How Resort Owners and Customers Perceive Ecosystems to be Affected by Changes in Water Level Regulation in Voyageurs National Park

By Lauren M. Meckle

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I. EXECUTIVE SUMMARY

In the year 2000, the International Joint Commission (IJC) implemented new rule curves for the operations of the dam in the Namakan Reservoir. The new rule curves reflected more natural water level conditions in an attempt to minimize the negative effects of the rule curves from 1970. In order to determine the ecological and economic effects of the 2000 rule curves, the IJC has organized a large scale research investigation. It is out of the tourism data that this project arises, and this data will be related back to the findings in environmental science.

The general findings of the environmental science studies done in Voyageurs National Park include: decreases in eutrophication (Christensen and Maki, 2014), decreases in chlorophyll *a* concentrations (Christensen et al., 2013), decreases in marsh habitat (Grabas et al., 2013), more natural water conditions (Luce and Metcalfe, 2014), increased survival of macroinvertebrates (McEwen and Butler, 2010), recovering aquatic plant communities (Meeker and Harris, 2009), and more positive effects on loon productivity and nesting success (Windels et al., 2013). These findings are discussed more in depth in the literature review section.

Through survey data, this study explores how resort owners and customers on Kabetogama Lake and Rainy Lake perceive the ecosystems to be affected by the changes in water level regulation and how these perceptions relate to the scientific findings. The variables that were examined were the importance of water levels, water quality, fish habitat, and wildlife habitat to the resort owners and customers; as well as if the goals of improved water levels, water quality, and quality of fishing were met according to the resort owners' and customers' perspectives.

The quantitative and qualitative results were essential to determining if less extreme water level fluctuations are perceived to lead to ecosystem improvements. According to the

results found in this paper, the answer to the overarching question of whether or not resort owners and customers perceive less extreme water level fluctuations in Voyageurs National Park to lead to ecosystem improvements is: it depends on which lake is being considered.

In general, the resort owners and customers on Kabetogama Lake appeared to be more satisfied with the ecological consequences that result from the 2000 rule curves than the people on Rainy Lake, although there is both satisfaction and dissatisfaction on both sides. Overall, the majority of resort owners as well as customers on Kabetogama Lake were mostly satisfied with the improvement of water quality, wildlife habitat, fish habitat, and water level consistency; and they agreed that the goals of improved water levels, water quality, and quality of fishing were being met. The only variable that both the resort owners and customers were unsatisfied with was the state of the wetland vegetation in which they indicated that it had not improved. Therefore, the null hypothesis should be rejected for those on Kabetogama Lake, and the alternative hypothesis that the resort owners and customers have noticed improvements to the ecosystems in Voyageurs National Park as a result of the 2000 rule curve changes should be accepted.

The results also indicate that on Rainy Lake, the majority of resort owners were dissatisfied with the lack of improvements to water quality, wildlife habitat, wetland vegetation, and water level consistency; they were neutral about improvements to fish habitat; and they were also dissatisfied about the goal of improved water levels, water quality, and quality of fishing not being met. Therefore, the null hypothesis for the resort owners on Rainy Lake should not be rejected that there were no perceived improvements to the ecosystems which result from the 2000 rule curve changes. The majority of customers on Rainy Lake were dissatisfied with the lack of improvements to water quality, wildlife habitat, fish habitat, and wetland vegetation; they

were neutral on whether water level consistency was improved; and they were satisfied with the improvements to fishing conditions as well as the goals of improved water levels, water quality, and quality of fishing being met. This variation means there isn't sufficient grounds to reject the null hypothesis and accept the alternative hypothesis for the customers of Rainy Lake.

II. INTRODUCTION AND PURPOSE OF STUDY

Voyageurs National Park is located on the border of northeastern Minnesota and southern Ontario (McEwen and Butler, 2010). It was established in 1975 and it spans 883 square kilometers (Windels et al., 2013). Half of the park's area is covered by water, and the recreation in the area is almost exclusively water-related (Christensen and Maki, 2014). The area consists of six main bodies of water that are divided in two sections for water level management purposes. One section is Rainy Lake and the other is the Namakan Reservoir, which is comprised of Namakan, Kabetogama, Crane, Sand Point, and Little Vermillion Lakes (Larson et al., 2014). About 96% of the water in Voyageurs National Park is in the Rainy Lake-Namakan Reservoir system (McEwen and Butler, 2010).

Starting in 1913, the water levels and flows were controlled in this system by privately owned dams or other water-control structures (Windels et al., 2013). From 1949 up until present day, the water levels have been managed by the International Joint Commission (IJC), a regulatory committee made up of representatives from both the United States and Canada, for the purpose of hydroelectric power generation (Christensen and Maki, 2014 and Larson et al., 2014). The IJC uses rule curves to indicate an appropriate range of water levels throughout the year and to specify the time of the year that water levels are at their peaks (Windels et al., 2013 and McEwen and Butler, 2010). The order issued by the IJC in 1970 allowed for fluctuations on Namakan Reservoir to be larger than what natural levels would be in an attempt to minimize

fluctuations on Rainy Lake (Larson et al., 2014). This management plan has since been found to be disturbing to the surrounding ecosystems in ways that negatively affected macrophytes, benthic organisms, beavers, otters, muskrats, fish, and aquatic birds (Christensen and Maki, 2014).

In January 2000 the IJC implemented a new order which was intended to reflect more natural water conditions and improve water quality (Christensen and Maki, 2014) by altering the magnitude and timing of the spring fill (Windels et al., 2013). The 2000 rule curves reduced the maximum winter drawdown from the 1970 levels of 2.5 meters to the new maximum drawdown of 1.5 meters in the Namakan Reservoir. The new rule curves also dictate that the reservoir must be re-filled to capacity by the end of May rather than late June, and that a gradual summer drawdown must occur rather than allowing water levels to be stable during the summer (McEwen and Butler, 2010). The new rule curves did not substantially change in Rainy Lake when compared to the Namakan Reservoir, which is why Rainy Lake is frequently used as the control system (Christensen and Maki, 2014). It is a result of the changes in rule curves that this project arises.

PURPOSE OF STUDY

The purpose of this study is to fill in information gaps. The IJC acknowledges they have incomplete information, which is why they developed a plan of study for the evaluation of the impacts of the 2000 rule curves. One of the things they want to do further research on is the economic impacts, specifically the effects the 2000 rule curves have on resorts located on Rainy Lake and Namakan Reservoir (Kallemeyn et al., 2009). Dr. Patrick Welle was hired by the IJC to investigate this question. My research will more specifically focus on resort owners' and customers' perceptions of the impact changing water levels have had on the ecology of the area

since the implementation of the 2000 rule curves. The intended audience of this study is the general public, resort owners, and resort customers in the Voyageur's National Park area. The goal of this study is to draw connections between literature on environmental science and how people perceive changes in ecology. The guiding question of this research project asks: are less extreme water-level fluctuations in Voyageurs National Park perceived by resort owners and customers to lead to ecosystem improvements? My null hypothesis is that the resort owners and customers have not noticed improvements to the ecosystems which result from the 2000 rule curve change. My alternative hypothesis is that the resort owners and customers have noticed improvements to the ecosystems in Voyageurs National Park which result from the 2000 rule curve change.

III. LITERATURE REVIEW

Christensen, V.G. and R.P. Maki. (2014)

The intent of Christensen and Maki's study was to see how the changes implemented in the 2000 rule curves affected the trophic states in Rainy, Kabetogama, Namakan, and Sand Point Lakes. The authors used data collected mainly by the National Parks Service and the United States Geological Survey between the years of 1977 and 2011. They analyzed and interpreted data from Secchi depth measurements, total phosphorus concentrations, and chlorophyll *a* concentrations.

They found that the new rule curves caused chlorophyll *a* levels in Black Bay of Rainy Lake and in Kabetogama Lake to decrease, thus causing a decrease in eutrophication[1] of the lakes. The trophic state index (TSI); a numerical index that classifies water bodies as

[1] Eutrophication is a process in which bodies of water gain excess nutrients which stimulate algae or plant growth.

oligotrophic, mesotrophic, or eutrophic based on Secchi depths or concentrations of total phosphorus or chlorophyll *a*; decreased for all lakes. TSI decreased significantly for Black Bay of Rainy Lake from 59 to 51 and for Kabetogama Lake from 57 to 50. This decrease is significant enough to cause a decrease in eutrophication of the lakes. The TSI numbers were similar in Rainy, Sand Point, and Namakan Lakes before and after the new rule curves, therefore these lakes remained oligotrophic.

