State of the Island Lake Watershed

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EXECUTIVE SUMMARY

To help ensure the health of their lake environments, residents of the summer villages at Island, Baptiste, and Skeleton Lakes have formed the Baptiste, Island, and Skeleton Lakes Watershed Management and Lake Stewardship Council (BISL). BISLôs vision for Island Lake is to ñmaintain a healthy lake and watershed, recognizing the importance of living within the capacity of the natural environment and providing sustainable recreational, residential, agricultural, and industrial benefitsò. This State of the Watershed report contributes to achieving the vision by describing the current condition of Island Lake and its watershed and assessing strategies to improve their health. The following four indicators of the health of Island Lake are assessed: water quality, fisheries, shoreline condition, and water level. In addition, land cover is evaluated due to the watershedôs influence on the lakeôs health. Each indicatorôs status and management options are assessed, and management and research priorities are recommended for improving the health of Island Lake. Due to limited information availability for some indicators and stressors, the assessment should be interpreted as approximate.

WATER QUALITY

Previous assessments of the lakeôs water quality have not identified significant issues. Of greatest concern are nutrient concentrations due to the potential for algal blooms, which can degrade aquatic habitat and recreational value. Island Lake does not experience algal blooms to the extent of neighbouring Baptiste Lake; total phosphorus (TP) and chlorophyll-a data collected from Island Lake indicate that the lake is in a mesotrophic state and presents a low health risk due to blue-green algae. Although phosphorus and chlorophyll-a levels suggest that nutrification is not of immediate concern at Island Lake, management of nutrient sources is recommended to avoid future increases in productivity that could degrade the lakeôs ecological and cultural value.

By altering the rate at which phosphorus enters the lake from the watershed, land use can affect lake primary productivity. Agriculture is the largest external source of phosphorus, and 29% of the watershed has been converted to farmland. Phosphorus input from livestock operations can likely be managed by containing runoff from wintering sites, although funding may be needed to help producers offset some of the costs. Perhaps more importantly, conversion of additional land to agriculture should be discouraged, especially given that soils in the watershed have severe to very severe limitations for agriculture. Other anthopogenic footprints such as roads and energy sector infrastructure contribute phosphorus through surface runoff, and these features should also be minimized. Phosphorus input from residential wastewater is likely small, but sound wastewater practices remain important to avoid future impacts.

Other factors contributing to eutrophication of Island Lake include internal loading, trophic cascade, and climate change. Phosphorus occurs in high concentration in lake sediments and can be solubilized into porewater and released into lakewater. The process, referred to as internal loading, may be highly significant at Island Lake because phosphorus is released directly from sediments to the euphotic zone due to the lakeôs shallow depth. Although internal loading at Island Lake may exceed all external phosphorus sources combined, practical opportunities to manage internal loading likely do not exist due to problems with effectiveness, cost, and side effects. Climate change may cause higher phosphorus concentrations due to higher precipitation and temperatures. As with internal loading, however, mitigation opportunities are limited. Rather, the potential for climate change to increase nutrification emphasizes the importance of minimizing other sources of phosphorus discussed in the report.

While nutrient input is an important control on primary productivity, the effect of trophic cascade may be similar in magnitude. The collapse of piscivorous fish populations (walleye and pike) have likely caused planktivorous fish populations (perch, cisco, etc.) to increase. The rise in planktivores causes their prey (zooplankton) to decline. The decreased abundance of zooplankton ultimately causes phytoplankton (i.e., algae) to increase. Populations of piscivorous fish have declined at Island Lake and the abundance of algae is higher than would be expected based solely on phosphorus concentration, suggesting that trophic cascade is contributing to abundant algae populations. Fishing regulations to recover fish populations to what they were prior to heavy angling pressure are needed to reduce the impact of trophic cascade.

FISHERIES

The fish community at Island Lake includes lake whitefish (*Coregonus clupeaformis*), northern pike (*Esox lucius*), white sucker (*Catostomus commersonii*), yellow perch (*Perca flavescens*), and walleye (*Sander vitreus*). Based on commercial harvests, the whitefish fishery appears to have remained stable or perhaps improved in recent decades. The northern pike fishery, however, has declined. Commercial harvest is just 5% of the recorded high from mid-last century, and an index net survey in 2008 found large pike to be rare. The walleye fishery is considered to be collapsed, and displayed the 6th lowest catch per unit effort of 66 lakes surveyed in Alberta. However, a historical survey concluded that the lake may have never supported a widespread fishery for walleye.

Overall, the status of the fishery is assessed as poor due to the degraded status of northern pike and walleye populations. These species are of particular importance from a management perspective due to their value to the recreational fishery, position atop the aquatic food web, and sensitivity to stressors such as angling. Strict regulations such as catch and release or a moratorium are likely needed to improve their status. More moderate regulations (slot size limits, shortened seasons) are unlikely to be successful due to the lakeǿs low productivity and the high angling pressure in the region. The current regulation for northern pike at Island Lake is an allowable catch of 1 fish (no size limit), while the walleye fishery is limited to catch and release but is not expected to recover. Further research is needed to assess the status of the northern pike fishery and identify suitable regulations.

Although angling pressure is the more serious threat, habitat degradation may also contribute to fish population declines, especially migration barriers that can occur at stream crossings and impede access of fish to spawning sites. Just over half (55%) of the culverts located along fish bearing streams in the watershed potentially impede fish movement due to beaver activity, hang, and high velocity. Blocked culverts should be cleaned-out, and hanging or high velocity culverts replaced. Combined with the implementation of a catch-and-release fishery or fishing moratorium, repair or replacement of substandard culverts would increase the likelihood of the fishery recovery by increasing recruitment during wet years.

WATER LEVEL

From 1996 to 2002, Island Lakeǿs water level dropped 0.86 m from its third highest to its lowest level since monitoring began in 1968. Although the water level has stabilized since then, the water level remained 0.38 m below the long-term average in 2009. The decline in lake level is likely in part attributable to climate, especially precipitation. Annual precipitation was below the long-term average each year during the period of rapid decline in Island Lakeǿs water level (1997-2002). This is the longest consecutive string of years with below average rainfall during the period for which water level data exist. While it seems likely that the low lake level is driven by climate, the relative importance of various sources of inflow and outflow is uncertain in the absence of current measurements; this uncertainty makes it difficult to prescribe management recommendations. Completion of a water balance study, informed by measurements of inflow, outflow, and withdrawals, would improve capacity to make informed management decisions regarding the lakeǿs water level.

The sustained period of low water level may have negative implications for the ecology of the lake and its recreational value. Human activities that serve to reduce inflow or increase outflow from the lake will negatively affect the lakeǿs water level and should be minimized. Culverts with drainage problems along streams entering the lake may be reducing inflow, and should be fixed. Water withdrawals from Island Lake should also be minimized. Installation of a weir at the lakeǿs outlet (Island Creek) has been suggested as a strategy to increase water levels at the lake. However, the effectiveness of a weir at controlling water level is uncertain. The rate of outflow through Island Creek has not been measured, but it has previously been described as having limited flow. Precipitation and evaporation are generally the primary determinants of a lakeǿs water level, and variability in climate could continue to cause fluctuation in water level even after the installation of a weir. Installation of a weir could also negatively impact the aquatic ecosystem by blocking fish migration, degrading habitat, and increasing nutrient levels.

SHORELINE CONDITION

Although shoreline vegetation is abundant at Island Lake, it is likely degraded along the shoreline of the Summer Villages of Island Lake and Island Lake South; BISL is completing an assessment of shoreline condition at the lake. The shoreline zone sustains the greatest diversity of plants and animals in the lake and provides essential ecosystem services including filtering runoff entering the lake and protecting the shoreline from erosion. Degradation of shoreline vegetation and substrate can inhibit these valuable services and should be minimized. Lake shorelines are environmental reserves to prevent pollution and provide public access, and cannot be altered without permission from municipal and provincial authorities. Shoreline vegetation is sometimes cleared at residences to improve waterfront access; enhanced communication and regulation of the environmental reserve at Island Lake could protect the integrity of the lakeôs shoreline.

PRIORITIZING MANAGEMENT OPTIONS

Assessment of the health of Island Lake was hindered by knowledge gaps. Of greatest concern are infrequent monitoring of water quality, irregular monitoring of fisheries, and lack of a current water balance study. Filling these knowledge gaps will improve capacity to monitor and manage the health of Island Lake. Sufficient information was available, however, to assess the general condition of Island Lake. Water quality is relatively good, the recreational fishery is likely collapsed, the water level is below average, and shoreline vegetation is generally abundant but degraded in the proximity of residences.

Several management options exist to improve the health of the lake. To help prioritize management options, opportunities to limit anthropogenic impacts to Island Lake have been ranked from 1 (high priority) to 5 (not recommended) based on their benefits, liabilities, and costs.

1. Options with high benefit and low cost were given first priority. This included restrictive fishery regulations, protection or restoration of shoreline habitat, and protection of remaining forest to limit nutrient input. These influential management options rely on proactive planning and responsible actions by residents and visitors rather than substantial financial investment.
2. Options with high benefit and high cost were given second priority. Controlling runoff from livestock wintering sites may be an influential option for limiting phosphorus input to the lake, but could require substantial investment.
3. Options with low or uncertain benefit and low cost were given third priority. Wastewater management and minimizing water withdrawals are low cost strategies to limit residential impact to water quality and quantity. Damaged culverts should be repaired to facilitate fish migration to spawning habitat and potentially increase inflow from Ghost Lake.
4. Options with low or uncertain benefit and high cost were given fourth priority. Replacing damaged culverts is expensive and has lower potential to improve the fishery that restrictive fish regulations. The effect of replacing culverts on water level is uncertain.
5. Options with liabilities or prohibitive cost were not recommended. BISL is cautioned against attempting to manipulate the lakeôs water level by controlling outflow. Lower than average precipitation has likely caused the low water level, and it is uncertain whether reducing outflow through Island Creek would be sufficient to offset the reduction in runoff. Further, damming Island Creek could increase nutrification of Island Lake and block fish migration. Another example of ecosystem manipulation that is unlikely to succeed is reducing internal phosphorus loading due to the strategyôs high ongoing cost.

Island Lake is valued by residents and visitors for the beauty, ecosystem services, and recreational opportunities that it provides. Although management challenges exist, the lakeôs water quality and relatively intact shoreline and watershed present opportunities for maintaining and restoring the integrity of the Island Lake ecosystem. Careful planning of future human activities at the lake and in the broader watershed will be essential for conserving the health of Island Lake for generations to come.

ACKNOWLEDGEMENTS

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1. INTRODUCTION

To help ensure the health of their lake environments, residents of the summer villages at Island, Baptiste, and Skeleton Lakes have formed the Baptiste, Island, and Skeleton Lakes Watershed Management and Lake Stewardship Council (BISL). BISLôs vision for Island Lake is to ñmaintain a healthy lake and watershed, recognizing the importance of living within the capacity of the natural environment and providing sustainable recreational, residential, agricultural, and industrial benefitsò. This State of the Watershed report contributes to achieving the vision by describing the current condition of Island Lake and its watershed and assessing strategies to improve their health.

