Keeyask Generation Project

Aquatic Effects Monitoring Plan

Juvenile Lake Sturgeon Movement Monitoring Report

AEMP-2019-02

KEEYASK

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2018 -2019

KEEYASK GENERATION PROJECT

AQUATIC EFFECTS MONITORING PLAN

REPORT #AEMP-2019-02

JUVENILE LAKE STURGEON MOVEMENT MONITORING IN THE NELSON RIVER BETWEEN CLARK LAKE AND THE LIMESTONE GENERATING STATION, OCTOBER 2017 TO OCTOBER 2018: YEAR 5 CONSTRUCTION

Prepared for

Manitoba Hydro

By

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SUMMARY

Background

The Keeyask Hydropower Limited Partnership (KHLP) was required to prepare a plan to monitor the effects of construction and operation of the Keeyask Generating Station (GS) on the environment. Besides measuring the accuracy of the predictions made and actual effects of the GS on the environment, monitoring results will provide information on how construction and operation of the GS will affect the environment and if more needs to be done to reduce harmful effects.

Construction of the Keeyask GS began in mid-July 2014 with the construction of cofferdams that blocked flow in the north and central channels of Gull Rapids (see instream structures map below). During the winter of 2015/2016 the Spillway Cofferdam, which partially blocks the south channel, was constructed. Beginning late in 2016 and continuing in 2017, the Tailrace Cofferdam was constructed. Work was completed in fall 2017 with the exception of an opening that was left to allow fish movement into and out of the cofferdam over the 2017/18 winter. This opening was closed in spring 2018, and the area was dewatered. The spillway was commissioned in August 2018. The South Dam Cofferdam was completed in fall 2018, blocking the channel and forcing the entire flow of the river through the spillway.

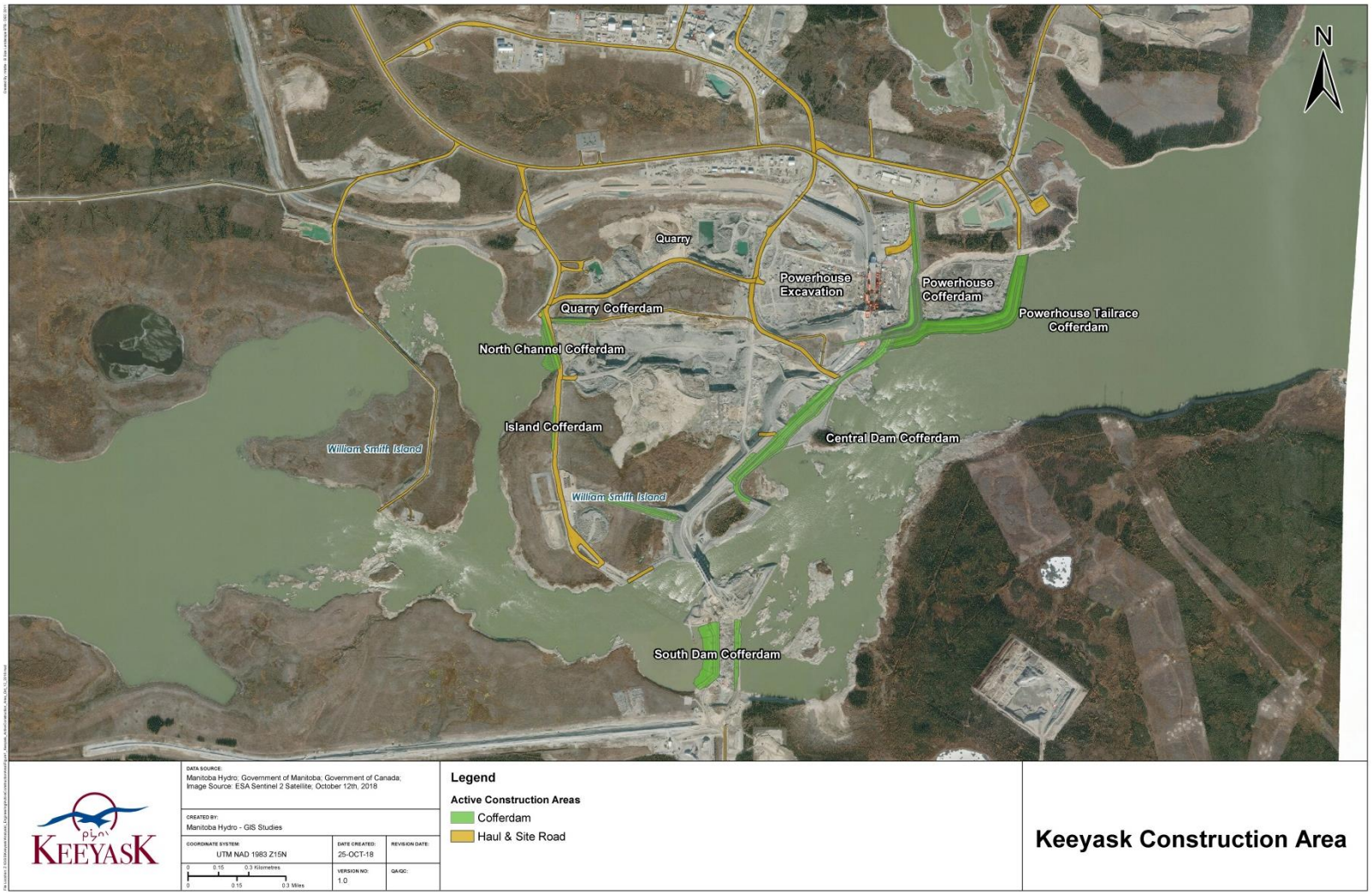
Lake Sturgeon were identified as one of the key species for monitoring. They were chosen because they are culturally important to local people, the local populations have been previously impacted, and construction and operation of the GS will change or negatively impact important habitat. The plan to monitor the impacts of GS construction and operation on sturgeon includes several types of studies:

- Estimating the number of adults;
- Estimating the number and growth of juveniles (less than 800 millimetres [mm] in length);
- Identifying spawning locations and numbers of spawning fish; and
- Recording seasonal habitat use and long distance movements (*i.e.*, over GS's or rapids) through movement studies.

The movement of juvenile Lake Sturgeon in Stephens Lake were monitored in 2011 and 2012, but because different methods are being used for the current study, the results of the two programs cannot be directly compared. Results of the 2011/2012 study showed that young Lake Sturgeon in Stephens Lake preferred to live in the deep water during the spring, summer and fall, but moved into nearby, shallower habitat outside the old river channel in winter. Also, it was unusual for juvenile Lake Sturgeon to travel large distances; instead they generally stayed in the upstream portion of the lake where water flows decreased downstream of Gull Rapids. No fish moved upstream through Gull Rapids or downstream through the Kettle GS.

Monitoring of juvenile sturgeon movement using the same methodology as described in the AEMP began in August 2013. The original acoustic tags reached the end of their battery lives in 2017; therefore, 40 juvenile Lake Sturgeon were implanted with acoustic tags in September 2017 to continue the movement study.

This report provides results of juvenile sturgeon movement monitoring conducted from October 2017 to October 2018. The movements of juvenile Lake Sturgeon were monitored for 10.5 months prior to changes to the river (pre-construction), and have been monitored for approximately four years and three months following the start of construction.



Satellite Imagery - October 12th, 2018

Map illustrating instream structures at the Keeyask Generating Station site, October 2018.

Why is the study being done?

Monitoring during construction is being done to answer three questions:

Is construction affecting the area that juvenile Lake Sturgeon occupy upstream and downstream of the construction site?

Monitoring sturgeon movement shows what areas of the river the sturgeon are using relative to the construction site and if these areas change during and after construction of the Keeyask GS.

Are there juvenile Lake Sturgeon close to the construction site?

If sturgeon are in the river close to the construction area, they could be harmed by high amounts of mud in the water or they could be trapped inside an area that will be drained.

How many juvenile Lake Sturgeon are moving through and/or away from Gull Rapids during construction and how far are they going?

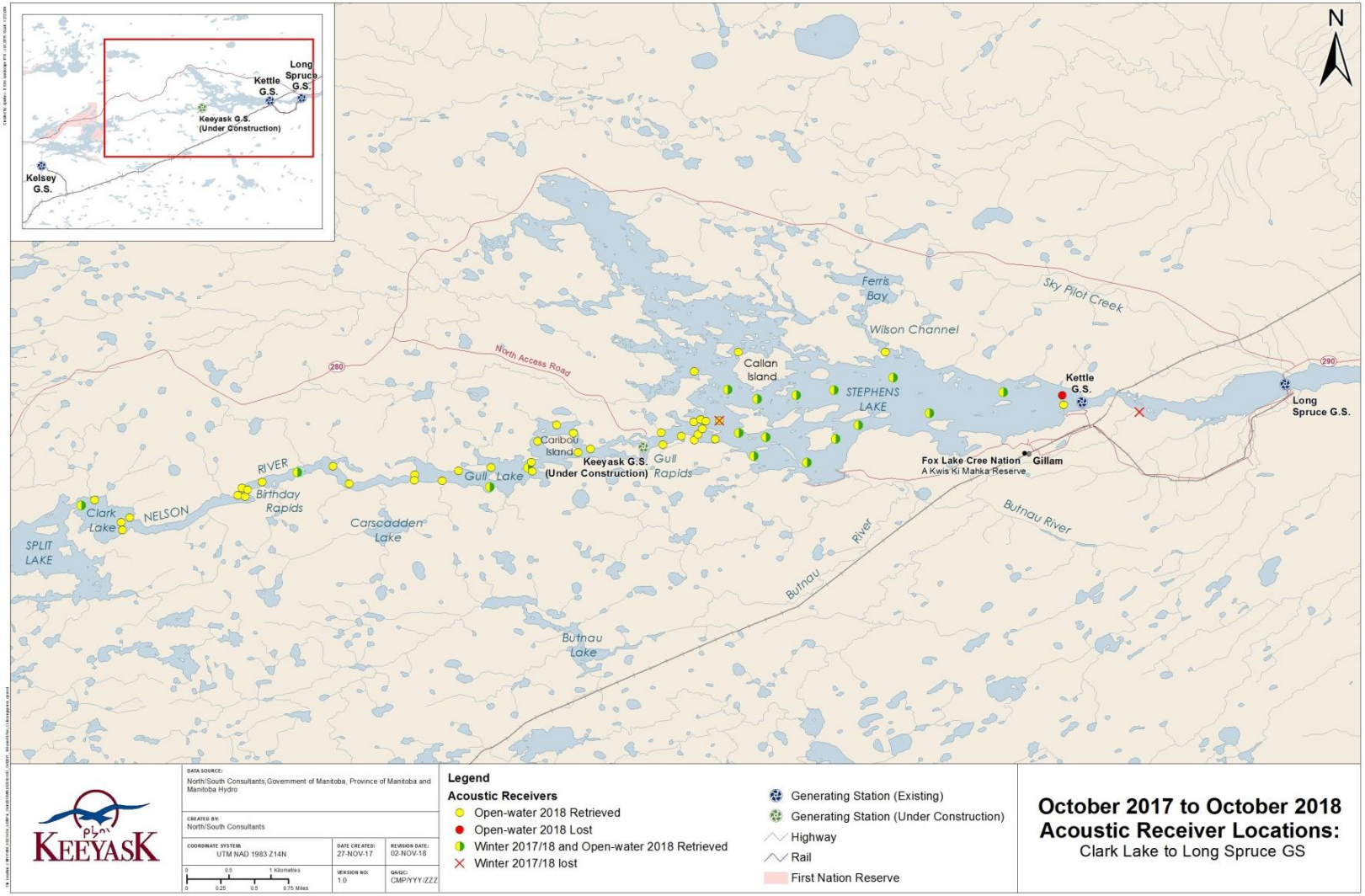
Movement studies tell us how many juvenile sturgeon are moving down through Gull Rapids, how far they travel up or downstream away from the site, whether they are leaving the Keeyask area completely and when they are making these movements. The distance they travel is monitored as far upstream as the inlet to Clark Lake and downstream as far as the Limestone Reservoir.

What was done?

The movements of juvenile sturgeon were tracked using acoustic telemetry. This is a technique in which a tag is surgically implanted inside a fish. The tag emits a sound signal (called a “ping”) that is picked up by receivers placed along the Nelson River between Clark Lake and the Limestone GS (see study area map below). Each fish is given a tag that transmits a unique ping which can be detected up to 1 km away from a receiver. By looking at the detections that were recorded by different receivers, the movement of each fish can be tracked. The tags are powered by batteries with a four-year life-span.

During fall 2013, 20 tags were applied to juvenile sturgeon in Gull Lake and 20 were applied to juveniles in Stephens Lake. Since these tags were nearing the end of their battery life in 2017, an additional 40 fish were tagged in September 2017 (20 in Gull Lake and 20 in Stephens Lake).

Surgery on a juvenile Lake Sturgeon (left and middle) to implant an acoustic tag (right).



Map showing the study area. The dots represent the locations of receivers in the river. The different colours represent receivers that were in the river at different times of the year.

What was found?

Overall, juvenile sturgeon do not move very far. Sturgeon in Stephens Lake move farther than those in Gull Lake. This is probably because sturgeon prefer deep water habitat, and there is more of it in Stephens Lake than in Gull Lake. Juveniles in Gull Lake like to stay in the few deep water sites in the lake and do not make many movements away from these sites. In Stephens Lake, even though there is more deep water habitat, juveniles spend most of their time in a few spots, relatively close to Gull Rapids.

In general, juvenile sturgeon tend to stay in the area in which they were tagged. The sturgeon that were tagged in Gull Lake in 2017 have not moved out of Gull Lake, either upstream or downstream. This is similar to what was seen for fish tagged in 2013, where only one fish made a movement upstream out of Gull Lake but returned back to the lake the same year. No other movements out of Gull Lake have been recorded since 2013. In Stephens Lake, three fish are known to have moved downstream past the Kettle GS since the start of the study: two of the fish tagged in 2013 (one moved before construction and one moved after construction) and one of the fish tagged in 2017 moved immediately after tagging. Low water levels prevented boats from being launched in the Long Spruce or Limestone reservoirs in 2018. As a result, it is unknown if more fish have moved downstream past the Kettle GS; however, detection of five juveniles near the downstream end of Stephens Lake during the winter, followed by no detections for the remainder of the study period, suggests that additional fish have moved past the GS.

The river was completely blocked off and the spillway was commissioned during August of 2018, meaning upstream movement out of Stephens Lake is no longer possible for fish. This is not likely to affect juvenile sturgeon movements, as no juvenile has ever been recorded moving over Gull Rapids, either upstream or downstream. Juvenile sturgeon in Gull Lake do not spend much time in the area near the construction site, but the ones in Stephens Lake do spend time right below the site.

Juvenile Lake Sturgeon.

What does it mean?

For the most part, monitoring has shown that juvenile sturgeon tend to stay in the same areas year after year, and these areas have not changed since construction started. However, five fish may have left Stephens Lake in winter 2017/2018, which, if it occurred, is different than has

been seen in any other year. The movement of juvenile sturgeon will continue to be monitored as construction of the Keeyask GS continues.

How far sturgeon move may also depend on the habitat that is available. For example, they may move farther when they have access to a long stretch of deep river channel. For this reason, the movements of sturgeon may change after the GS is built and Gull Lake becomes part of a deep reservoir.

What will be done next?

The original tags applied to juvenile Lake Sturgeon in 2013 are now expired and cannot be tracked by the receivers. The tags will continue to be inactive for the remainder of the Lake Sturgeon's lifespan, and will not negatively impact the fish. The 40 new tags applied in 2017 will allow the movements of juvenile Lake Sturgeon to be tracked until 2021. Tracking a new group of individual fish over the next four years will provide more information about what kinds of habitats juvenile Lake Sturgeon use over many years and if their behaviour changes as construction of the Keeyask GS progresses.

ACKNOWLEDGEMENTS

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1.0 INTRODUCTION

The Keeyask Generation Project (the Project) is a 695-megawatt (MW) hydroelectric generating station at Gull (Keeyask) Rapids on the lower Nelson River in northern Manitoba. The Project is approximately 725 kilometers (km) northeast of Winnipeg, 35 km upstream of the existing Kettle Generating Station, where Gull Lake flows into Stephens Lake, 60 km east of the community of Split Lake, 180 km east-northeast of Thompson and 30 km west of Gillam (Map 1). Construction of the Project began in July 2014.

The *Keeyask Generation Project: Response to EIS Guidelines*, completed in June 2012, provides a summary of predicted effects and planned mitigation for the Project. Technical supporting information for the aquatic environment, including a description of the environmental setting, effects and mitigation, and a summary of proposed monitoring and follow-up programs is provided in the *Keeyask Generation Project Environmental Impact Statement: Aquatic Environment Supporting Volume* (AE SV). As part of the licencing process for the Project, an Aquatic Effects Monitoring Plan (AEMP) was developed detailing the monitoring activities of various components of the aquatic environment including the focus of this report, juvenile Lake Sturgeon movement, for the construction and operation phases of the Project.

Monitoring of juvenile Lake Sturgeon movements was initiated in 2011, but the program was specifically focused on gaining a better understanding of juvenile Lake Sturgeon habitat preferences (water depth, water velocity, and substrate type) within Stephens Lake (Map 1). As pre-Project studies were not designed to record detailed movement patterns in the Clark Lake to Stephens Lake reach as a whole, results were not directly comparable to the movement data being collected under the AEMP, but they provided valuable insight into the behaviour of this life history stage in Stephens Lake (McDougall *et al.* 2013a, b). Data were collected across three seasons (open-water 2011, winter 2011/2012, and open-water 2012), and results suggested that during periods of open water, juvenile Lake Sturgeon preferred deep-water habitat within the old river channel in the upper 6 km of Stephens Lake, in an area where velocity decreases and substrate transitions from cobble, to gravel, to sand, and silt. During winter, juveniles moved farther downstream. None of the 20 tagged juvenile Lake Sturgeon in this study were observed to go upstream through Gull Rapids or downstream through the Kettle GS.

The Keeyask AEMP juvenile Lake Sturgeon movement monitoring program was initiated in August 2013 when 40 juvenile Lake Sturgeon were tagged with acoustic transmitters with a four-year battery life, 20 in Gull Lake and 20 in Stephens Lake (Map 1). In Gull and Stephens lakes, Lake Sturgeon are classified as juveniles if they have a fork length measuring less than 800 mm (Henderson *et al.* 2015). The original 40 transmitters were set to expire in August 2017. Therefore, in order to continue the study (after the batteries expired in the original 40 transmitters), an additional 40 transmitters were applied to juvenile Lake Sturgeon in September 2017, again with 20 applied in both Gull and Stephens lakes. The original 40 transmitters are now expired and are no longer being tracked in the study area.

The overall aim of this monitoring study is to describe juvenile Lake Sturgeon movement during the pre-construction (2013–July 2014) and construction (July 2014–2021) phases of the Project and to determine if disturbances associated with construction alter habitat use and coarse-scale movement patterns upstream and downstream of the Project (Map 2). Results will assist in identifying the use of key habitats (*i.e.*, rearing and foraging) during construction, the potential vulnerability of sturgeon to activities at the construction site (*i.e.,* if sturgeon use the area in the immediate vicinity of the construction site they may be vulnerable to stranding during dewatering), and the potential for increased emigration or avoidance of the construction site due to disturbance (*i.e.,* blasting, suspended sediment inputs, *etc*.).

The key questions for juvenile Lake Sturgeon movement monitoring during construction include:

- Do disturbances associated with construction alter coarse-scale movement/habitat use upstream and/or downstream of the construction site?
- Are sturgeon using habitat in the immediate vicinity of the construction site?
- Does the frequency of long-distance movements (and subsequent downstream emigration/entrainment) by juvenile Lake Sturgeon increase during construction?

This report provides results from October 2017 to October 2018, which is the fourth winter and fifth open-water period of monitoring conducted since construction of the Keeyask GS began in July 2014. The study area for the Lake Sturgeon movement study in 2018 extended from Clark Lake to the Long Spruce Reservoir (Map 1). Results from previous years dating back to 2013 are presented in Hrenchuk and Barth (2014), Lacho *et al.* (2015), and Lacho and Hrenchuk (2016, 2017, and 2018).

2.0 STUDY SETTING

The study area encompasses an approximately 110 km long reach of the Nelson River from Clark Lake to the upstream end of the Limestone Reservoir (Map 1). This section of river offers a diversity of physical habitat conditions, including a variety of substrate types, and variable water depths (range 0–30 m) and velocities. Water velocities were classified as low (0.2–0.5 metres per second [m/s]), moderate (0.5–1.5 m/s), or high (greater than 1.5 m/s), as described in the Keeyask AE SV.

Clark Lake is located immediately downstream of Split Lake, and approximately 42 km upstream of Gull Rapids (Map 1). Current is restricted to the main section of the lake, with off-current bays outside the main channel. The Assean River is the only major tributary to Clark Lake, and flows into the north side. Downstream from the outlet of Clark Lake, the Nelson River narrows and water velocity increases for a 3 km stretch, known as Long Rapids. For the next 7 km, the river widens, and water velocity decreases.

Birthday Rapids is located approximately 10 km downstream of Clark Lake and 30 km upstream of Gull Rapids (Maps 1 and 3). The drop in elevation from the upstream to downstream side of Birthday Rapids is approximately 2 m. The 14 km reach of the Nelson River between Birthday Rapids and Gull Lake is characterized as a large and somewhat uniform channel with medium to high water velocities. There are a few large bays with reduced water velocity and a number of small tributaries that drain into the Nelson River.

Gull Lake is a section of the Nelson River where the river widens, with moderate to low water velocity. Gull Lake is herein defined as the reach of the Nelson River beginning approximately 17 km upstream of Gull Rapids and 14 km downstream of Birthday Rapids, where the river widens to the north into a bay around a large point of land (Maps 1 and 3), and extending to the downstream end of Caribou Island, approximately 3 km upstream of Gull Rapids. Gull Lake has three distinct basins, the first extending from the upstream end of the lake downstream approximately 6 km to a large island; the second extending from the large island to Morris Point (a constriction in the river immediately upstream of Caribou Island); and the third extending from Morris Point to the downstream end of Caribou Island (Map 3).

Gull Rapids is located approximately 3 km downstream of Caribou Island on the Nelson River (Map 1). The rapids are approximately 2 km in length, and the river elevation drops approximately 11 m along its 2 km length. Two large islands and several small islands occur within the rapids, prior to the river narrowing; these features are within the Project footprint and have been substantially altered during construction (Map 2). A summary of construction activities at Gull Rapids is provided in Section 2.1.

Just below Gull Rapids, the Nelson River enters Stephens Lake (Map 4). Stephens Lake was formed in 1971 by construction of the Kettle GS. Between Gull Rapids and Stephens Lake, there is an approximately 6 km long reach of the Nelson River that, although affected by water regulation at the Kettle GS, remains riverine habitat with moderate velocity. Construction has

altered the flow distribution immediately downstream of Gull Rapids as all flow now passes via the south channel of Gull Rapids. In August 2018, flow was further constricted when the spillway was commissioned (see Section 2.1).

Construction of the Kettle GS flooded Moose Nose Lake (north arm) and several other small lakes that previously drained into the Nelson River, as well as the old channels of the Nelson River that now lie within the southern portion of the lake (Map 4). Major tributaries of Stephens Lake include the North and South Moswakot rivers that enter the north arm of the lake. Looking Back Creek is a second order stream that drains into the north arm of Stephens Lake (Map 1). Kettle GS is located approximately 40 km downstream of Gull Rapids.

The Long Spruce Reservoir was formed in 1979 by the construction of the Long Spruce GS. It is a 16 km reach of the Nelson River extending from Long Spruce GS upstream to Kettle GS (Manitoba Hydro Public Affairs 1999). Kettle River and Boots Creek are the only major tributaries flowing into Long Spruce Reservoir, with both tributaries entering the Reservoir on the south shore (Maps 1 and 5).

The Limestone Reservoir was formed in 1990 by the construction of the Limestone GS. It is a 23 km reach of the Nelson River extending from Limestone GS upstream to Long Spruce GS. Four tributaries of the Nelson River enter the Reservoir; Wilson Creek and Brooks Creek enter from the south, and Sky Pilot Creek and Leslie Creek enter from the north. Aquatic habitat within the Reservoir ranges from a riverine environment in the upper reach, to more lacustrine conditions just upstream of the Limestone GS.

2.1 CONSTRUCTION SUMMARY

Construction of the Keeyask GS began in mid-July 2014 with the construction of cofferdams in the north and central channels of Gull Rapids (Map 2). These cofferdams resulted in the dewatering of the north and central channels and the diversion of all flow to the south channel. Construction of the Spillway Cofferdam (SWCD), which extends into the south channel of Gull Rapids, was completed in 2015. The rock placement for the inner and outer groins of the Tailrace Cofferdam (TRCD) started in late 2016 and the impervious fill placement was completed in fall 2017. An opening was created to allow fish to move freely over the winter of 2017–2018. The opening was closed in spring 2018 and dewatering of the TRCD occurred in July, at which time a fish salvage was completed. In preparation for commissioning of the spillway, the SWCD was watered-up on both sides of the structure in June 2018. Removal of the SWCD started in early July and continued into August. The spillway was commissioned between August 3 and 7, 2018. Closing the south channel with the upstream South Dam Cofferdam (SDCD) commenced at the beginning of August and river closure was achieved on August 16. This closure and the work that continued to seal the cofferdam forced the entire river flow through the spillway. The downstream SDCD was completed in September and the area between the two cofferdams was dewatered, allowing for fish salvage to be completed by late September 2018. Work continued on the upstream SDCD until it was complete in late fall 2018.

2.2 FLOWS AND WATER LEVELS

From October 2017 to October 2018, Split Lake outflow ranged from about 2,800–4,000 m³/s. Flow typically fell in the range of about 3,000–3,500 m³/s, which is near the historical annual median flow of approximately 3,300 m³/s. Flow was generally higher during the 2017–2018 winter period, gradually declining from about 3,800 m³/s at the end of February 2018 to about 2,800 m³/s by the beginning of May. From early May 2018 to the beginning of July, flow gradually increased to about 3,500 m³/s and remained at that level to the end of July. The flow subsequently declined to about 2,800 m³/s by the end of September. Water levels varied in conjunction with the flows, ranging from about 153.4–155.2 m ASL on Gull Lake.

3.0 METHODS

3.1 ACOUSTIC TELEMETRY

Acoustic telemetry involves tracking movements of fish surgically implanted with internal acoustic transmitters (tags). Each transmitter emits a unique signal, recognizable by stationary receivers. When tagged fish come into range of a receiver (generally within 500 m to 1 km, depending on conditions), the transmitter code number, as well as the date and time, are stored in the receiver. Initially, the receiver array was designed to monitor adult Lake Sturgeon (Hrenchuk and Lacho 2019a); however, the same array is also used to monitor juvenile Lake Sturgeon, Walleye (Hrenchuk and Lacho 2019b), and Lake Whitefish (Lacho and Hrenchuk 2019).

3.1.1 ACOUSTIC TRANSMITTER APPLICATION

Acoustic transmitters (Vemco V13-1x, estimated 1,480 day battery life) were first applied to 40 juvenile Lake Sturgeon (fork lengths: 450–668 mm) in August and September 2013; 20 upstream and 20 downstream of Gull Rapids (Hrenchuk and Barth 2014). These transmitters expired during the fall of 2017. To continue juvenile Lake Sturgeon movement monitoring with a similar sample size, 40 tags (estimated 1,737 day battery life) were applied to juveniles in September 2017; 20 upstream and 20 downstream of Gull Rapids (Tables 1 and 2). Sturgeon tagged in September 2017 had fork lengths ranging from 360 to 578 mm (Lacho *et al.* 2018).

3.1.2 ACOUSTIC RECEIVERS

Since 2011, stationary acoustic receivers (VEMCO model VR2 and VR2W) have been used to continuously monitor tagged adult Lake Sturgeon in the Nelson River between Clark Lake and the Long Spruce GS. Juvenile Lake Sturgeon were included in the study in 2013 and tracked with the same array. In spring 2016, the receiver array was extended to the upper Limestone Reservoir, with the placement of two receivers downstream of the Long Spruce GS. The intent of adding these receivers was to determine whether fish that had moved into the Long Spruce Reservoir had continued to move downstream. As noted below, these receivers could not be set in 2018 due to low water conditions.

During the first four years of the construction phase of the Project (beginning in July 2014), receivers were deployed at the same sites as those established during the pre-construction phase (2011–2013). During the open-water period, receivers were deployed in calm water with a flat bottom free of large debris to maximize detection range, and spaced along the main river

channel throughout the study area to maximize spatial coverage. In Stephens Lake, receivers were placed at locations within pre-flood river channels, based on the observation that sturgeon tend to stay within river channels, even in flooded environments. At constrictions within the river channel, a series of receivers were deployed to create "gates" with the intent of recording all fish that passed by the river cross-section (described in Section 3.1.2.2).

The retrieval of receivers deployed during winter has proven challenging and several were lost in previous winters that were believed to have been moved by ice (Hrenchuk and Barth 2013). Because it appears that receivers will only remain safe from ice if deployed in calm areas at depths greater than 10 m, the number of possible receiver locations during winter, especially in Gull Lake, is limited.

3.1.2.1 WINTER 2017/2018

The stationary acoustic receiver array for the winter 2017/2018 (October 17, 2017, to April 30, 2018) period consisted of 20 receivers. Four were set upstream of Gull Rapids, 15 throughout Stephens Lake, and one in the Long Spruce Reservoir (Maps 3, 4, and 5). The winter 2017/2018 array did not differ from that used in winter 2016/2017; however, due to low water levels, the receiver in the Long Spruce Reservoir could not be retrieved at the end of the 2017/2018 winter period.

3.1.2.2 OPEN-WATER 2018

An array of 56 receivers was used during the 2018 open-water period (defined as May 1 to October 10, 2018). Twenty-seven were set upstream of Gull Rapids and 29 were set in Stephens Lake (Maps 6 and 7).

The 2018 open-water array differed slightly from arrays used in previous years. One receiver (#108002) was set in a new location upstream of Gull Rapids, closer to construction, at rkm -4.8 (Map 6). In Stephens Lake, one receiver set during open-water 2017 (rkm 23.5) was not reset due to its proximity to an additional receiver (#114241 at rkm 24.7; Map 7).

Due to low water levels, receivers could not be set in the Long Spruce or Limestone reservoirs during the 2018 open-water period. Several attempts were made to access the sites throughout the open-water period; however, a boat could not be safely launched in either area. Receivers will be set in both locations during open-water 2019 provided conditions are suitable.

Receiver "gates" were established in several key areas selected based on river morphology (channel restrictions) and characteristics of habitat (areas with low velocity adjacent to the main flow of the river). Receiver "gates" consisted of two or more acoustic receivers set parallel to flow to provide complete (or nearly complete) signal coverage of a river cross-section. Areas between the "gates" were referred to as river zones. Receiver gates provide confidence that movements past key points are being detected, which allows for extrapolation of coarse-scale positions (*i.e.*, which zone) during periods when fish remain undetected. When analyzing data,

fish detected within a zone that subsequently go undetected for a period of time without passing through a gate, are assumed to be within the zone in which they were last detected.

Four gates were established between Clark Lake and Gull Rapids (44.0, 34.0, 19.0, and 10.0 rkms upstream of Gull Rapids), and two were established in Stephens Lake (4.5 and 40.0 rkms downstream of Gull Rapids) (Maps 6 and 7). The area upstream of Gull Rapids was divided into five zones (Map 6; Zones 1–5), while Stephens Lake was divided into two zones (Map 7; Zones 6 and 7). The Long Spruce Reservoir is referred to as Zone 8 and the Limestone Reservoir as Zone 9. The location of the "gates" has remained consistent since first set in 2013.

On October 10, 2018, the majority of receivers were removed and a subset (n = 19) were redeployed to monitor movements during winter 2018/2019.

3.1.3 DATA ANALYSIS

False detections can arise on acoustic telemetry receivers due to code collisions and/or environmental noise (Pincock 2012). To filter out false detections, a fish was required to be detected at least two times within a 30-minute interval at a given stationary receiver. Single detections were filtered and not used in most analyses; however, in instances when fish went undetected for lengthy periods, and/or rapid movements were suspected, raw data were also explored. In no instance did examination of raw data suggest that consideration of a single detection would result in a different behaviour or movement pattern compared with the result when single detections were removed.

Movements were analysed in terms of rkm distance, with the base of Gull Rapids representing a distance of 0 rkm. The area located downstream of Gull Rapids (*i.e.*, Stephens Lake and the Long Spruce Reservoir) were given positive (+) distance values from Gull Rapids, while the area located upstream (*i.e.*, Gull and Clark lakes) were given negative (-) distance values (Figures 1 and 2). The average rkm distance from Gull Rapids was calculated over a 4-hour interval and plotted versus time for each fish. Total detection ranges were calculated by subtracting the furthest downstream detection location from the location of the furthest upstream detection. Proportion of time all fish spent within each river zone was calculated and plotted.

4.0 RESULTS

Section 4.1 provides a summary of movements observed between tagging in September 2017 and the end of the 2017 open-water period (October 16, 2017). Biological information for fish tagged upstream of Gull Rapids and in Stephens Lake in 2017 are provided in Tables 1 and 2. Tables 3 to 8 provide detection summaries associated with each tagged fish. Figures 1 and 2 show acoustic receiver locations during the study period. Figures 3 to 14 summarize movement range and proportional distribution of tagged fish both upstream and downstream of the construction site by season. Maps 3 to 9 provide maps of receiver and 2017 tag application locations. Appendices 1 and 2 provide movement summaries for the juvenile Lake Sturgeon tagged in September 2017.

4.1 2017 RESULTS SUMMARY

4.1.1 UPSTREAM OF GULL RAPIDS

Twenty juvenile Lake Sturgeon were tagged in Gull Lake in September 2017 (Table 1; Map 8). All juveniles were detected after tagging in Gull Lake; none were detected in Stephens Lake. Therefore, there were 20 juvenile Lake Sturgeon available for detection upstream of Gull Rapids at the beginning of the winter 2017/2018 season.

4.1.2 DOWNSTREAM OF GULL RAPIDS

Twenty juvenile Lake Sturgeon were tagged in Stephens Lake in September 2017 (Table 2; Map 9). All fish were detected after tagging. One juvenile Lake Sturgeon (#31691) moved downstream past the Kettle GS within 9 days of tagging. Therefore, at the beginning of the winter 2017/2018 season, there were 19 juveniles available for detection in Stephens Lake, and one in the Long Spruce Reservoir.

4.2 WINTER 2017/2018

4.2.1 UPSTREAM OF GULL RAPIDS

The winter receiver array consisted of four receivers deployed in the Nelson River between Clark Lake and Gull Rapids at rkms -48.2, -29.4, -12.4, and -10.3 (Figure 1). All four of the acoustic receivers were retrieved (Map 3). Eight of the 20 juvenile Lake Sturgeon (40%) were

detected, logging a total of 130,770 detections (range: 108–37,229 detections; Table 5). Juvenile sturgeon were only detected at the receivers at rkms -10.1 and -12.4, with the majority of detections occurring at rkm -10.1 (Figures 3 and 4). Five fish (#31768, #31770, #31771, #31775, and #31776) were detected at both receivers, while the remaining three fish (#31769, #31772, and #31777) were detected exclusively at rkm -10.3. Fish were detected for an average of 66 days, or for 34% of the 196 day winter period (standard deviation [StDev] = 38 days; range: 22-117 days; Table 5).

Individual movement graphs can be found in Appendix 1.

4.2.2 STEPHENS LAKE

Fifteen receivers were deployed in Stephens Lake during the 2017/2018 winter period, between rkms 5.2 and 36.1 (Figure 1). Fourteen of the 15 acoustic receivers were retrieved; one receiver (#122774) at rkm 5.8 could not be located and was likely moved by ice (Map 4).

Thirteen of the 19 juveniles (68%) were located during the winter period a total of 148,342 times (range: 7–65,106 detections per individual) (Table 6, Figures 5 and 6). Fish were detected for an average of 59 days, or for 30% of the 196 day winter period (StDev = 67 days; range: 1–187 days). The mean detection range was 7.4 rkm (StDev = 8.1 rkm; range = 0.0–19.5 rkm) (Table 6; Figure 5).

Individual movement graphs can be found in Appendix 2.

Three patterns of movement were observed:

- Seven of the thirteen fish (#31759, #31763, #31766, #31696, #31697, #31692, and #31695) remained in the upstream portion of Stephens Lake at, or upstream of, rkm 9.4 for the entire winter period.
- Five fish (#31762, #31689, #31690, #31693, and #31764) were detected spending time in areas both upstream and downstream of rkm 9.4
- One fish (#31758) was detected exclusively at rkm 13.9.

4.2.3 LONG SPRUCE RESERVOIR

Due to low water levels preventing safe access to the Long Spruce Reservoir in 2018, it was not possible to retrieve the receiver deployed at rkm 47.5 (Map 5). Therefore, there were no data collected from this area during winter 2017/2018 and open-water 2018. It remains unknown if the juvenile that moved downstream into the Long Spruce Reservoir in 2017 (#31761) remains in the reservoir, or if any additional fish moved downstream past the Kettle GS. Provided conditions are suitable, movement monitoring will resume in this area in 2019.

4.3 OPEN-WATER 2018

4.3.1 ACOUSTIC RECEIVER RETRIEVAL

All stationary acoustic receivers deployed upstream of Gull Rapids (n = 27) during the 2018 open-water period were successfully retrieved (Map 6). For the first time in 2018, a receiver was successfully deployed and retrieved closer to Keeyask construction at rkm -4.8 (#108002; Map 6). One of the 29 receivers deployed in Stephens Lake (#102966) at rkm 40.8 went missing part way through the study period (Map 7). No data were retrieved from this receiver after July 26, 2018; therefore the "gate" at the downstream end of Stephens Lake was no longer effective after this date. Due to low water levels, no receivers were set or retrieved in the Long Spruce or Limestone reservoirs.

4.3.2 UPSTREAM OF GULL RAPIDS

All twenty juvenile Lake Sturgeon available for detection upstream of Gull Rapids were detected during the open-water period (Table 7). These fish were detected between 173 and 78,858 times on 13 to 141 days (8–87%) of the 163 day open-water period (average = 99 days [61%], StDev = 42 days) (Table 7). Average total movement range was 4.1 rkm (StDev = 3.5 rkm; range: 0.3–12.1 rkm; Tables 4 and 7; Figure 7). Fish were only detected in the two zones closest to Gull Rapids (Zones 4 and 5); no fish were detected farther upstream than rkm -19.5, where the Nelson River enters Gull Lake (Table 7; Map 6). The majority of detections occurred at receivers between rkms -9.0 and -10.3 (Figure 8). Only one juvenile Lake Sturgeon (#31684) was detected at the receiver closest to Gull Rapids, at rkm -4.8.

4.3.2.1 PROPORTIONAL DISTRIBUTION

Juvenile Lake Sturgeon spent slightly more time in Zone 5 (mean = 51.2%; StDev = 47.2%) than Zone 4 (mean = 48.8%; StDev = 47.3%) (Table 3; Figure 9). The proportion of time spent in each zone remained relatively stable during the open-water season, with time spent in Zone 4 slightly increasing between late July and mid-September (Figure 10).

4.3.2.2 MOVEMENT PATTERNS

Eight fish were detected exclusively in Zone 4 during the open-water season (Figure 9). All eight fish were detected as far downstream as rkm -9.9:

- Two (#31769 and #31771) had very restricted ranges, being detected only as far upstream as rkm -10.3.
- One (#31777) was detected as far upstream as rkm -12.9.

- Two (#31772 and #31776) moved to rkm -15.0.
- Three (#31768, #31770 and #31775) were detected at rkm -17.4.

Six fish were only detected in Zone 5 (Figure 9):

- One (#31683) was detected only at the receivers at rkm -9.0 and -9.3 throughout the open-water season. This fish was captured on September 20 in a gill net set at rkm -9.2 during juvenile population monitoring (Burnett and Hrenchuk 2019). It was detected in the same restricted area both before and after capture.
- Three (#31774, #31779, and #31780) moved between rkm -9.3 and rkm -7.4.
- One (#31687) moved between rkm -9.3 and rkm -5.8.
- One (#31781) was only detected at the two farthest downstream receivers (rkm -5.8 and -4.8).

The remaining six fish were detected in both zones (Figure 9). With the exception of fish #31778, these fish had the majority of their detections in Zone 5:

- One (#31684) moved between rkm -9.9 and the farthest downstream receiver at rkm -4.8.
- Two (#31685 and #31686) moved between rkm -9.9 and rkm -9.0.
- One (#31773) was detected between rkm -9.9 and -7.4 for most of the open-water season, with one upstream movement to rkm -19.5 in August. This was the farthest upstream movement made by any tagged fish.
- One (#31778) was detected mainly between rkm -9.9 and -7.4 but made a single upstream movement as far as rkm -17.4.
- One (#31782) moved between rkm -12.9 and rkm -7.4.

