Keeyask Generation Project

Aquatic Effects Monitoring Plan

Juvenile Lake Sturgeon Movement Monitoring Report

AEMP-2020-02

KEEYASK

Manitoba Conservation and Climate Client File 5550.00
Manitoba Environment Act Licence No. 3107

2019 -2020

KEEYASK GENERATION PROJECT

AQUATIC EFFECTS MONITORING PLAN

REPORT #AEMP-2020-02

JUVENILE LAKE STURGEON MOVEMENT MONITORING IN THE NELSON RIVER BETWEEN CLARK LAKE AND THE LIMESTONE GENERATING STATION, OCTOBER 2018 TO OCTOBER 2019: YEAR 6 CONSTRUCTION

Prepared for

Manitoba Hydro

By

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June 2020

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This report should be cited as follows:

Hrenchuk, C.L. 2020. Juvenile Lake Sturgeon movement monitoring in the Nelson River between Clark Lake and the Limestone Generating Station, October 2018 to October 2019: Year 6 Construction. Keeyask Generation Project Aquatic Effects Monitoring Plan Report #AEMP-2020-02. A report prepared for Manitoba Hydro by North/South Consultants Inc., June 2020. xviii + 97 pp.

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. Almost all work in 2019 was in the dry. The construction activities included the excavation of the tailrace, construction of the tailrace spawning shoal, and completion of the dams and dykes.

Lake Sturgeon was identified as one of the key species for monitoring. They were chosen because they are culturally important to partner First Nations, local sturgeon 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:

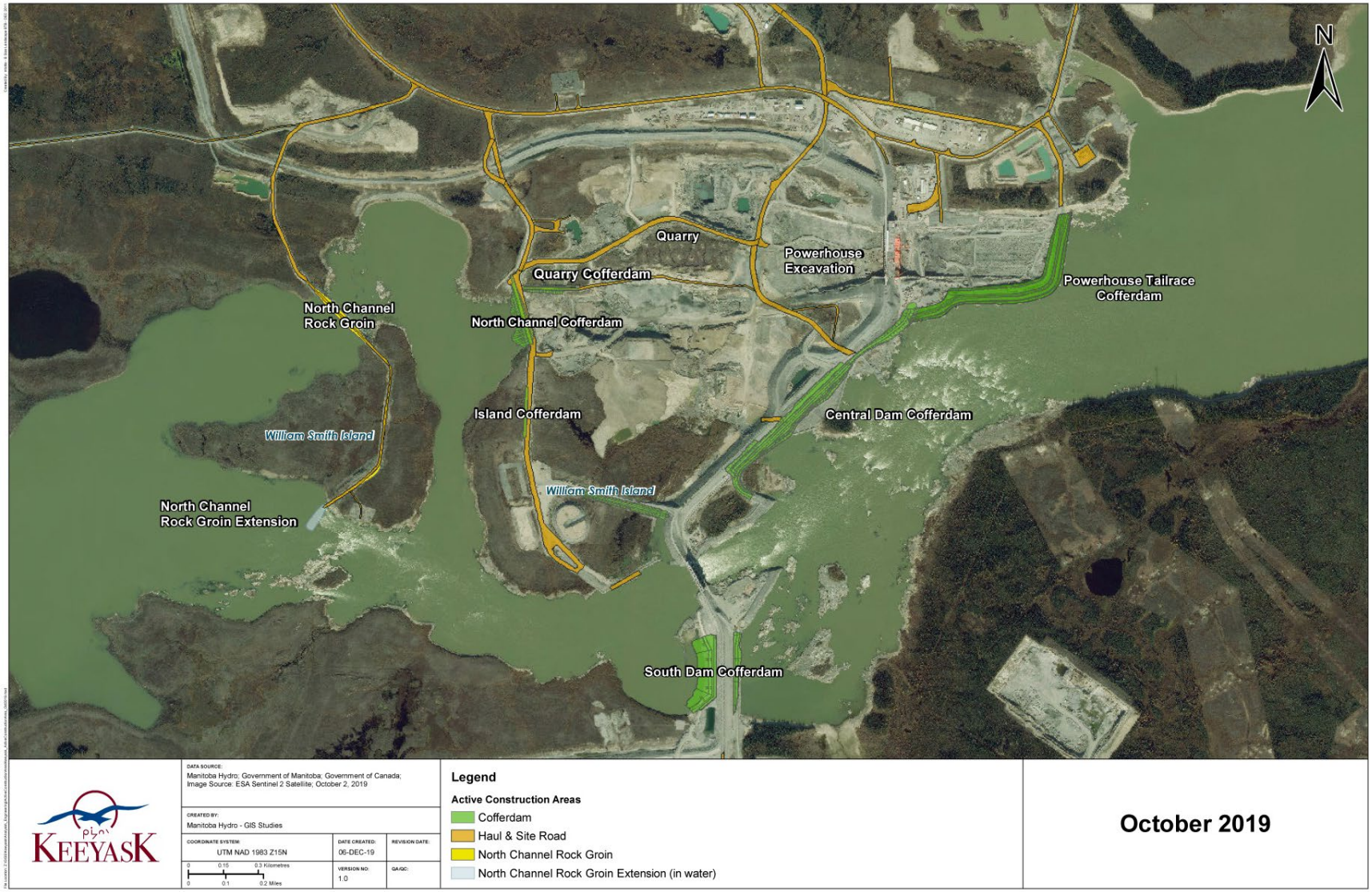
- Estimating the number of adults;
- Estimating the number and growth of juveniles (less than 800 millimetres [mm] in length);
- Identifying spawning locations and numbers of spawning fish; and
- Recording seasonal habitat use and long-distance movements (*i.e.*, over GS's or rapids) through movement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

Movements of juvenile Lake Sturgeon in Stephens Lake were monitored with acoustic transmitters 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 tagged juveniles moved upstream through Gull Rapids or downstream through the Kettle GS.

Monitoring juvenile sturgeon movement using the methodology described in the AEMP began in August 2013. Therefore, movements of juvenile Lake Sturgeon have been monitored for 10.5 months prior to changes to the river (pre-construction), and approximately five years and three months following the start of construction. The original 40 acoustic tags applied in 2013 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 study.

This report provides results of juvenile sturgeon movement monitoring conducted from October 2018 to October 2019.



Map illustrating instream structures at the Keeyask Generating Station site, October 2019.

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 the Keeyask GS during construction and how far are they going?

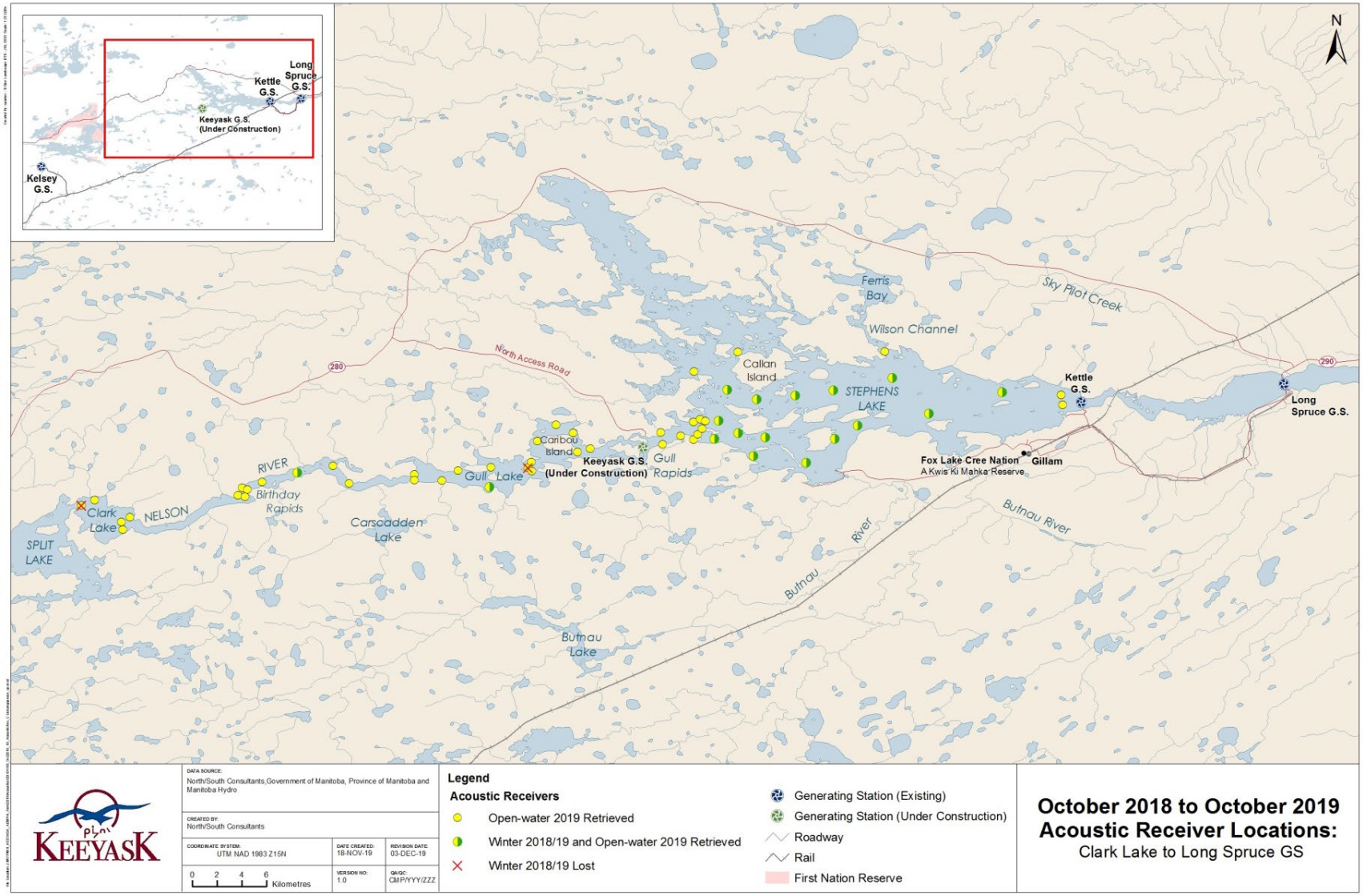
Movement studies tell us how many juvenile sturgeon are moving down through the Keeyask GS, how far they travel up or downstream away from the site, whether they are leaving the Keeyask area completely and when they are making these movements. The distance they travel is monitored as far upstream as 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. Fish are captured by using gillnets and then a tag is surgically implanted inside a fish. Tags are implanted through a small incision which is then closed with sutures. 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 Kettle GS (see study area map below). Access conditions have prevented receivers from being placed in the Long Spruce and Limestone Reservoirs since 2018. Each fish is given a tag that transmits a unique ping which can be detected up to 1 km away from a receiver. Each receiver records the detections and the information on the receivers is downloaded to a computer. 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 (including closing the incision with stitches) 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?

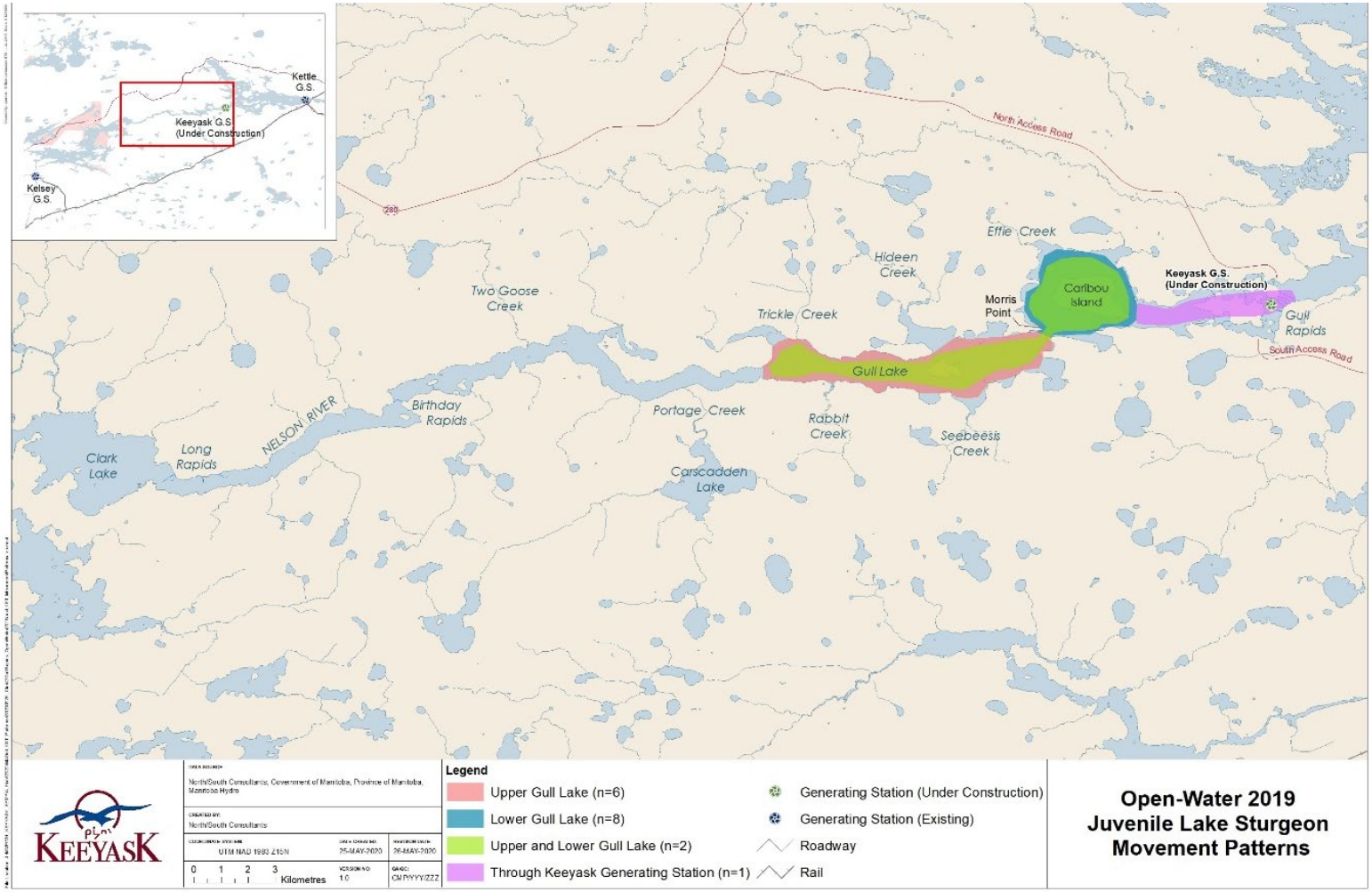
Overall, most juvenile sturgeon do not move very far. Sturgeon in Stephens Lake move farther than those in Gull Lake. This is probably because sturgeon prefer deep-water habitat, and there is more of it in Stephens Lake than in Gull Lake. Juveniles in Gull Lake like to stay in the few deep-water sites 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 the Keeyask GS.

In previous years, juvenile Lake Sturgeon have tended to stay in the area where they were tagged. For fish tagged in 2013, only one fish made a movement upstream out of Gull Lake but returned in the same year. No other movements out of Gull Lake were recorded since 2013 until 2019 when one fish tagged in Gull Lake moved downstream through the Keeyask GS spillway. This fish continued to move in Stephens Lake, showing that it survived the downstream movement.

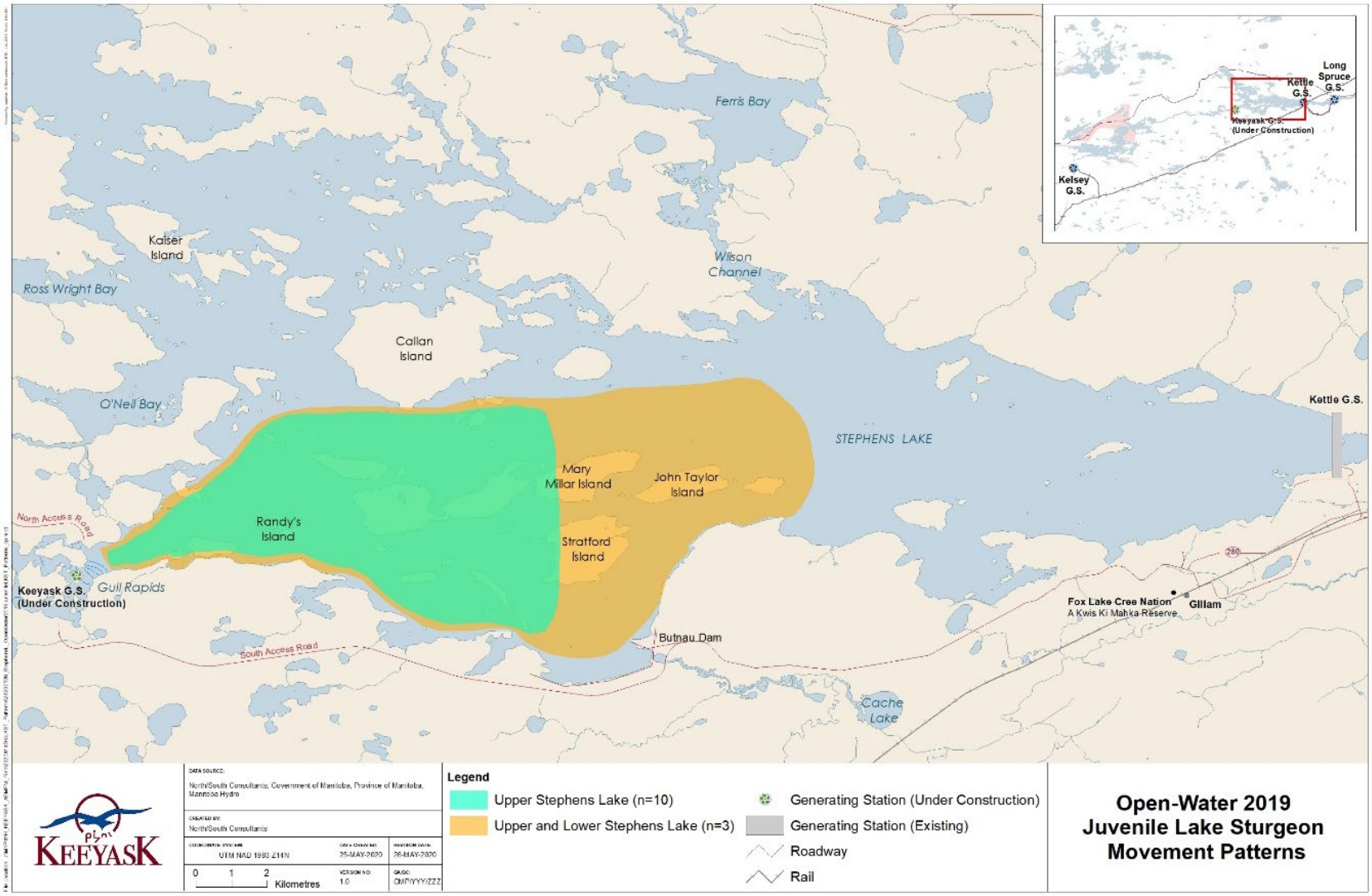
In Stephens Lake, three fish are known to have moved downstream past the Kettle GS since the start of the study: two fish tagged in 2013 moved (one before construction and one after construction), and one fish tagged in 2017, which moved immediately after tagging. It is suspected that seven more fish tagged in 2017 have moved downstream through the Kettle GS because they were last located in lower Stephens Lake and have not been detected again (six in 2017 and one in 2018). These fish may also have been harvested. Low water levels prevented boats from being launched in the Long Spruce or Limestone reservoirs in both 2018 and 2019. Because of this, it is not possible to be certain that these fish moved downstream.

At Keeyask, 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. This is not likely to affect juvenile sturgeon movements, as no juvenile has ever been recorded moving upstream over Gull Rapids. 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.



Map Summarizing movements of juvenile Lake Sturgeon in the Clark Lake to Keeyask Generating Station Area. Shaded areas represent movement patterns of sturgeon (numbers of sturgeon displaying each pattern are in legend).