Since the lakes in Voyageurs National Park vary in size and depth, each is affected differently by changes in water levels. Kabetogama Lake is relatively shallow and susceptible to eutrophication and yearly algal blooms. They found the Secchi depth transparency during August was greater after the implementation of new water level management for only Kabetogama Lake. This is important because it shows improved ecosystem health during the season when the lake is the most susceptible to algal blooms; better water clarity means better habitat for submerged macrophytes to grow as opposed to less healthy phytoplankton growth. This decrease in eutrophication can help reestablish more natural conditions and help maintain the area's resources for future generations.

Christensen, V. G., et al. (2013)

In this study, Christensen et al. compared their data to the results of previous research which was done by the US Geological Survey and the National Park Service before the 2000 rule curve changes. These previous studies looked at nutrient, algae, and nuisance bloom data as it related to water level changes in Kabetogama Lake (one of Voyageurs National Park's most eutrophic lakes). For their data collection, Christensen et al. collected water and sediment quality data in Voyageurs National Park from 2008-2009. Their two goals were to determine what affects the 2000 rule curves had on total phosphorus concentrations and algal productivity, and

whether internal phosphorus loading is a factor affecting total phosphorus concentrations and algal productivity in Kabetogama Lake.

This study is important in understanding that the alteration and degradation of surface waters can lead to better conditions for cyanobacteria to live. Therefore, there is an increased risk for toxins, such as microcystin, which are produced by cyanobacteria to be present in the water. Based on their results of the microcystin concentrations, the authors say the risk of toxins in Kabetogama Lake might be a concern for those who use the lake for drinking water or for recreation.

The study found that chlorophyll *a* concentrations have decreased since the 2000 rule curve changes and total phosphorous concentrations have not changed significantly since the 2000 rule curves were implemented. The authors suggest this result could be due to changes in residence time or nutrient loading. Changes in residence time, or the time it takes water to flow through a system, may affect phosphorus concentrations. Also, the changes in dam operations due to the 2000 rule curves could affect the residence time of phosphorous in Kabetogama Lake. Nutrient availability could be affected by the new water level management because there has been an increase in minimum water level due to the new rule curves. More natural water conditions may cause lower phosphorus loading due to less sediment drying and rewetting caused by water fluctuations, fewer nutrient inputs due to less decay of vegetation in the littoral zone, and lower nutrient concentrations resulting from an increased volume.

Grabas, G., et al. (2013)

The goal of this study was to assess the effects the 2000 rule curve changes had on the habitats of breeding marsh birds and amphibians. They used aerial photos of Rainy Lake and the Namakan Reservoir from before (1995-1997) and after (2008) the 2000 rule curve change. They

also did field surveys of the birds and amphibians to get the bigger picture of the community structure of the marsh. The focus of their study was to use a geographic information system (GIS) to map the types of vegetation which were affected by the change in water-level regulation. These vegetation types included emergent, meadow, and rooted and floating submersed plants.

The authors of this study found a decrease in areal extent between the two time periods for all marsh types in all lakes. The reservoir lakes (Namakan, Kabetogama, Sandpoint, Crane, and Little Vermilion Lakes) experienced a 21% decrease in marsh area, and the marsh area at Rainy Lake decreased by 24%. Notably, Crane Lake lost more than half of the meadow marsh area and Namakan Lake lost nearly half of the meadow marsh. Crane Lake and Kabetogama Lake were the areas where the loss of emergent marshes was most obvious. The rooted and floating aquatic plant communities were largely unaffected in Namakan Lake, but all other reservoir lakes experienced a decrease in these communities, especially in Kabetogama Lake. They also found this decrease in wetland extent to mean a significant loss of habitat for breeding marsh birds and amphibians within their study area. These results were unexpected because it has been suggested that natural water levels with a more gradual drawdown during the summer could support the more widespread growth of emergent vegetation. Therefore, the authors did further study and have suggested their results were due to the 1995-1997 time period having relatively low water levels and the water levels in 2008 were uncommonly high.

They were not able to conclude whether the changes in vegetation were a result of the 2000 rule curve changes or if they were from variation in water supply, therefore it is unclear how the 2000 rule curve changes have affected marsh vegetation in the study area. They do, however, conclude that water level regulation has the most influence on the extent of marshes in

the study area rather than inaccuracies in photo interpretation, GIS biases, or human disturbances.

Larson, J.H., et al. (2014)

The goal of the study designed by Larson et al. was to determine the relationship between fish mercury content and water level fluctuations. From 2004 to 2010, they collected young of the year perch during the same time each fall from six lakes in the Rainy-Namakan complex. They also used data collected by Sorensen from 2001 to 2003 for the six sites.

Their results showed a positive association between year to year maximum water level variations and fish mercury content. A one meter increase in maximum water levels in Crane Lake yielded a 108 ng per gram net weight increase in mercury content of fish, whereas the same water level change in Kabetogama Lake showed only a 5 ng per gram net weight increase in mercury content. The results of the mercury content in the young of the year perch that they sampled was variable. A possible explanation for the variation that they provide is due to the re-wetting of the lake sediments that are exposed during low water levels. The shallower the lake is the more sediment area will be exposed with the same decrease in water levels a deeper lake would experience. They recommended further research to be done so as to more specifically identify the conditions in which mercury content in fish is affected by water fluctuations.

Luce, J.J. and R.A. Metcalfe. (2014)

This study was conducted by Luce and Metcalfe for the International Joint Commission as a component of the 2009 Plan of Study. Their three main goals of this study were to note any changes in flow regime before and after the 2000 rule curves, determine the cause of the changes, and to investigate how habitat availability has been affected by changes in the duration and timing of water level fluctuations.

For their first goal, the authors noted at the International Falls/Fort Frances Dam that the majority of the time, the water conditions after the 2000 rule curves were either at very high or very low flows. They also found the rule curves after 2000 were more accurately targeted due to extreme runoff conditions during this time period. There was also no change observed in the frequency of maximum capacity flows before and after the 2000 rule curves. Furthermore, they found after the implementation of the 2000 rule curves that, for many months, there was a lower flow release rate for more time. They also observed more time was spent with the turbines running at or above maximum capacity which implies larger volumes of water were present during the period of time following the rule curve changes.

The authors also investigated whether the hydrologic trends that they noted were a result of the change in rule curves or if the behavior they observed was to be expected for natural rivers. They found that before the rule curve changes were implemented, the flows were outside the range of flow variability when compared to the control (local, unregulated rivers used as reference). The high water flows on Rainy River at the International Falls/Fort Frances Dam were lower than the highs on the unregulated rivers. The low water flows on Rainy River were found to be higher than the flows on the unregulated rivers. However, after the rule curves were implemented, the flow variability was not outside of the range of the unregulated reference rivers due to the dam operators holding the flows at the rule curve targets. This means that the flow regulation, as dictated by the rule curves, has helped Rainy River to be within the range of variability which is expected to be seen on unregulated rivers whose flow patterns are driven by climate. The high flows observed at the dam were lower in relationship to the unregulated river which suggests that flow regulation helps to make droughts on Rainy River less severe. They also observed that flow variability was greater after the rule curve change as there was an

increase in extreme weather events starting in 1995 and continuing into the 2000s. There was an increase in monthly precipitation and temperature after the 2000 rule curves were established. The authors took it a step further to investigate these trends by doing a simulation of flow metrics. Their findings did not support the hypothesis that a shift in flow regime was caused by the 2000 rule curves; the flows were found to be more similar to a natural flow regime. On the other hand, the variables that were observed by the authors, not simulated, suggest that trends are dependent upon the changes in rule curves. However, these changes in variables during the study period do not coincide with the year of the rule curve changes in 2000.

Luce and Metcalfe also looked at the changes in river bed flooding in Rainy River were a result of the implementation of the rule curves or other factors, such as climate. They found significant differences before and after the rule curves were implemented as far as water level and daily water levels go. Their results support the statement that the before and after hydraulic conditions on Rainy River are influenced by climate and reservoir levels. This means that flows were not solely influenced by changes in the rule curves. After examining the wetted perimeter of Rainy River, the authors compared the before and after rule curve conditions for the wetted perimeter. They found that after the rule curves were established, the wetted perimeter of the river increased for floodplain and baseflows. They also observed that as the distance downstream increased, the differences in wetted perimeter between the two time periods decreased. This is indicative of a decreased influence of the dam and an increased influence of tributaries. Before the 2000 rule curve changes, Rainy River experienced backwater effects which caused more frequent flooding of the channel and floodplain which, in turn, changed the river habitat to be more lentic. After the 2000 rule curve changes, the water levels were lowered closer to the water levels of the unregulated rivers in the area which caused a lesser backwater effect. In addition to

flow regulation in the Namakan Reservoir and Rainy Lake, this technique can serve as a potential management tool to maintain habitats along the Rainy River.