4.3.3 STEPHENS LAKE

Fourteen of the 19 juvenile Lake Sturgeon (74%) available for detection in Stephens Lake were detected during the open-water period. These fish were detected between 13,155 and 97,400 times over 74 to 154 days (45–94%) of the 163 day study period (average = 122 days (75%); StDev = 25 days) (Table 8). The average total movement range was 12.0 rkm (StDev = 5.7 rkm; range: 1.5–23.5 rkm; Table 4; Figure 11). No fish were detected farther downstream than rkm 24.7. The highest number of detections was logged by the receiver at rkm 7.9 (22.2%), followed by the receivers at rkm 4.5 (13.5%) and 4.3 (8.7%) (Figure 12). Twelve of the 14 fish (86%) were detected at the receivers closest to Gull Rapids (rkm 1.2) during the open-water period. The vast majority of detections (99.3%) occurred in the southern portion of Stephens Lake, with juveniles only detected at one receiver in the northern part of the lake (at rkm 16.8; Figure 12).

One juvenile Lake Sturgeon (#31760) was captured in a gill net set at rkm 4.7 during fall juvenile population monitoring on September 20, 2018 (Burnett and Hrenchuk 2019). This fish was live-released after capture.

4.3.3.1 PROPORTIONAL DISTRIBUTION

On average, fish spent slightly more time in Zone 7, farther from Gull Rapids (average = 53.4% of time, StDev = 33.9%), than in Zone 6 (average: 46.6%; StDev = 33.9%) (Table 3; Figures 13 and 14). Time spent in Zone 6 increased during mid-August, then remained relatively stable for the remainder of the open-water period (Figure 14). Fish spent an average of 32.9% of the time in Zone 6 between June 6 to August 10 (StDev =10.5%) and 60% of the time between August 11 and October 10 (StDev = 6.8%). Unlike in previous years, when juveniles spent more time in Zone 6 in the middle of the summer then moved back downstream by the end of the open-water season, juveniles remained in Zone 6 until the end of the open-water season.

4.3.3.2 MOVEMENT PATTERNS

All five fish that were not detected during the 2018 open-water period may have moved downstream through the Kettle GS:

- #31761 moved steadily downstream immediately after tagging at rkm 4.7 on September 13, 2017. It was last detected at rkm 40.9 on September 19, 2017, immediately upstream of the Kettle GS (Appendix A2-14).
- #31689 was last detected on January 8, 2018 at rkm 21.6 after moving steadily downstream from rkm 6.8 starting on December 28, 2017 (Appendix A2-2).
- Three fish (#31690, #31693, and #31764) were detected in the upstream portion of Stephens Lake in early winter 2017, and were last detected at rkm 24.7 between late November and early December, 2017 (appendices A2-3, A2-6, and A2-17).

Of the 14 fish located during the open-water period, one (#31688) was detected exclusively in Zone 6 (between rkm 1.2 and 2.7). The remaining 13 fish were detected in both Zones 6 and 7.

Four juveniles were detected at a single receiver set in the northern portion of Stephens Lake (rkm 16.8).

- Three (#31692, #31759, and #31766) were detected at this receiver briefly (7 to 90 times) while making upstream or downstream movements.
- One (#31760) was detected in the southern part of the lake between rkm 1.2 and 18.6 during most of the open-water period. It was captured on September 20 in a gill net set at rkm 4.7 as part of juvenile population monitoring (Burnett and Hrenchuk 2019). After it was captured, it moved steadily downstream until it was detected at rkm 16.8 in the northern portion of the lake on September 27. It was detected at this location until the end of the open-water period.

The remaining nine fish were detected exclusively at receivers in the southern portion of the lake:

- Two (#31694 and #31762) were detected as far upstream as rkm 2.7 and 3.8, respectively. Both fish made multiple movements between zones 6 and 7 during the open-water period.
- Five (#31696, #31697, #31763, #31765, and #31767) were detected moving between rkm 1.2 and 10.3.
- #31695 moved between rkm 1.2 and 7.9.
- #31758 was detected between rkm 1.2 and 13.9.

4.3.4 LONG SPRUCE RESERVOIR

As mentioned in Section 4.2.3., one juvenile Lake Sturgeon (#31761) was last detected in the Long Spruce Reservoir in September 2017. Due to low water levels, no receivers could be set during open-water 2018. Provided conditions are suitable, receivers will be set in this area in open-water 2019 to monitor potential fish passage.

4.3.5 LIMESTONE RESERVOIR

Due to low water levels, no receivers could be set in the Limestone Reservoir during open-water 2018. Provided conditions are suitable, receivers will be set in this area in open-water 2019 to monitor potential fish passage.

5.0 DISCUSSION

This study was initiated in 2013 with the long-term objective of assessing the impacts of construction and operation of the Keeyask GS on juvenile Lake Sturgeon movement. As predicted in the AEMP and the Keeyask EIS, potential impacts include increased emigration from the population and the loss of critical habitats. Acoustic transmitters applied in 2013 expired in September 2017 and additional fish were tagged upstream (20) and downstream (20) of the construction site in September 2017 to continue movement monitoring during construction of the GS.

The juvenile Lake Sturgeon tagged in 2017 generally exhibit similar movement patterns to the original 40 fish tagged in 2013, including small movement ranges and relatively few long distance movements. These movement patterns are consistent with juvenile behaviour before the start of construction (McDougall *et al*. 2013a, b) as well as observations in other systems (Holtgren and Auer 2004; Smith and King 2005; Barth *et al*. 2011; Trested *et al*. 2011).

Fish in Gull Lake continue to spend the majority of time in the areas near the boundary between Zones 4 and 5 as well as the areas north and west of Caribou Island. Similar to previous years, juveniles did not move upstream out of Gull Lake. Only one fish was detected at the upstream end of Gull Lake, but did not spend much time in the upper portion of the lake before returning downstream. Juveniles were detected at the downstream end of Gull Lake but did not spend much time in this area; less than 1% of total detections occurred at the three downstream receivers.

Consistent with previous years' observations, juveniles in Stephens Lake had larger average movement ranges compared to those upstream, which has been attributed to the greater amount of continuous deep water habitat available in this area compared to upstream of Gull Rapids (McDougall *et al* 2013a, b). Based on fish detected, only one fish moved in excess of 20 rkm in 2018, and the average open-water movement range was 12 rkm. One difference from previous years was the high proportion of juveniles that were not detected during the 2018 open-water season (26%) compared to previous years (0% undetected from 2013-2016; 20% undetected in 2017 when tags were likely starting to expire). Based on their last detected locations, it is likely that at least some of these fish moved downstream past the Kettle GS during the winter months. Since it was not possible to track fish downstream of the GS in 2018, it is necessary to wait for continued monitoring to see if these fish will be detected in Stephens Lake again in the future, or if they were detected at the receiver in the Long Spruce Reservoir that was not accessible in 2018.

5.1 EVALUATION OF METHODOLOGY

The movement patterns and habitat use of juvenile Lake Sturgeon make them an ideal species to track using acoustic telemetry. Since the study was initiated in 2013, consistently high

numbers of tagged fish have been detected during open-water periods both upstream and downstream of the construction site. Tracking has always been more effective during the open-water period compared to the winter, as there are limited locations where receivers can be deployed without the risk of being moved or damaged by ice. During the winter period, tracking is limited by the reduced number of receivers, especially in Gull Lake, where only four receivers are left in during the winter.

Although more fish went undetected in 2018 than in previous study years (Section 5.0), Lake Sturgeon continued to be detected for a comparable proportion of the study period. Fish tagged upstream of the Keeyask GS construction site were detected, on average, for 61% of the 162 day 2018 open-water study period (43–61% in previous years). Fish tagged in Stephens Lake tend to be detected more often, and on average were located for 75% of the 2018 open-water period (46–61% in previous years).

The quantity of data collected during winter is lower compared to the open-water period given that fewer receivers are used (only four upstream of Gull Rapids and 15 in Stephens Lake). During the 2017/2018 winter period, 40% of fish tagged upstream of Gull Rapids and 68% of fish tagged in Stephens Lake were detected for an average of 34 and 30% of the study period, respectively.

An additional receiver added to the array in Gull Lake during the 2018 open-water period allowed the tracking of fish movements closer to the construction site, at rkm -4.8. Only two juvenile Lake Sturgeon were detected briefly at this receiver, providing further confirmation that juveniles do not spend much time in the vicinity of the upstream end of the construction zone. This receiver will continue to be deployed as part of the upstream receiver array.

5.2 KEY QUESTIONS

The key questions, as described in the AEMP, for juvenile Lake Sturgeon movement monitoring during construction of the Keeyask GS are as follows:

Will the frequency of long-distance movements (and subsequent downstream emigration/ entrainment) by juvenile Lake Sturgeon increase during construction and operation of the Project?

Since monitoring began in 2013, juvenile Lake Sturgeon have consistently shown restricted movement ranges upstream of the construction site. Only one juvenile Lake Sturgeon (tagged in 2013) has moved upstream out of Gull Lake (in 2015); this fish moved back downstream into Gull Lake the same year and has not repeated the movement. No juvenile Lake Sturgeon has moved downstream through Gull Rapids since the beginning of the study.

In Stephens Lake, juveniles generally exhibit a similar pattern, displaying small movement ranges relative to the amount of available deep water habitat. Of the original 20 fish implanted with transmitters in 2013, only two moved downstream out of Stephens Lake during the four

years they were monitored, with one moving before construction, and one moving after construction. Of the 20 fish tagged in 2017, one has been confirmed to have moved downstream over the Kettle GS. This fish moved downstream shortly after tagging and its movement is likely related to tagging stress (Lacho *et al.* 2018). Five additional fish may have moved downstream through the Kettle GS in 2017 due to their last-detected positions and absence of detections during 2018, but this cannot be confirmed until tracking downstream of the Kettle GS continues in 2019.

Are juvenile Lake Sturgeon using habitat in the immediate vicinity of the construction site?

Monitoring has consistently shown that juvenile Lake Sturgeon upstream of Gull Rapids do not spend much time in the vicinity of the construction site. In 2018, a receiver was placed 4.8 rkm upstream of Gull Rapids, allowing fish to be tracked farther downstream than in previous years. Only two juvenile Lake Sturgeon were detected at this receiver, both only briefly. Detections at the three farthest downstream receivers comprised less than 1% of the total detections. Juveniles, both those tagged in 2013 and 2017, are consistently detected most often near the transition between Zones 4 and 5, as well as at the receivers on the north and east side of Caribou Island.

In contrast, juveniles in Stephens Lake have been frequently detected in the vicinity of the construction site since the study began. In 2018, 86% of detected fish were located by the receiver 1.2 rkm downstream of the site. Juveniles in Stephens Lake are therefore more susceptible to construction-related effects like increased sedimentation and flow changes.

Will disturbances associated with construction of the Keeyask GS alter coarse-scale movement upstream or downstream of the GS?

Movement patterns of juvenile Lake Sturgeon have remained relatively consistent since monitoring started in 2013. Upstream, juveniles are consistently located in the same area year after year, with only one upstream movement out of Gull Lake being recorded during five years of study. Juveniles in Stephens Lake tend to move more than in Gull Lake, likely due to higher quantities of deep water habitat, but movements still remain relatively restricted. Three movements downstream through the Kettle GS have been recorded in the 5 years of study. For the first time in 2018, fish in Stephens Lake remained in the upstream portion of the Lake for the duration of the open-water season. In previous years, fish have moved upstream in the summer and then returned downstream by the fall. The proportion of time spent in the zone closer to Gull Rapids increased soon after the spillway was commissioned in August. However, it should be noted that discharge in the Nelson River was also lower at this time than since the start of construction. Future monitoring will reveal if juveniles continue to spend more time in the upper portion of Stephens Lake. One change observed in 2018 was the high proportion of juveniles in Stephens Lake that went undetected during the open-water season. These fish may have moved downstream past the Kettle GS during the winter months. Future monitoring will confirm if these fish did actually move out of Stephens Lake.

6.0 SUMMARY AND CONCLUSIONS

- Juveniles implanted with acoustic transmitters in 2017 have now been tracked for a full year. The original 40 transmitters implanted in 2013 are expired and no longer active.
- Juvenile Lake Sturgeon continue to be tracked effectively using acoustic telemetry. In 2018, all 20 of the fish tagged upstream of Gull Rapids were detected during the open-water period, while 14 of the 19 fish in Stephens Lake were detected. Although the proportion of fish detected during the winter is lower due a smaller receiver array, the data collected during the winter period is still sufficient to meet the objectives of the study and answer the key questions from the AEMP.
- The key questions, as described in the AEMP, for juvenile Lake Sturgeon movement monitoring during construction of the Keeyask GS are as follows:
    - *Will the frequency of long-distance movements by juvenile Lake Sturgeon increase during construction and operation of the Project?*

      To date, there has not been a documented increase in the frequency of long-distance movement by juveniles. Upstream of Gull Rapids, no juvenile Lake Sturgeon have permanently moved out of the study area, either upstream or downstream, since monitoring began. Downstream, three juveniles have been confirmed to have moved downstream out of Stephens Lake through the Kettle GS (one between December 2013 and July 2014, one in 2016, and one in 2017). As noted previously, an additional five fish may have moved downstream out of Stephens Lake during winter 2017/2018.
    - *Are juvenile Lake Sturgeon using habitat in the immediate vicinity of the construction site?*

      Juvenile Lake Sturgeon upstream of Gull Rapids have consistently spent little time in the vicinity of the construction site since the beginning of the study. In contrast, juveniles are frequently detected by the receivers immediately downstream of the site in Stephens Lake, making these fish potentially susceptible to construction-related effects.
    - *Will disturbances associated with construction of the Keeyask GS alter coarse-scale movement upstream or downstream of the GS?*

      Juvenile Lake Sturgeon have exhibited similar movement patterns since the start of the study. Juveniles are consistently detected most often at the same receivers year after year, both upstream and downstream of the construction site. Movement ranges have remained consistent from year to year. One change in 2018 was the high proportion of fish in Stephens Lake that are suspected to have moved past the Kettle GS; continued monitoring will provide more information on the fate of these fish.

7.0 LITERATURE CITED

Barth, C.C., Anderson, W.J., Henderson, L.M. and Peake, S.J. 2011. Home range size and seasonal movement of juvenile Lake Sturgeon in a large river in the Hudson Bay Drainage Basin. Transactions of the American Fisheries Society 140: 1629-1641.

Burnett, D.C and Hrenchuk, C.L. 2019. Juvenile Lake Sturgeon population monitoring, fall 2018: Year 5 Construction. Keeyask Generation Project Aquatic Effects Monitoring Report #AEMP-2019-06. A report prepared for Manitoba Hydro by North/South Consultants Inc., June 2019. xvii + 117 pp.

Holtgren, J.M. and Auer, N.A. 2004. Movement and habitat of juvenile Lake Sturgeon (*Acipenser fulvescens*) in the Sturgeon River-Portage Lake system. Michigan Journal of Ecology 19: 419-429.

Henderson, L.M., Barth, C.C. and Hrenchuk, C.L. 2015. Juvenile Lake Sturgeon population monitoring, fall 2014: Year 1 Construction. Keeyask Generation Project Aquatic Effects Monitoring Report #AEMP-2015-03. A report prepared for Manitoba Hydro by North/South Consultants Inc. xi + 64 pp.

Hrenchuk, C.L. and Barth, C.C. 2013. Results of adult Lake Sturgeon movement monitoring in the Nelson River between Clark Lake and the Long Spruce Generating Station, October 2011 to October 2012. A report prepared for Manitoba Hydro by North/South Consultants Inc. viii + 137 pp.

Hrenchuk, C.L. and Barth, C.C. 2014. Results of juvenile Lake Sturgeon movement monitoring in the Nelson River between Clark Lake and the Long Spruce Generating Station, August to October, 2013. A report prepared for Manitoba Hydro by North/South Consultants Inc. ix + 75 pp.

Hrenchuk, C.L. and Lacho, C.D. 2019a. Adult Lake Sturgeon movement monitoring in the Nelson River between Clark Lake and the Limestone Generating Station, October 2017 to October 2018: Year 5 Construction. Keeyask Generation Project Aquatic Effects Monitoring Plan Report #AEMP-2019-01. A report prepared for Manitoba Hydro by North/South Consultants Inc., June 2019. xvii + 149 pp.

Hrenchuk, C.L. and Lacho, C.D. 2019b. Walleye movement monitoring in the Nelson River between Clark Lake and the Limestone Generating Station, October 2017 to October 2018: Year 5 Construction. Keeyask Generation Project Aquatic Effects Monitoring Plan Report #AEMP-2019-04. A report prepared for Manitoba Hydro by North/South Consultants Inc., June 2019. xv + 199 pp.

Lacho, C.D. and Hrenchuk, C.L. 2016. Juvenile Lake Sturgeon movement monitoring in the Nelson River between Clark Lake and the Long Spruce Generating Station, October 2014 to October 2015: Year 2 Construction. Keeyask Generation Project Aquatic Effects Monitoring Report #AEMP-2016-05. A report prepared for Manitoba Hydro by North/South Consultants Inc., June 2016. xiv + 96 pp.

Lacho, C.D. and Hrenchuk, C.L. 2017. Juvenile Lake Sturgeon movement monitoring in the Nelson River between Clark Lake and the Long Spruce Generating Station, October 2015 to October 2016: Year 3 Construction. Keeyask Generation Project Aquatic Effects Monitoring Report #AEMP-2017-02. A report prepared for Manitoba Hydro by North/South Consultants Inc., June 2017. xvi +100 pp.

Lacho, C.D., Hrenchuk, C.L. and Barth, C.C. 2018. Juvenile Lake Sturgeon movement monitoring in the Nelson River between Clark Lake and the Limestone Generating Station, October 2016 to October 2017: Year 4 Construction. Keeyask Generation Project Aquatic Effects Monitoring Plan Report #AEMP-2018-04. A report prepared for Manitoba Hydro by North/South Consultants Inc., June 2018. xviii + 153 pp.

Lacho, C.D. and Hrenchuk, C.L. 2019. Lake Whitefish movement monitoring in the Nelson River between Clark Lake and the Limestone Generating Station, October 2017 to October 2018: Year 5 Construction. Keeyask Generation Project Aquatic Effects Monitoring Plan Report #AEMP-2019-03. A report prepared for Manitoba Hydro by North/South Consultants Inc., June 2019. xv + 128 pp.

Lacho, C.D., Hrenchuk, C.L. and Barth, C.C. 2015. Results of juvenile Lake Sturgeon movement monitoring in the Nelson River between Clark Lake and the Long Spruce Generating Station, October 2013 to October 2014: Year 2 Construction. Keeyask Generation Project Aquatic Effects Monitoring Report #AEMP-2015-02. A report prepared for Manitoba Hydro by North/South Consultants Inc., June 2015. xvi + 92 pp.

Manitoba Hydro Public Affairs. December 1999. Long Spruce Generating Station. Brochure. 4 pp.

McDougall, C.A., Hrenchuk, C.L. and Barth, C.C. 2013a. Results of juvenile Lake Sturgeon movement and habitat utilization studies in Stephens Lake – 2011. A report prepared for Manitoba Hydro by North/South Consultants Inc. ix + 92 pp.

McDougall, C.A., Hrenchuk, C.L. and Barth, C.C. 2013b. Results of juvenile Lake Sturgeon movement in Stephens Lake – October 2011 to October 2012. A report prepared for Manitoba Hydro by North/South Consultants Inc. viii + 47 pp.

Pincock, D.G. 2012. False detections: What they are and how to remove them from detection data. VEMCO, DOC-004691, Bedford, Nova Scotia. Available: www.vemco.com/pdf/false detections.pdf. (April 2013).

Smith, K.M. and King, D. 2005. Movement and habitat use of yearling and juvenile Lake Sturgeon in Black Lake, Michigan. Transactions of the American Fisheries Society 134: 1159-1172.

Trested, D.G., Chan, M.D., Bridges, W.C. and Isely, J.J. 2011. Seasonal movement and mesohabitat usage of adult and juvenile Lake Sturgeon in the Grasse River, New York. Transactions of the American Fisheries Society 140: 1006-1014.

TABLES

Table 1: Acoustic tagging and biological data for the 20 juvenile Lake Sturgeon tagged upstream of Gull Rapids in 2017.

Tag ID	Floy Tag #	Date Tagged	Fork Length (mm)	Total Length (mm)	Weight (g)
31683	106469	12-Sep-17	505	579	800
31684	106464	09-Sep-17	432	501	600
31685	106460	09-Sep-17	410	460	550
31686	106456	09-Sep-17	504	584	1100
31687	106454	09-Sep-17	545	624	1200
31768	109632	14-Sep-17	459	532	700
31769	109633	14-Sep-17	462	516	600
31770	109636	14-Sep-17	442	511	650
31771	109637	14-Sep-17	470	541	600
31772	111031	15-Sep-17	518	598	1100
31773	109564	12-Sep-17	545	616	1000
31774	109565	12-Sep-17	481	559	800
31775	109570	13-Sep-17	459	519	600
31776	109571	13-Sep-17	410	479	400
31777	109626	13-Sep-17	578	662	1350
31778	106475	12-Sep-17	435	504	800
31779	109552	12-Sep-17	490	549	800
31780	109553	12-Sep-17	448	494	650
31781	109554	12-Sep-17	468	544	850
31782	109563	12-Sep-17	448	506	600

Table 2: Acoustic tagging and biological data for the 20 juvenile Lake Sturgeon tagged in Stephens Lake in 2017.

Tag ID	Floy Tag #	Date Tagged	Fork Length (mm)	Total Length (mm)	Weight (g)
31688	110782	16-Sep-17	436	498	625
31689	112905	15-Sep-17	445	515	625
31690	112914	14-Sep-17	433	480	525
31691	112917	14-Sep-17	487	554	750
31692	112921	14-Sep-17	453	529	400
31693	111065	13-Sep-17	494	553	900
31694	112919	14-Sep-17	390	445	375
31695	112909	15-Sep-17	455	521	650
31696	112901	15-Sep-17	440	496	700
31697	110795	16-Sep-17	433	500	600
31758	110787	16-Sep-17	375	429	425
31759	112915	14-Sep-17	445	508	575
31760	112924	14-Sep-17	363	398	280
31761	111075	13-Sep-17	435	507	500
31762	112903	15-Sep-17	434	487	525
31763	112904	15-Sep-17	457	520	725
31764	112913	14-Sep-17	440	503	500
31765	110788	16-Sep-17	505	569	950
31766	112918	14-Sep-17	360	400	300
31782	110552	15-Sep-17	455	505	675

Table 3: Proportion of time spent in each river zone by juvenile Lake Sturgeon implanted with acoustic transmitters upstream of Gull Rapids and in Stephens Lake during a portion of the 2014 (June 4 to October 10), 2015 (June 4 to October 11), 2016 (June 4 to October 19), 2017 (June 7 to October 16), and 2018 (June 6 to October 10) open-water periods.

Year Tagged	Study Year	Upstream of Gull Rapids					Stephens Lake	
		1	2	3	4	5	6	7
2013	2014	0.0	0.0	0.0	63.4	36.6	42.1	57.9
	2015	0.0	0.0	1.9	44.6	53.4	51.0	49.0
	2016	0.0	0.0	0.0	73.2	26.8	46.7	53.2
	2017	0.0	0.0	0.0	77.8	22.2	42.7	57.3
2017	2018	0.0	0.0	0.0	48.8	51.2	46.6	53.4

Table 4: Movement ranges (km) of juvenile Lake Sturgeon implanted with acoustic transmitters, including standard deviation (StDev), minimum range (Min), and maximum range (Max) upstream of Gull Rapids and in Stephens Lake during the 2014–2018 open-water periods.

Year Tagged	Study Year	Upstream of Gull Rapids				Stephens Lake			
		Average	StDev	Min	Max	Average	StDev	Min	Max
2013	2014	4.1	2.9	0.0	10	11.1	5.4	2.6	19.7
	2015	5.1	4.5	0.3	17.5	11.2	5.9	0.0	19.7
	2016	5.2	3.9	0.0	13.7	11.6	6.6	0.0	22.3
	2017	3.4	3.3	0.3	10.0	11.7	4.4	6.5	17.4
2017	2018	4.1	3.5	0.3	12.1	12.0	5.7	1.2	23.5

Table 5: Number of detections (n), number of days detected, farthest upstream (U/S) and downstream (D/S) river kilometer (rkm) detection sites, and detection range for each of 20 juvenile Lake Sturgeon implanted with acoustic transmitters and monitored upstream of Gull Rapids during winter 2017/2018.

Tag ID	n	# Days	U/S (rkm)	D/S (rkm)	Range (rkm)
31683	-	-	-	-	-
31684	-	-	-	-	-
31685	-	-	-	-	-
31686	-	-	-	-	-
31687	-	-	-	-	-
31768	5506	35	-12.4	-10.3	2.1
31769	37229	117	-10.3	-10.3	0.0
31770	7414	54	-12.4	-10.3	2.1
31771	14272	61	-12.4	-10.3	2.1
31772	34442	111	-10.3	-10.3	0.0
31773	-	-	-	-	-
31774	-	-	-	-	-
31775	1045	29	-12.4	-12.4	0.0
31776	108	22	-12.4	-10.3	2.1
31777	30754	98	-10.3	-10.3	0.0
31778	-	-	-	-	-
31779	-	-	-	-	-
31780	-	-	-	-	-
31781	-	-	-	-	-
31782	-	-	-	-	-

Table 6: Number of detections (n), number of days detected, farthest upstream (U/S) and downstream (D/S) river kilometer (rkm) detection sites, and detection range for each of 20 juvenile Lake Sturgeon implanted with acoustic transmitters and monitored downstream of Gull Rapids during winter 2017/2018.

Tag ID	n	# Days	U/S (rkm)	D/S (rkm)	Range (rkm)
31688	-	-	-	-	-
31689	1301	12	6.5	21.6	15.1
31690	1303	6	6.5	24.7	18.2
31691	-	-	-	-	-
31692	9	3	7.9	7.9	0.0
31693	1726	30	5.2	24.7	19.5
31694	-	-	-	-	-
31695	7	2	7.9	7.9	0.0
31696	25955	133	5.2	7.9	2.7
31697	65106	187	5.2	9.4	4.2
31758	35901	171	13.9	13.9	0.0
31759	7747	100	5.2	10.3	5.1
31760	-	-	-	-	-
31761	-	-	-	-	-
31762	3135	70	5.2	16.8	11.6
31763	2604	24	5.2	5.2	0.0
31764	3526	32	5.2	24.7	19.5
31765	-	-	-	-	-
31766	22	1	5.2	5.2	0.0
31767	-	-	-	-	-

Table 7: **Number of detections (n), number of days detected, farthest upstream (U/S) and downstream (D/S) river kilometer (rkm) detection sites, and detection range for each of 20 juvenile Lake Sturgeon implanted with acoustic transmitters and monitored upstream of Gull Rapids during the open-water seasons of 2017 and 2018 (Note: juveniles were tagged in September of 2017 so were not monitored for a full open-water season in 2017).**

Tag ID	2017					2018				
	n	# Days	U/S (rkm)	D/S (rkm)	Range (rkm)	n	# Days	U/S (rkm)	D/S (rkm)	Range (rkm)
31683	4718	33	-9.3	-7.4	1.9	31943	133	-9.3	-9	0.3
31684	5706	34	-9.3	-7.4	1.9	36007	109	-9.9	-4.8	5.1
31685	12846	35	-9.3	-7.4	1.9	4022	38	-9.9	-9	0.9
31686	9918	34	-9.3	-9	0.3	40702	107	-9.9	-9	0.9
31687	9880	32	-9.3	-9	0.3	10221	49	-9.3	-5.8	3.5
31768	1050	14	-10.1	-9.9	0.2	27068	130	-17.4	-9.9	7.5
31769	18816	28	-10.1	-9.5	0.6	16493	34	-10.3	-9.9	0.4
31770	17899	31	-10.1	-9.5	0.6	5455	87	-17.4	-9.9	7.5
31771	13740	31	-10.1	-9.5	0.6	78420	141	-10.3	-9.9	0.4
31772	9198	30	-10.1	-9.5	0.6	78858	137	-15	-9.9	5.1
31773	5954	32	-9.3	-7.4	1.9	24849	108	-19.5	-7.4	12.1
31774	8289	33	-9	-7.4	1.6	42167	134	-9.3	-7.4	1.9
31775	8804	17	-10.1	-9.5	0.6	2681	27	-17.4	-9.9	7.5
31776	14995	31	-10.1	-9.5	0.6	49473	131	-15	-9.9	5.1
31777	18412	31	-10.1	-9.5	0.6	29917	98	-12.9	-9.9	3.0
31778	12574	33	-9.3	-9	0.3	42749	119	-17.4	-7.4	10.0
31779	11059	33	-9.3	-7.4	1.9	47302	133	-9.3	-7.4	1.9
31780	5304	30	-9	-7.4	1.6	33306	132	-9.3	-7.4	1.9
31781	10304	33	-9.3	-7.4	1.9	173	13	-5.8	-4.8	1.0
31782	13002	33	-9.3	-9	0.3	42404	119	-12.9	-7.4	5.5

Table 8: **Number of detections (n), number of days detected, farthest upstream (U/S) and downstream (D/S) river kilometer (rkm) detection sites, and detection range for each of 20 juvenile Lake Sturgeon implanted with acoustic transmitters and monitored in Stephens Lake during the open-water seasons of 2017 and 2018 (Note: juveniles were tagged in September of 2017 so were not monitored for a full open-water season in 2017). Red-highlighted fish moved downstream over the Kettle GS in 2017.**

Tag ID	2017						2018				
	n	# Days	% Days	U/S (rkm)	D/S (rkm)	Range (rkm)	n	# Days	U/S (rkm)	D/S (rkm)	Range (rkm)
31688	6642	30	0.97	2.7	7.9	5.2	27068	74	1.2	2.7	1.5
31689	4861	30	0.94	1.2	13.9	12.7	-	-	-	-	-
31690	5300	32	0.97	1.2	7.9	6.7	-	-	-	-	-
31691	1255	7	0.21	4.1	42.7	38.6	-	-	-	-	-
31692	10971	32	0.97	1.2	13.9	12.7	17702	100	1.2	18.6	17.4
31693	8761	33	0.97	3.8	9.4	5.6	-	-	-	-	-
31694	8619	32	0.97	3.8	9.4	5.6	13155	81	2.7	18.6	15.9
31695	10767	31	0.97	2.7	7.9	5.2	47506	123	1.2	7.9	6.7
31696	10532	31	0.97	1.2	13.9	12.7	43099	154	1.2	10.3	9.1
31697	7764	30	0.97	3.8	10.3	6.5	97400	153	1.2	10.3	9.1
31758	31758	28	0.90	3.8	13.9	10.1	18719	141	1.2	13.9	12.7
31759	10329	32	0.97	2.7	10.3	7.6	37102	126	1.2	18.6	17.4
31760	938	17	0.52	1.2	3.8	2.6	25510	119	1.2	18.6	17.4
31761	394	6	0.18	4.3	40.9	36.6	-	-	-	-	-
31762	8175	30	0.94	3.8	9.4	5.6	39066	154	3.8	13.9	10.1
31763	14228	31	0.97	1.2	10.3	9.1	25869	130	1.2	10.3	9.1
31764	5769	32	0.97	3.8	10.3	6.5	-	-	-	-	-
31765	9509	30	0.97	2.7	9.4	6.7	35362	125	1.2	10.3	9.1
31766	3533	31	0.94	1.2	5.8	4.6	16440	104	1.2	24.7	23.5
31767	2549	24	0.75	1.2	4.4	3.2	30261	123	1.2	10.3	9.1

FIGURES

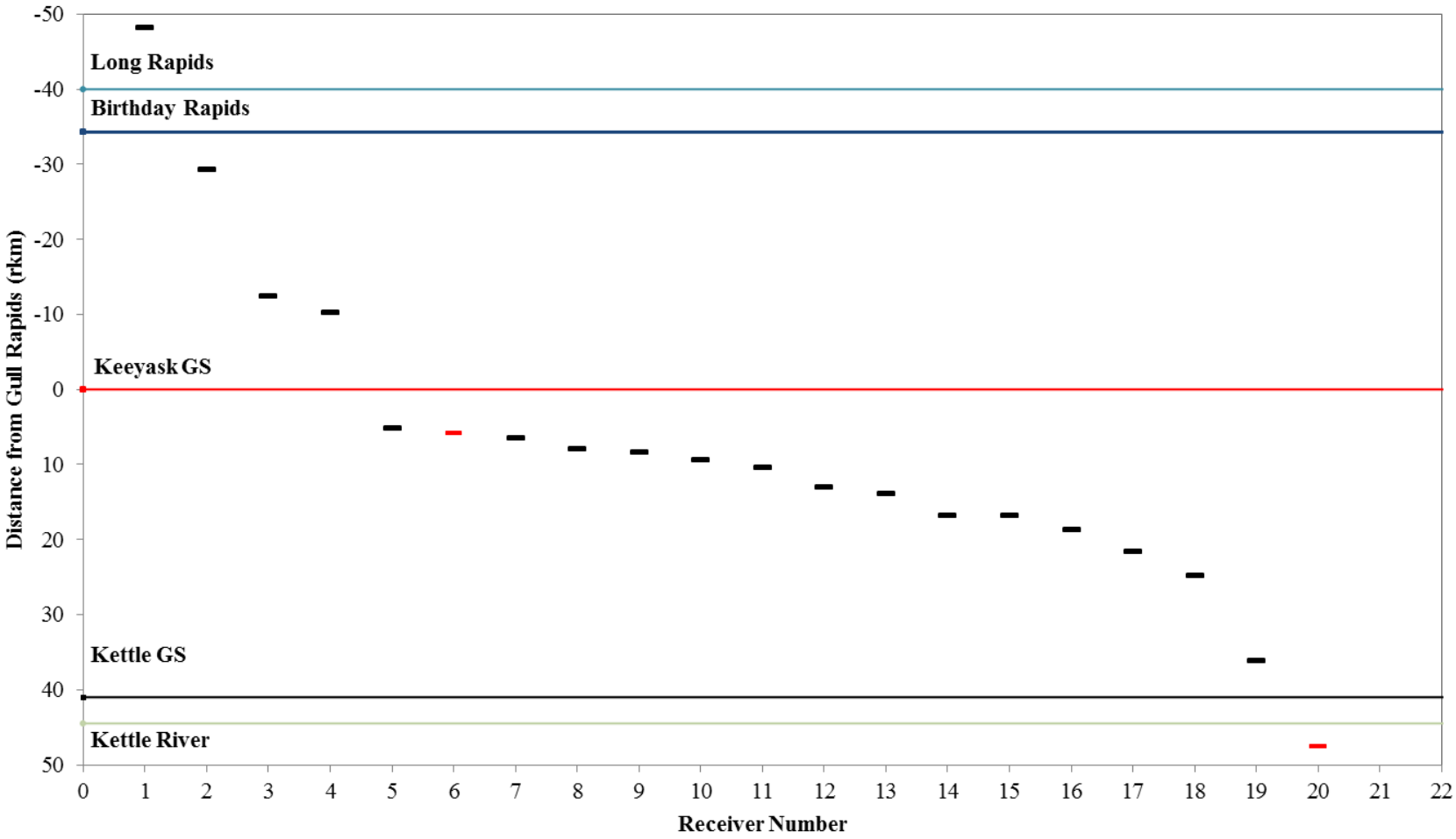


Figure 1: **Locations of stationary acoustic receivers (dashes) in relation to the base of Gull Rapids (rkm 0) and other major landmarks (lines) in the Nelson River between Clark Lake and the Long Spruce GS between October 2017 and June 2018. Red dashes indicate lost receivers.**

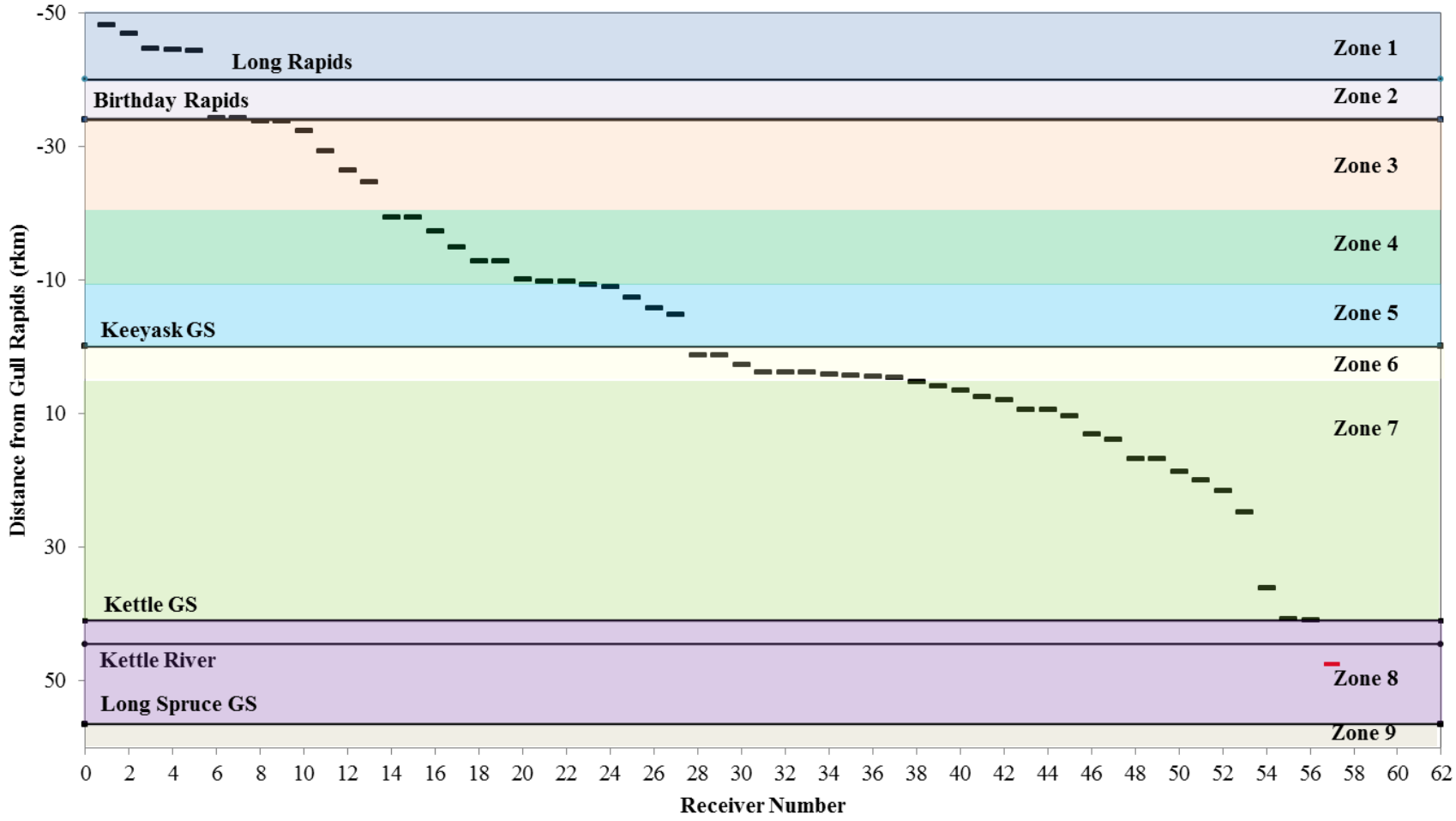


Figure 2: Locations of stationary acoustic receivers (dashes) in relation to the base of Gull Rapids (rkm 0) and other major landmarks (lines) in the Nelson River between Clark Lake and the Long Spruce GS between June and October, 2018. River zones are indicated by shading.