Map Summarizing movements of adult Lake Sturgeon in the Stephens Lake Area. Shaded areas represent movement patterns of sturgeon (numbers of sturgeon displaying each pattern are in legend).

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, two fish moved downstream through the Keeyask GS (one in 2016 and one in 2017) and seven fish may have left Stephens Lake (six in 2017 and one in 2018), which, if it occurred, differs from what 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 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 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 and the reservoir is impounded (scheduled for fall of 2020). Movement monitoring will continue until 2031.

ACKNOWLEDGEMENTS

We would like to thank Manitoba Hydro for the opportunity and resources to conduct this study.

Leslie Flett, Kelvin Kitchekeesik, Saul Mayham, and Tyler Kitchekeesik of Tataskweyak Cree Nation are thanked for their local expertise and assistance in conducting the field work.

The collection of biological samples described in this report was authorized by Manitoba Agriculture and Resource Development (previously Manitoba Sustainable Development), Fisheries Branch, under terms of the Scientific Collection Permit #18-19.

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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 kilometres (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 generating station (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, 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 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 2018 to October 2019, which is the fifth winter and sixth 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 2019 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 2018), and Lacho and Hrenchuk (2016, 2017, and 2019).

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 the Keeyask GS (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 the Keeyask GS (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 the Keeyask GS 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 the Keeyask GS. 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, now the site of the Keeyask GS, was located approximately 3 km downstream of Caribou Island on the Nelson River (Map 1). Prior to construction, the rapids were approximately 2 km in length, and the river elevation dropped approximately 11 m along the 2 km length. Two large islands and several small islands occurred within the rapids, prior to the river narrowing; these features are within the Project footprint and have now been either dewatered, incorporated into the GS or will be flooded after impoundment (Map 2). A summary of construction activities is provided in Section 2.1.

Just below the Keeyask GS, the Nelson River enters Stephens Lake (Maps 1 and 7). 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. After August 2018, all flow was has been passed through the Keeyask GS spillway (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 the Keeyask GS.

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 6).

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. Almost all work in 2019 was in the dry. The

construction activities included the excavation of the tailrace, construction of the tailrace spawning shoal, and completion of the dams and dykes.

2.2 FLOWS AND WATER LEVELS

From October 2018 to October 2019, calculated Split Lake outflows ranged from about 2,600 to 3,700 m^3/s. However, over most of the period, outflows ranged from approximately 3,000 to 3,500 m^3/s and were near the historical annual median flow of approximately 3,300 m^3/s. Outflow increased from about 2,600 to 3,600 m^3/s from October to December 2018, and then was variable through the remainder of the winter period. Between June and September 2019, the flow generally ranged from 3,300 to 3,500 m^3/s. Flows dropped to about 2,900 m^3/s in early October 2019 before rising again to almost 3,700 m^3/s by the end of the month. Water levels varied in conjunction with flows, ranging from about 153.2–155.0 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 the detection 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 2020a); however, the same array is also used to monitor juvenile Lake Sturgeon (the focus of this report), Walleye (Hrenchuk 2020b), and Lake Whitefish (Hrenchuk 2020c).

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 (now the Keeyask GS) (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 the Keeyask GS (Tables 1 and 2). Sturgeon tagged in September 2017 had fork lengths ranging from 360 to 578 mm (Lacho *et al.* 2018).

Following capture, Lake Sturgeon receiving tags were placed in a 76 L nesting fish tub fitted with an aquarium aerator for transport. All tagging was conducted on shore near the site of capture. Prior to transmitter implantation, Lake Sturgeon were anaesthetized in a solution of clove oil and ethanol, adapted from Anderson et al. (1997). When the Lake Sturgeon became immobile, they were placed in a surgery cradle ventral side up. Because the anesthetic renders a fish unable to ventilate on its own, freshwater was continuously pumped over the gills. A small incision was made through the ventral body wall using a sterilized scalpel. An acoustic transmitter was inserted into the body cavity and the incision was closed with sutures. Lake Sturgeon were monitored in a recovery tank until they were able to maintain equilibrium and had regained their strength. They were released in off-current areas near the original capture site.

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 or 2019 due to low water conditions.

During the first five 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, likely 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 is limited, especially in Gull Lake.

3.1.2.1 WINTER 2018/2019

The stationary acoustic receiver array for the winter 2018/2019 (October 11, 2018, to April 30, 2019) period consisted of 19 receivers. Four were set upstream of the Keeyask GS and 15 throughout Stephens Lake (Maps 3 and 4). Low water levels prevented boat access to the river section between Kettle GS and Long Spruce GS, and therefore, an acoustic receiver could not be set downstream of the Kettle GS during winter 2018/2019. A receiver set in this area in October 2017 has not yet been retrieved, however, it is unlikely that this receiver recorded data during winter 2018/2019 due to a lack of battery life. Other than this receiver, the winter 2018/2019 array did not differ from that used in winter 2017/2018.

3.1.2.2 OPEN-WATER 2019

An array of 57 acoustic receivers was used during the 2019 open-water period (defined as May 1 to October 7, 2019). Twenty-seven were set upstream of the Keeyask GS and 30 were set in Stephens Lake (Maps 5 and 6). The 2019 open-water array differed slightly from the array used in 2018. One receiver (#125101) was set in a new location in Stephens Lake, closer to the construction site, at rkm 0.6 (Map 6).

As in 2018, receivers could not be set in the Long Spruce or Limestone reservoirs during the 2019 open-water period due to low water levels. Receivers will be set in both locations during open-water 2020 provided conditions are suitable.

Receiver "gates" were established in several key areas selected by river morphology (channel restrictions) and habitat characteristics (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 the Keeyask GS (44.0, 34.0, 19.0, and 10.0 rkms upstream of the GS), and two were established in Stephens Lake (4.5 and 40.0 rkms downstream of the GS) (Maps 5 and 6). The area upstream of the Keeyask GS was divided into five zones (Map 5; Zones 1–5), while Stephens Lake was divided into two zones (Map 6; Zones 6 and 7). The Long Spruce Reservoir is referred to as Zone 8 and the Limestone Reservoir as Zone 9; however, monitoring did not occur in these areas in 2019. The location of the "gates" has remained consistent since initiation of the study in 2013.

On October 7, 2019, the majority of receivers were removed and a subset (n = 21) were redeployed to monitor movements during winter 2019/2020.

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 the Keeyask GS representing a distance of 0 rkm. The area located downstream of the Keeyask GS (*i.e.*, Stephens Lake and the Long Spruce Reservoir) were given positive (+) distance values from the GS, 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 the GS 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. The proportion of time that all fish spent within each river zone during each 4-hour interval was plotted and presented as a percentage of the study period. For example, a fish that spent 44% of the time between May 1 and May 31 within Zone 4 means that the fish was detected within Zone 4 for 44% of the 186 4-hour intervals between May 1 and May 31.

Rapid downstream movements observed within two weeks of tagging were classified as caused by tagging mortality or stress. It the fish made a rapid downstream movement within two weeks of tagging followed by upstream and downstream movements, it was classified as tagging stress. If a fish made a rapid downstream movement within two weeks of tagging and was not detected again or did not display upstream movements, it was classified as a tagging mortality. If a fish was not detected for more than one year, it was classified as missing.

4.0 RESULTS

Section 4.1 provides a summary of movements observed between tagging in September 2017 and the end of the 2018 open-water period (October 10, 2018), and Sections 4.2 and 4.3 detail results from winter 2018/19 and open-water 2019. Biological information for fish tagged upstream of the Keeyask GS 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 6 provide maps of receiver locations. Appendices 1 and 2 provide movement summaries for the juvenile Lake Sturgeon tagged in September 2017.

4.1 2017-2018 RESULTS SUMMARY

4.1.1 UPSTREAM OF THE KEEYASK GS

Twenty juvenile Lake Sturgeon were tagged in Gull Lake in September 2017 (Table 1). All juveniles were detected after tagging and none moved downstream through the Keeyask GS. Therefore, there were 20 juvenile Lake Sturgeon available to be detected upstream of the Keeyask GS at the beginning of the winter 2018/2019 season.

4.1.2 STEPHENS LAKE

Twenty juvenile Lake Sturgeon were tagged in Stephens Lake in September 2017 (Table 2). Since that time, one fish moved downstream out of Stephens Lake through the Kettle GS into the Long Spruce Reservoir:

- #31691 moved downstream past the Kettle GS within nine days of tagging in September, 2017 (Appendix A2-4).

An additional five fish are considered missing (*i.e.*, have not been detected for more than a year). It is possible that these fish moved downstream through the Kettle GS.

- #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).
- #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).
- #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). Because no receivers have been set in the Long Spruce Reservoir since open-water 2017, this fish is not discussed further.

Therefore, accounting for the one fish that moved downstream out of Stephens Lake and the five missing fish, 14 juveniles were available to be detected in Stephens Lake at the beginning of the winter 2018/2019 season.

4.2 WINTER 2018/2019

4.2.1 UPSTREAM OF THE KEEYASK GS

The 2018/2019 winter receiver array consisted of four receivers deployed in the Nelson River between Clark Lake and the Keeyask GS at rkms -48.2, -29.4, -12.4, and -10.3 (Figure 1; Map 3). Two of the four acoustic receivers were retrieved; the receivers at rkm -48.2 and -10.3 could not be located and were likely moved by ice (Map 3).

Four of the 20 juvenile Lake Sturgeon (20%) were detected, logging a total of 35,816 detections (range: 2–17,898 detections per individual; Table 5). Juvenile sturgeon were only detected at the receiver set at rkm -12.4 (Figures 3 and 4). Fish were detected for an average of 47 days, or for 23% of the 202 day, winter period (standard deviation [StDev] = 47 days; range: 1–97 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 2018/2019 winter period, between rkms 5.2 and 36.1 (Figure 1; Map 4). All of the 15 receivers were retrieved at the end of the study period.

Eleven of the 14 juveniles (79%) were located during the winter period, logging a total of 131,401 detections (range: 32–51,477 detections per individual; Table 6). Fish were detected for an average of 71 days, or for 35% of the 202 day winter period (StDev = 58 days; range: 2–165 days). The mean detection range was 5.9 rkm (StDev = 8.6 rkm; range = 0.0–30.3 rkm) (Table 6; Figure 5).

The majority of detections were logged in the southern portion of Stephens Lake at rkms 7.9 (n = 72,152; 55%) and 10.3 (n = 36,974; 28%) (Figure 6). Four fish moved into the northern portion of Stephens Lake and were detected at rkms 6.5 (n = 1,737; 1%), 8.4 (n = 9,539; 7%), 13.0 (n = 561; 0.4%), 16.8 (n = 553; 0.4%), and 21.6 (n = 155; 0.1%) (Figure 6).

As in winter 2017/2018, three general patterns of movement were observed:

- Six of the eleven fish (#31694, #31695, #31759, #31762, #31763, and #31765) remained in the upstream portion of Stephens Lake at, or upstream of rkm 10.3, for the entire winter period.
- Three (#31692, #31697, and #31766) were located in areas both upstream and downstream of rkm 10.3.
- Two fish were detected exclusively in lower Stephens Lake.
    - #31758 moved between rkm 10.6 and 13.9.
    - #31760 was detected exclusively at rkm 16.8.

Individual movement graphs can be found in Appendix 2.

4.3 OPEN-WATER 2019

4.3.1 ACOUSTIC RECEIVER RETRIEVAL

All stationary acoustic receivers deployed upstream of the Keeyask GS (n = 27) and in Stephens Lake (n = 30) during the 2019 open-water period were successfully retrieved (Map 6). The receiver array was the same as in 2018; however, an additional receiver was deployed in Stephens Lake 0.6 km downstream of the spillway on the South shore (#125101; Map 6).

4.3.2 UPSTREAM OF THE KEEYASK GS

Seventeen of the 20 juvenile Lake Sturgeon (85%) available for detection upstream of the Keeyask GS were detected during the open-water period (Table 7, Figure 7). These fish were detected between 566 and 67,609 times on 3 to 140 days (2–88%) of the 160 day open-water period (average = 105 days [66%], StDev = 39 days) (Table 7). Average total movement range was 2.6 rkm (StDev = 2.4 rkm; range: 0.0–8.1 rkm; Table 4; Figure 7). Fish were only detected in the two zones closest to the Keeyask GS (Zones 4 and 5); no fish were detected farther upstream than rkm -17.4 (Table 7; Map 5). The majority of detections (n = 482,613; 97%) occurred at receivers between rkms -9.0 and -10.3 (Figure 8).

Two fish (#31776 and #31778) were detected at the receiver closest to the Keeyask GS, at rkm -4.8. One of these two fish (#31778) moved downstream through the Keeyask GS spillway into Stephens Lake. It was detected as far downstream as rkm 9.4 and had a total overall movement range of 18.4 rkm (Figure 7). This represents the first downstream movement since monitoring began in 2013, and is discussed further in section 4.3.2.2.

All three fish that were not detected during open-water 2019 were detected regularly within Gull Lake until the end of open-water 2018:

- #31685 was tagged on September 9, 2017 at rkm -9.3. It was detected exclusively in lower Gull Lake until October 5, 2018, when it was last detected at rkm -9.3 (Appendix A1-3).
- #31687 was tagged on September 9, 2017 at rkm -9.4. It was last detected on August 13, 2018 at rkm -9.3 (Appendix A1-5).
- #31769 was tagged on September 14, 2017 at rkm -11.3. It was last detected in Gull Lake at rkm -9.9 on June 21, 2018 (Appendix A1-7).

A single fish (#31776) was captured during juvenile Lake Sturgeon population monitoring conducted from September 10–20, 2019. Capture details can be found in Burnett and Hrenchuk (2020).

4.3.2.1 PROPORTIONAL DISTRIBUTION

Individual juvenile Lake Sturgeon (not including the one fish that moved downstream through the Keeyask GS) spent slightly more time in the lower basin of Gull Lake (Zone 5) in 2019 (mean = 52%; StDev = 50%) than the upper basin (Zone 4; mean = 48%; StDev = 50%) (Table 3; Figure 9). As in open-water 2018, the proportion of time spent in each zone remained relatively stable during the open-water season, with time spent in Zone 4 slightly increasing in late-July (Figure 10).

4.3.2.2 MOVEMENT PATTERNS

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

- Three (#31771, #31772, and #31782) showed restricted movement ranges, and were only detected between rkm -12.5 and -9.9.
- One (#31770) was detected as far upstream as rkm -12.9.
- One (#31775) moved to rkm -15.0.
- One (#31768) was detected at rkm -17.4.

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

- Four (#31683, #31684, #31779, and #31781) moved between rkm -9.3 and -9.0.
- Three (#31773, #31774, and #31780) moved between rkm -9.3 and rkm -7.4.
- One (#31686) was detected exclusively at rkm -9.3.

Two fish were detected in both zones, but spent the majority of the study period in Zone 4 (Figure 9):

- #31776 moved between rkm -9.9 and the farthest downstream receiver at rkm -4.8.
- #31777 was only detected in Zone 5 at rkm -9.3 at the beginning of the open-water period (until June 12) before moving upstream into Zone 4.

The remaining fish (#31778) moved downstream through the Keeyask GS spillway into Stephens Lake.

- This fish was detected exclusively within Gull Lake (rkm -17.4 and -7.4) since it was tagged on September 12, 2017. It was detected within lower Gull Lake (rkm -9.0 to -4.8) at the beginning of the 2019 open-water period (May 23 to 25).
- It was first detected in Stephens Lake on June 25, and displayed upstream and downstream movements, indicating it survived passage. It was last detected on July 6 at rkm -9.4.
- This fish represents the first downstream movement by a juvenile Lake Sturgeon through Gull Rapids (now the Keeyask GS spillway) since monitoring began in 2013.

4.3.3 STEPHENS LAKE

Thirteen of the 14 juvenile Lake Sturgeon (93%) available for detection in Stephens Lake were located during the 2019 open-water period. These fish were detected between 13,002 and 52,297 times over 101 to 142 days (63–89%) of the 160 day study period (average = 124 days [78%]; StDev = 13 days) (Table 8). The average total movement range was 9.9 rkm (StDev = 4.1 rkm; range: 0.0–15.9 rkm; Table 4; Figure 11). No fish were detected farther upstream than rkm 1.2 or farther downstream than rkm 18.6. The majority of detections were logged by the receiver at rkm 7.9 (16.5%), followed by those at rkms 4.6 (15.8%) and 3.9 (15.2%) (Figure 12).

The single fish (#31692) that was not detected during open-water 2019 was last detected during winter 2018/2019 in lower Stephens Lake. It began moving downstream on November 21, 2018 and was last detected at rkm 36.1 upstream of the Kettle GS on February 22, 2019. It is likely that this fish moved downstream through the Kettle GS.

Two fish (#31759 and #31765) were captured during juvenile Lake Sturgeon population monitoring conducted from September 11–21, 2019. Capture details can be found in Burnett and Hrenchuk (2020).

4.3.3.1 PROPORTIONAL DISTRIBUTION

On average, fish spent more time in Zone 7, farther from the Keeyask GS (average = 59%; StDev = 36%), than in Zone 6 (average: 41%; StDev = 36%) (Table 3; Figure 13). Time spent in Zone 6 increased at the end of August, then remained relatively stable for the remainder of the open-water period (Figure 14). Fish spent an average of 36% of the time in Zone 6 between June 1 and August 26 (StDev =9%) and 50% of the time between August 27 and October 7 (StDev = 3%). This is similar to the pattern observed in 2018.

4.3.3.2 MOVEMENT PATTERNS

Of the 13 fish located during the open-water period, one (#31688) was detected exclusively in Zone 6 (at rkm 1.2). The remaining 12 fish were detected in both Zones 6 and 7.

Two juveniles were detected within the northern portion of Stephens Lake.

- #31697 moved between the southern and northern portions of Stephens Lake throughout the open-water season. It was detected in the northern portion at rkms 6.5 and 9.4 a total of 266 times.
- #31760 moved to rkm 16.5 in the northern portion of the lake at the end of the 2018 open-water period. It remained at this location until June 18, 2019 when it began to move upstream. It was detected in the southern portion of Stephens Lake between rkm 4.6 and 10.3 for the remainder of the 2019 open-water period.

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

- Three (#31758, #31759, and #31762) were detected as far upstream as rkm 2.7 and 3.9, making multiple movements between zones 6 and 7.
- Three (#31696, #31763, and #31765) were detected moving between rkm 1.2 and 10.3.
- #31695 moved between rkm 1.2 and 7.9.
- #31767 was detected between rkm 1.2 and 13.9.
- #31694 made a single downstream movement as far downstream as rkm 16.5 in July, but returned upstream and moved between rkm 4.3 and 10.3 for the remainder of the open-water period.
- #31766 remained in lower Stephens Lake for the majority of the open-water period, moving between rkm 10.3 and 18.6.

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 movements away from the construction area in response to noise and other disturbances, potential stranding of Lake Sturgeon at the construction site, and the loss of habitats due to sedimentation downstream of the Keeyask GS. Monitoring results are being used to identify: key habitats for juvenile Lake Sturgeon; the potential vulnerability of juvenile Lake Sturgeon to activities at the construction site (*e.g.*, stranding during dewatering); and the potential for increased emigration during construction. Acoustic transmitters that were applied in 2013 expired during 2017, thus additional fish were tagged in 2017 to continue movement monitoring during construction and reservoir impoundment.

In Gull Lake, juvenile Lake Sturgeon tagged in 2017 generally exhibit similar movement patterns to the original 20 fish tagged in Gull Lake in 2013. Since inception of the study, juveniles have continued to spend the majority of time near the boundary of Gull Lake that separates the middle and lower basins (Zones 4 and 5) as well as the areas north and west of Caribou Island (Figure 8). Similar to previous years, juveniles did not move upstream out of Gull Lake in 2019; however, a single fish moved downstream through the Keeyask GS spillway. This represents the first observation of a downstream movement out of Gull Lake since the study began in 2013 (discussed in Section 5.2). As was observed in each year of this study, juvenile Lake Sturgeon in Gull Lake continued to occupy small home ranges.