Island Lake is located approximately 20 km northwest of the town of Athabasca and is well used for recreational activities such as fishing and boating. Although much of the shoreline is poorly suited for development due to poorly drained soils (Mitchell and Prepas 1990), a number of cottages are located along the southwestern shore in the summer villages of Island Lake and Island Lake South. As its name suggests, the medium-sized (7.81 km^2) lake contains numerous islands. The lakeôs small watershed and shallow depth differentiate it from nearby Baptiste Lake. The drainage area to lake area ratio is low (8.1) relative to Baptiste (23), with the consequence that fewer nutrients drain into the lake and algal growth is not as pronounced. With the exception of the deeper northern basin, most of Island Lake is sufficiently shallow to remain mixed and well-oxygenated throughout the summer (Alberta Environment 1989). Another implication of the lakeôs shallow depth is abundant emergent vegetation along most of the shoreline (Mitchell and Prepas 1990).

BISLôs goals are to: 1) improve water quality to predevelopment conditions; 2) have property owners implement best practices to maintain and restore lake and stream health; and 3) increase public awareness and engagement in land stewardship through increased knowledge and dialogue about the effects of land use on water quality, water quantity and aquatic habitats. To help inform actions towards these goals, this state of the watershed report evaluates the following four indicators of the health of Island Lake: water quality, fisheries, shoreline condition, and water level. In addition, land cover is evaluated due to the watershedôs influence on the lakeôs health. Each indicatorôs status and management options are assessed. Due to limited information availability for some indicators and stressors, the assessment should be interpreted as approximate. The report concludes by recommending management and research priorities for improving the health of Island Lake.

2. LAND COVER

Island Lakeôs 6007 ha watershed (Trew et al. 1987) is located within the boreal natural region which is characterized by cold winters, short but warm summers, and moderate precipitation. Boreal mixedwood forests that are typical of the region support a diverse assemblage of wildlife including 76 bird species, and 33 mammal species, and numerous insect and arthropod species (Stelfox 1995). Human population density in the watershed is low, with almost all residential development isolated to the summer villages of Island Lake and Island Lake South. Clearing for agriculture began in the early 1900ôs (Mitchell and Prepas 1990), and farming is the dominant land use in the watershed. Agricultural conversion is greatest in the south, as well as along Highway 2 which transects the watershed. A large portion of the watershed remains forested, however, especially in the north (Figure 1).

In the southern boreal region, increased nutrient runoff caused by the clearing of land for agriculture and lakeshore development is the dominant cause of eutrophication of lakes that leads to excessive algal growth (Schindler and Lee 2010). Although not discussed further in this report, the status of land cover also affects other ecological attributes of the watershed including wildlife populations and the provision of ecosystem services such as carbon storage.

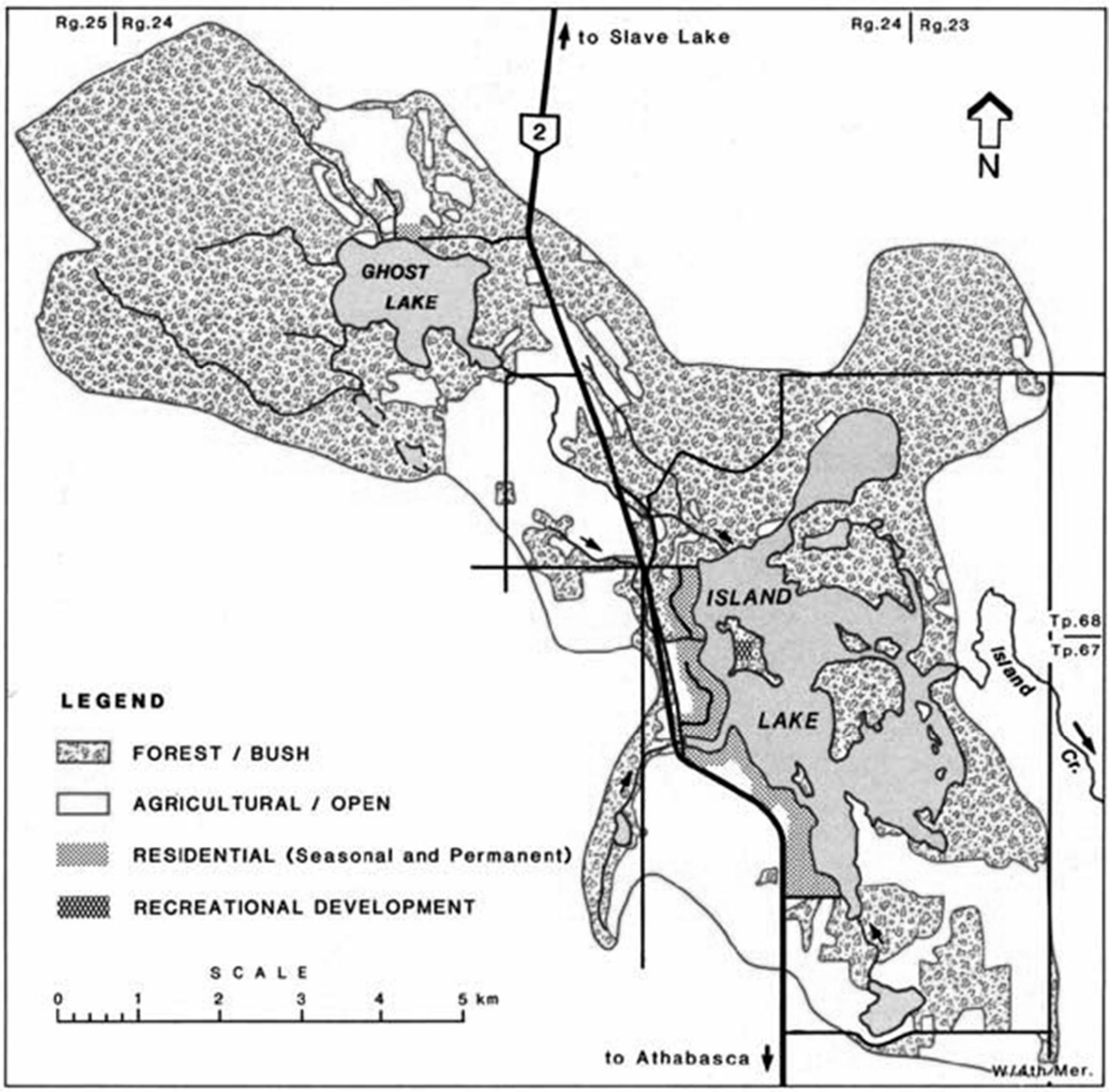

Figure 1. Island Lake watershed as of 1985. Copied from Mitchell and Prepas (1990).

2.1 STATUS

29% of the watershed converted to farmland

Landscape composition was assessed using the most recent Alberta Vegetation Inventory (AVI) data available (1989/1990) and a data layer that identified forest cutovers as of 2000[1]. AVI data permitted classification of landcover into three forest types (deciduous, coniferous, and mixedwood), five natural nonforest types (lakes, shrubland, wetland, grassland, nonvegetated), and two agricultural types (cropland and pasture). AVI data were not available for a portion of the southeastern corner of the watershed, and its composition was assumed to be the same as the portion of the watershed for which AVI data exist.

Deciduous forest is the dominant natural landcover in the watershed, with lesser amounts of coniferous and mixedwood forest as well as wetland and other nonforested landcover types such as shrubs and grass (Table 1). As of 1989/1990, the majority (92%) of forest in the watershed was between 61 and 120 years of age (Figure 2). Major land uses in the watershed include agriculture, transportation, oil and gas exploration, and settlements. The watershed does not overlap with a Forest Management Agreement area, and forestry operations do not occur. Agriculture is the dominant land use type, with approximately 22% of the landscape converted to pasture and a further 8% converted to cropland. If Island Lake is typical of its broader region, agricultural expansion in recent years has been low. Between the 2001 and 2006 Agricultural Censuses, farmland in Athabasca County No. 12 increased at a rate of 0.015% per year (Statistics Canada 2008a, 2008b). Other anthropogenic landcover in the watershed includes 208 ha of settlements[2], 58 km of roads, 129 km of seismic lines, and 23 km of pipelines[3]. In contrast to agriculture, human settlement within the region has accelerated. According to census data, the population of the summer villages of Island Lake and Island Lake South grew by 243% between 1991 and 2006 (Figure 3).

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[1] More recent changes to the composition of the Baptiste Lake watershed were assessed from inspection of 2008 orthophotos. The inspection concluded that agricultural land had only expanded nominaly (2%). Such an inspection has not yet been completed for Island Lake.

[2] Settlement area is based on areas of the Summer Villages of Island Lake (145 ha) and Island Lake South (63 ha) from the 2006 census.

[3] The length of roads, seismic lines, and pipelines is based on a linear feature dataset.

Table 1. Composition of the terrestrial portion of Island Lakeõs watershed, based on AVI data. Not included is a portion of the southeastern corner of the watershed for which AVI data were not available.

Cover Type	Percent of Watershed
Deciduous forest	44%
Coniferous forest	9%
Mixedwood forest	9%
Shrubland	4%
Wetland	2%
Grassland	1%
Nonvegetated	1%

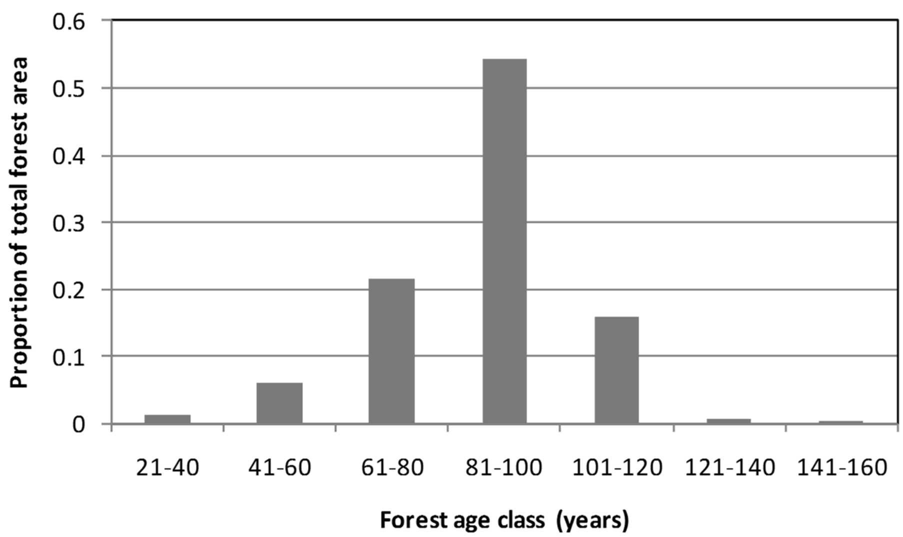

Figure 2. Forest age-class distribution within the Island Lake watershed.