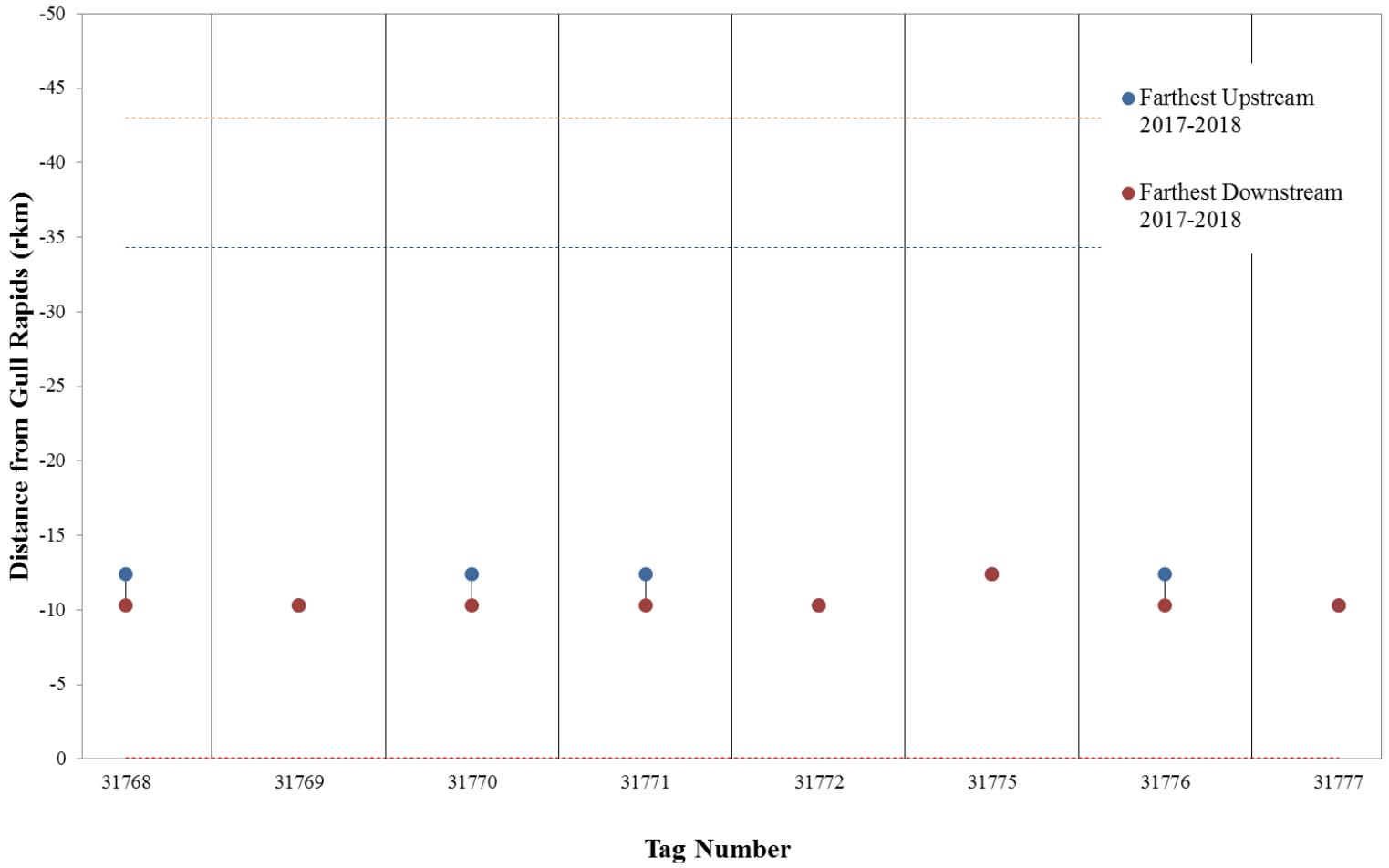


Figure 3: **Detection ranges for acoustic tagged juvenile Lake Sturgeon detected between Clark Lake and Gull Rapids during the winter 2017/2018 period. Only fish detected during this period are shown. Dashed horizontal lines represent location of Gull Rapids (red), Birthday Rapids (blue), and the entrance to Clark Lake (orange).**

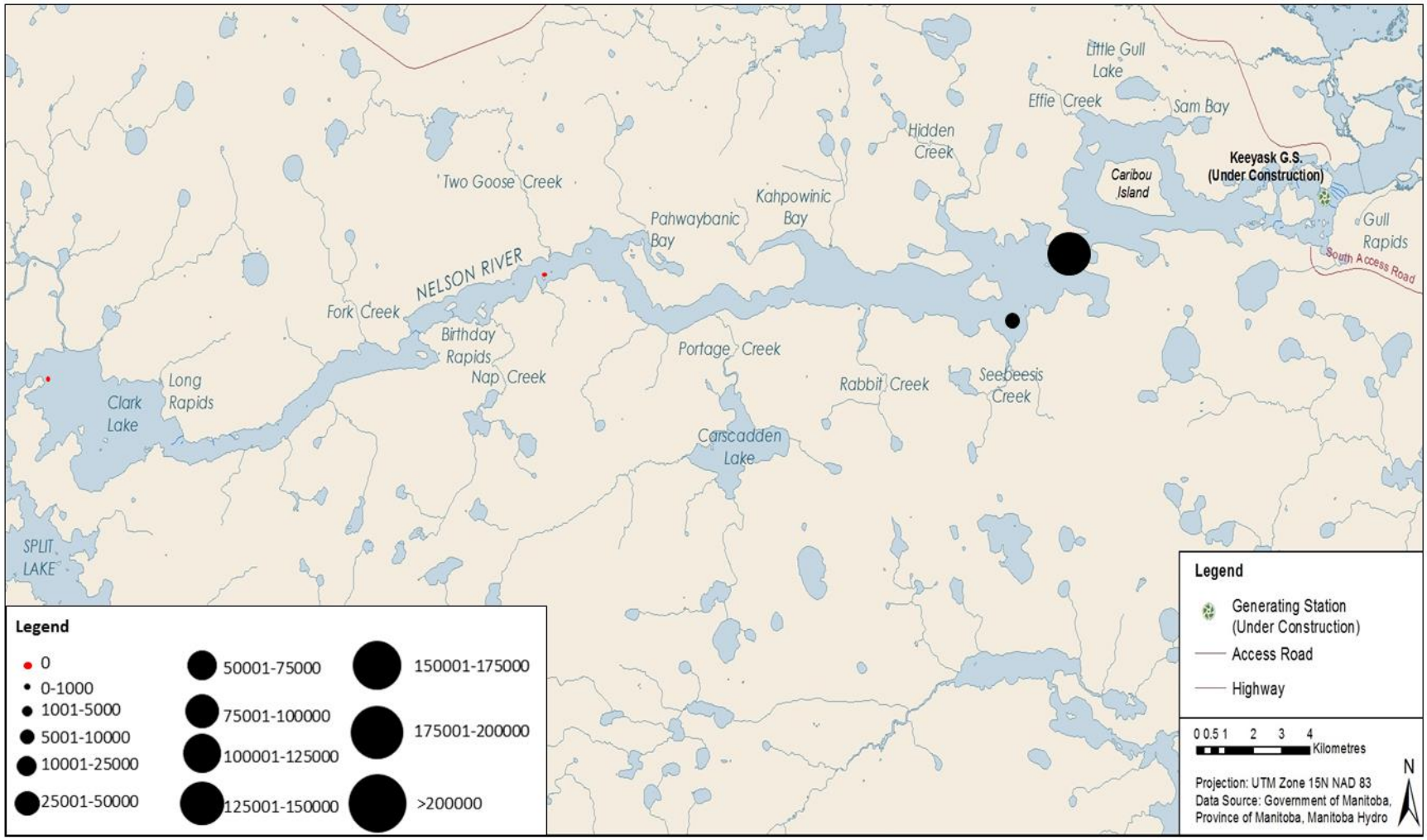


Figure 4: Relative number of detections at each acoustic receiver set between Clark Lake and Gull Rapids during winter 2017/2018 (October 17 to April 30). Number of detections indicated by size of bubble (defined in legend). Receivers with no detections indicated with red dot.

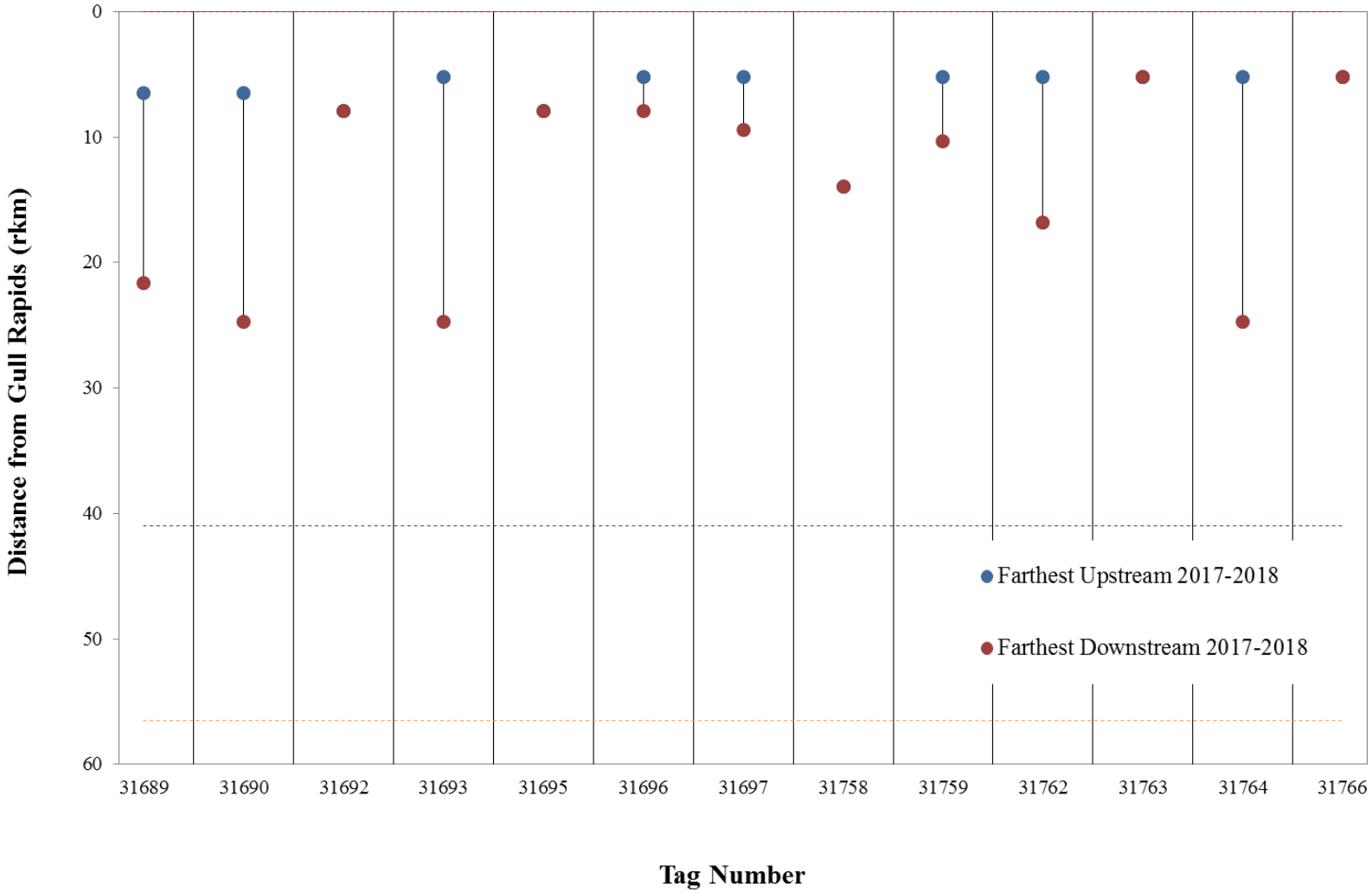


Figure 5: **Detection ranges for acoustic tagged juvenile Lake Sturgeon detected downstream of Gull Rapids during the winter 2017/2018 period. Only fish detected during the period are shown Dashed horizontal lines represent locations of Gull Rapids (red), Kettle GS (blue), and Long Spruce GS (orange).**

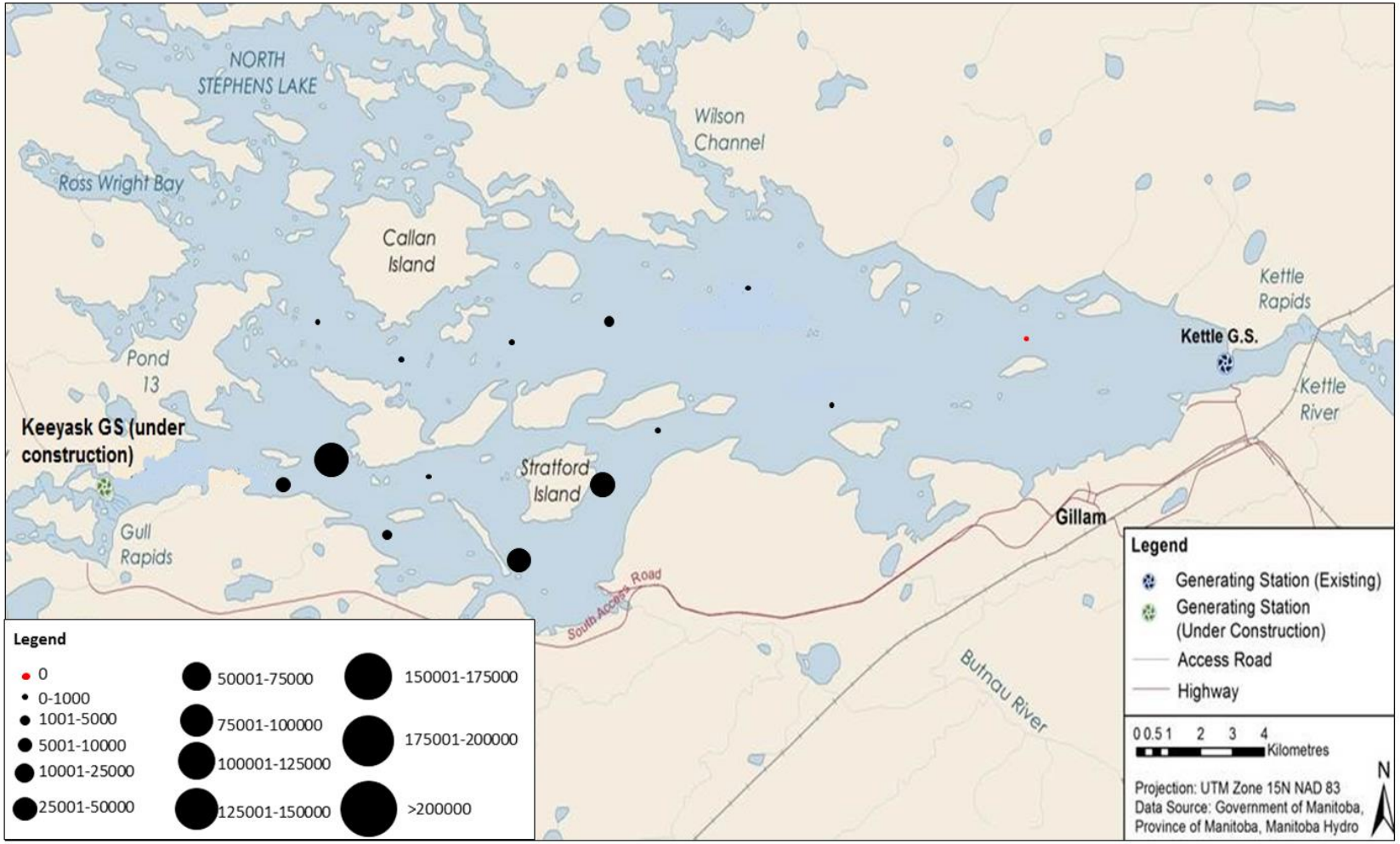


Figure 6: Relative number of detections at each acoustic receiver set in Stephens Lake during winter 2017/2018 (October 17 to April 30). Number of detections indicated by size of bubble (defined in legend). Receivers with no detections indicated with red dot.

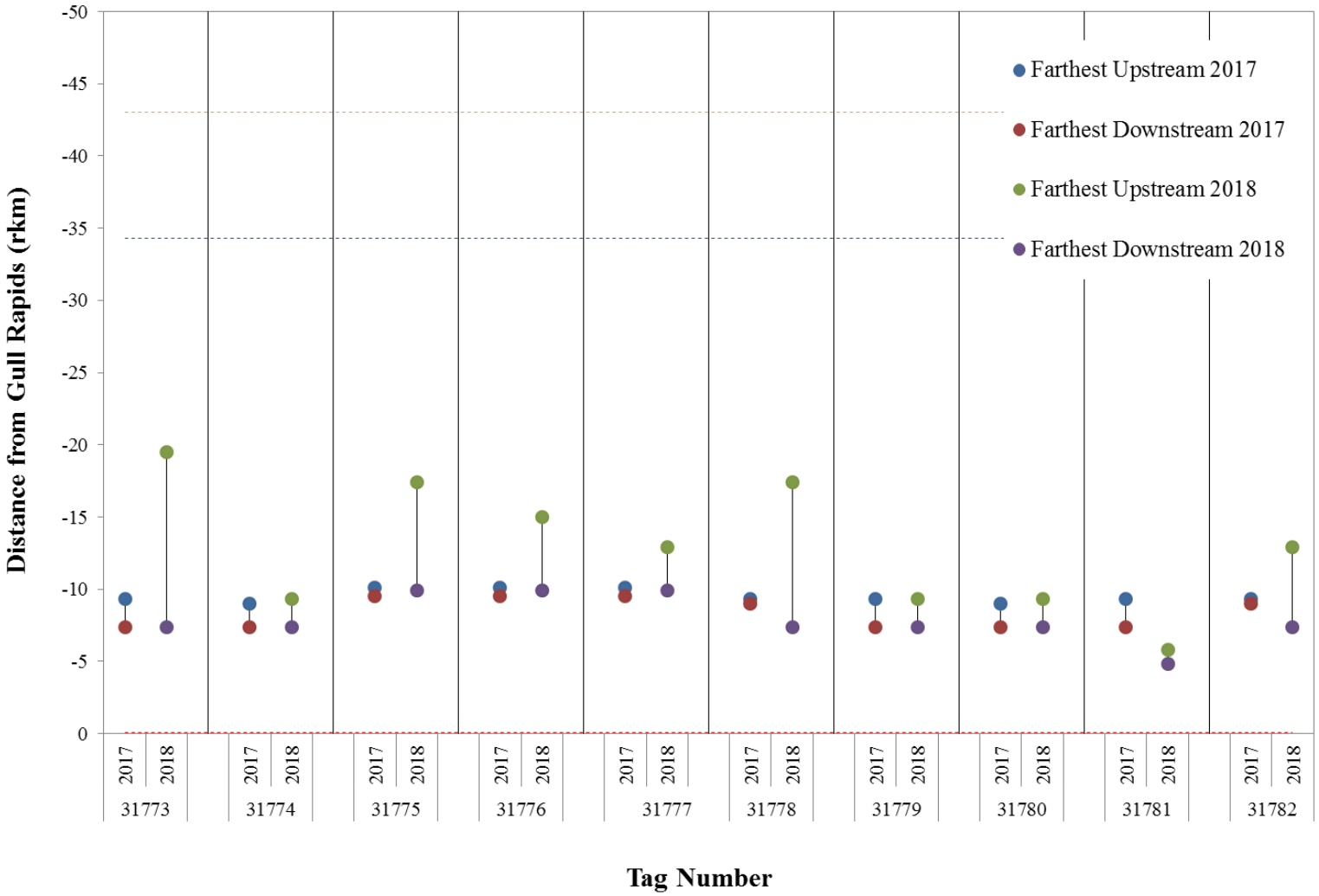


Figure 7: **Detection ranges for acoustic tagged juvenile Lake Sturgeon between Clark Lake and Gull Rapids during the open-water periods of 2017-2018. Dashed horizontal lines represent location of Gull Rapids (red), Birthday Rapids (blue), and the entrance to Clark Lake (orange).**

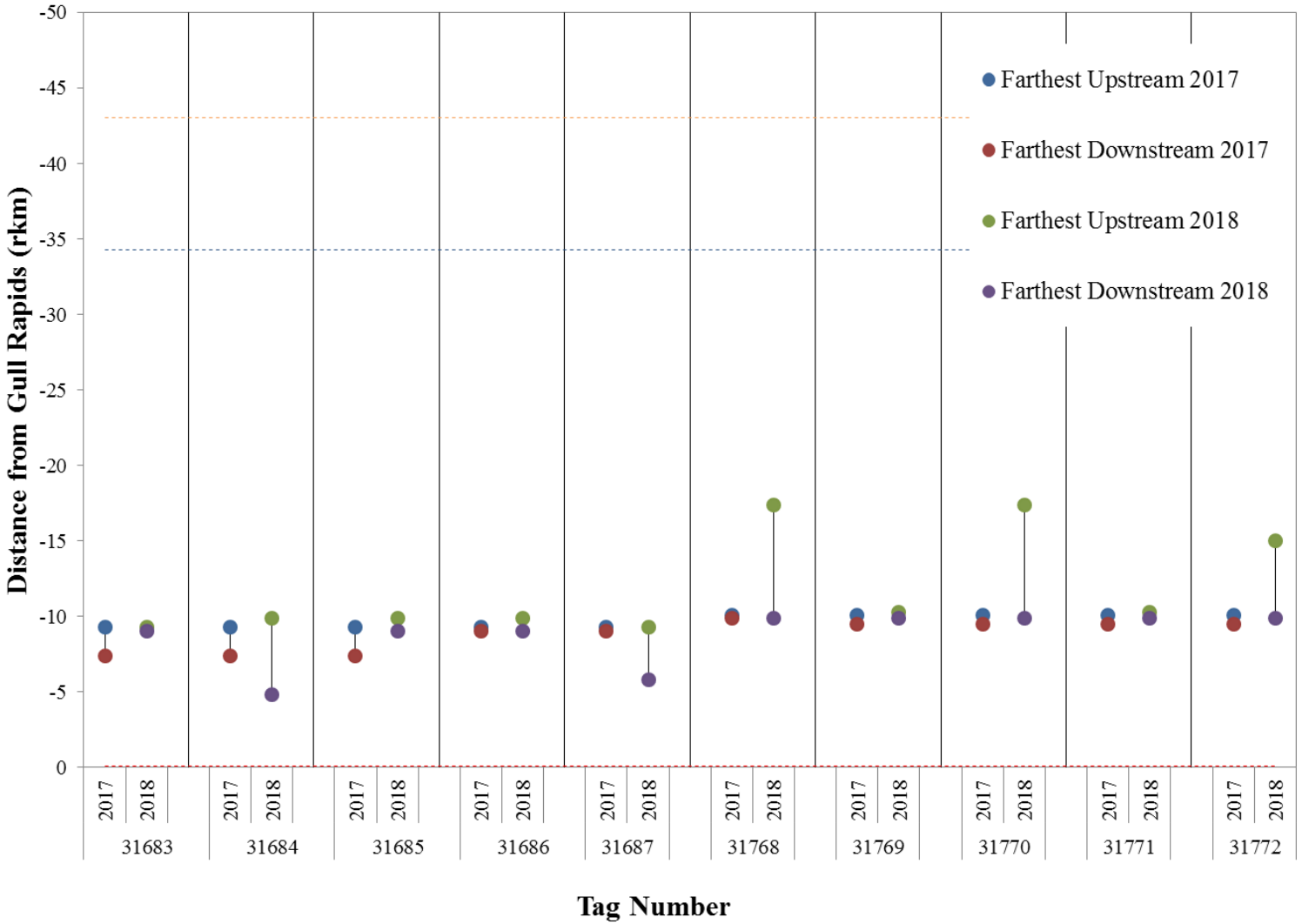


Figure 7: Detection ranges for acoustic tagged juvenile Lake Sturgeon between Clark Lake and Gull Rapids during the open-water periods of 2017–2018. Dashed horizontal lines represent location of Gull Rapids (red), Birthday Rapids (blue), and the entrance to Clark Lake (orange) (continued).

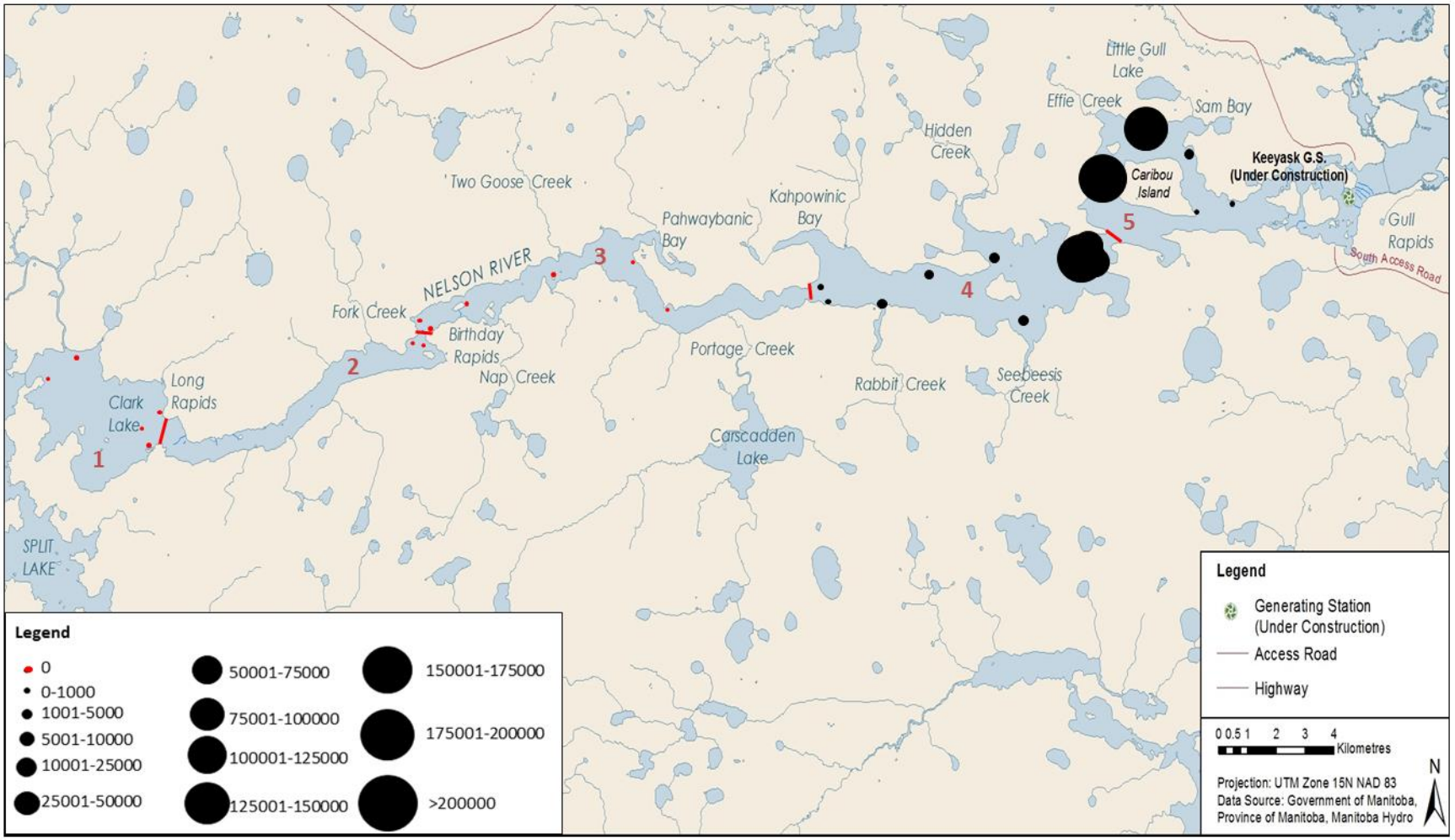


Figure 8: Relative number of detections at each acoustic receiver set in the Nelson River between Clark Lake and Gull Rapids during the 2018 open-water period (May 1 to October 10). Number of detections indicated by size of bubble (defined in legend). Receivers with no detections indicated with red dot.

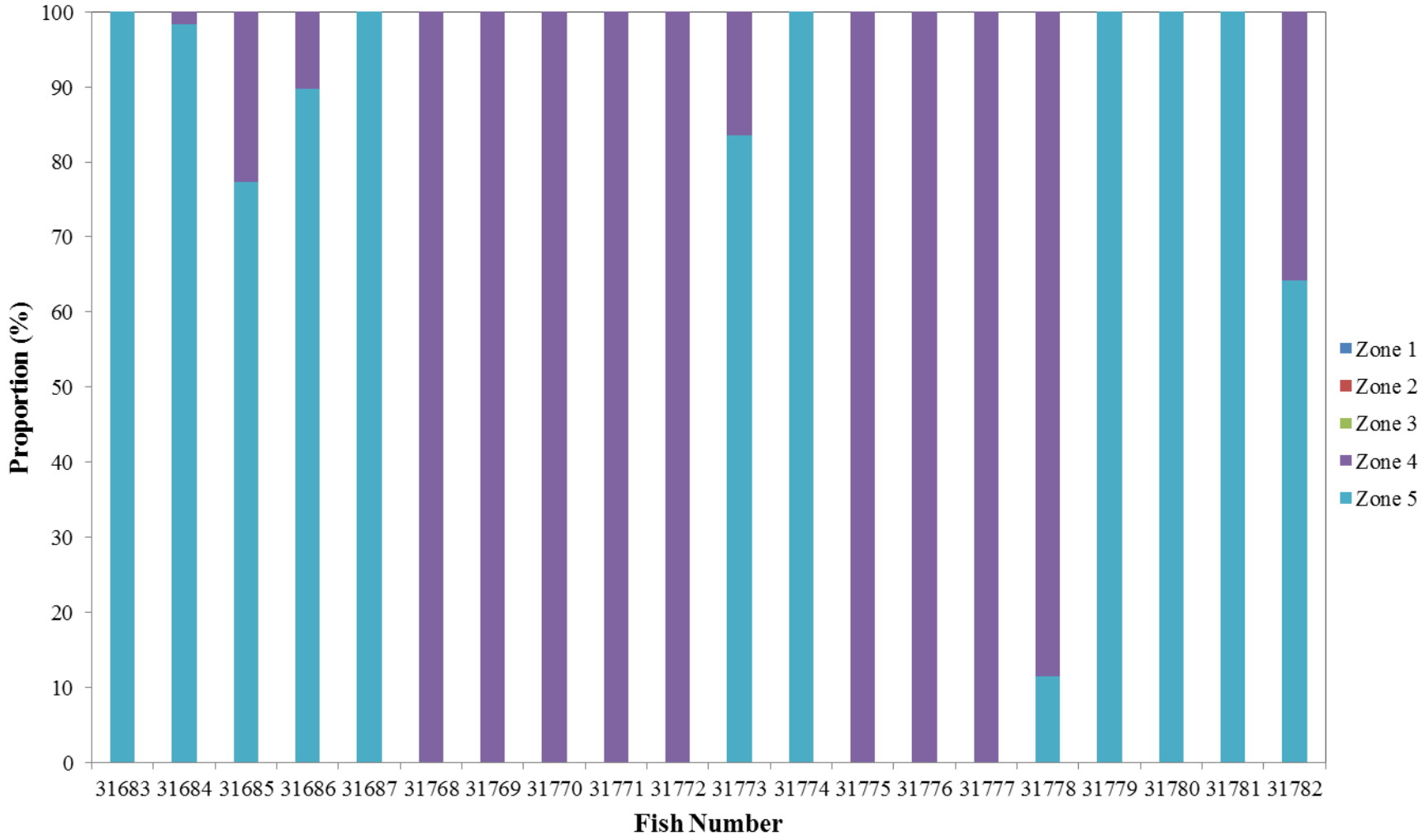


Figure 9: Proportional distributions by zone for individual juvenile Lake Sturgeon between Clark Lake and Gull Rapids during a portion of the 2018 open-water period (June 6 to October 10).

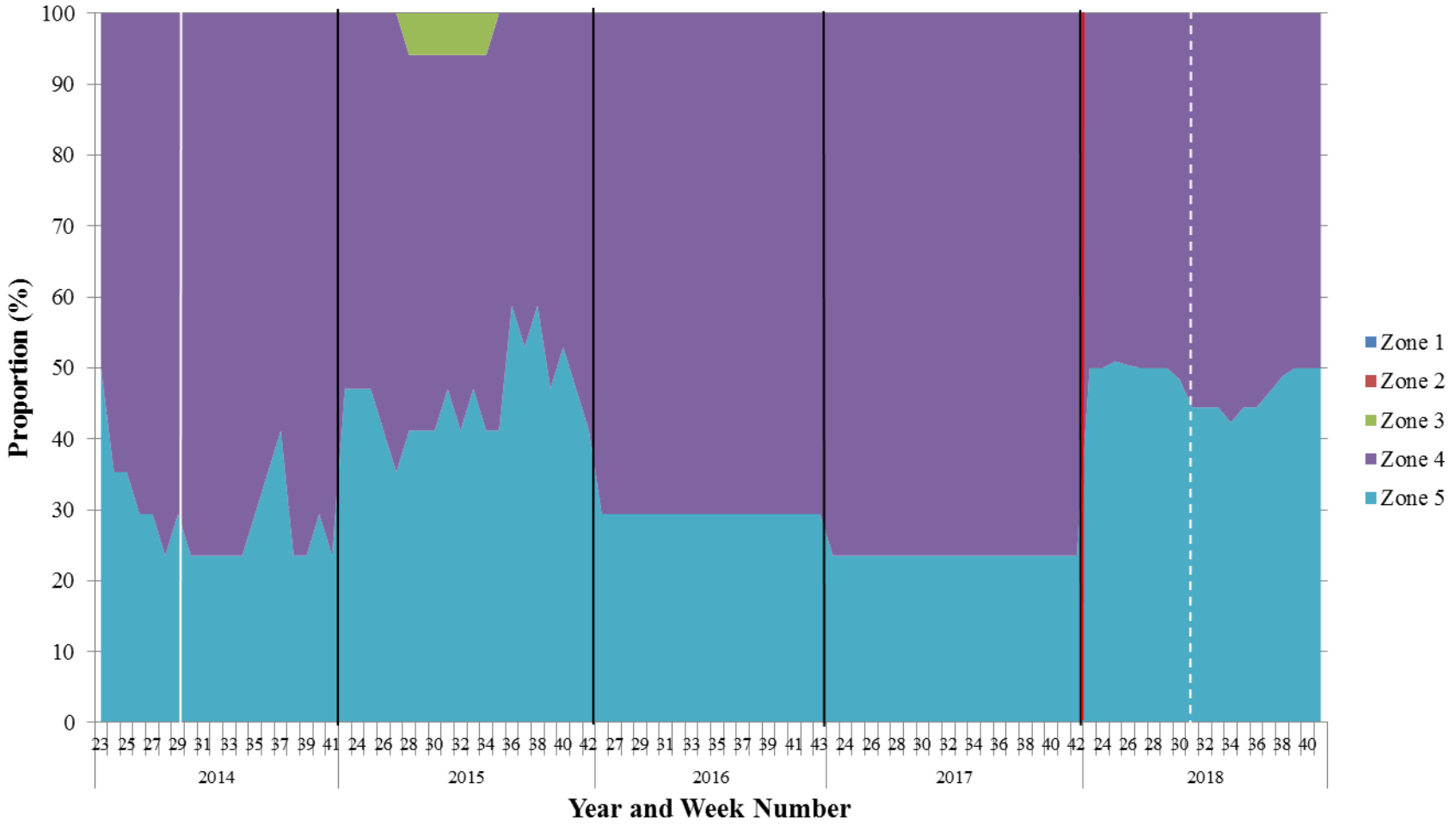


Figure 10: **Proportional distribution by zone per week for juvenile Lake Sturgeon between Clark Lake and Gull Rapids during a portion of the open-water periods of 2014 (June 4 to October 10), 2015 (June 4 to October 11), 2016 (June 25 to October 19), 2017 (June 7 to October 16), and 2018 (June 6 to October 10). White solid line indicates start of construction while white dashed line indicates start of spillway operation. Red solid line indicates when tags expired and new fish were tagged.**

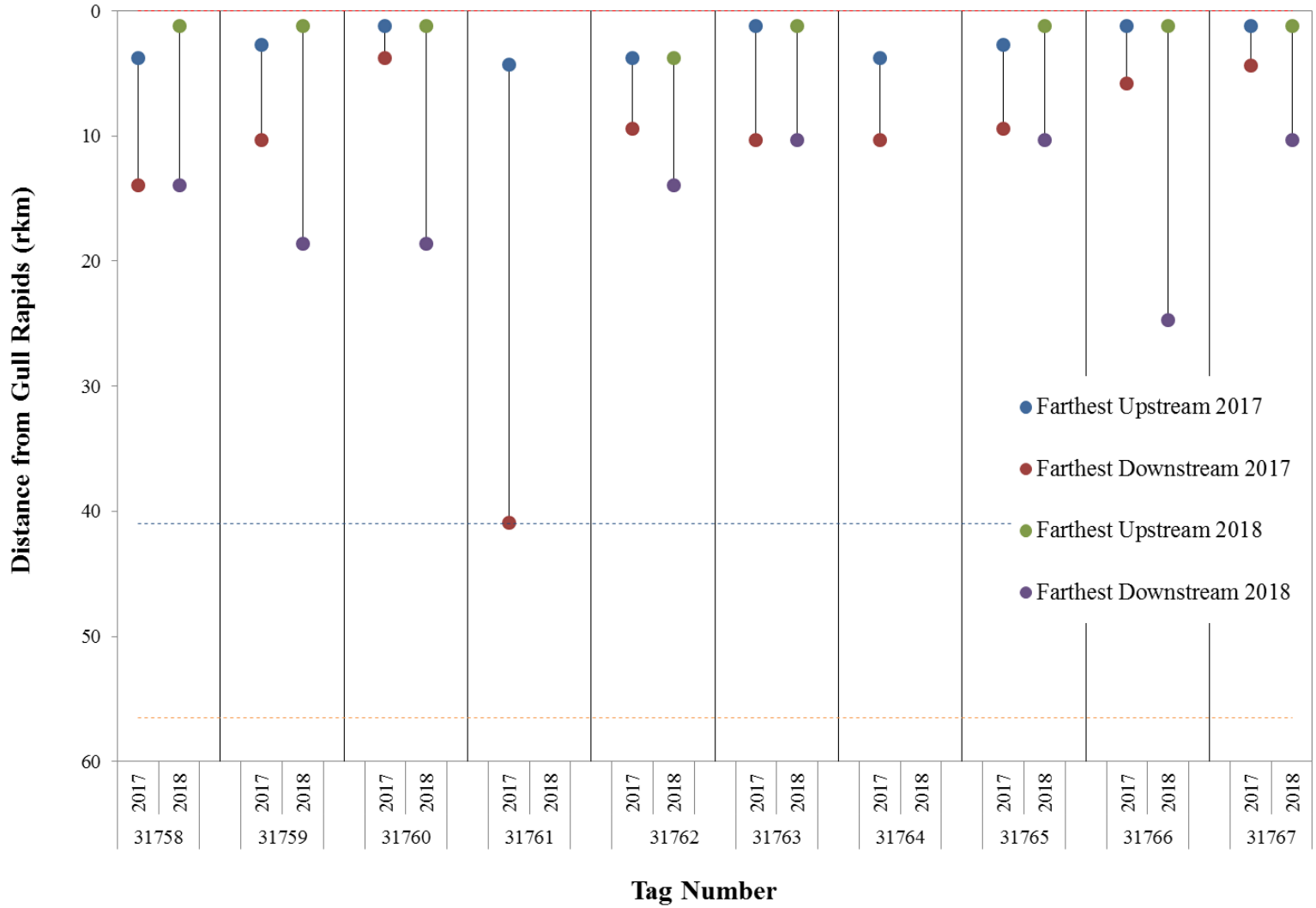


Figure 11: Detection ranges for acoustic tagged juvenile Lake Sturgeon downstream of Gull Rapids during the open-water periods of 2017–2018. Dashed horizontal lines represent locations of Gull Rapids (red), Kettle GS (blue), and Long Spruce GS (orange).

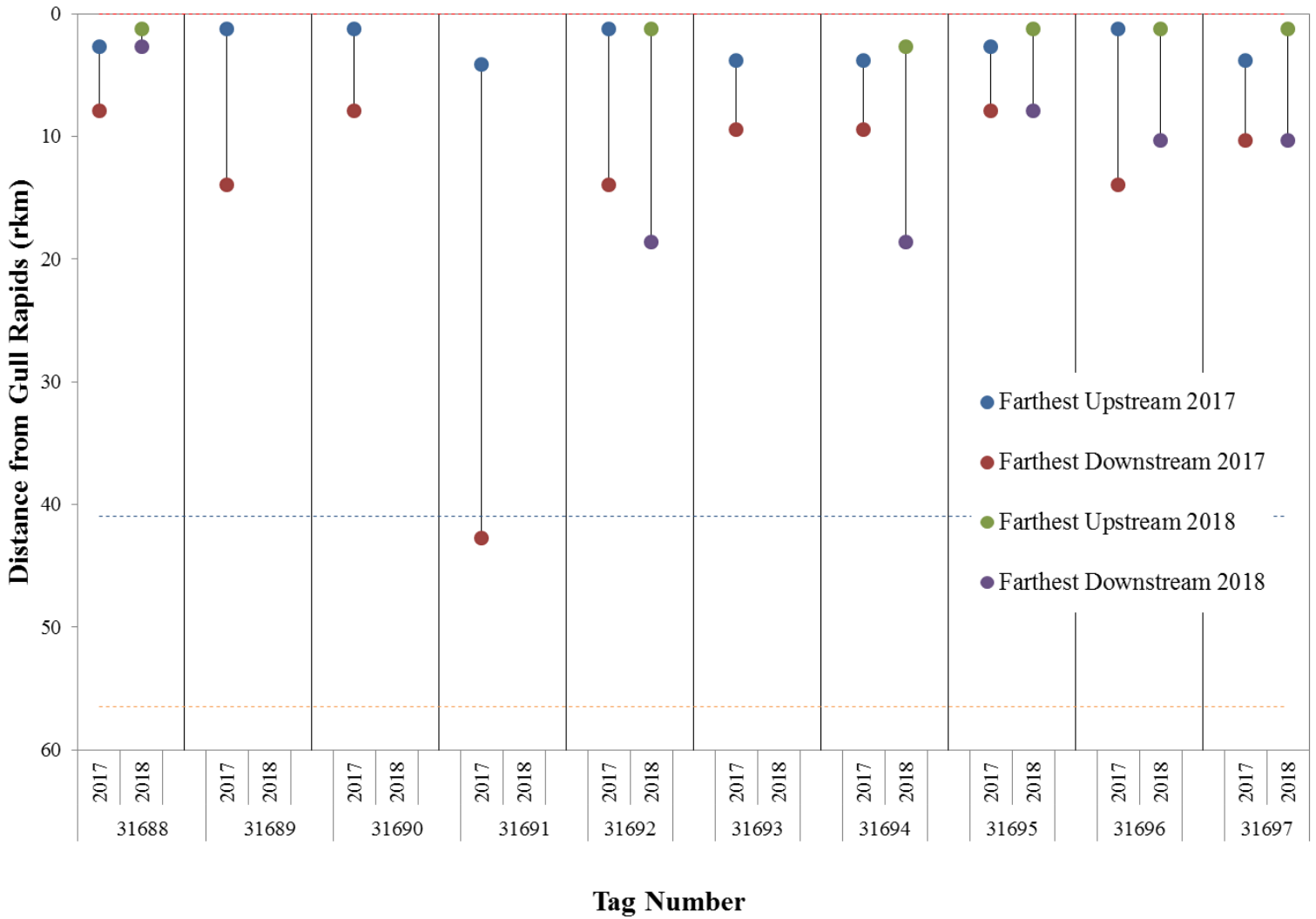


Figure 11: Detection ranges for acoustic tagged juvenile Lake Sturgeon downstream of Gull Rapids during the open-water periods of 2017–2018. Dashed horizontal lines represent locations of Gull Rapids (red), Kettle GS (green), and Long Spruce GS (purple) (continued).

