

Skeleton Lake and Ball's Gravel Pit Biological Assessment

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1.0 Executive Summary

Diverting water from Ball's Gravel Pit in an attempt to bring up declining water levels in Skeleton Lake requires a License to Divert Water from Alberta Environment. As part of this license, a biological assessment must be completed in order to ensure that there will be no detrimental effects to the receiving water body.

From a biological stand point, it is unlikely that diversion of this water would have any long term negative impacts on the water quality of Skeleton Lake. The gravel pit water is groundwater, and consequently is very low in nutrients, particularly phosphorus, which is an extremely important consideration for a phosphorus limited, eutrophic system like Skeleton Lake. The hardness of water in Skeleton Lake may increase slightly, and there will be an increase in the population of *Daphnia*, a large species of zooplankton, into the lake, which is predicted to have minimal impact to the lake in the long term. Diversion from the gravel pit to the lake may be a viable option for returning water levels in Skeleton Lake to normal levels. However, the lake may be hydrologically connected to the gravel pit, therefore diverting water without a thorough consideration of groundwater connections in the area may prove to be futile.

2.0 Introduction

Skeleton Lake water levels have dropped dramatically in the last 10 years, and members of the Skeleton Lake Stewardship Association are exploring the possibility of diverting water from a nearby gravel pit into the lake in order to return water levels to normal. The gravel pit is located just east of the lake and the operators regularly dewater the pit in order to obtain access to the gravel. Water from this pit, which is groundwater fed, would then be piped directly to the lake.

In order to obtain a License to Divert Water from Alberta Environment, a biological assessment of the potential impacts to the lake must be prepared. This assessment would examine parameters such as water quality, phytoplankton, zooplankton, and fish populations in both water bodies in order to determine if there would be introduction of any detrimental species into the receiving water body.

Common water quality parameters of concern that have been examined in this assessment include nutrient levels (such as total phosphorus, nitrogen, nitrate-nitrite), salinity, pH, sulphate, iron, and others. An assessment and identification of all phytoplankton and zooplankton has been completed. However, fish populations have not been addressed due to the lack of fish within the gravel pit. The introduction of aquatic plants to the lake was also deemed to not be a concern in this situation.

3.0 Methods

Ball's Gravel Pit and Skeleton Lake locations were both sampled on October 9, 2006 by a professional biologist from Aquality Environmental Consulting Ltd. Composite samples representative of the entire euphotic zone were taken from both locations. Three separate sample spots were chosen in the gravel pit, six locations were sampled in the north bay of Skeleton Lake, and twelve sites were sampled in the south bay. This resulted in one sample bottle from the gravel pit, two sample bottles from the northern bay, and three sample bottles from the south bay. The GPS coordinates and euphotic depths for the sites appear in Table 1.

Water samples were taken using a 3 m clear plastic euphotic tube with a one-way foot valve, and collected in a sterile 20L polyethylene jug. Once the 20L jug was full, the water was thoroughly mixed and subsamples were poured into 1L brown high density polyethylene (HDPE) sample bottles. Algal subsamples were collected from deepest spots in the gravel pit and the two bays of the lake using the euphotic tube and 20L plastic jug, and stored in 250mL white HDPE bottles and preserved with Lugol's solution. Zooplankton samples were collected from the deepest locations as well, at twice the euphotic depth, using a plankton tow net with a diameter of approximately 10 inches and a netting size of 64 microns. Three tows were taken at each sample location, and the net was then rinsed out with lake water. Zooplankton samples were stored in 250mL white HDPE bottles and preserved with 7% formalin solution.

Water samples were analyzed for the following parameters:

- Total nitrogen
- Total phosphorus
- Total Kjeldahl nitrogen
- Nitrate-nitrite
- Ammonium
- Chloride
- Sulphate
- Alkalinity
- Bicarbonate
- Carbonate
- Conductivity
- pH
- Colour
- Turbidity
- Non filterable residue
- Chlorophyll a

Phytoplankton and zooplankton samples were identified to species level; biomass and density were determined for each individual species and the total sample.

Water quality analysis was performed by the University of Alberta Limnology Laboratory, and algal and zooplankton identification was performed by Bio-Limno Research & Consulting, Inc.

Table 1. GPS coordinates and euphotic depth for all sample locations.

Location	N	W	Euphotic Depth (m)
Gravel Pit Site 1	54 37.742'	112 34.245'	10
Gravel Pit Site 2	54 37.732'	112 34.179'	11
Gravel Pit Site 3	54 37.686'	112 33.950'	10
Skeleton Lake North Bay Site 1	54 38.498'	112 42.011'	3
Skeleton Lake North Bay Site 2	54 38.449'	112 41.837'	3
Skeleton Lake North Bay Site 3	54 38.545'	112 42.414'	2.6
Skeleton Lake North Bay Site 4	54 38.545'	112 42.414'	2.6
Skeleton Lake North Bay Site 5	54 38.584'	112 42.914'	3
Skeleton Lake North Bay Site 6	54 38.764'	112 42.513'	3
Skeleton Lake South Bay Site 1	54 36.973'	112 44.009'	3
Skeleton Lake South Bay Site 2	54 36.852'	112 43.792'	2.6
Skeleton Lake South Bay Site 3	54 37.001'	112 43.645'	2.6
Skeleton Lake South Bay Site 4	54 37.034'	112 43.183'	2.6
Skeleton Lake South Bay Site 5	54 36.534'	112 42.966'	2.2
Skeleton Lake South Bay Site 6	54 36.424'	112 43.157'	3.2
Skeleton Lake South Bay Site 7	54 36.367'	112 43.292'	2.8
Skeleton Lake South Bay Site 8	54 36.178'	112 43.433'	2.8
Skeleton Lake South Bay Site 9	54 36.097'	112 42.563'	2.4
Skeleton Lake South Bay Site 10	54 36.028'	112 42.351'	2.6
Skeleton Lake South Bay Site 11	54 35.968'	112 42.510'	2.8
Skeleton Lake South Bay Site 12	54 36.028'	112 42.715'	3

4.0 Results

4.1 Water Quality

Phosphorus can be one of the most important limiting nutrients in aquatic environments and is an essential nutrient in most organisms. Too much phosphorus can lead to eutrophication of water bodies, which means an excessive growth of phytoplankton and plants in response to high nutrient levels. When the plant growth becomes excessive, it leads to large amounts of decaying organic matter which can deplete the water of dissolved oxygen and suffocate fish populations. Decaying matter can also leave the water with an undesirable taste, odour, and colour, leaving it potentially unsafe for recreation or human consumption. The water can become filled with large mats of algae, some of which are toxic to humans and other aquatic organisms (i.e. *Microcystis*). The Alberta Surface Water Quality Guideline for the protection of freshwater aquatic life is 0.05 mg/L (50 µg/L) of phosphorus.

As seen in Figure 1, Skeleton Lake north bay had higher average total phosphorus levels (46.89 µg/L) than the south bay (41.66 µg/L). Ball's Gravel Pit was considerably lower in mean total phosphorus at 7.41 µg/L.

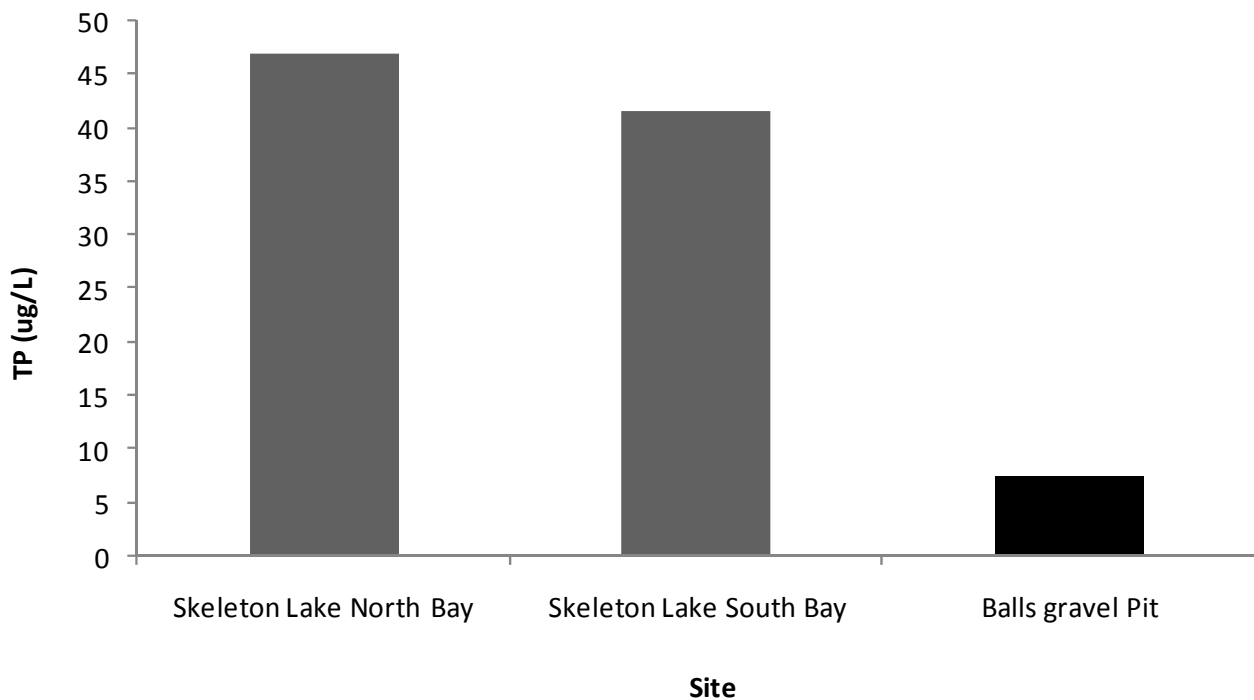


Figure 1. Total phosphorus (TP) levels in both bays of Skeleton Lake and in Ball's Gravel Pit on October 9, 2006.