McEwen, D.C. and M.G. Butler. (2010)

McEwen and Butler investigated the effects changing water levels in Voyageurs National Park have on benthic invertebrates. They collected samples from both Rainy Lake (the control lake) and the Namakan Reservoir (the impact lake) after the change in water level management in 2004-2005. They used data previously collected by Kraft in 1984-1985 along with their samples (which were collected at the same locations as Kraft's) to determine if there was a change in the structure of macroinvertebrate communities after the changes in water level management.

Relative to the Rainy Lake, they found changes in the community structure of macroinvertebrates in the Namakan Reservoir at the 1-2 meter depths, but not at 3-5 meter depths. This is likely because shallower areas are more directly affected by changes in sediment exposure and ice formation. Based on rule curve regulations, the 2 meter depth samples from 1984-85 would have been exposed in Namakan during the winter, whereas the 2 meter depth samples from 2004-05 would have been underwater during the winter. This means there were higher mortality rates due to exposure and ice crystal formation before changes in regulation.

They also found that since the establishment of the 2000 rule curves, the Namakan Reservoir had lower macroinvertebrate densities relative to Rainy Lake. They argue this could be related to decreases in productivity. The 1970 rule curves made for a more productive system because the greater drawdowns allowed the sun's radiation to penetrate a greater percentage of the water column during spring and summer which, in turn, allowed algae to be more productive. The increased drawdown also increased allochthonous material; as the reservoir filled, the

shorelines were disturbed and coarse woody debris, leaf litter, and other organics were deposited into the littoral zone, resulting in more productive habitats for invertebrates.

Meeker, J.E. and A.G. Harris. (2009)

Meeker and Harris studied Namakan Reservoir, Lac la Croix, and Rainy Lake. The water level fluctuations on the Namakan Reservoir are the most extreme, whereas they are least extreme on Rainy Lake, and the most natural water level conditions occur on the unregulated Lac la Croix Lake. In an effort to create a baseline for monitoring wetland vegetation, Meeker and Harris compared the three basins and made observations on the impacts of water level regulation since 1987, the time when the middle of the rule curves began to be targeted by dam operators. This reduced extreme water level fluctuations on the Namakan Reservoir and provided conditions for a gradual decline in water levels for the remainder of the growing months.

The purpose of their study was to establish a baseline for wetland monitoring at Voyageurs National Park. They also wanted to observe how aquatic plant communities have responded to the implementation of the 2000 rule curves. Lac la Croix was used as a control site because it is not regulated, and the responses of the aquatic plant communities in Rainy Lake and the Namakan Reservoir were compared to this site.

Meeker and Harris monitored 31 sites; 10 sites were on Rainy Lake, 10 on Lac la Croix, and 11 on the Namakan Reservoir. In the areas they sampled, they observed that Rainy Lake had a significantly different shoreline community, as far as species composition goes, than Namakan Reservoir and Lac la Croix. Rainy Lake had more annual species, whereas Lac la Croix had many species common to poor fens[2] and few emergent aquatic plants. Lac la Croix also had more herbaceous plant cover than Namakan which the authors speculate may be due to fen plant

[2] Poor fens are transitional bogs with poor nutrients in the soil and consist of dense, low-growing sedges and other small plants

species intolerance to flooding and competition with trees and shrubs. They concluded that although the composition of species was different, there was little variation in total plant cover or species richness along the shorelines between the basins. Their findings suggest that shoreline communities are influenced by water level management.

At the 1.25 meter depth, the authors found that the vegetation structure on the Namakan Reservoir has changed since 1987. The reservoir used to be dominated by mat-forming species, and since 2002 low and tall submergent plants have begun to dominate. The authors speculate this change could mean the wetland communities are responding to the changes in the rule curves, and the aquatic community has started to recover due to the higher water levels in late winter which prevent the ice from scouring away submergents. Despite all of this, the authors observed the Namakan Reservoir has fewer emergent plants and less floating leaf cover than the other basins, as well as fewer species than Lac la Croix. Furthermore, the authors observed that Lac la Croix has a significantly different species composition of the aquatic vegetation communities at the 1.25 meter depth. Lac la Croix also has more floating leaf vegetation and less tall submergent vegetation than the other two lakes.

At the 2 meter depth, there was no significant difference observed in total vegetation cover or species richness between the three basins. However, the differences between vegetation structure and composition can be seen at the 2 meter depth. Floating leaf vegetation and less tall submergent vegetation was dominant in Lac la Croix. At the 2 meter depth, Lac la Croix also had more vegetation diversity and vegetation structural diversity than the other two basins. The difference in vegetative structure can be connected to the intermediate level of disturbance on Lac la Croix because it does not experience extreme fluctuations like the Namakan Reservoir, nor does it have the stable water levels of Rainy Lake. The authors also found Rainy Lake to be

dominated by tall submergents which is due to the fact that stable water levels encourage the growth of submergents.

Another component to this study was to assess the vegetative changes over time by comparing the previously-collected 1987 data to the data collected by the authors in 2002. Since 1987, the aquatic vegetation has changed in all three basins. The vegetation in the Namakan Reservoir appears to be returning to a more natural state due to reduced water level fluctuation as it now has more structural diversity and fewer mat-forming species. Namakan had fewer emergent and floating leaf cover species than the other basins, and it had significantly fewer overall species than Lac la Croix. They found that the vegetation on Rainy Lake and on the Namakan Reservoir are becoming more similar to the vegetation of Lac la Croix, suggesting the wetland communities have become more similar to each other in 2002 than they used to be in 1987. They also found that tall submergent plant species have benefited from the changes in rule curves, and mat-forming species have declined. They also found that shorelines have experienced, in particular, an increase in woody cover in all three basins since 1987. This finding can be explained by the new rule curves' water level peak occurring in late May which is then followed by a slow decline in water level for the rest of the months of the growing season. However, changes in dam operations may not be the only factor which has influenced this change to woody species. On this point, the authors suggest further studies to be conducted in order to see if water level management or other factors, such as climate change, may have a bigger influence.

The authors also observed that peatland development; including bogs, shore fens, and sedge meadows, in the three basins have been influenced by different hydroregimes. The peatlands along Rainy Lake and the Namakan Reservoir have developed after the dams were

constructed in the early 1900s, making them relatively new as far as peatland development goes. Rainy Lake has the smallest water level fluctuations, and fens dominated by *Sphagnum* moss are the most frequent due to the species' lack of flood tolerance. Lac la Croix has intermediate water levels; therefore, flood tolerant shore fens are the most common on this lake. *Typha* was commonly found in the Namakan Reservoir, relatively few were present in Rainy Lake, and almost none were present in Lac la Croix. Overall, these observations were important in establishing a baseline for future monitoring of peatlands.

Wild rice surveys were also conducted in 2004 on Rainy Lake and the Namakan Reservoir, however there was not enough consistently collected data before the 2000 rule curves to statistically compare the conditions before and after the changes in water level regulation. Nonetheless, this provided a baseline for future monitoring of wild rice. This study also created a baseline for monitoring changes in invasive species along shorelines.

Meeker, J.E. and A.G. Harris. (2011)

For this study, Meeker and Harris completed an additional year of research for the International Joint Commission's review of the effects the 2000 rule curves on aquatic plants. Using the same methods in 2010 as they had previously used in 2002-2005, the authors returned to the same sites on Rainy Lake, Lac la Croix, and the Namakan Reservoir where they collected data in 2002-2005 to gather more data on the abundance and composition of aquatic plant communities located near the shore in order to determine how strong of effects the 2000 rule curves have had on the vegetation.

By comparing the results of the 2002-2005 and 2010 studies, the authors found a clear difference in vegetation composition and structure at the 1.25 meter and the 2 meter depths. Since the biggest influence in vegetative composition and structure is water depth as a

consequence of historical water level changes, the authors were able to attribute this difference directly to the rule curves.