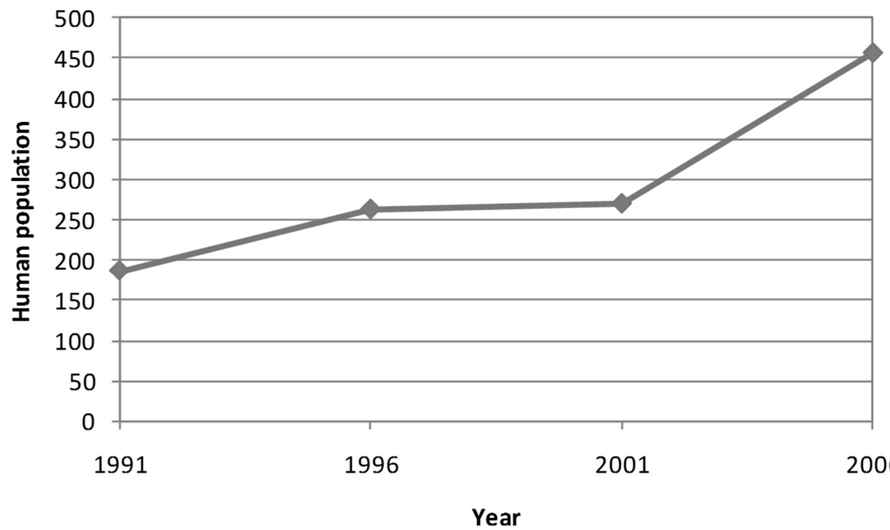

Figure 3. Human population of the Summer Villages of Island Lake and Island Lake South between 1991 and 2006. Source: Statistics Canada[4]

The drainage basin of the smaller Ghost Lake accounts for the western 37% percent of the broader Island Lake watershed. Ghost Lakeös drainage basin is more intact than the broader watershed, with approximately 10% converted to agriculture[5] and little residential development. As discussed in Section 3, only a portion of the nutrients flowing into Ghost Lake from its drainage basin are released to Island Lake through the creek that links the two waterbodies. As such, water quality in Island Lake is more heavily influenced by the eastern two thirds of its watershed that does not lie within Ghost Lakeös drainage basin.

3. WATER QUALITY

Previous assessments have not identified significant water quality issues. The lake is well buffered against acidification (ALMS 2005, Mitchell and Prepas 1990), the water column is well aerated (ALMS 2005), and water clarity is reasonable (ALMS 2005). Of greatest concern are nutrient concentrations due to the positive effect of phosphorus and nitrogen on algal biomass. Algal blooms cause a variety of problems including decreased recreational value (e.g. unpleasant odour and unsightly conditions), and exposure of humans and wildlife to toxins released by blue-green algae. Rapid die-off of an algal bloom also depletes dissolved oxygen when the algae decompose, which can cause fish

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[4] Community Profiles based on 1991, 1996, 2001, and 2006 population censuses are available for Island Lake and Island Lake South at http://www12.statcan.ca/census-recensement/2006/dp-pd/prof/92-591/index.cfm?Lang=E.

[5] The composition of the Ghost Lake portion of the watershed was estimated based on information from Trew et al. (1987). Using runoff coefficients of 0.1 kg/ha/year and 0.5 kg/ha/year for forest and agricultural land, respectively, Trew et al. (1987) estimated that phosphorus loading from the 2201 ha Ghost Lake watershed was 304.2 kg/year. This implies a watershed composition of 1990.75 ha of forested land and 210.25 ha of agricultural land.

kills if depletion of dissolved oxygen is sufficiently severe. Island Lake does not experience algal blooms to the extent of neighbouring Baptiste Lake. However, nutrients and algal biomass appear to have increased in recent decades and the most recent water quality assessment concluded the lake to be eutrophic (i.e., highly productive) (ALMS 2005).

3.1 STATUS

Mesotrophic. Low health risk due to blue-green algae

The water quality of Island Lake was assessed using total phosphorus (TP) and chlorophyll-a data collected from Island Lake since 1983 (Alberta Environment 2005). While data for additional water quality indicators are available, these two indicators provide a succinct representation of water quality given the biophysical characteristics of the lake and the primary stressors. These indicators demonstrate that the lake is in a mesotrophic state and presents a low health risk due to blue-green algae. Although TP and chlorophyll-a concentrations increased between 1984 and 2005, insufficient data exist to assess whether the pattern represents directional trend (Alberta Lake Management Society 2005).

3.1.1 Total Phosphorus

Algae in Island Lake are phosphorus limited[6]. Within a given year, TP levels increase in the late summer, perhaps due to the release of phosphorus-rich water that has accumulated over sediments (Alberta Environment 1989). Although mean TP increased between 1984 and 2005[7,] insufficient data exist to examine temporal trend (Alberta Lake Management Society 2005). The change in mean TP between years could be the result of differences in the timing of sampling and interannual variation in TP between years, rather than differences in the overall phosphorus concentration of the lake. The increase in maximum TP between 1984 and 2005 (Figure 4) also suggests that phosphorus levels have risen, but this result may be an artifact of whether timing of data collection in a given year happened to coincide with the timing of high phosphorus concentration for that year. More frequent water quality sampling is needed at Island Lake to determine whether phosphorus levels have indeed changed over time.

Using TP concentration as an indicator of trophic status (Kelker 2000), mean concentrations indicate that Island Lake was mesotrophic across all years sampled. Maximum concentrations indicate that the lake became eutrophic in the late summer of

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[6] Algae require a nitrogen to phosphorus ratio of 7.2 to 1 (Trew et al. 1987). The mean ratio of total nitrogen to total phosphorus from water quality data collected from Lake Baptiste between 1983 and 2006 was 42, and the lowest recorded ratio was 17. The consistently high ratio demonstrates that nitrogen is available in excess relative to phosphorous.

[7] Water quality data was also collected in 2006. However, only one sample was collected relative to the 6 to 7 samples collected in 1983, 1984 and 2005. Comparing the sample with mean water quality across samples from the other years could be misleading because it does not capture interannual variation. Therefore, the 2006 sample was excluded from the analysis.

2005. Unlike neighbouring Baptiste Lake, however, phosphorus levels did not reach hypereutrophic levels.

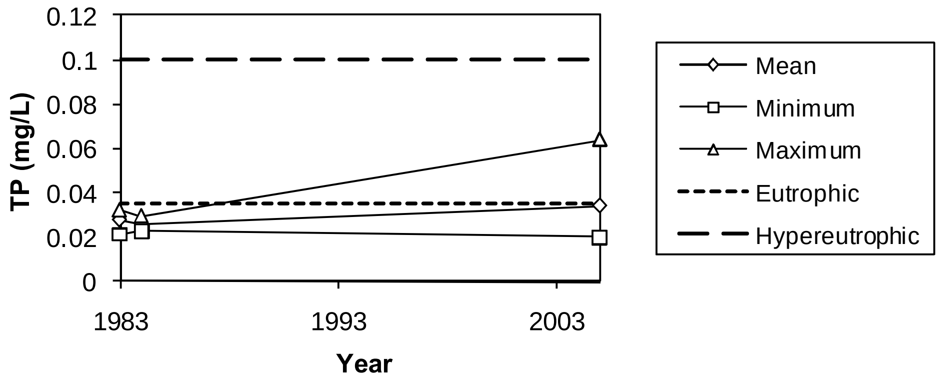

Figure 4. Mean, minimum and maximum yearly TP concentrations at Island Lake between 1983 and 2005. TP concentrations exceeding the ŕEutrophicò line indicate that the lake is eutrophic. Thresholds between trophic conditions are from Kelker (2000).

3.1.2 Chlorophyll-a

Chlorophyll-a, a pigment produced by plants, increases in concentration during periods of high algal growth. High algal growth can present health risks if cyanobacteria (blue-green algae) are present because of the toxins that they produce. Although cyanobacteria were reported to have dominated the lakeĉs phytoplankton community by late August in 1983, a bloom did not occur (Mitchell and Prepas 1990) and nuisance blooms of cyanobacteria are reported to be infrequent (Alberta Environment 1989). To further assess the risk of adverse health effects at Island Lake, a World Health Organization guideline (WHO 2003) was compared to chlorophyll-a levels collected at the lake[8]. Although chlorophyll-a itself is not toxic, high levels of chlorophyll-a are indicative of high cyanobacterial growth and therefore cyanotoxins. The mean chlorophyll-a level at Island Lake did not exceed the low health risk guideline in 1984 and 2005, and only slightly exceeded the guideline in 1983. Maximum chlorophyll-a level exceeded the low health risk guideline in all years due to the increase in chlorophyll-a level in late summer. However, unlike Baptiste Lake, at no point did chlorophyll-a concentration exceed the moderate health risk guideline. Toxins from cyanobacteria therefore appear to pose only a low health risk.

Chlorophyll-a concentration is also an indicator of lake productivity. In all years, average chlorophyll-a concentration was at the low end of the range (8-25) considered

[8] According to the guideline, there is a relatively low probability of adverse health effects at 10 εg/L chlorophyll-a and a moderate probability of adverse health effects at 50 εg/L chlorophyll-a. At 10 εg/L chlorophyll-a, health risks are short-term symptoms such as skin irritation and gastrointestinal illness, and providing information for visitors to swimming areas is advised. At 50 εg/L chlorophyll-a, there is potential for long-term illness and swimming should be discouraged and risk advisory signs posted.

indicative of a eutrophic lake (Alberta Environment 2009). The lake was mesotrophic during the spring and early summer, however, as demonstrated by minimum chlorophyll-a concentrations that were consistently below 8 εg/L. Chlorophyll-a concentrations increased in the late summer, but did not exceed the hypereutrophic threshold of 25 εg/L.

Chlorophyll-a concentrations appear to be stable, but trend cannot be reliably assessed because data are only available for three years.

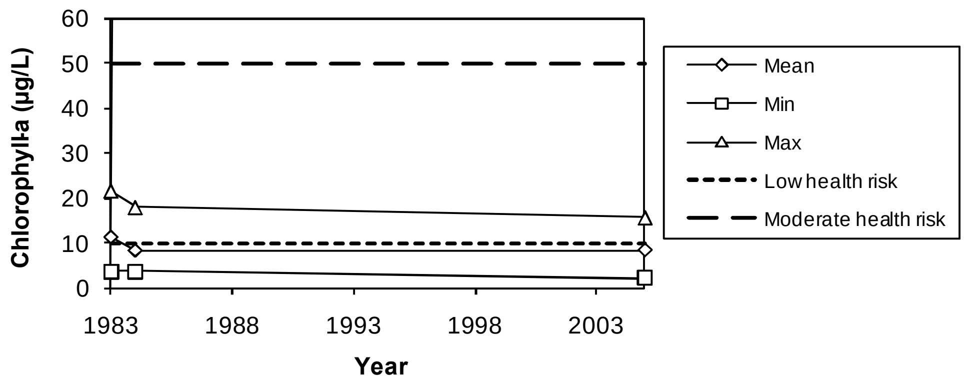

Figure 5. Mean, minimum and maximum yearly chlorophyll-a concentrations at Island Lake between 1983 and 2005. Chlorophyll-a concentrations were occasionally high enough to be considered a low health risk due to the presence of cyanotoxins, but remained well below the moderate health risk threshold after which swimming should be discouraged.