Chlorophyll *a* is used as a measure of phytoplankton productivity. Therefore, a large chlorophyll *a* concentration indicates a large amount of phytoplankton. The amount of chlorophyll *a* is generally correlated with phosphorus concentrations.

Chlorophyll *a* levels were highest in Skeleton Lake south bay at 16.95 µg/L, and Ball's Gravel Pit had no detectable chlorophyll *a* levels (Figure 2).

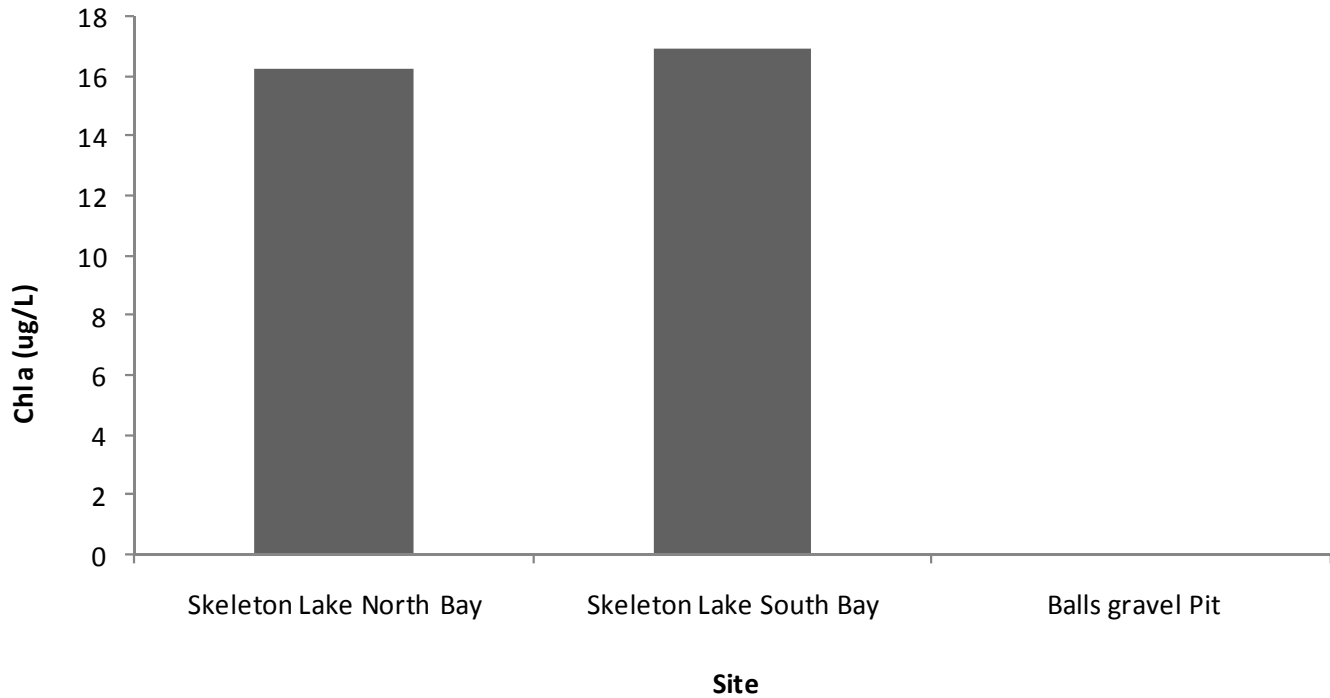


Figure 2. Chlorophyll *a* (Chl *a*) levels in both bays of Skeleton Lake and Ball's Gravel Pit on October 9, 2006. NOTE: The Chl *a* value for Ball's Gravel Pit was below the method detection limit (0.2 µg/L per 200 mL of sample).

Nitrogen is a nutrient that is essential to most organisms and can be limiting in some environments. Like excess phosphorus, excess nitrogen can contribute increased phytoplankton growth. The Alberta Surface Water Quality Guideline for the protection of freshwater aquatic life is 1.0 mg/L (1000 µg/L) of nitrogen.

Total nitrogen was highest in Skeleton Lake north bay, averaging 1470 µg/L, and lowest in the gravel pit, with a mean of 495 µg/L (Figure 3).

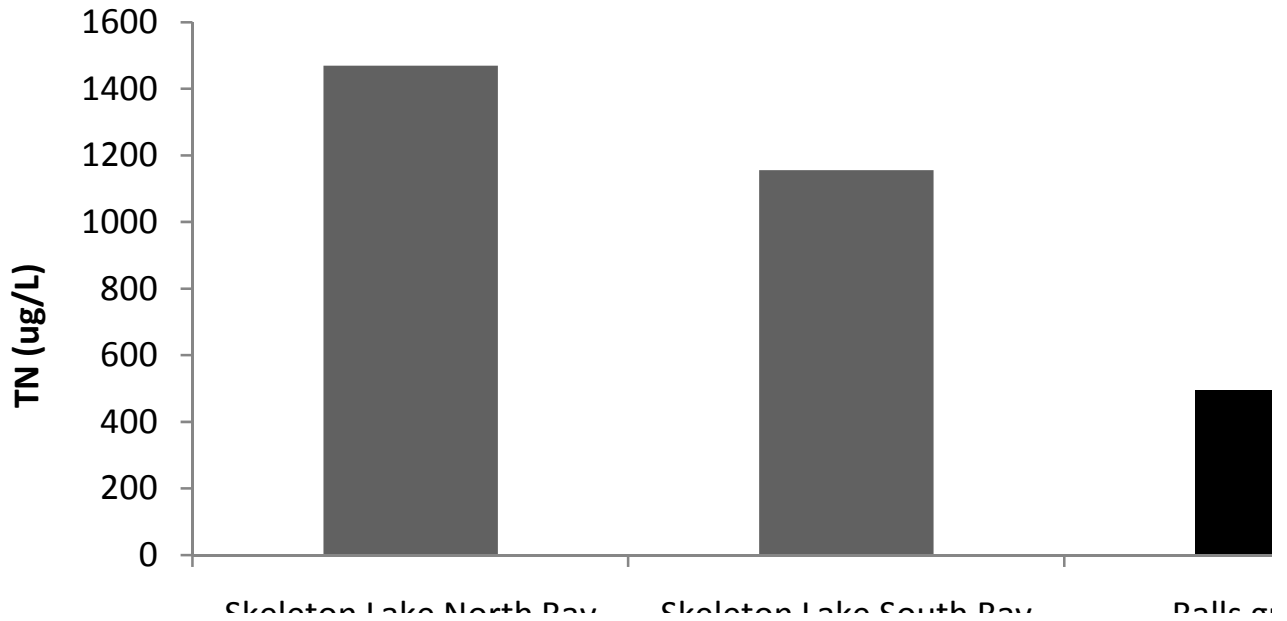


Figure 3. Total nitrogen (TN) levels in both bays of Skeleton Lake and Ball's Gravel Pit on October 9, 2006.

Total kjeldahl nitrogen is the combination of organically bound nitrogen and ammonia. Organic nitrogen is nitrogen that originated in living material (i.e. nitrogen in wastes from organisms). Ammonia is an inorganic form of nitrogen that is transformed to ammonium by bacteria.

Total kjeldahl nitrogen (TKN) levels were highest in Skeleton Lake north bay, averaging 1464.65 µg/L, and lowest in the gravel pit, averaging 487.82 µg/L (Figure 4).

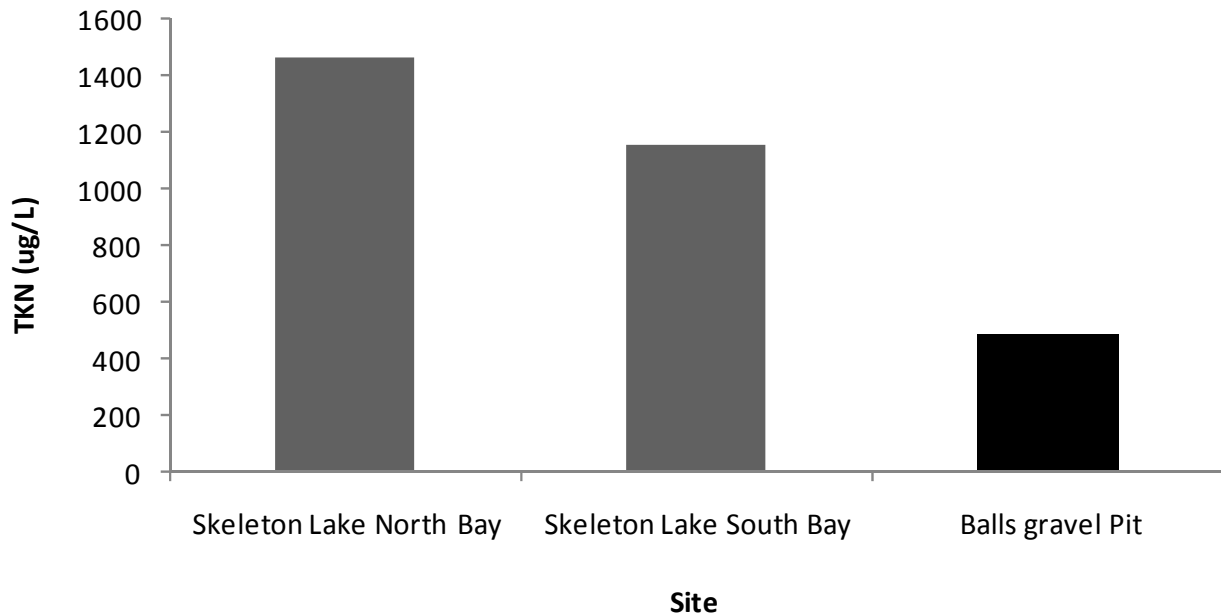


Figure 4. Total Kjeldahl nitrogen (TKN) levels in both bays of Skeleton Lake and in Ball's Gravel Pit on October 9, 2006.