The authors also found that there continued to be differences in aquatic vegetation between water bodies. Lac la Croix had a different composition than Rainy Lake at the 1.25 and the 2 meter depth, but was only clearly different from the Namakan Reservoir at the 1.25 meter depth. The Namakan Reservoir and Rainy Lake were found to be more similar at the 1.25 meter depth than they were in 1987. Although there is no way to know for certain what the species assemblages looked like before the dams were built, it is likely that the three basins used to have similar species pools, and the reservoir draw-down conditions in the Namakan Reservoir is the most likely reason why some species are still scarce or absent in Namakan.

When the 2002-2005 study was compared to the 2010 study, the authors found some changes in total vegetative cover in Lac la Croix and Rainy Lake where they had not expected changes, and they found little change in the Namakan Reservoir where they thought there would be change. They also noted there was little change in the abundance of individual species between the 2002-2005 study and the 2010 study as 8 out of the top 10 species in 2010 were the same species that dominated in 2002-2005. Although the comparison of the 1987 and 2002 data showed a significant increase in tall submergent vegetation in the Namakan Reservoir, the comparison of the 2002 and 2010 data indicated no changes. This suggests that the vegetation began to experience changes between 1987 and 2002 as the water levels in the Namakan Reservoir began to be regulated, especially by the 2000 rule curves. The decrease in amplitude of water level fluctuations due to rule curves has made for a more stable hydrological environment which helps to explain the changes in vegetation that have occurred in the Namakan Reservoir since 1987. The authors suggest the reason for finding so few changes from 2002 to 2010 is due

to the fact that the aquatic vegetation had begun to change in the 1980s when water levels were becoming steadier, and by 2002 the vegetation had already stabilized.

Windels, S.K., et al. (2013)

The study by Windels et al. focused on how the human manipulations of water levels in Voyageurs National Park affects loon nesting success and productivity. They surveyed loon territories from 2004 to 2006 on Rainy Lake and the Namakan Reservoir and compared it to Reiser's productivity and nest outcome data that was collected from 1983 to 1986 to determine the effects of the 2000 rule curve changes.

They found that changes in the rule curves had a positive effect on loon productivity and nesting success in the Namakan Reservoir. The comparison of the samples from the two time periods showed Loon productivity increased by 95% in the Namakan Reservoir. Despite this fact, they observed a decline in nesting success with flooding and nest predation being the major causes. The decline was less evident on the Namakan Reservoir than on Rainy Lake, suggesting the 2000 rule curves that decreased the magnitude of water level changes and caused water levels to peak earlier in the season (thus increasing the number of days in the breeding season) had a positive effect on nest success in the reservoir. "Therefore, even though overall nest success on Namakan decreased since the 1980s, the percentage of loon pairs that attempted nests increased, and consequently overall productivity increased under the 2000 rule curves, both in total numbers of chicks and number of chicks/territorial pair" (page 9).

IV. METHODS

During the summer of 2014, Dr. Patrick Welle and his graduate student, Jerry Smith, traveled to Voyageurs National Park to conduct interviews for Dr. Welle's research project. His research examined the impacts the International Joint Commission's 2000 rule curves for dam

water level management have had on the region. Dr. Welle focused his interview efforts on resorts on Rainy Lake and near the Namakan Reservoir. His questionnaires asked resort owners and resort customers about their perceptions of how changing water levels have affected tourism activity in the area. The surveys were designed to reflect the impact of changing water levels over several years, rather than just one year that could have been an anomaly in hydrologic conditions. The list of resorts to be visited was compiled through a combined effort by Dr. Welle, Smith, and myself. We used Dr. Welle's contacts in the area and did research to assemble a master list of resorts in northeastern Minnesota and southern Ontario. We recorded the resort names, addresses, websites, phone numbers, and which lake they were located on in a Microsoft Excel file. We also categorized them according to their types of accommodation (resort, lodge/cabins/camping, hotels, or other accommodations) to further narrow down potential places of business to interview. Letters were then sent to specific resorts to notify them of Dr. Welle's interest in interviewing them for the study being done for the IJC. Although Dr. Welle interviewed people on Kabetogama Lake, Rainy Lake (United States side as well as Ontario), and Crane Lake; I focused my research on Kabetogama Lake and the United States side of Rainy Lake because these two lakes were more prevalent in the environmental science literature I reviewed.

After the in-person interviews were completed, the qualitative data, which consisted of the open-ended responses and explanations on the questionnaires from the customers and owners, were recorded by Dr. Welle and me in Microsoft Word documents. Also, Dr. Welle entered all of the quantitative data from the questionnaires into SPSS for later data analysis. Many of the quantitative questions used Likert Scales which allowed the data to be coded into SPSS and analyzed for my project.

The research question that guided the qualitative data section was: did the resort owners and customers on Kabetogama Lake and Rainy Lake note improvements to variables; such as water quality, wildlife habitat, fish habitat, wetland vegetation, and water level consistency; that were found in the literature? The responses in the surveys which corresponded with the main themes from the literature review (such as water quality, wildlife habitat, etc.) were highlighted and then tallied categorically for both the customer and resort owner surveys (see Appendix A for tables).

There were two research questions that guided the quantitative data analysis. The first question was: do the opinions of resort owners and customers differ between Kabetogama Lake and Rainy Lake in regards to the importance they place on water-level management for different variables, such as water levels, water quality, walleye habitat, northern pike habitat, and wildlife habitat? The second questions was: do the opinions of resort owners and customers differ between Kabetogama Lake and Rainy Lake in regards to the goals of the 2000 rule curves; such as more favorable water levels, better water quality, and improved fishing; being met? Frequency tables, means, and t-tests were generated for the quantitative data using SPSS for this thesis (See Appendix B for tables). Two quantitative question series from the surveys which were selected for analysis; the same two series of questions were selected for resort owners and customers. The first question for both groups of people was: "We would like to know the importance you place on the management of water levels for your enjoyment of this area. Please state the importance you place on water levels for your recreational experience using the responses shown on this card. The response options are: not important at all, not very important, somewhat important, very important, or extremely important?" This question used a Likert scale where 1 was "not important at all" and 5 was "extremely important." The mean calculated for this question reflects

this scale. The second question for both groups of people was: "A goal of the 2000 rule curves (policies for water-level management) was to make water levels more favorable for water-based recreation and tourism. Would you agree that this goal has been met? Please respond: Strongly Agree, Agree, Neutral, Disagree, or Strongly Disagree for the following questions... (a) water levels are more favorable? (b) 2000 rule curves have made water quality better? (c) 2000 rule curves have made the quality of fishing better?" This question used a Likert scale where 1 was "strongly agree" and 5 was "strongly disagree." The mean calculated for this question reflects this scale. The statistics in the frequency tables consisted only of cases with valid data, missing values were excluded, and only valid percentages were reported. The frequencies were reported as percentages in Tables 5, 6, 8, and 9 so that the percent for Kabetogama Lake was listed before Rainy Lake [i.e. (Kabetogama Lake %/Rainy Lake %)]. The statistics in the t-test analysis were based on the cases with no missing or out-of-range data for any variable; missing values were excluded; equal variances were assumed for all; and the confidence interval was 0.95, thus giving a critical p-value of 0.05.

The results of the two research questions were combined in order to answer the overarching research question (see discussion section): are less extreme water-level fluctuations in Voyageurs National Park perceived to lead to ecosystem improvements?

V. RESULTS

V.I Qualitative Results

The research question that guided the qualitative data section was: did the resort owners and customers on Kabetogama Lake and Rainy Lake note improvements to variables that were found in the literature; such as water quality, wildlife habitat, fish habitat, wetland vegetation,

and water level consistency? The results for the resort owners' verbatim responses can be found in Tables 1 and 3, and the results for the customers' verbatim responses can be seen in Tables 2 and 4.

Resort Owners: Water Quality

The qualitative results revealed that out of all of the resort owners on Kabetogama Lake who commented on water quality, five owners stated the water quality has improved since the 2000 rule curves were implemented. They stated the "green scum has disappeared" and there is "no slime in areas like there used to be." On the other hand, only one owner on Kabetogama Lake said the water quality wasn't improved. The single survey that contradicted the anticipated improvement explained their answer by saying the water clarity was improved but the quality was not. There were only two resort owners on Rainy Lake who commented on water quality, and both of them said the water quality was not improved by the 2000 rule curves because there are "algal blooms [occurring] due to high water."