3.2 MANAGEMENT

Phosphorus and chlorophyll-a levels suggest that nutrification is not of immediate concern at Island Lake. Management of nutrient sources is still recommended, however, to avoid future increases in productivity that could degrade the lakeȏs ecological and cultural value. Alberta Environment (1989) provided a theoretical assessment of external phosphorus supply (Table 1). The assessment identified runoff from agricultural land as the largest source (37%) and sewage as the smallest source (2%). Although internal loading was not quantified, Mitchell and Prepas (1990) concluded that it may contribute more TP than all external sources combined. Opportunities to manage these and other potential contributors to eutrophication are now discussed.

Table 2. Theoretical external phosphorus supply to Island Lake (Alberta Environment 1989).

Source	Input (kg TP/year)	Percentage
Forest runoff	240	29
Agricultural runoff	296	37
Residential runoff	67	8
Precipitation, dustfall	172	21
Flow from Ghost Lake	25	3
Sewage effluent	16	2

3.2.1 Agriculture

Agricultural runoff can contain high levels of phosphorus from manure, fertilizer, and soil. Research in the neighbouring Baptiste Lake watershed reported that the rate of phosphorus export from a subwatershed containing cow-calf operations was over five times that of subwatersheds dominated by forest or cropland (Cooke and Prepas 1998). Based on results from Cooke and Prepas (1998), Carlson (2008) derived TP export coefficients for forest, cropland, and cow-calf operations of 12.25 kg/km^2/year, 13 kg/km^2/year, and 239 kg/km^2/year, respectively. These coefficients were applied to pasture area (1213 ha) in the Island Lake watershed (not including the Ghost Lake watershed)[9] to estimate that pasture may contribute as much as 2.5 tonnes TP/year in excess of natural (i.e., forest) levels.

The estimate that pasture runoff contributes 2.5 tonnes TP/year is a worst-case estimate that assumes that cattle have unrestricted access to streams and are fed and wintered next to streams at all pastures within the watershed. Further, the coefficients are based on in-stream measurements and do not account for potential uptake of phosphorus by fluvial sediments prior to reaching the lake. In contrast, Alberta Environment (1989) estimated that agriculture contributed 298 kg TP/year to Island Lake. Even at this lower estimate, however, agriculture is still the largest potential external source of phosphorus to Island Lake. As such, taking steps to minimize phosphorus export from agricultural land is important for limiting nutrification of Island Lake. As reflected by the high phosphorus export coefficient estimated for cow-calf operations (239 kg/km^2/year) relative to cropland (13 kg/km^2/year), management efforts should focus on cattle. Rotational grazing, alternate water sources, and fencing can be used to separate livestock from riparian areas (Alberta Agriculture, Food and Rural Development 2000). Also beneficial is the conservation of riparian areas due to their capacity to buffer aquatic systems from contaminated runoff. Of greatest importance is safe storage and disposal of the large

[9] Based on available AVI data, 21.8% of the watershed is estimated to be pasture and a further 5.8% is estimated to be cropland. Applying these percentages to the 6007 ha watershed results in pasture and cropland areas of 1310 ha and 348 ha, respectively. Approximately 13% of this agricultural land is estimated to be within the Ghost Lake subwatershed. Therefore, pasture and cropland area not including the Ghost Lake subwatershed is estimated to be 1140 ha and 303 ha, respectively.

amount of manure that accumulates at wintering areas. Phosphorus load associated with cattle generally occurs during spring runoff when accumulated manure from wintering sites can be washed away during high spring runoff events. At a Baptiste Lake subwatershed containing cattle operations, 75% of the phosphorus load was delivered during spring runoff (Cooke and Prepas 1998). Corrals and manure storage can be located away from waterbodies and berms, and ditches and lagoons can be built to prevent the transport of manure from wintering sites in surface runoff (Alberta Agriculture, Food and Rural Development 2000). At a wintering site in central Alberta, the diversion of manure runoff to a lagoon resulted in the elimination of all detectable phosphorus export (Wuite and Chanasyk 2003).

Ensuring that wintering sites do not contribute phosphorus to surface runoff is potentially the most influential strategy available for limiting phosphorus export to Island Lake. Such strategies are costly, however. Based on information gathered from a site in central Alberta, phosphorus load reductions achieved by diverting runoff and relocating wintering sites was estimated to cost $49 per kg TP and $75-108 per kg TP, respectively (Wuite and Chanasyk 2003). If such strategies are pursued, funding may be needed to help producers offset some of the costs.

3.2.2 Residential Wastewater

Residential wastewater contains high levels of phosphorus and therefore can contribute to eutrophication if wastewater is allowed to flow into the lake. The total phosphorus in wastewater created by the villages of Island Lake and Island Lake South is estimated to equal 0.5 tonnes TP per year[10]. Residences in the watershed are not connected to a central wastewater collection system but rather use holding tanks, septic tanks, pit toilets and gray water pits to dispose of domestic wastewater. Holding tanks, septic systems, and pit toilets, if managed properly, should not result in the flow of substantial nutrients into Island Lake. Wastewater that is pumped out of holding tanks in the region is disposed of at a sewage lagoon located a considerable distance from the lake. Septic systems are also likely to be effective given that the clay soils in the watershed have a high phosphorus retention capacity (Trew et al. 1987). Pit toilets are also unlikely to be a substantial source of nutrients provided that human sewage, and not also grey water, is deposited into the pit. In the absence of grey water, there is insufficient water in the sewage to allow significant flow of the sewage and accompanying nutrients beyond the pit. The clay soils in the watershed should also contribute to the capacity of pit toilets to retain sewage, and some pit toilets are lined to further prevent flow. However, in contrast to pit toilets, grey water pits are likely to result in phosphorus flow into lake water. Grey water is high in phosphorus and, due to the high volume of water usually sent to the pit in

[10] Based on data from the town of Athabasca, per capita TP production is estimated to be 0.93kg/year (Trew et al. 1987). The 456 residents (based on 2006 census) of the Summer Villages of Island Lake and Island Lake South are therefore estimated to produce 424 kg TP/year. In addition, the 160 dwellings that are not occupied by usual residents (based on the 2006 census) produce an estimated 77 kg TP/year, based on the assumption that the average occupancy of each non-resident dwelling is 0.52 capita-years per year (Trew et al. 1987). Therefore, total phosphorus production by the Summer Villages of Island Lake and Island Lake South is 501 kg TP/year.

surges, can flow through soil or overflow and move into the lake (Richard Zwicker, Executive Director, Rtd., Alberta Onsite Wastewater ContractorsôAssociation, pers. com.).

When estimating phosphorus loading from sewage at Island Lake, Alberta Environment (1989) assumed that 4% of sewage effluent enters the lake. When this factor is applied to the estimated 0.5 tonnes TP that is produced annually by the villages of Island Lake and Island Lake South, a loading estimate of 20 kg TP per year is derived. As such, wastewater is likely a small contributor of phosphorus to Island Lake. However, the high quantity of phosphorus contained in wastewater (i.e., an estimate 0.5 tonnes TP per year) emphasizes the importance of ensuring that wastewater does not enter the lake. The most important practice is to eliminate the use of grey water pits at all lakeshore dwellings. Additional practices focus on maintaining waste water disposal systems in proper working order. Overflowing of holding and septic tanks must be avoided, and owners should be diligent in locating and fixing leaks. Pit toilets should be lined to prevent seepage of sewage during high runoff events.

3.2.3 Forest Conversion

Anthropogenic footprints such as roads, residential lots, and oil and gas infrastructure can increase phosphorus levels in runoff due to increased exposure of soil to water and wind and perhaps increased mineralization of phosphorus. Information on phosphorus export from anthropogenic footprint is limited. The Maine Department of Environmental Protection (2000) estimated that phosphorus export from all road types is 3.5 kg TP/ha/year and that phosphorus export from residential lots, not including septic systems, is 0.25-0.35 kg TP/ha/year. Coefficients for oil and gas footprints such as pipelines, seismic lines, and well sites were not provided. In the absence of coefficients, it is assumed that the export coefficient for roads (3.5 kg TP/ha/year) applies to oil and gas infrastructure. Applying the coefficients to the area of roads (76 ha)[11], residential footprint (208 ha), and oil and gas infrastructure (94 ha)[12], phosphorus export from footprint is estimated to be 657 kg TP/year. This estimate should be regarded as highly uncertain due to the paucity of information on phosphorus runoff rates from anthropogenic footprints. For example, if oil and gas infrastructure are assumed to instead cause no increase in phosphorus runoff, the total estimated phosphorus export from footprints is reduced from 675 to 328 kg TP/year.

[11] Based on analysis of a linear footprint dataset, Island Lake is estimated to contain 23 km of 2 lane road, 29 km of unimproved road, and 6 km of truck trails. Based on typical widths in the neighboring Alberta Pacific Forest Management Agreement Area, 2 land roads were assumed to be 24 m wide and unimproved road and truck trails were assumed to be 6 m wide. The total area of road in the watershed is therefore estimated to equal 76 ha.

[12] Based on analysis of a linear footprint dataset, Island Lake is estimated to contain 130 km of seismic lines and 23 km of pipelines. Based on typical widths in the neighboring Alberta Pacific Forest Management Agreement Area, seismic line and pipeline widths were assumed to be 4.5 m and 15 m, respectively. The total area of oil and gas infrastructure in the watershed is therefore estimated to equal 94 ha.

Phosphorus loading from anthropogenic footprint may increase in the future if forest conversion continues. Residential footprint will likely grow to accommodate a growing population; continued gas exploration would require new wells, pipelines, and seismic lines; and the road network may also expand. However, gradual reclamation of abandoned industrial footprint may at least partially offset the growth in new footprint. Indeed, a scenario analysis for neighbouring Baptiste Lake concluded that reclamation of existing gas infrastructure had the potential to offset growth in residential footprint and roads (Carlson 2008). Nevertheless, minimizing future expansion of anthropogenic footprint will serve to reduce phosphorus export to Island Lake.

Due to the high potential phosphorus export coefficient associated with cattle, expansion of agriculture could cause phosphorus loading at Island Lake to increase in the future. A proactive management strategy to manage future increases in phosphorus loading could be to plan land use such that future conversion of land to agriculture in the watershed is limited. The cost of restricting agricultural expansion is likely low given that soils in the watershed have severe to very severe limitations for agriculture[13]. Perhaps reflecting its low economic viability, agricultural expansion in Athabasca County No. 12 between 2001 and 2006 was limited to 0.015% per year[14].