Juveniles tagged in Stephens Lake continued to display larger average movement ranges compared to those in Gull Lake, which has been attributed to the greater amount of continuous deep-water habitat available in this area compared to upstream of the Keeyask GS (McDougall *et al* 2013a, b). No juvenile Lake Sturgeon moved downstream through the Kettle GS in 2019 (discussed in Section 5.2).

5.1 EVALUATION OF METHODOLOGY

The movement patterns and habitat use of juvenile Lake Sturgeon make them an ideal species to study using acoustic telemetry. Since the study was initiated in 2013, the proportion of tagged fish detected, and the number of detections associated with each tagged fish during the open-water period, has remained consistently high 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 in winter without the risk of being moved or damaged by ice. Fish tagged upstream of the Keeyask GS were detected, on average, for 66% of the days within the 160 day 2019 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 78% of the 2019 open-water period (46–75% in previous years).

One additional receiver was added to the array during the 2019 open-water period. A receiver was deployed at rkm 0.6 (in Stephens Lake) in order to monitor movements in close proximity to the Keeyask GS spillway. No juvenile Lake Sturgeon were detected at this receiver. Although juvenile Lake Sturgeon have been consistently detected close to construction (at rkm 1.2) since the study began in 2013, water velocity in the area immediately downstream of the spillway is likely too high for juvenile Lake Sturgeon. This receiver will continue to be deployed as part of the Stephens Lake receiver array.

5.2 KEY QUESTIONS

The key questions 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 movement monitoring began in 2013, juvenile Lake Sturgeon upstream of the Keeyask GS have consistently occupied small home ranges. Only one juvenile Lake Sturgeon (tagged in 2013) moved upstream out of Gull Lake (in 2015); this fish returned downstream in the same year and did not repeat the movement. In May 2019, a single juvenile Lake Sturgeon (tagged in 2017) moved downstream through the Keeyask GS spillway. This represents the first downstream movement since monitoring began. This fish displayed upstream and downstream movement in Stephens Lake, and therefore is known to have survived passage.

In Stephens Lake, juveniles generally exhibit a similar pattern, displaying small movement ranges relative to the amount of available deep-water habitat; however, the level of downstream emigration is higher. The number of juvenile Lake Sturgeon that have moved downstream through the Kettle GS has varied each year. Although fish were only tracked for 10.5 months prior to the onset of construction, one fish moved downstream through Kettle GS during this time (Table 9). In the five years of monitoring since the onset of construction, five fish (including one confirmed and four suspected) known/suspected to have moved downstream through the Kettle GS independent of tagging stress: one in 2016, three in 2017, and one in 2018 (Table 9). It should be noted that the four fish suspected of moving downstream were last in lower Stephens Lake (as far upstream of the Kettle GS as rkm 20) and not recorded again; these fish may also have been natural or harvest mortalities. An additional two fish moved downstream through the Kettle GS in 2017 (one confirmed and one suspected), however, these movements occurred within two weeks of tagging and were attributed to tagging stress.

Overall, the number of juvenile Lake Sturgeon that have moved downstream through Gull Rapids/the Keeyask GS has remained low. The number of fish travelling through (entrained) the Kettle GS (independent of tagging) is higher, however, the number of downstream movements has fluctuated annually with no clear increasing or decreasing pattern. The number of fish entrained each year ranged from zero (in 2013) to one (in 2014) prior to the onset of construction,

and zero (in 2015 and 2019) to three (in 2017) during construction. It is unclear why the number of fish entrained through the Kettle GS was marginally higher in 2017. Coincidentally, a large number of Walleye tagged with acoustic transmitters also emigrated out of Stephens Lake in 2017, which was attributed to record high flows in the area (Hrenchuk and Lacho 2018).

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

Monitoring has consistently shown that juvenile Lake Sturgeon upstream of the Keeyask GS do not spend much time near the construction site. In 2019, detections at the three farthest downstream receivers (rkm 7.4, 5.8, and 4.8) comprised less than 3% 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 near the construction site. In 2019, no juveniles were detected at a receiver placed 0.6 rkm downstream of the Keeyask GS spillway, however, 43% of detected fish were located by a receiver located 1.2 rkm downstream of the Keeyask GS. Because of this, Juveniles in Stephens Lake are likely more susceptible to construction-related effects like increased sedimentation and flow changes due to their proximity to construction.

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 of the Keeyask GS, juveniles are consistently located in the same area year after year. Fish are most frequently located near the boundary of Gull Lake that separates the middle and lower basins (Zones 4 and 5) as well as the areas north and west of Caribou Island. Average movement ranges during the open-water period remain similar each year, ranging from 3.4 rkm (in 2017 and 2019) to 5.2 rkm (in 2016). 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. Average movement ranges during the open-water period have ranged from 9.6 rkm (in 2019) to 12.0 rkm (in 2018).

6.0 SUMMARY AND CONCLUSIONS

- Juveniles (n=40) implanted with acoustic transmitters in 2017 have now been tracked for two years. The original 40 transmitters implanted in 2013 are no longer active.
- Juvenile Lake Sturgeon continue to be tracked effectively using acoustic telemetry. More fish went undetected in open-water 2019 (15% upstream of the Keeyask GS and 32% in Stephens Lake) than in previous years (0% of fish from 2013–2016 and 20% in 2017 when tags were likely starting to expire). However, the fish that were detected were located for the majority of the 2019 open-water period (66% upstream of the Keeyask GS and 78% in Stephens Lake).
- 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?*

      Overall, the number of juvenile Lake Sturgeon that have moved downstream through Gull Rapids/the Keeyask GS has remained low, with the first downstream movement recorded in 2019. The number of fish entrained through the Kettle GS (independent of tagging stress) is higher, however, the number of downstream movements has fluctuated annually with no clear increasing or decreasing pattern. The number of fish entrained each year ranged from zero (in 2013) to one (in 2014) prior to the onset of construction, and zero (in 2015 and 2019) to three (in 2017) during construction. It is unclear why the number of fish entrained through the Kettle GS was marginally higher in 2017. A large number of Walleye tagged with acoustic transmitters also emigrated out of Stephens Lake in 2017, which was attributed to record high flows in the area (Hrenchuk and Lacho 2018).
    - *Are juvenile Lake Sturgeon using habitat in the immediate vicinity of the construction site?*

      Juvenile Lake Sturgeon upstream of the Keeyask GS have consistently spent little time near 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. However, no juvenile Lake Sturgeon were detected by a receiver placed 0.6 rkm downstream of the Keeyask GS spillway in 2019.
    - *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 at the same receivers year after year, both upstream and downstream of the Keeyask GS.

- The acoustic tags that were originally implanted in 2013 have expired, while the 40 tags implanted in 2017 will last until 2021. Movements will continue to be monitored through GS construction, impoundment, and operation.

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TABLES

Table 1: Acoustic-tag and biological information for each juvenile Lake Sturgeon tagged with an acoustic transmitter in the Nelson River upstream of the Keeyask GS, fall 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-tag and biological information for each juvenile Lake Sturgeon tagged with an acoustic transmitter in Stephens Lake, fall 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 (now the Keeyask GS) 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), 2018 (June 6 to October 10), and 2019 (June 2 to October 7) open-water periods.

Year Tagged	Study Year	Upstream of Gull Rapids[1]					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
	2019	0.0	0.0	0.0	47.6	52.4	40.7	59.3

1. Beginning in 2019, Gull Rapids is referred to as the Keeyask GS.

Table 4: Movement range (km) of juvenile Lake Sturgeon implanted with acoustic transmitters, including standard deviation (StDev), minimum (Min), and maximum (Max) distance upstream of Gull Rapids (now the Keeyask GS) and in Stephens Lake during the 2014–2019 open-water periods.

Year Tagged	Study Year	Upstream of Gull Rapids[1]					Stephens Lake				
		n[2]	Average	StDev	Min	Max	n	Average	StDev	Min	Max
2013	2014	20	4.1	2.9	0.0	10	18	11.1	5.4	2.6	19.7
	2015	19	5.1	4.5	0.3	17.5	18	11.2	5.9	0.0	19.7
	2016	19	5.2	3.9	0.0	13.7	17	11.6	6.6	0.0	22.3
	2017	18	3.4	3.3	0.3	10.0	13	11.7	4.4	6.5	17.4
2017	2018	20	4.1	3.5	0.3	12.1	14	12.0	5.7	1.2	23.5
	2019	16	2.6	2.4	0.0	8.1	13	9.6	4.1	0.0	15.9

1. Beginning in 2019, Gull Rapids is referred to as the Keeyask GS.
2. Number of fish detected.

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 the Keeyask GS during the 2017/2018 (October 17, 2017 to April 30, 2018) and 2018/2019 (October 11, 2018 to April 30, 2019) winter periods.

Tag ID	Date tagged	2017/2018					2018/2019				
		n	# Days	Furthest U/S (rkm)	Furthest D/S (rkm)	Range (rkm)	n	# Days	Furthest U/S (rkm)	Furthest D/S (rkm)	Range (rkm)
31683	12-Sep-17	-	-	-	-	-	-	-	-	-	-
31684	9-Sep-17	-	-	-	-	-	-	-	-	-	-
31685	9-Sep-17	-	-	-	-	-	-	-	-	-	-
31686	9-Sep-17	-	-	-	-	-	-	-	-	-	-
31687	9-Sep-17	-	-	-	-	-	-	-	-	-	-
31768	14-Sep-17	5506	35	-12.4	-10.3	2.1	2	1	-12.4	-12.4	0.0
31769	14-Sep-17	37229	117	-10.3	-10.3	0.0	-	-	-	-	-
31770	14-Sep-17	7414	54	-12.4	-10.3	2.1	17898	76	-12.4	-12.4	0.0
31771	14-Sep-17	14272	61	-12.4	-10.3	2.1	33	12	-12.4	-12.4	0.0
31772	15-Sep-17	34442	111	-10.3	-10.3	0.0	-	-	-	-	-
31773	12-Sep-17	-	-	-	-	-	-	-	-	-	-
31774	12-Sep-17	-	-	-	-	-	-	-	-	-	-
31775	13-Sep-17	1045	29	-12.4	-12.4	0.0	17883	97	-12.4	-12.4	0.0
31776	13-Sep-17	108	22	-12.4	-10.3	2.1	-	-	-	-	-
31777	13-Sep-17	30754	98	-10.3	-10.3	0.0	-	-	-	-	-
31778	12-Sep-17	-	-	-	-	-	-	-	-	-	-
31779	12-Sep-17	-	-	-	-	-	-	-	-	-	-
31780	12-Sep-17	-	-	-	-	-	-	-	-	-	-
31781	12-Sep-17	-	-	-	-	-	-	-	-	-	-
31782	12-Sep-17	-	-	-	-	-	-	-	-	-	-

Table 1: 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 2017/2018 (October 17, 2017 to April 30, 2018) and 2018/2019 (October 11, 2018 to April 30, 2019) winter periods. Tag id highlighted yellow = lost tags. Tag id highlighted red = moved downstream through Kettle GS.

Tag ID	Date tagged	2017/2018					2018/2019				
		n	# Days	Furthest U/S (rkm)	Furthest D/S (rkm)	Range (rkm)	n	# Days	Furthest U/S (rkm)	Furthest D/S (rkm)	Range (rkm)
31688	16-Sep-17	-	-	-	-	-	-	-	-	-	-
31689	15-Sep-17	1301	12	6.5	21.6	15.1	-	-	-	-	-
31690	14-Sep-17	1303	6	6.5	24.7	18.2	-	-	-	-	-
31691	14-Sep-17	-	-	-	-	-	-	-	-	-	-
31692	14-Sep-17	9	3	7.9	7.9	0.0	1338	29	5.8	36.1	30.3
31693	13-Sep-17	1726	30	5.2	24.7	19.5	-	-	-	-	-
31694	14-Sep-17	-	-	-	-	-	51477	165	5.2	10.3	5.1
31695	15-Sep-17	7	2	7.9	7.9	0.0	5887	78	5.8	8.4	2.6
31696	15-Sep-17	25955	133	5.2	7.9	2.7	-	-	-	-	-
31697	16-Sep-17	65106	187	5.2	9.4	4.2	9831	99	5.8	13	7.2
31758	16-Sep-17	35901	171	13.9	13.9	0.0	1260	40	10.6	13.9	3.3
31759	14-Sep-17	7747	100	5.2	10.3	5.1	16397	130	5.2	7.9	2.7
31760	14-Sep-17	-	-	-	-	-	101	8	16.8	16.8	0.0
31761	13-Sep-17	-	-	-	-	-	-	-	-	-	-
31762	15-Sep-17	3135	70	5.2	16.8	11.6	29754	140	5.2	10.3	5.1
31763	15-Sep-17	2604	24	5.2	5.2	0.0	32	2	5.2	5.2	0.0
31764	14-Sep-17	3526	32	5.2	24.7	19.5	-	-	-	-	-
31765	16-Sep-17	-	-	-	-	-	53	5	5.8	5.8	0.0
31766	14-Sep-17	22	1	5.2	5.2	0.0	15271	88	5.2	13.9	8.7
31767	15-Sep-17	-	-	-	-	-	-	-	-	-	-

Table 2: 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 tagged and monitored upstream of Keeyask GS during the open-water 2017 (May 1 to October 16), 2018 (May 1 to October 10), and 2019 (May 1 to October 7) periods. Tag id highlighted purple = moved downstream through Gull Rapids/the Keeyask GS.

Tag ID	Date tagged	2017					2018					2019				
		n	# Days	U/S (rkm)	D/S (rkm)	Range (rkm)	n	# Days	U/S (rkm)	D/S (rkm)	Range (rkm)	n	# Days	U/S (rkm)	D/S (rkm)	Range (rkm)
31683	12-Sep-17	4718	33	-9.3	-7.4	1.9	31943	133	-9.3	-9	0.3	40792	136	-9.3	-9.0	0.3
31684	9-Sep-17	5706	34	-9.3	-7.4	1.9	36007	109	-9.9	-4.8	5.1	28126	125	-9.3	-9.0	0.3
31685	9-Sep-17	12846	35	-9.3	-7.4	1.9	4022	38	-9.9	-9	0.9	-	-	-	-	-
31686	9-Sep-17	9918	34	-9.3	-9	0.3	40702	107	-9.9	-9	0.9	38228	128	-9.3	-9.3	0.0
31687	9-Sep-17	9880	32	-9.3	-9	0.3	10221	49	-9.3	-5.8	3.5	-	-	-	-	-
31768	14-Sep-17	1050	14	-10.1	-9.9	0.2	27068	130	-17.4	-9.9	7.5	31550	120	-17.4	-9.9	7.5
31769	14-Sep-17	18816	28	-10.1	-10	0.6	16493	34	-10.3	-9.9	0.4	-	-	-	-	-
31770	14-Sep-17	17899	31	-10.1	-9.5	0.6	5455	87	-17.4	-9.9	7.5	4929	58	-12.9	-9.9	3.0
31771	14-Sep-17	13740	31	-10.1	-9.5	0.6	78420	141	-10.3	-9.9	0.4	36862	115	-12.5	-9.9	2.6
31772	15-Sep-17	9198	30	-10.1	-9.5	0.6	78858	137	-15	-9.9	5.1	67609	140	-12.5	-9.9	2.6
31773	12-Sep-17	5954	32	-9.3	-7.4	1.9	24849	108	-19.5	-7.4	12.1	16674	114	-9.3	-7.4	1.9
31774	12-Sep-17	8289	33	-9	-7.4	1.6	42167	134	-9.3	-7.4	1.9	22305	106	-9.3	-7.4	1.9
31775	13-Sep-17	8804	17	-10.1	-9.5	0.6	2681	27	-17.4	-9.9	7.5	2859	62	-15.0	-9.9	5.1
31776	13-Sep-17	14995	31	-10.1	-9.5	0.6	49473	131	-15	-9.9	5.1	29508	105	-12.9	-4.8	8.1
31777	13-Sep-17	18412	31	-10.1	-9.5	0.6	29917	98	-12.9	-9.9	3.0	39441	131	-10.2	-9.3	0.9
31778	12-Sep-17	12574	33	-9.3	-9	0.3	42749	119	-17.4	-7.4	10.0	566	3	-9.0	9.4	18.4
31779	12-Sep-17	11059	33	-9.3	-7.4	1.9	47302	133	-9.3	-7.4	1.9	47534	135	-9.3	-9.0	0.3
31780	12-Sep-17	5304	30	-9	-7.4	1.6	33306	132	-9.3	-7.4	1.9	38052	137	-9.3	-7.4	1.9
31781	12-Sep-17	10304	33	-9.3	-7.4	1.9	173	13	-5.8	-4.8	1.0	5945	43	-9.3	-9.0	0.3
31782	12-Sep-17	13002	33	-9.3	-9	0.3	42404	119	-12.9	-7.4	5.5	44580	126	-12.5	-9.9	2.6

Table 3: 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 tagged and monitored in Stephens Lake during the open-water 2017 (May 1 to October 16), 2018 (May 1 to October 10), and 2019 (May 1 to October 7) periods. Tag id highlighted yellow = lost tags. Tag id highlighted red = moved downstream through Kettle GS.

Tag ID	Date tagged	Fork length (mm)	Weight (g)	2017					2018					2019				
				n	# Days	U/S (rkm)	D/S (rkm)	Range (rkm)	N	# Days	U/S (rkm)	D/S (rkm)	Range (rkm)	n	# Days	U/S (rkm)	D/S (rkm)	Range (rkm)
31688	28-May-16	510	1500	30	1	2.7	7.9	5.2	27068	74	1.2	2.7	1.5	27193	117	1.2	1.2	0.0
31689	28-May-16	433	1050	30	1	1.2	13.9	12.7	-	-	-	-	-	-	-	-	-	-
31690	27-May-16	480	1200	32	1	1.2	7.9	6.7	-	-	-	-	-	-	-	-	-	-
31691	27-May-16	412	800	7	0	4.1	42.7	38.6	-	-	-	-	-	-	-	-	-	-
31692	28-May-16	486	-	32	1	1.2	13.9	12.7	17702	100	1.2	18.6	17.4	-	-	-	-	-
31693	28-May-16	507	1650	33	1	3.8	9.4	5.6	-	-	-	-	-	-	-	-	-	-
31694	28-May-16	375	560	32	1	3.8	9.4	5.6	13155	81	2.7	18.6	15.9	15913	124	4.3	16.5	12.2
31695	28-May-16	491	1700	31	1	2.7	7.9	5.2	47506	123	1.2	7.9	6.7	52297	140	1.2	7.9	6.7
31696	28-May-16	442	950	31	1	1.2	13.9	12.7	43099	154	1.2	10.3	9.1	43128	127	1.2	10.3	9.1
31697	28-May-16	530	1825	30	1	3.8	10.3	6.5	97400	153	1.2	10.3	9.1	22941	130	2.7	13.0	10.3
31758	30-May-16	322	500	28	1	3.8	13.9	10.1	18719	141	1.2	13.9	12.7	30068	119	2.7	13.9	11.2
31759	30-May-16	460	1325	32	1	2.7	10.3	7.6	37102	126	1.2	18.6	17.4	29872	137	2.7	13.9	11.2
31760	30-May-16	374	600	17	1	1.2	3.8	2.6	25510	119	1.2	18.6	17.4	17664	117	3.9	18.6	14.7
31761	30-May-16	398	900	6	0	4.3	40.9	36.6	-	-	-	-	-	-	-	-	-	-
31762	29-May-16	508	1625	30	1	3.8	9.4	5.6	39066	154	3.8	13.9	10.1	50261	142	3.9	10.3	6.4
31763	31-May-16	522	1875	31	1	1.2	10.3	9.1	25869	130	1.2	10.3	9.1	32315	131	1.2	10.3	9.1
31764	31-May-16	480	1300	32	1	3.8	10.3	6.5	-	-	-	-	-	-	-	-	-	-
31765	31-May-16	482	1400	30	1	2.7	9.4	6.7	35362	125	1.2	10.3	9.1	26941	101	1.2	10.3	9.1
31766	30-May-16	404	975	31	1	1.2	5.8	4.6	16440	104	1.2	24.7	23.5	13002	104	2.7	18.6	15.9
31767	30-May-16	452	1250	24	1	1.2	4.4	3.2	30261	123	1.2	10.3	9.1	22366	124	1.2	13.9	12.7

Table 9: Number and proportion of tagged juvenile Lake Sturgeon that have moved downstream through Gull Rapids (now the Keeyask GS) and the Kettle GS each year since studies began in 2013. The total number of movements, the proportion of movements suspected to have occurred due to tagging stress or mortality (*i.e.*, within two weeks of tagging), and the adjusted number of movements interpreted to have occurred outside of tagging stress (*i.e.*, total movements minus movements due to stress) are provided. Grey highlighting indicates movements that occurred prior to the onset of construction.

