associated water quality problems such as high pH, low dissolved oxygen, low water clarity, and undesirable algal species.

Tui chub (*Gila bicolor*), a zooplanktivorous, benthivorous minnow, was introduced to Diamond Lake sometime before 1954 and around 1990. Dense populations observed after 2001 (Jackson et al. 2004) coincided with toxigenic blooms of the blue-green algal species *Anabaena*. Eradication of Tui chub from the lake in 1954 and 2006 lead to improved water quality. The health of stocked rainbow trout, competitors with Tui chub for large zooplankton and benthic invertebrates, also improved after the eradication to Tui chub.

Although trout exert less predation pressure on large herbivorous zooplankton than Tui chub (Eilers et al. 2007), trout stocking levels and stock timing can affect large herbivorous zooplankton populations (Hembre and Megard 2005). Stocking rates to Diamond Lake have ranged up to 500,000 fingerling trout (Figure 1).

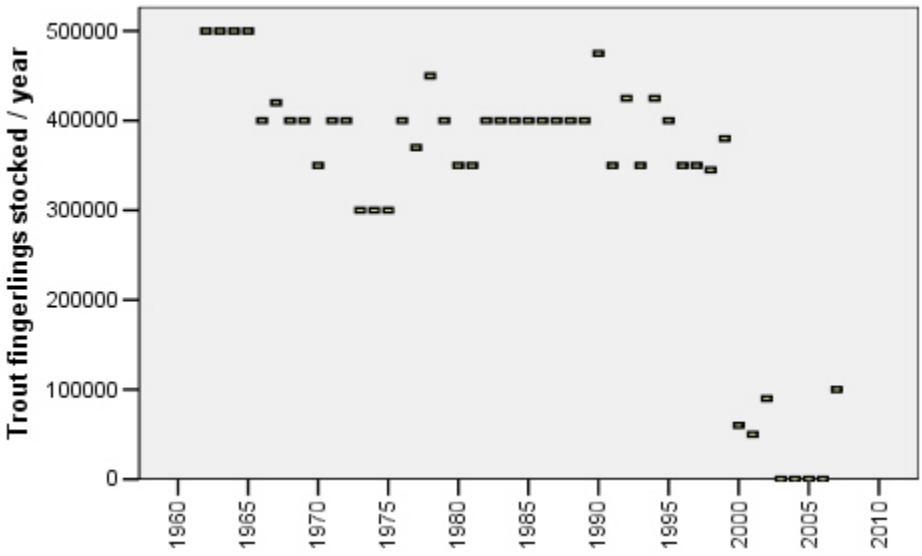

Figure 1. Number of trout fingerlings stocked per year at Diamond Lake

Because of the potential impact of trout stocking on water quality, Eilers (2003) proposed and modified (Eilers et al. 2008) the Diamond Lake Fish Stocking Index (FSI) to help guide fisheries and water quality management. The FSI consists of a series of water quality and fish health parameters normalized to a scale of zero to ten; ten being the worst water quality condition. FSI parameters were selected based on their theoretical response and measurable sensitivity to top down controls by planktivores and include:

- Secondary consumer parameters
  - Trout growth, condition and survival
- Primary consumer parameters
  - Large *Daphnia sp.* density, benthic macroinvertebrate biomass, and amphipod density
- Primary producer parameters
  - Chlorophyll a, *Anabaena sp.* density, and Secchi disc transparency
- Chemical parameters
  - Surface water dissolved oxygen concentration, hypolimnetic dissolved oxygen concentration, and surface water pH

This report will evaluate FSI data collected by Portland State University (PSU) during the summer of 2007 in relation to the historical record of FSI data. Parameters that were not included or were eliminated from the FSI will also be evaluated.. These parameters include edible zooplankton, phytoplankton biovolume, and depth integrated primary production. Data used for long term analysis include data collected by PSU and data compiled in Eilers' Diamond Lake Database v5 (Eilers (2003b), Lauer (1979), ODEQ, ODFW, Salinas and Larson (1995), and Salinas (1996; 1997; 1998; 1999; 2000; 2001; 2002; 2003; 2004; 2005)). The number of sampling events per year has varied over the time period (Table 1); consequently, observed trends must be treated with caution. Data collected by PSU during 2006 (Sytsma et al. 2007) and 2007 have been graded according to Data Quality Objectives (Appendix A) and reside in a Microsoft Access Database (Appendix B). Non-standardized parameters will be assessed because the emphasis of this report is to evaluate the individual parameters rather than the comparisons between parameters. Trout health FSI parameters will not be evaluated since the dataset is not available. All time series data are presented as boxplots of annual data (Figure 2), with the exception of hypolimnetic dissolved oxygen which is presented as boxplots of annual July through August data.

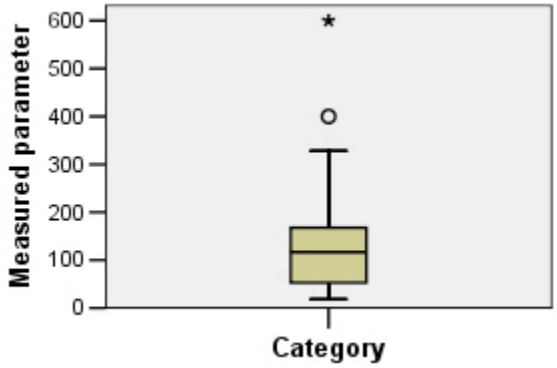

Figure 2. Example of boxplots used in the remainder of this document. Boxes represent interquartile ranges of data, whiskers represent ranges of non-outlier data, circles represent outlier values (1.5-3X IQR) and asterisks represent extreme values (>3X IQR).

Table 1. Count of dates with data collected at Diamond Lake site DLA

	Surface chl-a	Zoo-plankton	Secchi trans.	Phyto-plankton	Surface pH	Hypo-limnetic DO	Surface dissolved oxygen	Primary productivity
1962	ND	ND	9	ND	ND	ND	ND	ND
1963	ND	ND	7	ND	ND	ND	ND	ND
1964-1970	ND	ND	ND	ND	ND	ND	ND	ND
1971	8	ND	5	ND	5	3	4	5
1972	5	ND	5	ND	5	2	6	6
1973	4	ND	6	1 (NB)	6	2	6	4
1974	5	ND	6	6 (NB)	6	2	5	2
1975	5	ND	9	6 (NB)	6	2	6	4
1976	6	ND	6	6 (NB)	4	2	4	4
1977	7	ND	7	7 (NB)	7	2	7	6
1978-1991	ND	ND	ND	ND	ND	ND	ND	ND
1992	4	ND	4	4	4	2	4	3
1993	6	ND	4	5	6	3	6	5
1994	2	3	3	3	4	2	4	1
1995	3	3	3	2		1	3	2
1996	3	3	3	3	3	1	3	2
1997	3	3	3	3	3	1	3	2
1998	ND	7	7	7	7	4	7	5
1999	4	4	3	3	5	2	5	4
2000	3	3	3	3	2	1	2	3
2001	8	5	13	13	8	4	10	5
2002	10	5	41	39	9	3	10	5
2003	4	5	76	23	15	8	15	3
*2004	NA	6	NA	NA	NA	NA	NA	1
*2005	NA	4	29	22	NA	NA	NA	1
*2006	5	5	5	5	5	2	5	1
*2007	3	3	25	3	3	2	3	1

* Some data collected after 2004 are not available. ND = no data collected; NA = no data available; NB = no phytoplankton biovolume measurements.

Primary consumer parameters

Eilers et al. (2008) proposed three parameters that characterize the impact of grazing pressure by trout and Tui chub on primary consumers: benthic macroinvertebrate biomass, amphipods as a percentage of the total number of benthic organisms sampled, and the combined density of the large herbivorous zooplankton *Daphnia pulicaria* and *Daphnia rosea*. Truemper (2007) found that both benthic parameters are sensitive to both Tui chub grazing pressure and trout stocking between 1948 and 2007 (Figure 3).

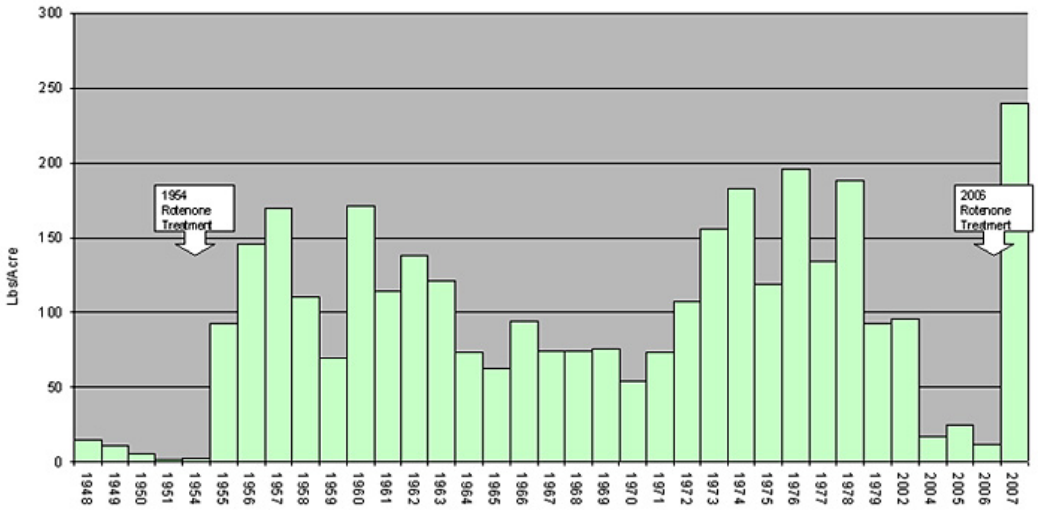

Figure 3. Benthic macroinvertebrate biomass (Truemper 2007).

The historical record of zooplankton in Diamond Lake is not as extensive as the benthic invertebrate dataset; however, at least three sampling dates per year have been completed between 1994 and 2007. The density of two of the most abundant large herbivorous zooplankton in the dataset, *Daphnia pulicaria* and *Daphnia rosea*, do not appear to be related over the time period (Figure 4; Figure 5) and consequently, their sum may not be a good a candidate for an index parameter over the time period. *D. pulicaria* practically disappeared from the dataset during the period of Tui chub grazing pressure while *D. rosea* maintained a population. It must be noted however, that the 1994-2007 period includes only one year without Tui chub. *D. pulicaria* plus *D. rosea* may prove useful as an index of trout grazing pressure.

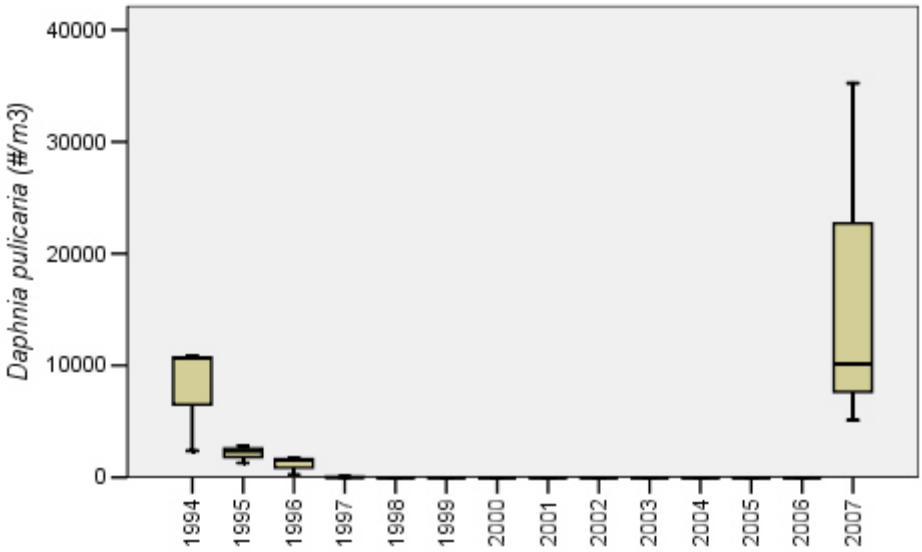

Figure 4. Density of *Daphnia pulicaria* in Diamond Lake between 1994 and 2007.