Nitrate and nitrite are both inorganic forms of nitrogen. As ammonia (NH_3) is broken down by bacterial action, nitrite is formed and is then converted to the more stable form, which is nitrate. Nitrate is also readily available for phytoplankton uptake. High nitrate levels can contribute to methemoglobinemia ("blue baby" syndrome). This condition, usually in infants, impairs the ability of blood to carry oxygen (CCME, 2002). The Canadian Council of Ministers of the Environment (CCME) Guideline for Agriculture (Livestock) for nitrate-nitrite is 100 mg/L. The CCME Guideline for nitrite for the Protection of Aquatic Life is 0.06 mg/L (60 $\mu\text{g/L}$); there is currently no guideline for nitrate.

Nitrate-nitrite levels were highest in the gravel pit, averaging 7.18 $\mu\text{g/L}$, and lowest in Skeleton Lake south bay at 4.15 $\mu\text{g/L}$ (Figure 5).

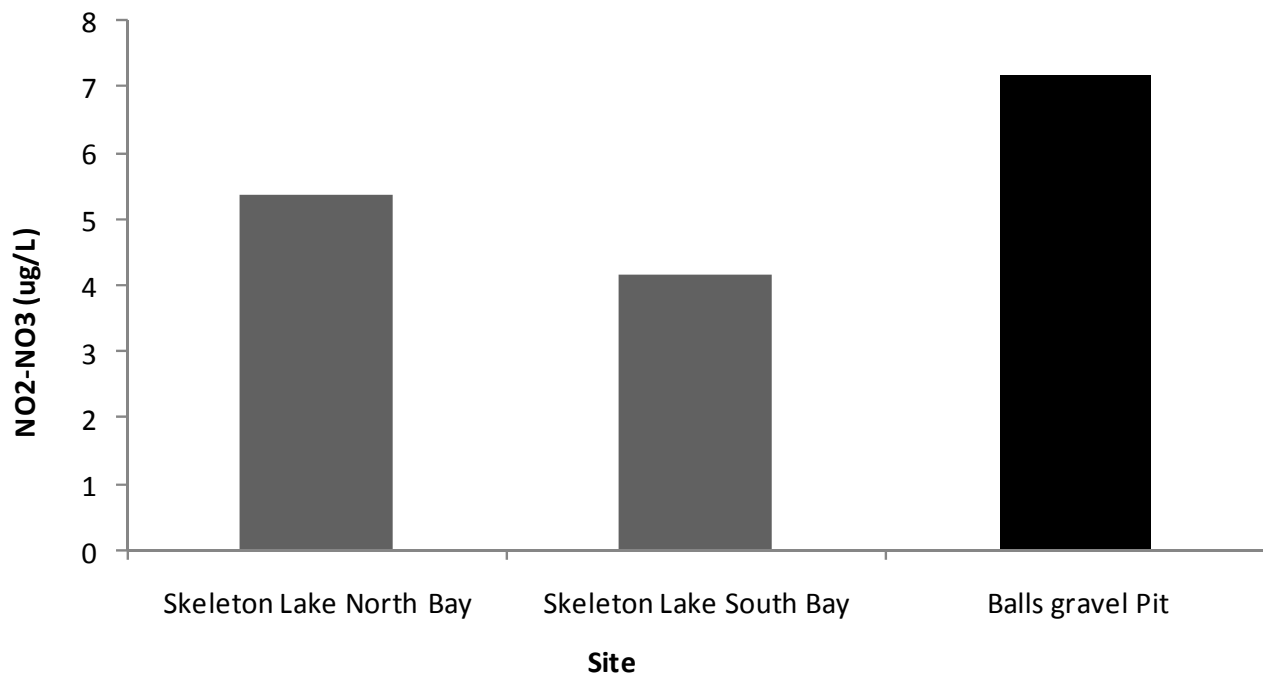


Figure 5. Nitrate-nitrite ($\text{NO}_2\text{-NO}_3$) levels in both bays of Skeleton Lake and in Ball's Gravel Pit on October 9, 2006.

Ammonium is another inorganic form of nitrogen that is readily available for phytoplankton use. Ammonium levels were highest in Skeleton Lake north bay, averaging 152.5 µg/L, and lowest in Skeleton Lake south bay, averaging 10.14 µg/L (Figure 6).

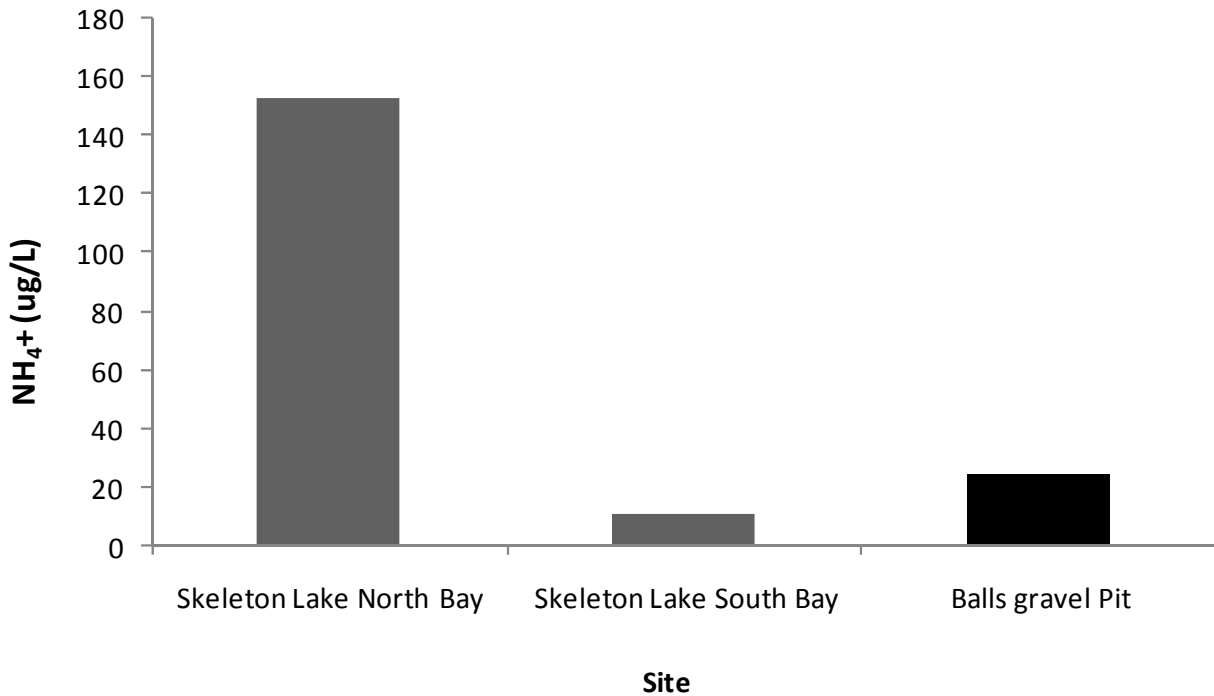


Figure 6. Ammonium (NH₄⁺) levels in both bays of Skeleton Lake and in Ball's Gravel Pit on October 9, 2006.

Conductivity measures the ability of an aqueous solution to carry an electrical current. It is affected by the presence of dissolved and suspended solids and can be used as an indicator of general lake health. A change in conductivity may indicate the presence of pollution (i.e. sewage, stormwater runoff, oil/gas, etc.). Conductivity was highest in the gravel pit, averaging 1011 $\mu\text{S}/\text{cm}$, and lowest in the northern bay of Skeleton Lake, averaging 362.5 $\mu\text{S}/\text{cm}$ (Figure 7).