Year	Gull Rapids/Keeyask GS									Kettle GS								
	Total Movements[1]			Tagging Stress/Mortality[2]			Other[3]			Total Movements[1]			Tagging Stress/Mortality[2]			Other[3]		
	Total Fish	Total Move	%[4]	# Fish Tagged	Total Move	%[5]	Total Fish	Total Move	%[4]	Total Fish[6]	Total Move	%	# Fish Tagged	Total Move	%[4]	Total Fish	Total Move	%
2013	20	0	0	20	0	0	20	0	0	20	0	0	20	0	0	20	0	0
2014	19	0	0	0	-	-	19	0	0	19	1	5	0	-	-	19	1	5
2015	19	0	0	0	-	-	19	0	0	18	0	0	0	-	-	18	0	0
2016	19	0	0	0	-	-	19	0	0	18	1	6	0	-	-	18	1	6
2017	19	0	0	20	0	0	19	0	0	17	5	14	20	2	10	17	3	8
2018	20	0	0	0	-	-	20	0	0	19	1	5	0	-	-	19	1	5
2019	20	1	5	0	-	-	20	1	5	15	0	0	0	-	-	15	0	0

1. Includes all downstream movements, including those that are interpreted to have occurred due to tagging stress and mortality.
2. Includes only juvenile Lake Sturgeon that moved downstream within two weeks of tagging. These movements are likely caused by tagging stress or mortality
3. Does not include fish interpreted to have moved downstream due to tagging stress or mortality.
4. Proportion is calculated as a percentage of the total number of fish available for detection in the current year.
5. Proportion is calculated as a percentage of those tagged in the current year.

6. Includes all fish tagged in Stephens Lake as well as those that moved downstream from Gull Lake.

FIGURES

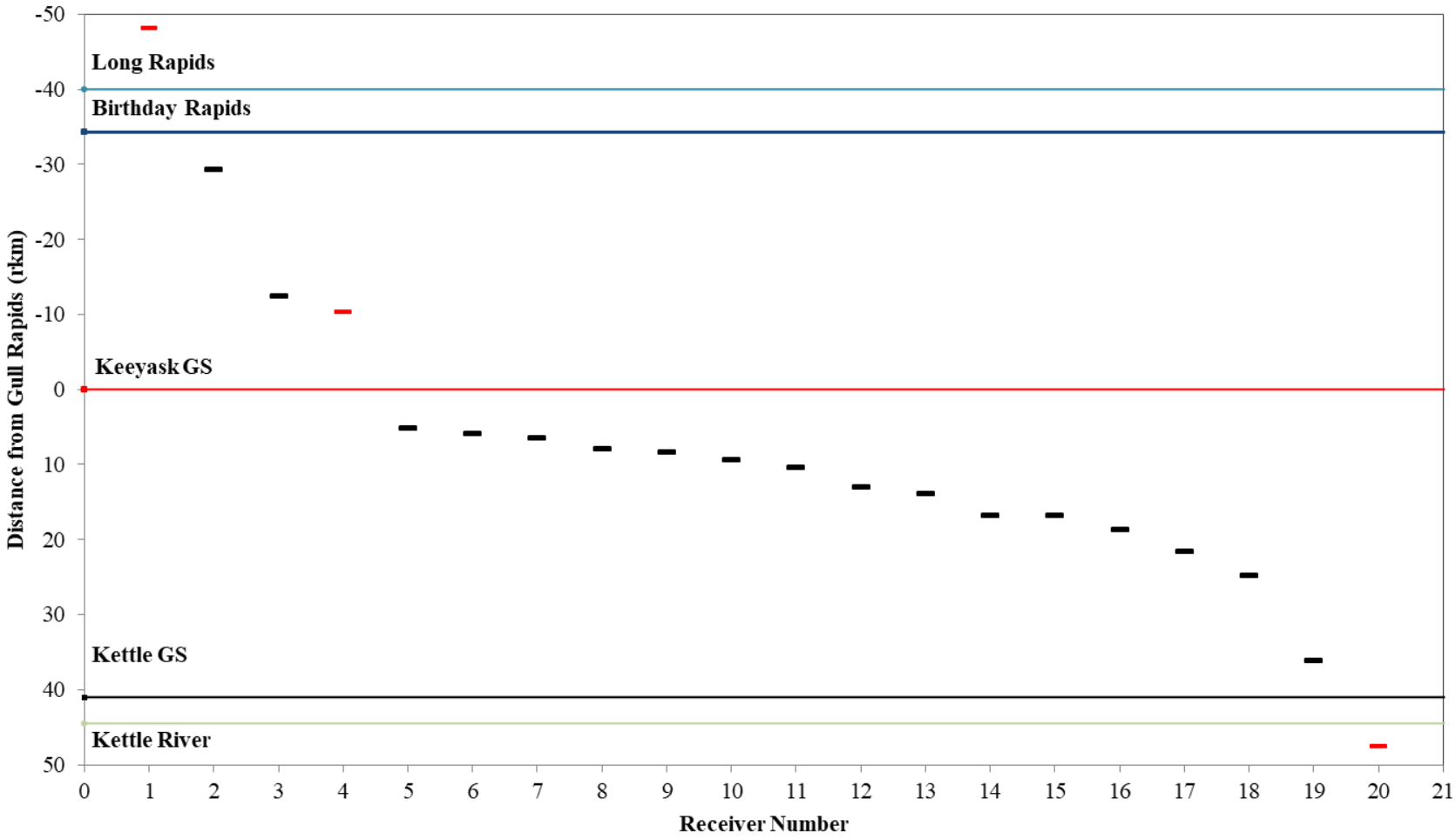


Figure 1: **Locations of stationary acoustic receivers (dashes) in relation to the base of the Keeyask GS (rkm 0) and other major landmarks (lines) in the Nelson River between Clark Lake and the Long Spruce GS between October 2018 and June 2019. Red dashes indicate lost receivers.**

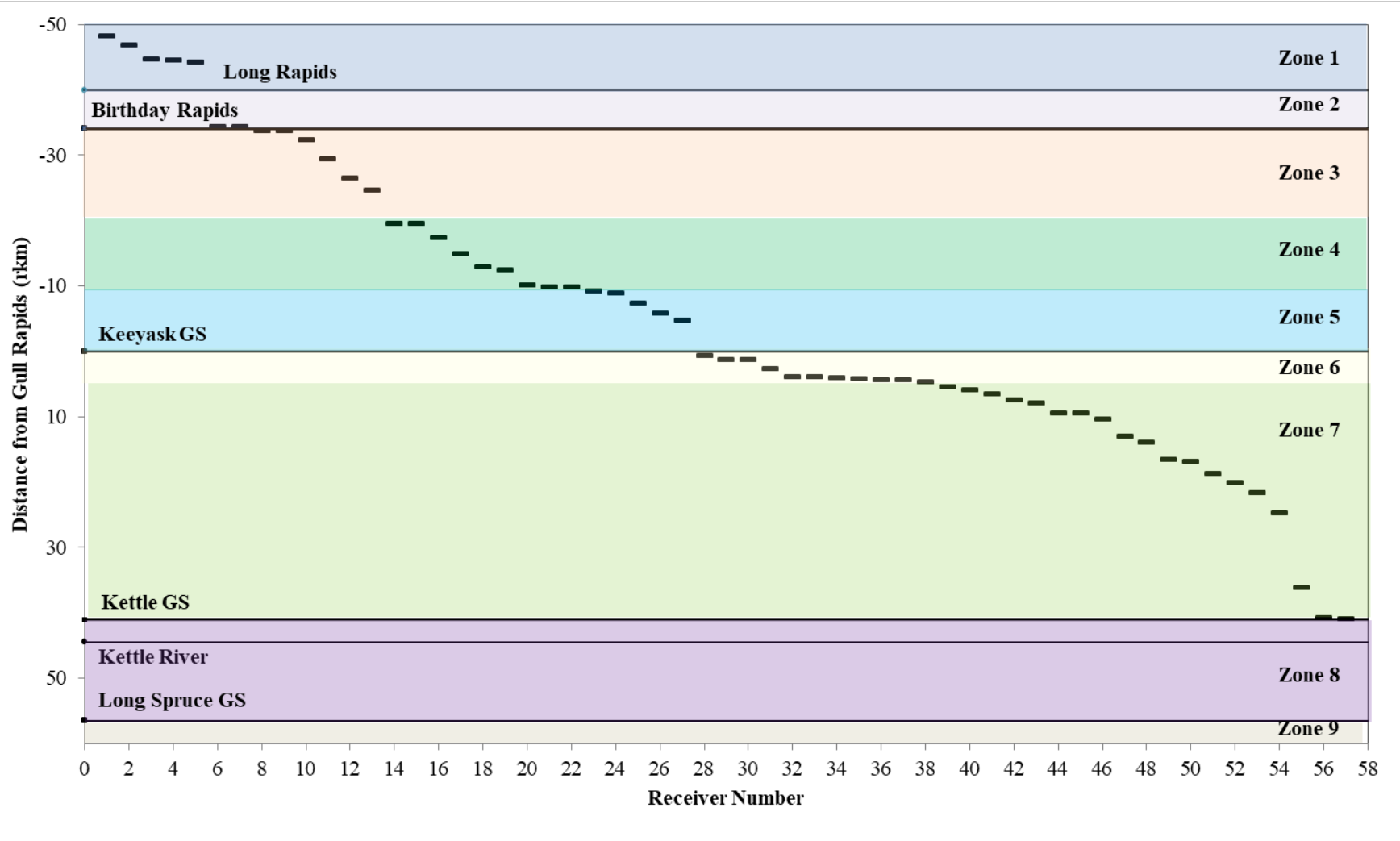


Figure 2: **Locations of stationary acoustic receivers (dashes) in relation to the base of the Keeyask GS (rkm 0) and other major landmarks (lines) in the Nelson River between Clark Lake and the Long Spruce GS between June and October, 2019. River zones are indicated by different colours.**

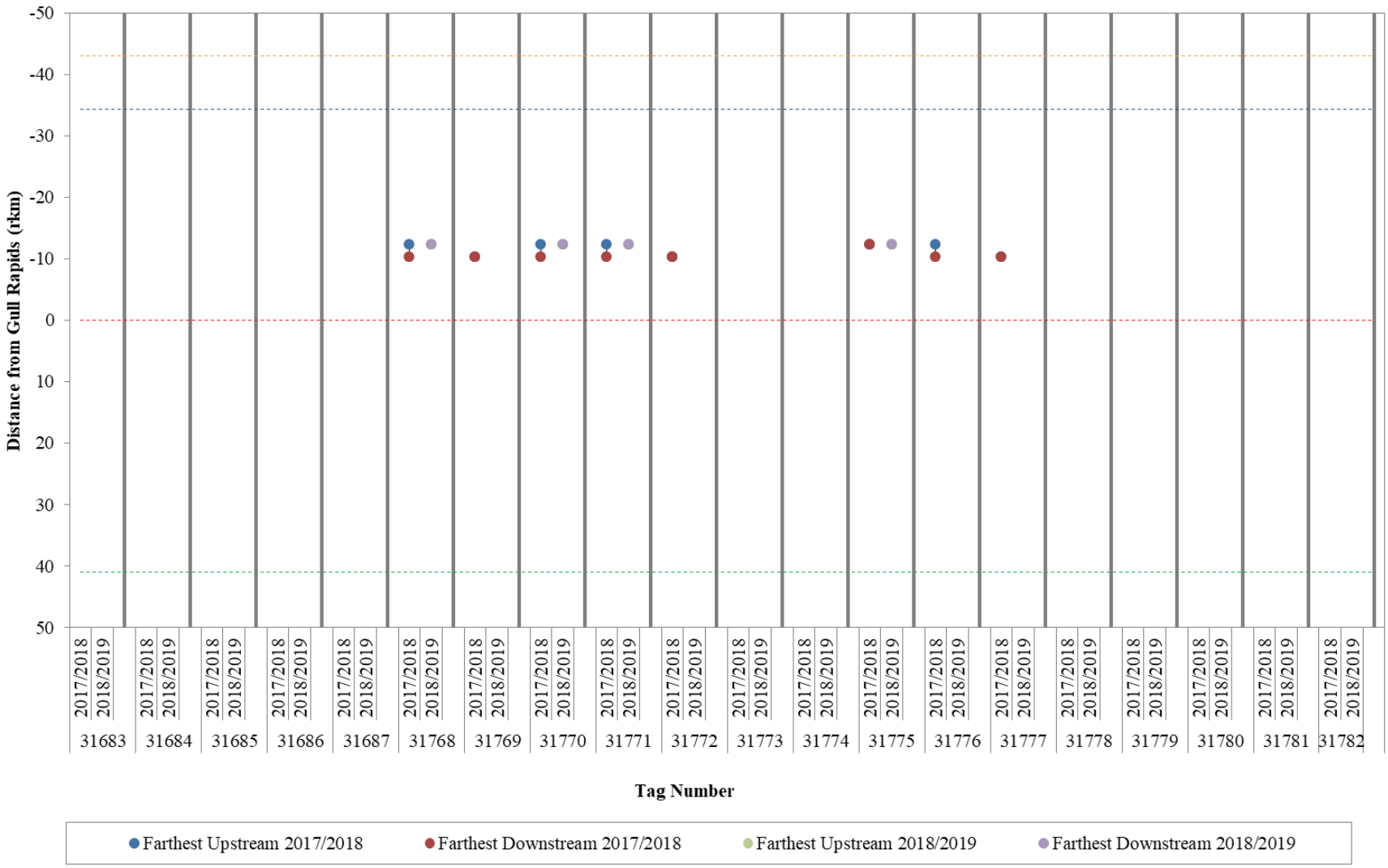


Figure 3: Detection ranges for acoustic tagged juvenile Lake Sturgeon detected between Clark Lake and the Keeyask GS during the winter period (2017–2019). Horizontal dotted lines indicate locations of landmarks (orange = Clark Lake outlet; blue = Birthday Rapids, red = the Keeyask GS; green = Kettle GS).

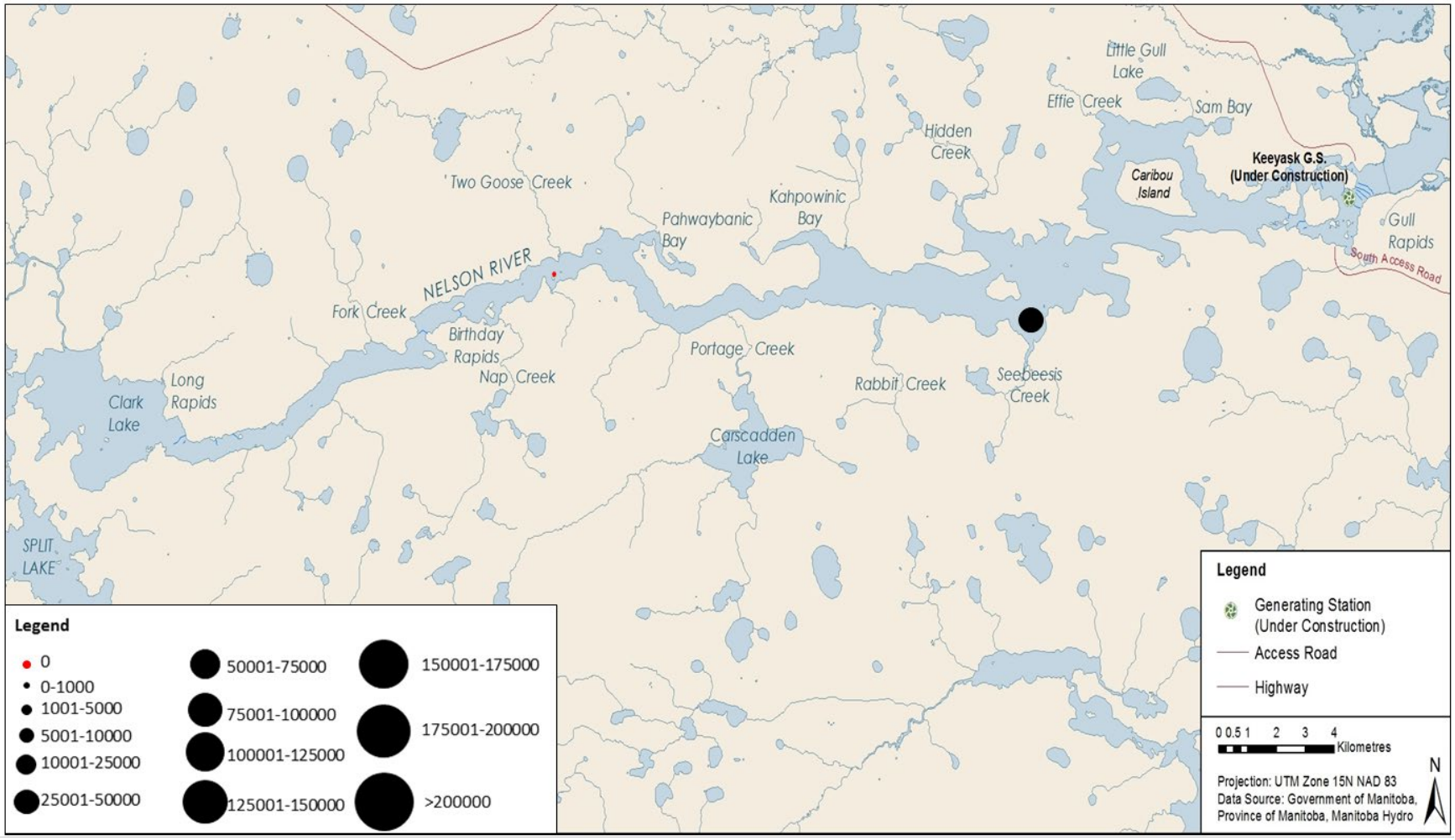


Figure 4: **Relative number of detections at each acoustic receiver set between Clark Lake and the Keeyask GS during winter 2018/2019 (October 11, 2018, to April 30, 2019). Number of detections indicated by size of bubble (defined in legend). Receivers with no detections indicated with red dot.**

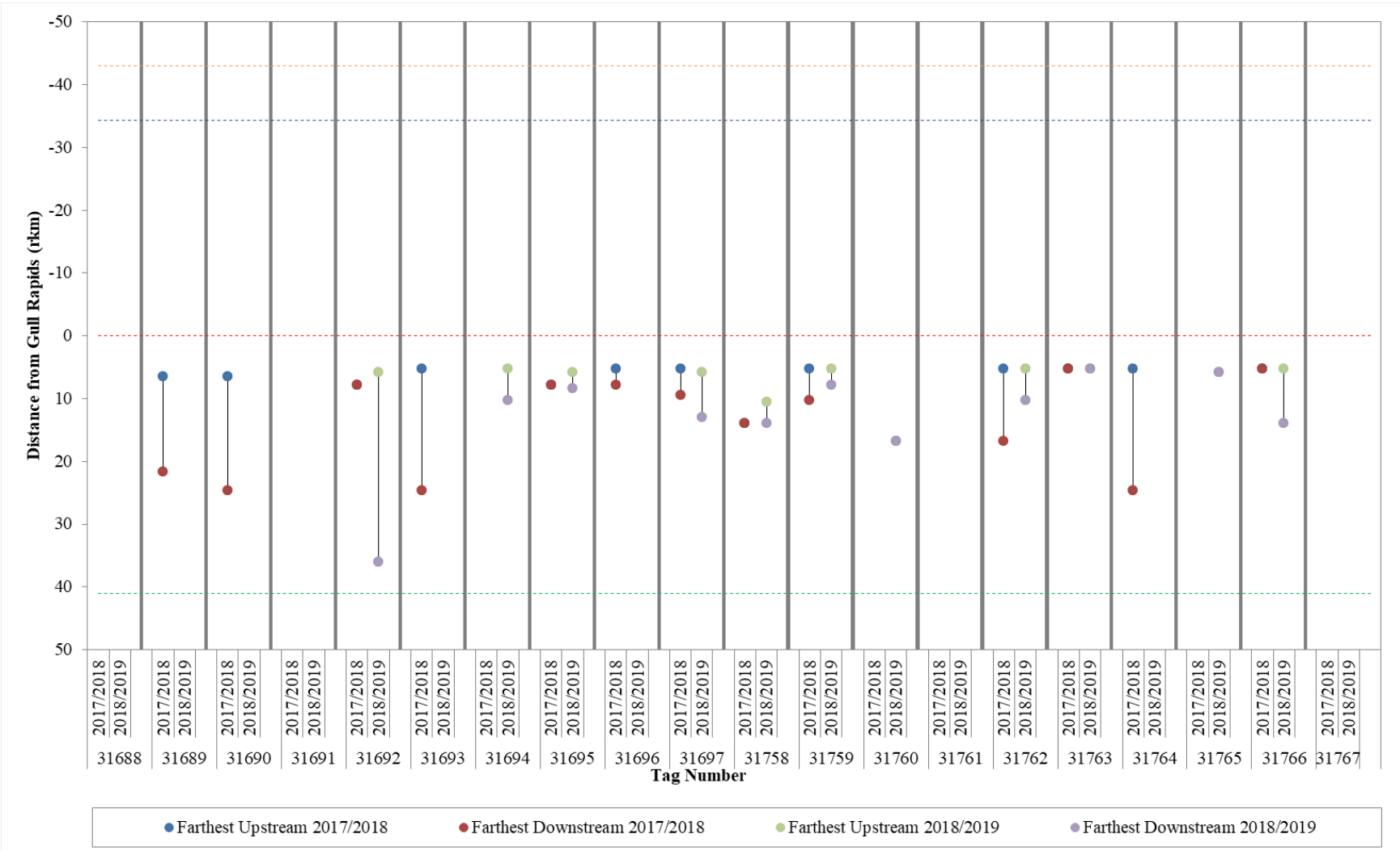


Figure 5: Detection ranges for acoustic tagged juvenile Lake Sturgeon detected in Stephens Lake during the winter period (2017–2019). Horizontal dotted lines indicate locations of landmarks (orange = Clark Lake outlet; blue = Birthday Rapids, red = the Keeyask GS; green = Kettle GS).