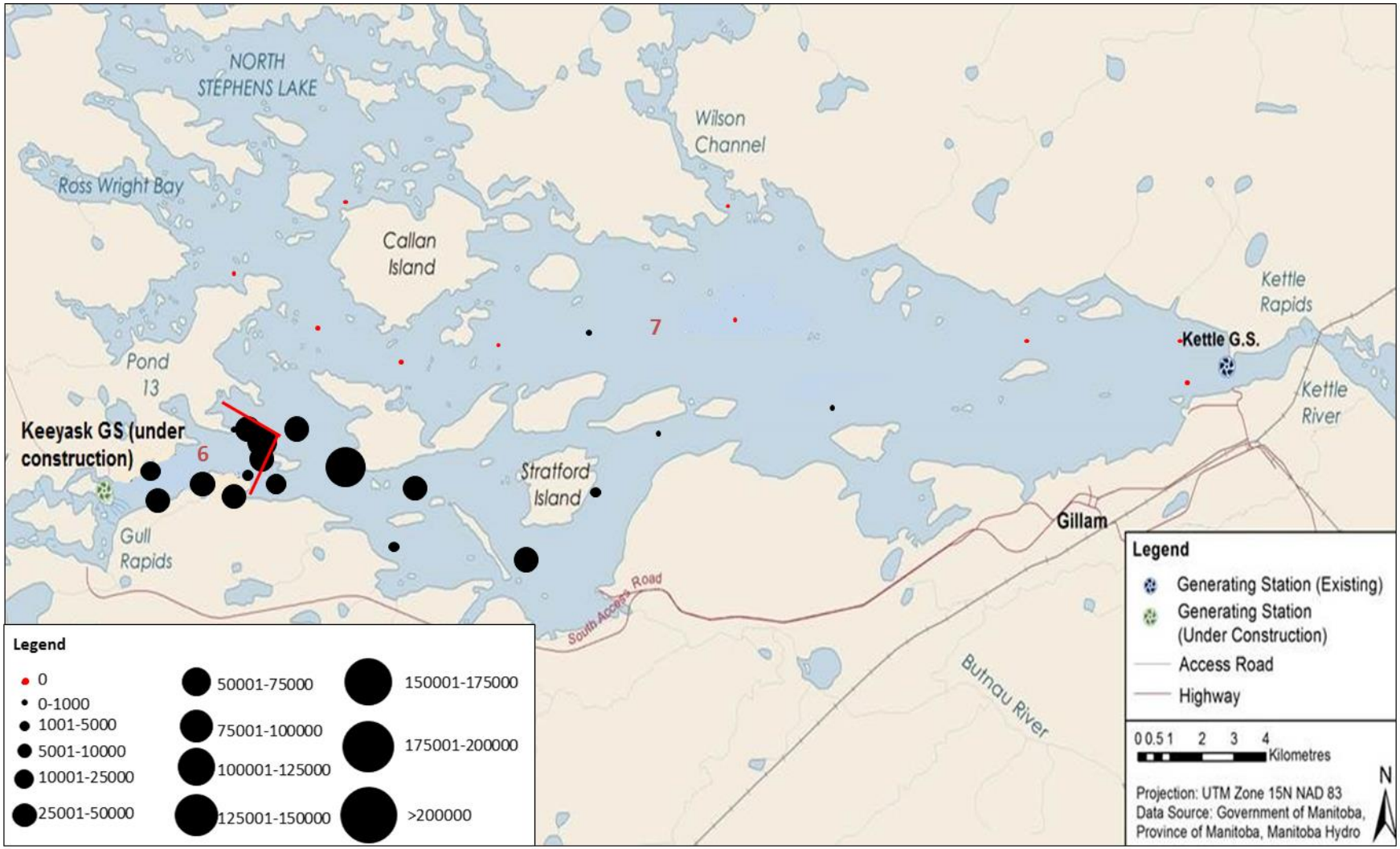


Figure 12: Relative number of detections at each acoustic receiver set in Stephens Lake during the 2018 open-water period (May 1 to October 10). Number of detections indicated by size of bubble (defined in legend). Receivers with no detections indicated with red dot.

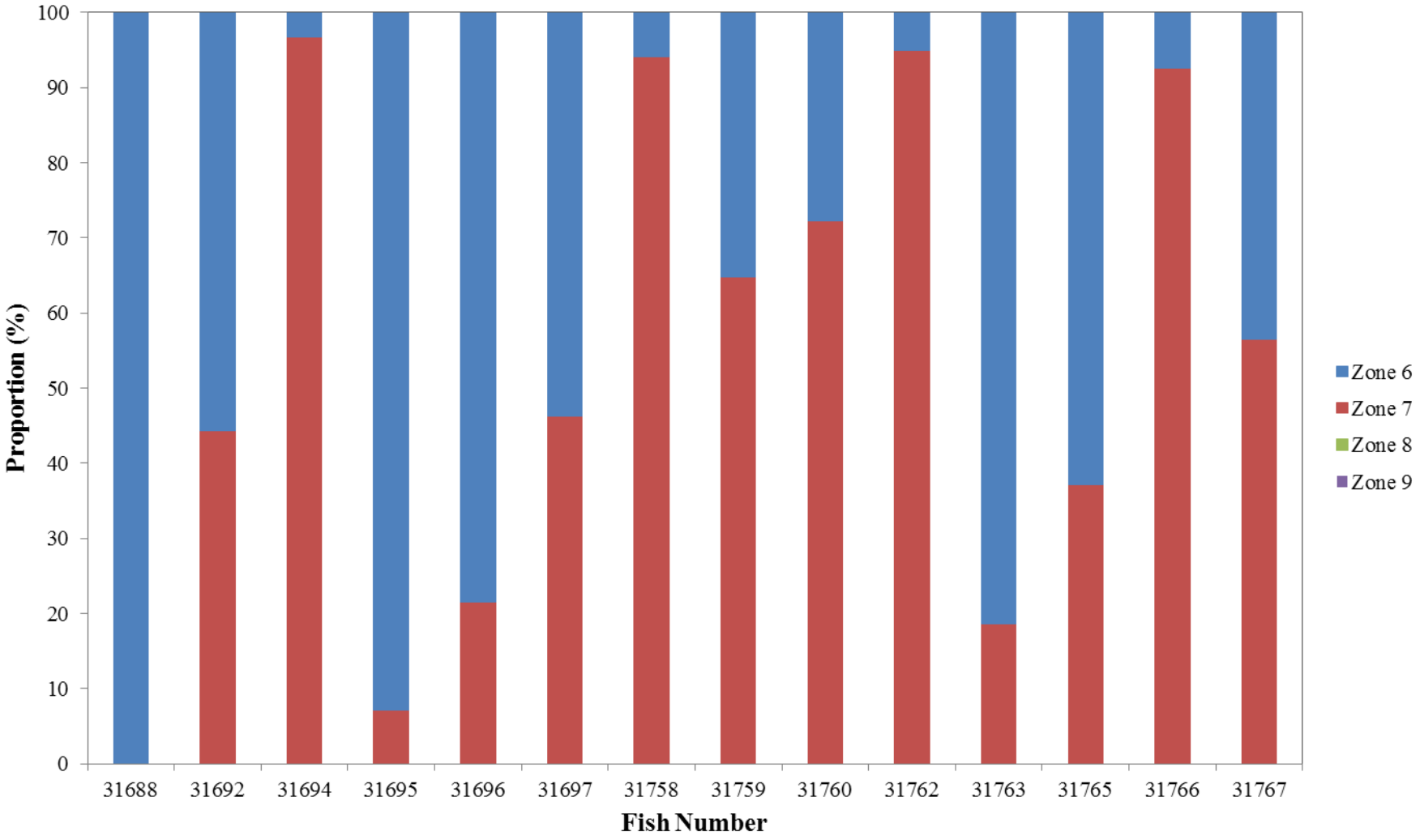


Figure 13: Proportional distributions by zone for individual juvenile Lake Sturgeon downstream of Gull Rapids during a portion of the 2018 open-water period (June 6 to October 10).

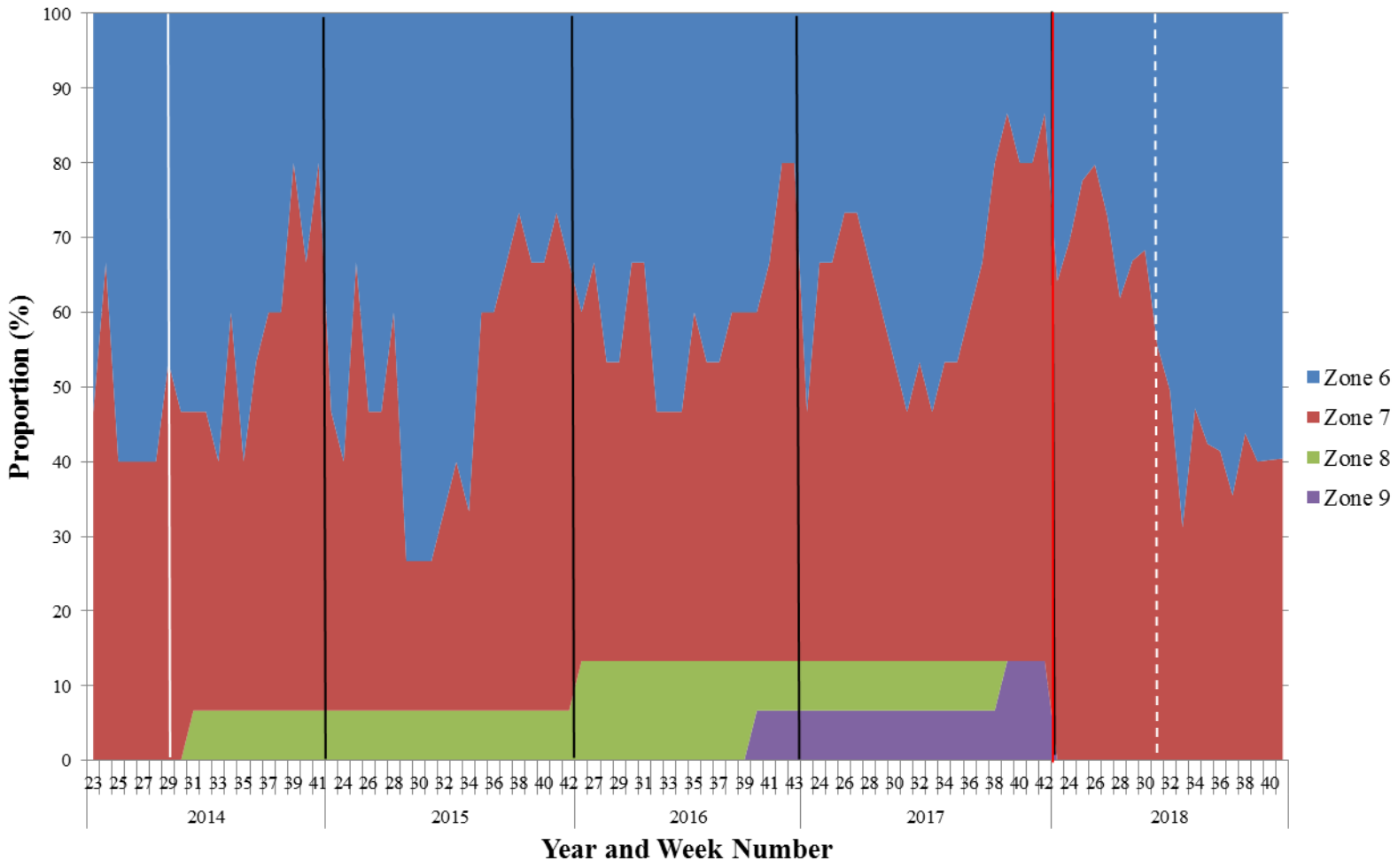
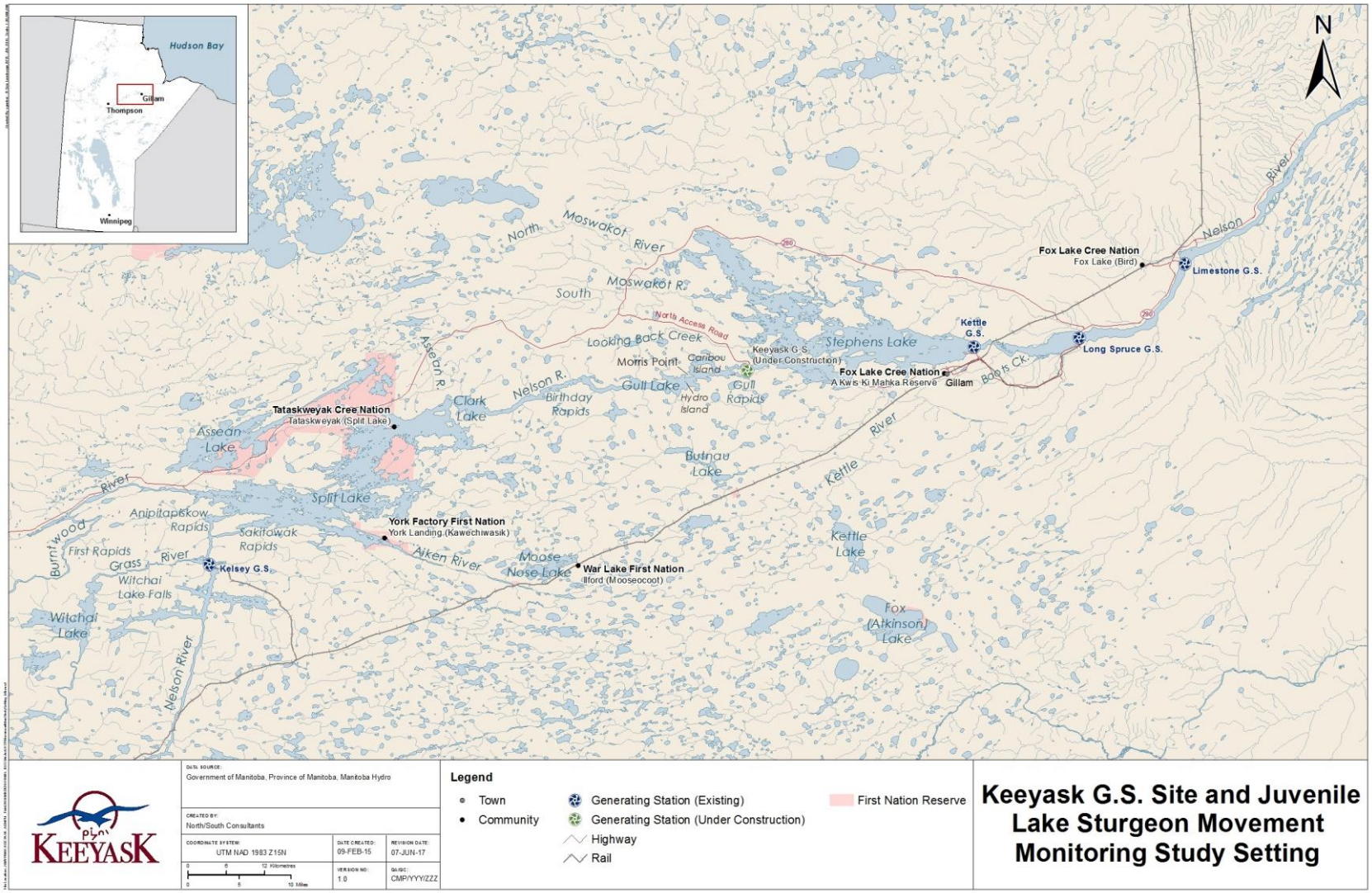
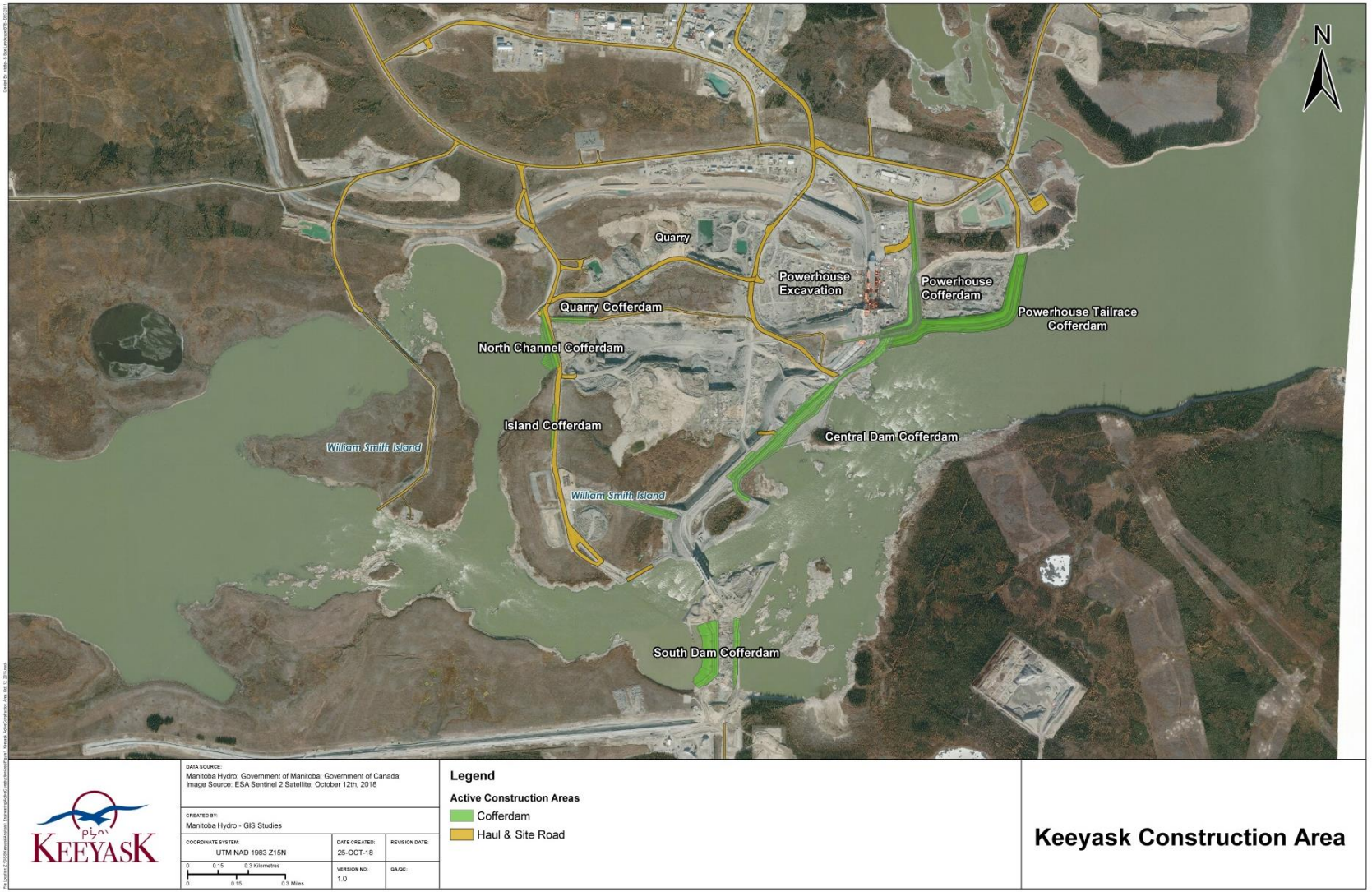


Figure 14: Proportional distribution by zone per week for juvenile Lake Sturgeon downstream of Gull Rapids during a portion of the open-water periods of 2014 (June 4 to October 10), 2015 (June 4 to October 11), 2016 (June 25 to October 19), 2017 (June 7 to October 16), and 2018 (June 6 to October 10). White solid vertical line indicates start of construction while white dashed line indicates start of spillway operation. No receivers were in place in zones 8 or 9 in 2018. Red solid line indicates when tags expired and new fish were tagged.

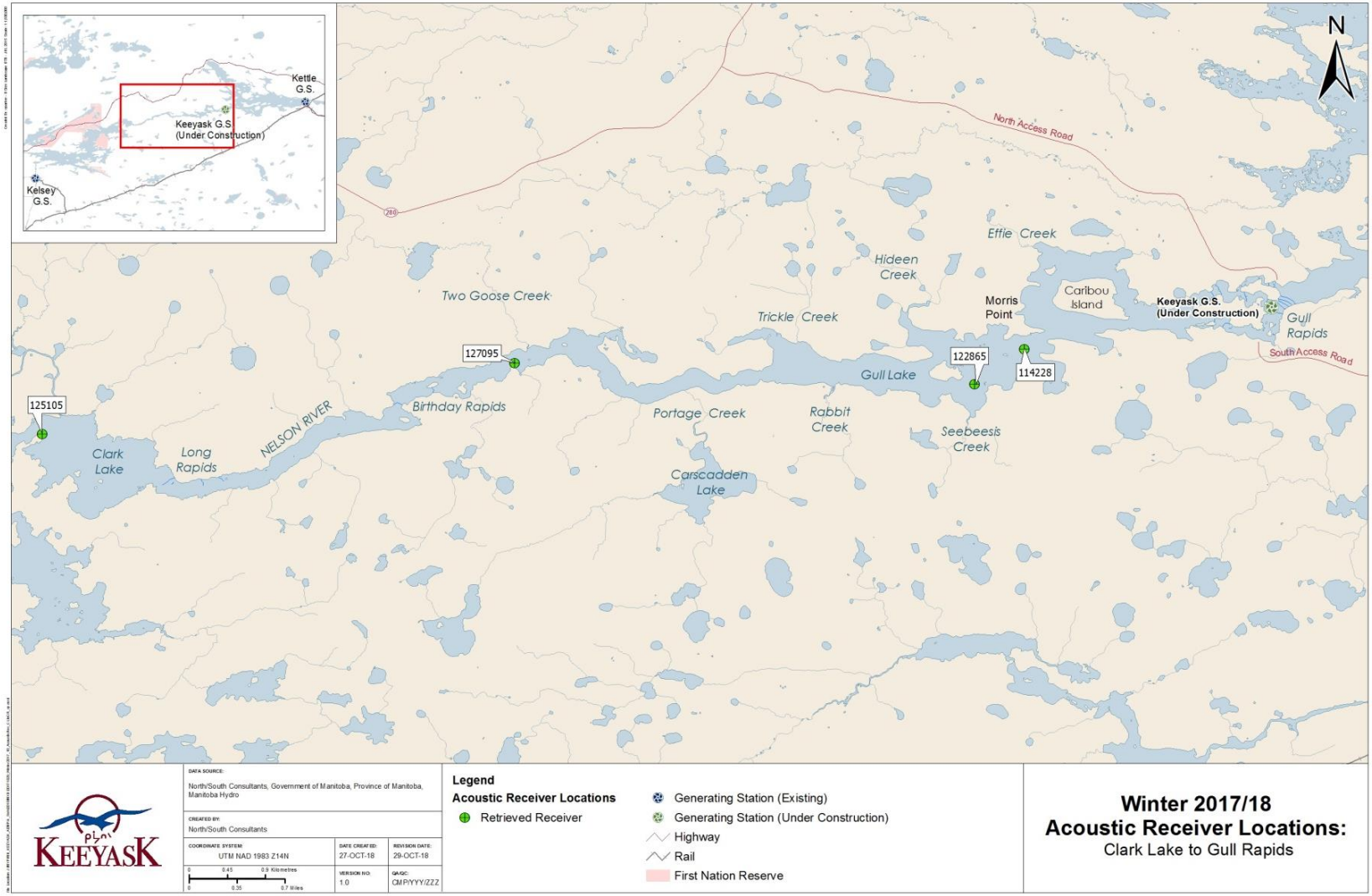
MAPS



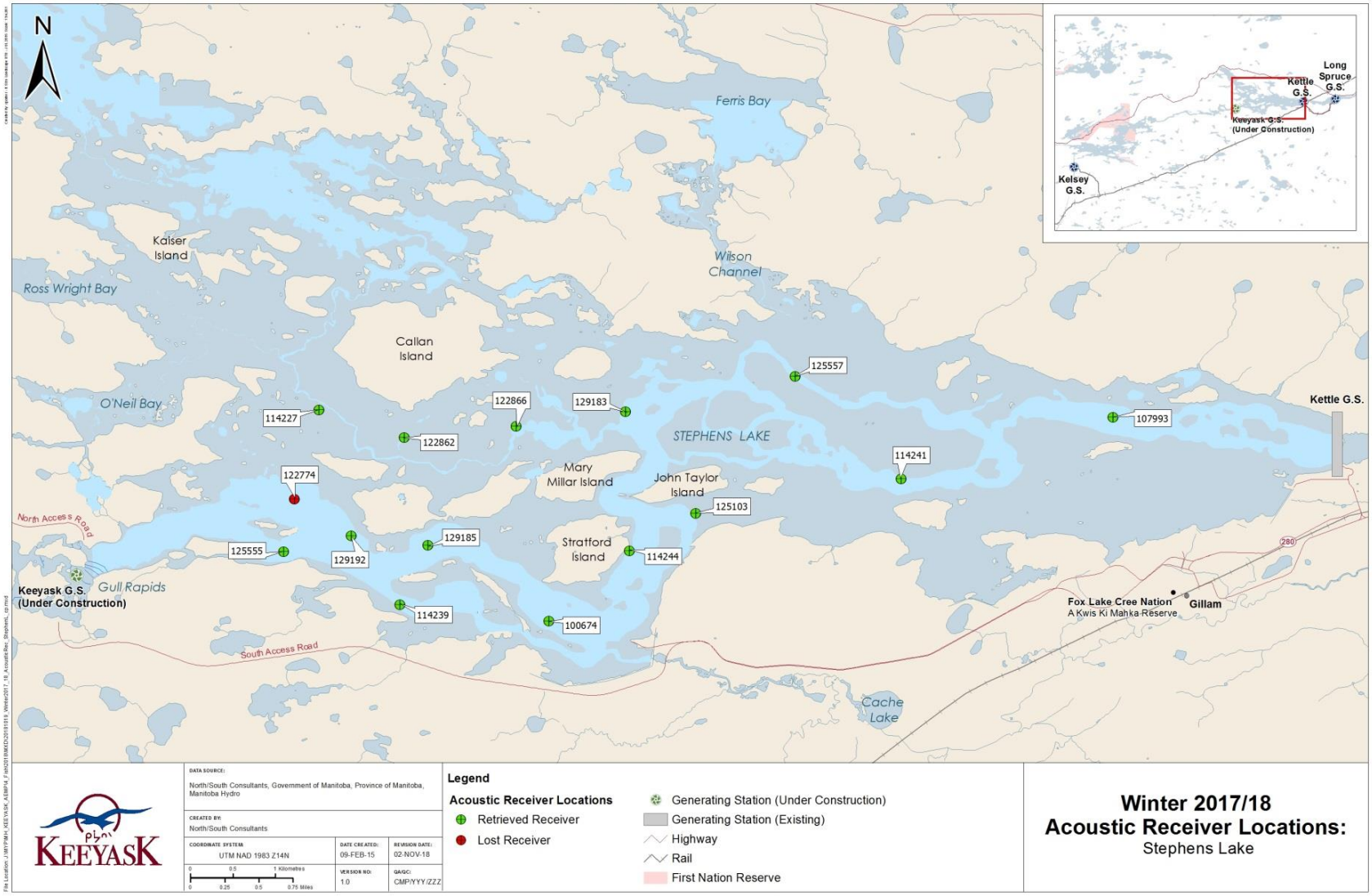
Map 1: Map of the Nelson River showing the site of the Keeyask Generating Station and the juvenile Lake Sturgeon movement monitoring study setting.



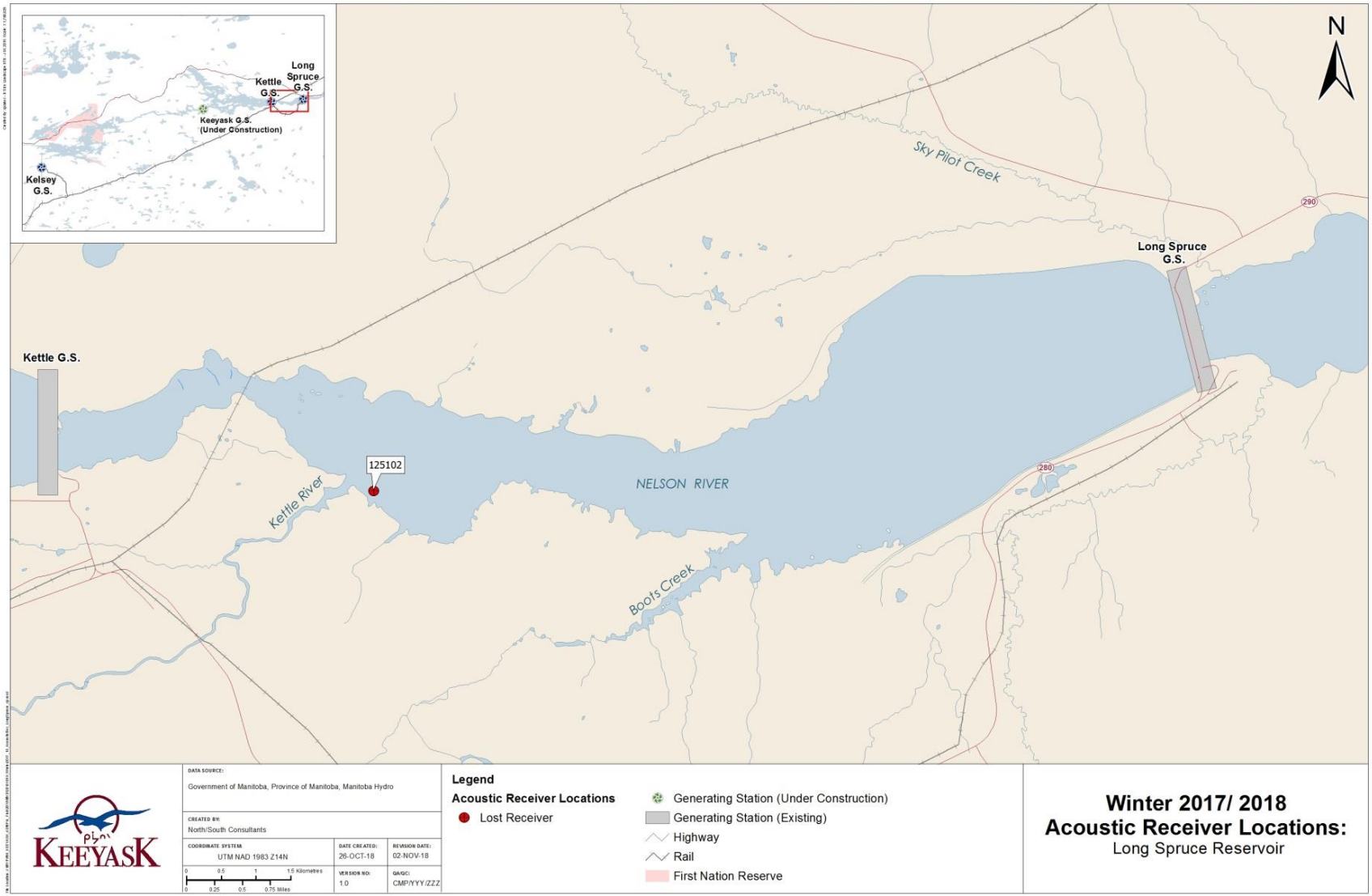
Map 2: Map of instream structures at the Keeyask Generating Station site, October 2018.



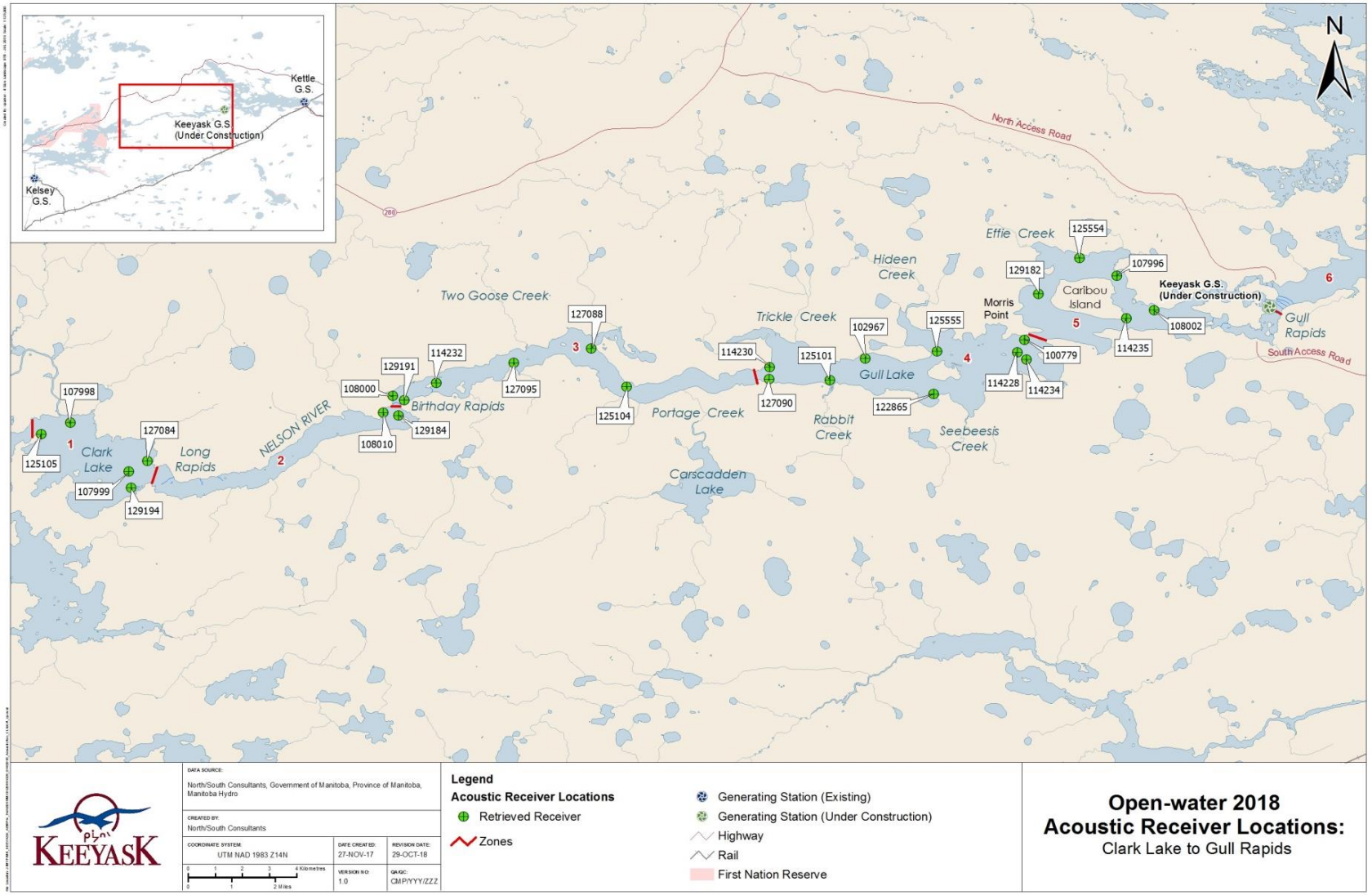
Map 3: Locations of stationary receivers set in the Nelson River from Clark Lake to Gull Rapids between October 2017 and June 2018.



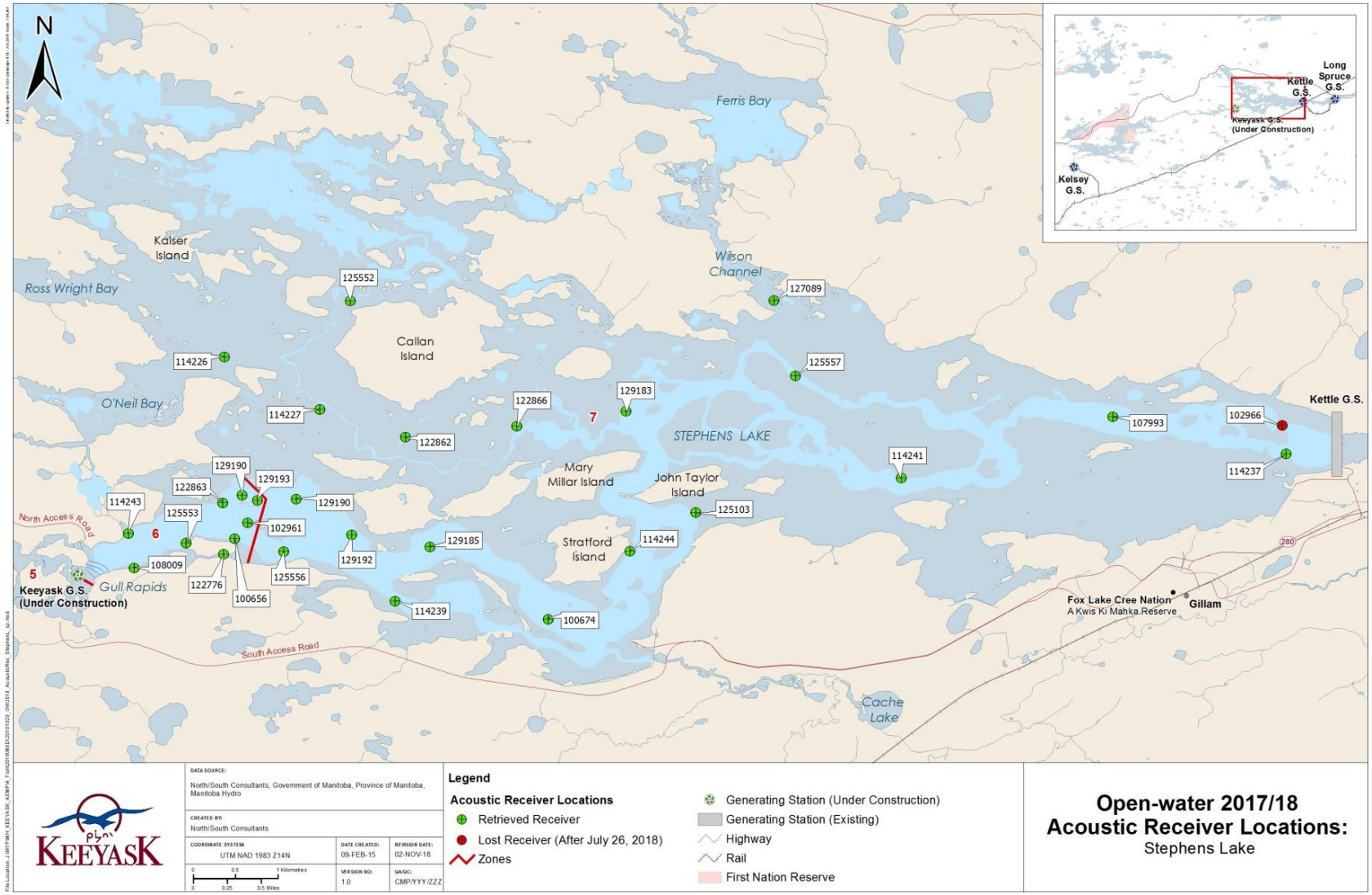
Map 4: Locations of stationary receivers set in Stephens Lake from Gull Rapids to Kettle GS between October 2017 and June 2018. The former (pre-impoundment) river channel is shown in light blue.