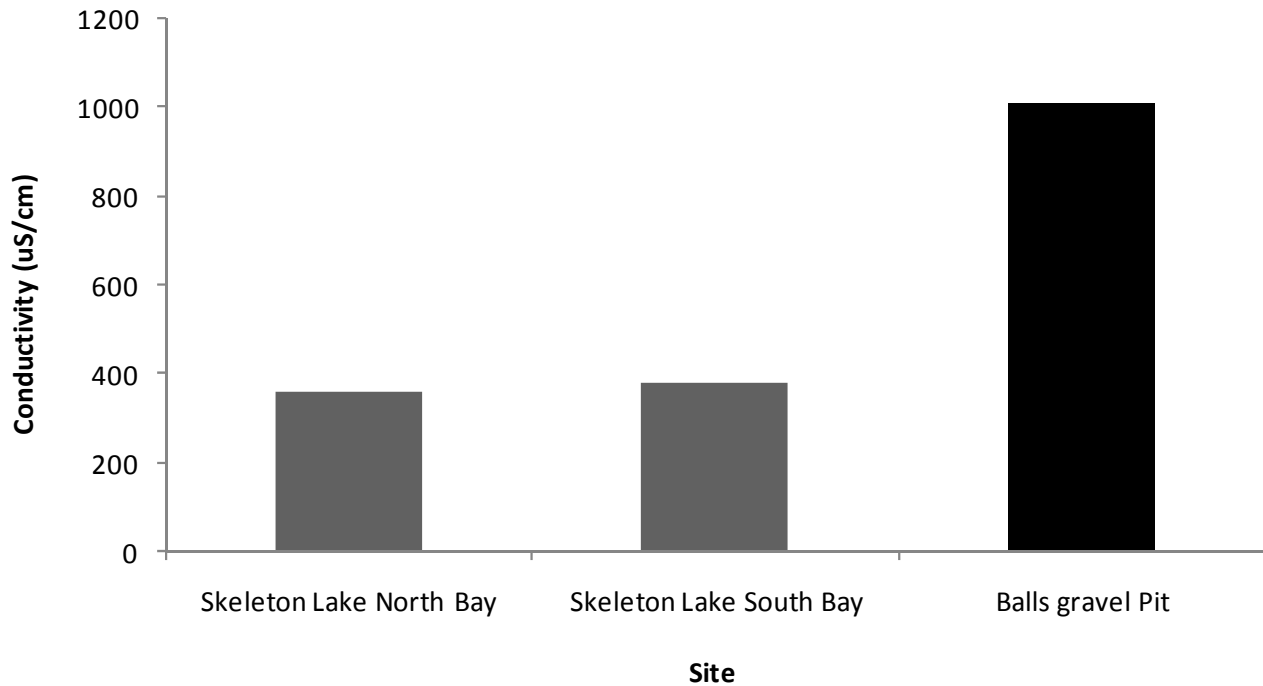


Figure 7. Conductivity levels in both bays of Skeleton Lake and in Ball's Gravel Pit on October 9, 2006.

Carbonate can be used as a measure of water hardness or buffering capacity (the ability of the water to resist a change in pH). A greater carbonate concentration means that there is a larger buffering capacity. A lake with a larger buffering capacity would be more resistant to changes in pH and would remain more stable than a lake with a lower buffering capacity.

Carbonate levels were highest in Skeleton Lake south bay, averaging 6.01 mg/L, and lowest in the gravel pit, with no detectable carbonate (Figure 8).

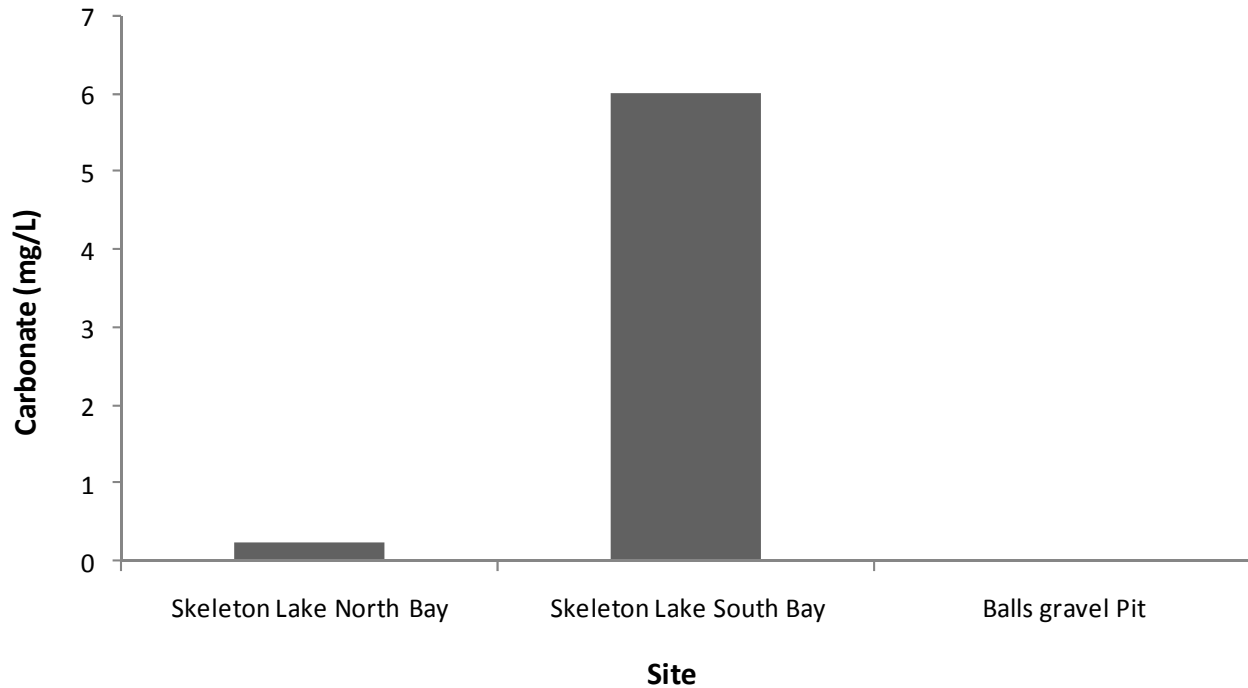


Figure 8. Carbonate levels in Skeleton Lake and Ball's Gravel Pit, 2006. NOTE: The carbonate level in Ball's Gravel Pit was 0.0 mg/L.

Sulphate is a naturally occurring substance that contains sulphur and oxygen. It is present in various mineral salts that are found in soil. Sulphate forms salts with a variety of elements including barium, calcium, magnesium, potassium and sodium (Government of Saskatchewan, 2003). Sulphate may be leached from the soil and is commonly found in most water supplies. There are several other sources of sulphate in water including decaying plant and animal matter, numerous chemical products including ammonium sulphate fertilizers, treatment of water with aluminum sulphate (alum) or copper sulphate. Human activities such as the combustion of fossil fuels and sour gas processing can also be a source of sulphate.

Sulphate is generally considered to be non-toxic. High amounts of various sulphate salts may give drinking water an offensive taste. Depending upon the type of sulphate salt(s) present in the water, most people begin to notice an offensive taste at concentrations ranging from 250 to 1,000 mg/L.

Sulphate levels were much higher in the gravel pit compared to the lake. Sulphate reached 336.55 mg/L in the gravel pit, while the lake had 2.01 mg/L on average (Figure 9).

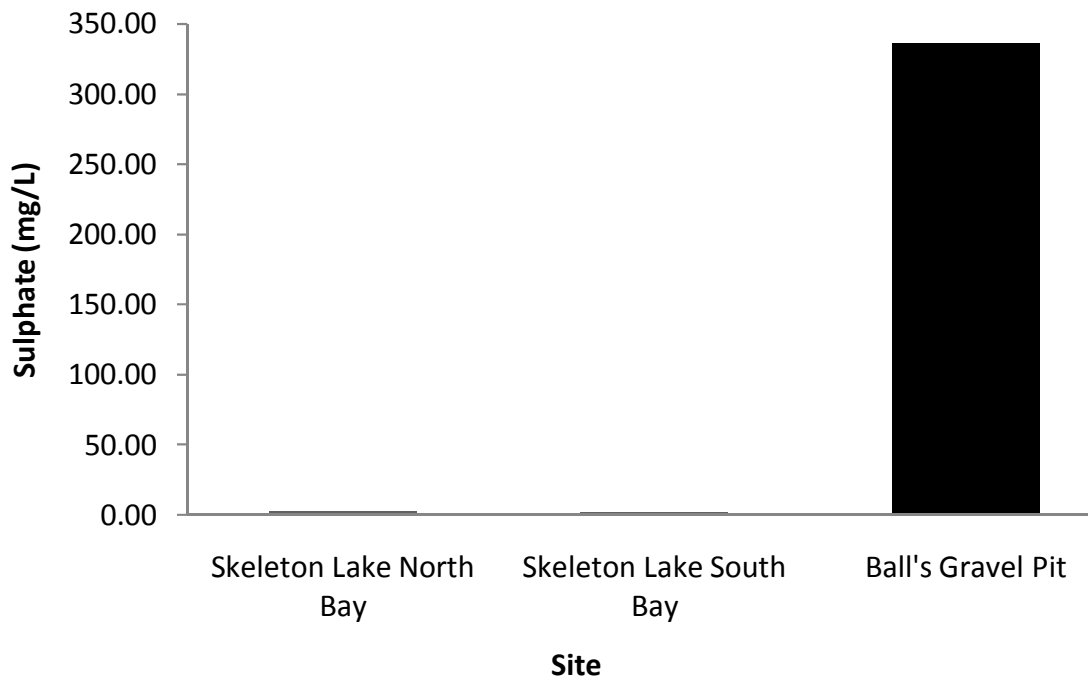


Figure 9. Sulphate levels in Ball's Gravel Pit and Skeleton Lake, 2006.