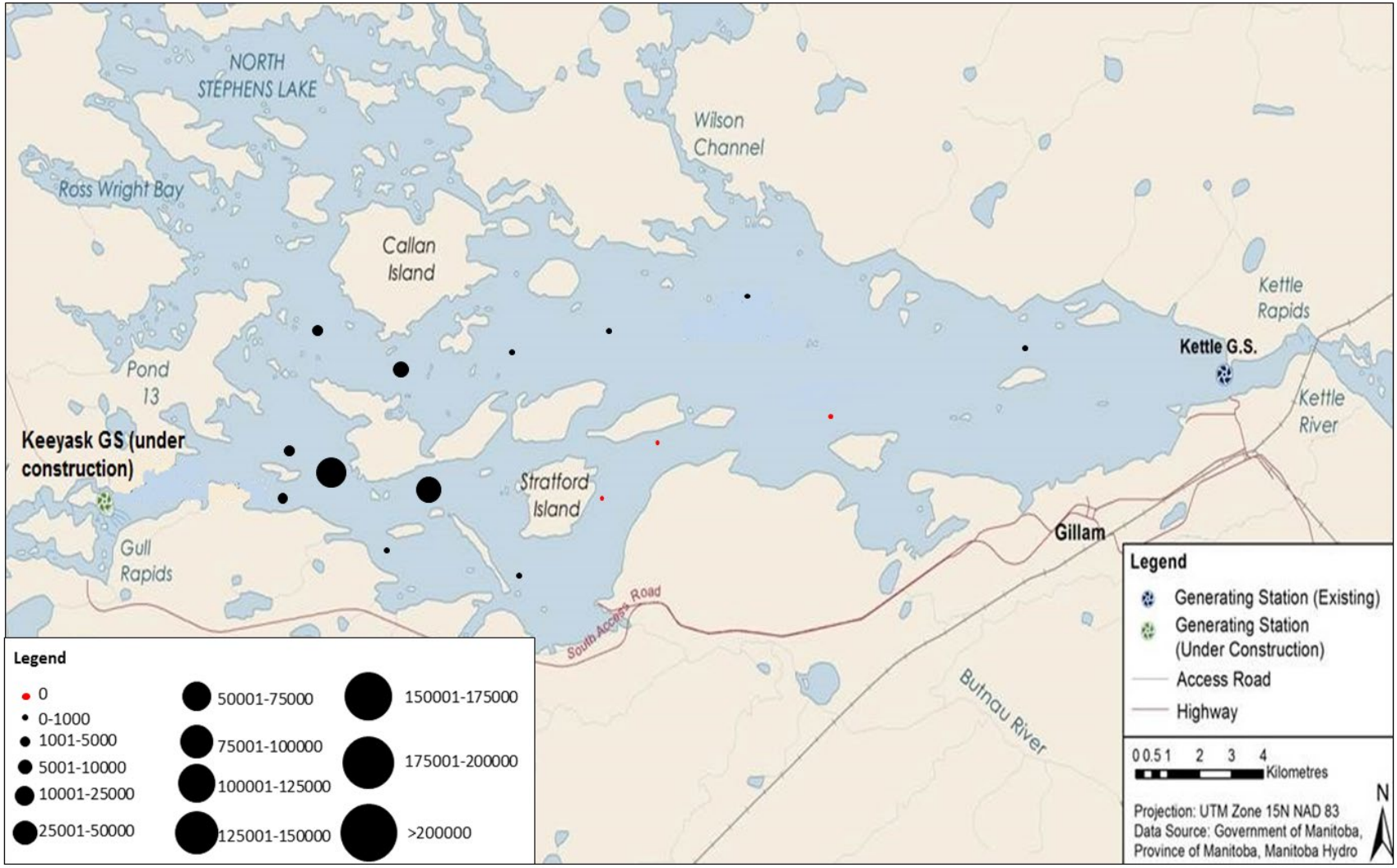


Figure 6: Relative number of detections at each acoustic receiver set in Stephens Lake during winter 2018/2019 (October 11, 2018, to April 30, 2019). Number of detections indicated by size of bubble (defined in legend). Receivers with no detections indicated with red dot.

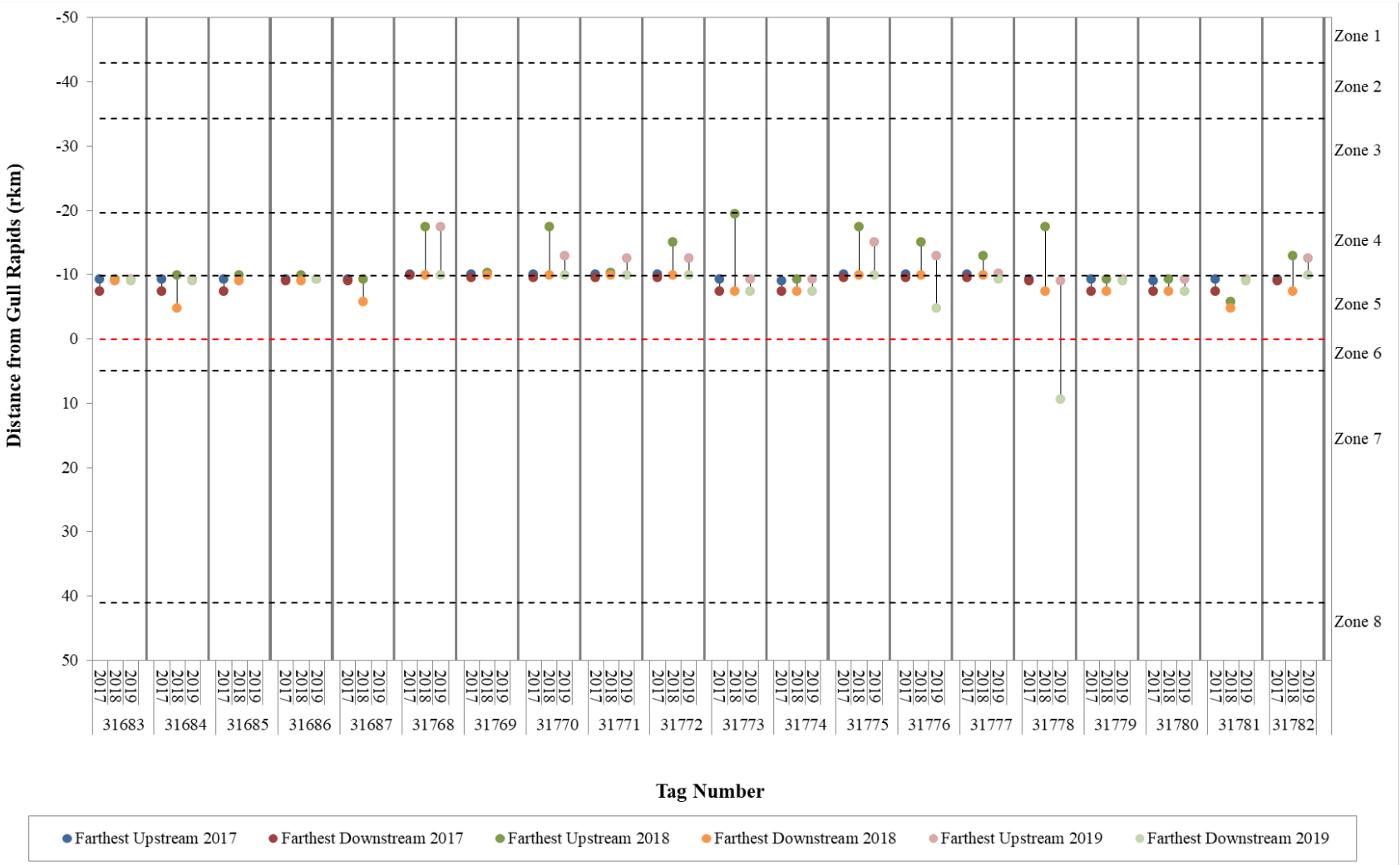


Figure 7: Detection ranges for individual juvenile Lake Sturgeon tagged with acoustic transmitters upstream of Gull Rapids/the Keeyask GS during the open-water period (2017–2019). Horizontal dotted lines demarcate zones with the red line representing the Keeyask GS.

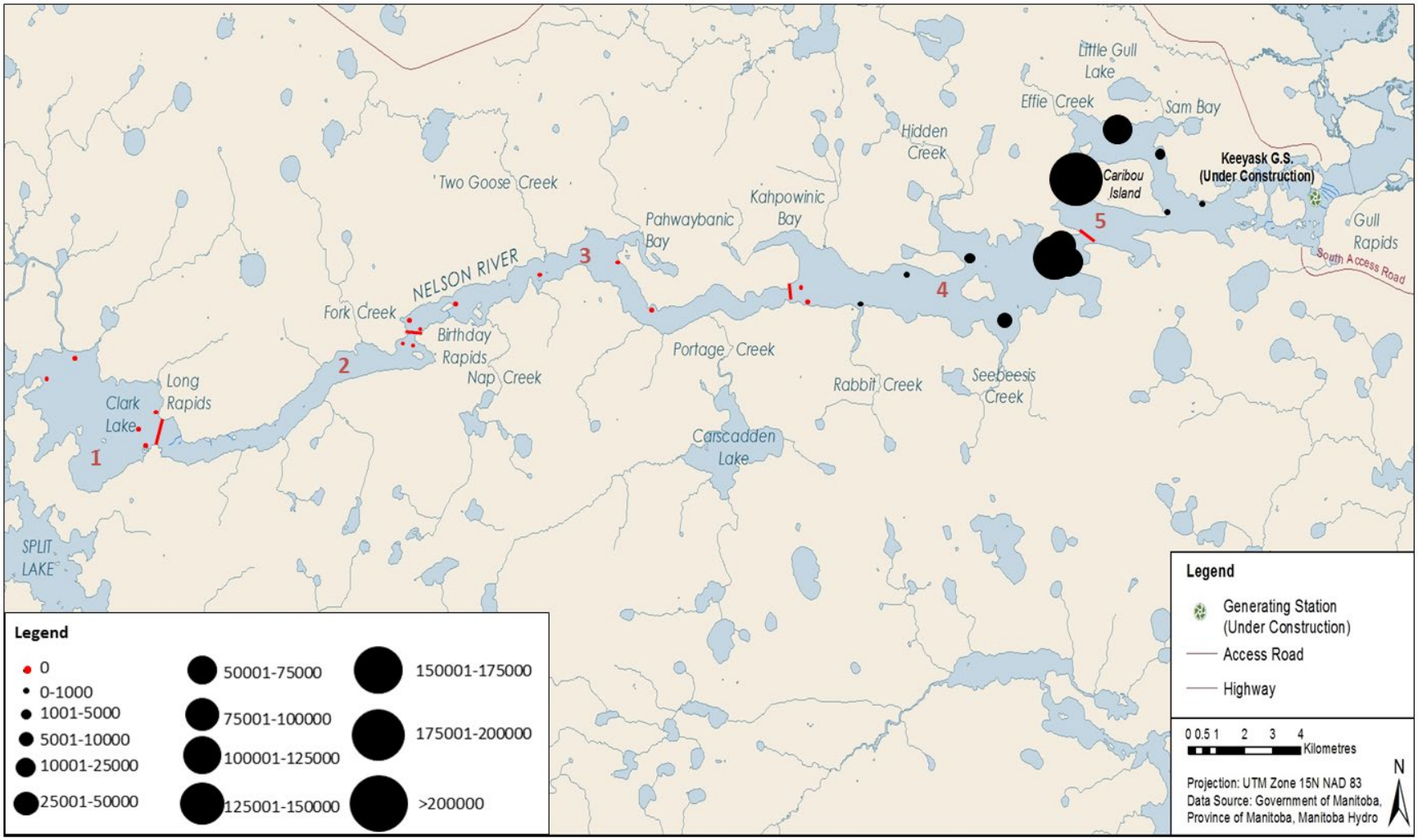


Figure 8: **Relative number of detections at each acoustic receiver set in the Nelson River between Clark Lake and the Keeyask GS during the 2019 open-water period (May 1 to October 7). Number of detections indicated by size of bubble (defined in legend). Receivers with no detections indicated with red dot. The river is divided into five "zones" based on placement of receiver "gates."**

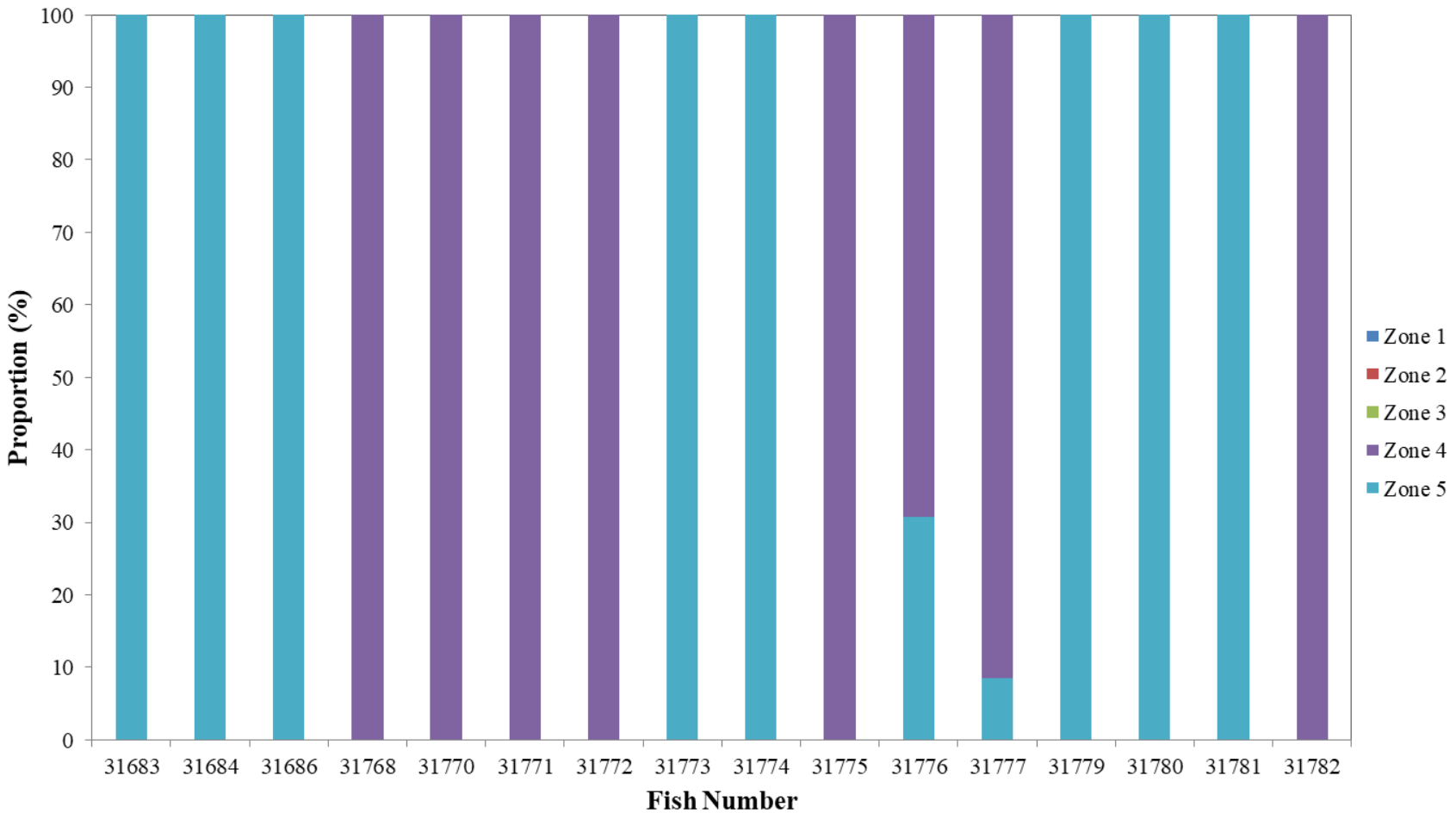


Figure 9: Proportional distributions by zone for individual juvenile Lake Sturgeon between Clark Lake and the Keeyask GS during a portion of the 2019 open-water period (June 2 to October 7). The single fish that moved downstream through the Keeyask GS during open-water 2019 was not included in the analysis.