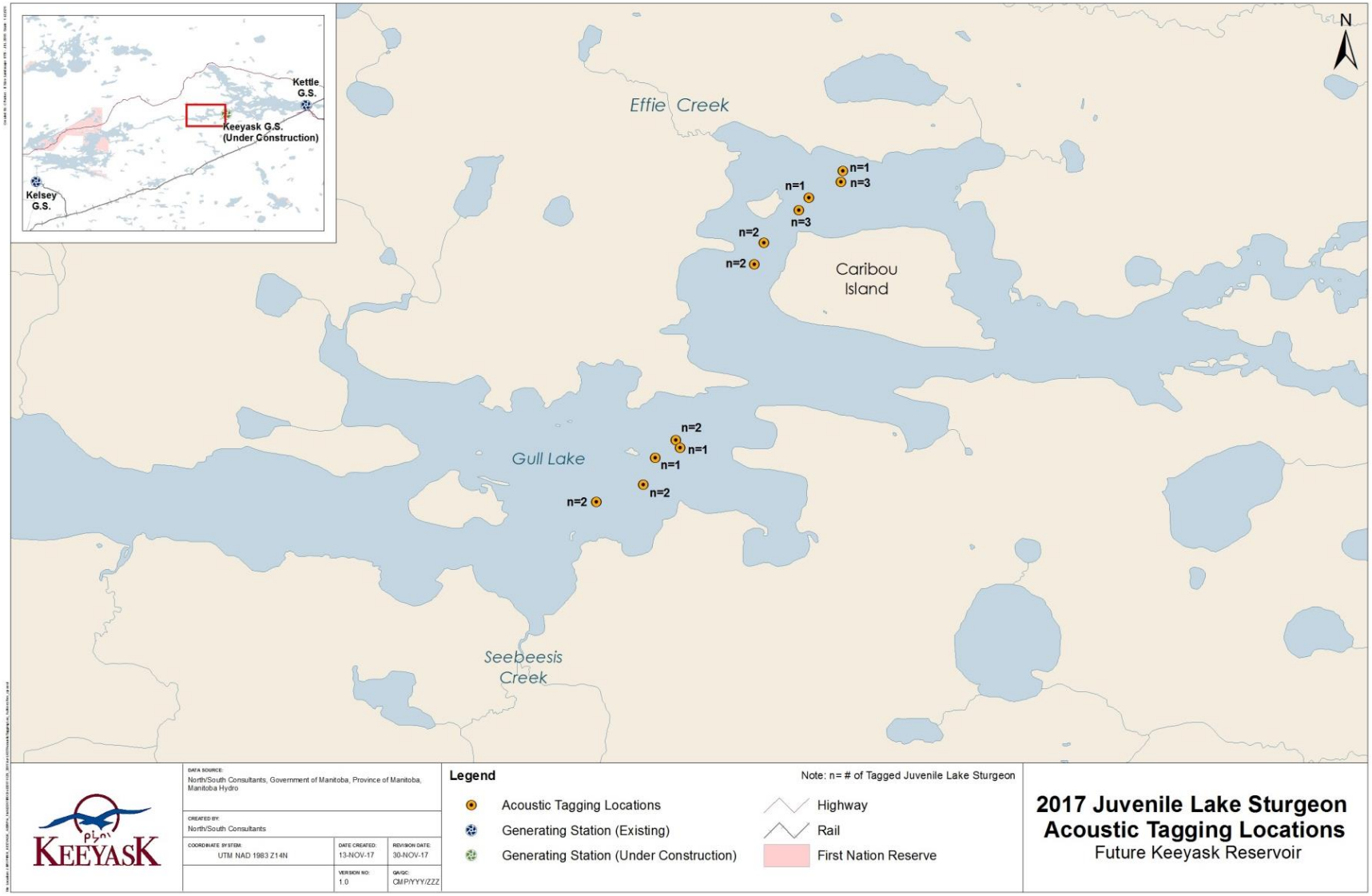
Map 5: Location of the stationary receiver set in the Long Spruce Reservoir between October 2017 and June 2018.



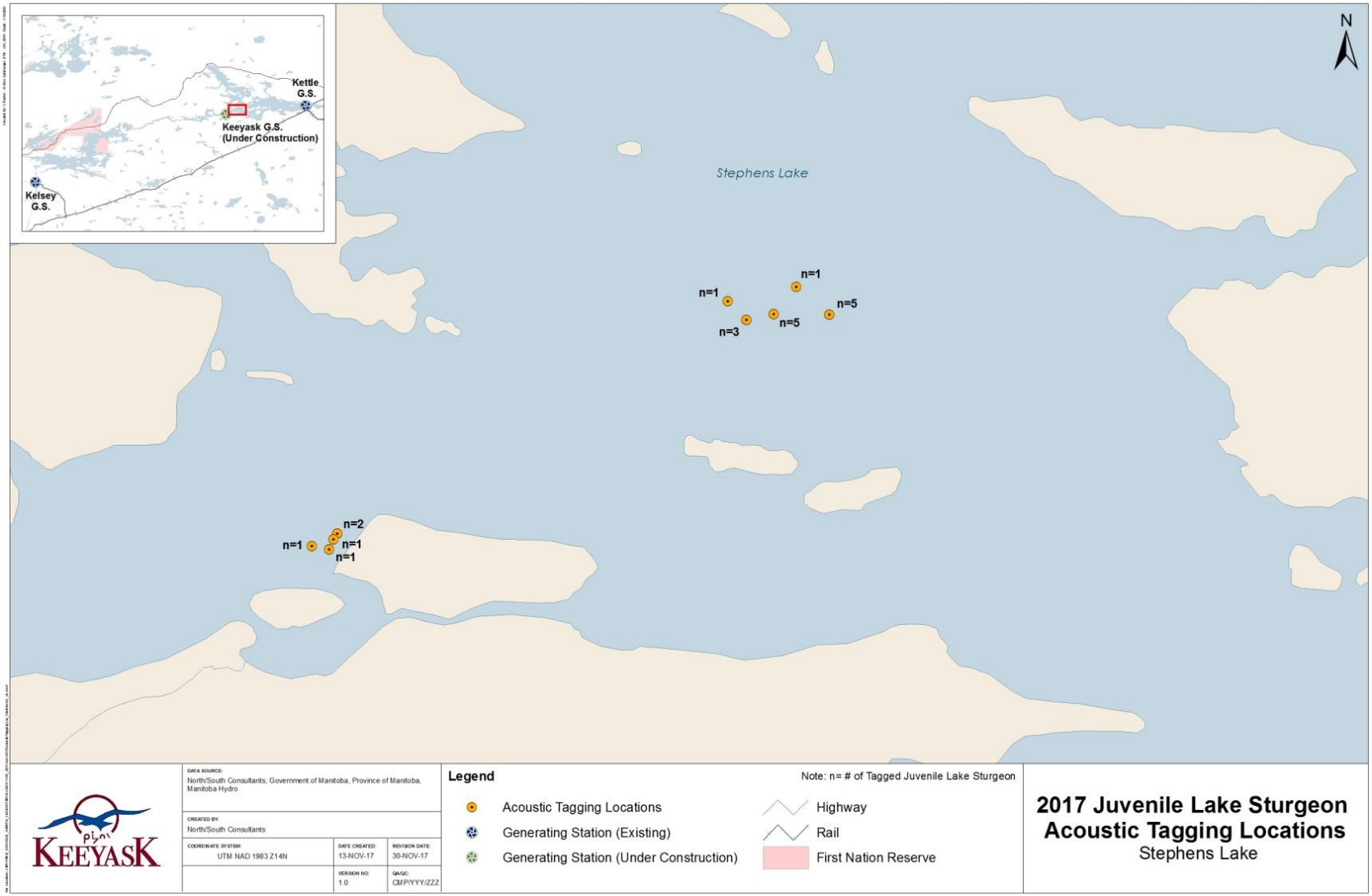
Map 6: **Locations of stationary receivers set in the Nelson River from Clark Lake to Gull Rapids between June and October 2018. The river is divided into five "zones" based on placement of receiver "gates."**



Map 7: **Locations of stationary receivers set in Stephens Lake between June and October 2018. The river is divided into two "zones" based on placement of receiver "gates." The pre-impoundment river channel is shown in light blue.**



Map 8: Locations of juvenile Lake Sturgeon acoustic transmitter application upstream of Gull Rapids, September 2017.



Map 9: Locations of juvenile Lake Sturgeon acoustic transmitter application in Stephens Lake, September 2017.

APPENDICES

APPENDIX 1: LOCATION SUMMARY FOR INDIVIDUAL ACOUSTIC TAGGED JUVENILE LAKE STURGEON UPSTREAM OF GULL RAPIDS, SEPTEMBER 2017 TO OCTOBER 2018

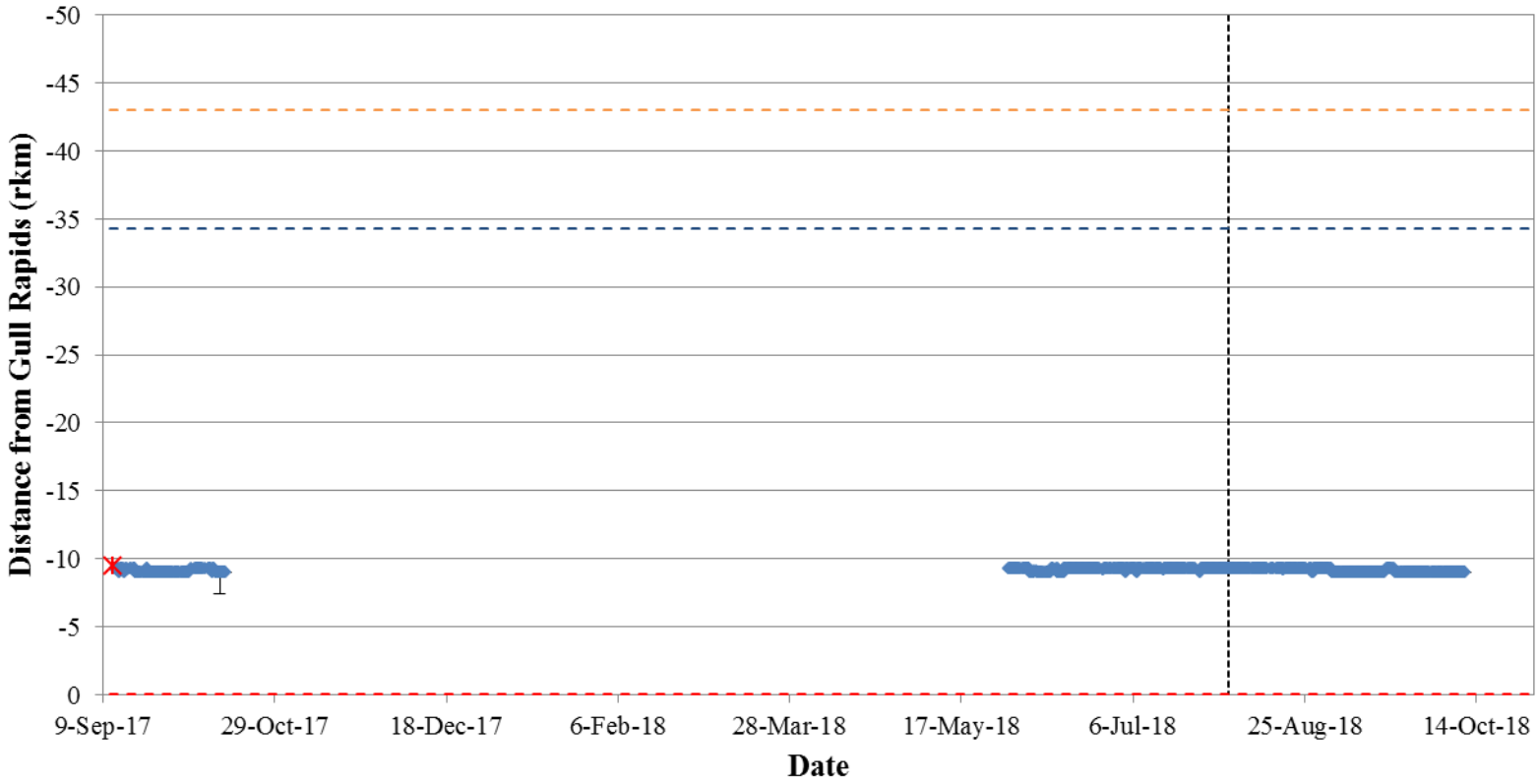


Figure A1-1: Position of a Lake Sturgeon tagged with an acoustic transmitter (code #31683) in Gull Lake in relation to Gull Rapids (rkm 0), from 9 September, 2017 to 10 October, 2018. Date and location of tagging is indicated by red X. Error bars are shown in solid black. Horizontal dashed lines indicate the positions of Gull Rapids (red), Birthday Rapids (blue), and the entrance to Clark Lake (orange). Dashed black vertical line indicates start of spillway operation (Aug 3, 2018).

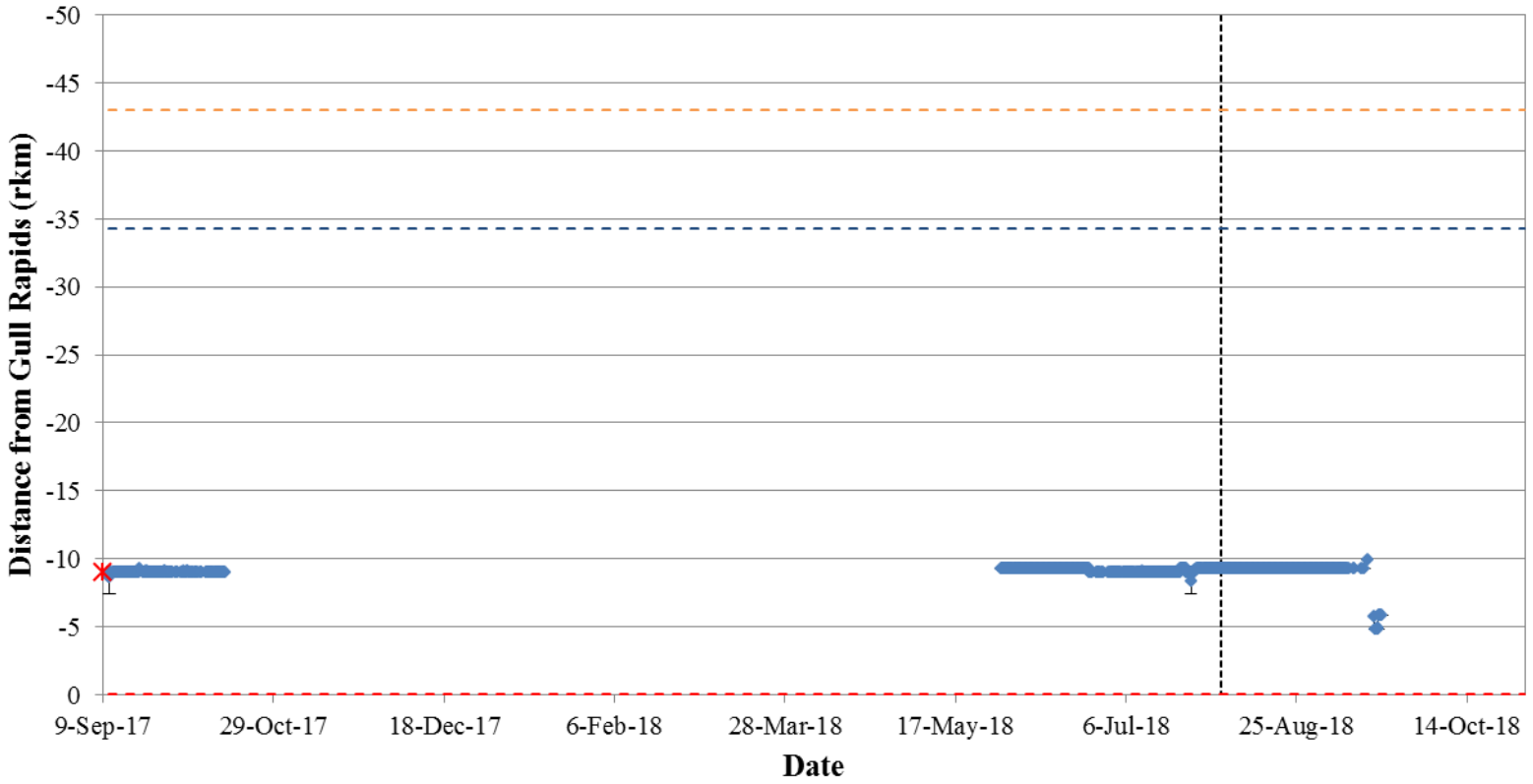


Figure A1-2: Position of a Lake Sturgeon tagged with an acoustic transmitter (code #31684) in Gull Lake in relation to Gull Rapids (rkm 0), from 9 September, 2017 to 10 October, 2018. Date and location of tagging is indicated by red X. Error bars are shown in solid black. Horizontal dashed lines indicate the positions of Gull Rapids (red), Birthday Rapids (blue), and the entrance to Clark Lake (orange). Dashed black vertical line indicates start of spillway operation (Aug 3, 2018).

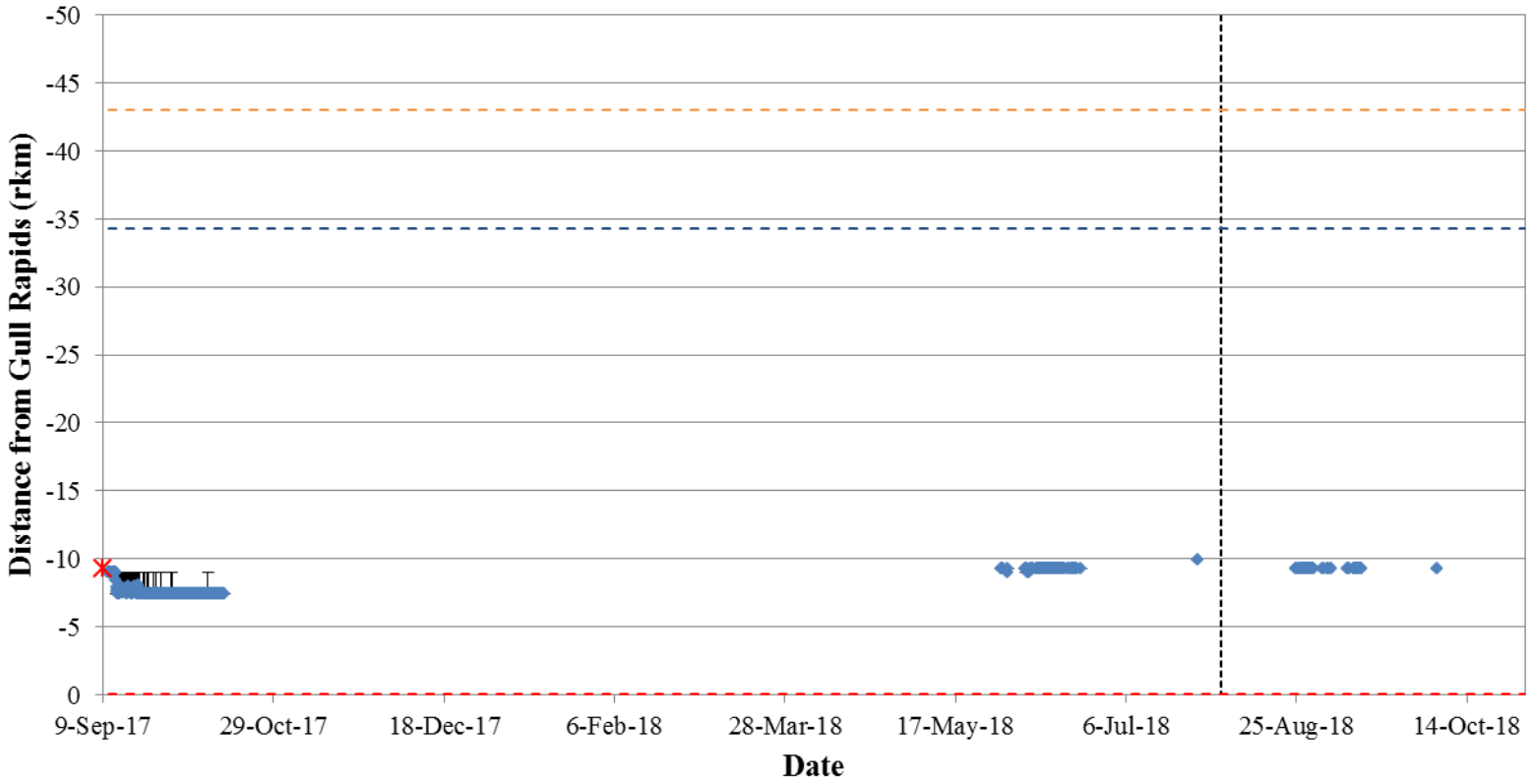


Figure A1-3: Position of a Lake Sturgeon tagged with an acoustic transmitter (code #31685) in Gull Lake in relation to Gull Rapids (rkm 0), from 9 September, 2017 to 10 October, 2018. Date and location of tagging is indicated by red X. Error bars are shown in solid black. Horizontal dashed lines indicate the positions of Gull Rapids (red), Birthday Rapids (blue), and the entrance to Clark Lake (orange). Dashed black vertical line indicates start of spillway operation (Aug 3, 2018).

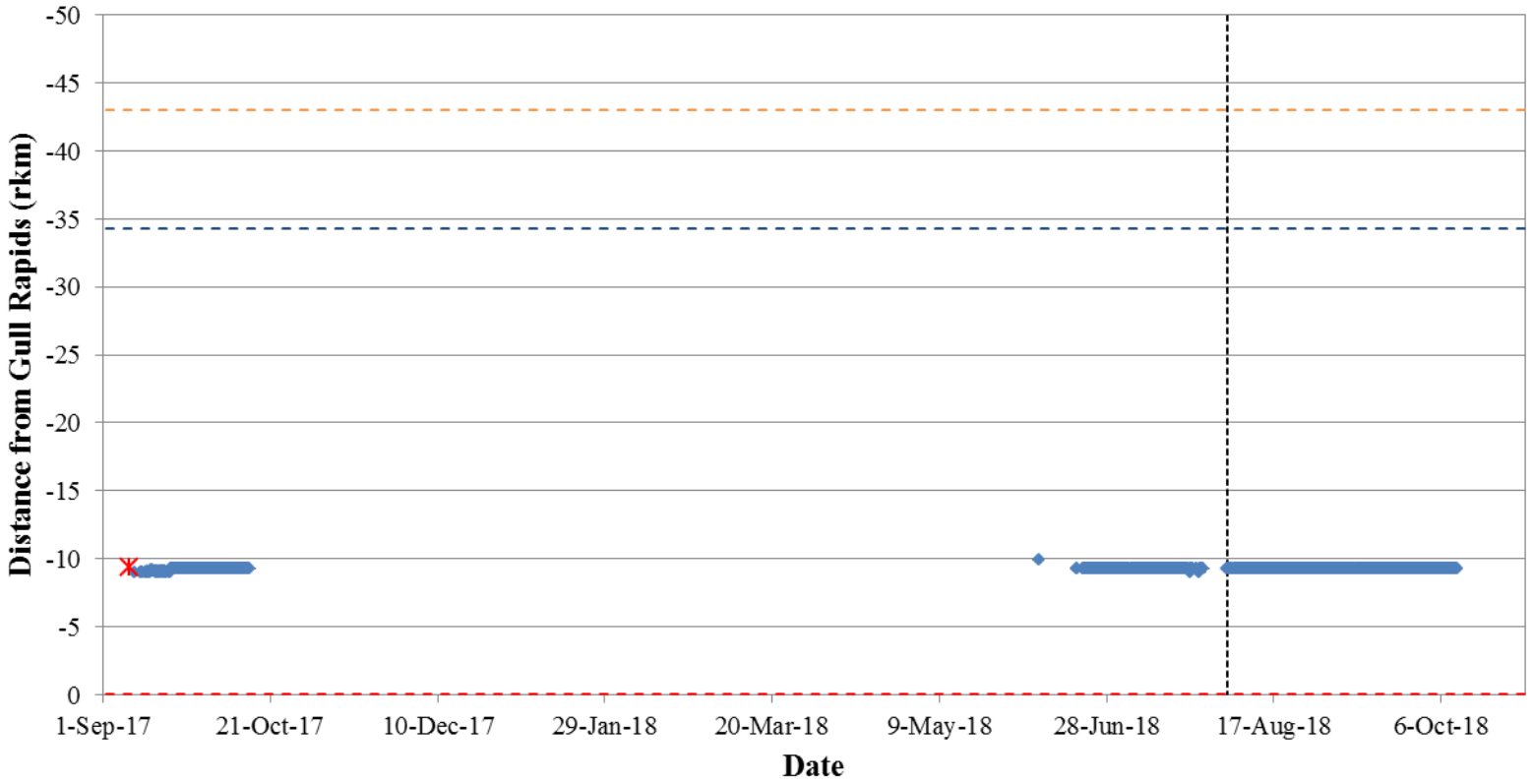


Figure A1-4: Position of a Lake Sturgeon tagged with an acoustic transmitter (code #31686) in Gull Lake in relation to Gull Rapids (rkm 0), from 9 September, 2017 to 10 October, 2018. Date and location of tagging is indicated by red X. Error bars are shown in solid black. Horizontal dashed lines indicate the positions of Gull Rapids (red), Birthday Rapids (blue), and the entrance to Clark Lake (orange). Dashed black vertical line indicates start of spillway operation (Aug 3, 2018).

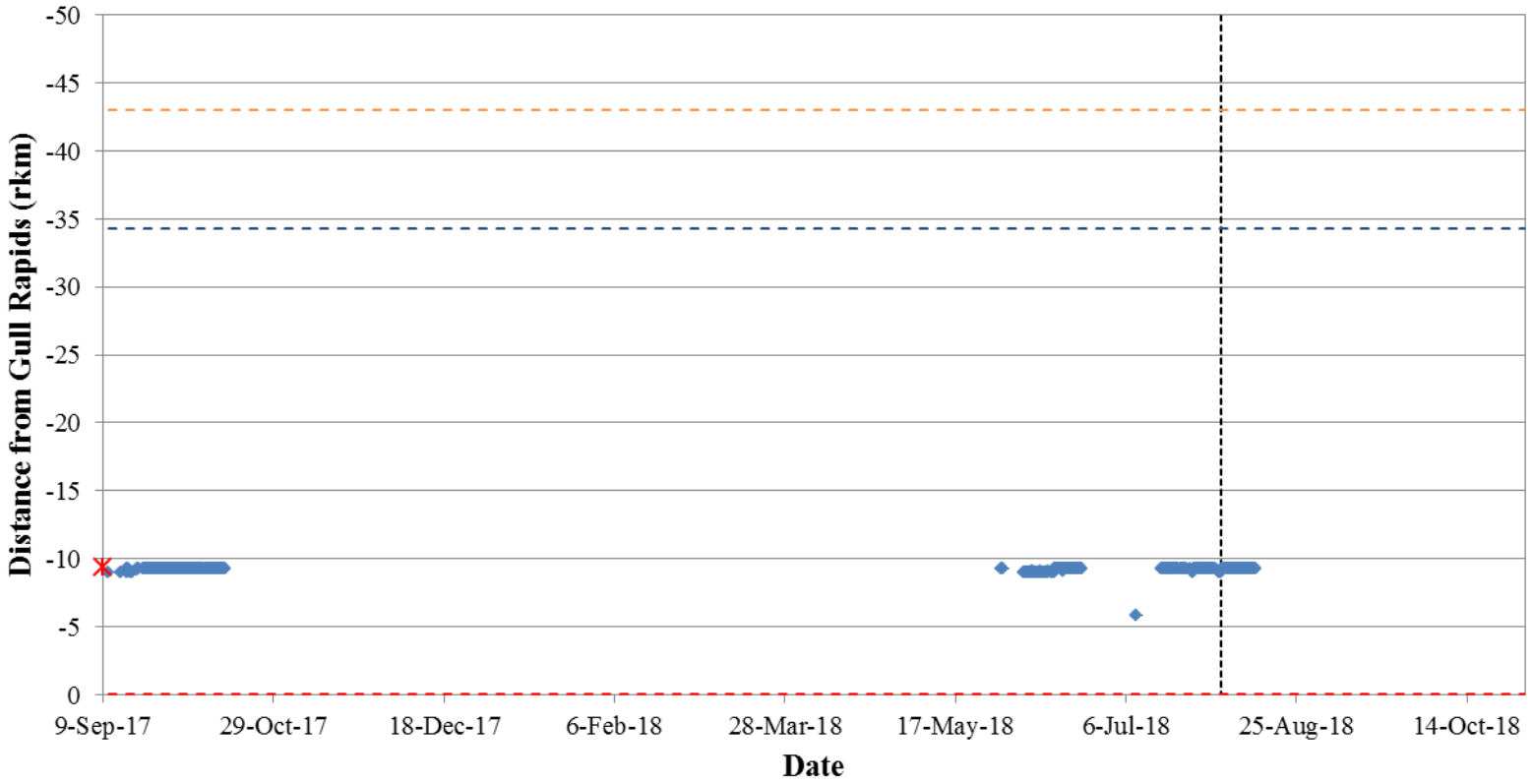


Figure A1-5: Position of a Lake Sturgeon tagged with an acoustic transmitter (code #31687) in Gull Lake in relation to Gull Rapids (rkm 0), from 9 September, 2017 to 10 October, 2018. Date and location of tagging is indicated by red X. Error bars are shown in solid black. Horizontal dashed lines indicate the positions of Gull Rapids (red), Birthday Rapids (blue), and the entrance to Clark Lake (orange). Dashed black vertical line indicates start of spillway operation (Aug 3, 2018).

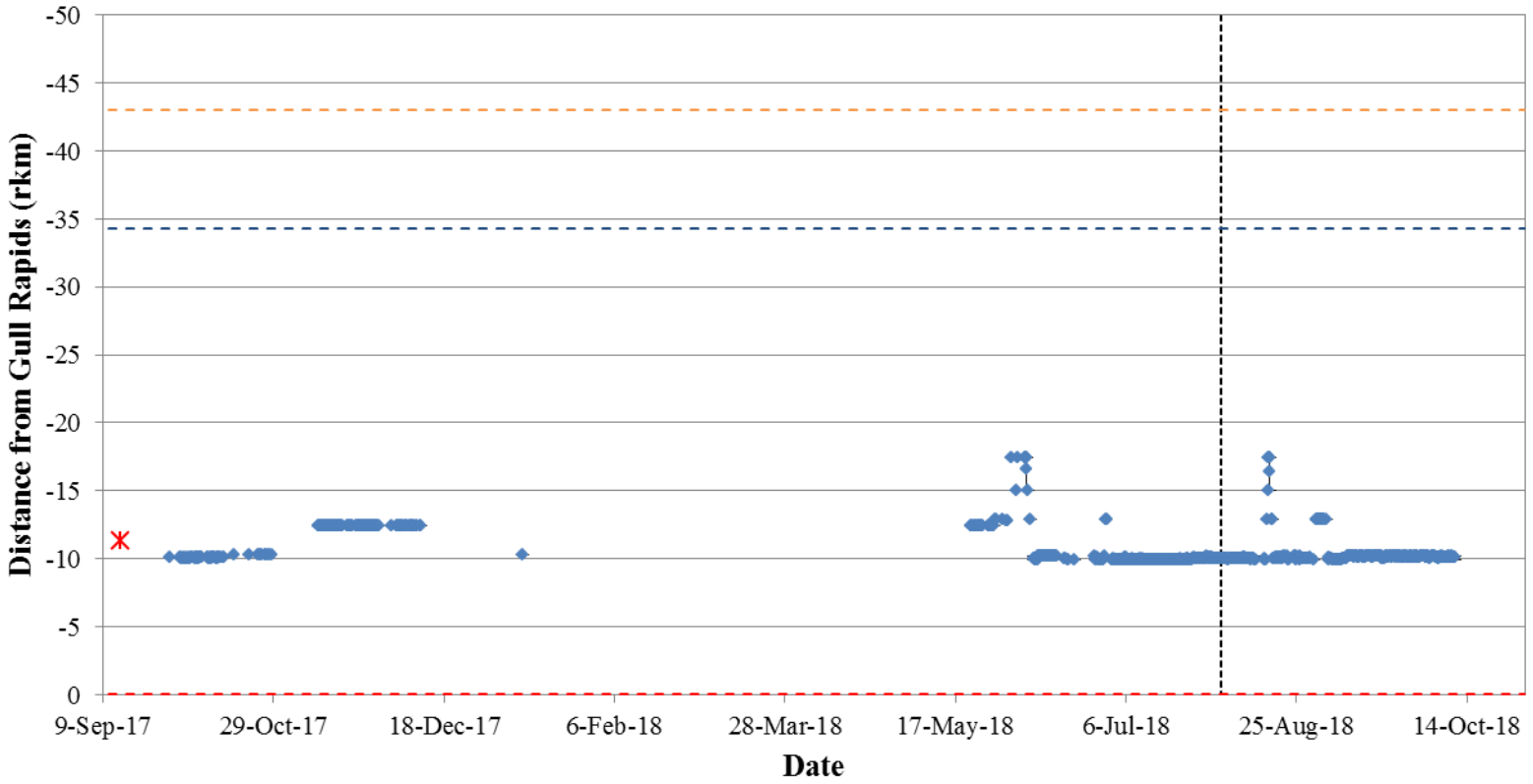


Figure A1-6: Position of a Lake Sturgeon tagged with an acoustic transmitter (code #31768) in Gull Lake in relation to Gull Rapids (rkm 0), from 9 September, 2017 to 10 October, 2018. Date and location of tagging is indicated by red X. Error bars are shown in solid black. Horizontal dashed lines indicate the positions of Gull Rapids (red), Birthday Rapids (blue), and the entrance to Clark Lake (orange). Dashed black vertical line indicates start of spillway operation (Aug 3, 2018).

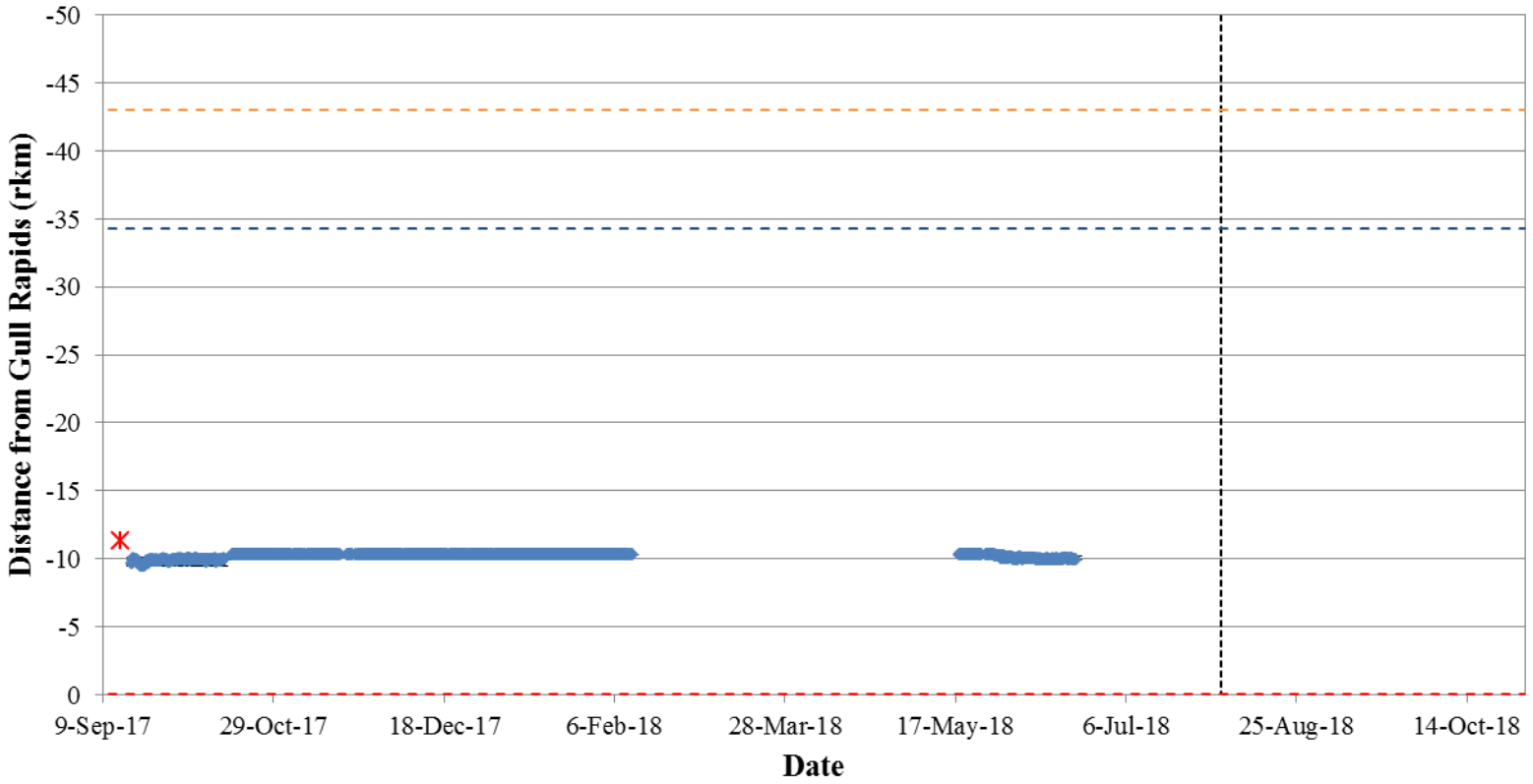


Figure A1-7: Position of a Lake Sturgeon tagged with an acoustic transmitter (code #31769) in Gull Lake in relation to Gull Rapids (rkm 0), from 9 September, 2017 to 10 October, 2018. Date and location of tagging is indicated by red X. Error bars are shown in solid black. Horizontal dashed lines indicate the positions of Gull Rapids (red), Birthday Rapids (blue), and the entrance to Clark Lake (orange). Dashed black vertical line indicates start of spillway operation (Aug 3, 2018).

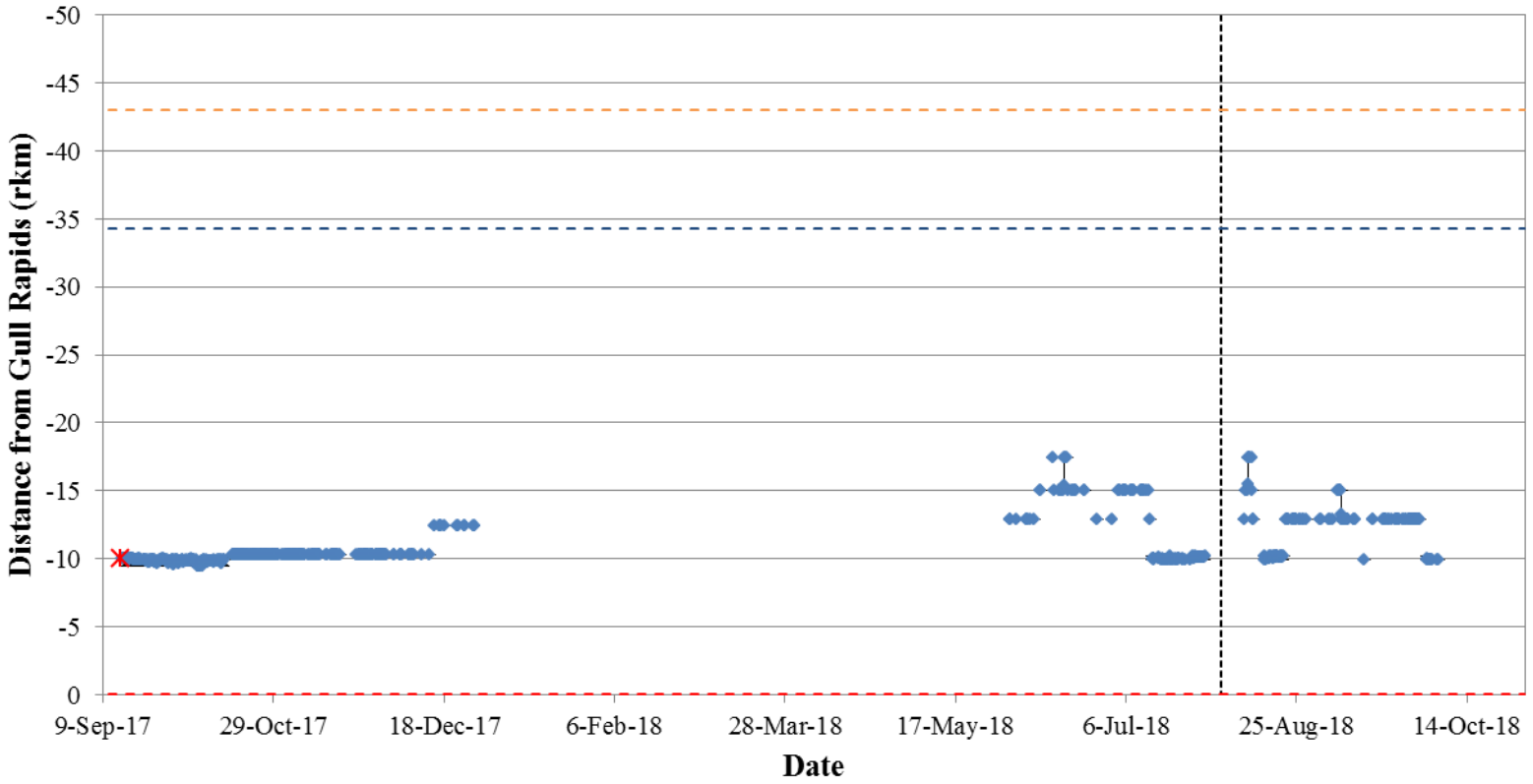


Figure A1-8: Position of a Lake Sturgeon tagged with an acoustic transmitter (code #31770) in Gull Lake in relation to Gull Rapids (rkm 0), from 9 September, 2017 to 10 October, 2018. Date and location of tagging is indicated by red X. Error bars are shown in solid black. Horizontal dashed lines indicate the positions of Gull Rapids (red), Birthday Rapids (blue), and the entrance to Clark Lake (orange). Dashed black vertical line indicates start of spillway operation (Aug 3, 2018).