3.2.4 Ghost Lake

The western 37% of the Island Lake watershed flows into Ghost Lake prior to entering Island Lake through a creek. Ghost Lake therefore acts as a trap for a substantial portion of phosphorus export from the broader Island Lake watershed. Trew et al. (1987) estimated that 76% of phosphorus input to Ghost Lake is retained and that the remaining 24% is ultimately transported to Island Lake. Based on an estimated composition of 1991 ha of forest, 170 ha of pasture, and 45 ha of cropland, and assuming the phosphorus export coefficients discussed previously[15], phosphorus input to Ghost Lake is estimated to equal as much as 656 kg TP per year. This is a maximum estimate that assumes that cattle manure runs off into tributaries. If phosphorus retention by Ghost Lake is 76%, phosphorus input to Island Lake from Ghost Lake is estimated to equal as much as 157 kg TP per year. Avoiding future increases in phosphorus input from Ghost Lake hinges on preventing runoff from cattle operations and limiting forest conversion in the Ghost Lake watershed, as discussed previously for the Island Lake watershed.

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[13] Soils in the watershed are associated with land capability classes 4 and 5from the Soil Capability Classification of Agriculture (http://geogratis.cgdi.gc.ca/cgi-bin/geogratis/cli/agriculture.pl). Soils in class 4 ñhave severe limitations that restrict the range of crops or require special conservation practicesò. Soils in class 5 ñgave very severe limitations that restrict their capability in producing perennial forage cropsò.

[14] Between the 2001 and 2006 agriculture censuses, farm area in Athabasca County No. 12 grew only slightly from 2,802.59 km^2 (Statistics Canada 2008a) to 2,804.68 km^2 (Statistics Canada 2008b), which is equivalent to an annual growth in farm area of 0.015% relative to 2001.

[15] Based on results from Cooke and Prepas (1998), Carlson (2008) derived TP export coefficients for forest, cropland, and cow-calf operations of 12.25 kg/km^2/year, 13 kg/km^2/year, and 239 kg/km^2/year, respectively.

3.2.5 Internal Loading

Phosphorus occurs in high concentration in lake sediments and can be solubilized into porewater and released into lakewater, a process referred to as internal loading. Internal loading may be highly significant at Island Lake due to its shallow depth (Trew et al. 1987). Most of the lake is less than 6-m deep such that the majority of sediments release phosphorus directly to the euphotic zone (Mitchell and Prepas 1990)[16]. Evidence of the release of phosphorus from sediments is that phosphorus concentration at the sediment-water interface at Island Lake was found to be three times greater than in the euphotic zone (Shaw and Prepas 1990). Based on the phosphorus concentration of sediment porewater, the potential rate of release of soluble reactive phosphorus (SRP) from sediments was estimated to equal 0.1 mg m^{-2} d^{-1} (Shaw and Prepas 1990). This release rate is lower than Baptiste (0.3 mg SRP m^{-2} d^{-1}), but Island Lakeôs shallower depth means that much more of the phosphorus is released directly to the euphotic zone.

Although internal loading at Island Lake may exceed all external phosphorus sources combined (Mitchell and Prepas 1990), practical opportunities to manage internal loading likely do not exist. As discussed in more detail by Carlson (2008), treatment options are either ineffective, cost prohibitive, or have unacceptable side effects. Oxygenation or iron application to reduce the rate at which phosphorus is released from sediments was determined to be ineffective based on testing using sediments from Baptiste Lake and two other nearby lakes (Burley et al. 2001). Application of aluminum to form phosphorus precipitates was effective at reducing lakewater phosphorus, but is problematic due to aluminum toxicity concerns (Burley et al. 2001). Lime application to form phosphorus precipitates was also effective at reducing lakewater phosphorus (Burley et al. 2001), but is likely cost prohibitive (Carlson 2008). An alternative to chemical treatments are in-lake physical controls such as withdrawal of phosphorus rich water from the hypolimnion or artificial circulation to achieve destratification. However, these techniques are likely to be cost prohibitive (Carlson 2008) and their effectiveness is suspect given that stratification does not occur across most of the lake due to its shallow depth.

3.2.6 Climate

In the coming decades, temperature and precipitation is expected to increase in the forest region of the Prairie Provinces in response to climate change (Sauchyn and Kulshreshtha 2008). Higher precipitation will cause increased stream flow and potentially increased external input of phosphorus to the lake (Schindler 2006). At the same time, higher temperatures will cause increased evaporation. If loss of lake water due to evaporation outweighs the addition of water from increased precipitation, residence time[17] will increase. Increased residence time causes the concentration of chemicals to increase,

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[16] Phosphorus release from sediments tends to be more influential in shallow lakes because the phosphorus is released directly into surface waters where it can support algal growth. In contrast, phosphorus from sediments in deeper lakes is released into the hypolimnium and does not reach surface waters until lake mixing.

[17] Residence time refers to the time needed to replace the volume of the lake with inflowing water.

resulting in increased phosphorus concentration and eutrophication (Schindler 1998). Changes in residence time have the potential to have a large impact; a doubling of residence time has roughly the same impact on lake phosphorus concentration as does doubling phosphorus input (Schindler 1978). Climate change may also increase the relative abundance of cyanobacteria bacteria, many of which prefer warmer water (Paerl and Huisman 2008). As a result, the extent and toxicity of algal blooms may both increase.

The impact of climate change on lake phosphorus concentration is difficult to manage because of the phenomenonȢs global scale. Residence time, and therefore phosphorus concentration, could conceivably be reduced by increasing outflow from the lake, although the benefit might be at least partially offset by an associated decline in lake level. A decline in lake level could also negatively affect other values such as fish spawning habitat and boating. As a result, attempting to increase lake outflow is not recommended. Rather, the potential for climate change to increase nutrification emphasizes the importance of minimizing other sources of phosphorus discussed in this report.

3.2.7 Trophic Cascade

While nutrient input is an important control on primary productivity, the effect of trophic cascade may be similar in magnitude (Carpenter and Kitchell 1987). Northern lakes, including Island, typically display a simple trophic structure with four levels: piscivorous fish (walleye and pike), which feed on planktivorous fish (perch, cisco, etc.), which feed on zooplankton, which feed on phytoplankton. Studies have demonstrated that a decline in piscivore abundance can cause planktivore abundance to rise due to reduced predation pressure (Schindler 2006). A rise in planktivore abundance causes predation pressure on zooplankton to increase, with the result that larger zooplankton species in particular decrease in abundance. The decreased abundance of large-bodied zooplankton ultimately causes phytoplankton to increase. This process, called trophic cascade, can cause large changes to the phytoplankton community. For example, a lake from which piscivorous fish were removed displayed primary productivity that was six times higher than a lake with an intact fish community (Carpenter et al. 2001). Research has also demonstrated that lakes with healthy piscivorous fish communities may not experience high algal production even when nutrient levels are high due to the ability of abundant zooplankton to control algal biomass (Carpenter et al. 1995).

Island Lake is likely susceptible to trophic cascade due to its simple food chain. Also contributing to the lakeȢs susceptibility is the abundance of Daphnia (Mitchell and Prepas 1990), a type of zooplankton that can enhance the trophic cascading effect (Schindler 2006). Most importantly, populations of piscivorous fish have likely collapsed due to over-fishing. The importance of trophic cascade to Island LakeȢs productivity is supported by differences in trophic status as assessed by phosphorus vs. chlorophyll-a concentration. Phosphorus concentration is an indirect measure of trophic status and in effect assumes that phosphorus is the primary mechanism responsible for lake productivity. Chlorophyll-a concentration, on the other hand, provides a direct measure of trophic status. The average phosphorus concentration across available water monitoring data (1983, 1984, and 2005) indicated a mesotrophic lake, whereas the average chlorophyll-a concentration from the same data set indicated a eutrophic lake (Alberta Environment 2009). The tendency for phosphorus concentration to underestimate the algae concentration as indicated by chlorophyll-a suggests that another mechanism is also contributing to the lake's productivity. This mechanism may be trophic cascade caused by over-fishing. Restoring fish populations may therefore serve to curtail algal growth caused by phosphorus loading. An important exception is that grazers (i.e. zooplankton) appear to have little influence on blue-green algae (Carpenter et al. 1995, Carpenter et al. 2001). Therefore, while overall algae growth may be reduced by restoration of the walleye and northern pike fisheries, control of blue-green algae must rely on controlling nutrient levels.

4. FISHERIES

The fish community at Island Lake includes lake whitefish (*Coregonus clupeaformis*), northern pike (*Esox lucius*), white sucker (*Catostomus commersonii*), yellow perch (*Perca flavescens*), and walleye (*Sander vitreus*). The lake is known for its large whitefish, and supports a modest whitefish commercial fishery every second year (Boyd 2010). Unfortunately, data from which to assess status and trend of Island Lake's fisheries are limited. Here, we use commercial harvest data, a historical fish survey, and 2008 index netting and seining results to assess the status of the white fish, northern pike, and walleye fisheries.

4.1 STATUS

Stable whitefish fishery, degraded northern pike fishery, and collapsed walleye fishery

The whitefish fishery appears to have remained stable or perhaps improved in recent decades. Commercial harvest from 1992 to 2008 averaged 11,585 kg per year (Heather Lovely, Sustainable Resource Development, pers. comm.). In comparison, the highest commercial harvest before this period was 8,963 kg in 1958/59 (Mitchell and Prepas 1990). Although recent harvest exceeds historical levels, it is uncertain whether this reflects an improved quality of the fishery or higher fishing pressure. Between 1992 and 2009, commercial catch rates fluctuated with no apparent trend (Figure 6).

In contrast to whitefish, it appears that the northern pike fishery has declined. The highest recorded commercial harvest of northern pike was 2381 kg in 1947/48 (Mitchell and Prepas 1990), but declined to sporadic catches by the 1960s (Valastin and Sullivan 1996). Commercial harvest data from 1992 to 2009 indicate an average harvest of just 127 kg per year (Heather Lovely, Sustainable Resource Development, pers. comm.). The decline in commercial harvest is consistent with findings from a historical survey of the lake's sport fishery based on interviews with residents from the region (Valastin and Sullivan 1996). Those interviewed spoke of high catch rates, and sizes in the range of three to eight pounds. The survey concluded that the lake's pike fishery, which at one time was very good, has declined. The current status of the lake's northern pike fishery is somewhat uncertain because fisheries management research is insufficient (Boyd 2010). An index net survey completed in 2008 found northern pike to be the most abundant species, but large pike (>63 cm) were rare (Boyd 2010). The index net survey is designed for assessing the status of the walleye fishery, and standards for assessing the status of the pike fishery from net survey results are not yet available. However, based on the outcome of the index net survey, the allowable catch for northern pike was reduced from 3 fish over 63 cm to 1 fish (no size limit). A lake inventory was also completed at Island Lake in 2008 (Morgan 2008). Seining at six sites found one north pike, in addition to 125 yellow perch and one white sucker.