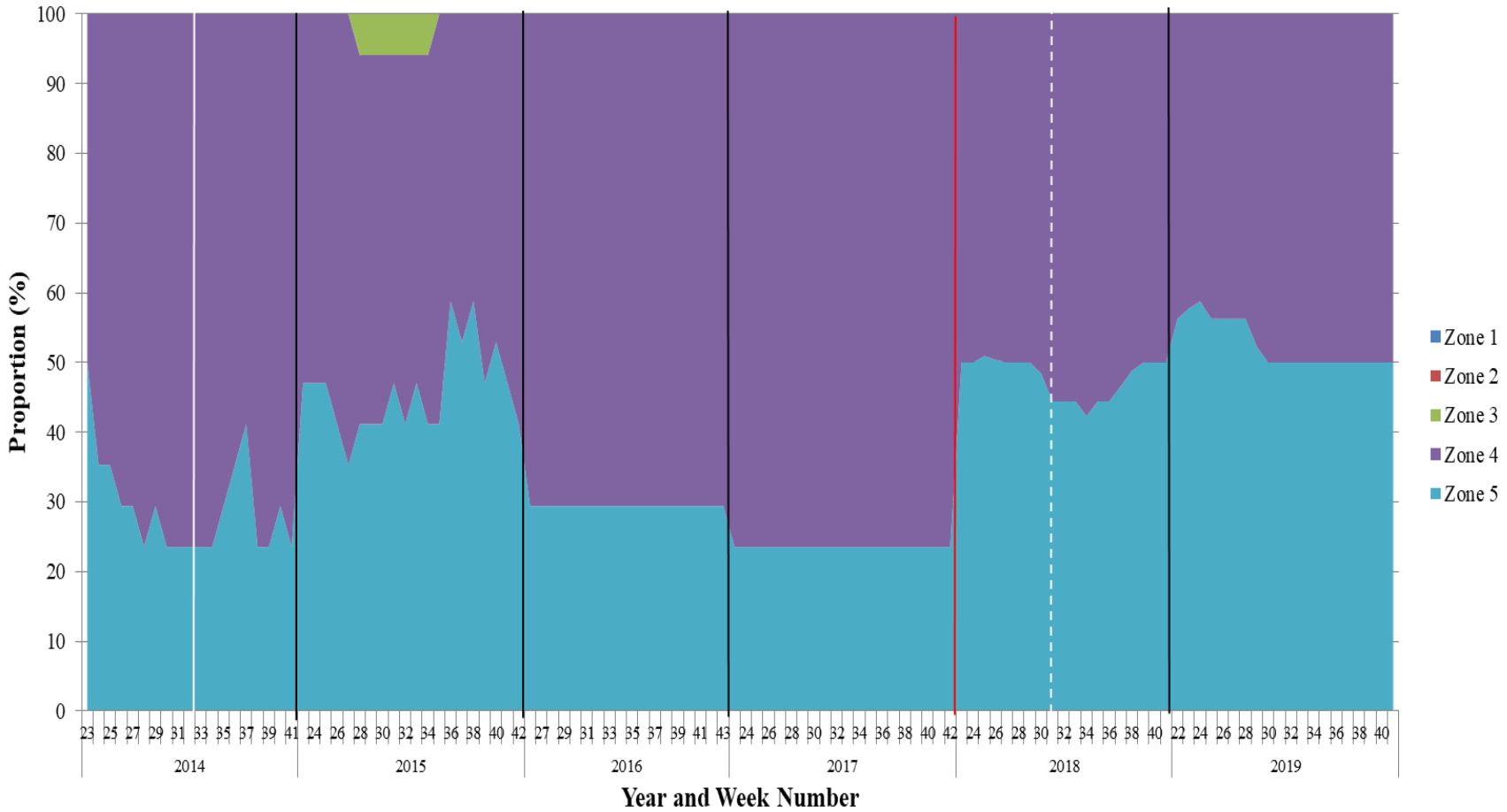


Figure 10: **Proportional distribution by zone per week for juvenile Lake Sturgeon between Clark Lake and Gull Rapids/the Keeyask GS during a portion of the open-water periods of 2014 (June 4 to October 10), 2015 (June 4 to October 11), 2016 (June 25 to October 19), 2017 (June 7 to October 16), 2018 (June 6 to October 10), and 2019 (June 2 to October 7). 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.**

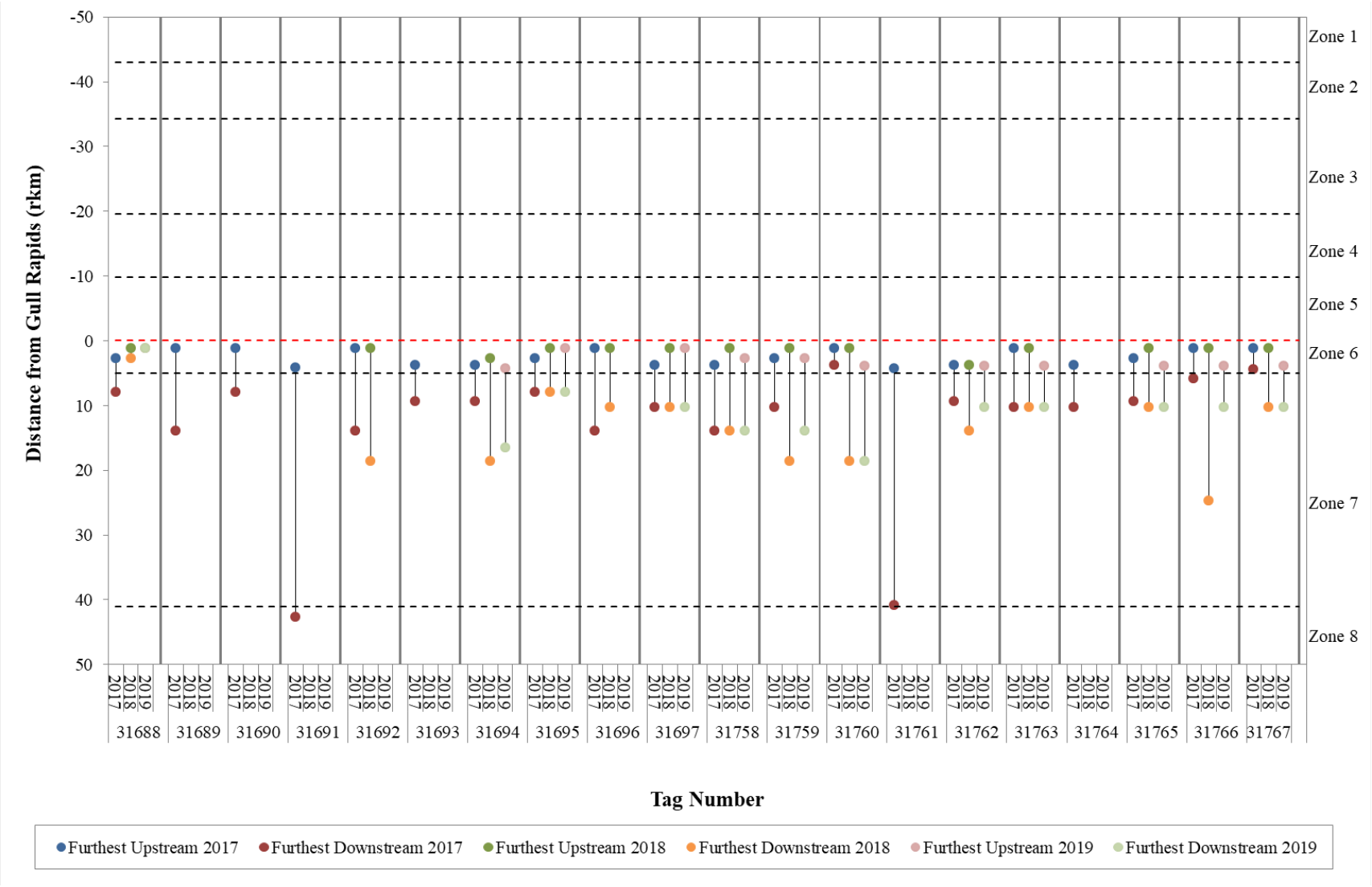


Figure 11: Detection ranges for acoustic tagged juvenile Lake Sturgeon in Stephens Lake during the open-water periods of 2017–2019. Horizontal dotted lines demarcate zones with the red line representing the Keeyask GS.

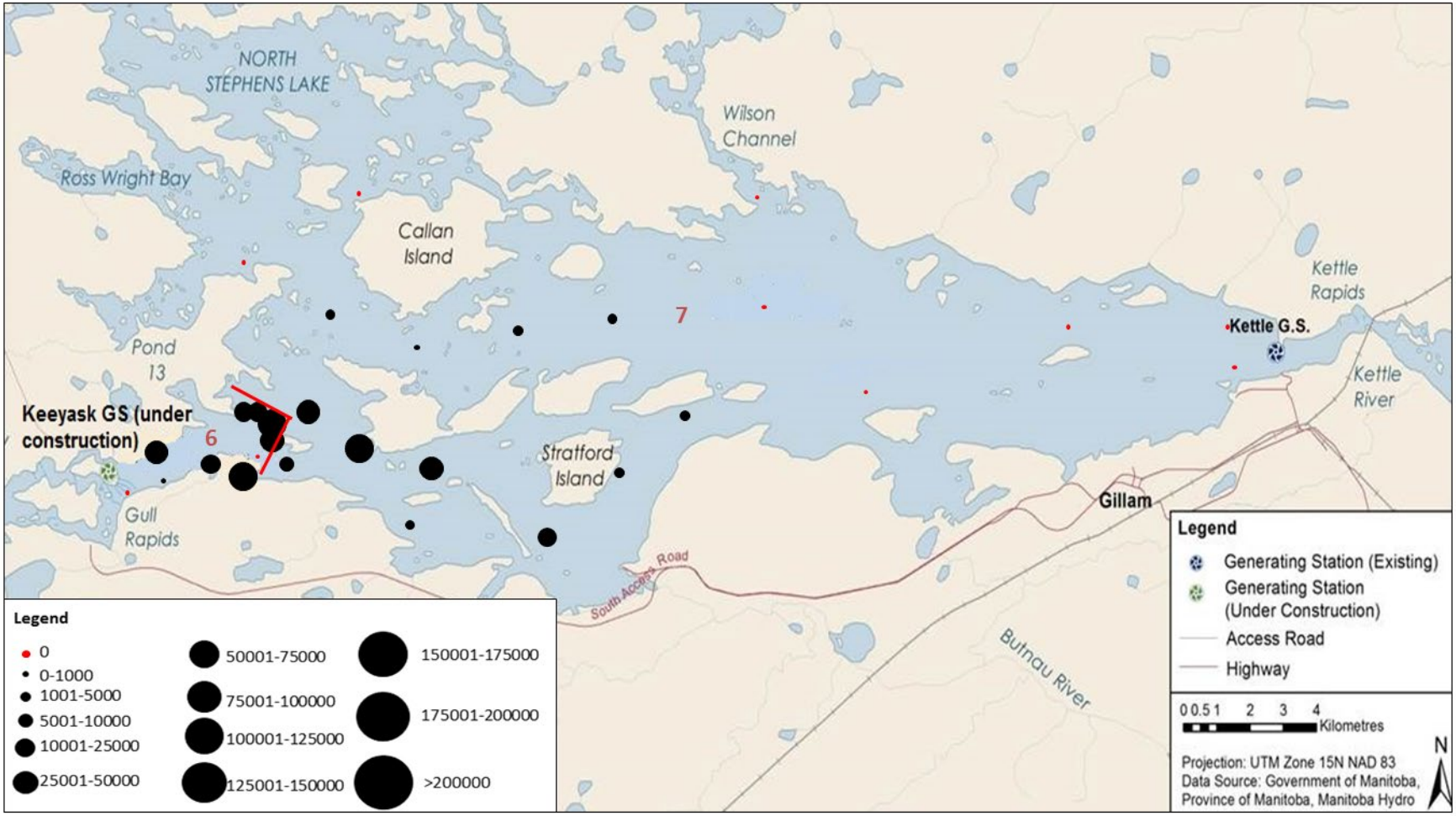


Figure 12: Relative number of detections at each acoustic receiver set in Stephens Lake during the 2019 open-water period (May 1 to October 7). Number of detections indicated by size of bubble (defined in legend). Receivers with no detections indicated with red dot.

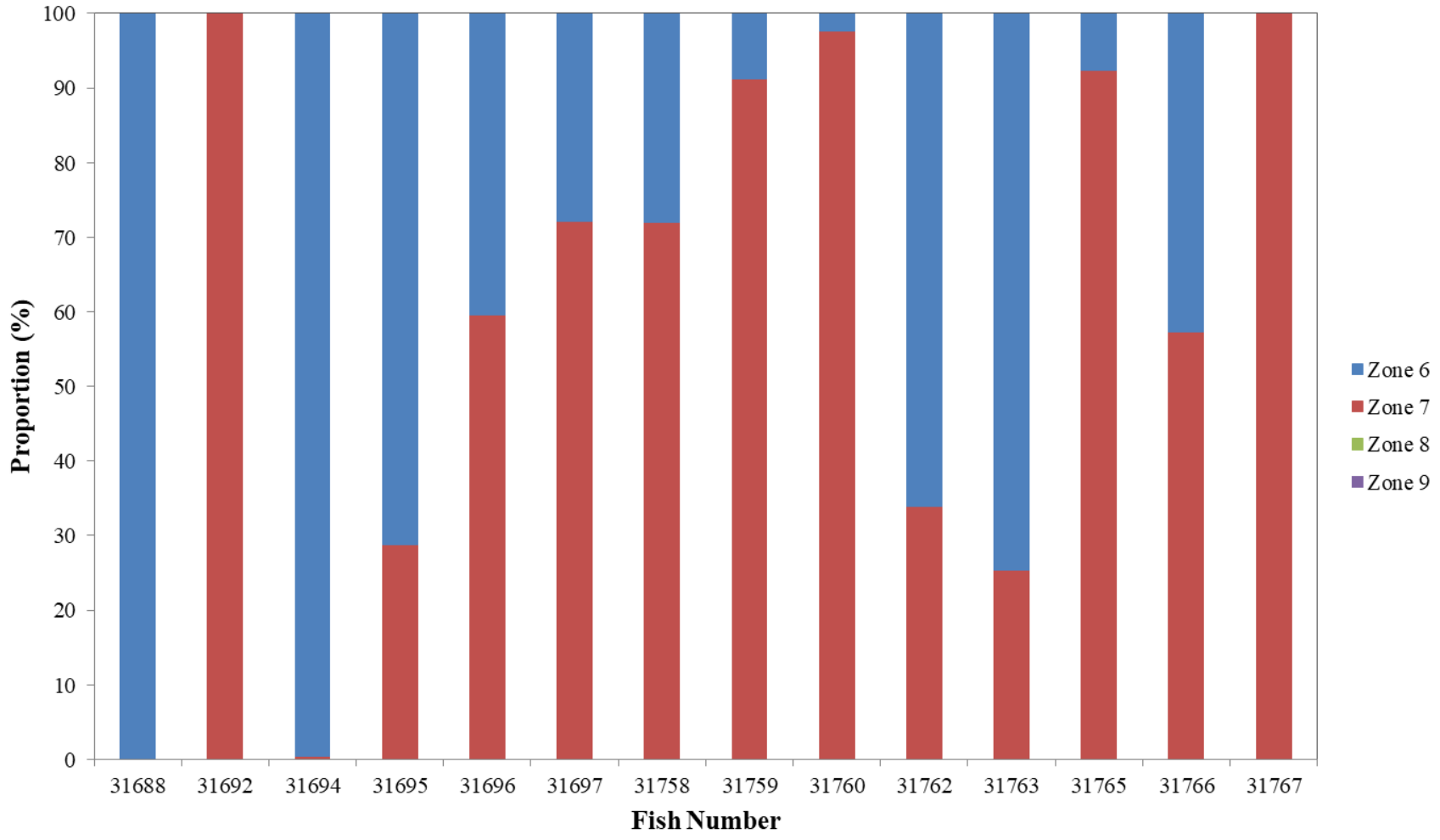


Figure 13: Proportional distributions by zone, for individual juvenile Lake Sturgeon tagged with acoustic transmitters in Stephens Lake during a portion of the 2019 open-water period (June 2 to October 2).