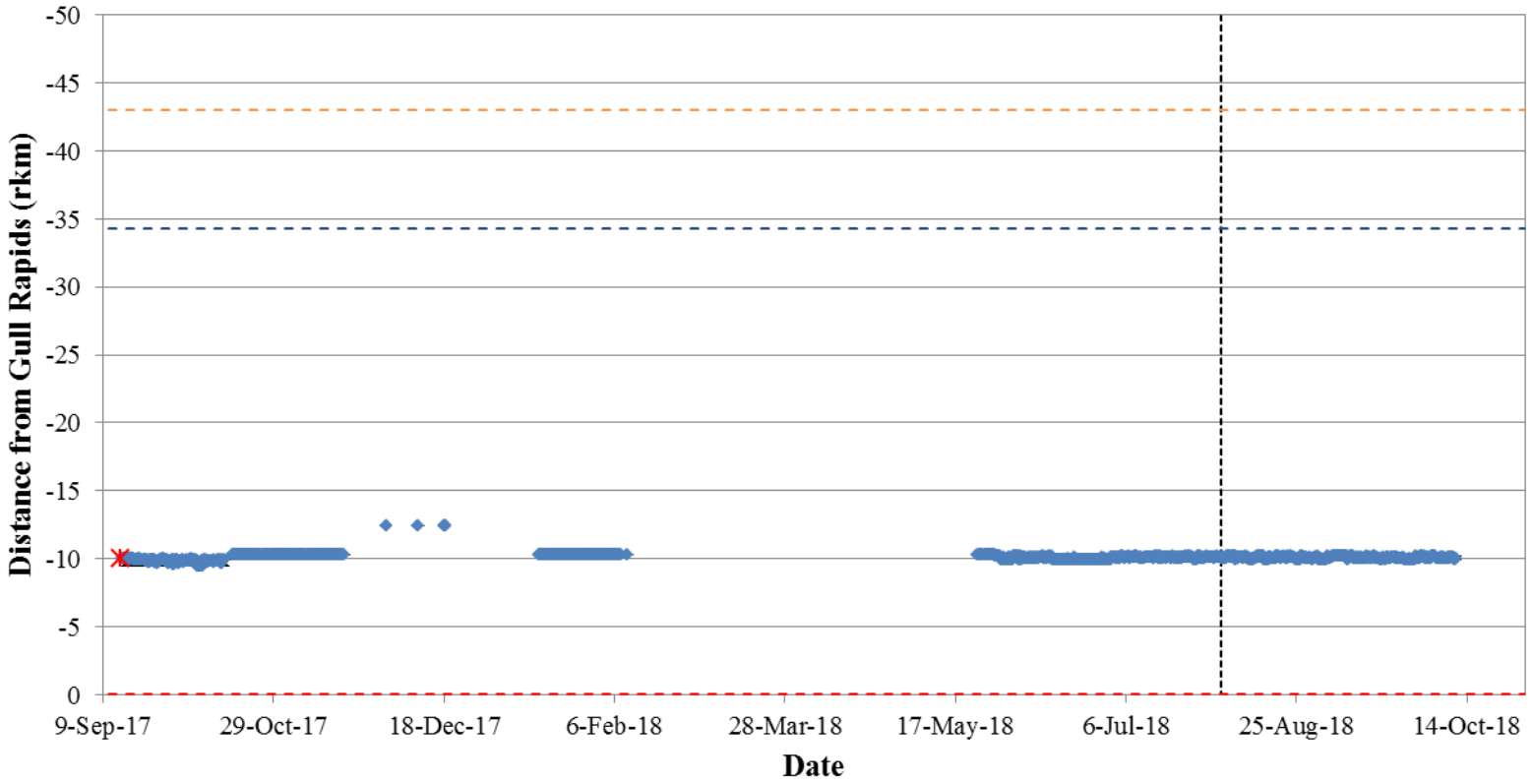


Figure A1-9: Position of a Lake Sturgeon tagged with an acoustic transmitter (code #31771) in Gull Lake in relation to Gull Rapids (rkm 0), from 9 September, 2017 to 10 October, 2018. Date and location of tagging is indicated by red X. Error bars are shown in solid black. Horizontal dashed lines indicate the positions of Gull Rapids (red), Birthday Rapids (blue), and the entrance to Clark Lake (orange). Dashed black vertical line indicates start of spillway operation (Aug 3, 2018).

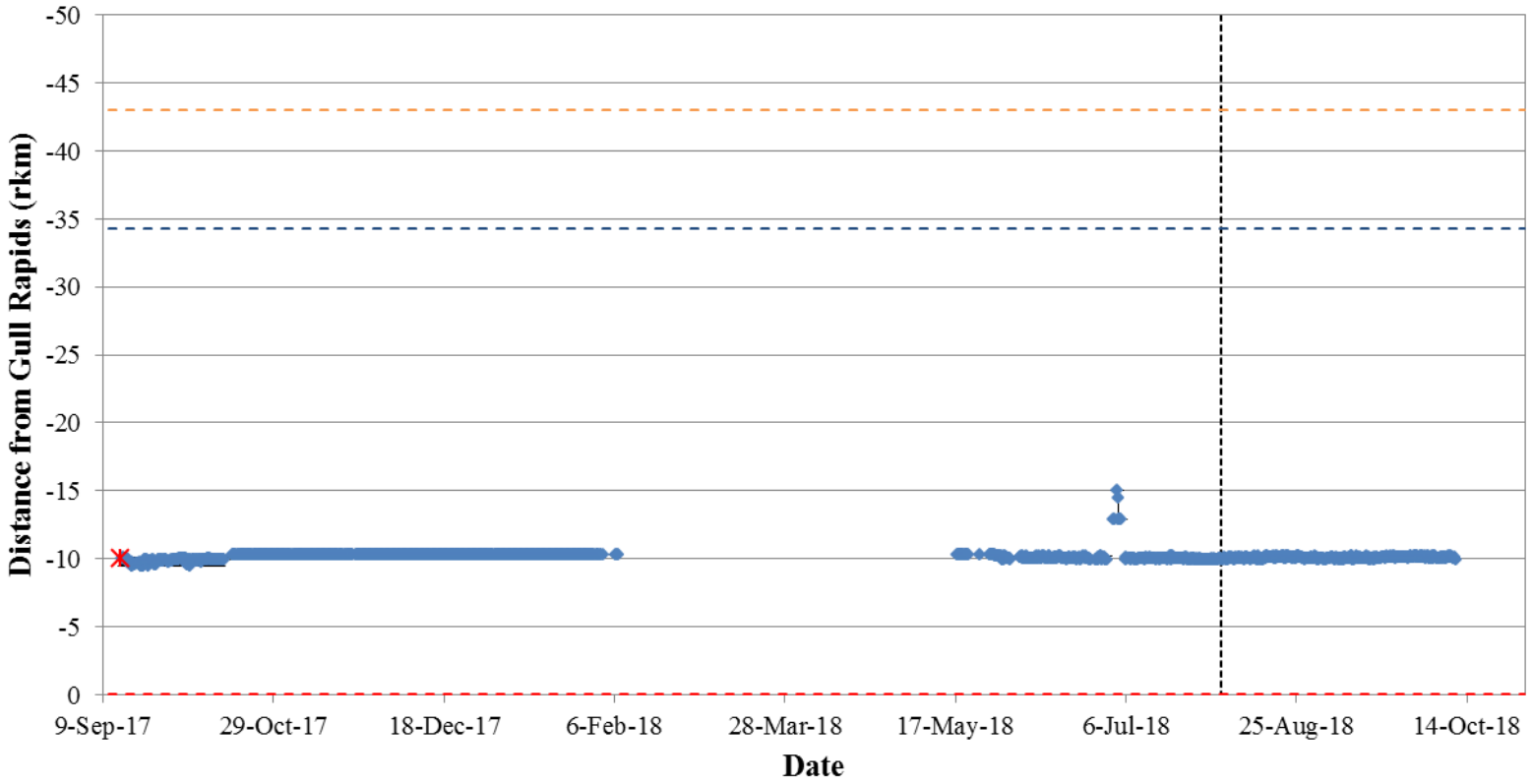


Figure A1-10: Position of a Lake Sturgeon tagged with an acoustic transmitter (code #31772) in Gull Lake in relation to Gull Rapids (rkm 0), from 9 September, 2017 to 10 October, 2018. Date and location of tagging is indicated by red X. Error bars are shown in solid black. Horizontal dashed lines indicate the positions of Gull Rapids (red), Birthday Rapids (blue), and the entrance to Clark Lake (orange). Dashed black vertical line indicates start of spillway operation (Aug 3, 2018).

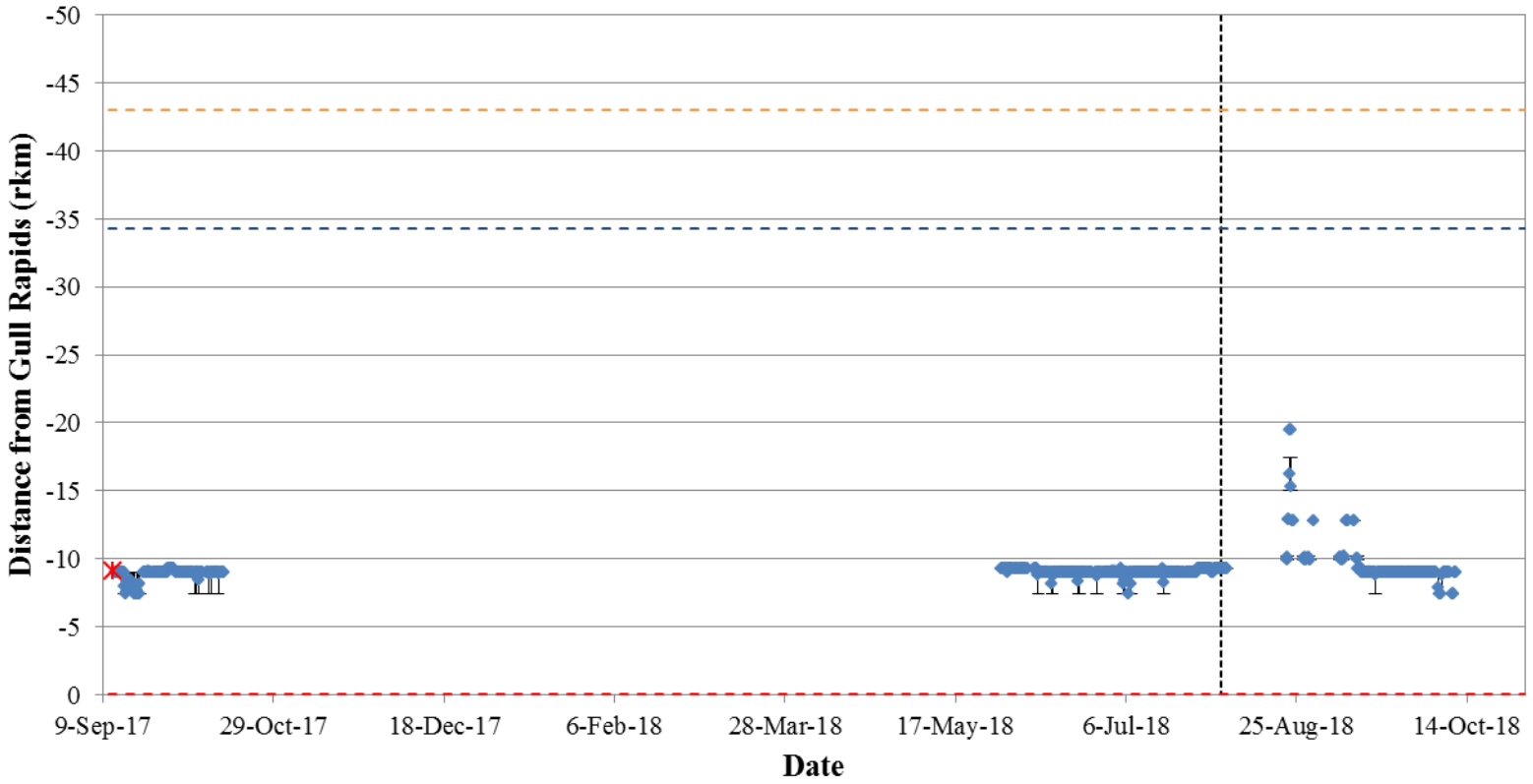


Figure A1-11: Position of a Lake Sturgeon tagged with an acoustic transmitter (code #31773) in Gull Lake in relation to Gull Rapids (rkm 0), from 9 September, 2017 to 10 October, 2018. Date and location of tagging is indicated by red X. Error bars are shown in solid black. Horizontal dashed lines indicate the positions of Gull Rapids (red), Birthday Rapids (blue), and the entrance to Clark Lake (orange). Dashed black vertical line indicates start of spillway operation (Aug 3, 2018).

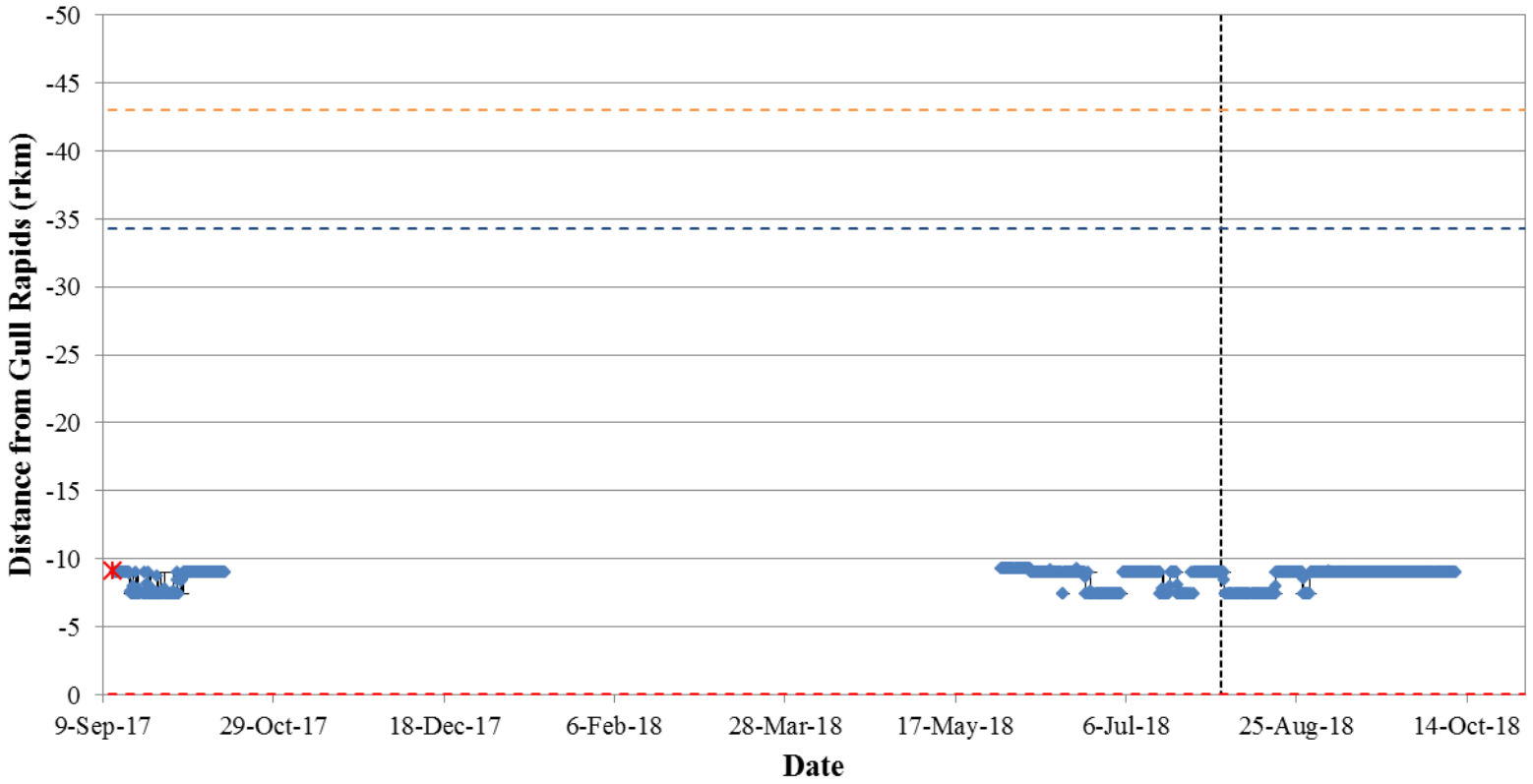


Figure A1-12: Position of a Lake Sturgeon tagged with an acoustic transmitter (code #31774) in Gull Lake in relation to Gull Rapids (rkm 0), from 9 September, 2017 to 10 October, 2018. Date and location of tagging is indicated by red X. Horizontal dashed lines indicate the positions of Gull Rapids (red), Birthday Rapids (blue), and the entrance to Clark Lake (orange). Dashed black vertical line indicates start of spillway operation (Aug 3, 2018).

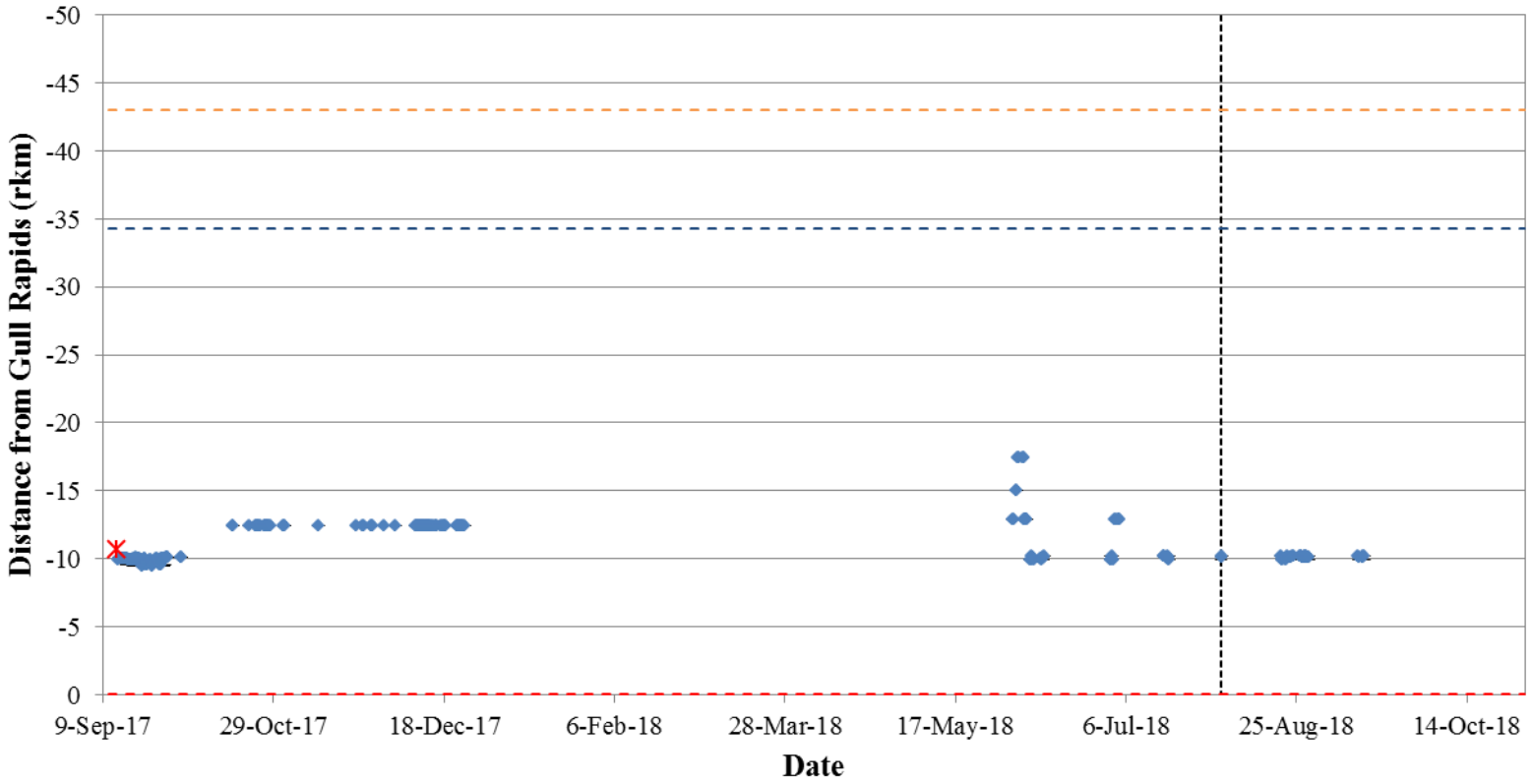


Figure A1-13: Position of a Lake Sturgeon tagged with an acoustic transmitter (code #31775) in Gull Lake in relation to Gull Rapids (rkm 0), from 9 September, 2018 to 10 October, 2018. Date and location of tagging is indicated by red X. Error bars are shown in solid black. Horizontal dashed lines indicate the positions of Gull Rapids (red), Birthday Rapids (blue), and the entrance to Clark Lake (orange). Dashed black vertical line indicates start of spillway operation (Aug 3, 2018).

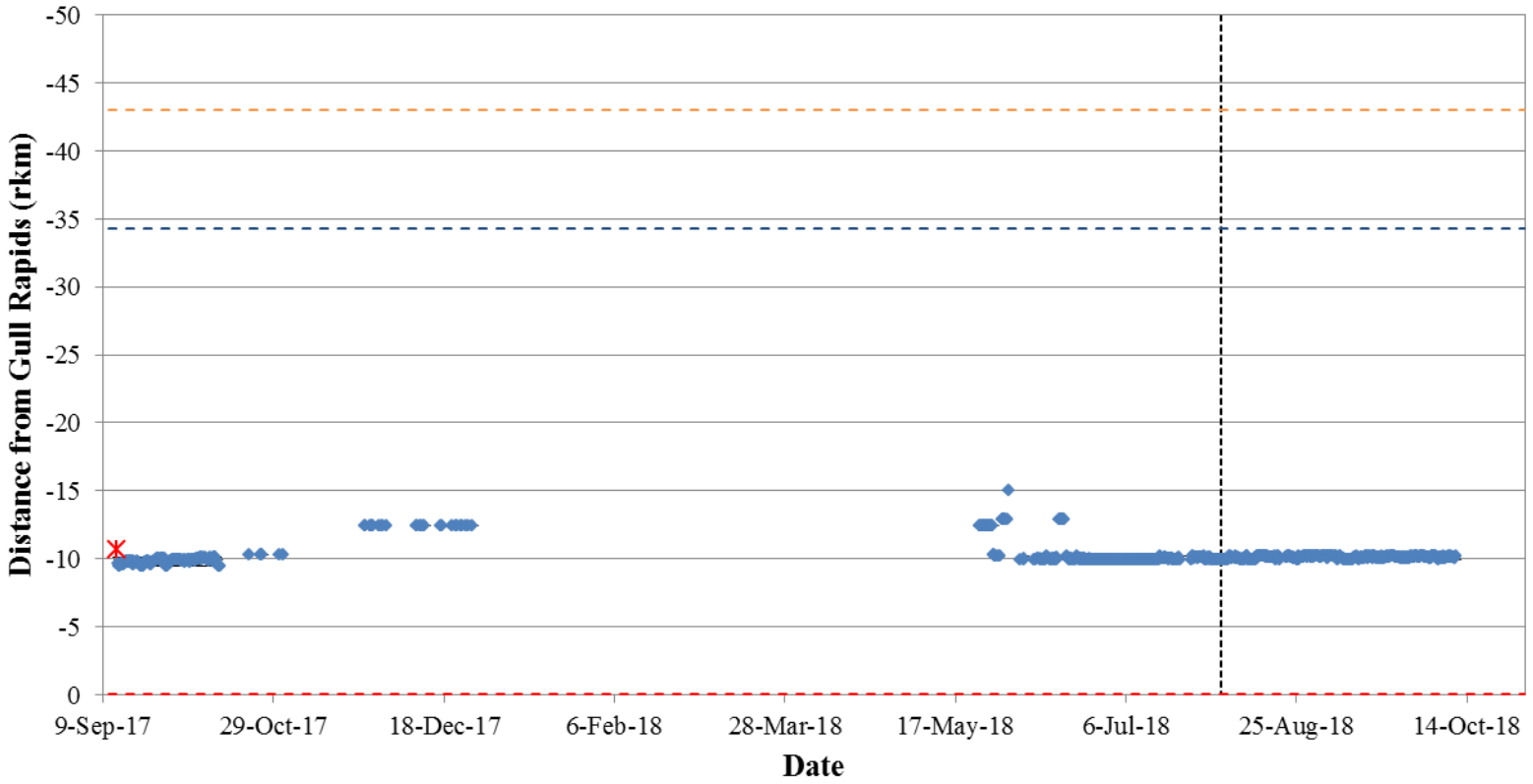


Figure A1-14: Position of a Lake Sturgeon tagged with an acoustic transmitter (code #31776) in Gull Lake in relation to Gull Rapids (rkm 0), from 9 September, 2017 to 10 October, 2018. Date and location of tagging is indicated by red X. Error bars are shown in solid black. Horizontal dashed lines indicate the positions of Gull Rapids (red), Birthday Rapids (blue), and the entrance to Clark Lake (orange). Dashed black vertical line indicates start of spillway operation (Aug 3, 2018).

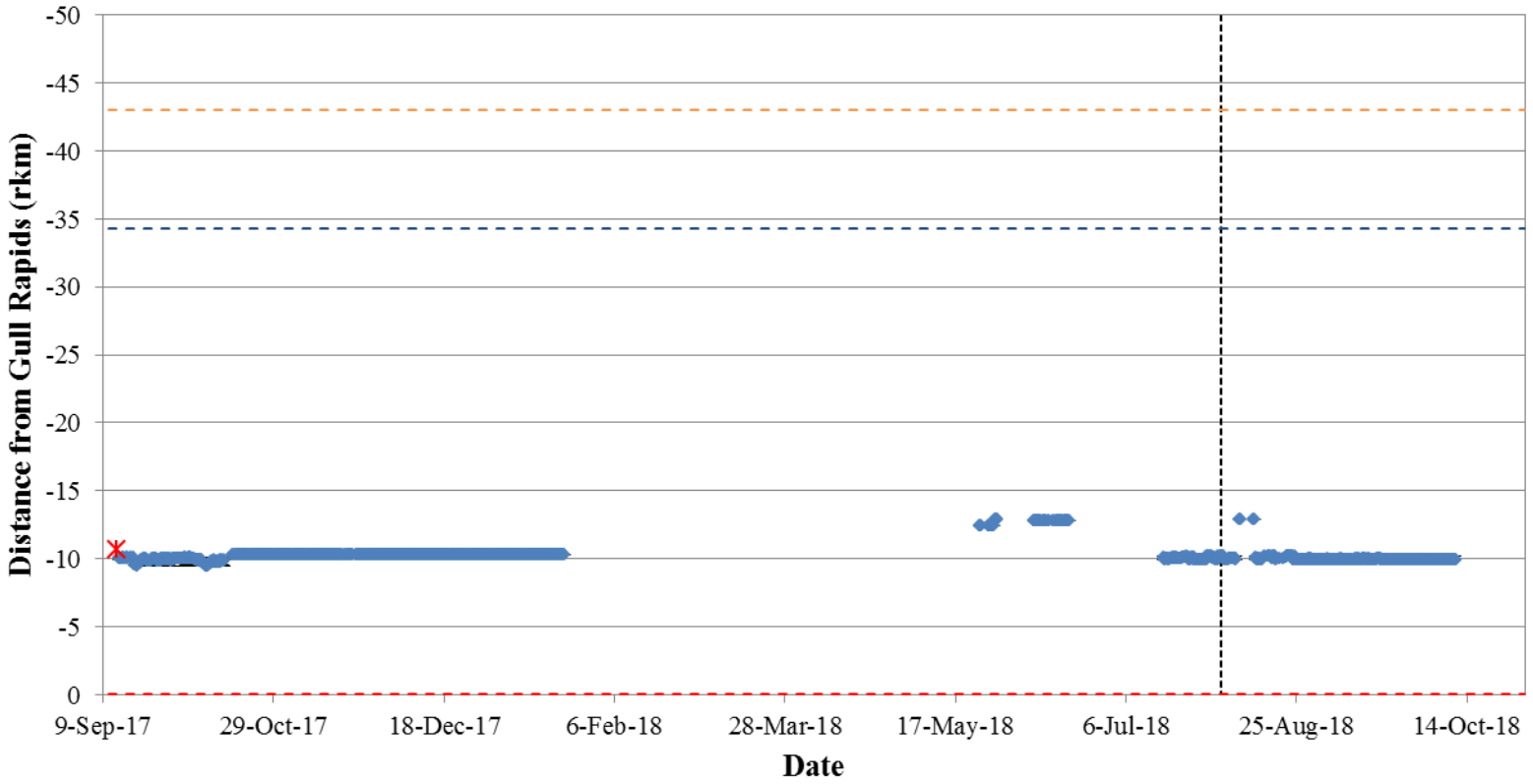


Figure A1-15: Position of a Lake Sturgeon tagged with an acoustic transmitter (code #31777) in Gull Lake in relation to Gull Rapids (rkm 0), from 9 September, 2017 to 10 October, 2018. Date and location of tagging is indicated by red X. Error bars are shown in solid black. Horizontal dashed lines indicate the positions of Gull Rapids (red), Birthday Rapids (blue), and the entrance to Clark Lake (orange). Dashed black vertical line indicates start of spillway operation (Aug 3, 2018).

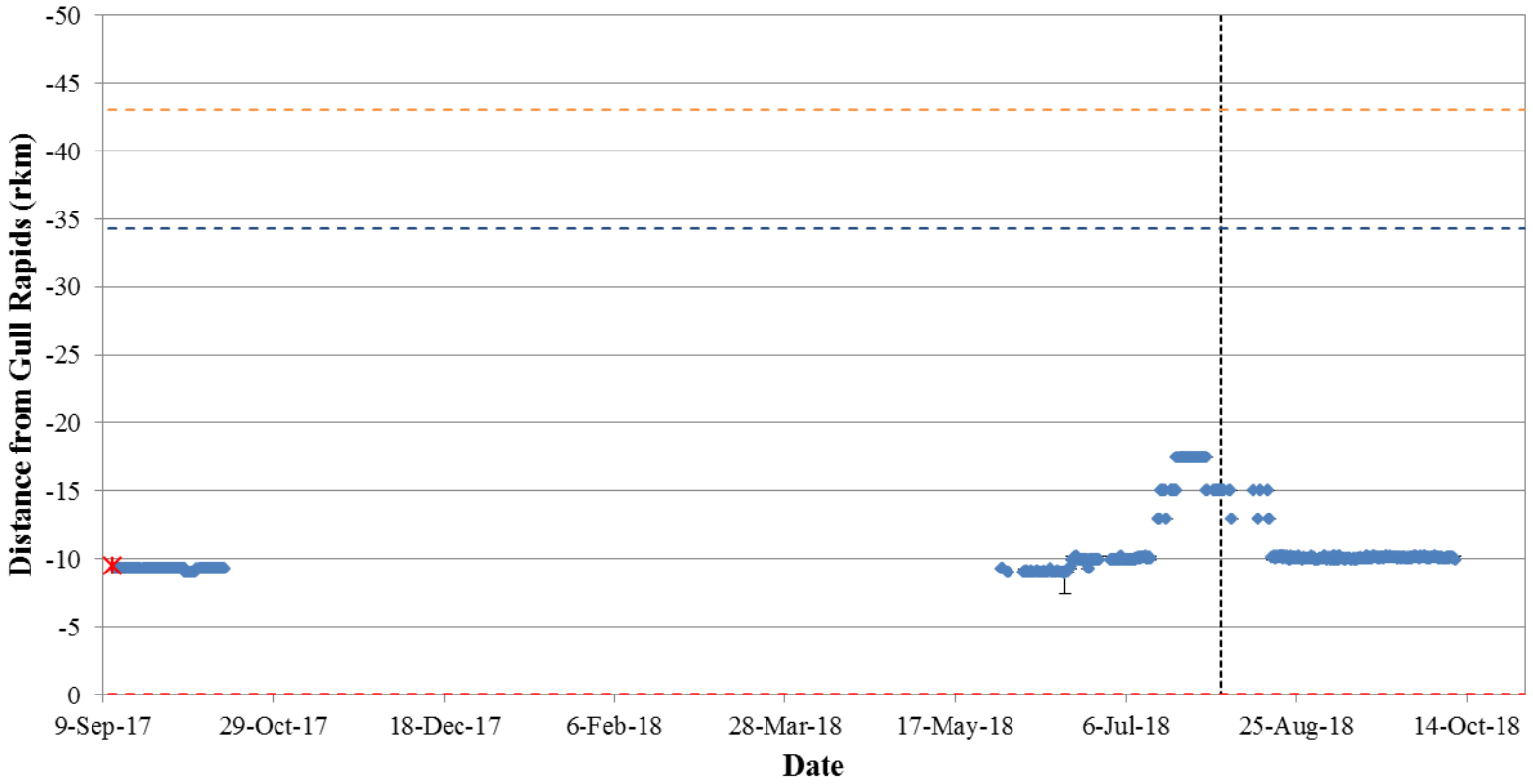


Figure A1-16: Position of a Lake Sturgeon tagged with an acoustic transmitter (code #31778) in Gull Lake in relation to Gull Rapids (rkm 0), from 9 September, 2017 to 10 October, 2018. Date and location of tagging is indicated by red X. Error bars are shown in solid black. Horizontal dashed lines indicate the positions of Gull Rapids (red), Birthday Rapids (blue), and the entrance to Clark Lake (orange). Dashed black vertical line indicates start of spillway operation (Aug 3, 2018).

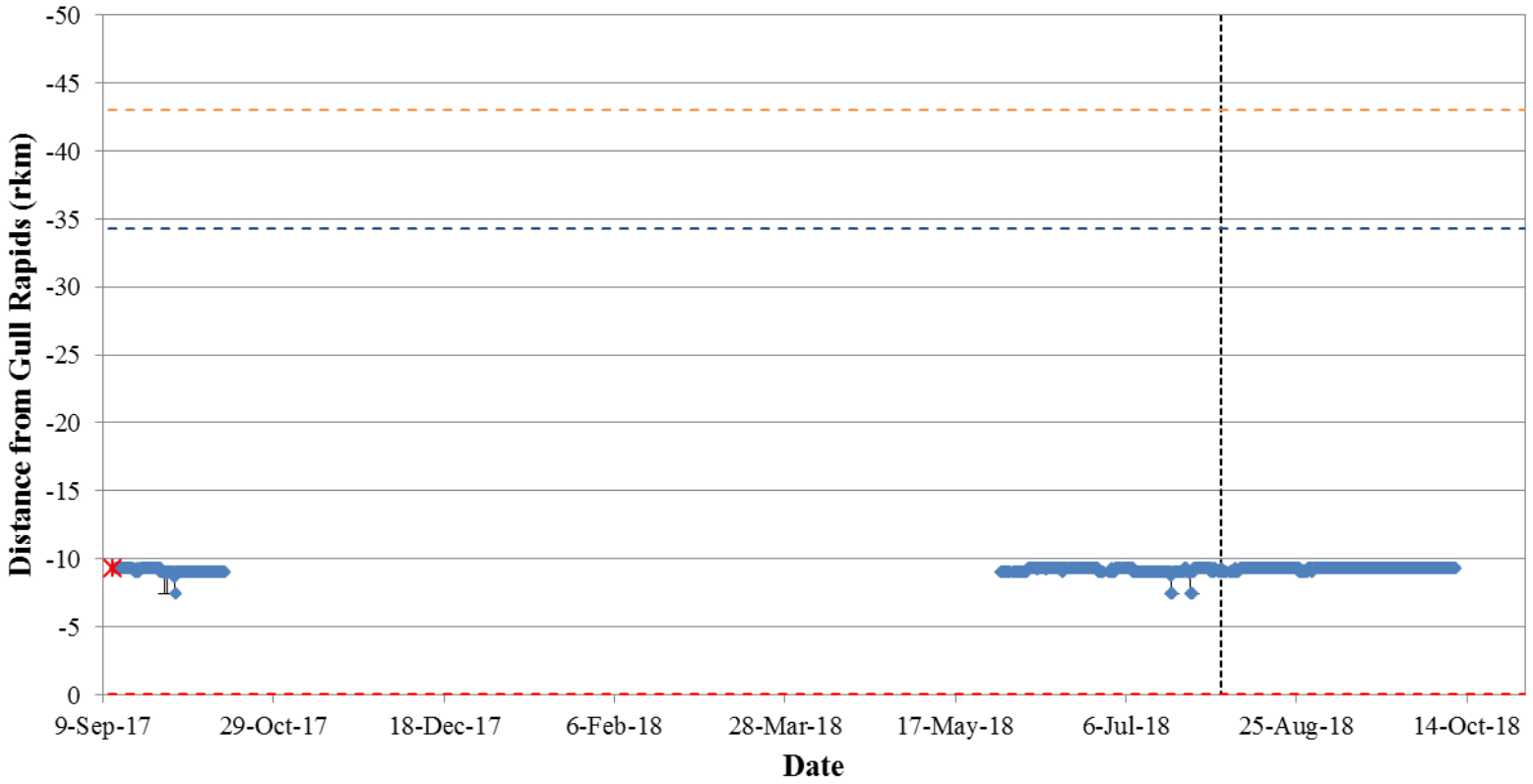


Figure A1-17: Position of a Lake Sturgeon tagged with an acoustic transmitter (code #31779) in Gull Lake in relation to Gull Rapids (rkm 0), from 9 September, 2017 to 10 October, 2018. Date and location of tagging is indicated by red X. Error bars are shown in solid black. Horizontal dashed lines indicate the positions of Gull Rapids (red), Birthday Rapids (blue), and the entrance to Clark Lake (orange). Dashed black vertical line indicates start of spillway operation (Aug 3, 2018).

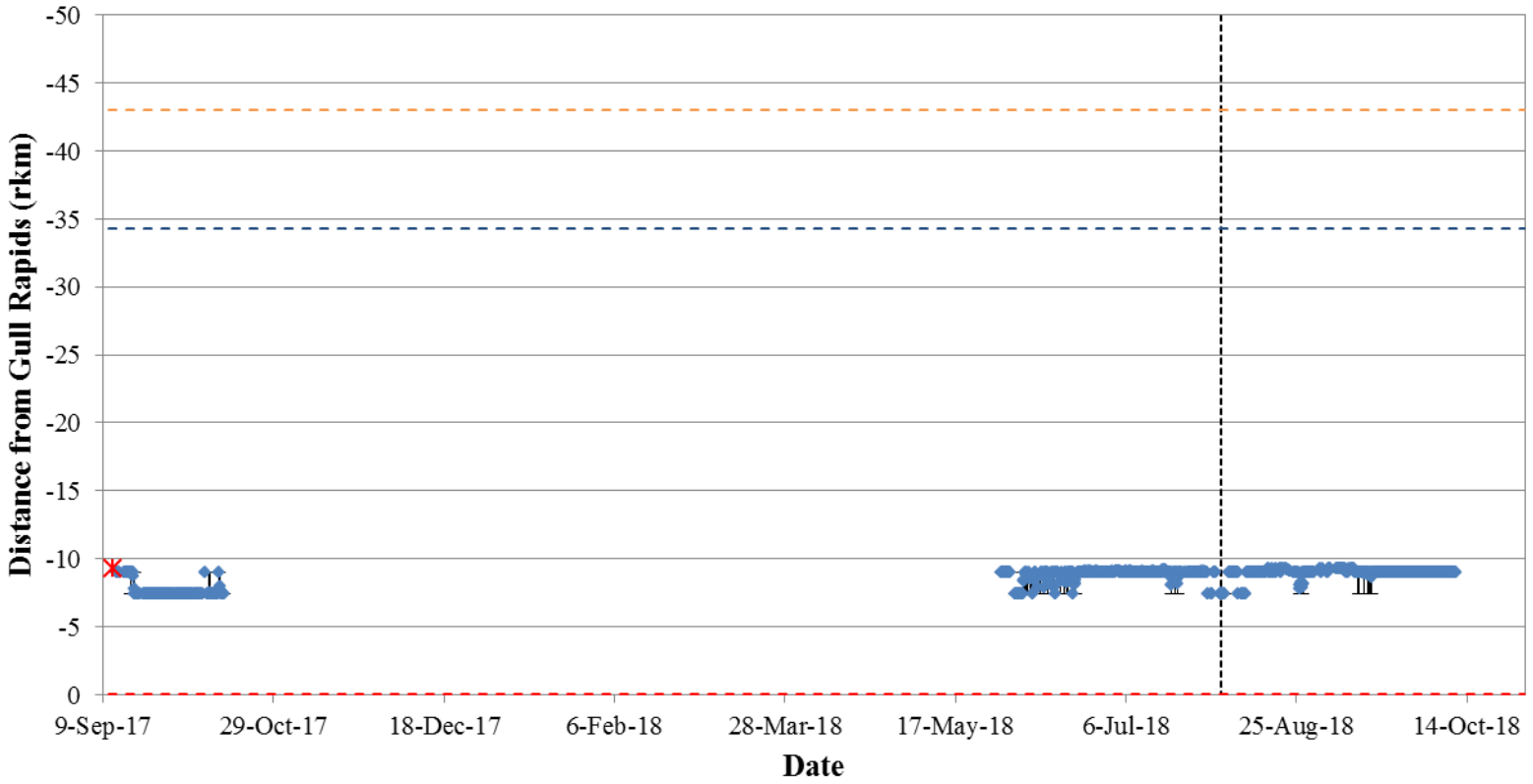


Figure A1-18: Position of a Lake Sturgeon tagged with an acoustic transmitter (code #31780) in Gull Lake in relation to Gull Rapids (rkm 0), from 9 September, 2017 to 10 October, 2018. Date and location of tagging is indicated by red X. Error bars are shown in solid black. Horizontal dashed lines indicate the positions of Gull Rapids (red), Birthday Rapids (blue), and the entrance to Clark Lake (orange). Dashed black vertical line indicates start of spillway operation (Aug 3, 2018).