Resort Owners: Wildlife Habitat

There were eight resort owners on Kabetogama Lake that noted improved wildlife habitat and zero resort owners on this lake who have not seen improvements since the 2000 rule curve changes. The owners commented that the improvements to wildlife habitat have "helped loons and birds because pre-2000 the rising water flooded nests and they'd float away for loons and grebes." One owner even described Voyageurs National Park as a "Mecca for wildlife," and another saw "the population of river otters in the park has increased due to the 2000 rule curves." However, on Rainy Lake, four resort owners stated the wildlife habitat has not improved since the new water regime, and no one commented that they've seen improvements. On Rainy Lake,

water levels have been higher so they have commented that there are "no loons, ducks or geese because the water came up."

Resort Owners: Fish Habitat

In regards to fish habitat on Kabetogama Lake, 15 resort owners declared they have seen improvements since the 2000 rule curve change, and none commented that there were no improvements. One resort owner commented that "there are plenty of spawning areas now." Another noted that "higher spring levels make for better northern pike spawning habitat [whereas] the old curves left these areas dry." On Rainy Lake, one resort owner said fish habitats have been improved because the lower water levels have made for "better places for minnows to hide," and one resort owner contradicted this by saying they "do not agree that increased spawning habitat was due to the 2000 rule curves."

Resort Owners: Wetland Vegetation

Only one resort owner on Kabetogama Lake commented on the state of wetland vegetation, and this one owner said that it has not improved since the 2000 rule curves because "bog peat flows downstream and piles up on the docks after rains." On Rainy Lake, six resort owners said the conditions have not improved. They have seen effects like shoreline erosion, flooded wild rice, and detached floating bogs due to high water. Zero people on Rainy Lake have said it has improved with the new hydroregime.

Resort Owners: Water Level Consistency

On the issue of water level consistency on Kabetogama Lake, 13 resort owners have seen improved, more consistent water levels. One owner said it has been "smooth sailing for the last 10 years because of adequate water" levels. Others stated, "I hope they leave [the water levels] as

is. It has worked much better" and "we would rather have water curve now than what it used to be because we can't stop the rain." Two resort owners on Kabetogama Lake noted otherwise and said the consistency of water levels has not improved. They commented that a "happy medium needs to be met" and the dam operators "need to watch the weather more." On Rainy Lake, only one resort owner said they thought the water levels have been more consistent, whereas eight resort owners said the water level consistency has not improved since the 2000 rule curves. One owner said, "The fluctuations are not as consistent as they once were, and we do not feel like dam is operating properly."

Resort Customers: Water Quality

Of the resort customers who were interviewed on Kabetogama Lake, three noted improvements to water quality since the 2000 rule curves, and two customers reported that the water quality has not improved. Those who saw improvements commented there are now "fewer times of algae blooms." The two customers who did not see improvements said that "blooms happen in warmer water" and "Wooden Frog [on Kabetogama Lake] is less pristine." On Rainy Lake, one customer commented that water quality has not improved since the new water level regime, and zero customers on this lake saw water quality improvements. The comment the customer gave about unimproved water levels was "water quality is related to water levels and goes lower when levels go up."

Resort Customers: Wildlife Habitat

Two customers on Kabetogama Lake commented on improvements to wildlife habitat since the change in water level regulation. One customer commented at length, "we see otters, beavers, ducks, and loons. Adequate water is better for seeing wildlife. Low water is too low for beaver huts and so forth." One customer said the habitats have not been improved on

Kabetogama Lake stating, "The nesting areas for loons are heavily impacted [by the high water] and the loon population is way down." On Rainy Lake, one customer said wildlife habitat has not improved since 2000 because "high water years hurt habitats." There were no customers who commented that wildlife habitat has improved on Rainy Lake.

Resort Customers: Fish Habitat

Improvements to fish habitat was noted by six customers on Kabetogama Lake, and zero customers reported that fish habitats have not improved since the new hydroregime. One customer who commented on improvements to fish habitat said "water levels are extremely important for fish spawning … [and the new] water levels have improved things such as better spawning." On Rainy Lake, two customers commented that fish habitat has not improved since 2000, and one customer has noted improvements. The one customer who saw improvements said the "walleye fishery is doing very well." On the other hand, one of the customers who did not see improvements said this was due to "high water levels changing fishing habitat and walleye patterns."

Resort Customers: Fishing Conditions

On the topic of fishing conditions, 11 customers on Kabetogama Lake have noted improvements, and two have noted that conditions have not improved since the implementation of the 2000 rule curves. One customer specifically indicated "water levels have made fishing better," and another said that since the new curve, "Kabetogama Lake is now always fishable." The customers who have not seen improvements commented that high water levels which cover the docks affected fishing conditions negatively because they couldn't be used. On Rainy Lake, two customers reported improved fishing conditions since 2000, and one commented that conditions have not improved. The customer who has not seen improvements said, "The late 90s

had better fishing than we have now. Some advocate the new rule curves are good for fish; if so, why hasn't it improved?" One of the two customers who have seen improvements to fishing conditions commented, "Fishing is better due to rule curves in conjunction with protective slot for walleyes and pike on both sides of the border."

Resort Customers: Wetland Vegetation

Only one customer commented on the state of wetland vegetation on Kabetogama Lake, noting that conditions have not improved since the new rule curves. They noted there is now "more foliage and submerged trees in the water during high water." However, on Rainy Lake four customers have commented that wetland vegetation has not improved since 2000. They commented that high water has brought soil erosion, flooded wild rice, and more unattached floating bogs. No customers on either lake saw improvements to wetland vegetation.

Resort Customers: Water Level Consistency

In regards to water level consistency on Kabetogama Lake, nine customers noted consistency has improved since 2000, and two customers commented that water level consistency has not improved since the new curves. One customer that saw improvements commented that dam operators "have done a better job at controlling levels," and another said that there are "not as many fluctuations [and the fluctuations that do occur] are not as severe because they're not as low." The customers who did not see improvements said, "There seems to be no control over water levels," and "we never know what to expect for water levels." On Rainy Lake, two customers reported improvements in water level consistency, and two noted that the consistency has not improved since the 2000 rule curves. One customer who saw improvements commented that "more consistent water levels at specific times of the year (say, each July) makes it more predictable when navigating the waters." On the other hand, one customer who

said water level consistency has not improved noted that water levels "vary a foot in range," and the other customer said the water levels on Rainy Lake are "poorly controlled."

V.II Quantitative Results

The research question that guided the quantitative data analysis was: do the opinions of resort owners and customers differ between Kabetogama Lake and Rainy Lake in regards to (1) the importance they place on water-level management for different variables, such as water levels, water quality, walleye habitat, northern pike habitat, and wildlife habitat; and (2) the goals of the 2000 rule curves being met; such as more favorable water levels, better water quality, and improved fishing? The results shown in Table 5 indicate that, on average, Kabetogama Lake resort owners rank five variables (water levels, water quality, walleye habitat, northern pike habitat, and wildlife habitat) to be anywhere from very important to extremely important. On Rainy Lake, the data indicates that resort owners consider water levels, water quality, and walleye habitat to be ranked from very important to extremely important. Also on Rainy Lake, the data shows that resort owners consider northern pike habitat and wildlife habitat to be somewhat important to extremely important. The t-test in Table 7 reveals that differences in the views of the resort owners on Kabetogama Lake and Rainy Lake about walleye habitat importance are statistically significant ($p= 0.029$ which is less than the p-value of 0.05). When looking back at the means for walleye habitat, it becomes clear that the owners on Kabetogama Lake believe walleye habitat is more important (the average is 4.65 which indicates it is closer to extremely important) than the owners on Rainy Lake (the average is 4.17 which indicates it is closer to very important).