Iron is a trace element required by both plants and animals. It is a vital part of the oxygen transport mechanism in the blood (haemoglobin) of all vertebrates, macrophytes (aquatic plants) and some invertebrate animals. Iron is a natural component of water and soils and water bodies contain variable amounts of iron depending on the geological area and other chemical components of the waterway. Like sulphate, iron is generally considered to be non-toxic. However, when iron concentrations reach 0.3 mg/L there can potentially be negative effects on freshwater aquatic life (CCME Guideline for the Protection of Aquatic Life, 1999).

Iron levels were much higher in the gravel pit compared to the lake. Iron was 0.14 mg/L in the gravel pit and averaged 0.5 mg/L and 0.2 mg/L in the north bay and south bay of the lake, respectively (Figure 10).

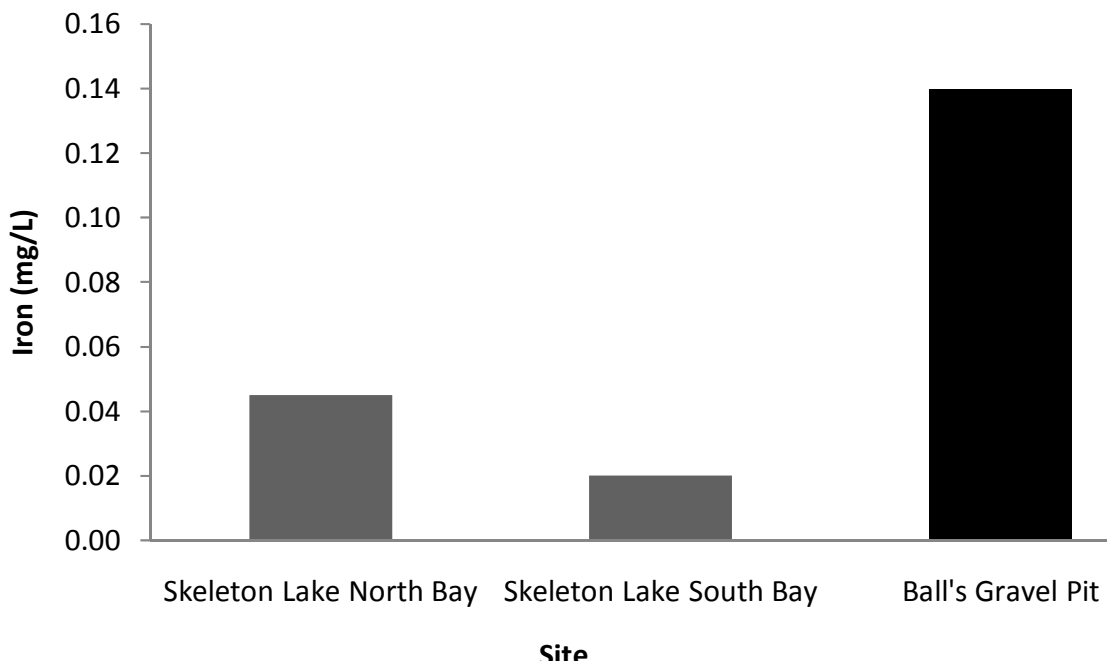


Figure 10. Iron levels in Ball's Gravel Pit and Skeleton Lake, 2006.

Some parameters were very similar between sites; for example, pH, colour, non filterable residue, bicarbonate, alkalinity, chloride, iron and turbidity. Generally speaking, the gravel pit had lower values for all these parameters, except for chloride, iron, alkalinity and bicarbonate; for these parameters, higher levels were seen in the gravel pit.

4.2 Algae and Zooplankton

Algal density was highest in Skeleton Lake north bay, as seen in Figure 11, and lowest in the gravel pit. Table 2 lists all the species found in the samples, as well as the density numbers and biomass.

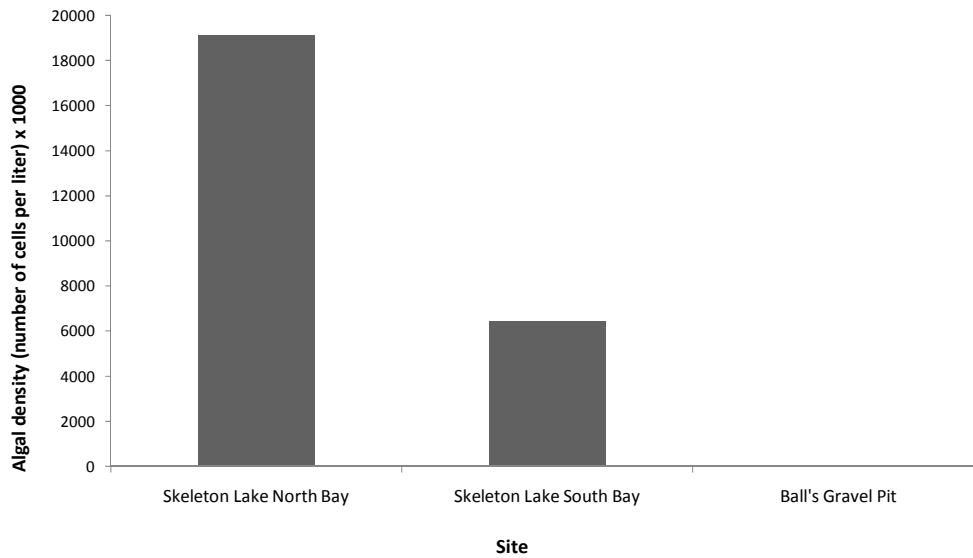


Figure 11. Algal density in both bays of Skeleton Lake and in Ball's Gravel Pit on October 9, 2006. Figure courtesy of M. Agbeti (2006), Bio-Limno Research & Consulting Inc. NOTE: The algal density for the Ball's Gravel pit was 54.45 cells/L x 1000.

Algal biomass was highest in Skeleton Lake south bay, and the gravel pit had very few detectable phytoplankton (Figure 12).

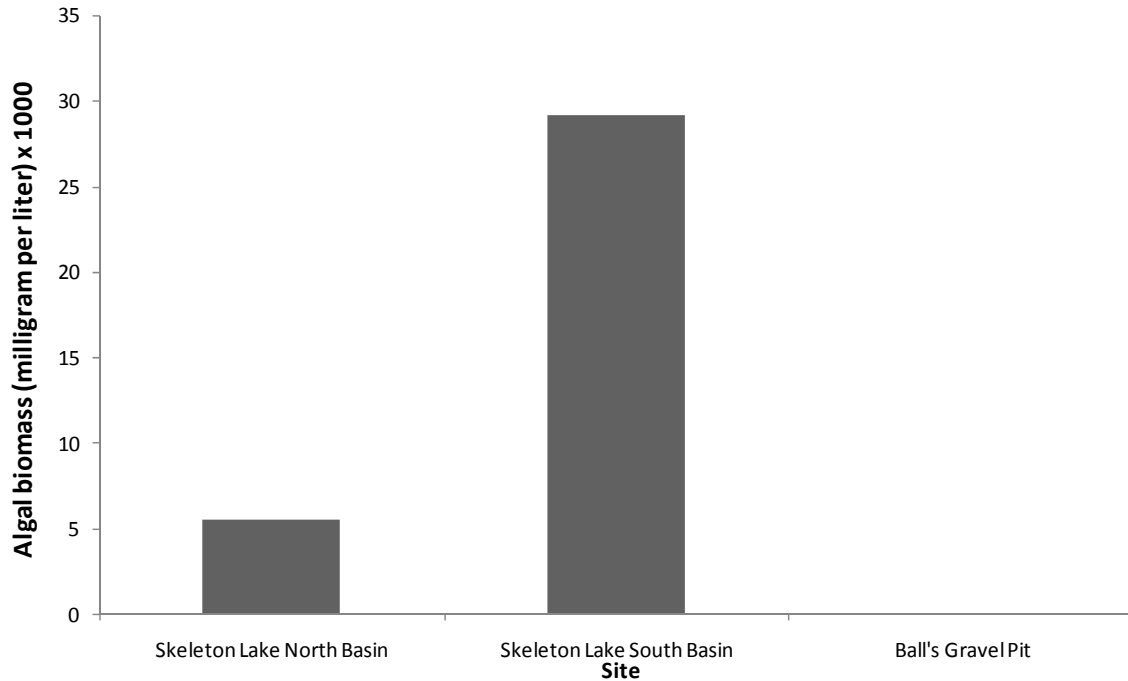


Figure 12. Algal biomass in both bays of Skeleton Lake and in Ball's Gravel Pit on October 9, 2006. Figure courtesy of M. Agbeti (2006), Bio-Limno Research & Consulting Inc. NOTE: The algal biomass for Ball's Gravel Pit was 0.007 mg/L x 1000

Table 2. Phytoplankton density (number of units/L) and biomass (mg/m³) in the North and South Basins of Skeleton Lake and Ball's Gravel Pit. Table courtesy of M. Agbeti (2006), Bio-Limno Research & Consulting Inc.