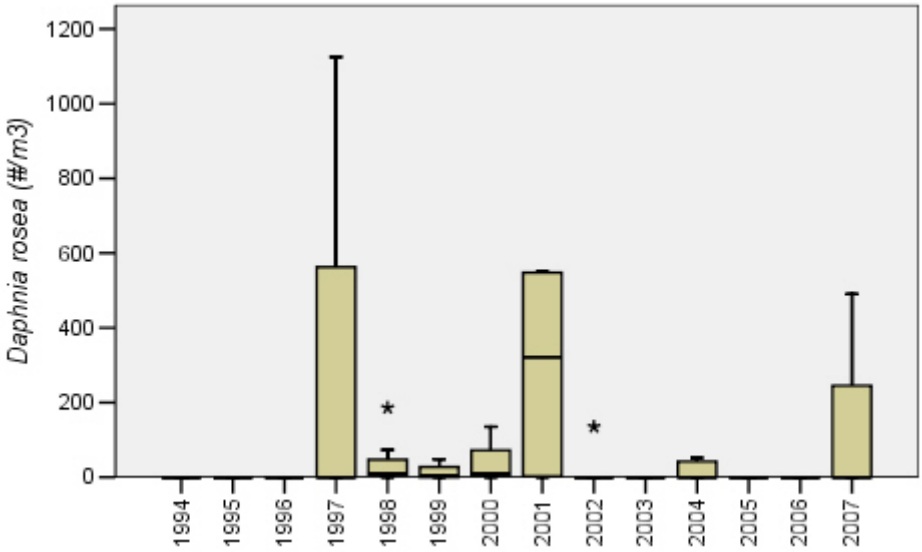

Figure 5. Density of *Daphnia rosea* in Diamond Lake between 1994 and 2007.

The percent of the zooplankton population that is "edible" to trout returned to levels observed early in the Tui chub infestation after eradication (Figure 6). The edibility criterion is primarily based on zooplankton size (Allan Vogel, ZP's Taxonomic Service). The density of smaller non-"edible" zooplankton such as *Daphnia galeata* (Figure 7), *Diaphanosoma brachyurum* (Figure 8), and *Ceriodaphnia pulchella* (Figure 9) increased along with the Tui chub population and decreased after Tui chub eradication. This suggests either increased predation pressure by large zooplankton or competition with large zooplankton for food. As Eilers et al. (2008) noted, rotifer density did not decline after Tui chub eradication (Figure 10). Rotifer density, therefore, may not be a sensitive measure of top down impacts of zooplanktivores in Diamond Lake.

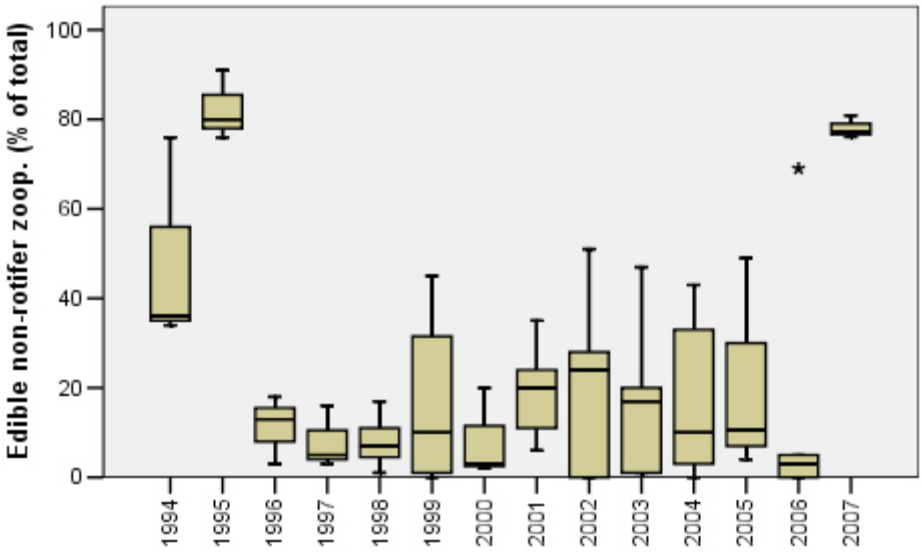

Figure 6. Percent of the zooplankton population that is "edible" to trout according ZP's Taxonomic Service criteria.

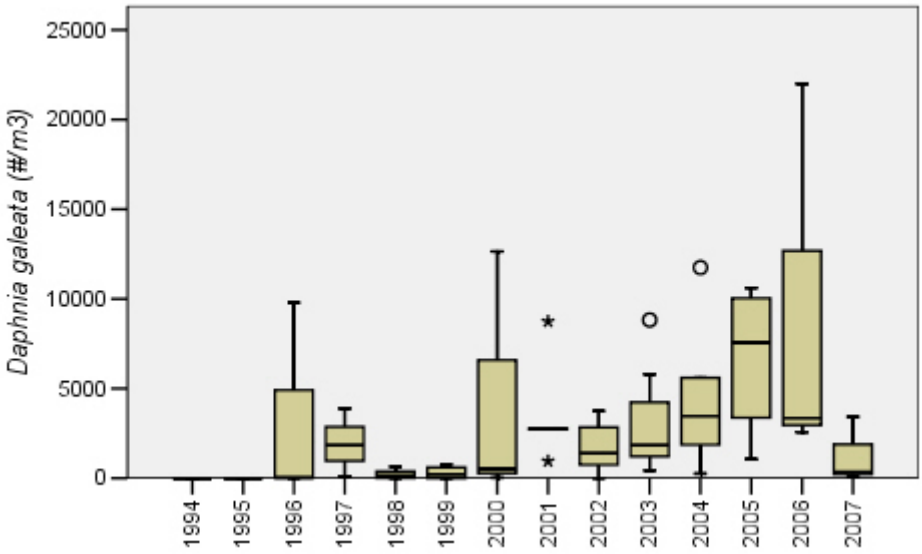

Figure 7. Density of *Daphnia galeata* in Diamond Lake between 1994 and 2007.

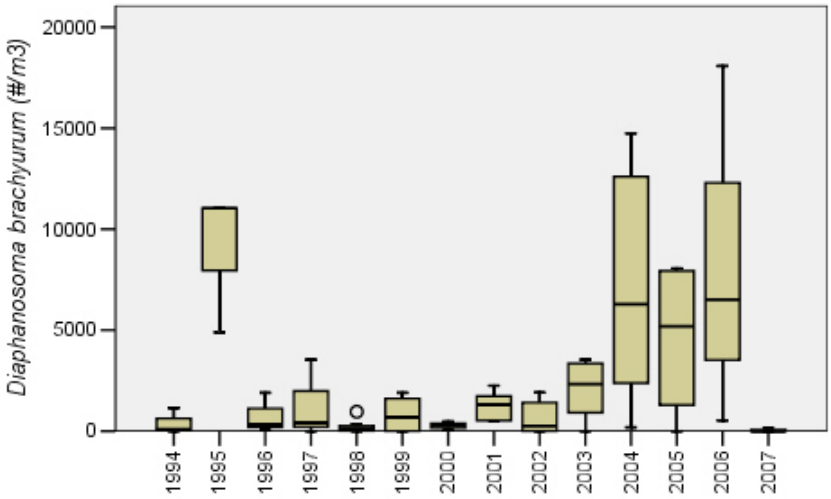

Figure 8. Density of *Diaphanosoma brachyurum* in Diamond Lake between 1994 and 2007.

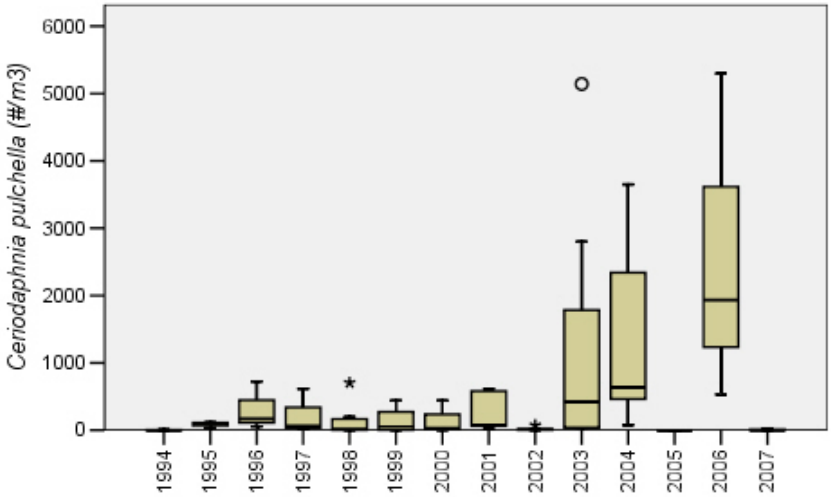

Figure 9. Density of *Ceriodaphnia pulchella* in Diamond Lake between 1994 and 2007.

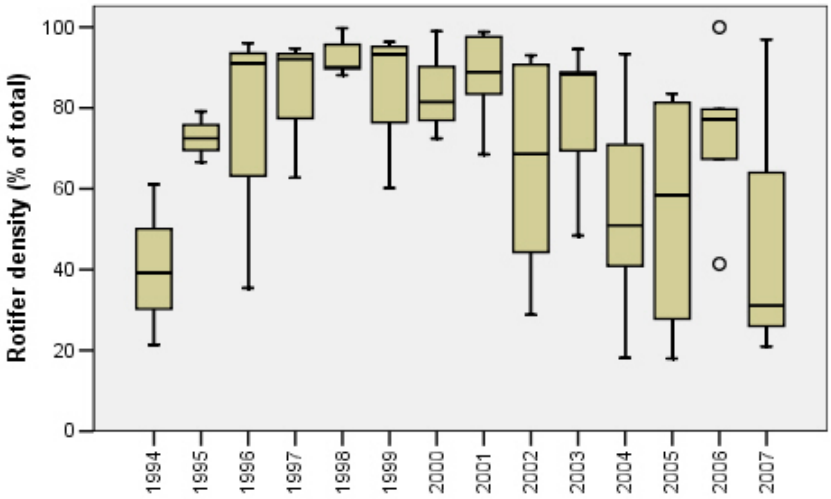

Figure 10. Rotifers as a percent of the total zooplankton population.

Primary producer parameters

Eilers et al. (2008) proposed three primary producer parameters to characterize the impact of grazing pressure by trout and Tui chub on primary consumers: chlorophyll a concentration, *Anabaena* species density, and Secchi disc transparency. Primary productivity will data will also be presented.

Chlorophyll a concentrations in surface waters do not appear to follow the hypothesized trend of low concentrations during periods of abundant large, herbivorous zooplankton; and high concentrations when large zooplankton are rare (Figure 11). For example, during the period from 1996 though 2000 there were few large herbivorous zooplankton and "edible" zooplankton, yet chlorophyll a concentrations were less than 10µg/l. Part of this divergence from the hypothesis may be due to chlorophyll a analysis methods, variation in the amount of chlorophyll a by algal species, or the depth distribution of algae. Regardless of the cause of the divergence, chlorophyll a concentrations at the surface may not be a sensitive indicator of the top down effects of large zooplankton grazing pressure in Diamond Lake. Areal chlorophyll a concentration, rather than depth specific chlorophyll a concentration, may be a more sensitive FSI parameter.

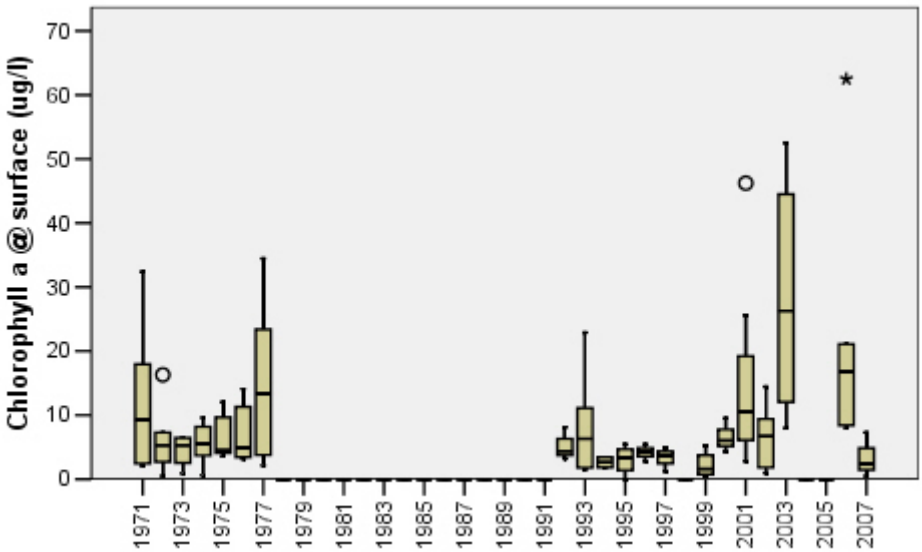

Figure 11. Chlorophyll a concentration in Diamond Lake site DLA surface water.