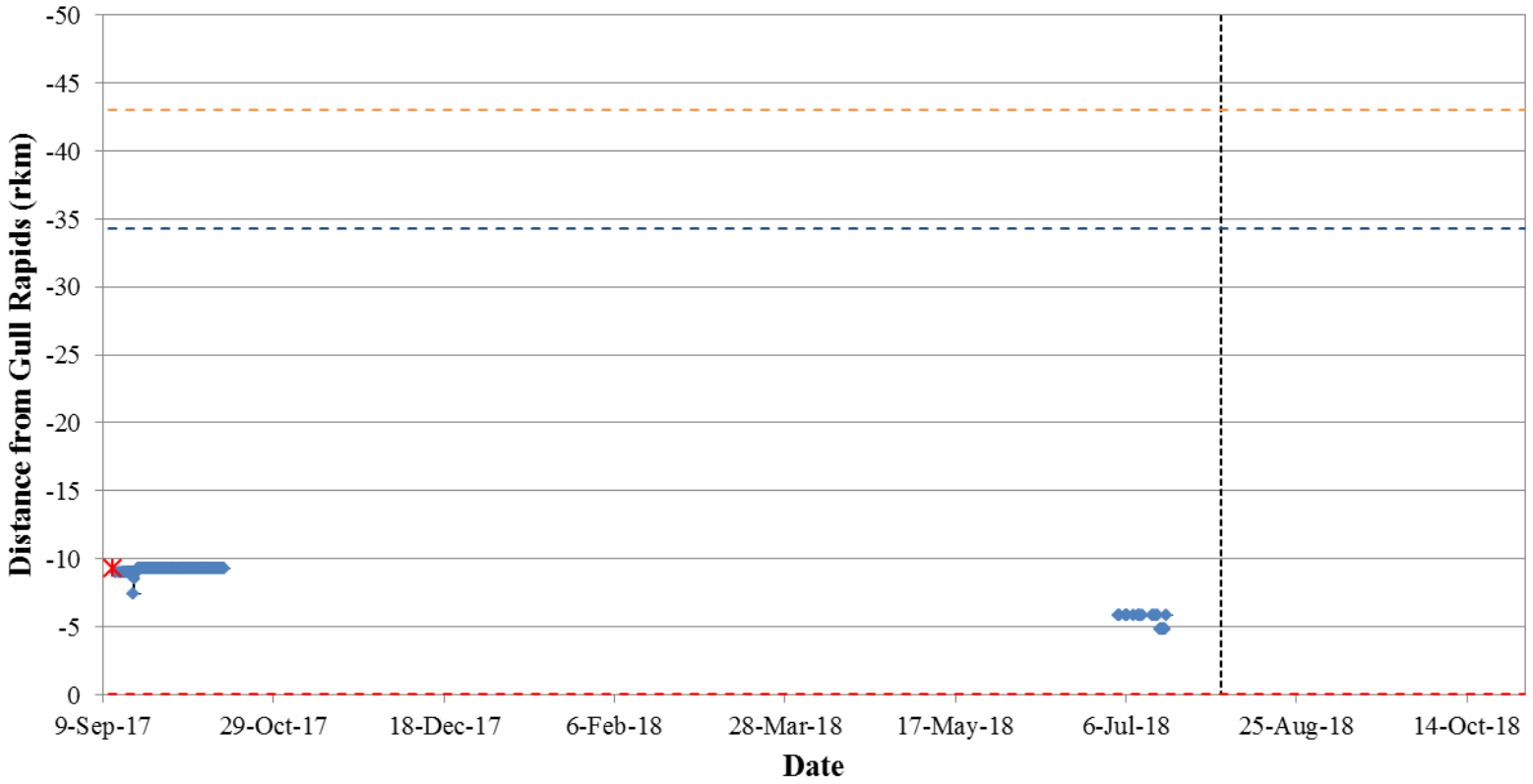


Figure A1-19: Position of a Lake Sturgeon tagged with an acoustic transmitter (code #31781) in Gull Lake in relation to Gull Rapids (rkm 0), from 9 September, 2017 to 10 October, 2018. Date and location of tagging is indicated by red X. Error bars are shown in solid black. Horizontal dashed lines indicate the positions of Gull Rapids (red), Birthday Rapids (blue), and the entrance to Clark Lake (orange). Dashed black vertical line indicates start of spillway operation (Aug 3, 2018).

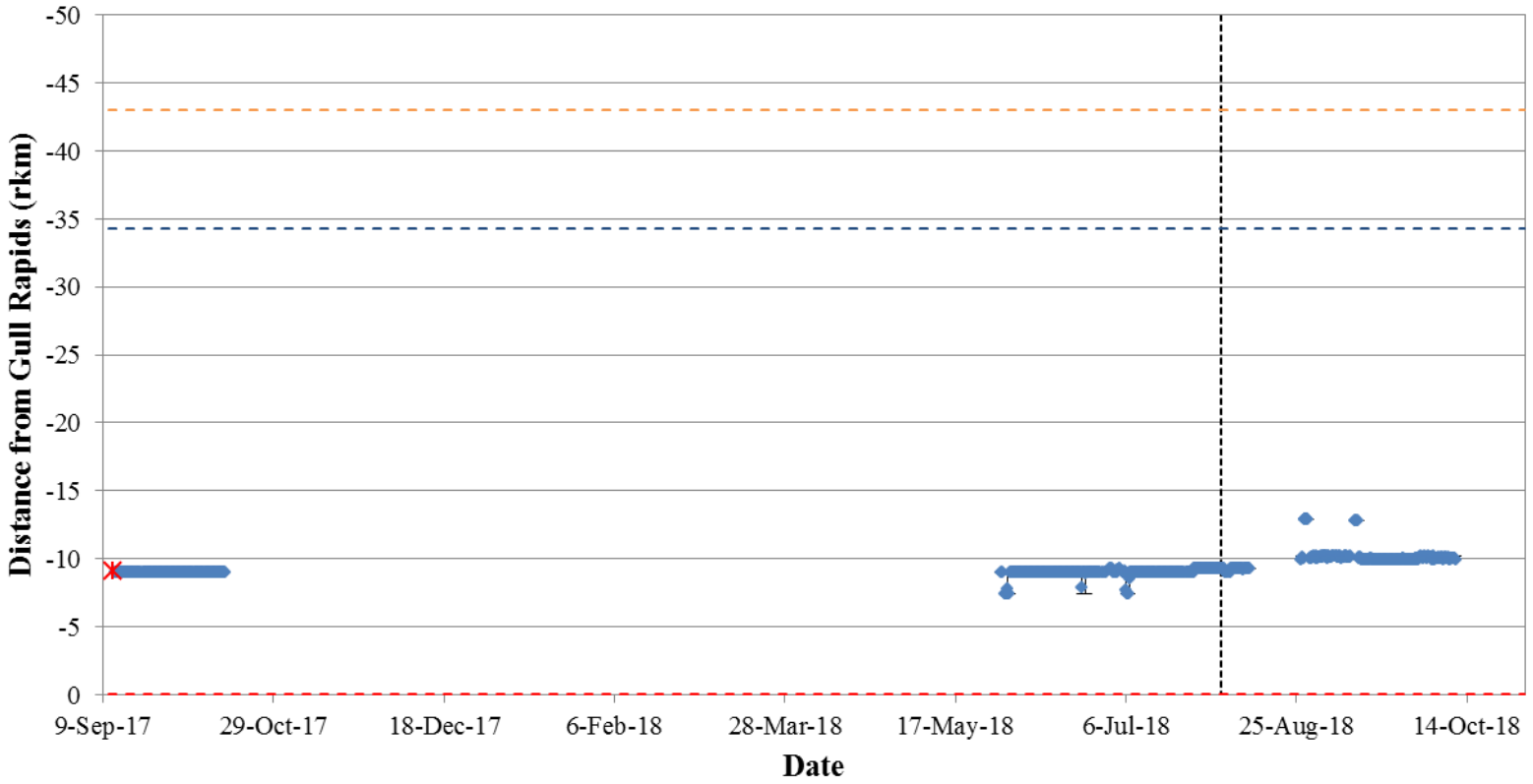


Figure A1-20: Position of a Lake Sturgeon tagged with an acoustic transmitter (code #31782) in Gull Lake in relation to Gull Rapids (rkm 0), from 9 September, 2017 to 10 October, 2018. Date and location of tagging is indicated by red X. Error bars are shown in solid black. Horizontal dashed lines indicate the positions of Gull Rapids (red), Birthday Rapids (blue), and the entrance to Clark Lake (orange). Dashed black vertical line indicates start of spillway operation (Aug 3, 2018).

APPENDIX 2:
LOCATION SUMMARY FOR INDIVIDUAL ACOUSTIC TAGGED JUVENILE LAKE STURGEON DOWNSTREAM OF GULL RAPIDS, SEPTEMBER 2017 TO OCTOBER 2018

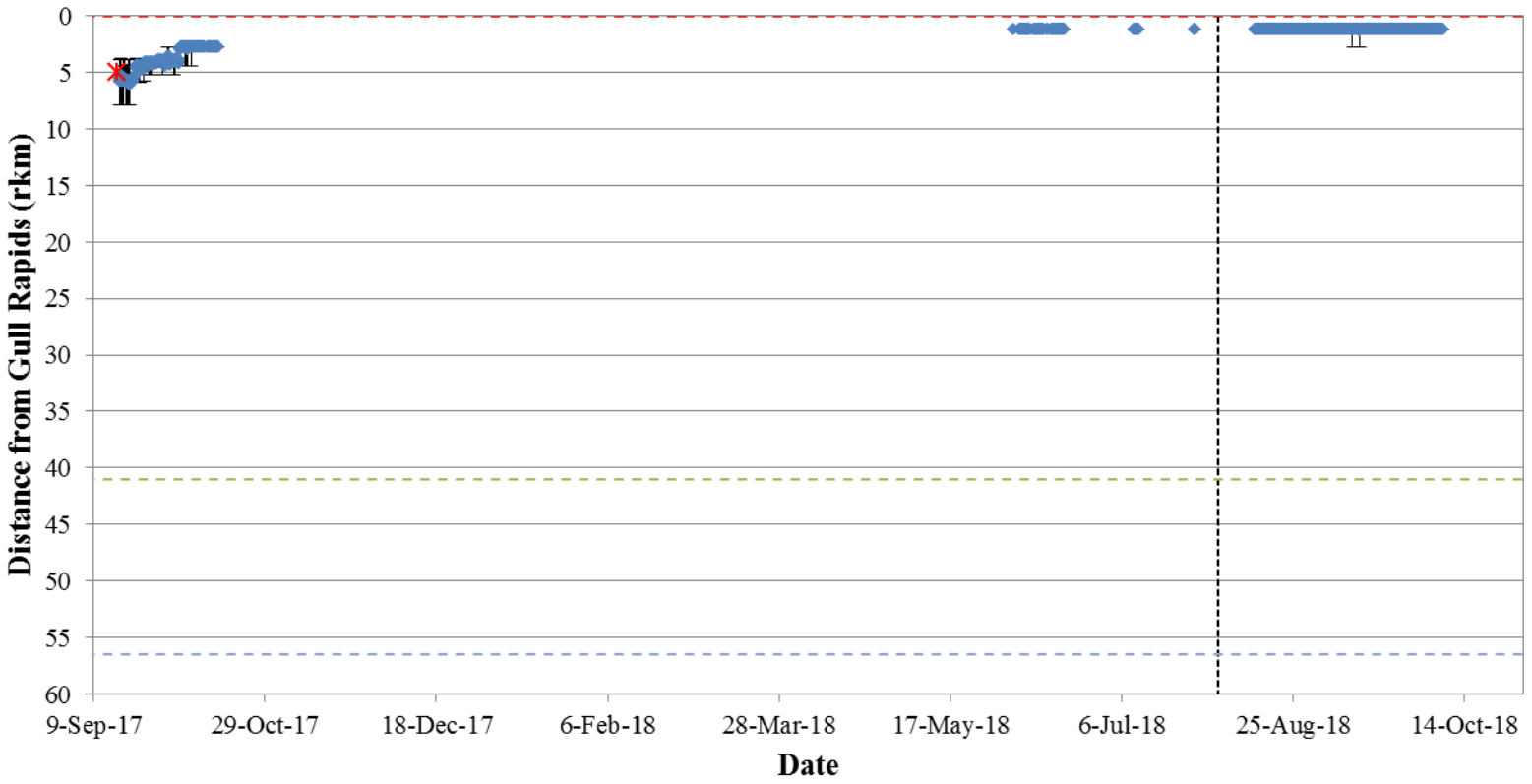


Figure A2-1: Position of a Lake Sturgeon tagged with an acoustic transmitter (code #31668) in Stephens Lake in relation to Gull Rapids (rkm 0), 9 September 2017 to 10 October, 2018. Date and location of tagging is indicated in red. Error bars are shown in solid black. Horizontal dashed lines indicate the positions of Gull Rapids (red), Kettle GS (green), and Long Spruce GS (blue). Dashed black vertical line indicates start of spillway operation (Aug 3, 2018).

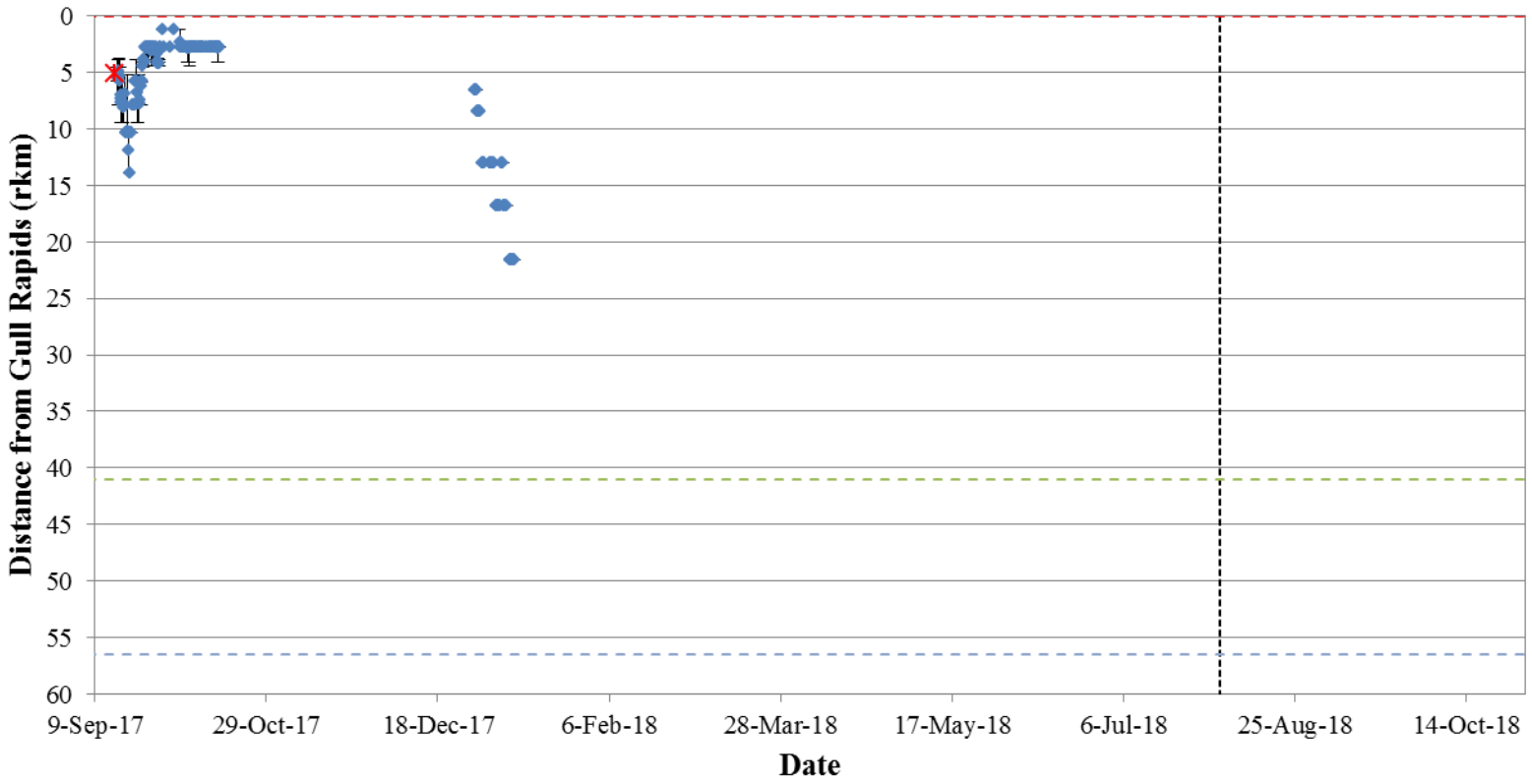


Figure A2-2: Position of a Lake Sturgeon tagged with an acoustic transmitter (code #31689) in Stephens Lake in relation to Gull Rapids (rkm 0), from 9 September, 2017 to 10 October, 2018. Date and location of tagging is indicated in red. Error bars are shown in solid black. Horizontal dashed lines indicate the positions of Gull Rapids (red), Kettle GS (green), and Long Spruce GS (purple). Dashed black vertical line indicates start of spillway operation (Aug 3, 2018).

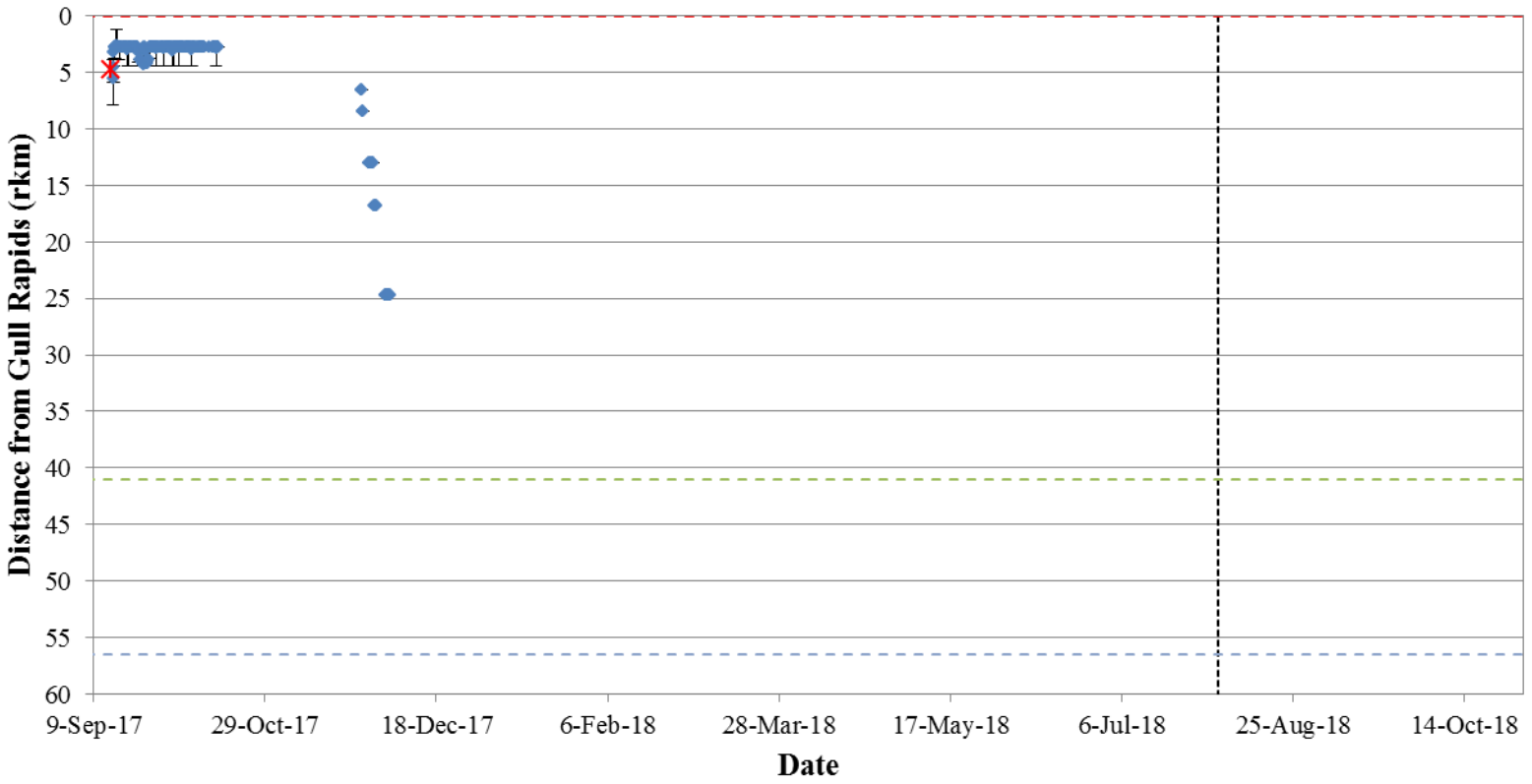


Figure A2-3: Position of a Lake Sturgeon tagged with an acoustic transmitter (code #31690) in Stephens Lake in relation to Gull Rapids (rkm 0), from 9 September, 2017 to 10 October, 2018. Date and location of tagging is indicated in red. Error bars are shown in solid black. Horizontal dashed lines indicate the positions of Gull Rapids (red), Kettle GS (green), and Long Spruce GS (purple). Dashed black vertical line indicates start of spillway operation (Aug 3, 2018).

Figure A2-4: Position of a Lake Sturgeon tagged with an acoustic transmitter (code #31691) in Stephens Lake in relation to Gull Rapids (rkm 0), from 9 September, 2017 to 10 October, 2018. Date and location of tagging is indicated in red. Error bars are shown in solid black. Horizontal dashed lines indicate the positions of Gull Rapids (red), Kettle GS (green), and Long Spruce GS (purple). Dashed black vertical line indicates start of spillway operation (Aug 3, 2018).

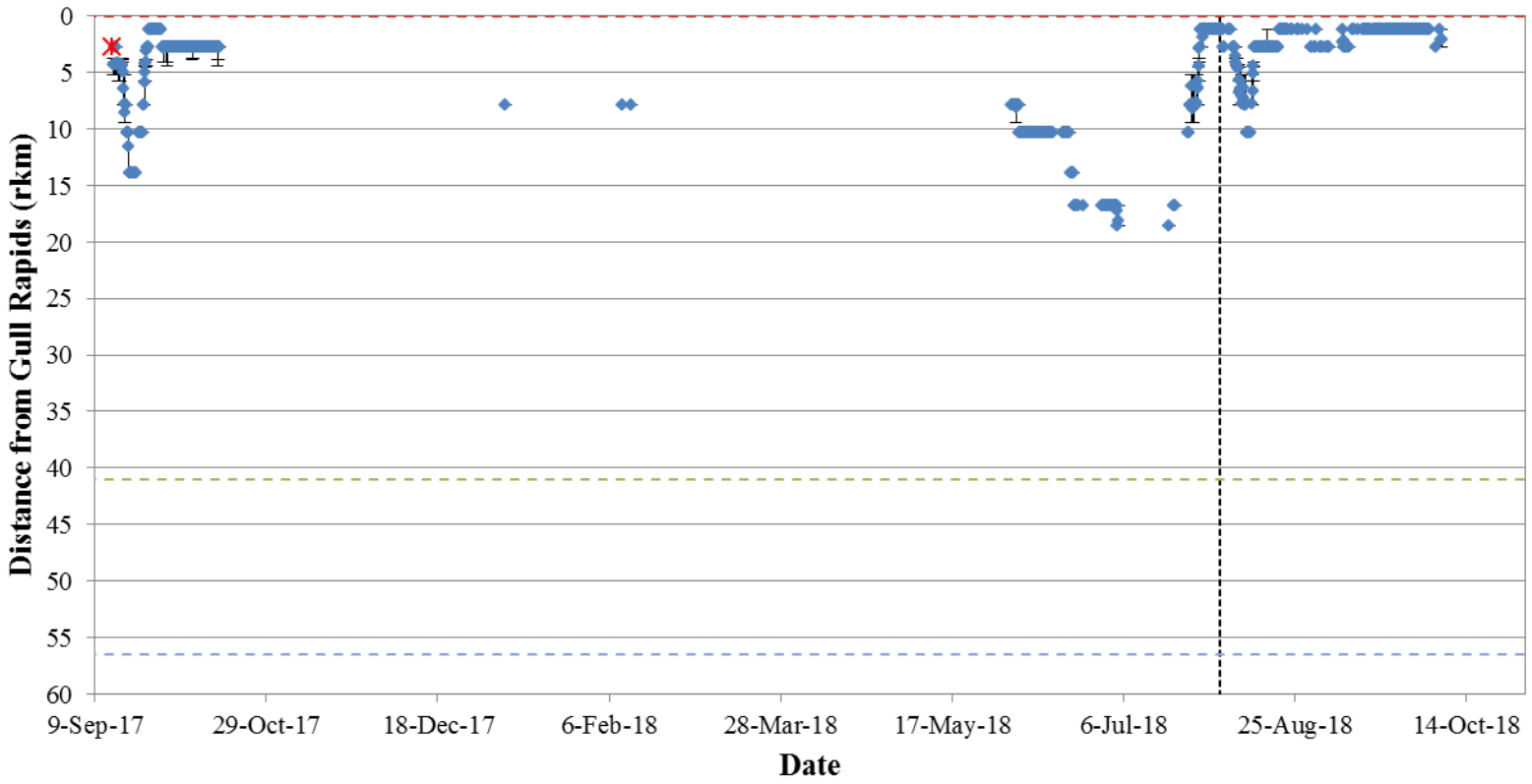


Figure A2-5: Position of a Lake Sturgeon tagged with an acoustic transmitter (code #31692) in Stephens Lake in relation to Gull Rapids (rkm 0), from 9 September, 2017 to 10 October, 2018. Date and location of tagging is indicated in red. Error bars are shown in solid black. Horizontal dashed lines indicate the positions of Gull Rapids (red), Kettle GS (green), and Long Spruce GS (purple). Dashed black vertical line indicates start of spillway operation (Aug 3, 2018).

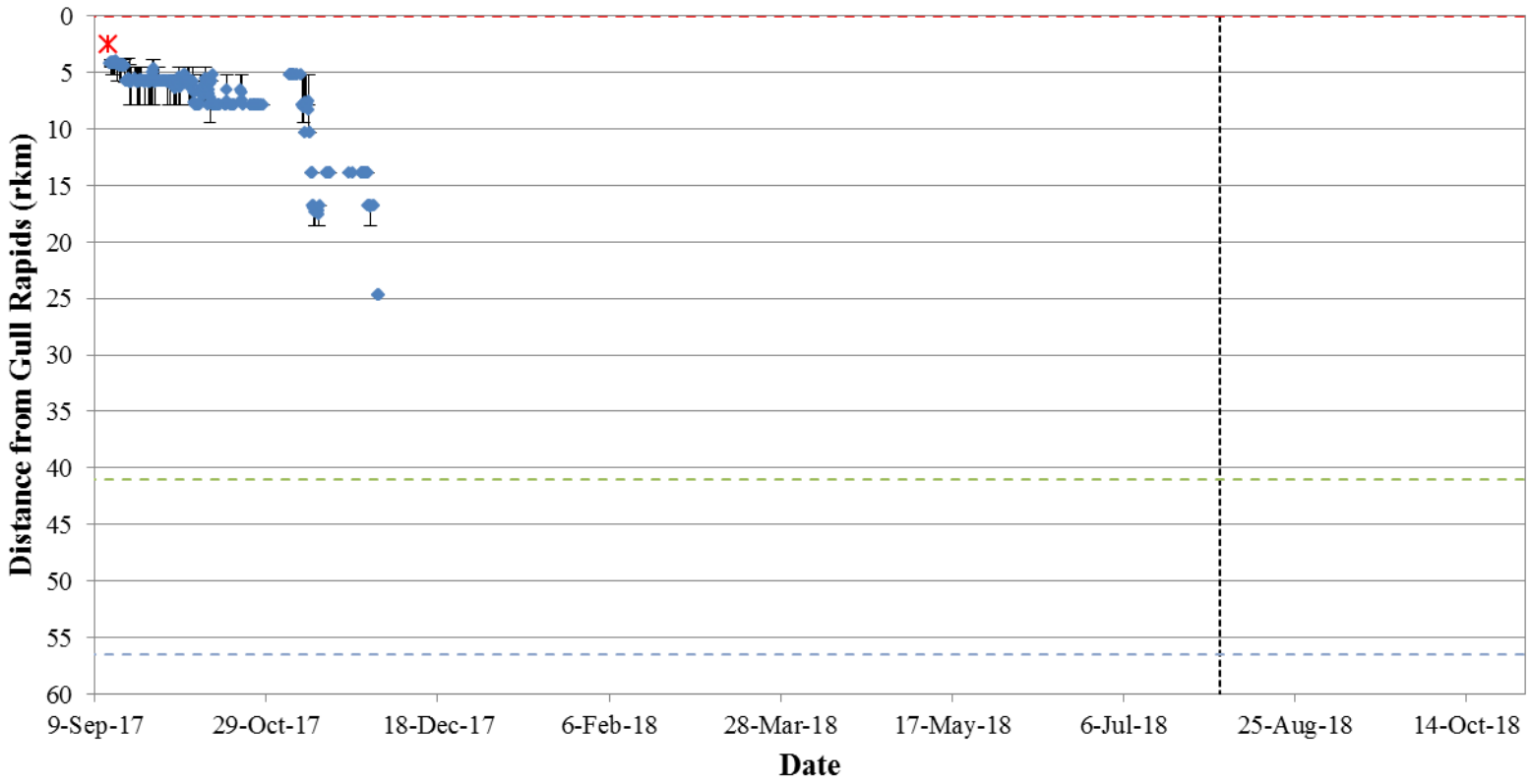


Figure A2-6: Position of a Lake Sturgeon tagged with an acoustic transmitter (code #31693) in Stephens Lake in relation to Gull Rapids (rkm 0), from 9 September, 2017 to 10 October, 2018. Date and location of tagging is indicated in red. Error bars are shown in solid black. Horizontal dashed lines indicate the positions of Gull Rapids (red), Kettle GS (green), and Long Spruce GS (purple). Dashed black vertical line indicates start of spillway operation (Aug 3, 2018).

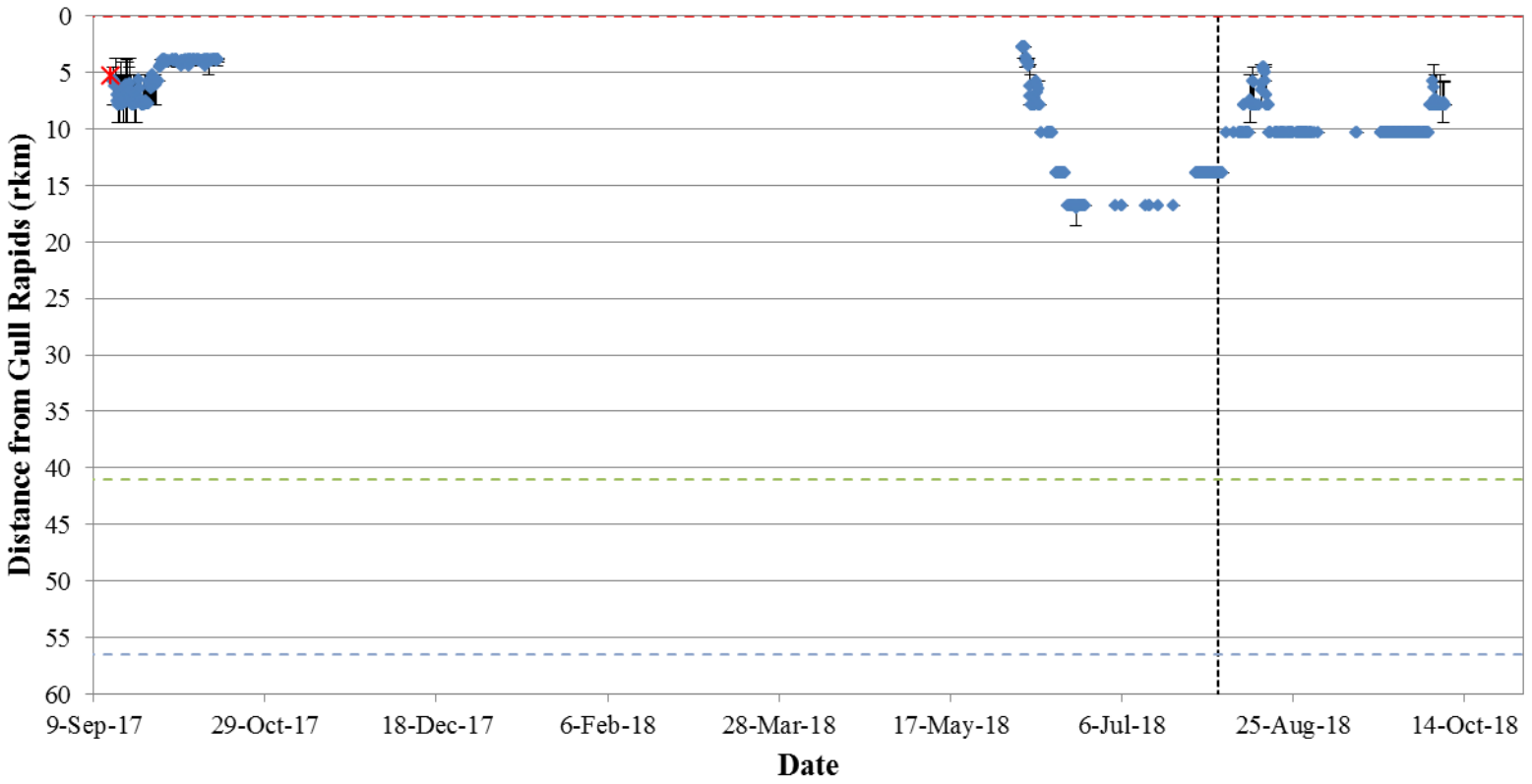


Figure A2-7: Position of a Lake Sturgeon tagged with an acoustic transmitter (code #31694) in Stephens Lake in relation to Gull Rapids (rkm 0), from 9 September, 2017 to 10 October, 2018. Date and location of tagging is indicated in red. Error bars are shown in solid black. Horizontal dashed lines indicate the positions of Gull Rapids (red), Kettle GS (green), and Long Spruce GS (purple). Dashed black vertical line indicates start of spillway operation (Aug 3, 2018).

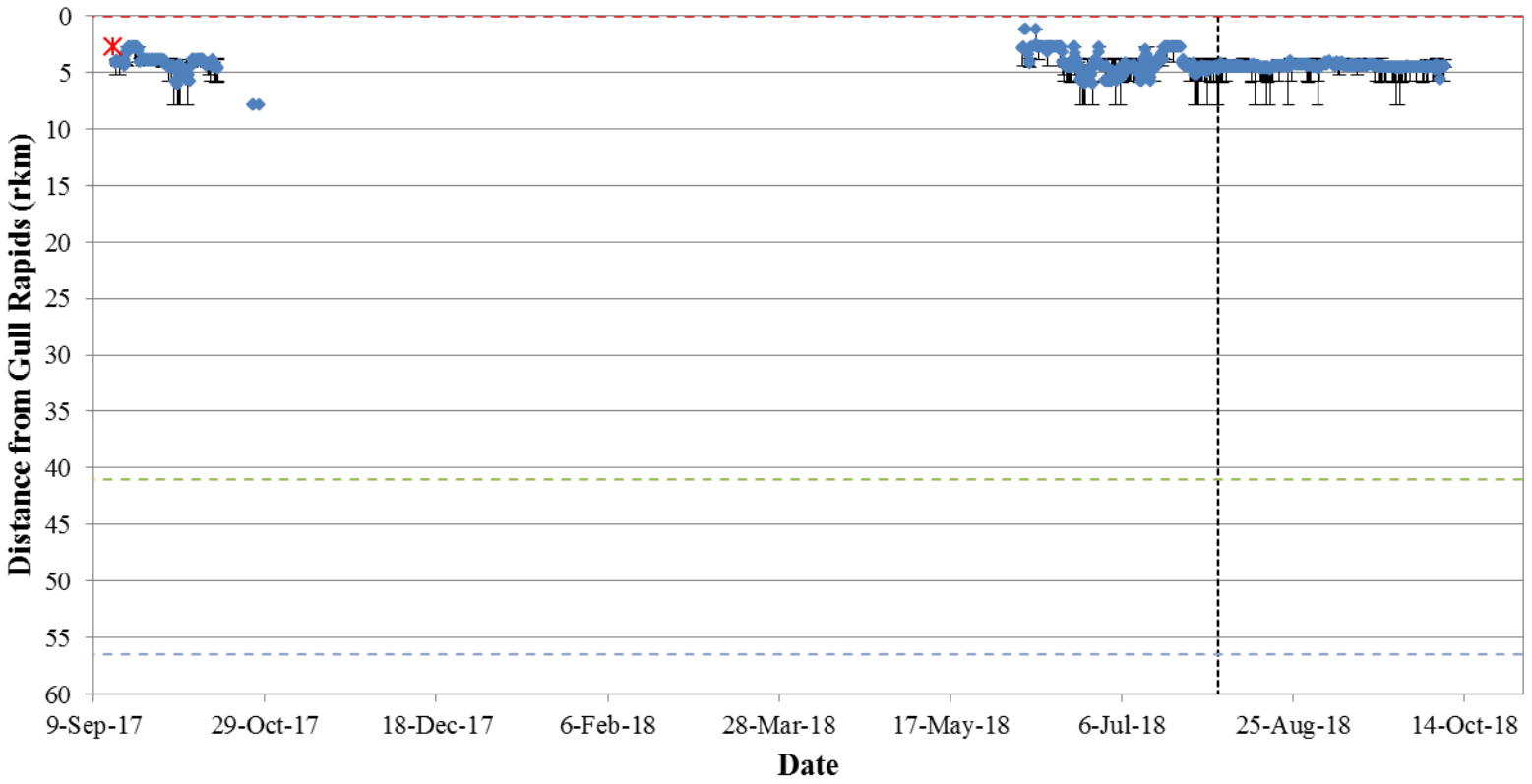


Figure A2-8: Position of a Lake Sturgeon tagged with an acoustic transmitter (code #31695) in Stephens Lake in relation to Gull Rapids (rkm 0), from 9 September, 2017 to 10 October, 2018. Date and location of tagging is indicated in red. Error bars are shown in solid black. Horizontal dashed lines indicate the positions of Gull Rapids (red), Kettle GS (green), and Long Spruce GS (purple). Dashed black vertical line indicates start of spillway operation (Aug 3, 2018).