Table 6 shows that when resort owners on Kabetogama Lake were asked if they believe the goals were met after the 2000 rule curves were implemented, the average response was that

they strongly agreed to agreed that the goals of more favorable water levels and better quality of fishing were met. On average, the data on the resort owners on Kabetogama Lake also indicated that they felt neutral or agreement towards the goal of better water quality being achieved. On Rainy Lake, the average response was that resort owners were neutral to being in disagreement with the goals of improved water quality and better quality of fishing being met. Also on Rainy Lake, the data showed that on average, the resort owners disagreed to strongly disagreed that the goal of having more favorable water levels since the 2000 rule curves was being met. The t-test in Table 7 reveals that the views of the resort owners on Kabetogama Lake and Rainy Lake differed in regards to the goals of water levels, water quality, and quality of fishing being met. An average of 2.13 for resort owners on Kabetogama Lake indicates a general agreement on the improvements of water quality, whereas an average of 3.43 for resort owners on Rainy Lake indicates general disagreement on improvements to water quality; the p-value of 0.001 is much lower than the p-value of 0.05, therefore it is statistically significant, and the resort owners have differing opinions on whether or not water quality has been improved. Furthermore, the t-test gave a p-value of 0 for both water levels and quality of fishing goals for the resort owners. This indicates that resort owners on Kabetogama Lake agreed that the goals of improved water levels and quality of fishing (with means of 1.88 and 1.50 respectively) were being met, whereas the resort owners on Rainy Lake disagreed that the goals of improvements to water levels and quality of fishing were being met (with means of 4.29 and 3.43 respectively); they fell on opposite sides of the spectrum which is why the p-value was 0 and the t-scores (-5.567 and -7.022, respectively) were so far from the mean.

The results shown in Table 8 indicates that resort customers on Kabetogama Lake consider water levels, water quality, walleye habitat, and wildlife habitat to be ranked from very

important to extremely important. Also on Kabetogama Lake, the data shows that resort customers consider northern pike habitat to be somewhat important to extremely important. On average, the resort customers on Rainy Lake rank five variables (water levels, water quality, walleye habitat, northern pike habitat, and wildlife habitat) to be anywhere from very important to extremely important. The t-test in Table 10 reveals that the views of the resort customers on Kabetogama Lake and Rainy Lake about the importance of water quality ($p=0.049$), walleye habitat ($p=0.011$), and northern pike ($p=0.043$) is statistically significant. For all three cases, the customers on Rainy Lake gave more importance to these three variables than the customers on Kabetogama Lake.

Table 9 shows that when resort customers on Kabetogama Lake were asked if they believe the goals were met after the 2000 rule curves were implemented, the average response was that they felt neutral to agreement that all three goals of more favorable water levels, improved water quality, and better quality of fishing were being met. Customers on Rainy Lake felt strong agreement to agreement that the goals of more favorable water levels and better water quality were being met. Also on Rainy Lake, the customers felt agreement to neutral towards the goal of improved quality of fishing being met. The t-test in Table 10 reveals that the views of the resort customers on Kabetogama Lake and Rainy Lake differ significantly about improvements to water quality ($p=0.015$). Customers on Kabetogama Lake felt much more neutral towards the conditions improving than the customers on Rainy Lake who thought the water quality to be more favorable.

VI. DISCUSSION AND CONCLUSION

Discussion: Water Quality

In regards to water quality, the majority of both the owners and the customers on Kabetogama Lake noted improvements with comments such as the "green scum has disappeared" (Tables 1 and 3). However, on Rainy Lake, neither the owners nor the customers noted improvements (Tables 2 and 4). These results for Kabetogama Lake are consistent with the literature, but the results for Rainy Lake are not consistent with the literature. A study by Christensen and Maki in 2014 found that chlorophyll *a* levels in Rainy Lake and Kabetogama Lake decreased, thus the decrease in eutrophication led to improved water quality and more natural conditions. A different study done in 2013 by Christensen and Maki concluded that the 2000 rule curves, which created more natural water conditions and increased the minimum water level, may lead to lower phosphorus loading due to less sediment drying and rewetting caused by drastic water fluctuations. Lower phosphorus levels would restrict the possibility of large algal blooms (Christensen et al., 2013).

The resort owners on both Kabetogama Lake and Rainy Lake indicated that water quality was a factor that is between very important and extremely important to them for recreational purposes (Table 5); since the resort owners agree on the importance of water quality, this is not a statistically significant result (Table 7. $p=1$). However, the resort owners on Kabetogama Lake and Rainy Lake disagree about water quality goals being met (Table 7. $p=0.001$). The resort owners on Kabetogama Lake tend to agree more that the 2000 rule curves have made water quality more favorable than those on Rainy Lake who tend to disagree that water quality goals are being met. Disagreements about water quality can also be seen when comparing the customer responses on Kabetogama Lake and Rainy Lake. Customers on Rainy Lake give a significantly

higher importance to water quality than those on Kabetogama Lake (Table 10. p=0.049). Those customers who visit Rainy Lake also more strongly agree that water quality goals are being met than those on Kabetogama Lake, although the customers on Kabetogama Lake also agree that water quality goals are being met (Table 10. p=0.015). The differences between opinions of the resort customers and resort owners on the goals of water quality goals being met could be due to the time of year they see the lakes' conditions and the duration of their stay. The resort owners live in the area for the full season so they might have a more complete idea of what the water quality conditions are like than the customers who are only around for a few weeks at a time.

Discussion: Wildlife Habitat

In regards to wildlife habitat, the majority of both owners and customers on Kabetogama Lake commented that conditions have improved with the new hydroregime, with one owner noting that the 2000 rule curves have "helped loons and birds because the pre-2000 rising water flooded nests and they'd float away for loons and grebes" (Tables 1 and 3). However, on Rainy Lake, the resort owners and customers noted that wildlife habitat has not improved since the 2000 rule curves (Tables 2 and 4). The Rainy Lake results are consistent with the literature. A study done by Grabas et al. in 2013 found that Kabetogama Lake experienced a 21% decrease in marsh area and Rainy Lake's marsh area decreased by 24%. This decrease in wetland extent caused a significant loss in habitat for breeding marsh birds and amphibians (Grabas et al., 2013). Although Grabas et al. found a 24% decrease in marsh area which led to a decrease in breeding area, a study by Windels et al. in 2013 found that the changes in rule curves have had a positive effect on loon productivity and nesting success in the Namakan Reservoir (which includes Kabetogama Lake). They found that the percentage of loon pairs that tried to nest increased which led to an increase in overall productivity as far as the number of chicks per

territorial pair goes (Windels et al., 2013). Therefore, the results for Kabetogama Lake are also consistent with the scientific findings.

The resort owners on both Kabetogama Lake and Rainy Lake had similar opinions on the importance of wildlife habitat (Table 5); therefore it was not a statistically significant result (Table 7). The resort customers on the two lakes also agreed on the importance of wildlife habitat (Table 8), therefore this was also an insignificant result (Table 10). However, the means for the resort customers are higher than the means for the resort owners which indicates that visitors to the area think wildlife habitat is more important than the people who own the resorts. This could be because one of the main reasons why people visit parks is to see animals while hiking or camping, and one of the main goals of national parks is to "to conserve the scenery and the natural and historic objects and the wildlife therein" (National Park Service, 2000).

Discussion: Fish Habitat

As far as fish habitat is concerned, the majority of resort owners and customers on Kabetogama Lake commented that they have seen improvements to fish habitat (Tables 1 and 3). One resort owner noted that "higher spring levels make for better northern pike spawning habitat [whereas] the old curves left these areas dry." This perception is consistent with the scientific literature because since the 2000 rule curves were implemented, the aquatic plant communities in the lakes in the Namakan Reservoir, including Kabetogama Lake, have begun to recover due to higher water levels in the later winter (Meeker and Harris, 2009). This means there are more diverse and dense aquatic plant communities which are essential for providing spawning habitat for fish (Cohen and Radomski, 1993). However, on Rainy Lake the owners who commented on improvements to fish habitat were split evenly; one said they saw improvements and the other said they didn't (Table 2). Also on Rainy Lake, the majority of customers said the fish habitats

were not improved (Table 4). This discrepancy between findings could be explained by the fact that, in general, people (especially the resort owners) are less satisfied with the consistency of water levels on Rainy Lake (Table 2) which could contribute to their opinion that less favorable water levels lead to less beneficial, less consistent fish habitats.

On the surveys, the importance of fish habitat was broken down into walleye habitat and northern pike habitat. The importance of walleye habitat to resort owners was statistically significant ($p=0.029$), meaning the resort owners on Kabetogama Lake gave more importance to walleye habitat than the resort owners on Rainy Lake (Table 5). The opinions of the resort owners on Kabetogama Lake and Rainy Lake did not differ significantly in terms of the importance of northern pike habitat (Table 7); however, the means were lower for northern pike habitat than the means for walleye habitat (Table 5), indicating that walleye habitat is more important to resort owners than northern pike habitat. This is most likely due to the fact that "walleye are the most sought-after fish in Minnesota" (Department of Natural Resources, 2015). The opinions of the resort customers on the two lakes differed in regards to the importance of both walleye and northern pike habitat (Table 10). The customers on Rainy Lake gave more importance to both walleye habitat and northern pike habitat than the customers on Kabetogama Lake (Table 8). More research into the economic impact fishing has on these two lakes needs to be done in order to explain this significant difference because the scientific literature is not able to explain this at this time.