Anabaena species density in surface waters follows a similar pattern to chlorophyll a concentrations (Figure 12). Median annual densities were highest during the 1970's under high trout stocking rates and also during the latter part of the Tui chub infestation. Lowest densities occurred between 1993 and 2000 during the early part of the infestation, and after Tui chub eradication. Direct comparison of *Anabaena* density between the 1973-1977 and 1992-2007 datasets, however, is problematic due to changes in sample collection and counting protocol. *Anabaena* was, however, the dominant late summer algal species during the 1970's; therefore, the potential exists for blooms in the absence of Tui chub.

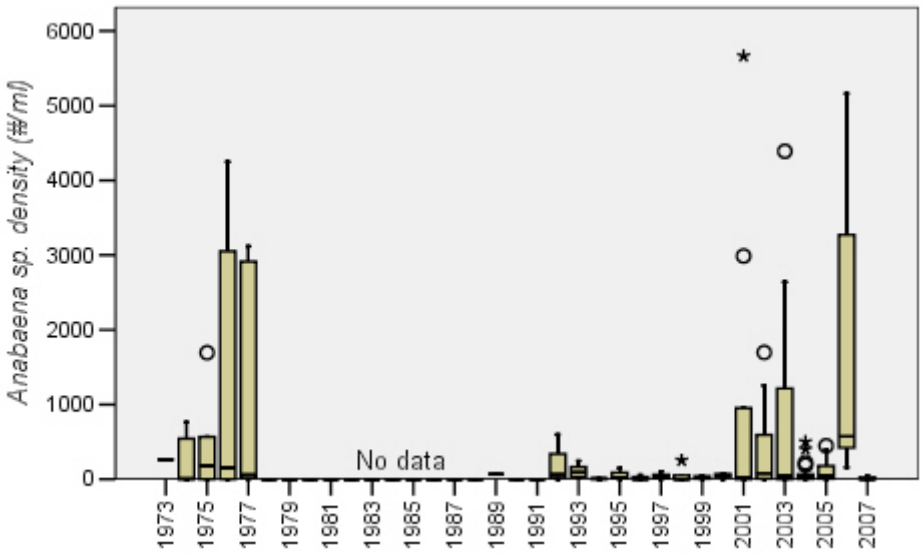

Figure 12. *Anabaena species* density in Diamond Lake site DLA surface water. Density values for two dates, 7/21/76 (30226 cells/ml) and 8/18/77 (9054 cells/ml) are off scale.

Secchi disc transparency measurements are determined by the inherent properties of the water and external factors. Inherent properties include the amount, depth distribution, and size distribution of particles in the water; and the dissolved humic color content of the water. External factors include wave conditions, time of day, and the skill and eyesight of the observer. Since Diamond Lake has little inorganic turbidity and humic color, Secchi transparency measurements are primarily an integration of water column algal density, algal size distribution, and external factors. Secchi transparencies in Diamond Lake between 1962 and 2007 have ranged from less than one meter to nearly 12m (Figure 13). The lowest median annual values occurred during the period immediately preceding eradication of Tui chub, 2001 though 2006. Secchi transparencies improved remarkably in 2007 after the Tui chub eradication.

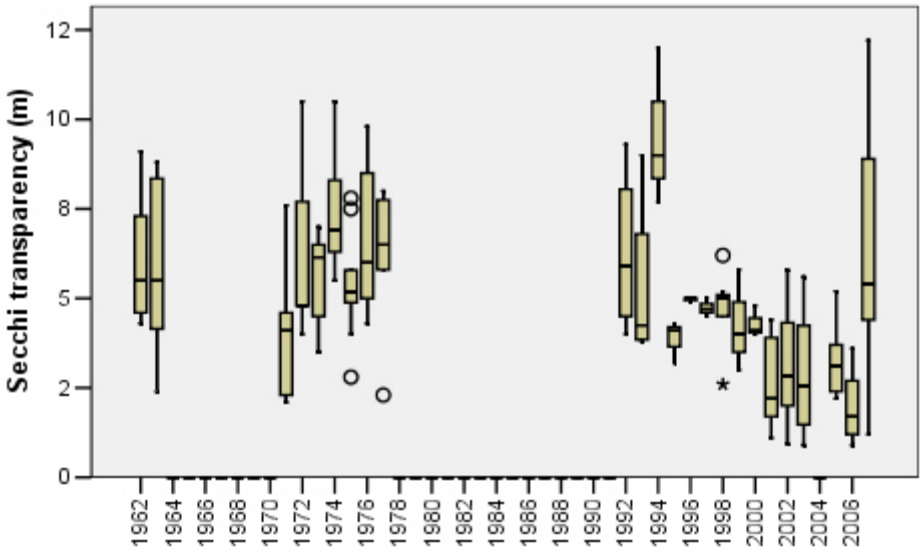

Figure 13. Secchi disc transparency at Diamond Lake site DLA

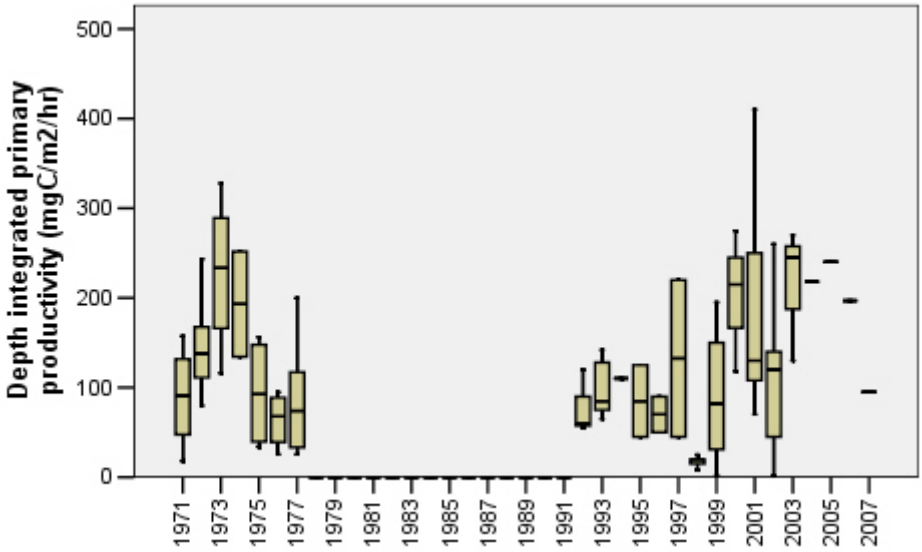

Figure 14. Depth integrated primary productivity measured with the ^{14}C radioisotopic method.

Depth integrated primary productivity has been measured in Diamond Lake since 1971 with the exception of the period from 1978 to 1991 (Figure 14). Since 2004, primary productivity has been measured once per year during mid-summer. The productivity estimate in 2007 declined from higher values in previous years.

Chemical Parameters

Eilers et al. (2008) proposed three chemical parameters to characterize the impact of grazing pressure by trout and Tui chub on water quality: surface water dissolved oxygen, depth to anoxic water, and surface water pH. These parameters are all determined by a balance between primary production, metabolic respiration, decomposition processes, and equilibration rates with the atmosphere. Since primary production and respiration oscillate on a diel cycle, surface water pH and dissolved oxygen concentrations also oscillate on a diel cycle, and the range of the oscillation in a given lake is dependent on the amount of production and respiration. Factors that are not on a diel cycle such as temperature, the amount of light hitting a lake, and wind speed also affect pH and dissolved oxygen concentrations in surface water. During the daytime during periods of higher productivity, these factors lead to higher and more variable pH and dissolved oxygen concentrations. Daytime dissolved oxygen concentrations at Diamond Lake appeared to be more variable during the period from 1999 to 2003 (Figure 15). pH values at the surface declined in 2007 after very high values prior to the eradication of Tui chub (Figure 16).

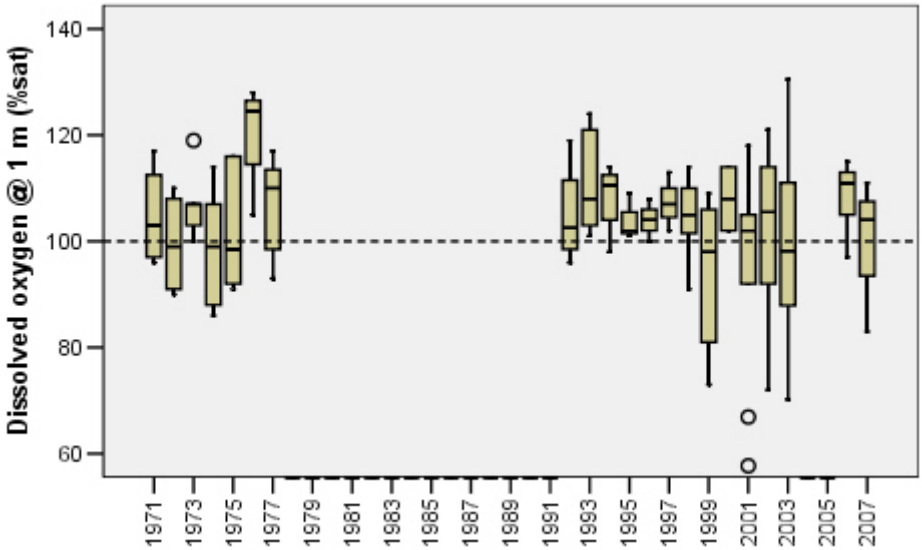

Figure 15. Diamond Lake surface water dissolved oxygen concentration as a percent of saturation.

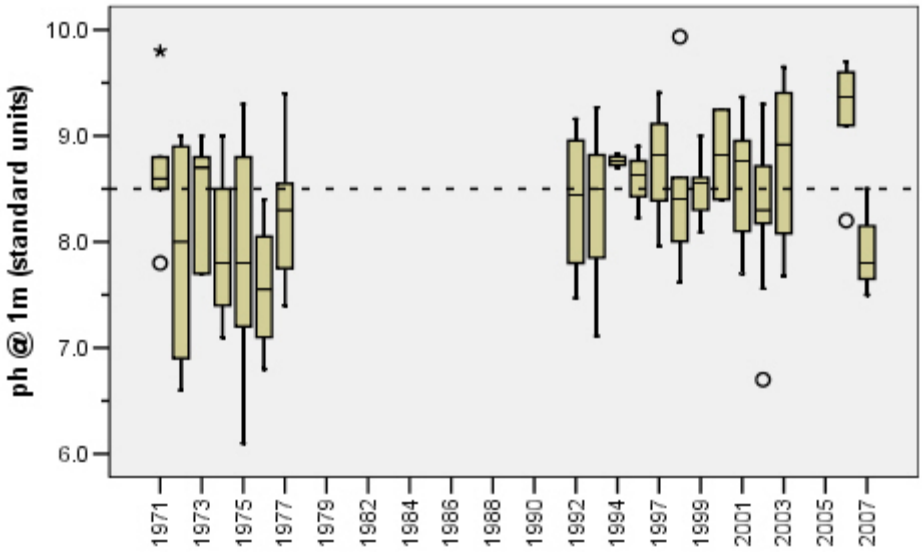

Figure 16. Surface water pH values at Diamond Lake.

Because light is too low to support signification primary production in the hypolimnion and gases cannot diffuse through the thermocline, oxygen concentrations in the hypolimnion are primary determined by decomposition of organic material. Higher delivery of organic matter from the productive surface water leads to faster rates of oxygen consumption and low oxygen concentrations. Eilers et al. (2008) suggests using depth to anoxia as a FSI parameter, however, the historic record does not have complete detailed oxygen depth profiles. There is a longer historic record of dissolved oxygen concentration at 13m so we suggest using 13m dissolved oxygen concentration during July through August as an FSI parameter. Dissolved oxygen concentrations at 13m have not recovered to levels measured during the early or pre- Tui chub infestation period. This may be because of the increased biological oxygen demand in the lake due to decomposing Tui-chub carcasses following eradication.