Phytoplankton	Skeleton Lake North Basin		Skeleton Lake South Basin		Ball's Gravel Pit	
	Density units/L	Biomass mg/m ³	Density units/L	Biomass mg/m ³	Density units/L	Biomass mg/m ³
CYANOBACTERIA (Blue-green Algae)						
<i>Anabaena</i> sp 1	136135	112.908	0	0	0	0
<i>Anabaena</i> sp 2	0	0	85084	38.491	0	0
<i>Aphanocapsa delicatissima</i> West & West	17016	10.692	187186	77.696	0	0
<i>Aphanizomenon flos-aquae</i> (Linne) Ralfs	1123119	3972.104	884881	2496.598	0	0
<i>Aphanocapsa rivularis</i> (Carm.) Rabenhorst	0	0	17016	171.073	0	0
<i>Aphanocapsa</i> sp	34033	654.355	0	0	0	0
<i>Limnothrix</i> sp	340339	108.631	0	0	0	0
<i>Microcystis ichthyoblabe</i> Kuetzing	0	0	17016	21.384	0	0
<i>Gomphosphaeria aponina</i> Kuetzing	0	0	34033	85.537	0	0
<i>Oscillatoria limnetica</i> Lemmerman	0	0	119118	71.423	0	0
<i>Phormidium</i> sp Kuetzing ex. Gormont	17016	38.491	0	0	0	0
<i>Planktolyngbya contorta</i> Lemmermann	17016	6.415	17016	8.554	0	0
<i>Planktolyngya limnetica</i> Lemmermann	782780	218.118	119118	43.624	0	0
<i>Pseudanabaena limnetica</i> Komarek	850848	77.411	136135	48.97	0	0
<i>Snowella lacustris</i> (Chodat) Komarek et Hindak	0	0	136135	163.589	0	0
CHLOROPHYCEAE (Green Algae)						
<i>Ankyra judayi</i> (G.M. Smith) Fott	17016	0.249	17016	1.426	0	0
<i>Ankistrodesmus spiralis</i> (Turner) Lemmermann	17016	2.281	0	0	0	0
<i>Chlamydomonas</i> sp 1	0	0	0	0	20420	3.079
<i>Chlamydomonas</i> sp 2	0	0	17016	4.562	0	0
<i>Choricystis (colonial)</i>	170169	68.429	0	0	0	0
<i>Choricystis (solitary)</i>	15349300	128.59	3267256	23.371	0	0
<i>Elakatothrix genevensis</i> (Reverdin) Hindak	34033	1.443	85084	4.21	0	0

Table 2. Continued...

Phytoplankton	Skeleton Lake North Basin		Skeleton Lake South Basin		Ball's Gravel Pit	
	Density units/L	Biomass mg/m ³	Density units/L	Biomass mg/m ³	Density units/L	Biomass mg/m ³
<i>Eudorina</i> sp	0	0	34033	59.305	0	0
<i>Monoraphidium braunii</i> Naegeli	34033	0.499	0	0	0	0
<i>Monoraphidium griffithii</i> (Berkeley) Komarkova-Legenerova	17016	2.005	0	0	0	0
<i>Oocystis borgei</i> Snow	0	0	17016	72.991	0	0
<i>Oocystis parva</i> W. & G.S. West	0	0	17016	32.076	0	0
<i>Pediastrum simplex</i> Meyen	0	0	17016	15396.58	0	0
<i>Scenedesmus bicaudatus</i> Dedus	0	0	17016	2.566	0	0
<i>Schroderia setigera</i> (Schroed.) Lemmermann	0	0	17016	0.143	0	0
<i>Staurastrum</i> sp	17016	24.449	0	0	0	0
DIATOMS						
<i>Aulacoseira granulata</i> (Ehrenberg) Simonsen	0	0	17016	72.171	0	0
<i>Aulacoseira</i> spp	0	0	187186	9753.735	0	0
Centric diatom (6-10 um)	17016	6.683	119118	46.778	0	0
<i>Fragilaria crotonensis</i> Kitton	0	0	17016	5.445	0	0
<i>Rhizosolenia longiseta</i> Ehrenberg	34033	7.698	17016	1.711	0	0
<i>Synedra</i> spp	0	0	51049	5.973	0	0
CRYPTOPHYCEAE						
<i>Cryptomonas marsonii</i> Skuja	0	0	51050	53.46	6806	2.737
<i>Rhodomonas minuta</i> Skuja	68067	15.397	527525	119.324	0	0
<i>Rhodomonas minuta</i> var. <i>nanoplanctonica</i> Skuja	0	0	102101	5.132	27227	1.369
EUGLENOPHYCEAE						
<i>Phacus</i> sp	17016	14.256	85084	250.907	0	0
TOTAL	19110033	5471.104	6432384	2913881	54453	7.185

Ball's Gravel Pit demonstrated the highest zooplankton biomass, as seen in Figure 13, while Skeleton Lake south bay had the lowest biomass. Table 3 lists all the zooplankton species identified in the samples, as well as their associated biomass and density.

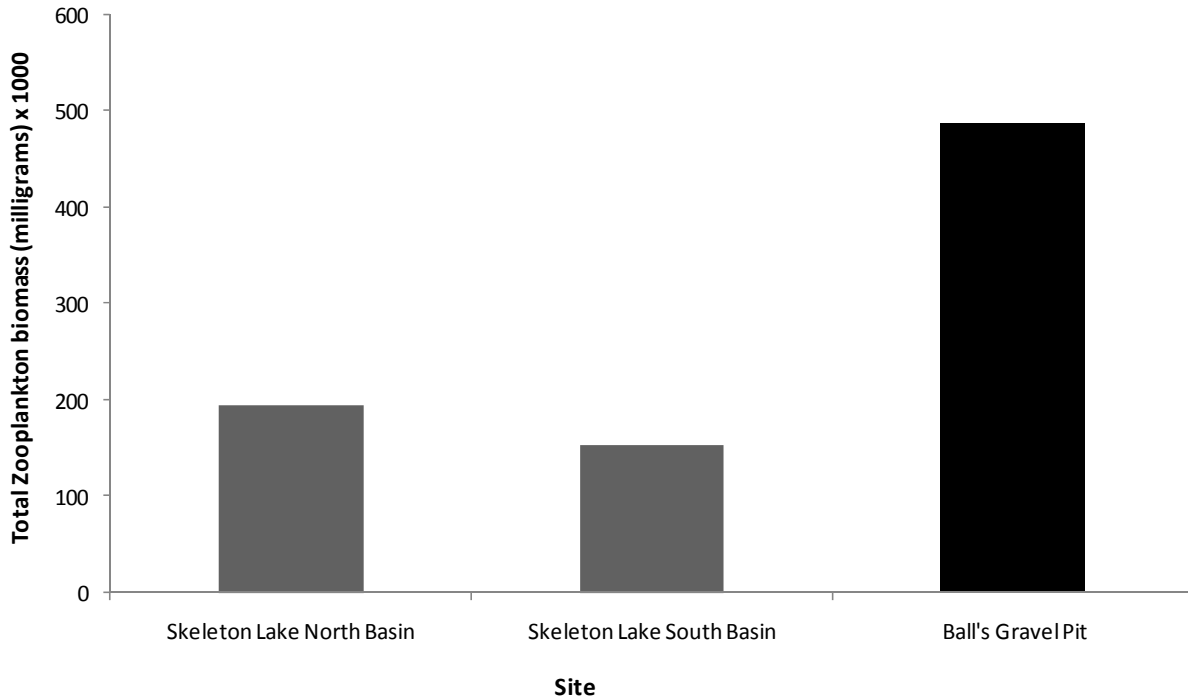


Figure 13. Zooplankton biomass in both bays of Skeleton Lake and in Ball's Gravel Pit on October 9, 2006. Figure courtesy of M. Agbeti (2006), Bio-Limno Research & Consulting Inc.

Zooplankton density was highest in Skeleton Lake south bay and lowest in the gravel pit (Figure 14).

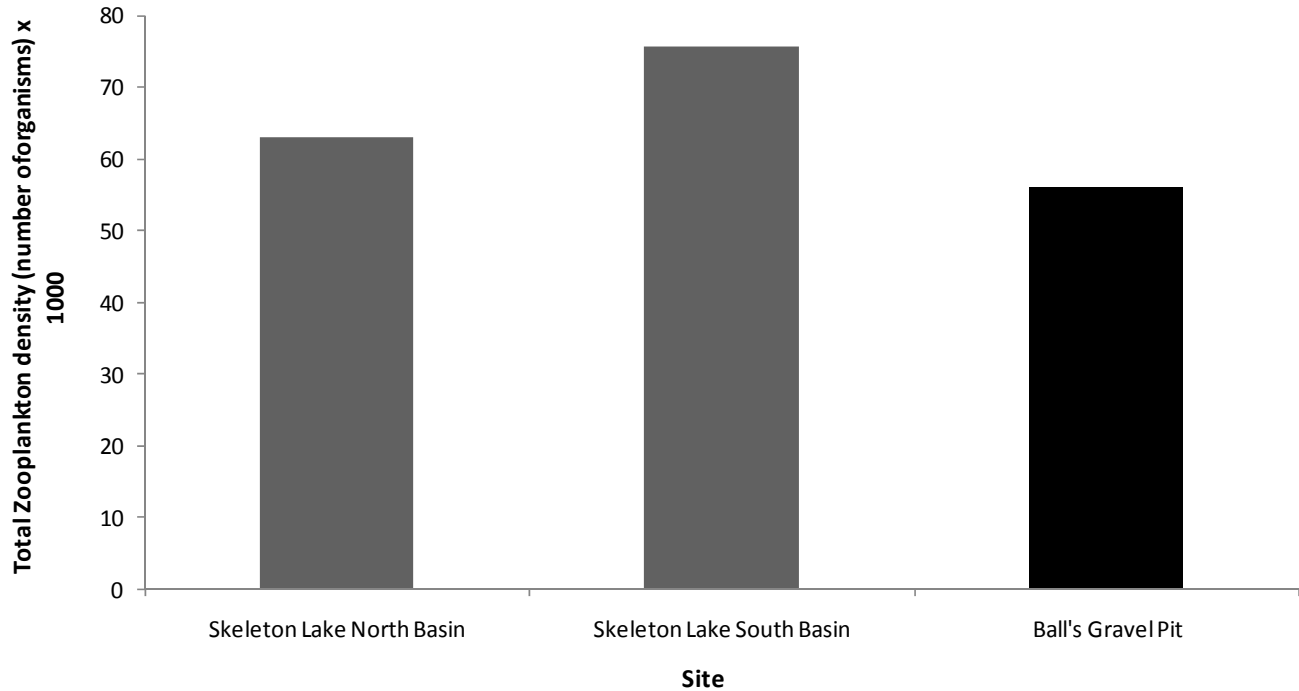


Figure 14. Zooplankton density in both bays of Skeleton Lake and in Ball's Gravel Pit on October 9, 2006. Figure courtesy of M. Agbeti (2006), Bio-Limno Research & Consulting Inc.