Discussion: Fishing Conditions

In regards to fishing conditions, there were no verbatim comments made by resort owners on either Kabetogama Lake or Rainy Lake about their importance. However, the majority of customers on both Kabetogama Lake and Rainy Lake commented they have seen improvements

to fishing conditions. The majority of customers in agreement said something to the effect of "fishing is better due to rule curves in conjunction with protective slot for walleyes and pike on both sides of the border." When asked if the 2000 rule curves have made the quality of fishing better, the resort owners on the two lakes had differing opinions (Table 7). The resort owners on Kabetogama Lake were in significantly more agreement that the new hydroregime improved the quality of fishing than those resort owners on Rainy Lake (Table 6). This is likely related to the fact that owners on Kabetogama Lake are more satisfied with how the water levels have improved since the 2000 rule curves than the resort owners on Rainy Lake (Table 6); more consistent water levels are related to better fish habitat because there is a lack of drying and rewetting of sediments (Christensen et al., 2013, Cohen and Radomski, 1993) in which fish spawn. However, the resort customers on the two lakes were in agreement that the quality of fishing has improved since 2000, as the results in Table 10 were not significant.

Discussion: Water Levels

As far as water level consistency goes, the majority of both the resort owners and customers on Kabetogama Lake noted improved water level consistency since the 2000 rule curves (Tables 1 and 3). However, the majority of resort owners on Rainy Lake commented that conditions have not improved (Table 2), and the customers were split with half noting improvements and half commenting that water levels are not more consistent (Table 4). The major complaints of the resort owners and customers on Rainy Lake was that water levels were less consistent due to lack of the dams operators' control over water levels and the unusually wet weather in 2014. One Rainy Lake resort owner commented that "changes are expected, but extremes are the issue when outside the rule curves." These observations are to be expected on Kabetogama Lake, but the observations on Rainy Lake are inconsistent with what was expected

for water level changes; according to Christensen and Maki (2014) the new rule curves did not substantially change in Rainy Lake when compared to the Namakan Reservoir, which is why Rainy Lake is frequently used as the control system.

There was no difference of opinion about the importance of water levels for recreation between the resort owners on Kabetogama Lake and the resort owners on Rainy Lake (Table 7) as owners on both lakes placed heavy importance on water levels (Table 5). Although the owners on both lakes rate water levels as important, there is, however, disagreement as to whether or not water levels have been more favorable since 2000 (Table 7). The resort owners on Kabetogama Lake agreed that water levels are more favorable, whereas the resort owners on Rainy Lake disagreed that the new hydroregime provides favorable water levels. This discrepancy is similar to the issue stated above about water level consistency; the water levels are correctly assumed to be perceived as more favorable on Kabetogama Lake, but the water levels are not viewed as more beneficial on Rainy Lake. This contradicts the literature because the goal of the International Joint Commission's 2000 rule curves was to move towards more natural water conditions that were beneficial for Rainy Lake and the Namakan Reservoir (Kallemeyn et al., 2009).

There was no difference in opinion about the importance of water levels for recreation between the resort customers on Kabetogama Lake and the resort customers on Rainy Lake (Table 10) as customers on both lakes placed heavy importance on water levels (Table 8). There was also no disagreement between customers on the two lakes as to the water level favorability (Table 10); customers from both lakes agreed that the water levels have been more favorable since the new hydroregime in 2000. This situation where the customers view the new hydroregime as beneficial and some resort owners do not believe the 2000 rule curves have

improved water levels could be a result of the customers only seeing the area for a portion of the year during their visit instead of seeing the variation in water levels throughout the year since there can be a maximum drawdown of 1.5 meters each year (McEwen and Butler, 2010).

Discussion: Wetland Vegetation

In regards to wetland vegetation, the resort owners and customers on both Kabetogama Lake and Rainy Lake noted that conditions have not improved; there were no verbatim comments that said the state of the wetland vegetation was improved. Wetland vegetation was a theme that came up in the comments of both the resort owners and the customers, but it was not statistically analyzed because there was no question with a Likert scale in the surveys that allowed for analysis. However, it is related to water levels which were data that were statistically analyzed. The more natural (higher than pre-2000 levels) and consistent water levels that accompany the 2000 rule curves (Luce and Metcalfe, 2014) have caused resort owners to see things like shoreline erosion, flooded wild rice and detached floating bogs. This is consistent with what Meeker and Harris found in their 2009 study. They found that wetland communities are responding to changes in rule curves and that shoreline communities are being influenced by water level management (Meeker and Harris, 2009).

CONCLUSION

The quantitative and qualitative results were essential to determining if less extreme water level fluctuations in Voyageurs National Park are perceived by resort owners and customers to lead to ecosystem improvements. According to the results found in this paper, the answer to the overarching question of whether or not resort owners and customers perceive less

extreme water level fluctuations in Voyageurs National Park to lead to ecosystem improvements is: it depends on which lake is being considered.

In general, the resort owners and customers on Kabetogama Lake appeared to be more satisfied with the ecological consequences that result from the 2000 rule curves than the people on Rainy Lake, although there is both satisfaction and dissatisfaction on both sides. The results indicate that overall, the majority of resort owners as well as customers on Kabetogama Lake were mostly satisfied with the improvement of water quality, wildlife habitat, fish habitat, and water level consistency; and they agreed that the goals of improved water levels, water quality, and quality of fishing were being met. The only variable that both the resort owners and customers were unsatisfied with was the state of the wetland vegetation in which they indicated that it had not improved. Therefore, the null hypothesis should be rejected for those on Kabetogama Lake, and the alternative hypothesis that the resort owners and customers have noticed improvements to the ecosystems in Voyageurs National Park as a result of the 2000 rule curve changes should be accepted.

The results also indicate that on Rainy Lake, the majority of resort owners were dissatisfied with the lack of improvements to water quality, wildlife habitat, wetland vegetation, and water level consistency; they were neutral about improvements to fish habitat; and they were also dissatisfied about the goal of improved water levels, water quality, and quality of fishing not being met. Therefore, the null hypothesis for the resort owners on Rainy Lake should not be rejected that there were no perceived improvements to the ecosystems which result from the 2000 rule curve changes. The majority of customers on Rainy Lake were dissatisfied with the lack of improvements to water quality, wildlife habitat, fish habitat, and wetland vegetation; they were neutral on whether water level consistency was improved; and they were satisfied with the

improvements to fishing conditions as well as the goals of improved water levels, water quality, and quality of fishing being met. This variation means there isn't sufficient grounds to reject the null hypothesis and accept the alternative hypothesis for the customers of Rainy Lake.

One limitation of this study is that there were no quantitative scientific data collected; only the themes from the literature were used due to the steep learning curve associated with this project. Another limitation was that not every resort owner or customer chose to elaborate on their survey responses by making additional comments (especially those which used Likert scales), thus there is a possibility that not all opinions were expressed and recorded. This limitation affects the process of searching for themes in the survey responses when gathering the qualitative data; the whole story may not be represented. This paper also encompasses only a small fraction of an international research project, therefore there needs to be more research done and data collected to more accurately answer the question of whether or not the social science perspectives truly correlate with the scientific findings. Also, since there is little change on Rainy Lake with the new rule curves (thus, the reason why Rainy Lake is frequently used as the control lake in experiments), the aspect that becomes most important in understanding the environmental and social impacts on Rainy Lake is the higher frequency of periods with high water that are above the allowable maximum water level. It is the extreme water levels that are the issue which arise from an increase in extreme weather events starting in 1995 and continuing into the 2000s (Luce and Metcalfe, 2014).

Since there has been little research done for the International Joint Commission which incorporates social science and scientific finding, it is essential to expand upon this study in order to fully understand what is occurring in Voyageurs National Park. Since all resort owners were accounted for in the interviews (67 is the total population), future research on this type of

question that compares lakes should be done with larger sample sizes of resort customers. Increased sample sizes would make the results more accurate and the outliers more obvious. It would also be more likely that the customer surveys would reflect a larger portion of the tourism season since customers spend time in Voyageurs National Park periodically. There should also be a qualitative section which allows for additional comments that accompanies each quantitative question with a Likert scale. That way, the interviewees would be encouraged to expand on their answer to get a more complete story from the data when it is analyzed.