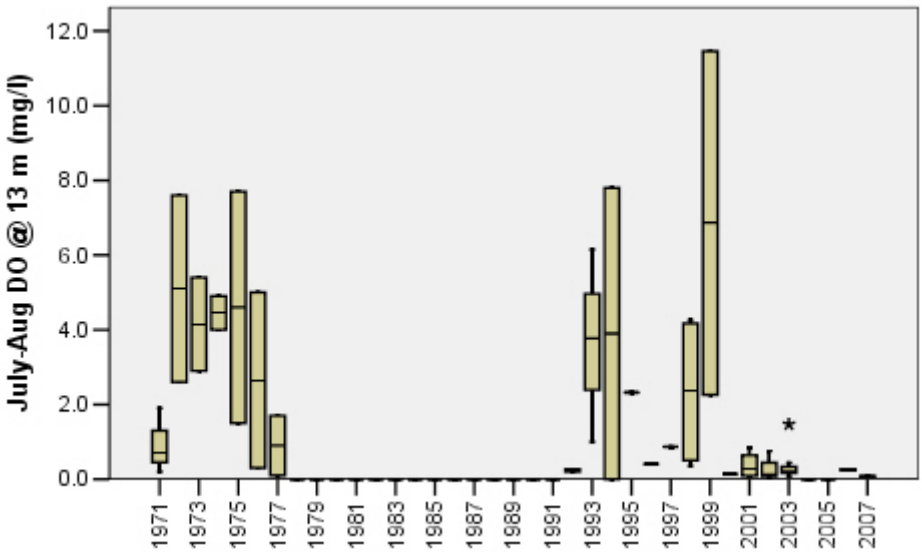

Figure 17. July – August dissolved oxygen concentration at 13m.

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Appendix A. Data quality report for 2007 data

Introduction

This interim report summarizes the quality of data collected from Diamond Lake by Portland State University Center for Lakes and Reservoirs during the 2007 field-sampling season. Water samples were collected and in situ measurements were conducted at the deepest site in Diamond Lake (site DLA) on July 16th 2007, August 6th 2007, and September 23rd 2007. Samples and measurements were also conducted at the outlet of Diamond Lake (LCO site) during the July 16th sampling event. Samples and measurements were conducted as specified by the USDA Willamette National Forest. Chemical samples were analyzed by the Cooperative Chemical Analytical Laboratory (CCAL) in Corvallis, Oregon according to standard methods. Phytoplankton and chlorophyll a analyses were conducted by Aquatic Analysts in White Salmon, Washington. Zooplankton analysis was conducted by ZP's Taxononmic Service in Aberdeen, Washington and by Phycotech, Inc. in North Bend, Indiana. All data are stored in a Microsoft Access database (see Appendix B).

Chemistry Grab Sample Quality Assurance

The quality of chemical grab samples was assured through 1) submittal of field equipment blank samples to assure samples are free of contamination from sampling equipment, filtration equipment, and sample bottles; 2) submittal of replicate grab samples to evaluate the precision of field sampling procedures; and 3) through lab replicate samples to evaluate the precision of laboratory procedures. CCAL also conducts extensive laboratory accuracy quality assurance procedures to ensure analytical precision.One set of filtered and unfiltered field equipment blank samples were submitted to CCAL each sampling event. Concentrations were at or below minimum detection limits for ammonia, nitrate plus nitrite nitrogen, total nitrogen, soluble reactive phosphorus, total phosphorus, and dissolved silica (Table 2). Conductivity and alkalinity blank measurements were at or below minimum levels of quantification, but above detection limits. Dissolved and total organic carbon measurements were also above detection limits during all sampling events, and above the minimum level of quantification during the September 23, 2007 sampling event, however, lake samples were over 10 times the concentration of blank samples.

Table 2. Field equipment blank measurements compared with laboratory detection limits and minimum levels of detection. Values in bold are above the CCAL detection limit.

Parameter	Minimum level of quantification	Detection limit	7/16/2007	8/6/2007	9/23/2007
NH_3 (mg/l)	0.032	0.01	0.00	0.00	0.00
NO_3+NO_2 (mg/l)	0.003	0.001	0.000	0.000	0.000
TN (mg/l)	0.032	0.01	0.00	0.01	0.00
SRP (mg/l)	0.003	0.001	0.001	0.000	0.000
TP (mg/l)	0.003	0.002	0.001	0.001	0.000
Si (mg/l)	0.6	0.2	0.0	0.0	0.0
DOC (mg/l)	0.16	0.05	**0.16**	**0.14**	**0.21**
TOC (mg/l)	0.16	0.05	**0.12**	**0.11**	**0.18**
ALK (mg/l)	0.6	0.2	**0.29**	**0.29**	**0.27**

COND (µS/cm)	1.3	0.4	**1.2**	**1.1**	**1.3**

One set of filtered and unfiltered field replicate samples were submitted each sampling event. The relative percent difference (RPD) between replicate pairs was less than 20% for all but three replicate pairs for three parameters (Table 3). Soluble reactive phosphorus replicates collected from 1m on 9/23/0 7 had a 29% RPD, however, the absolute difference was only 1 µg/l. Ammonia replicates pairs collected from 13 m on 8/6/07 and total nitrogen samples collected from 13 m on 7/16/07 were each greater than 20% RPD.

Table 3. Field replicate grab sample measurements. Replicate pairs with greater than 20% relative percent difference (RPD) are listed in bold.

Parameter	Date	Depth (m)	Primary Value	Replicate Value	RPD (%)
NH_3 (mg/l)	7/16/2007	13	0.347	0.36	4
	8/6/2007	13	0.471	0.575	**20**
	9/23/2007	1	0.034	0.035	3
NO_3+NO_2 (mg/l)	7/16/2007	13	0.001	0.001	0
	8/6/2007	13	0.000	0.000	0
	9/23/2007	1	0.009	0.009	0
TN (mg/l)	7/16/2007	13	1.12	0.82	**31**
	8/6/2007	13	0.95	1.07	12
	9/23/2007	1	0.44	0.47	7
SRP (mg/l)	7/16/2007	13	0.138	0.138	0
	8/6/2007	13	0.15	0.177	17
	9/23/2007	1	0.003	0.004	**29**
TP (mg/l)	7/16/2007	13	0.175	0.175	0
	8/6/2007	13	0.22	0.266	19
	9/23/2007	1	0.029	0.035	19
Si (mg/l)	7/16/2007	13	4.16	4.09	2
	8/6/2007	13	4.81	4.95	3
	9/23/2007	1	4.02	4.05	1
DOC (mg/l)	7/16/2007	13	2.75	2.77	1
	8/6/2007	13	2.65	2.65	0
	9/23/2007	1	2.75	2.74	0
TOC (mg/l)	7/16/2007	13	2.75	2.72	1
	8/6/2007	13	2.72	2.72	0
	9/23/2007	1	2.83	2.84	0
ALK	7/16/2007	13	5.31	5.31	0
(mg HCO_3/l)	8/6/2007	13	5.5	5.64	3
	9/23/2007	1	4.7	4.73	1
COND (µS/cm)	7/16/2007	13	45.8	45.8	0
	8/6/2007	13	47.9	49.4	3
	9/23/2007	1	39.2	39.7	1

The CCAL laboratory conducted replicate analyses for nine of the parameters analyzed as part of their routine quality assurance procedures for assessing analytical precision. All but one set of analytical replicates has less than 10% RPD (Table 4). Replicate

analysis of the total organic carbon equipment blank sample had a 12% RDP, however, absolute concentrations were near the minimum level of quantification.

Table 4. Laboratory replicate measurements of field grab samples.

Parameter	Date	Depth (m)	Primary Value	Replicate Value	RPD (%)
ALK (mg/l as HCO_3)	7/16/2007	Equip. blk.	0.29	0.29	0
	8/6/2007	13	5.67	5.64	1
COND (mg/l)	7/16/2007	Equip. blk	1.2	1.1	9
	8/6/2007	13	49.4	49.4	0
DOC (mg/l)	7/16/2007	1	2.48	2.52	2
	8/6/2007	13	2.65	2.66	0
	9/23/2007	7	2.56	2.75	7
SRP (mg/l)	7/16/2007	Equip. blk	BDL	BDL	0
	8/6/2007	13	0.15	0.151	1
pH (units)	7/16/2007	Equip. blk	5.7	5.7	0
	8/6/2007	13	6.9	6.9	0
Silica (mg/l)	8/6/2007	1	3.68	3.65	1
TOC (mg/l)	7/16/2007	Equip. blk	0.12	0.11	9
	9/23/2007	Equip. blk	0.18	0.16	12
TN (mg/l)	7/16/2007	1	0.38	0.37	3
	9/23/2007	1	0.47	0.47	0
TP (mg/l)	7/16/2007	13	0.175	0.178	2
	8/6/2007	11	0.072	0.072	0

In-situ Measurement Quality Assurance

Multiparameter water quality sondes were used to measure temperature, pH, conductivity, and dissolved oxygen down vertical profiles into the water column. Precision of measurements was evaluated by repeating measurements at depths back up the water column. All multiparameter data met Oregon DEQ precision targets for grade "A" data (Table 5).

Table 5. Multiparameter sonde precision targets and measured data grades.

Parameter	Precision Target	Date	Depth (m)	Downcast Value	Upcast Value	Difference	Quality Grade
Temperature (ºC)	1.5	7/16/2007	1	21.3	21.3	0.0	A
		7/16/2007	8	19.5	20.0	0.5	A
		7/16/2007	13	14.3	14.3	0.0	A
		8/6/2007	1	20.6	20.7	0.1	A
		8/6/2007	5	20.6	20.6	0.0	A
		8/6/2007	8	20.5	20.5	0.0	A
		8/6/2007	13	16.2	16.3	0.1	A
		9/23/2007	1	15.2	15.2	0.0	A
pH (units)	0.3	7/16/2007	1	7.6	7.6	0.0	A
		7/16/2007	8	7.0	7.0	0.0	A
		7/16/2007	13	6.4	6.4	0.0	A
		8/6/2007	1	8.3	8.4	0.1	A
		8/6/2007	5	8.2	8.4	0.1	A
		8/6/2007	8	8.2	8.2	0.0	A
		8/6/2007	13	6.3	6.3	0.0	A
		9/23/2007	1	7.1	7.1	0.0	A
Conductivity (µS/cm)	10%	7/16/2007	1	37	37	0%	A
		7/16/2007	8	36	37	3%	A

		7/16/2007	13	46	46	0%	A
		8/6/2007	1	38	38	0%	A
		8/6/2007	5	38	38	0%	A
		8/6/2007	8	38	38	0%	A
		8/6/2007	13	53	52	2%	A
		9/23/2007	1	37	38	3%	A
Optical dissolved oxygen (mg/l)	0.3	7/16/2007	1	7.58	7.58	0.0	A
		7/16/2007	8	6.77	6.57	0.2	A
		7/16/2007	13	0.11	0.08	0.0	A
		8/6/2007	1	8.31	8.36	0.0	A
		8/6/2007	5	8.27	8.29	0.0	A
		8/6/2007	8	8.28	8.03	0.3	A
		8/6/2007	13	0.09	0.07	0.0	A
		9/23/2007	1	6.94	6.93	0.0	A

Accuracy of dissolved oxygen measurements were evaluated through comparison with Winkler titration of grab samples. Winkler titration concentrations and sonde measurements from 1m on each of the sample dates all met the 0.2 mg/l difference requirements for Oregon DEQ grade "A" quality data (Table 6). Comparisons at three of the five other depths did not meet grade "A" requirements. This problem may have been due to the sharp changes in oxygen with depth coupled with the difficulty in collecting grab samples from an exact depth. The 1.6 mg/l difference between the 13 m Winkler titration concentration and the sonde measurement on 7/16/07 may have been due to contamination of the anoxic or near-anoxic grab sample being contaminated with atmospheric oxygen during the sampling and oxygen fixing process.

Accuracy of pH measurements was evaluated through comparison with pH measured in grab samples with an Orion pH meter. All data collected was either DEQ grade "A" (<0.2 units) or grade "B" (< 0.5 units) (Table 7). Each sampling date, however, had one grade "B" measurement so all multiparameter pH data was graded as "B" quality.

Table 6. Multiparameter sonde accuracy grades based comparisons with Winkler oxygen titrations. Grade "A" data requires less than a 0.2 unit difference between grab sample and multiparameter pH.

Date	Depth (m)	Hydrolab LDO (mg/l)	Winkler DO (mg/l)	Difference	Grade
7/16/2007	1	7.6	7.6	0.0	A
	8	6.8	7.4	0.6	B
	13	0.1	1.7	1.6	C
8/6/2007	1	8.3	8.1	0.2	A
	13	0.1	0.1	0.0	A
9/23/2007	1	6.9	6.9	0.0	A
	7	6.8	6.8	0.0	A
	13	5.8	6.1	0.3	B

Table 7. Multiparameter sonde accuracy grades based comparisons with Orion pH measurements. Grade A data requires less than a 0.2 unit difference between grab sample and multiparameter pH.