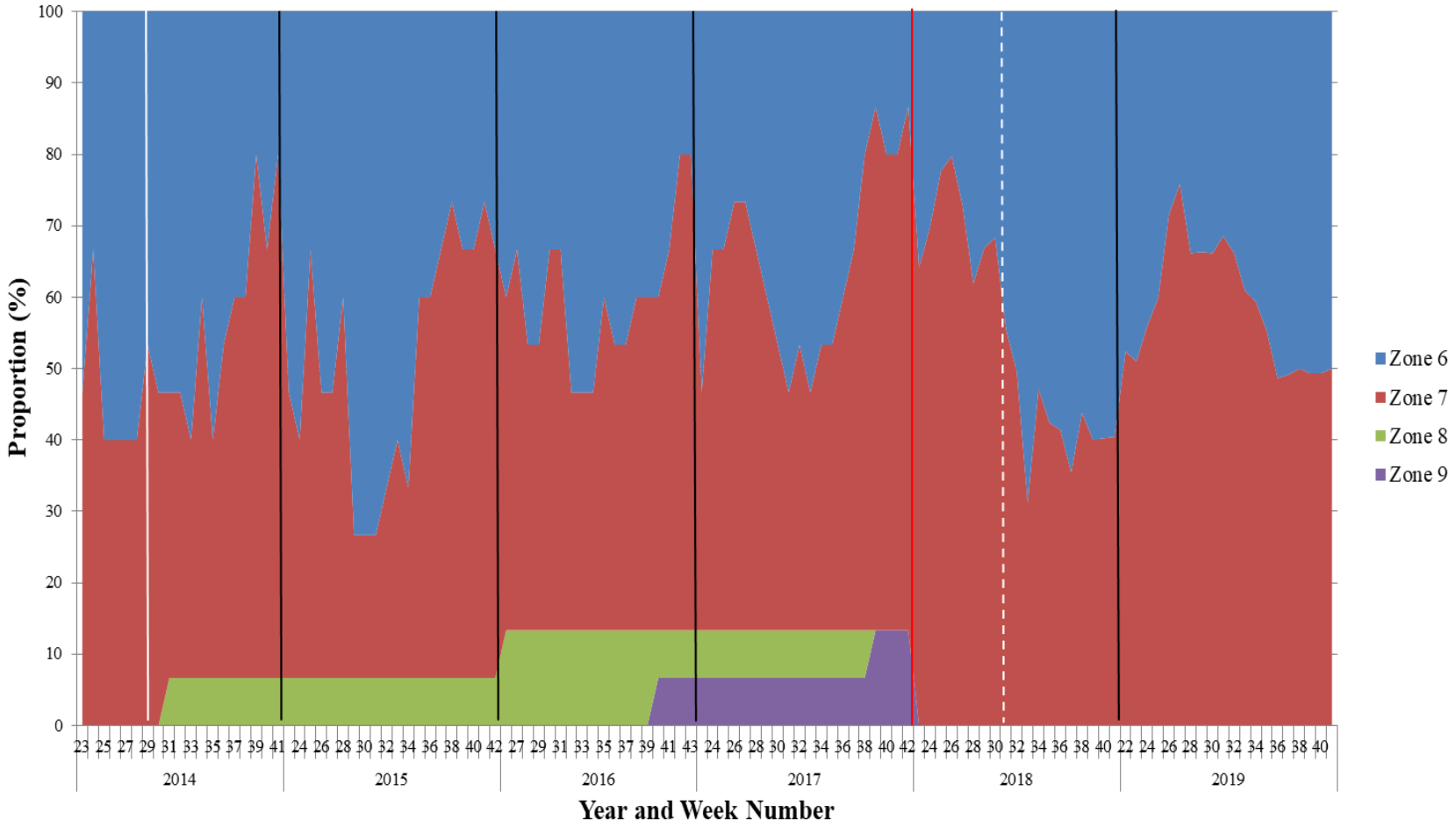
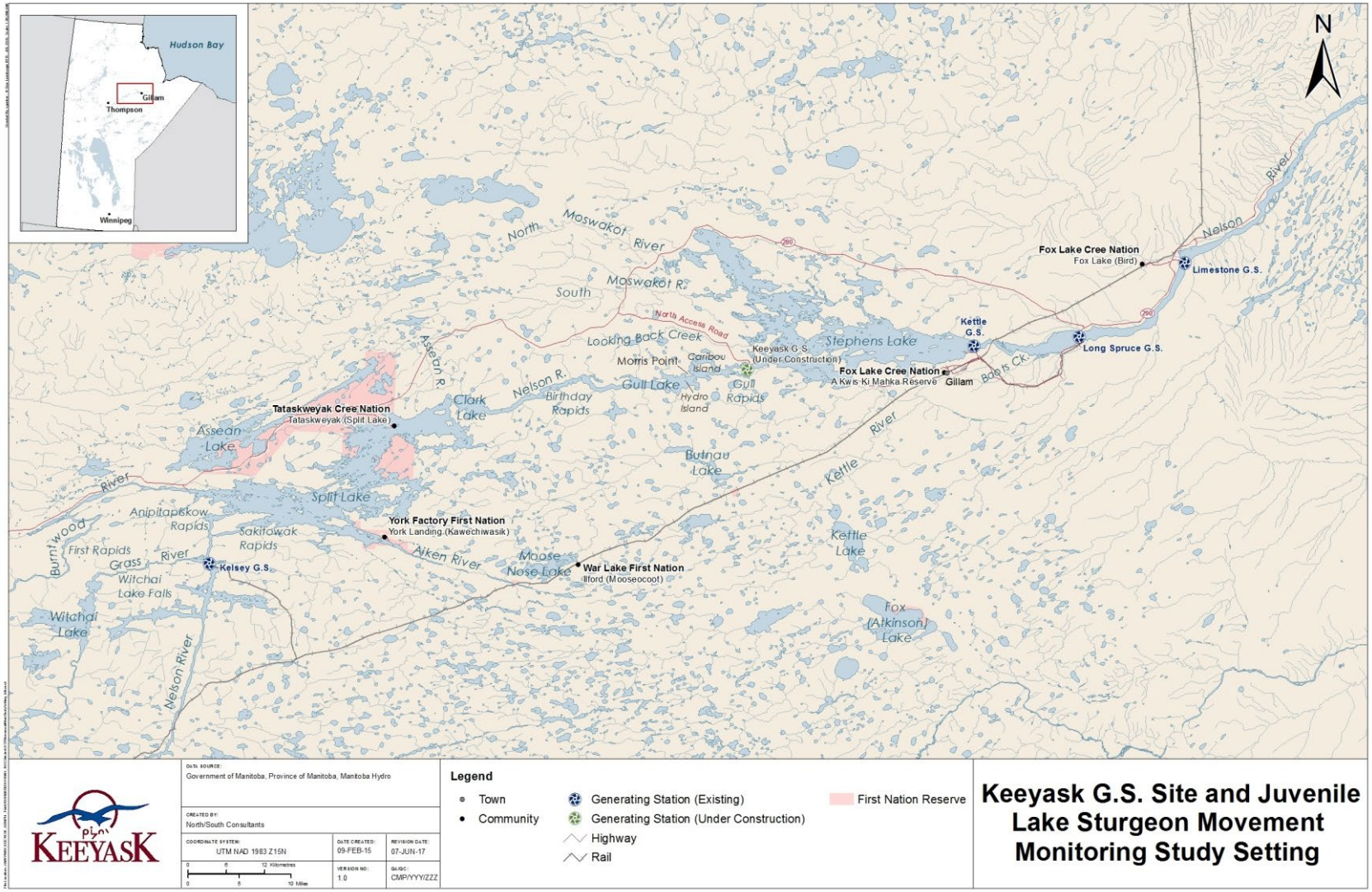
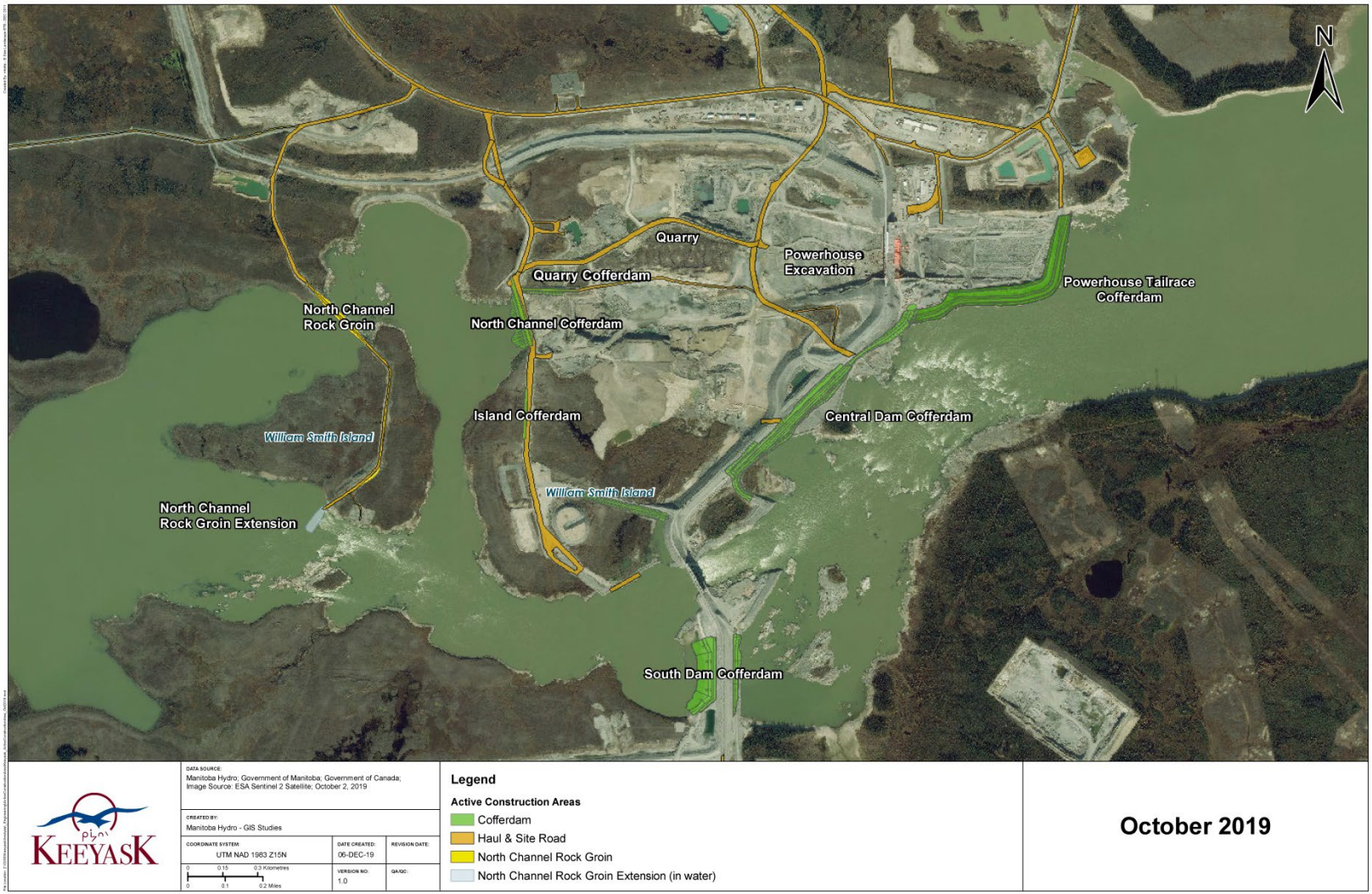


Figure 14: Proportional distribution by zone per week for juvenile Lake Sturgeon downstream of Gull Rapids/the Keeyask GS during a portion of the open-water periods of 2014 (June 4 to October 10), 2015 (June 4 to October 11), 2016 (June 25 to October 19), 2017 (June 7 to October 16), 2018 (June 6 to October 10), and 2014 (June 2 to October 7). 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 or 2019. Red solid line indicates when tags expired and new fish were tagged.

MAPS

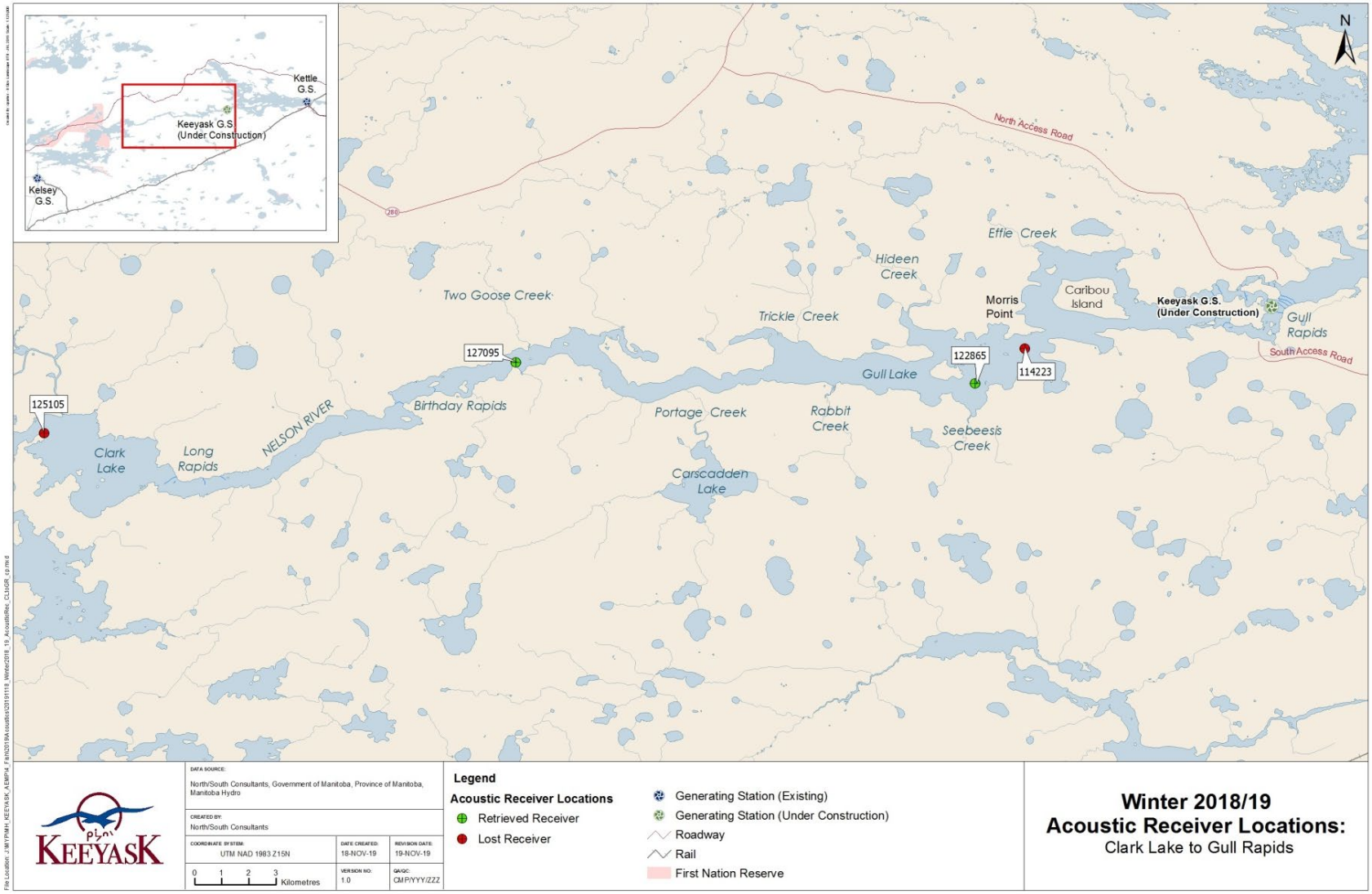


Map 1: Map of the Nelson River showing the site of the Keeyask Generating Station and the juvenile Lake Sturgeon movement monitoring study setting.

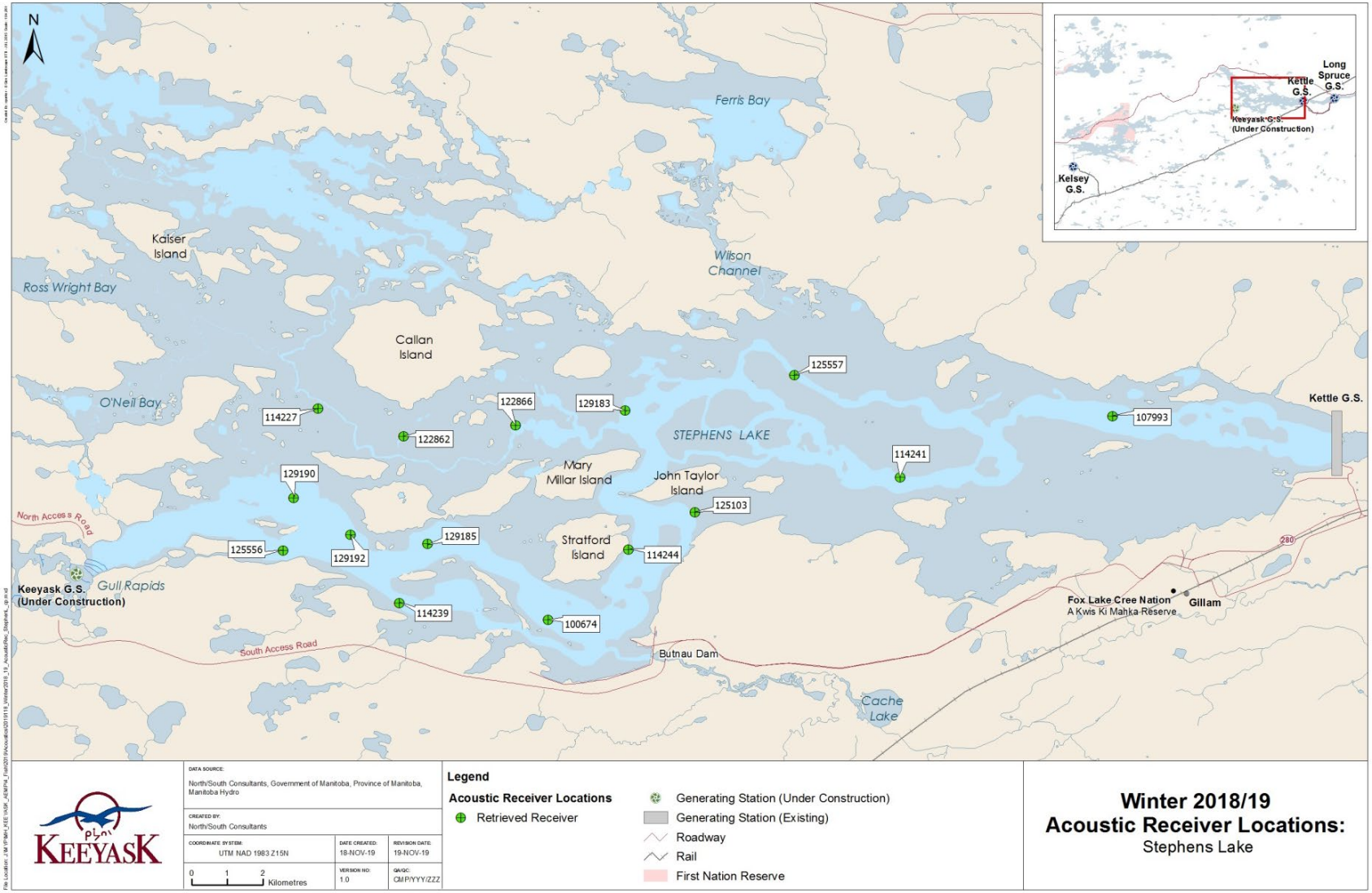


Satellite Imagery - October, 2019

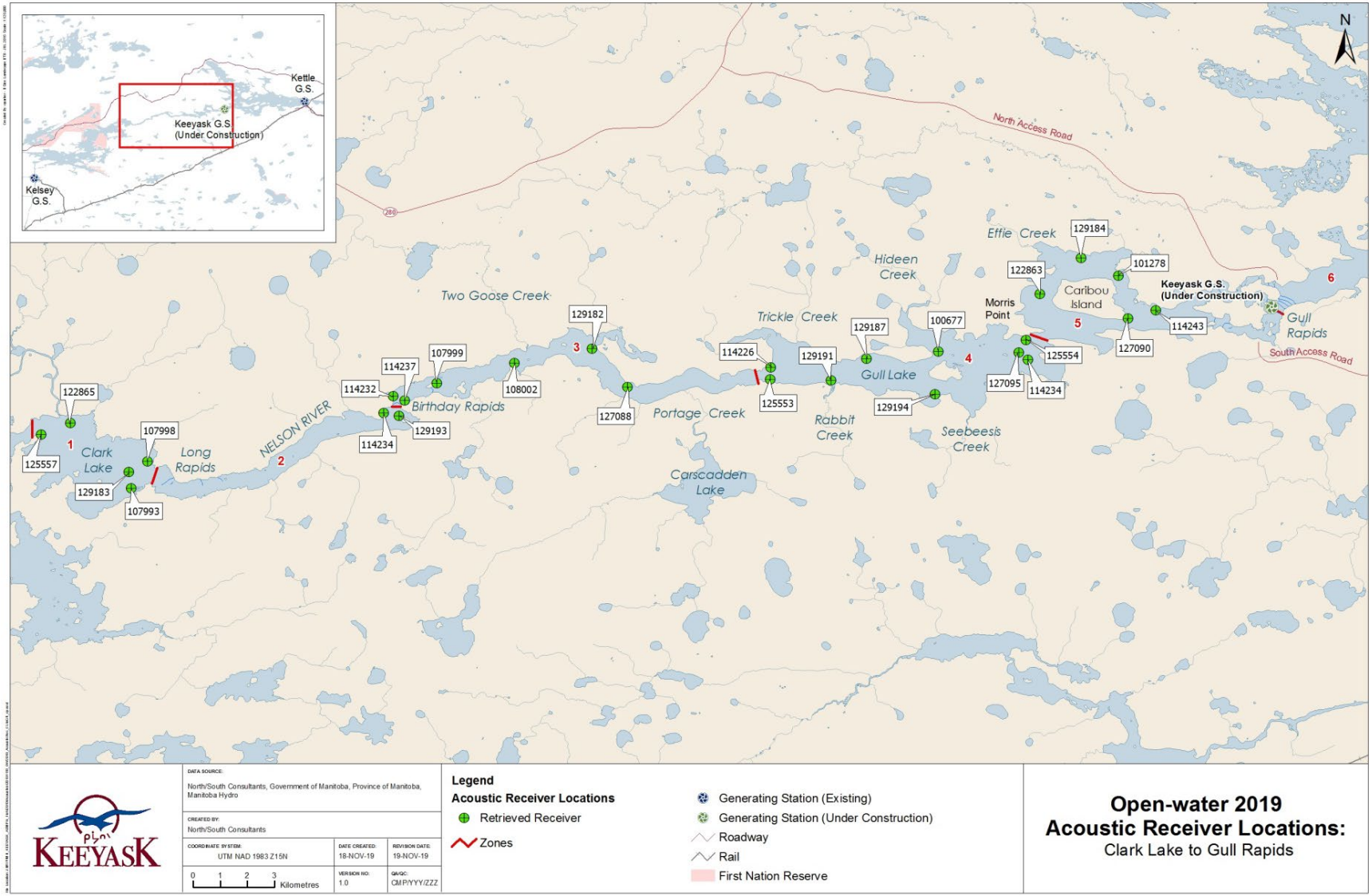
Map 2: Map of instream structures at the Keeyask Generating Station site, October 2019.