Table 3. Zooplankton density (number of organisms/m³) and biomass (micrograms/m³) in the North and South Basins of Skeleton Lake and Ball's Gravel Pit. Table courtesy of M. Agbeti (2006), Bio-Limno Research & Consulting Inc.

Zooplankton	Skeleton Lake North Basin		Skeleton Lake South Basin		Ball's Gravel Pit	
	Density no./m ³	Biomass mg/m ³	Density no./m ³	Biomass mg/m ³	Density no./m ³	Biomass mg/m ³
ROTIFERA						
<i>Conochilus unicornis</i>	0	0	2654.40	1452.10	0	0
<i>Collotheca mutabils</i>	853.20	381.68	0	0	0	0
<i>Kellicotia longispina</i>	1706.40	1243.78	884.80	644.92	294.93	214.97
<i>Keratella cochlearis</i>	6399.00	3229.09	23889.60	12055.26	2359.47	1190.64
<i>Polyathra vulgaris</i>	4692.60	2855.58	4424.00	2692.13	589.87	358.95
<i>Polyathra dolicoptera</i>	0	0	0	0	589.87	302.61
<i>Pompholyx sulcata</i>	0	0	3539.20	2185.47	0	0
Calanoid (nauplii)	426.60	537.99	0	0	1474.67	1859.73
Cyclopoid (nauplii)	853.20	1218.72	884.80	1263.86	9437.87	13481.17
OTHERS (CILIOPHORA)						
<i>Opercularia</i> sp	23463.00	33514.86	11060.00	15798.25	884.80	1263.86
CALANOIDA						
<i>Acanthodiaptomus denticornis</i>					24764.0	243616.9
<i>Leptodiaptomus sicilis</i>	8885.3	83365.7	6696.0	62824.5		
Calanoid copepodid	74.7	282.3	0	0	2706.0	10231.8
CYCLOPOIDA						
<i>Dicyclops bicuspidatus</i>	9109.3	48211.0	1426.0	7547.1	0	0
<i>Acanthocyclops vernalis</i>	0	0	0	0	1804.0	5332.0
<i>Mesocyclops edax</i>	373.3	4974.9	0	0	0	0
Cyclopoid copepodid	1717.3	2926.1	682.0	1162.0	1312.0	2235.4

Table 3. Continued...

Zooplankton	Skeleton Lake North Basin		Skeleton Lake South Basin		Ball's Gravel Pit	
	Density no./m ³	Biomass mg/m ³	Density no./m ³	Biomass mg/m ³	Density no./m ³	Biomass mg/m ³
CLADOCERA						
<i>Daphnia galatea mendotae</i>	597.3	4901.9	3596.0	29509.8	0	0
<i>Daphnia rosea</i>	0	0	0	0	1230.0	10052.8
<i>Daphnia pulex</i>	0	0	0	0	8528.0	197910.3
<i>Diaphanosoma brachyurum</i>	672.0	5437.1	620.0	5016.4	0	0
<i>Chydorus sphericus</i>	3061.3	2327.0	15190.0	11546.2	0	0
Cladocera (immature)	0	0	0	0	82	14.0
TOTAL	62884.67	195407.69	75546.80	153698.02	56057.47	488065.17

5.0 Discussion

5.1 Water Quality

Due to the eutrophic (nutrient-rich) nature of Skeleton Lake, one of the most critical considerations when considering a water diversion is the addition of excess nutrients, which could push the lake into a hypereutrophic state, causing excessive algal growth. Using the averaged values for total phosphorus and total nitrogen in Skeleton Lake, we can see that the Redfield ratio for the lake is roughly 30:1, meaning it is a phosphorus limited system, so any addition of phosphorus would greatly increase the productivity of the lake. As seen in the graphs above, the gravel pit is quite low in phosphorus (<10 µg/L) and has no detectable chlorophyll *a*, making it oligotrophic in nature (AENV, 2006). This would mean that the addition of the gravel pit water to the lake would have minimal effect on the lake water quality and would likely not contribute to the development of algae.

Conductivity, alkalinity, sulphates and bicarbonates are high in the gravel pit water, which are typical characteristics of groundwater. This would add more solutes to Skeleton Lake and would increase the buffering capacity and increase the lake water hardness, but this would not have an otherwise adverse effect on the water quality in the lake.

5.2 Algae and Zooplankton

Algal abundance (both densities and biomasses) in Skeleton (north bay) and Skeleton (south bay) were several times higher than that of Gravel Pit (Figures 10 and 11; Table 2). Algal species richness (i.e. number of species) was extremely low in Ball's Gravel Pit (2 taxa), compared to Skeleton north bay (21 taxa) and Skeleton south bay (30 taxa). The algal abundance and species composition in Skeleton Lake relative to Ball's Gravel Pit would indicate that Skeleton Lake is more productive, which is reflected in the higher nutrient levels seen in Skeleton Lake. Cyanobacteria, which include toxic bloom-forming forms, were also present only in Skeleton Lake and not in the gravel pit. Several of the algal taxa recorded are indicators of eutrophic conditions. For example, both *Aphanizomenon-flos-aquae* (recorded in both basins of Skeleton Lake), and *Aulacoseira granulata* (found in the south basin only) are indicative of eutrophic conditions (Wetzel 1983, Reynolds, 1984). These species were not found in Ball's Gravel Pit. *Chlamydomonas spp* is a green alga that was found only in the Gravel Pit; it is a common phytoplankton and is not expected to cause any problems if introduced to the lake (Agbeti pers. comm., 2007).

Zooplankton species richness in the two basins of Skeleton Lake did not differ substantially from that recorded in Ball's Gravel Pit (Table 3). Total zooplankton abundance (number of organisms) in Ball's Gravel Pit and the two basins of Skeleton Lake were quite similar (Fig. 14). Ball's Gravel Pit, however, had the largest total zooplankton biomass (Figure 13). *Daphnia*, a large-sized zooplankton, was found in Ball's Gravel Pit, but not in either basin of Skeleton Lake. This consequently contributed to the substantially large total zooplankton biomass in Ball's Gravel Pit relative to the two basins of Skeleton Lake. Historically, *Daphnia* have been found in Skeleton Lake, and it is likely that if more than one sampling event had occurred it would have been identified in the samples.

With the exception of detection of *Daphnia* in Ball's Gravel's Pit and its absence in Skeleton Lake, the zooplankton community in Ball's Gravel Pit and the two basins of Skeleton Lake were fairly similar. In contrast, the phytoplankton assemblage in the two systems was very different. Ball's Gravel Pit could be described as devoid of phytoplankton relative to Skeleton Lake. Based on the phytoplankton and zooplankton data available, diversion of water from Ball's Gravel Pit into Skeleton Lake would not result in introduction of any new detrimental organisms into Skeleton Lake. The increase in *Daphnia* concentrations may lead to increased consumption of phytoplankton from Skeleton Lake, which could in turn lead to more bioavailable nutrients within the water column. Further zooplankton sampling for *Daphnia* density and biomass within Skeleton Lake itself may be required in the summer of 2007 to determine the full effect of additional *Daphnia* from Ball's Gravel Pit.

6.0 Conclusions

From a water quality standpoint, the addition of water from Ball's Gravel Pit into Skeleton Lake has low potential for negative impacts to the lake. The addition of nutrients is not a concern due to the oligotrophic nature of the gravel pit, and a slight increase in water hardness is unlikely to have a negative effect on the lake. It is recommended, however, that water quality monitoring, as well as phytoplankton and zooplankton monitoring, be performed monthly on the gravel pit and lake water throughout the first year of the diversion in order to ensure there are no detrimental effects to the lake. Once a full year of monitoring has been completed, it can be decided if further monitoring is required throughout the course of diversion.

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8.0 Glossary

Aerobic: In freshwater systems, an environment that contains oxygen.

Alkalinity: A measure of the hydroxyl ion concentration in a solution expressed as a pH value between 7 and 14. Alkalinity is a capacity factor that represents the acid-neutralizing capacity of a system (CCME 1999).

Algae: Plant or plantlike organisms, usually aquatic, capable of synthesizing their own food by photosynthesis. They occur in relative proportion to the amount of nutrients available. They are food for some fish and small aquatic animals (i.e. zooplankton). Includes the green, yellow-green, brown, red and cyanobacteria.