Date	Depth (m)	Hydrolab LIS pH	Orion pH	Difference	Grade
7/16/2007	1	7.6	7.8	0.2	A
	13	6.4	6.8	0.4	B
8/6/2007	1	8.3	8.5	0.3	B
	11	6.4	6.6	0.2	A
	13	6.3	6.4	0.1	A
9/23/2007	1	7.1	7.4	0.3	B

13	6.9	7.4	0.5	B
1	7.1	7.5	0.4	B

Biological Sample Quality Assurance

Biological samples collected include phytoplankton, chlorophyll a, and zooplankton. The precision of phytoplankton density estimates was evaluated through comparison of replicate samples submitted to Aquatic Analysts during each sampling event. Two abundance based similarity indices were used to evaluate precision (Table 8). Both indices are on a scale of zero, no similarity, to one, 100% similarity between samples. The Bray-Curtis index consistently suggested lower similarity between replicate pairs than the Morisita-Horn index.

Table 8. Numbers of shared species and species abundance based similarity for replicate phytoplankton samples submitted to Aquatic Analysts.

	Number of species present in sample			Similarity index	
Date	Primary	Replicate	Shared	Morisita-Horn	Bray-Curtis
7/16/07	8	8	5	0.73	0.47
8/6/07	8	8	6	0.86	0.75
9/23/07	9	10	7	0.80	0.52

Chlorophyll a replicate samples collected from one meter agreed to within 20% on two of the sample dates (Table 9). There was an 82% difference between replicate samples on the 7/16/07 sampling date; however, this corresponds to less than a 1µg/l difference.

Table 9. Relative percent difference between replicate pairs of chlorophyll a samples submitted to Aquatic Analysts.

	Chlorophyll a (µg/l)		Relative percent
Date	Primary sample	Replicate sample	difference
7/16/07	0.5	1.2	**82**
8/6/07	7.3	8.8	19
9/23/07	2.4	2.2	9

The accuracy of zooplankton enumeration and identification was evaluated through comparison of split samples submitted to two analytical labs: ZP's Taxonomic Service and Phycotech, Inc. Estimates of total zooplankton density were 9% different between labs on 7/16/07, 21% different on 8/6/07, and 1% different on 9/23/07 (Table 10). Much of the difference in density on the 8/6/07 sample date is accounted for by low total density and differences in the density of Rotifera. ZP's Taxonomic Service reported considerably more taxa than Phycotech Inc (Table 11).

Table 10. Relative percent difference between zooplankton density measured by ZP's taxonomic Service and Phycotech, Inc.

		Density (#/m3)		Relative
Sample date	Grouping/species	ZP's Taxonomic Service	Phycotech Inc.	percent difference
7/16/07	Daphnia pulicaria	35243	43343	21
	Cladocera	46025	49535	7
	Copepoda	679	3538	136
	Rotifera	12148	11499	5
	Miscellaneous zooplankters	302	0	-
	All zooplankton	59154	64572	9

8/6/07	Daphnia pulicaria	5098	5482	7
	Cladocera	5393	5789	7
	Copepoda	1489	1523	2
	Rotifera	3082	5180	51
	Miscellaneous zooplankters	118	0	-
	All zooplankton	10082	12492	21
9/23/07	Daphnia pulicaria	10175	10449	3
	Cladocera	11056	14927	30
	Copepoda	2186	0	-
	Rotifera	396572	391080	1
	Miscellaneous zooplankters	64	0	-
	All zooplankton	409877	406007	1

Table 11. Number of zooplankton taxa reported by ZP's Taxonomic Service and Phycotech, Inc.

	Number of zooplankton taxa reported	
Sample date	ZP's Taxonomic Service	Phycotech Inc.
7/16/07	14	11
8/6/07	17	7
9/23/07	21	5

Appendix B. 2006-2007 MS Access Database Description

A Microsoft Access database (DLA_2007_2007.db1) was created to store data collected by PSU and perform the function of linking different types of data collected at the same date, depth, and site. The database consists of three categories of linked tables: event tables, result tables, and lookup tables (Figure 18). Event tables include the "Sampling Events" table and the "Depth Events" table. Unique records in the "Sampling Events" table (named FieldEventID) are defined by sampling location, date, organization, and personnel. Each unique record in the "Sampling Events" table is joined to the "Depth Events" table by the "FieldEventID" record. Unique records in the "Depth Events" table (named Field_Sample_ID) are defined by the sample type, and sample depth. The Field_Sample_ID field is used to link the "Depth Events" table to nine results tables which include chemistry grab sample results (RSLT_Chem), Secchi results (RSLT_Secchi), Winkler dissolved oxygen grab sample results (RSLT_Winkler), phytoplankton grab sample results (RSLT_phyto), chlorophyll a grab sample results (RSLT_chla), field pH grab sample results (RSLT_ph), zooplankton tow results (RSLT_zoop), photosynthetically active radiation results (RSLT_PAR), and multiparameter sonde results (RSLT_sonde). Sonde and PAR tables have a nearest half meter depth field in addition to a measured depth field so that Sonde and PAR measurements can be linked to grab sample data in other result tables.

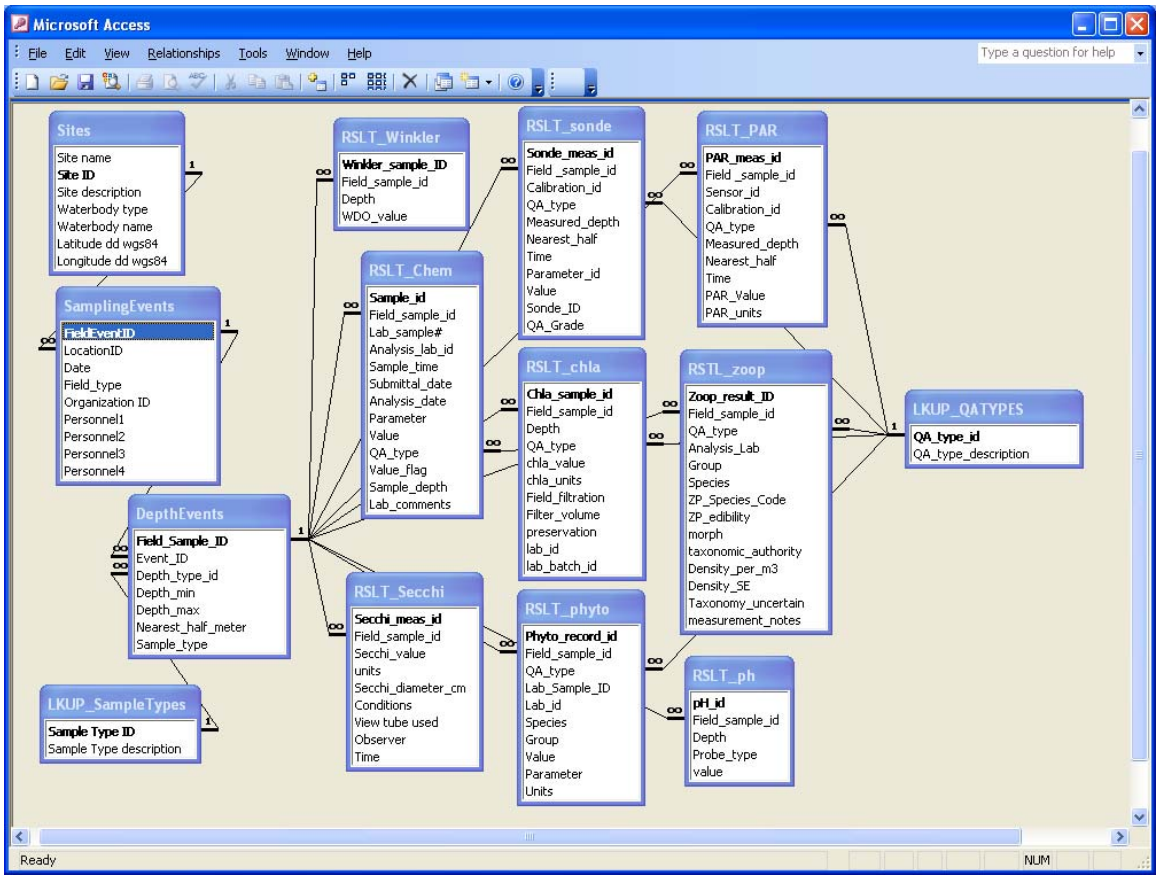

Figure 18. 2006-2007 Diamond Lake Microsoft Access database structure.

There are three lookup tables included in the database. The “Sites” lookup table contains detailed location information of each site and is linked to the “Sampling Events” table by the “SiteID” field. The “LKUP_QATYPES” lookup table contains descriptions of the types of quality assurance designations available for each sample. Designations include field primary samples, field replicate samples, field split samples, field blank samples, and lab replicate samples. The “LKUP_QATYPES” table is linked to results tables by the QA_type_id field. The “LKUP_Sample_types” lookup table contains descriptions of the sample types that are available which include horizontal composite, vertical composite, discrete depth, horizontally integrated, and vertically integrated samples

Appendix C. 2007 CCAL chemistry data.

Parameter	Site ID	Date	Time	Depth (m)	Value	Units	Value flag
Alkalinity							
	DLA	7/16/07	9:31	1	4.55	mg/l as CaCO3	
	DLA	7/16/07	10:24	8	4.55	mg/l as CaCO3	
	DLA	7/16/07	10:09	13	5.31	mg/l as CaCO3	
	DLA	8/6/07	8:53	1	4.52	mg/l as CaCO3	
	DLA	8/6/07	9:24	11	4.79	mg/l as CaCO3	
	DLA	8/6/07	9:37	13	5.64	mg/l as CaCO3	
	DLA	9/23/07	9:02	1	4.73	mg/l as CaCO3	
	DLA	9/23/07	9:30	7	4.73	mg/l as CaCO3	
	DLA	9/23/07	9:50	13	4.78	mg/l as CaCO3	
	LCO	7/16/07	7:11	0.1	4.67	mg/l as CaCO3	
Ammonia nitrogen							
	DLA	7/16/07	9:31	1	0.010	mg/l	
	DLA	7/16/07	10:24	8	0.020	mg/l	
	DLA	7/16/07	10:09	13	0.360	mg/l	
	DLA	8/6/07	8:53	1	0.002	mg/l	BDL
	DLA	8/6/07	9:24	11	0.149	mg/l	
	DLA	8/6/07	9:37	13	0.575	mg/l	
	DLA	9/23/07	9:02	1	0.035	mg/l	
	DLA	9/23/07	9:30	7	0.034	mg/l	
	DLA	9/23/07	9:50	13	0.086	mg/l	
	LCO	7/16/07	7:11	0.1	0.012	mg/l	
Conductivity							
	DLA	7/16/07	9:31	1	38.1	uS/cm	
	DLA	7/16/07	10:24	8	38.2	uS/cm	
	DLA	7/16/07	10:09	13	45.8	uS/cm	
	DLA	8/6/07	8:53	1	38.1	uS/cm	
	DLA	8/6/07	9:24	11	41.4	uS/cm	
	DLA	8/6/07	9:37	13	49.4	uS/cm	
	DLA	9/23/07	9:02	1	39.7	uS/cm	
	DLA	9/23/07	9:30	7	39.3	uS/cm	
	DLA	9/23/07	9:50	13	40.0	uS/cm	
	LCO	7/16/07	7:11	0.1	39.0	uS/cm	
Dissolved organic carbon							
	DLA	7/16/07	9:31	1	2.52	mg/l	
	DLA	7/16/07	10:24	8	2.60	mg/l	
	DLA	7/16/07	10:09	13	2.77	mg/l	
	DLA	8/6/07	8:53	1	2.59	mg/l	
	DLA	8/6/07	9:24	11	2.59	mg/l	
	DLA	8/6/07	9:37	13	2.65	mg/l	
	DLA	9/23/07	9:02	1	2.74	mg/l	
	DLA	9/23/07	9:30	7	2.75	mg/l	
	DLA	9/23/07	9:50	13	2.66	mg/l	
	LCO	7/16/07	7:11	0.1	2.61	mg/l	

Appendix C (cont.). CCAL chemistry data.