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APPENDIX A: Qualitative Response Tables

Table 1. Opinions of Owners on Improvement of Variables on Kabetogama Lake

Owners on Kabetogama Lake	Improved	Not Improved
Water Quality	5	1
Wildlife Habitat	8	0
Fish Habitat	15	0
Wetland Vegetation	0	1
Water Level Consistency	13	2

Table 2. Opinions of Owners on Improvement of Variables on Rainy Lake

Owners on Rainy Lake	Improved	Not Improved
Water Quality	0	2
Wildlife Habitat	0	4
Fish Habitat	1	1
Wetland Vegetation	0	6
Water Level Consistency	1	8

Table 3. Opinions of Customers on Improvement of Variables on Kabetogama Lake

Customers on Kabetogama Lake	Improved	Not Improved
Water Quality	3	0
Wildlife Habitat	2	1
Fish Habitat	6	0
Fishing Conditions	11	2
Wetland Vegetation	0	1
Water Level Consistency	9	2

Table 4. Opinions of Customers on Improvement of Variables on Rainy Lake

Customers on Rainy Lake	Improved	Not Improved
Water Quality	0	1
Wildlife Habitat	0	1
Fish Habitat	1	2
Fishing Conditions	2	1
Wetland Vegetation	0	4
Water Level Consistency	2	2

APPENDIX B: Quantitative Survey Questions

Question for resort owners: We would like to know the importance you place on the management of water levels for your enjoyment of this area. Please state the importance you place on water levels for your recreational experience using the responses shown on this card. The response options are not important at all (1), not very important (2), somewhat important (3), very important (4), or extremely important (5)?

Table 5. Frequency Table with Means for Resort Owners on Importance of Variables (Kabetogama Lake %/Rainy Lake %)

OWNERS (Kabetogama%/Rainy Lake%)	Not Important At All (1)	Not Very Important (2)	Somewhat Important (3)	Very Important (4)	Extremely Important (5)	Mean
Water Levels	(0%/0%)	(0%/0%)	(3.8%/0%)	(38.5%/41.7%)	(57.7%/58.3%)	(4.54/4.58)
Water Quality	(0%/0%)	(0%/0%)	(7.7%/0%)	(34.6%/50%)	(57.7%/50%)	(4.50/4.50)
Walleye Habitat	(0%/0%)	(0%/0%)	(0%/25%)	(34.6%/33.3%)	(65.4%/41.7%)	(4.65/4.17)
Northern Pike Habitat	(0%/0%)	(0%/0%)	(30.8%/41.7%)	(34.6%/33.3%)	(34.6%/25%)	(4.04/3.83)
Wildlife Habitat	(0%/0%)	(0%/8.3%)	(19.2%/25%)	(38.5%/50%)	(42.3%/16.7%)	(4.23/3.75)

Question for resort owners: A goal of the 2000 Rule Curves (policies for water-level management) was to make water levels more favorable for water-based recreation and tourism. Would you agree that this goal has been met? Please respond Strongly Agree (1), Agree (2), Neutral (things are the same - 3), Disagree (4) or Strongly Disagree (5).

a. Water levels are more favorable? SA A Neutral D SD

b. 2000 Rule Curves have made water quality better? SA A Neutral D SD

c. 2000 Rule Curves have made the quality of fishing better? SA A Neutral D SD

Table 6. Frequency Table with Means for Resort Owners on Agreement of Goal Achievement (Kabetogama Lake %/Rainy Lake %)

OWNERS (Kabetogama%/Rainy Lake%)	Strongly Agree (1)	Agree (2)	Neutral (3)	Disagree (4)	Strongly Disagree (5)	Mean
Water Levels	(43.8%/0%)	(37.5%/0%)	(12.5%/0%)	(0%/71.4%)	(6.3%/28.6%)	(1.88/4.29)
Water Quality	(25%/0%)	(37.5%/0%)	(37.5%/57.1%)	(0%/42.9%)	(0%/0%)	(2.13/3.43)
Quality of Fishing	(56.3%/0%)	(37.5%/0%)	(6.3%/57.1%)	(0%/42.9%)	(0%/0%)	(1.50/3.43)

Table 7. T-test For Resort Owner Data

OWNERS (Equal Variances Assumed for All)	t	Sig. (2-tailed)	Std. Error Difference
Importance of Water Levels	-0.229	0.82	0.196
Importance of Water Quality	0	1	0.214
Importance of Walleye Habitat	2.275	0.029	0.214
Importance of Northern Pike Habitat	0.711	0.482	0.289
Importance of Wildlife Habitat	1.729	0.092	0.278
Goal of Water Levels	-5.567	0	0.433
Goal of Water Quality	-3.893	0.001	0.335
Goal of Quality of Fishing	-7.022	0	0.275

Question for resort customers: We would like to know the importance you place on the management of water levels for your enjoyment of this area. Please state the importance you place on water levels for your recreational experience using the responses shown on this card. The response options are not important at all (1), not very important (2), somewhat important (3), very important (4), or extremely important (5)?

Table 8. Frequency Table with Means for Resort Customers on Importance of Variables (Kabetogama Lake %/Rainy Lake %)

CUSTOMERS (Kabetogama%/Rainy Lake%)	Not Important At All (1)	Not Very Important (2)	Somewhat Important (3)	Very Important (4)	Extremely Important (5)	Mean
Water Levels	(0%/0%)	(6.3%/0%)	(3.1%/0%)	(53.1%/57.1%)	(37.5%/42.9%)	(4.22/4.43)
Water Quality	(0%/0%)	(6.3%/0%)	(0%/0%)	(56.3%/14.3%)	(37.5%/85.7%)	(4.25/4.86)
Walleye Habitat	(0%/0%)	(0%/0%)	(6.3%/0%)	(50%/0%)	(43.8%/100%)	(4.38/5)
Northern Pike Habitat	(3.1%/0%)	(3.1%/0%)	(37.5%/28.6%)	(40.6%/0%)	(15.6%/71.4%)	(3.63/4.43)
Wildlife Habitat	(3.1%/0%)	(6.3%/0%)	(12.5%/0%)	(43.8%/28.6%)	(34.4%/71.4%)	(4.00/4.71)

Question for resort customers: A goal of the 2000 Rule Curves (policies for water-level management) was to make water levels more favorable for water-based recreation and tourism. Would you agree that this goal has been met? Please respond Strongly Agree (1), Agree (2), Neutral (things are the same - 3), Disagree (4) or Strongly Disagree (5).

a. Water levels are more favorable? SA A Neutral D SD

b. 2000 Rule Curves have made water quality better? SA A Neutral D SD

c. 2000 Rule Curves have made the quality of fishing better? SA A Neutral D SD

Table 9. Frequency Table with Means for Resort Customers on Agreement of Goal Achievement (Kabetogama Lake %/Rainy Lake %)

CUSTOMERS (Kabetogama%/Rainy Lake%)	Strongly Agree (1)	Agree (2)	Neutral (3)	Disagree (4)	Strongly Disagree (5)	Mean
Water Levels	(24.2%/57.1%)	(42.4%/14.3%)	(21.2%/14.3%)	(3%/14.3%)	(9.1%/0%)	(2.30/1.86)
Water Quality	(9.4%/28.6%)	(34.4%/71.4%)	(50%/0%)	(3.1%/0%)	(3.1%/0%)	(2.56/1.71)
Quality of Fishing	(21.9%/42.9%)	(28.1%/28.6%)	(40.6%/0%)	(9.4%/28.6%)	(0%/0%)	(2.38/2.14)

Table 10. T-test For Data on Resort Customers

CUSTOMERS (Equal Variances Assumed for All)	t	Sig. (2-tailed)	Std. Error Difference
Importance of Water Levels	-0.665	0.51	0.316
Importance of Water Quality	-2.038	0.049	0.298
Importance of Walleye Habitat	-2.687	0.011	0.233
Importance of Northern Pike Habitat	-2.097	0.043	0.383
Importance of Wildlife Habitat	-1.801	0.08	0.397
Goal of Water Levels	0.918	0.365	0.486
Goal of Water Quality	2.561	0.015	0.331
Goal of Quality of Fishing	0.546	0.588	0.425