Anaerobic: In freshwater systems, an environment that is devoid of oxygen.

Anoxic: In freshwater systems, anoxic refers to a lack of dissolved oxygen. Bacterial decomposition of excessive organic matter under winter ice cover frequently causes anoxia.

Anthropogenic: Literally, "human origin", such as sewage inputs into a freshwater system.

Bioavailable: Refers to nutrients and compounds that are available for use by living things.

Biomass: The total mass of living organisms of one or more species per unit area or of all the species in a community.

Buffering Capacity: The ability of the water to resist changes in pH (i.e. changes in acidity or alkalinity).

Chlorophyll a: A measure of phytoplankton productivity in freshwaters, which is empirically positively correlated with phosphorus concentrations.

Colour: A measure of the degree to which water is stained by dissolved organic compounds (such as humic acids). Lakes with high colour are less transparent to light penetration.

Composite Sample: A series of water samples taken at a given time from several locations combined into a single sample.

Conductivity: An indication of the ionic strength of freshwater, determined by measuring its ability to conduct electricity.

Cyanobacteria: Also known as blue-green algae, cyanobacteria are a group of aquatic bacteria that obtain their energy through photosynthesis. These are part of the phytoplankton assemblage and are capable of fixing carbon dioxide and nitrogen. Some produce toxic compounds.

Euphotic Tube: A clear polyethylene (plastic) tube with a one-way foot valve used to sample a column of water from the euphotic zone.

Euphotic zone: The euphotic zone is defined as the upper layer of water into which sufficient light penetrates to allow phytoplankton growth.

Eutrophic: Refers to aquatic environments that have abundant nutrients and high rates of productivity. In eutrophic water bodies such as lakes, ponds and slow-moving rivers, oxygen levels below the surface layer may be depleted. Opposite of oligotrophic (CCME 1999).

Eutrophication: The natural and/or anthropogenic processes by which the nutrient content of natural waters is increased, generally resulting in an increase of biotic productivity and biomass (CCME 1999).

Guidelines: Generic numerical concentrations or narrative statements that are recommended as upper limits to protect and maintain the specified uses of air, water, sediment, soil or wildlife. These values are not legally binding (CCME 1999).

Hardness: The concentration of all metallic cations, except those of the alkali metals, present in water. In general, hardness is a measure of the concentration of calcium and magnesium ions in water and is frequently expressed as mg/L calcium carbonate equivalent (CCME 1999).

Hypereutrophic: Refers to aquatic environments that have very high nutrients and very high rates of productivity. Algal blooms are common in these lakes, often lasting throughout the summer and well into autumn. Oxygen depletion can occur throughout the year and may extend to the surface, leading to fish kills. (Hyper = over, above, excessive).

Mesotrophic: Refers to aquatic environments with moderate nutrient concentrations and sufficient rates of productivity to sustain aquatic life. (Meso = "middle").

Morphometry: The measurement of the shape of a lake, usually with depth contours.

Nitrogen: A nutrient necessary for the growth and development of animals and plants.

Oligotrophic: An aquatic environment that has a low nutrient concentration (phosphorus and nitrogen) and low productivity (i.e. low chlorophyll *a* concentrations). These water bodies tend to have clear water and sufficient oxygen throughout the year to support fish and other aquatic organisms

pH: A logarithmic scale used to measure the acidity of water.

Phosphorus: A nutrient necessary for the growth and development of animals and plants. Typically the limiting nutrient in aquatic systems.

Phytoplankton: Photosynthetic aquatic organisms. Includes algae, diatoms and crysophytes.

Redfield Ratio: The molecular ratio between carbon, nitrogen and phosphorus in phytoplankton (C:N:P).

Salinity: In inland fresh waters, the salinity is the sum of the ionic composition of the four major cations (calcium, magnesium, sodium and potassium) and anions (carbonate, sulfate, chloride and nitrate) in mass or milliequivalents per liter (Wetzel and Likens, 2000).

Secchi disk: An 8-inch (20 cm) disk with 2 alternating black and white quadrants used to measure water transparency to light penetration. Transparency decreases as color, suspended sediments, or algal abundance increases.

Species Richness: The total number of species found at a given time in a given area.

Taxa: A name designating an organism or group of organisms. A taxon is assigned a rank and can be placed at a particular level in a systematic hierarchy reflecting evolutionary relationships.

Total Kjeldahl Nitrogen (TKN): A measure of the sum of organic nitrogen and ammonia nitrogen.

Trophic: Refers to the nutrient availability and productivity status of a waterbody.

Zooplankton: Aquatic heterotrophic (animal like) organisms that prey on phytoplankton and other zooplankton. Includes *Daphina*, *Rotifera* and Copepods, etc.

Appendix A
Raw Water Chemistry Data

Sample ID	Date	Site	NH ₄ ⁺ (µg/L)	NO ₂ +NO ₃ (µg/L)	TN (µg/L)	TKN (µg/L)	TP (µg/L)	Cl (mg/L)	SO ₄ (mg/L)	Fe (mg/L)
75305	10-Oct-06	Ball's Gravel Pit	24.10	7.18	495.00	487.82	7.41	5.83	336.55	0.14
75306	10-Oct-06	Skeleton Lake North Bay	156.00	3.91	1,480.00	1,476.09	51.49	4.16	2.94	0.06
75307	10-Oct-06	Skeleton Lake North Bay	149.00	6.80	1,460.00	1,453.20	42.29	3.94	2.35	0.03
75308	10-Oct-06	Skeleton Lake South Bay	9.52	3.85	1,140.00	1,136.15	44.39	3.82	1.56	0.02
75309	10-Oct-06	Skeleton Lake South Bay	10.70	4.17	1,160.00	1,155.83	39.77	3.79	1.56	0.02
75310	10-Oct-06	Skeleton Lake South Bay	10.20	4.44	1,170.00	1,165.56	40.84	3.94	1.62	0.02
		Mean North	152.50	5.36	1,470.00	1,464.65	46.89	4.05	2.65	0.05
		Mean South	10.14	4.15	1,156.67	1,152.51	41.66	3.85	1.58	0.02

Sample ID	Date	Site	Alk (mg/L as CaCO ₃)	Bicarb (mg/L)	Carb (mg/L)	Cond (µS/cm)	pH	Color (mg/L Pt)	Turb (NTU)	NFR (mg/L)	Chl-a (µg/L)
75305	10-Oct-06	Ball's Gravel Pit	244.84	298.52	0.00	1,011.00	7.98	9.10	0.56	5.00	<MDL
75306	10-Oct-06	Skeleton Lake North Bay	185.60	225.69	0.30	361.00	8.30	12.40	2.40	5.00	18.22
75307	10-Oct-06	Skeleton Lake North Bay	187.21	227.91	0.17	364.00	8.30	12.10	2.50	7.00	14.25
75308	10-Oct-06	Skeleton Lake South Bay	198.29	230.11	5.73	380.00	8.45	10.40	2.80	14.50	17.85
75309	10-Oct-06	Skeleton Lake South Bay	200.43	232.29	5.95	379.00	8.45	10.80	2.60	11.50	16.44
75310	10-Oct-06	Skeleton Lake South Bay	200.67	231.75	6.35	381.00	8.47	10.10	2.60	<MDL	16.57
		Mean North	186.41	226.80	0.24	362.50	8.30	12.25	2.45	6.00	16.24
		Mean South	199.80	231.38	6.01	380.00	8.45	10.43	2.67	13.00	16.95

MDL – method detection limit

Appendix B

Plankton Report

Plankton Comparison of Skeleton Lake (North and South) and Ball's Gravel Pit

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Bio-Limno Research & Consulting

Algal abundance (both densities and biomasses) in Skeleton (North) and Skeleton (South) were several times higher than that of Gravel Pit (Figs 1 and 2; Table 1). Algal species richness (i.e. number of species) was extremely low in Ball's Gravel Pit (2 taxa), compared to Skeleton North (21 taxa) and Skeleton South (30 taxa). The algal abundance and species composition in Skeleton Lake, relative to Ball's Gravel Pit, would suggest that Skeleton Lake is more productive, which could be associated with higher nutrient levels in Skeleton Lake than in Ball's Gravel Pit. Cyanobacteria, which include toxic bloom-forming forms, was also more abundant in Skeleton Lake compared to Gravel Pit. Several of the algal taxa recorded are indicators of eutrophic conditions. For example, both *Aphanizomenon-flos-aquae* (recorded in both basins of Skeleton Lake), and *Aulacoseira granulata* (found in South basin only) are indicative of eutrophic conditions (Wetzel 1983, Reynolds, 1984). These species were not found in Ball's Gravel Pit.

Zooplankton species richness in the two basins of Skeleton Lake did not differ substantially from that recorded in Ball's Gravel Pit (Table 2). Total zooplankton abundance (number of organisms) in Ball's Gravel Pit and the two basins of Skeleton Lake were quite similar (Fig. 3). Ball's Gravel Pit, however, had the largest total zooplankton biomass (Fig. 4). *Daphnia*, a large-sized zooplankton, was found in Ball's Gravel Pit only, but not in either basin Skeleton Lake. This consequently contributed to the substantially large total zooplankton biomass in Ball's Gravel Pit, relative to the two basins of Skeleton Lake.

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