Parameter	Site ID	Date	Time	Depth (m)	Value	Units	Value flag
Dissolved silica							
	DLA	7/16/07	9:31	1	3.38	mg/l	
	DLA	7/16/07	10:24	8	3.36	mg/l	
	DLA	7/16/07	10:09	13	4.09	mg/l	
	DLA	8/6/07	8:53	1	3.65	mg/l	
	DLA	8/6/07	9:24	11	4.23	mg/l	
	DLA	8/6/07	9:37	13	4.95	mg/l	
	DLA	9/23/07	9:02	1	4.05	mg/l	
	DLA	9/23/07	9:30	7	4.04	mg/l	
	DLA	9/23/07	9:50	13	4.35	mg/l	
	LCO	7/16/07	7:11	0.1	3.25	mg/l	
Dissolved solids							
	DLA	7/16/07	9:31	1	30	mg/l	
	DLA	7/16/07	10:24	8	29	mg/l	
	DLA	7/16/07	10:09	13	36	mg/l	
	DLA	8/6/07	8:53	1	33	mg/l	
	DLA	8/6/07	9:24	11	40	mg/l	
	DLA	8/6/07	9:37	13	48	mg/l	
	DLA	9/23/07	9:02	1	34	mg/l	
	DLA	9/23/07	9:30	7	31	mg/l	
	DLA	9/23/07	9:50	13	34	mg/l	
	LCO	7/16/07	7:11	0.1	29	mg/l	
Nitrate+nitrite nitrogen							
	DLA	7/16/07	9:31	1	0.001	mg/l	BDL
	DLA	7/16/07	10:24	8	0.001	mg/l	BDL
	DLA	7/16/07	10:09	13	0.001	mg/l	BDL
	DLA	8/6/07	8:53	1	0.001	mg/l	BDL
	DLA	8/6/07	9:24	11	0.000	mg/l	BDL
	DLA	8/6/07	9:37	13	0.000	mg/l	BDL
	DLA	9/23/07	9:02	1	0.009	mg/l	
	DLA	9/23/07	9:30	7	0.009	mg/l	
	DLA	9/23/07	9:50	13	0.008	mg/l	
	LCO	7/16/07	7:11	0.1	0.001	mg/l	BDL
pH							
	DLA	7/16/07	9:31	1	7.6	Standard units	
	DLA	7/16/07	10:24	8	7.6	Standard units	
	DLA	7/16/07	10:09	13	7.3	Standard units	
	DLA	8/6/07	8:53	1	7.8	Standard units	
	DLA	8/6/07	9:24	11	7.1	Standard units	
	DLA	8/6/07	9:37	13	6.9	Standard units	
	DLA	9/23/07	9:02	1	7.5	Standard units	
	DLA	9/23/07	9:30	7	7.4	Standard units	
	DLA	9/23/07	9:50	13	7.3	Standard units	
	LCO	7/16/07	7:11	0.1	7.7	Standard units	

Appendix C (cont.). CCAL chemistry data.

Parameter	Site ID	Date	Time	Depth (m)	Value	Units	Value flag
Soluble reactive phosphorus							
	DLA	7/16/07	9:31	1	0.002	mg/l	
	DLA	7/16/07	10:24	8	0.002	mg/l	
	DLA	7/16/07	10:09	13	0.138	mg/l	
	DLA	8/6/07	8:53	1	0.001	mg/l	BDL
	DLA	8/6/07	9:24	11	0.034	mg/l	
	DLA	8/6/07	9:37	13	0.177	mg/l	
	DLA	9/23/07	9:02	1	0.004	mg/l	
	DLA	9/23/07	9:30	7	0.003	mg/l	
	DLA	9/23/07	9:50	13	0.010	mg/l	
	LCO	7/16/07	7:11	0.1	0.001	mg/l	BDL
Total nitrogen							
	DLA	7/16/07	9:31	1	0.37	mg/l	
	DLA	7/16/07	10:24	8	0.33	mg/l	
	DLA	7/16/07	10:09	13	0.82	mg/l	
	DLA	8/6/07	8:53	1	0.39	mg/l	
	DLA	8/6/07	9:24	11	0.55	mg/l	
	DLA	8/6/07	9:37	13	1.07	mg/l	
	DLA	9/23/07	9:02	1	0.47	mg/l	
	DLA	9/23/07	9:30	7	0.52	mg/l	
	DLA	9/23/07	9:50	13	0.48	mg/l	
	LCO	7/16/07	7:11	0.1	0.32	mg/l	
Total organic carbon							
	DLA	7/16/07	9:31	1	2.55	mg/l	
	DLA	7/16/07	10:24	8	2.59	mg/l	
	DLA	7/16/07	10:09	13	2.72	mg/l	
	DLA	8/6/07	8:53	1	2.63	mg/l	
	DLA	8/6/07	9:24	11	2.66	mg/l	
	DLA	8/6/07	9:37	13	2.72	mg/l	
	DLA	9/23/07	9:02	1	2.84	mg/l	
	DLA	9/23/07	9:30	7	2.82	mg/l	
	DLA	9/23/07	9:50	13	2.81	mg/l	
	LCO	7/16/07	7:11	0.1	2.59	mg/l	
Total phosphorus							
	DLA	7/16/07	9:31	1	0.020	mg/l	
	DLA	7/16/07	10:24	8	0.022	mg/l	
	DLA	7/16/07	10:09	13	0.175	mg/l	
	DLA	8/6/07	8:53	1	0.033	mg/l	
	DLA	8/6/07	9:24	11	0.072	mg/l	
	DLA	8/6/07	9:37	13	0.266	mg/l	
	DLA	9/23/07	9:02	1	0.035	mg/l	
	DLA	9/23/07	9:30	7	0.029	mg/l	
	DLA	9/23/07	9:50	13	0.038	mg/l	
	LCO	7/16/07	7:11	0.1	0.025	mg/l	

Appendix D. 2007 Zooplankton density at Diamond Lake DLA site

Date	Group	Analysis Lab	Species	Density (#/m3)
7/16/07				
	Cladocera			
		Phycotech Inc.	*Chydorus sphaericus*	1769
		Phycotech Inc.	*Daphnia ambigua*	2654
		Phycotech Inc.	*Daphnia pulicaria*	43343
		Phycotech Inc.	*Daphnia sp.*	885
		Phycotech Inc.	*Leptadora kindtii*	885
		ZP's Taxonomic Service	*Chydorus sphaericus*	6866
		ZP's Taxonomic Service	*Daphnia mendotae*	3426
		ZP's Taxonomic Service	*Daphnia pulicaria*	35243
		ZP's Taxonomic Service	*Daphnia rosea x laevis*	490
	Copepoda			
		Phycotech Inc.	*Calanoid copepodites*	885
		Phycotech Inc.	*Calanoid nauplii*	2654
		ZP's Taxonomic Service	*copepod nauplii*	302
		ZP's Taxonomic Service	*cyclopoid copepodites*	151
		ZP's Taxonomic Service	*epischurid copepodites*	151
		ZP's Taxonomic Service	*Macrocyclops albidus*	76
	Miscellaneous Zooplankters			
		ZP's Taxonomic Service	*chironomid larvae*	151
		ZP's Taxonomic Service	*dipteran larvae*	76
		ZP's Taxonomic Service	*water mites*	76
	Rotifera			
		Phycotech Inc.	*Ascomorpha sp.*	885
		Phycotech Inc.	*Conochilus unicornis*	885
		Phycotech Inc.	*Kellicottia longispina*	885
		Phycotech Inc.	*Keratella cochlearis*	8845
		ZP's Taxonomic Service	*Keratella cochlearis*	11997
		ZP's Taxonomic Service	*Polyarthra doliochoptera*	76
		ZP's Taxonomic Service	*Synchaeta sp.*	76

Appendix D (cont.). Zooplankton density.

Date	Group	Analysis Lab	Species	Density (#/m3)
8/6/07				
	Cladocera			
		Phycotech Inc.	*Daphnia ambigua*	305
		Phycotech Inc.	*Daphnia pulicaria*	5484
		ZP's Taxonomic Service	*Chydorus sphaericus*	170
		ZP's Taxonomic Service	*Daphnia mendotae*	86
		ZP's Taxonomic Service	*Daphnia pulicaria*	5098
		ZP's Taxonomic Service	*Leptodora kindti*	39
	Copepoda			
		Phycotech Inc.	*Calanoid nauplii*	1219
		Phycotech Inc.	*cyclopoid copepodites*	305
		ZP's Taxonomic Service	*copepod nauplii*	1228
		ZP's Taxonomic Service	*cyclopoid copepodites*	170
		ZP's Taxonomic Service	*epischurid copepodites*	52
		ZP's Taxonomic Service	*Macrocyclops albidus*	26
		ZP's Taxonomic Service	*Microcyclops varicans*	13
	Miscellaneous Zooplankters			
		ZP's Taxonomic Service	*dipteran larvae*	78
		ZP's Taxonomic Service	*water mites*	39
	Rotifera			
		Phycotech Inc.	*Conochilus unicornis*	2133
		Phycotech Inc.	*Gastropus hyptopus*	1523
		Phycotech Inc.	*Keratella cochlearis*	1523
		ZP's Taxonomic Service	*Ascomorpha sp.*	39
		ZP's Taxonomic Service	*Keratella cochlearis*	2899
		ZP's Taxonomic Service	*Monostyla lunaris*	26
		ZP's Taxonomic Service	*Philodina sp.*	13
		ZP's Taxonomic Service	*Polyarthra doliochoptera*	13
		ZP's Taxonomic Service	*Synchaeta sp.*	91

Appendix D (cont.). Zooplankton density.

Date	Group	Analysis Lab	Species	Density (#/m3)
9/23/07				
	Cladocera			
		Phycotech Inc.	*Daphnia ambigua*	4478
		Phycotech Inc.	*Daphnia pulicaria*	10449
		ZP's Taxonomic Service	*Bosmina longirostris*	21
		ZP's Taxonomic Service	*Ceriodaphnia pulchella*	21
		ZP's Taxonomic Service	*Chydorus sphaericus*	276
		ZP's Taxonomic Service	*Daphnia mendotae*	351
		ZP's Taxonomic Service	*Daphnia pulicaria*	10175
		ZP's Taxonomic Service	*Diaphanosoma brachyurum*	149
		ZP's Taxonomic Service	*Eurycercus lamellatus*	21
		ZP's Taxonomic Service	*Leptodora kindti*	21
		ZP's Taxonomic Service	*Simocephalus serrulatus*	21
	Copepoda			
		ZP's Taxonomic Service	*copepod nauplii*	1061
		ZP's Taxonomic Service	*cyclopoid copepodites*	955
		ZP's Taxonomic Service	*Cyclops vernalis*	106
		ZP's Taxonomic Service	*epischurid copepodites*	21
		ZP's Taxonomic Service	*Macrocyclops albidus*	42
	Miscellaneous Zooplankters			
		ZP's Taxonomic Service	*ostracods*	42
		ZP's Taxonomic Service	*stonefly larvae*	21
	Rotifera			
		Phycotech Inc.	*Keratella cochlearis*	346300
		Phycotech Inc.	*Polyarthra doliochoptera*	38809
		Phycotech Inc.	*Trichocerca sp.*	5971
		ZP's Taxonomic Service	*Ascomorpha sp.*	679
		ZP's Taxonomic Service	*Conochilus unicornis*	8828
		ZP's Taxonomic Service	*Keratella cochlearis*	367372
		ZP's Taxonomic Service	*Polyarthra doliochoptera*	15618
		ZP's Taxonomic Service	*Synchaeta sp.*	4074

Appendix E. 2007 Diamond Lake at deepest point (site DLA) phytoplankton biovolume measured by Aquatic Analysts.