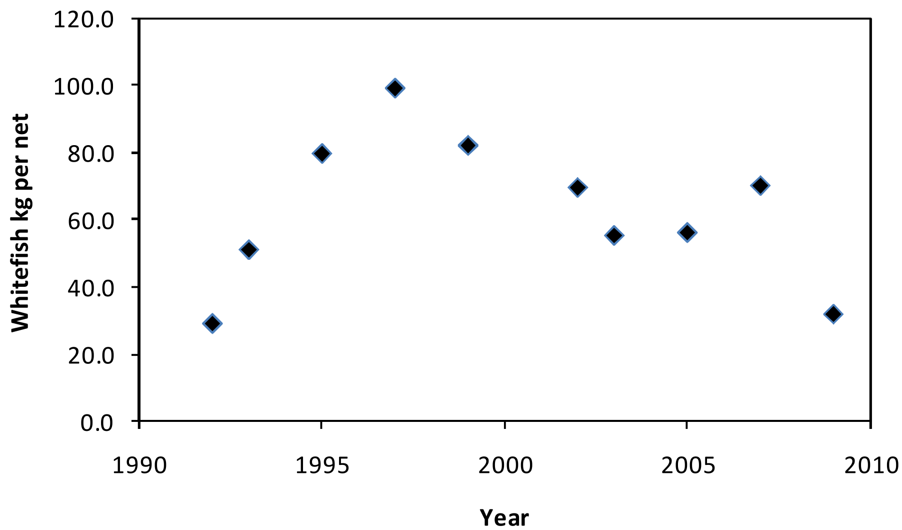

Figure 6. Island Lake whitefish commercial catch per net. Data provided by Heather Lovely, Sustainable Resource Development.

Based on the fall walleye index netting survey completed in 2008, the walleye population at Island Lake was assessed as collapsed (Boyd 2010). Out of 66 lakes surveyed in Alberta, Island Lake had the 6th lowest walleye catch per unit effort, with 1.0 fishÅ100m^{-2}Å24hrs^{-1} compared to a provincial average of 18.1. Despite the existing angling regulation of catch and release, recovery of the walleye fishery is thought to be unlikely (Boyd 2010). Indeed, commercial harvests have always been sporadic and a historical survey concluded that the lake may have never supported a widespread fishery for walleye (Valastin and Sullivan 1996).

In summary, while Island Lake appears to support a stable whitefish fishery, the northern pike fishery has declined and the walleye fishery is collapsed. Overall, the status of the fishery is assessed as poor due to the degraded status of northern pike and walleye populations. These species are of particular importance from a management perspective due to their value to the recreational fishery, position atop the aquatic food web, and sensitivity to stressors such as angling (Post et al. 2002).

4.2 MANAGEMENT

4.2.1 Angling

Unsustainable rates of angling have caused wide-spread declines in Albertan recreational fisheries (Post et al. 2002), and sustainable management of angling is likely important to the recovery of Island Lakeês fish populations. The almost complete absence of large (>63 cm) pike in the 2008 index net survey suggests that angling pressure is too high to sustain a quality fishery. As discussed by Carlson (2008) in the context of nearby Baptiste Lake, strict regulations such as catch and release or a moratorium are likely needed to improve the status of recreational fisheries in the region. More moderate regulations (slot size limits, shortened seasons) are unlikely to be successful because lakes in northern Alberta are susceptible to angling due to their low productivity and high angling pressure in the region. The current regulation for northern pike at Island Lake is an allowable catch of 1 fish (no size limit), while the walleye fishery is limited to catch and release but is not expected to recover (Boyd 2010). Further research is needed to assess the status of the northern pike fishery and identify suitable regulations.

4.2.2 Stream Crossings

Where roads intersect streams (i.e. watercourse crossings), upstream fish passage is potentially impeded with negative implications for recruitment due to decreased access to spawning areas. Of 27 watercourse crossings in the watershed, one is by bridge and the remainder use culverts[18] (Stanislawski 2008). If undersized, improperly installed, or poorly maintained, culverts can prevent fish passage due to high water velocity within the culvert, blockage within the culvert, or hang. A hanging culvert develops when water exiting a culvert scours the stream bed and, over time, causes the downstream end of a culvert to hang above the stream water level, thereby impeding upstream movement of fish into the culvert (Park et al. 2008).

A survey of watercourse crossings in the Island Lake watershed and outlet creek (Figure 7) was conducted in August 2008 (Stanislawski 2008). The culverts were generally found to be in poor condition. More than half (58%) of culverts used at watercourse crossings were found to be not draining properly, 85% exhibited distortion[19], and at least 45% had inlets or outlets that were not embedded and/or overhanging. Streams in the watershed are generally too small to support fisheries but are likely used during spawning runs (Valastin and Sullivan 1996). Of the 26 watercourse crossings that used culverts, eleven were rated as having fish or the potential for fish at least on a seasonal basis[20] (Stanislawski 2008). These crossings, for the most part, were located along the inflow creek from Ghost Lake and outflow creek from Island Lake. Six of the fish rated

[18] One further watercourse crossing exhibited drainage and should have had a culvert, but no culvert was evident. In addition, culverts were used at three road cross-drain sites, which refers to waterflow across a road that is not part of a natural watercourse.

[19] Distortion refers to a crushed culvert inlet and/or outlet, vertical or horizontal compression of the culvert, or bending of the culvert (i.e., banana shape).

[20] Potential for fish presence was based on a variety of parameters including presence of fish habitat, channel size, proximity to larger bodies of water, and seasonal discharge.

crossings presented one or more impediments to fish movement. The most prevalent impediment to fish movement was blockage by beaver activity (five crossings), followed by overhang (two crossings), and high water velocity (one crossing).

Stanislawski (2008) also assessed sedimentation problems at watercourse crossings. Introduction of sediment into streams from the roads was found at just one crossing but an additional eight crossings contributed sediment from erosion of the culvert. In no case was the introduction of sediment sufficient to cause visible downstream sediment transport. In addition, the watercourse crossings where sediments were deposited were not fish bearing. In summary, the introduction of sediments at crossings did not appear to be a major impact and is not considered further in this report.

Stanislawski (2008) provides that following recommendations to mitigate the problems observed at watercourse crossings. Blocked culverts should be cleaned-out by work crews with spades. Hanging culverts should be replaced, as should culverts with high water velocity due to being of an insufficient size. Crushed inlets or outlets should be straightened. Fish bearing watercourses should be given priority, and maintenance efforts should initially focus on easier fixes (i.e., culvert cleaning and straightening as opposed to replacement). New culverts should be large enough to handle maximum water flows, placed in direction of the watercourseôs flow, and embedded at least 25% below the stream bed. To minimize future damage to culverts, crossing markings should be installed and maintained at both culvert ends to prevent impacts by graders, mowers, and brush removers which can damage culverts and constrict flow. Culverts should be monitored on an annual basis, and during above average water flows.

Although watercourse crossings are problematic, angling pressure is the more serious threat to fish populations at Island Lake. Spawning runs during wet years would likely be insufficient to recover the fishery if angling pressure is not also reduced. However, combined with the implementation of a catch-and-release fishery or fishing moratorium, repair or replacement of substandard culverts would increase the likelihood of the fishery recovering by increasing recruitment during wet years.

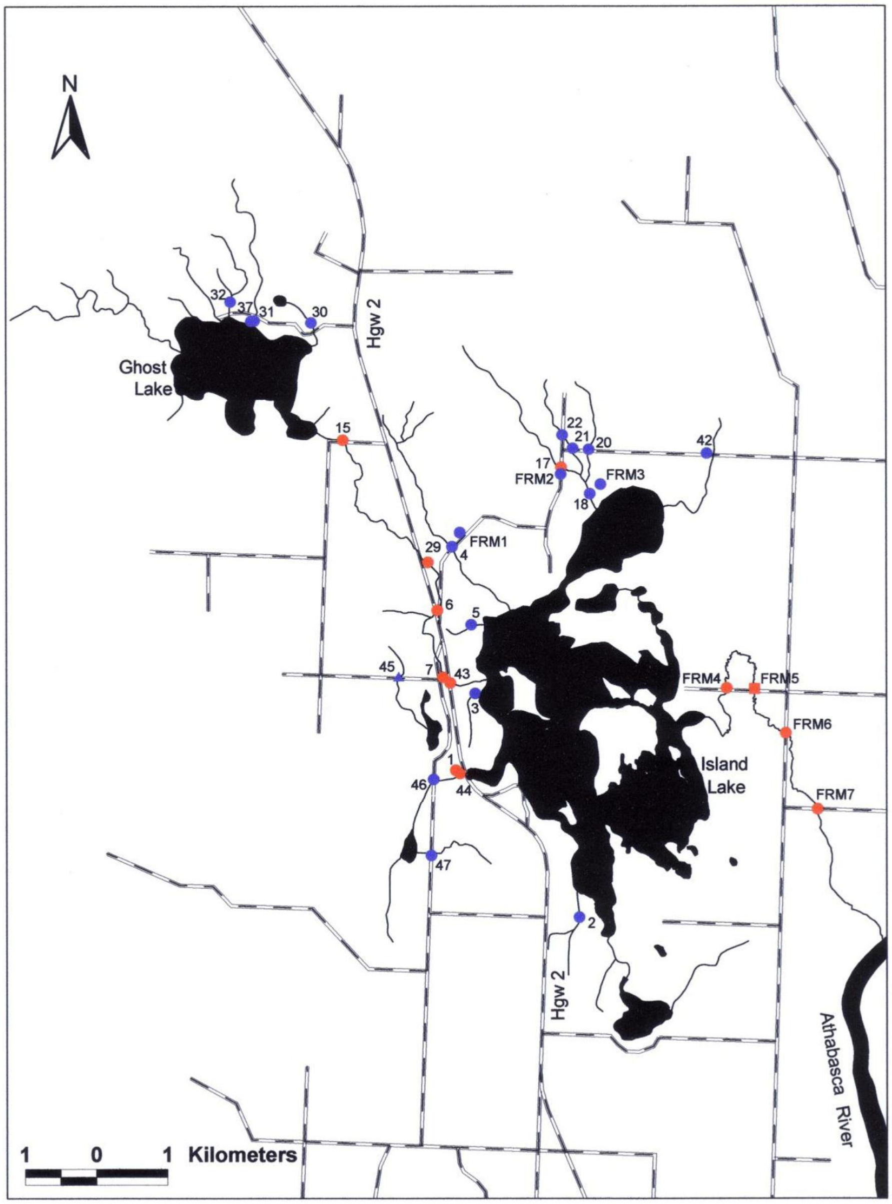

Figure 7. Map of the Island Lake drainage including major highways and roads and the 31 watercourse crossing/drainage sites surveyed from August 23, 2008 to August 26, 2008. Culverts are represented by circles, no-culvert site is represented by a triangle and bridge is represented by a square. Sites rated as having fish are represented by red symbols and sites rated as having no fish are represented by blue symbols.

5. LAKE WATER LEVEL

5.1 STATUS

Below normal

From 1996 to 2002, Island Lakeôs water level dropped 0.86 m from its third highest to its lowest level since monitoring began in 1968 (Figure 8)[21]. Although the water level has stabilized since then, the water level remained 0.38 m below the long-term average in 2009. The sustained period of low water level may have negative implications for the ecology of the lake. Declining water level has likely exposed shoreline weedbeds with negative implications for fish spawning and nursery habitat. If the decline in water level is the result of reduced inflow, the lakeôs residence time may have increased which could contribute to eutrophication by increasing nutrient concentrations over time. The low water level is also reported to be negatively impacting the lakeôs recreational value. The boat launch at the north end of the lake is reported to be out of the water and unusable, and some landowners have extended their docks into the lake to accommodate the low water level[22].