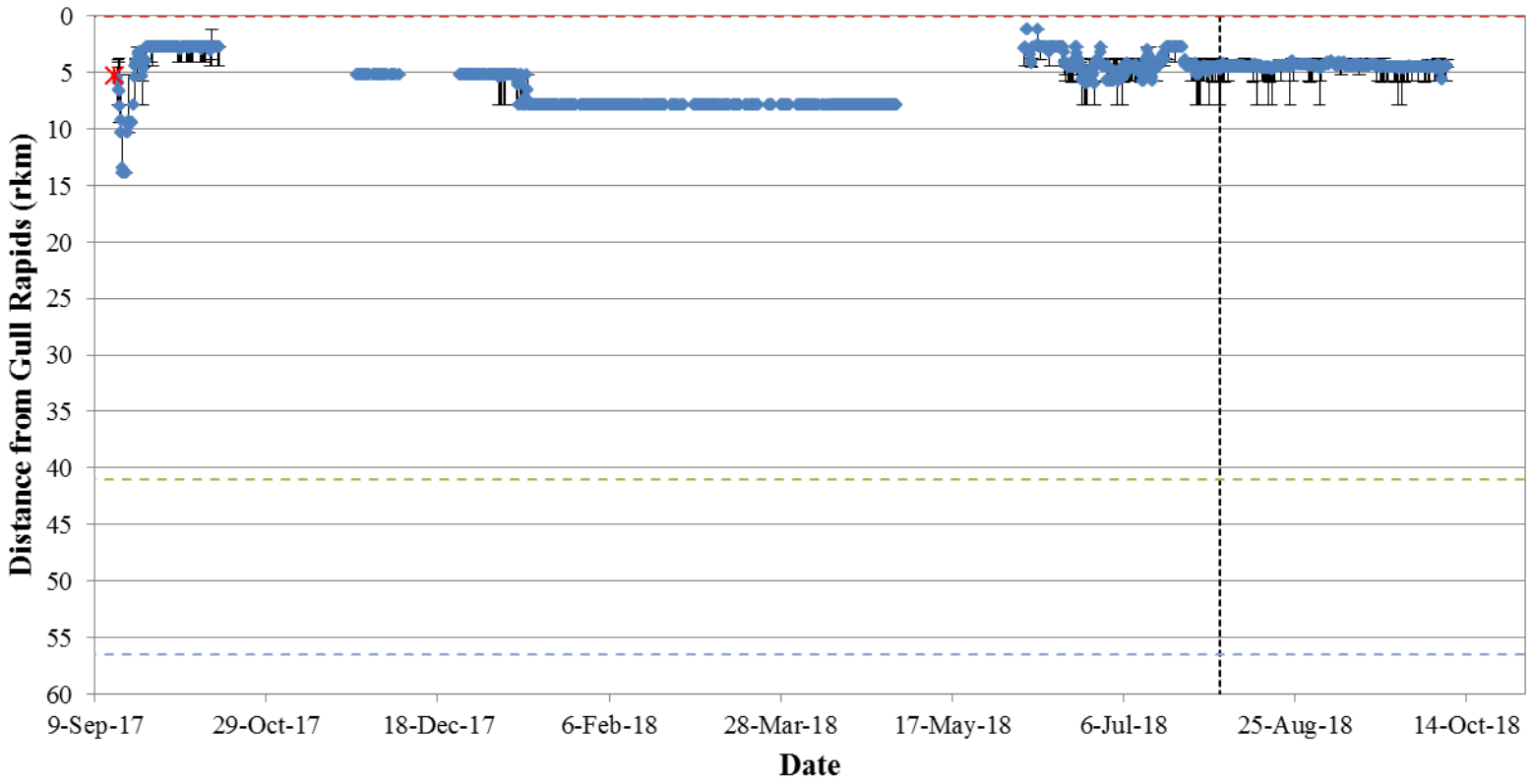


Figure A2-9: Position of a Lake Sturgeon tagged with an acoustic transmitter (code #31696) in Stephens Lake in relation to Gull Rapids (rkm 0), from 9 September, 2017 to 10 October, 2018. Date and location of tagging is indicated in red. Error bars are shown in solid black. Horizontal dashed lines indicate the positions of Gull Rapids (red), Kettle GS (green), and Long Spruce GS (purple). Dashed black vertical line indicates start of spillway operation (Aug 3, 2018).

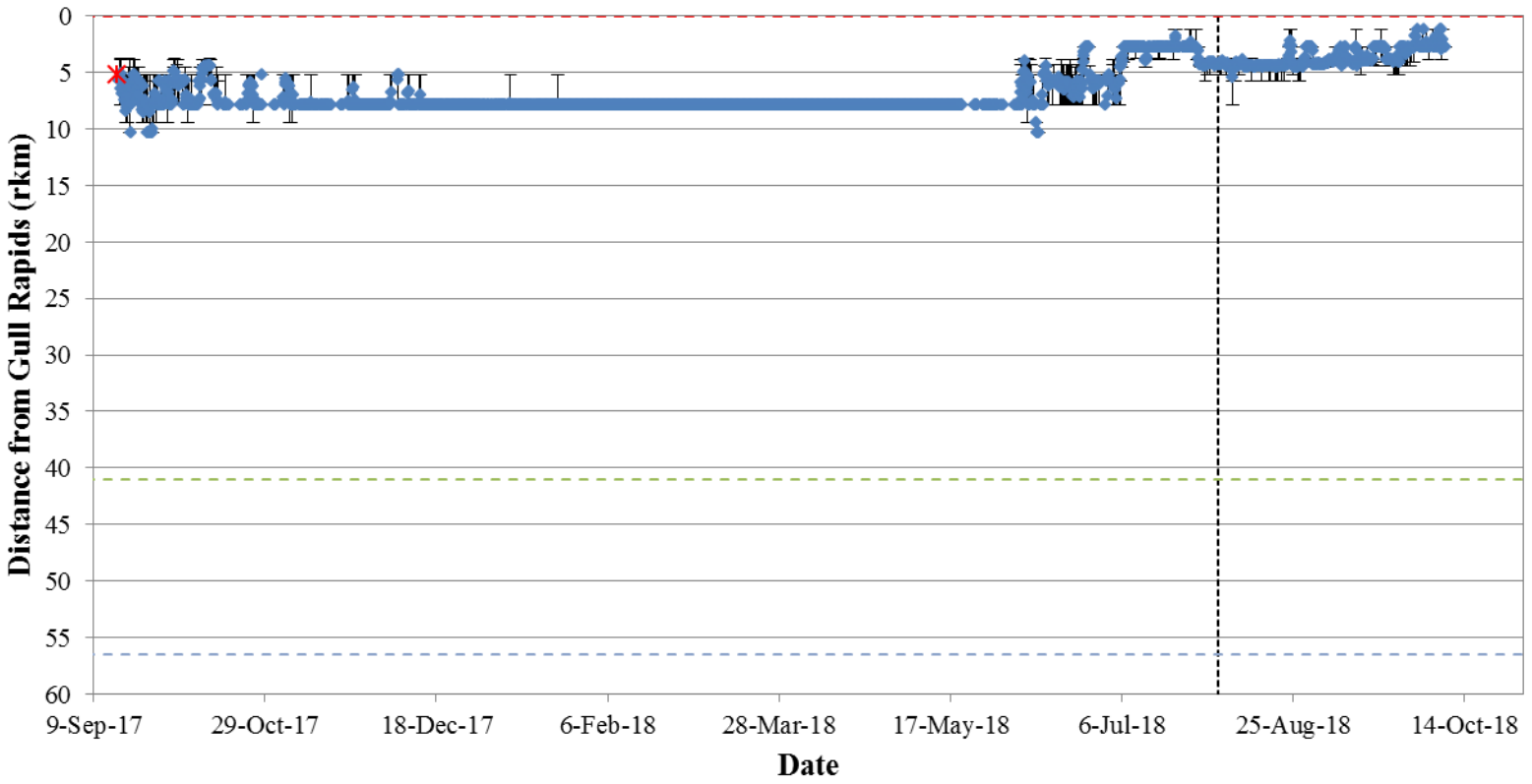


Figure A2-10: Position of a Lake Sturgeon tagged with an acoustic transmitter (code #31697) in Stephens Lake in relation to Gull Rapids (rkm 0), from 9 September, 2017 to 10 October, 2018. Date and location of tagging is indicated in red. Error bars are shown in solid black. Horizontal dashed lines indicate the positions of Gull Rapids (red), Kettle GS (green), and Long Spruce GS (purple). Dashed black vertical line indicates start of spillway operation (Aug 3, 2018).

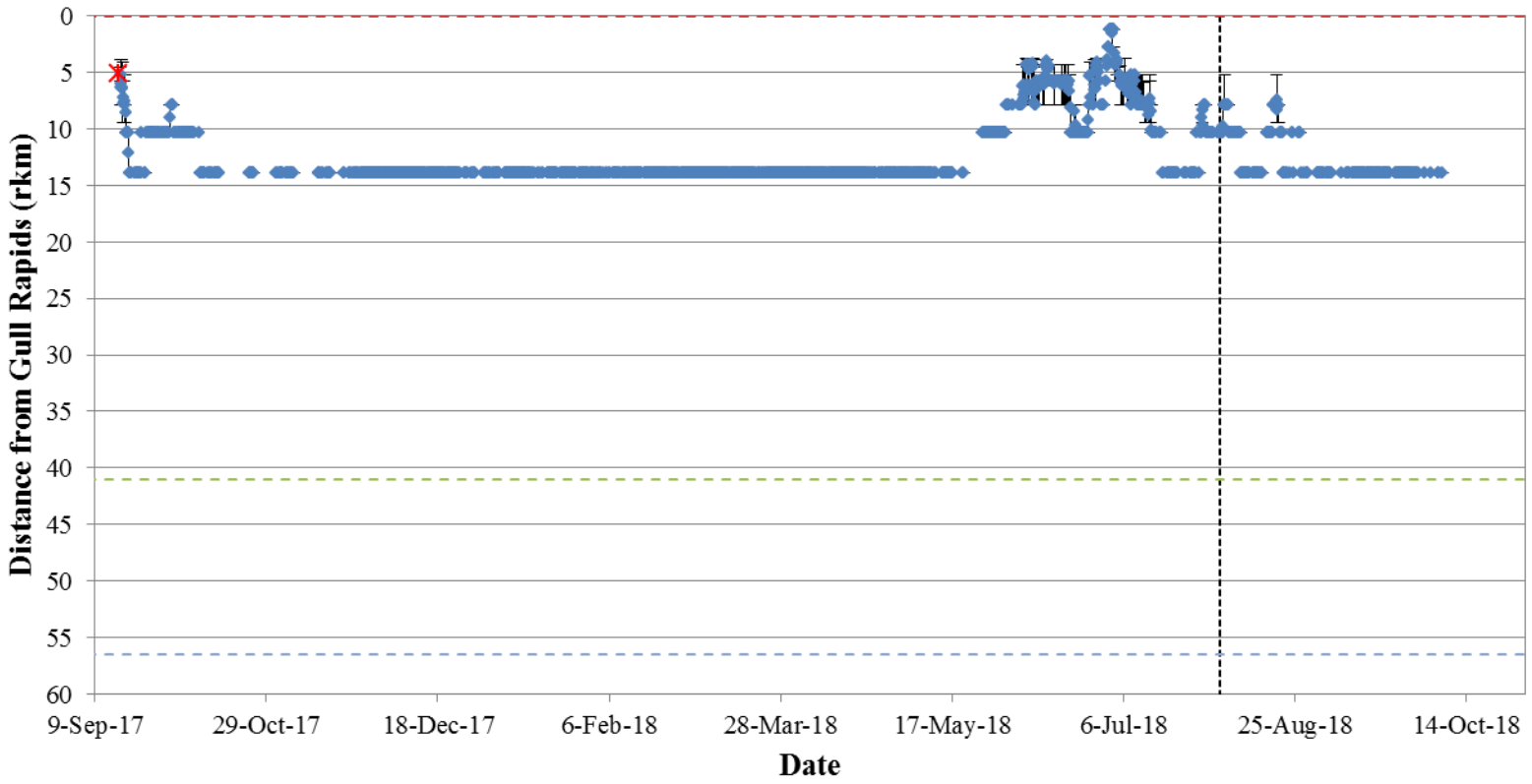


Figure A2-11: Position of a Lake Sturgeon tagged with an acoustic transmitter (code #31758) in Stephens Lake in relation to Gull Rapids (rkm 0), from 9 September, 2017 to 10 October, 2018. Date and location of tagging is indicated in red. Error bars are shown in solid black. Horizontal dashed lines indicate the positions of Gull Rapids (red), Kettle GS (green), and Long Spruce GS (purple). Dashed black vertical line indicates start of spillway operation (Aug 3, 2018).

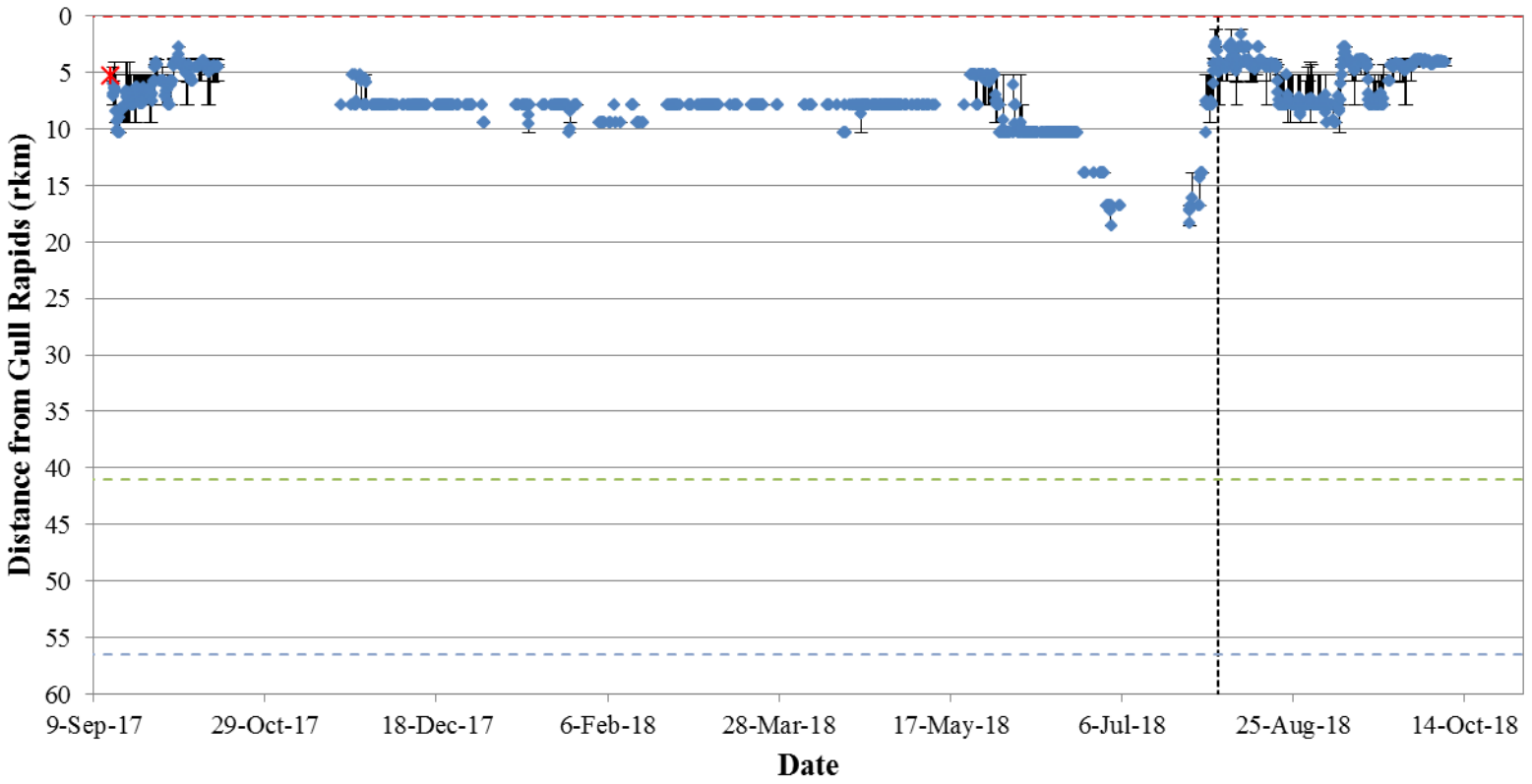


Figure A2-12: Position of a Lake Sturgeon tagged with an acoustic transmitter (code #31759) in Stephens Lake in relation to Gull Rapids (rkm 0), from 9 September, 2017 to 10 October, 2018. Date and location of tagging is indicated in red. Error bars are shown in solid black. Horizontal dashed lines indicate the positions of Gull Rapids (red), Kettle GS (green), and Long Spruce GS (purple). Dashed black vertical line indicates start of spillway operation (Aug 3, 2018).

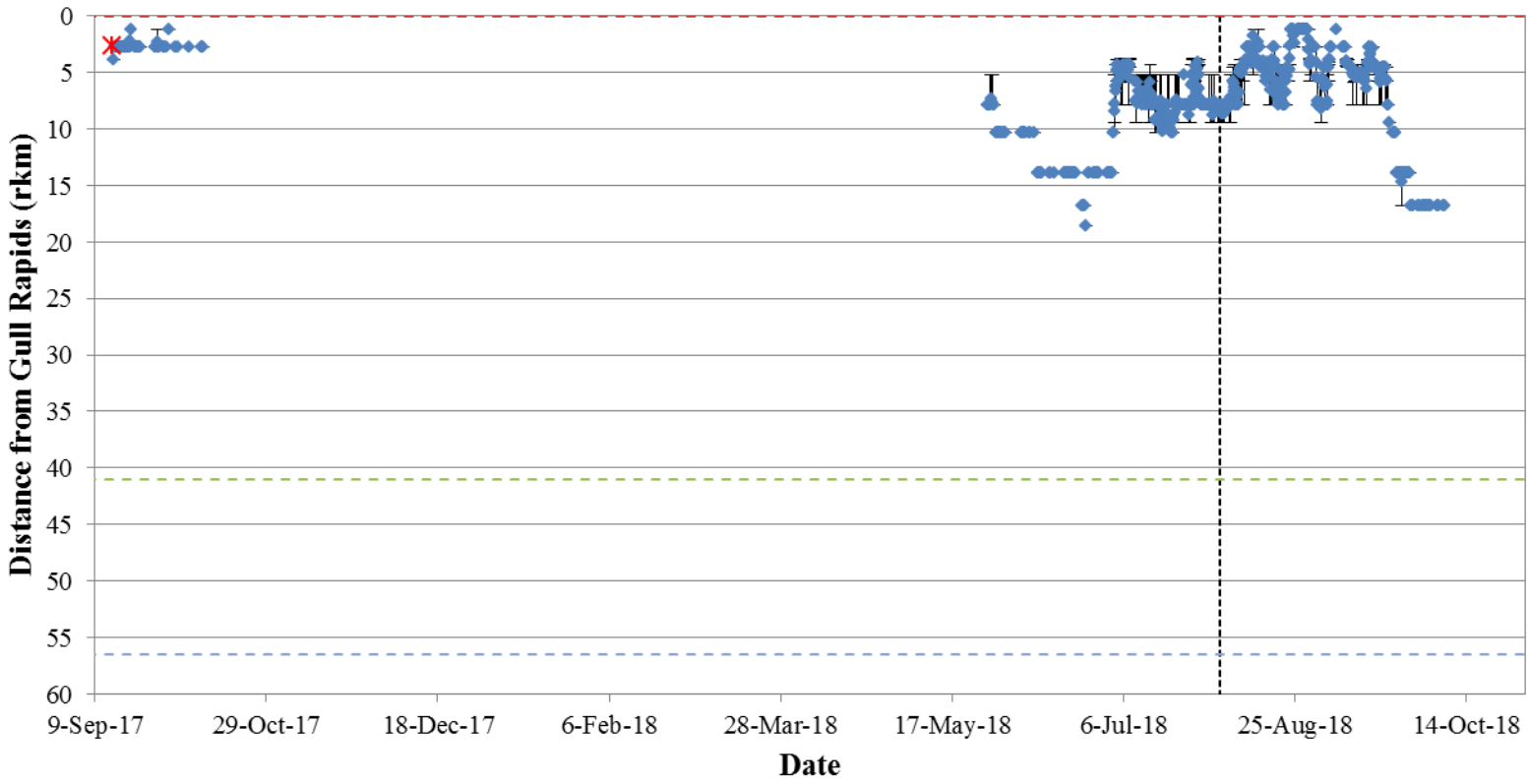


Figure A2-13: Position of a Lake Sturgeon tagged with an acoustic transmitter (code #31760) in Stephens Lake in relation to Gull Rapids (rkm 0), from 9 September, 2017 to 10 October, 2018. Date and location of tagging is indicated in red. Error bars are shown in solid black. Horizontal dashed lines indicate the positions of Gull Rapids (red), Kettle GS (green), and Long Spruce GS (purple). Dashed black vertical line indicates start of spillway operation (Aug 3, 2018).

Figure A2-14: Position of a Lake Sturgeon tagged with an acoustic transmitter (code #31761) in Stephens Lake in relation to Gull Rapids (rkm 0), from 13 September, 2017 to 10 October, 2018. Date and location of tagging is indicated in red. Error bars are shown in solid black. Horizontal dashed lines indicate the positions of Gull Rapids (red), Kettle GS (green), and Long Spruce GS (purple). Dashed black vertical line indicates start of spillway operation (Aug 3, 2018).

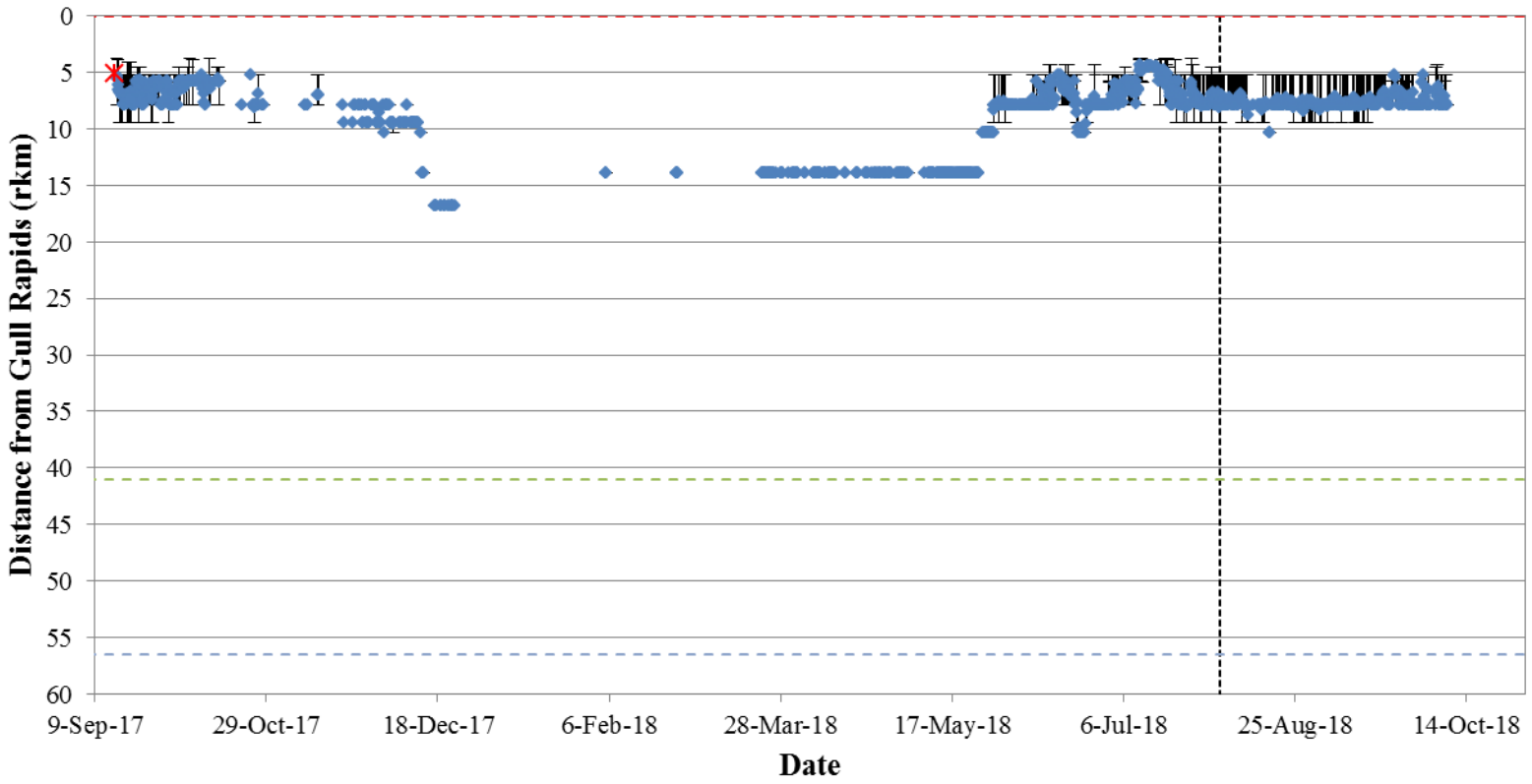


Figure A2-15: Position of a Lake Sturgeon tagged with an acoustic transmitter (code #31762) in Stephens Lake in relation to Gull Rapids (rkm 0), from 9 September, 2017 to 10 October, 2018. Date and location of tagging is indicated in red. Error bars are shown in solid black. Horizontal dashed lines indicate the positions of Gull Rapids (red), Kettle GS (green), and Long Spruce GS (purple). Dashed black vertical line indicates start of spillway operation (Aug 3, 2018).

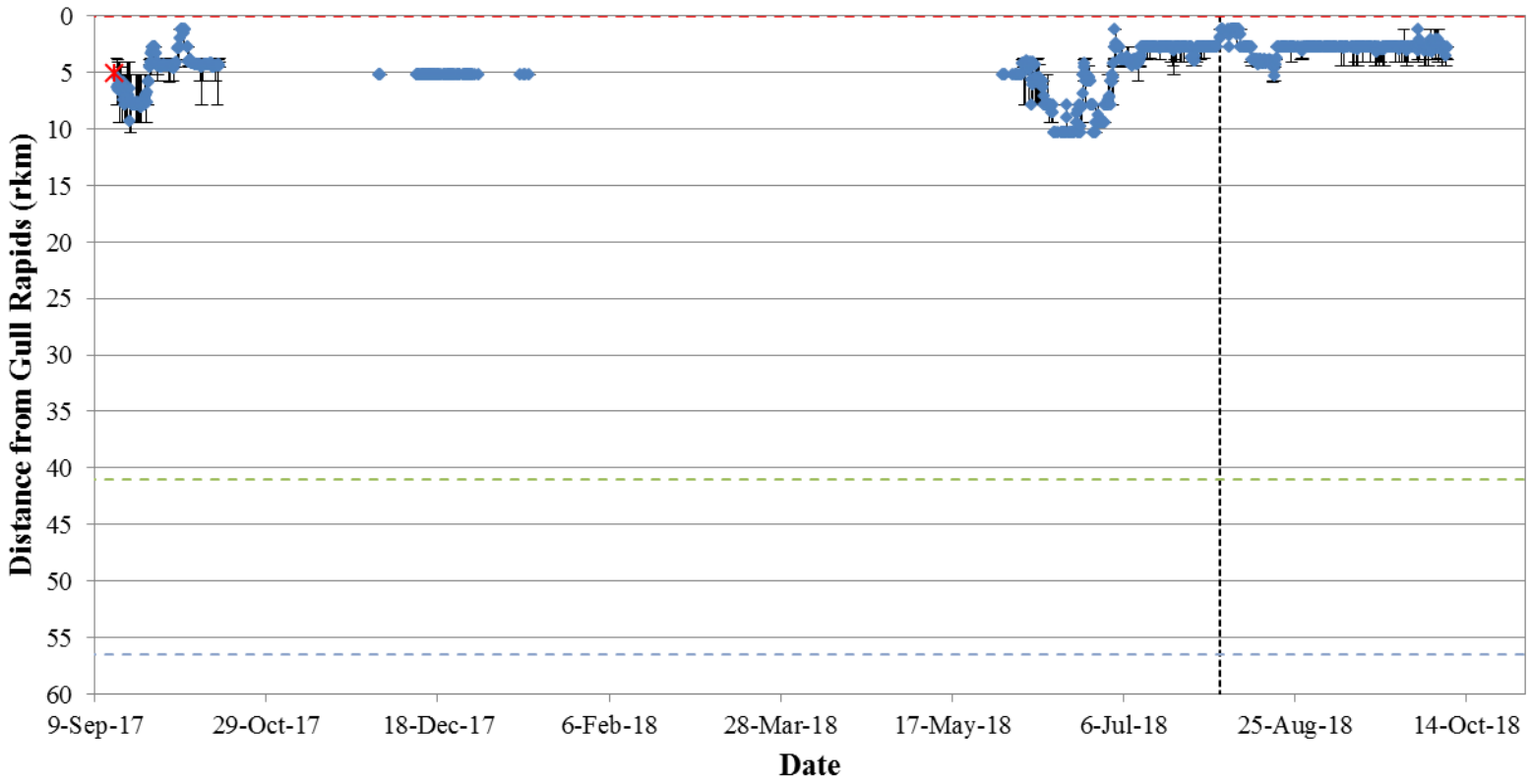


Figure A2-16: Position of a Lake Sturgeon tagged with an acoustic transmitter (code #31763) in Stephens Lake in relation to Gull Rapids (rkm 0), from 9 September, 2017 to 10 October, 2018. Date and location of tagging is indicated in red. Error bars are shown in solid black. Horizontal dashed lines indicate the positions of Gull Rapids (red), Kettle GS (green), and Long Spruce GS (purple). Dashed black vertical line indicates start of spillway operation (Aug 3, 2018).

Figure A2-17: Position of a Lake Sturgeon tagged with an acoustic transmitter (code #31764) in Stephens Lake in relation to Gull Rapids (rkm 0), from 9 September, 2017 to 10 October, 2018. Date and location of tagging is indicated in red. Error bars are shown in solid black. Horizontal dashed lines indicate the positions of Gull Rapids (red), Kettle GS (green), and Long Spruce GS (purple). Dashed black vertical line indicates start of spillway operation (Aug 3, 2018).

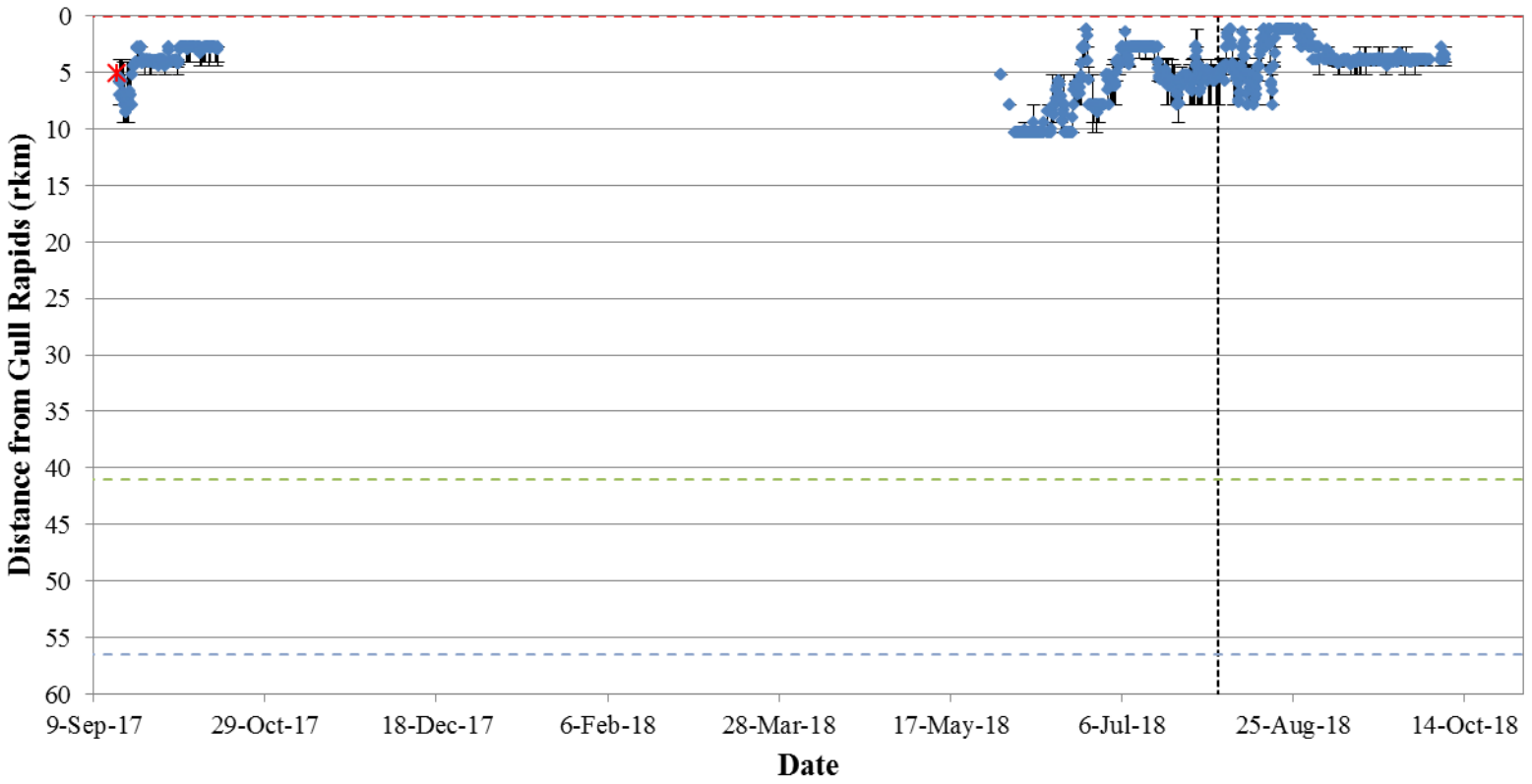


Figure A2-18: Position of a Lake Sturgeon tagged with an acoustic transmitter (code #31765) in Stephens Lake in relation to Gull Rapids (rkm 0), from 9 September, 2017 to 10 October, 2018. Date and location of tagging is indicated in red. Error bars are shown in solid black. Horizontal dashed lines indicate the positions of Gull Rapids (red), Kettle GS (green), and Long Spruce GS (purple). Dashed black vertical line indicates start of spillway operation (Aug 3, 2018).

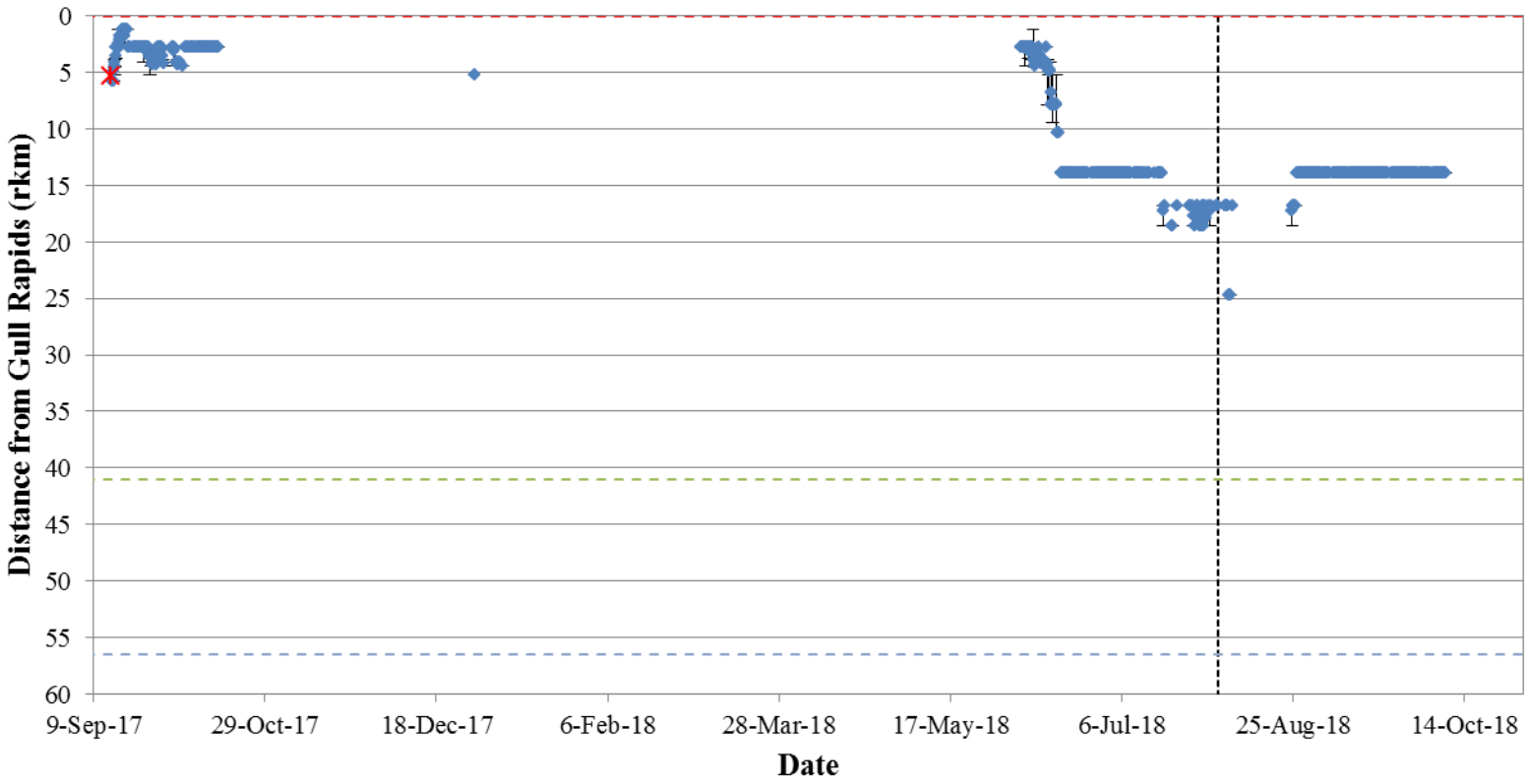


Figure A2-19 Position of a Lake Sturgeon tagged with an acoustic transmitter (code #31766) in Stephens Lake in relation to Gull Rapids (rkm 0), from 9 September, 2017 to 10 October, 2018. Date and location of tagging is indicated in red. Error bars are shown in solid black. Horizontal dashed lines indicate the positions of Gull Rapids (red), Kettle GS (green), and Long Spruce GS (purple). Dashed black vertical line indicates start of spillway operation (Aug 3, 2018).

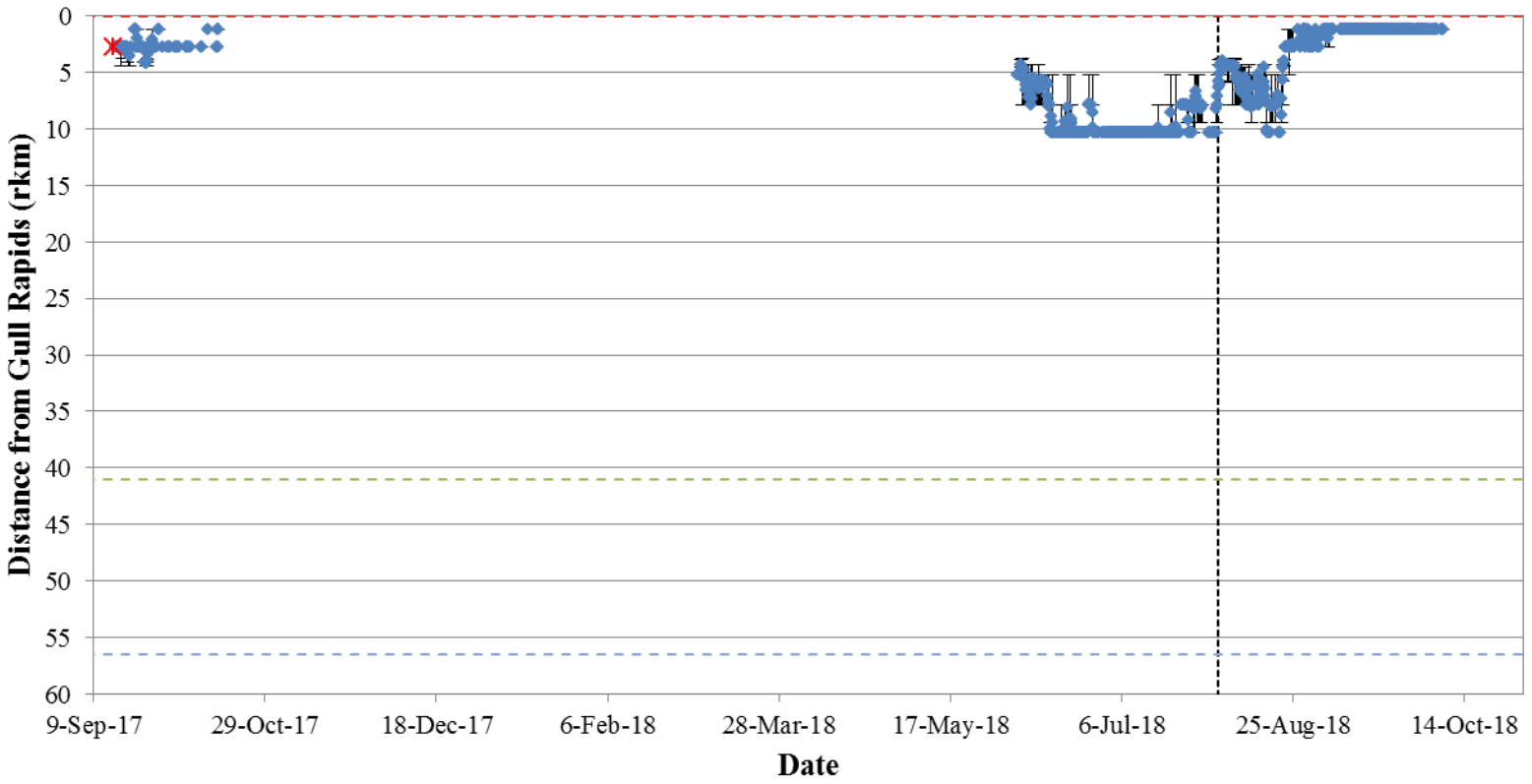


Figure A2-20: Position of a Lake Sturgeon tagged with an acoustic transmitter (code #31767) in Stephens Lake in relation to Gull Rapids (rkm 0), from 9 September, 2017 to 10 October, 2018.Date and location of tagging is indicated in red. Error bars are shown in solid black. Horizontal dashed lines indicate the positions of Gull Rapids (red), Kettle GS (green), and Long Spruce GS (purple). Dashed black vertical line indicates start of spillway operation (Aug 3, 2018).