Date	Depth (m)	Species name	Taxonomic group	Biovolume (μm^3/ml)	Biovolume (% of total)
16-Jul-07	1				
		Chromulina sp.	chrysophyte	38144	20.8
		Cryptomonas erosa	cryptophyte	64172	35.0
		Rhodomonas minuta	cryptophyte	7629	4.2
		Asterionella formosa	diatom	14809	8.1
		Glenodinium sp.	dinoflagellate	7853	4.3
		Ankistrodesmus falcatus	green	561	0.3
		Sphaerocystis schroeteri	green	50261	27.4
	8				
		Chromulina sp.	chrysophyte	40664	70.0
		Cryptomonas erosa	cryptophyte	9611	16.5
		Rhodomonas minuta	cryptophyte	3512	6.0
		Asterionella formosa	diatom	4066	7.0
		Ankistrodesmus falcatus	green	231	0.4
	13				
		Cryptomonas erosa	cryptophyte	12447	25.2
		Cryptomonas ovata	cryptophyte	2176	4.4
		Asterionella formosa	diatom	23946	48.5
		Synedra delicatissima	diatom	831	1.7
		Ankistrodesmus falcatus	green	696	1.4
		Chlamydomonas sp.	green	409	0.8
		Sphaerocystis schroeteri	green	705	1.4
		Ulothrix sp.	green	8163	16.5
06-Aug-07	1				
		Chromulina sp.	chrysophyte	3956	1.7
		Cryptomonas erosa	cryptophyte	12343	5.4
		Rhodomonas minuta	cryptophyte	4114	1.8
		Glenodinium sp.	dinoflagellate	5539	2.4
		Ankistrodesmus falcatus	green	989	0.4
		Chlamydomonas sp.	green	2571	1.1
		Sphaerocystis schroeteri	green	199389	87.0
		Unidentified flagellate	unknown	158	0.1
	11				
		Chromulina sp.	chrysophyte	545	0.3
		Cryptomonas erosa	cryptophyte	7080	4.3
		Rhodomonas minuta	cryptophyte	545	0.3
		Fragilaria vaucheria	diatom	980	0.6
		Nitzschia palea	diatom	613	0.4
		Ceratium hirundinella	dinoflagellate	33357	20.3
		Glenodinium sp.	dinoflagellate	4765	2.9
		Ankistrodesmus falcatus	green	596	0.4
		Sphaerocystis schroeteri	green	116154	70.6

Appendix E (cont.). Diamond Lake phytoplankton biovolume.

Date	Depth (m)	Species name	Taxonomic group	Biovolume (μm^3/ml)	Biovolume (% of total)
06-Aug-07	13				
		Chromulina sp.	chrysophyte	1057	1.6
		Cryptomonas erosa	cryptophyte	22902	34.4
		Rhodomonas minuta	cryptophyte	1409	2.1
		Achnanthes minutissima	diatom	147	0.2
		Cocconeis placentula	diatom	8104	12.2
		Nitzschia capitellata	diatom	2114	3.2
		Synedra delicatissima	diatom	1938	2.9
		Synedra radians	diatom	2114	3.2
		Synedra rumpens	diatom	411	0.6
		Glenodinium sp.	dinoflagellate	4111	6.2
		Ankistrodesmus falcatus	green	705	1.1
		Chlamydomonas sp.	green	5726	8.6
		Oocystis pusilla	green	634	1.0
		Sphaerocystis schroeteri	green	14850	22.3
		Unidentified flagellate	unknown	352	0.5
23-Sep-07	1				
		Anabaena flos-aquae	bluegreen	84563	16.8
		Chromulina sp.	chrysophyte	10570	2.1
		Cryptomonas erosa	cryptophyte	152682	30.3
		Rhodomonas minuta	cryptophyte	4463	0.9
		Fragilaria construens	diatom	7893	1.6
		Melosira ambigua	diatom	199229	39.5
		Nitzschia capitellata	diatom	4228	0.8
		Ankistrodesmus falcatus	green	881	0.2
		Sphaerocystis schroeteri	green	39463	7.8
	7				
		Anabaena flos-aquae	bluegreen	58463	12.6
		Chromulina sp.	chrysophyte	8853	1.9
		Cryptomonas erosa	cryptophyte	95545	20.6
		Rhodomonas minuta	cryptophyte	4009	0.9
		Fragilaria crotonensis	diatom	98218	21.2
		Melosira ambigua	diatom	197753	42.7
		Ankistrodesmus falcatus	green	626	0.1
	13				
		Anabaena flos-aquae	bluegreen	11332	6.3
		Chromulina sp.	chrysophyte	6799	3.8
		Cryptomonas erosa	cryptophyte	64817	36.1
		Cryptomonas ovata	cryptophyte	9785	5.4
		Rhodomonas minuta	cryptophyte	113	0.1
		Melosira ambigua	diatom	80092	44.6
		Navicula menisculus upsaliensis	diatom	1161	0.6
		Navicula radiosa	diatom	3683	2.1
		Ankistrodesmus falcatus	green	1700	0.9
		Unidentified flagellate	unknown	113	0.1

Appendix F. 2007 Diamond Lake at deepest point (site DLA) phytoplankton density measured by Aquatic Analysts.

				Density	
Date	Depth (m)	Species name	Taxonomic group	(#/ml)	(% of total)
16-Jul-07	1				
		Chromulina sp.	chrysophyte	1907	76.2
		Cryptomonas erosa	cryptophyte	123	4.9
		Rhodomonas minuta	cryptophyte	381	15.2
		Asterionella formosa	diatom	45	1.8
		Glenodinium sp.	dinoflagellate	11	0.4
		Ankistrodesmus falcatus	green	22	0.9
		Sphaerocystis schroeteri	green	11	0.4
	8				
		Chromulina sp.	chrysophyte	2033	90.5
		Cryptomonas erosa	cryptophyte	18	0.8
		Rhodomonas minuta	cryptophyte	176	7.8
		Asterionella formosa	diatom	9	0.4
		Ankistrodesmus falcatus	green	9	0.4
	13				
		Cryptomonas erosa	cryptophyte	24	28.4
		Cryptomonas ovata	cryptophyte	1	1.5
		Asterionella formosa	diatom	20	23.9
		Synedra delicatissima	diatom	1	1.5
		Ankistrodesmus falcatus	green	16	19.4
		Chlamydomonas sp.	green	1	1.5
		Sphaerocystis schroeteri	green	1	1.5
		Ulothrix sp.	green	19	22.4
06-Aug-07	1				
		Chromulina sp.	chrysophyte	198	24.5
		Cryptomonas erosa	cryptophyte	24	2.9
		Rhodomonas minuta	cryptophyte	206	25.5
		Glenodinium sp.	dinoflagellate	8	1.0
		Ankistrodesmus falcatus	green	40	4.9
		Chlamydomonas sp.	green	8	1.0
		Sphaerocystis schroeteri	green	316	39.2
		Unidentified flagellate	unknown	8	1.0
	11				
		Chromulina sp.	chrysophyte	27	7.5
		Cryptomonas erosa	cryptophyte	14	3.7
		Rhodomonas minuta	cryptophyte	27	7.5
		Fragilaria vaucheria	diatom	3	0.9
		Nitzschia palea	diatom	3	0.9
		Ceratium hirundinella	dinoflagellate	3	0.9
		Glenodinium sp.	dinoflagellate	7	1.9
		Ankistrodesmus falcatus	green	24	6.5
		Sphaerocystis schroeteri	green	255	70.1

Appendix F (cont.).Diamond Lake at deepest point (site DLA) phytoplankton density measured by Aquatic Analysts.

Date	Depth (m)	Species name	Taxonomic group	Density (#/ml)	Density (% of total)
06-Aug-07	13				
		Chromulina sp.	chrysophyte	53	16.4
		Cryptomonas erosa	cryptophyte	44	13.6
		Rhodomonas minuta	cryptophyte	70	21.8
		Achnanthes minutissima	diatom	3	0.9
		Cocconeis placentula	diatom	18	5.5
		Nitzschia capitellata	diatom	6	1.8
		Synedra delicatissima	diatom	3	0.9
		Synedra radians	diatom	6	1.8
		Synedra rumpens	diatom	3	0.9
		Glenodinium sp.	dinoflagellate	6	1.8
		Ankistrodesmus falcatus	green	23	7.3
		Chlamydomonas sp.	green	18	5.5
		Oocystis pusilla	green	3	0.9
		Sphaerocystis schroeteri	green	50	15.5
		Unidentified flagellate	unknown	18	5.5
23-Sep-07	1				
		Anabaena flos-aquae	bluegreen	47	3.7
		Chromulina sp.	chrysophyte	529	41.7
		Cryptomonas erosa	cryptophyte	294	23.1
		Rhodomonas minuta	cryptophyte	223	17.6
		Fragilaria construens	diatom	12	0.9
		Melosira ambigua	diatom	70	5.6
		Nitzschia capitellata	diatom	12	0.9
		Ankistrodesmus falcatus	green	35	2.8
		Sphaerocystis schroeteri	green	47	3.7
	7				
		Anabaena flos-aquae	bluegreen	58	6.0
		Chromulina sp.	chrysophyte	443	45.7
		Cryptomonas erosa	cryptophyte	184	19.0
		Rhodomonas minuta	cryptophyte	200	20.7
		Fragilaria crotonensis	diatom	8	0.9
		Melosira ambigua	diatom	50	5.2
		Ankistrodesmus falcatus	green	25	2.6
	13				
		Anabaena flos-aquae	bluegreen	11	1.9
		Chromulina sp.	chrysophyte	340	56.6
		Cryptomonas erosa	cryptophyte	125	20.8
		Cryptomonas ovata	cryptophyte	6	0.9
		Rhodomonas minuta	cryptophyte	6	0.9
		Melosira ambigua	diatom	23	3.8
		Navicula menisculus upsaliensis	diatom	6	0.9
		Navicula radiosa	diatom	11	1.9
		Ankistrodesmus falcatus	green	68	11.3
		Unidentified flagellate	unknown	6	0.9

Appendix G. 2007 Diamond Lake site DLA chlorophyll a concentration measured by Aquatic Analysts.

		Chlorophyll a (ug/l)	
Date	Depth (m)	Primary sample	Replicate sample
16-Jul-07	1	0.5	-
	8	0.5	-
	13	0.5	1.2
06-Aug-07	1	7.3	8.8
	11	10.2	-
	13	7.4	-
23-Sep-07	1	2.4	2.2
	7	3.4	-
	13	2.0	-

Appendix H. 2007 Diamond Lake Secchi disc transparency at site DLA.

Date	Time	Observer	View tube used	Conditions	Secchi transparency (m)
16-Jul-07	9:55	Rich Miller	no	very choppy	9.1
06-Aug-07	9:11	Rich Miller	no	light wind	5.7
	9:14	Kit Rouhe	no	light wind	5.2
	10:00	Rich Miller	no	light wind	5.6
23-Sep-07	10:34	Rich Miller	no	light wind	5.4

Appendix I. 2007 Diamond Lake at deepest point (site DLA) sonde data.

Parameter	Date	Depth (m)	Time	Value	Data Grade
Conductivity (µS/cm)					
	16-Jul-07				
		0.51	9:27	37	A
		1.04	9:32	37	A
		2.09	9:34	37	A
		2.99	9:37	37	A
		4.02	9:39	37	A
		5.02	9:42	37	A
		5.98	9:44	37	A
		7.09	9:45	37	A
		8.09	9:47	36	A
		9.06	9:49	37	A
		9.95	9:52	38	A
		11.01	9:55	39	A
		12.07	9:58	41	A
		13.05	10:02	46	A
		13.99	10:04	47	A
	6-Aug-07				
		0.99	8:56	38	A
		2.15	8:59	38	A
		3.09	9:02	38	A
		3.95	9:05	38	A
		4.92	9:07	38	A
		6.09	9:09	38	A
		7.01	9:11	38	A
		7.95	9:16	38	A
		9.04	9:19	38	A
		9.95	9:22	38	A
		10.95	9:25	41	A
		12.13	9:28	44	A
		13.03	9:38	53	A
		13.53	9:42	57	A
	23-Sep-07				
		1.04	9:09	37	A
		1.95	9:13	37	A
		3.05	9:17	37	A
		3.98	9:20	37	A
		4.99	9:23	37	A
		5.99	9:27	37	A
		7.04	9:31	37	A
		7.05	10:05	37	A
		7.95	9:35	37	A
		9.01	9:39	37	A
		10.01	9:42	37	A
		10.98	9:47	37	A
		12	9:50	37	A
		13.06	9:53	38	A
		13.95	9:59	41	A

Appendix I (continued). Diamond Lake at deepest point (site DLA) sonde data.