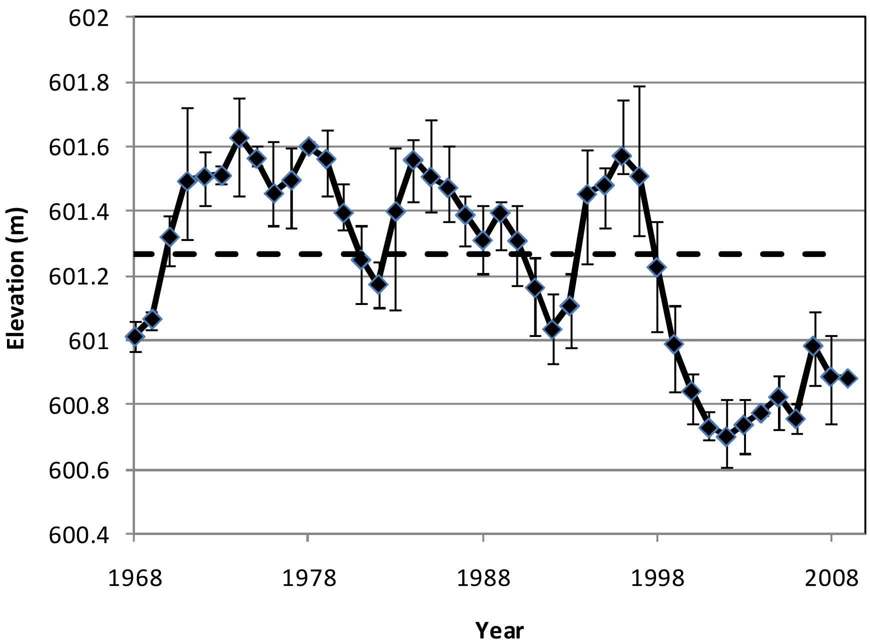

Figure 8. Lake level at Island Lake between 1968 and 2009. Water level is typically measured multiple times each year. Lake levels in the figure reflect the mean water level measurement for a given year, with the error bars representing maximum and minimum recorded water levels. The dotted line represents the average lake level across years.

[21] Island Lake water level data were provided by Mike Coffill, Alberta Environment.
[22] Reported by Jim Montague is his letter to BISL dated July 6, 2010.

The decline in lake level is likely in part attributable to changes in precipitation (Figure 9). Annual precipitation was below the long-term average each year during the period of rapid decline in Island Lakeôs water level (1997-2002). This is the longest consecutive string of years with below average rainfall during the period for which water level data exist. Further, 1997-2002 contains the three lowest levels of precipitation between 1968 and 2006. The average precipitation during the period of 1997 to 2002 was 377 mm. This is a 25% decline relative to the preceding period of 1968 to 1996. When this drop in precipitation is compared to the balance between inflow (i.e., from precipitation through runoff) and evaporation, it is apparent that a negative water balance at the lake may have occurred. Based on estimates from Alberta Environment (1989), total inflow is approximately 25% higher than total evaporation[23]. A 25% decline in precipitation could therefore result in a negative water balance when the approximate nature of the data, as well as outflow from the lake and water withdrawals[24], are considered. Also contributing to the decline in lake level may have been increased evaporation. Evaporation is positively affected by temperature, and higher than average temperatures occurred four out of six years between 1997 and 2002 (Figure 10).

[23] According to Alberta Environment (1989), total inflow to Island Lake is 6.8 x 10^6 m^3/year and evaporation is 5.0 x 10^6 m^3/year.

[24] Based on the 2006 census, the Summer Villages of Island Lake and Island Lake South have a population of 456 residents plus 160 dwellings not occupied by usual residents and are assumed to have an occupancy of 0.52 capita-years per year (Trew et al. 1987). Including occassional residents, the total occupancy at the villages is estimated to be 539 per-capita years per year. In 1999, average household use of water in Canada was 343 liters per capita per day (, or 125,195 liters per capita per year. Applying this consumption rate to Island Lakeôs occupancy of 539, water consumption is estimated to equal 67,480 m^3. However, it is no known what portion of Island Lake household water consumption is withdrawn from Island Lake.

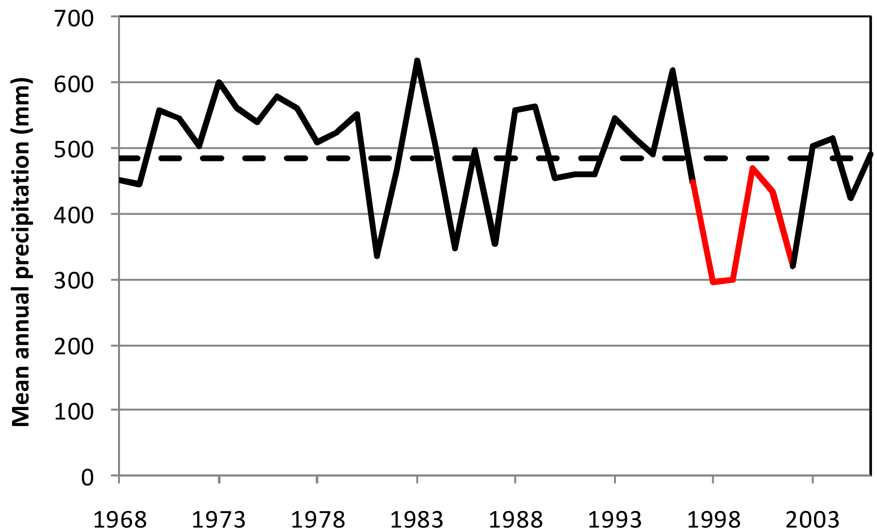

Figure 9. Mean annual precipitation at Island Lake between 1968 and 2006. The red portion of the time series identifies years during which Island Lakeǒs water level rapidly declined (1997-2002). Precipitation data are from ClimateAB v3.21, a program that provides interpolated climate data for Alberta (Wang et al. 2008).

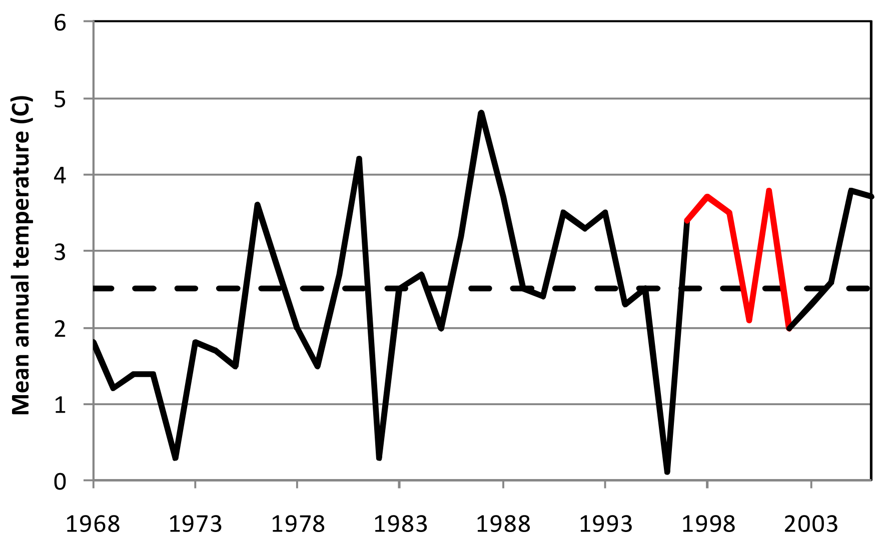

Figure 10. Mean annual temperature at Island Lake between 1968 and 2006. The red portion of the time series identifies years during which Island Lakeǒs water level rapidly declined (1997-2002). Temperature data are from ClimateAB v3.21, a program that provides interpolated climate data for Alberta (Wang et al. 2008).

Other potential factors contributing to the decline in water level at Island Lake include changes in inflow from groundwater and/or Ghost Lake, water withdrawals, and outflow to the Athabasca River. Groundwater accounts for only a small proportion (~4%) of total water inflow at Island Lake (Mitchell and Prepas 1990) and is therefore unlikely to account for changes in lake level. Water withdrawals at the lake are unknown but also likely have a minor impact given the low population density in the watershed and the absence of industrial withdrawals. Inflow from Ghost Lake may be restricted by culverts at watercourse crossings along the creek. Two of the five culverts along the creek are not draining properly due improper installation and beaver activity (Stanislawski 2008), and this could negatively affect the lakeŏs water level. Conversely, blockage of a culvert along Island Creek by a beaver dam may be reducing outflow (Stanislawski 2008) and therefore positively affecting the lakeŏs water level. However, a community member has expressed concern that outflow through Island Creek may have actually increased in recent years and contributed to the decline in the lakeŏs water level. The community member reports that a beaver dam restricted outflow from the lake in the past and caused the lakeŏs water level to increase.

In summary, Island Lakeŏs water level has decreased substantially in recent years with negative implications for ecological and cultural values. Lower than average precipitation has likely contributed to the decline in water level. Water withdrawals and blocked culverts may have also affected water level, but data are not available to assess their relative importance.

5.2 MANAGEMENT

The sustained period of below average water level at Island Lake is likely of concern to residents due to its negative affect on boating and shoreline access. While it seems likely that the low lake level is driven by climate, the relative importance of various sources of inflow and outflow is uncertain in the absence of current measurements; this uncertainty makes it difficult to prescribe management recommendations. Completion of a water balance study, informed by measurements of inflow, outflow, and withdrawals, would improve capacity to make informed management decisions regarding the lakeŏs water level.

Human activities that serve to reduce inflow or increase outflow from the lake will negatively affect the lakeŏs water level and should be minimized. Culverts with drainage problems along streams entering the lake may be reducing inflow, and should be fixed. The creek linking Ghost and Island Lakes is the largest source of inflow, and maintenance of problem culverts along that creek should be prioritized. Water withdrawals from Island Lake should also be minimized.

Installation of a weir at the lakeŏs outlet (Island Creek) has been suggested as a strategy to increase water levels at the lake. However, the effectiveness of a weir at controlling water level is uncertain. The rate of outflow through Island Creek has not been measured, but it has previously been described as having limited flow (Mitchell and Prepas 1990). Further, a study of watercrossings along the creek found that the watercourse crossing closest to the lake was blocked by a beaver dam resulting in significant upstream flooding, which also suggests that flow through the creek may be limited. As recommended previously, an assessment of the lakeŏs water balance is needed to provide updated information on the importance of various factors affecting the lakeôs water level, including outflow. However, if flow through Island Creek is limited, installation of a weir may not have a large impact on the lakeôs water level. Precipitation and evaporation are generally the primary determinants of a lakeôs water level, and variability in climate could continue to cause fluctuation in water level even after the installation of a weir (Mitchell and Prepas 1990).