Parameter	Date	Depth (m)	Time	Value	Data Grade
Dissolved oxygen, luminescent (mg/l)					
	16-Jul-07				
		0.51	9:27	7.6	C
		1.04	9:32	7.58	C
		2.09	9:34	7.56	C
		2.99	9:37	7.56	C
		4.02	9:39	7.53	C
		5.02	9:42	7.5	C
		5.98	9:44	7.46	C
		7.09	9:45	7.45	C
		8.09	9:47	6.77	C
		9.06	9:49	5.54	C
		9.95	9:52	5.22	C
		11.01	9:55	3.32	C
		12.07	9:58	2.17	C
		13.05	10:02	0.11	C
		13.99	10:04	0.1	C
	6-Aug-07				
		0.99	8:56	8.31	B
		2.15	8:59	8.3	B
		3.09	9:02	8.31	B
		3.95	9:05	8.29	B
		4.92	9:07	8.27	B
		6.09	9:09	8.27	B
		7.01	9:11	8.28	B
		7.95	9:16	8.28	B
		9.04	9:19	8	B
		9.95	9:22	6.64	B
		10.95	9:25	0.72	B
		12.13	9:28	0.09	B
		13.03	9:38	0.09	B
		13.53	9:42	0.09	B
	23-Sep-07				
		1.04	9:09	6.94	B
		1.95	9:13	6.94	B
		3.05	9:17	6.89	B
		3.98	9:20	6.89	B
		4.99	9:23	6.89	B
		5.99	9:27	6.86	B
		7.04	9:31	6.83	B
		7.05	10:05	6.83	B
		7.95	9:35	6.84	B
		9.01	9:39	6.82	B
		10.01	9:42	6.77	B
		10.98	9:47	6.58	B
		12	9:50	6.34	B
		13.06	9:53	5.78	B
		13.95	9:59	3.42	B

Appendix I (continued). Diamond Lake at deepest point (site DLA) sonde data.

Parameter	Date	Depth (m)	Time	Value	Data Grade
Dissolved oxygen, luminescent (percent of saturation)					
	16-Jul-07				
		0.51	9:27	104	C
		1.04	9:32	103.8	C
		2.09	9:34	103.5	C
		2.99	9:37	103.3	C
		4.02	9:39	102.8	C
		5.02	9:42	102.4	C
		5.98	9:44	101.8	C
		7.09	9:45	101.6	C
		8.09	9:47	89.3	C
		9.06	9:49	71.7	C
		9.95	9:52	67.2	C
		11.01	9:55	41.8	C
		12.07	9:58	26.9	C
		13.05	10:02	1.3	C
		13.99	10:04	1.2	C
	6-Aug-07				
		0.99	8:56	111.2	B
		2.15	8:59	111.1	B
		3.09	9:02	111.1	B
		3.95	9:05	110.9	B
		4.92	9:07	110.6	B
		6.09	9:09	110.6	B
		7.01	9:11	110.7	B
		7.95	9:16	110.7	B
		9.04	9:19	106.9	B
		9.95	9:22	88.5	B
		10.95	9:25	9.5	B
		12.13	9:28	1.2	B
		13.03	9:38	1.1	B
		13.53	9:42	1	B
	23-Sep-07				
		1.04	9:09	83	B
		1.95	9:13	83	B
		3.05	9:17	82.4	B
		3.98	9:20	82.3	B
		4.99	9:23	82.3	B
		5.99	9:27	82	B
		7.04	9:31	81.6	B
		7.05	10:05	81.6	B
		7.95	9:35	81.7	B
		9.01	9:39	81.5	B
		10.01	9:42	80.8	B
		10.98	9:47	78.6	B
		12	9:50	75.6	B
		13.06	9:53	68.1	B
		13.95	9:59	40	B

Appendix I (continued). Diamond Lake at deepest point (site DLA) sonde data.

Parameter	Date	Depth (m)	Time	Value	Data Grade
Redox potential (mV)					
	16-Jul-07				
		0.51	9:27	240	not graded
		1.04	9:32	236	not graded
		2.09	9:34	236	not graded
		2.99	9:37	238	not graded
		4.02	9:39	238	not graded
		5.02	9:42	235	not graded
		5.98	9:44	238	not graded
		7.09	9:45	233	not graded
		8.09	9:47	256	not graded
		9.06	9:49	263	not graded
		9.95	9:52	265	not graded
		11.01	9:55	267	not graded
		12.07	9:58	262	not graded
		13.05	10:02	135	not graded
		13.99	10:04	53	not graded
	6-Aug-07				
		0.99	8:56	212	not graded
		2.15	8:59	212	not graded
		3.09	9:02	211	not graded
		3.95	9:05	209	not graded
		4.92	9:07	208	not graded
		6.09	9:09	210	not graded
		7.01	9:11	210	not graded
		7.95	9:16	207	not graded
		9.04	9:19	208	not graded
		9.95	9:22	230	not graded
		10.95	9:25	276	not graded
		12.13	9:28	11	not graded
		13.03	9:38	-116	not graded
		13.53	9:42	-149	not graded
	23-Sep-07				
		1.04	9:09	199	not graded
		1.95	9:13	197	not graded
		3.05	9:17	194	not graded
		3.98	9:20	194	not graded
		4.99	9:23	194	not graded
		5.99	9:27	191	not graded
		7.04	9:31	189	not graded
		7.05	10:05	175	not graded
		7.95	9:35	189	not graded
		9.01	9:39	190	not graded
		10.01	9:42	186	not graded
		10.98	9:47	186	not graded
		12	9:50	187	not graded
		13.06	9:53	189	not graded
		13.95	9:59	194	not graded

Appendix I (continued). Diamond Lake at deepest point (site DLA) sonde data.

Parameter	Date	Depth (m)	Time	Value	Data Grade
Photosynthetically active radiation (uE)					
	16-Jul-07				
		0.51	9:27	1662	not graded
		1.04	9:32	930	not graded
		2.09	9:34	666	not graded
		2.99	9:37	627	not graded
		4.02	9:39	373	not graded
		5.02	9:42	270	not graded
		5.98	9:44	269	not graded
		7.09	9:45	205	not graded
		8.09	9:47	146	not graded
		9.06	9:49	99	not graded
		9.95	9:52	74	not graded
		11.01	9:55	49	not graded
		12.07	9:58	31	not graded
		13.05	10:02	21	not graded
		13.99	10:04	12	not graded
	6-Aug-07				
		0.99	8:56	702	not graded
		2.15	8:59	377	not graded
		3.09	9:02	255	not graded
		3.95	9:05	187	not graded
		4.92	9:07	122	not graded
		6.09	9:09	79	not graded
		7.01	9:11	54	not graded
		7.95	9:16	40	not graded
		9.04	9:19	27	not graded
		9.95	9:22	20	not graded
		10.95	9:25	12	not graded
		12.13	9:28	6	not graded
		13.03	9:38	3	not graded
		13.53	9:42	1	not graded
	23-Sep-07				
		1.04	9:09	100	not graded
		1.95	9:13	72	not graded
		3.05	9:17	50	not graded
		3.98	9:20	43	not graded
		4.99	9:23	32	not graded
		5.99	9:27	19	not graded
		7.04	9:31	10	not graded
		7.05	10:05	44	not graded
		7.95	9:35	6	not graded
		9.01	9:39	4	not graded
		10.01	9:42	1	not graded
		10.98	9:47	7	not graded
		12	9:50	1	not graded
		13.06	9:53	0	not graded
		13.95	9:59	3	not graded

Appendix I (continued). Diamond Lake at deepest point (site DLA) sonde data.

Parameter	Date	Depth (m)	Time	Value	Data Grade
pH (standard units)					
	16-Jul-07				
		0.51	9:27	7.6	B
		1.04	9:32	7.6	B
		2.09	9:34	7.59	B
		2.99	9:37	7.53	B
		4.02	9:39	7.52	B
		5.02	9:42	7.55	B
		5.98	9:44	7.48	B
		7.09	9:45	7.55	B
		8.09	9:47	7.01	B
		9.06	9:49	6.77	B
		9.95	9:52	6.67	B
		11.01	9:55	6.51	B
		12.07	9:58	6.47	B
		13.05	10:02	6.39	B
		13.99	10:04	6.38	B
	6-Aug-07				
		0.99	8:56	8.25	B
		2.15	8:59	8.23	B
		3.09	9:02	8.2	B
		3.95	9:05	8.24	B
		4.92	9:07	8.24	B
		6.09	9:09	8.21	B
		7.01	9:11	8.21	B
		7.95	9:16	8.24	B
		9.04	9:19	8.15	B
		9.95	9:22	7.34	B
		10.95	9:25	6.4	B
		12.13	9:28	6.2	B
		13.03	9:38	6.26	B
		13.53	9:42	6.31	B
	23-Sep-07				
		1.04	9:09	7.09	C
		1.95	9:13	7.08	C
		3.05	9:17	7.1	C
		3.98	9:20	7.07	C
		4.99	9:23	7.07	C
		5.99	9:27	7.09	C
		7.04	9:31	7.12	C
		7.05	10:05	7.08	C
		7.95	9:35	7.09	C
		9.01	9:39	7.04	C
		10.01	9:42	7.11	C
		10.98	9:47	7.07	C
		12	9:50	7.01	C
		13.06	9:53	6.89	C
		13.95	9:59	6.56	C

Appendix I (continued). Diamond Lake at deepest point (site DLA) sonde data.

Parameter	Date	Depth (m)	Time	Value	Data Grade
Temperature ()					
	16-Jul-07				
		0.51	9:27	21.32	A
		1.04	9:32	21.32	A
		2.09	9:34	21.31	A
		2.99	9:37	21.25	A
		4.02	9:39	21.21	A
		5.02	9:42	21.18	A
		5.98	9:44	21.15	A
		7.09	9:45	21.13	A
		8.09	9:47	19.49	A
		9.06	9:49	18.56	A
		9.95	9:52	18.24	A
		11.01	9:55	17.23	A
		12.07	9:58	16.46	A
		13.05	10:02	14.26	A
		13.99	10:04	14.04	A
	6-Aug-07				
		0.99	8:56	20.58	A
		2.15	8:59	20.58	A
		3.09	9:02	20.58	A
		3.95	9:05	20.57	A
		4.92	9:07	20.57	A
		6.09	9:09	20.55	A
		7.01	9:11	20.55	A
		7.95	9:16	20.54	A
		9.04	9:19	20.51	A
		9.95	9:22	20.42	A
		10.95	9:25	19.54	A
		12.13	9:28	18.56	A
		13.03	9:38	16.22	A
		13.53	9:42	15.57	A
	23-Sep-07				
		1.04	9:09	15.16	A
		1.95	9:13	15.17	A
		3.05	9:17	15.17	A
		3.98	9:20	15.17	A
		4.99	9:23	15.17	A
		5.99	9:27	15.16	A
		7.04	9:31	15.16	A
		7.05	10:05	15.16	A
		7.95	9:35	15.16	A
		9.01	9:39	15.16	A
		10.01	9:42	15.14	A
		10.98	9:47	15.14	A
		12	9:50	15.02	A
		13.06	9:53	14.47	A
		13.95	9:59	14.24	A

Appendix I (continued). Diamond Lake at deepest point (site DLA) sonde data.

Parameter	Date	Depth (m)	Time	Value	Data Grade
Turbidity (NTU)					
	16-Jul-07				
		0.51	9:27		not graded
		1.04	9:32		not graded
		2.09	9:34		not graded
		2.99	9:37		not graded
		4.02	9:39		not graded
		5.02	9:42		not graded
		5.98	9:44		not graded
		7.09	9:45		not graded
		8.09	9:47		not graded
		9.06	9:49		not graded
		9.95	9:52		not graded
		11.01	9:55		not graded
		12.07	9:58		not graded
		13.05	10:02		not graded
		13.99	10:04		not graded
	6-Aug-07				
		0.99	8:56	4	not graded
		2.15	8:59	1	not graded
		3.09	9:02	2	not graded
		3.95	9:05	2	not graded
		4.92	9:07	1	not graded
		6.09	9:09	2	not graded
		7.01	9:11	1	not graded
		7.95	9:16	1	not graded
		9.04	9:19	1	not graded
		9.95	9:22	2	not graded
		10.95	9:25	1	not graded
		12.13	9:28	2	not graded
		13.03	9:38	3	not graded
		13.53	9:42	4	not graded
	23-Sep-07				
		1.04	9:09	1	not graded
		1.95	9:13	5	not graded
		3.05	9:17	2	not graded
		3.98	9:20	1	not graded
		4.99	9:23	1	not graded
		5.99	9:27	2	not graded
		7.04	9:31	1	not graded
		7.05	10:05	1	not graded
		7.95	9:35	1	not graded
		9.01	9:39	1	not graded
		10.01	9:42	1	not graded
		10.98	9:47	1	not graded
		12	9:50	1	not graded
		13.06	9:53	1	not graded
		13.95	9:59	1	not graded