Installation of a weir could also negatively impact the lakeôs ecology. A weir could pose a barrier to upstream fish migration from the Athabasca River, which would isolate the lakeôs fish populations with negative implications to their long-term viability. Island Creek is a fish bearing stream, and impeding fish movement through the construction of a weir would likely be in contravention of the Fisheries Act. Installation of a weir could also degrade the downstream environment along Island Creek due to reduced flow. If the weir successfully reduced water level fluctuation, the lakeôs fish habitat may decline. Natural fluctuations in water level act to maintain plant diversity in aquatic systems, which in turn supports a diversity of fish species (Schindler et al. 2004). Restricting outflow through the installation of a weir would also reduce the rate of water renewal at the lake, leading to increased nutrient concentrations and potentially eutrophication (Schindler et al. 2004).

6. SHORELINE CONDITION

Shoreline vegetation is abundant at Island Lake. Emergent vegetation is most plentiful in the northeastern region of the main basin, along sections of the north and south shores, around islands, and along the north shore of the north basin (Mitchess and Prepas 1990). The most common species are Bulrush (*Scirpus* sp.) and water lilies (*Nuphar* sp.), with lesser amounts of cattail (*Typha* sp.), sedge (*Carex* sp.), pondweeds, (*Potamogeton* sp.) and northern water milfoil (*Myriophyllum exalbescens*).

By dampening the energy of wave action and holding soils in place, shoreline vegetation helps limit erosion (Association of Summer Villages of Alberta 2006). Shoreline vegetation also protects water quality by removing nutrients from runoff. In addition to these services, the shoreline zone sustains the greatest diversity of plants and animals in a lake ecosystem (Valastin 1999). Aquatic plants produce oxygen for fish and provide spawning and rearing habitat for many species including northern pike which attach their eggs to the stalks of plants. Other types of animals supported by shoreline vegetation include birds, amphibians, reptiles, and some mammals such as muskrat (Chambers 2004).

Shoreline vegetation can also be considered a nuisance to boaters and shoreline residents, and indeed the density of shoreline vegetation at Island Lake has previously been considered excessive by lake users (Mitchell and Prepas 1990). Shoreline vegetation is sometimes cleared at residences to improve waterfront access. However, clearing of lakefront vegetation can increase shoreline erosion, degrade habitat, and increase nutrient input (Valastin 1999).

6.1 STATUS

To be determined based on shoreline vegetation survey completed by BISL

6.2 MANAGEMENT

Disturbance to shoreline vegetation and substrate should be minimized to maintain and restore shoreline condition (Valastin 1999). According to Alberta's Municipal Government Act, lake shorelines are environmental reserves to prevent pollution and provide public access, and cannot be altered without permission from the municipal authority (Association of Summer Villages of Alberta 2006). In addition, modification of beds or banks of a lake requires prior approval from the Public Lands and Forest Division and Alberta Environment (Association of Summer Villages of Alberta 2006). However, most property owners are likely not aware of these policies that are intended to protect the shoreline environment (McMillan 2000). Enhanced communication and regulation of the environmental reserve at Island Lake could protect the integrity of the lake's shoreline.

7. CONCLUSIONS AND RECOMMENDATIONS

Assessment of the health of Island Lake was hindered by knowledge gaps. Of greatest concern are infrequent monitoring of water quality, irregular monitoring of fisheries, and lack of a current water balance study. Filling these knowledge gaps will improve capacity to monitor and manage the health of Island Lake.

Sufficient information was available, however, to assess the general condition of Island Lake. The lake's water level is below average. Water quality is relatively good, although phosphorus levels may have increased through time. The recreational fishery is likely collapsed, but the commercial whitefish fishery is stable. Shoreline vegetation is generally abundant, but degraded along the shoreline of the Summer Villages of Island Lake and Island Lake South. These attributes of the lake reflect the combined influence of human activities and natural processes. Human activities have likely contributed to nutrification, but internal loading and reduced water levels are also influential. The sustained period of low water levels is likely due to lower than average precipitation over the past decade. The decline in the northern pike population is likely due to overfishing, but the poor walleye fishery is probably the natural condition for the lake.

Several opportunities exist to improve the status of the lake due to the range of stressors that are affecting the lake's health. Effort should focus on limiting human impacts rather than attempting to control natural processes. Attempts at manipulating the ecosystem may not succeed or, worse, have undesirable consequences. The low water level is probably of concern to residents due to its negative effect on boating and shoreline access. However, BISL is cautioned against attempting to manipulate the lake's water level by controlling outflow. Lower than average precipitation has likely caused the low water level, and it is uncertain whether reducing outflow through Island Creek would be sufficient to offset the reduction in runoff. Further, damming Island Creek could increase nutrification of Island Lake and block fish migration. Another example of ecosystem manipulation that is unlikely to succeed is reducing internal phosphorus loading due to the strategyӳ high ongoing cost.

To help prioritize management options, opportunities to limit anthropogenic impacts to Island Lake have been ranked based on their benefits, liabilities, and costs (Table 3). The assessment is coarse and the ranking should be considered approximate. The potential benefits of management options were qualitatively assigned relative values of high or low, or identified as uncertain. Liabilities of management options were also identified to highlight actions that may have a substantial negative effect on some aspect of the lakeӳ health. Funding to improve or maintain Island Lakeӳ health is limited, and lower cost options should be prioritized to achieve the greatest impact within budgetary constraints. Management options were assessed as having low or high relative costs. Low cost options are those associated with little or no upfront investment but that instead rely on responsible actions by residents and visitors, diligent but inexpensive maintenance, or proactive planning. High cost options are those that require substantial upfront investment either by individual residents of the watershed or by government. After assessing benefits, liabilities, and cost, the management options were assigned a priority level ranging from 1 to 4 as follows:

1. options with high benefit and low cost were given first priority;
2. options with high benefit and high cost were given second priority;
3. options with low or uncertain benefit and low cost were given third priority;
4. options with low or uncertain benefit and high cost were given fourth priority; and
5. options with liabilities or prohibitive cost were not recommended.

Management options ranked as first priority include restrictive fishery regulations, protection or restoration of shoreline habitat, and protection of remaining forest. Implementing a catch and release fishery or fishing moratorium is probably the only option for reversing the decline in the northern pike fishery that has likely been caused by angling pressure. Similarly, protection or restoration of shoreline habitat is the most influential strategy available for maintaining shoreline integrity. Both of these management options rely on responsible actions by residents and visitors rather than substantial financial investment. It should be noted, however, that while the financial cost of strategies such as restrictive fishery regulations and restoring shoreline habitat are low, they may be undesirable to some residents because they require changes in lifestyle. The cost of protecting forest is hard to estimate because the incurred cost is due to lost opportunities for future agricultural expansion. Soils in the watershed have limited suitability for agriculture, and agricultural expansion has been low in recent years. Due to the regionӳ low suitability for agriculture, protection of forest from agricultural expansion is assessed as having relatively low cost.

If livestock wintering sites in the watershed are hydrologically connected to tributaries, controlling their runoff is likely the most influential management strategy available for limiting the amount of phosphorus entering Island Lake. The strategy is ranked as second priority, however, due to the high cost of relocating or modifying wintering sites. Widespread adoption of the strategy may require coordination with one or more levels of government to offset costs incurred by farmers.

Third priority management strategies are those with low benefits and costs. Although these strategies have low potential to improve lake health relative to other strategies, their benefits are not negligible and they should be pursued because of their low cost. Residents and cottagers should be diligent in their control of wastewater to minimize their contribution to the nutrification of Island Lake. Similarly, water withdrawals should be minimized to avoid exacerbating low lake levels that are likely primarily driven by climate. In addition, damaged and blocked culverts along fish-bearing streams should be repaired according to recommendations by Stanislawski (2008). A possible exception is blocked culverts along Island Creek because of the potential effect of their clearing on the lakeφs water level. However, inhibiting fish movement up the creek from the Athabasca River isolates Island Lake fish populations, thereby increasing their risk of extirpation due to demographic, genetic, and environmental stochasticity (Park et al. 2008). It is recommended that a water balance study be completed so that a more informed decision can be made regarding whether blocked culverts along Island Creek should be cleared.

Some culverts in the watershed are damaged beyond repair and should be replaced. Replacing damaged culverts is expensive, however, and has lower potential to improve the fishery that restrictive fish regulations. Due to high cost yet low benefit, culvert replacement is ranked as fourth priority.

Three of the recommended management strategies are primarily focused on reducing phosphorus inputs to Island Lake. Given the mesotrophic status of Island Lake, the need to implement these strategies may be questioned. However, phosphorus levels may have increased over the past two decades and the lake was eutrophic for a portion of the most recent year of monitoring (2005). In addition, the lake is at risk of further eutrophication due to predicted increases in regional temperature and precipitation. Eutrophication of Island Lake would alter its ecology and could have a substantial adverse impact to Island Lakeφs recreational values. Minimizing external phosphorus input is a prudent strategy for maintaining Island Lakeφs water quality.

Island Lake is valued by residents and visitors for the beauty, ecosystem services, and recreational opportunities that it provides. Although management challenges exist, the lakeφs water quality and relatively intact shoreline and watershed present opportunities for maintaining and restoring the integrity of the Island Lake ecosystem. Careful planning of future human activities at the lake and in the broader watershed will be essential for conserving the health of Island Lake for generations to come.

Table 3. Prioritization of management strategies for Island Lake based on their potential benefits, liabilities, and cost. See text for details.

Management strategy	Benefits				Liabilities	Cost	Priority level
	Water level	Fishery	Water quality	Shoreline			
Restrictive fishery		High	Uncertain			Low	1
Protect shoreline		Low		High		Low	1
Forest protection			High			Low	1
Control runoff from wintering sites			High			High	2
Residential wastewater management			Low			Low	3
Minimize water withdrawal	Uncertain					Low	3
Repair damaged culverts	Uncertain[25]	Low	Uncertain[26]		Uncertain effect to water level[27]	Low	3[28]
Replace culverts	Uncertain[22]	Low	Uncertain[23]		Uncertain effect to water level[24]	High	4[25]
Weir	Uncertain				Block fish migration Water quality[29]	Uncertain	Not recommended
Liming			High			Cost prohibitive	Not recommended

[25] Repair or replacement of blocked culverts along tributaries may increase the water level due to increased inflow, but the magnitude of the effect is uncertain.
[26] Repair or replacement of blocked culverts along Island Creek may reduce residence time (and thereby reduce phosphorus concentration) due to increased outflow, but the magnitude of the effect is uncertain.
[27] Repair or replacement of blocked culverts along Island Creek may reduce water level by increasing outflow, but the magnitude of the effect is uncertain.
[28] Completion of a water balance study is recommended prior to clearing or replacing blocked culverts along Island Creek, to assess a potential negative impact to lake water level.
[29] May increase nutrient concentration by increasing residence time (i.e., by reducing outflow)

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