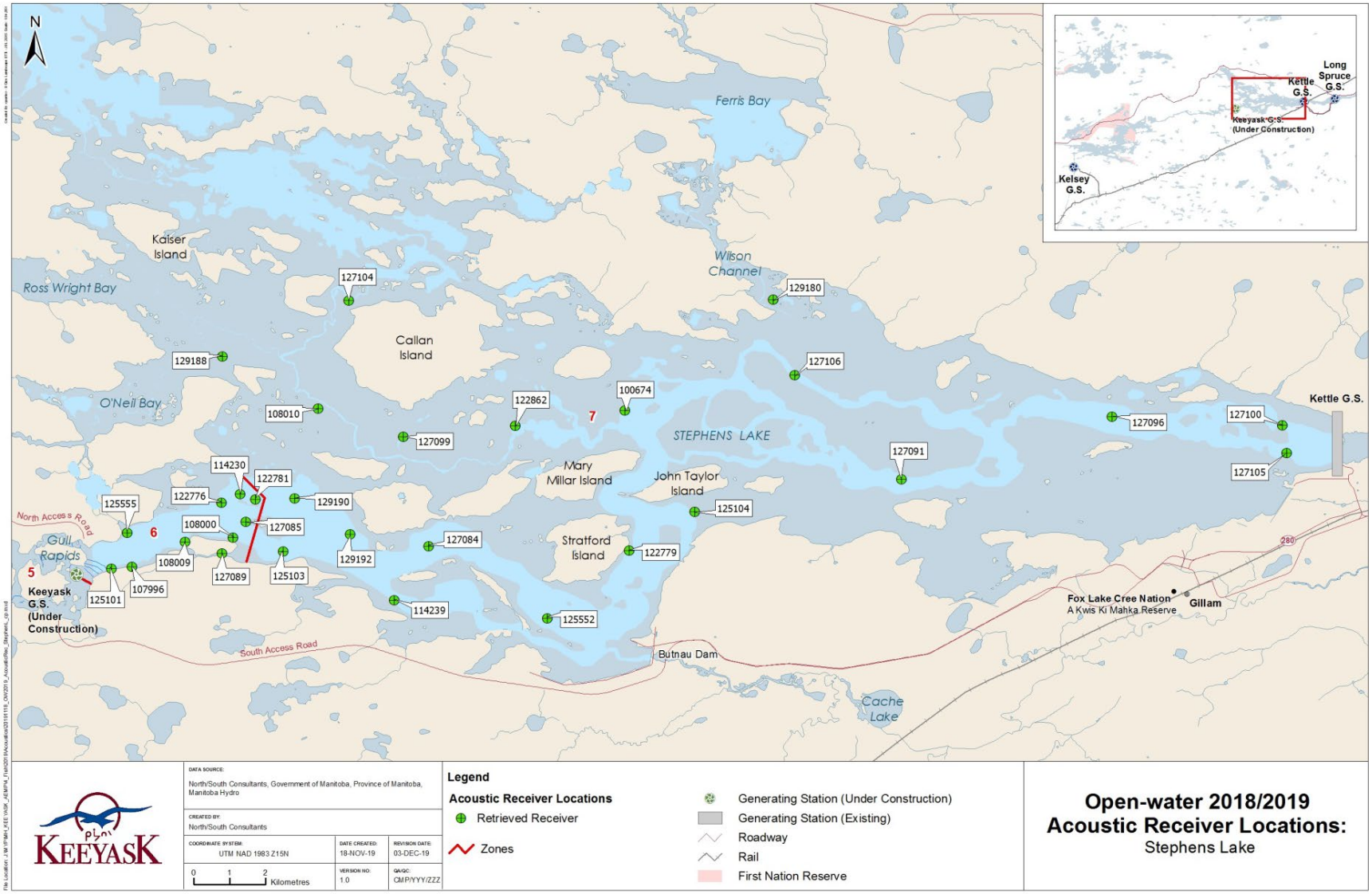
Map 3: Locations of stationary receivers set in the Nelson River from Clark Lake to the Keeyask GS between October 2018 and June 2019.



Map 4: Locations of stationary receivers set in Stephens Lake from the Keeyask GS to Kettle GS between October 2018 and June 2019. The former (pre-impoundment at Kettle GS) river channel is shown in light blue.



Map 5: Locations of stationary receivers set in the Nelson River from Clark Lake to the Keeyask GS between June and October 2019. The river is divided into five "zones" based on placement of receiver "gates."



Map 6: Locations of stationary receivers set in Stephens Lake between June and October 2019. The river is divided into two "zones" based on placement of receiver "gates." The pre-impoundment river channel is shown in light blue.

APPENDICES

APPENDIX 1: LOCATION SUMMARY FOR INDIVIDUAL ACOUSTIC TAGGED JUVENILE LAKE STURGEON UPSTREAM OF THE KEEYASK GS, SEPTEMBER 2017 TO OCTOBER 2019

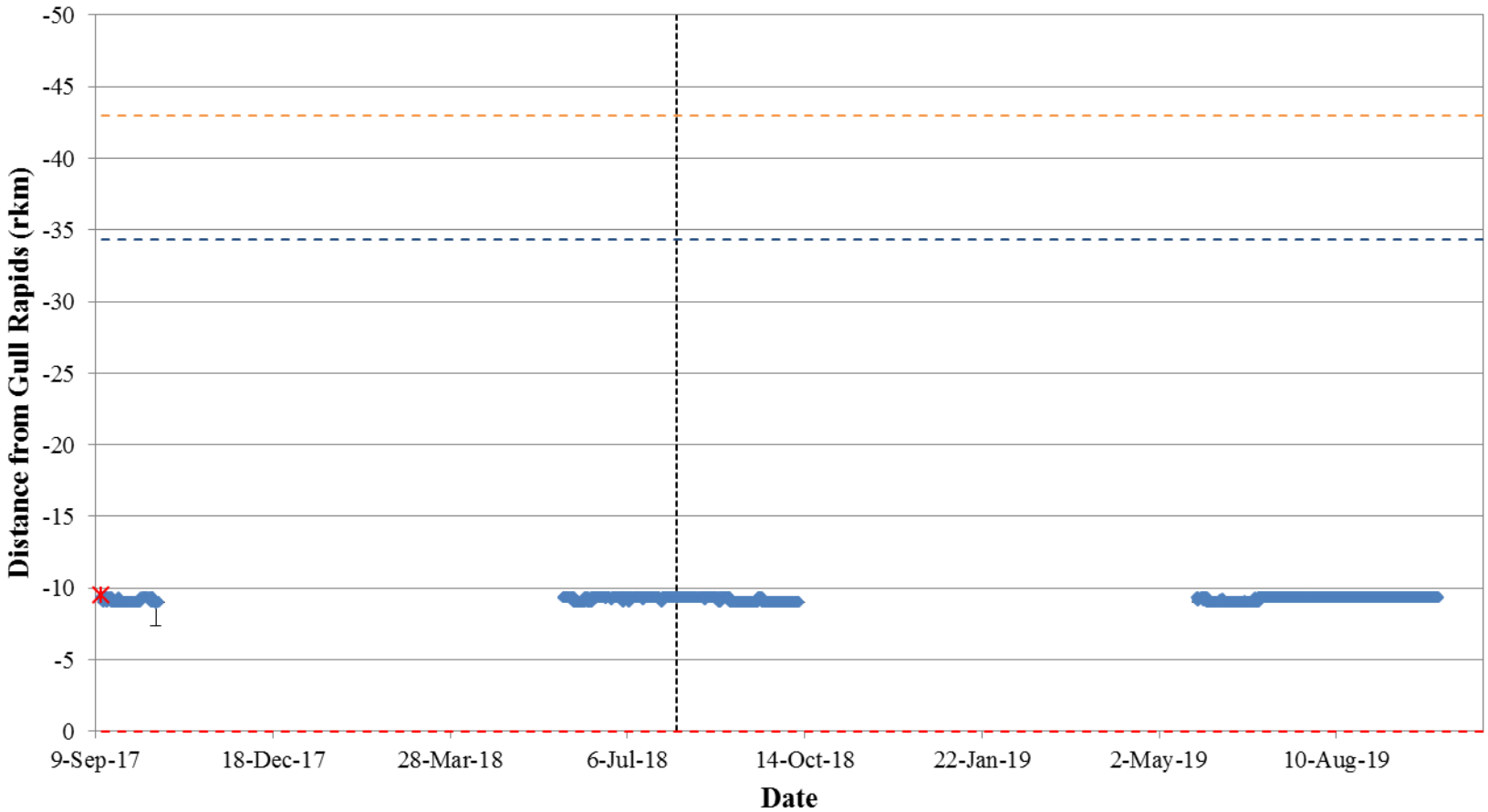


Figure A1-1: Position of a Lake Sturgeon tagged with an acoustic transmitter (code #31683) in Gull Lake in relation to the Keeyask GS (rkm 0), from September 9, 2017 to October 7, 2019. Date and location of tagging is indicated by a red X. Error bars are shown in solid black. Horizontal dashed lines indicate the positions of Keeyask GS (red), Birthday Rapids (blue), and the entrance to Clark Lake (orange). Dashed black vertical line indicates start of spillway operation (Aug 3, 2018).

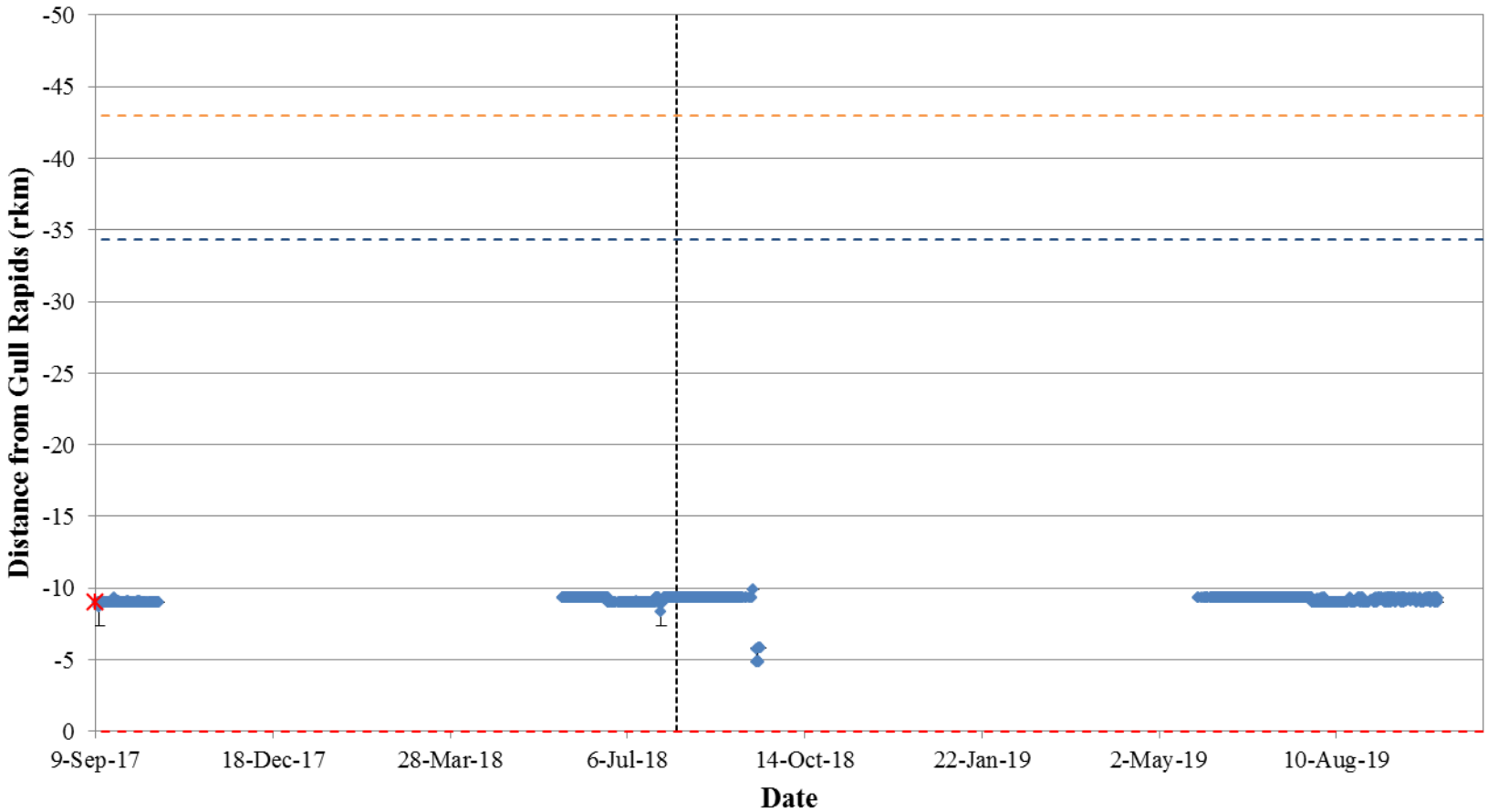


Figure A1-2: Position of a Lake Sturgeon tagged with an acoustic transmitter (code #31684) in Gull Lake in relation to the Keeyask GS (rkm 0), from September 9, 2017 to October 7, 2019. Date and location of tagging is indicated by a red X. Error bars are shown in solid black. Horizontal dashed lines indicate the positions of Keeyask GS (red), Birthday Rapids (blue), and the entrance to Clark Lake (orange). Dashed black vertical line indicates start of spillway operation (Aug 3, 2018).

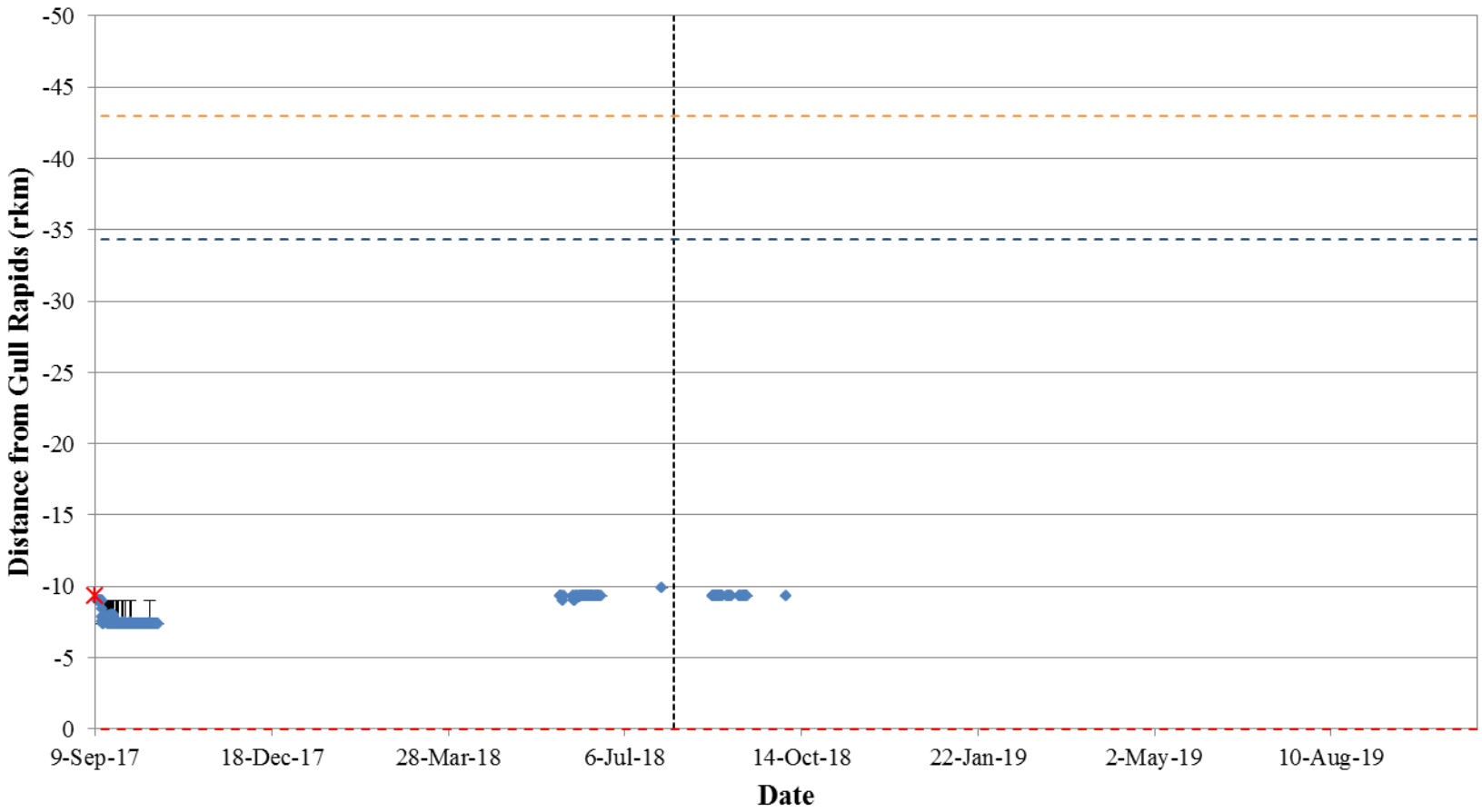


Figure A1-3: Position of a Lake Sturgeon tagged with an acoustic transmitter (code #31685) in Gull Lake in relation to the Keeyask GS (rkm 0), from September 9, 2017 to October 7, 2019. Date and location of tagging is indicated by a red X. Error bars are shown in solid black. Horizontal dashed lines indicate the positions of Keeyask GS (red), Birthday Rapids (blue), and the entrance to Clark Lake (orange). Dashed black vertical line indicates start of spillway operation (Aug 3, 2018).

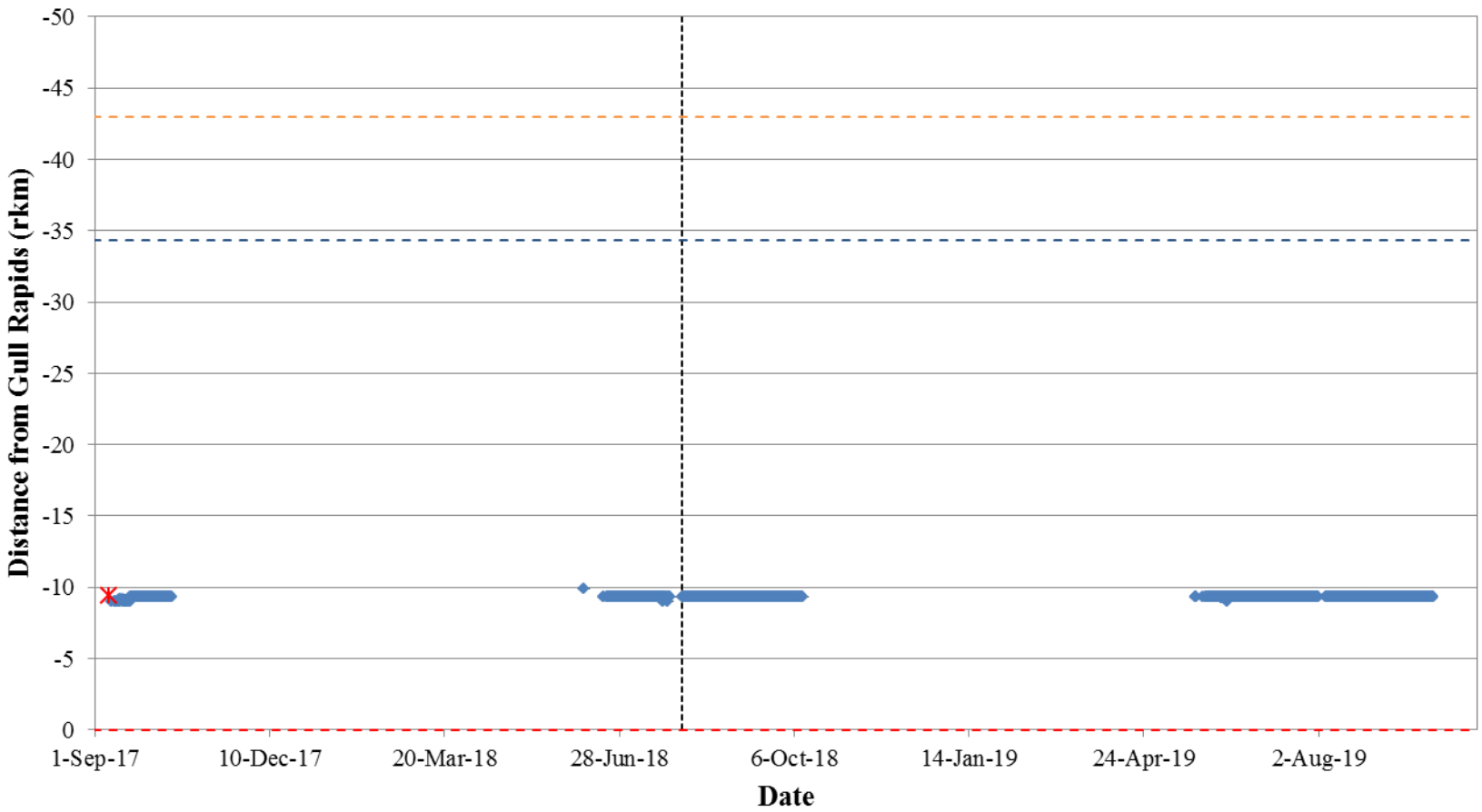


Figure A1-4: Position of a Lake Sturgeon tagged with an acoustic transmitter (code #31686) in Gull Lake in relation to the Keeyask GS (rkm 0), from September 9, 2017 to October 7, 2019. Date and location of tagging is indicated by a red X. Error bars are shown in solid black. Horizontal dashed lines indicate the positions of Keeyask GS (red), Birthday Rapids (blue), and the entrance to Clark Lake (orange). Dashed black vertical line indicates start of spillway operation (Aug 3, 2018).

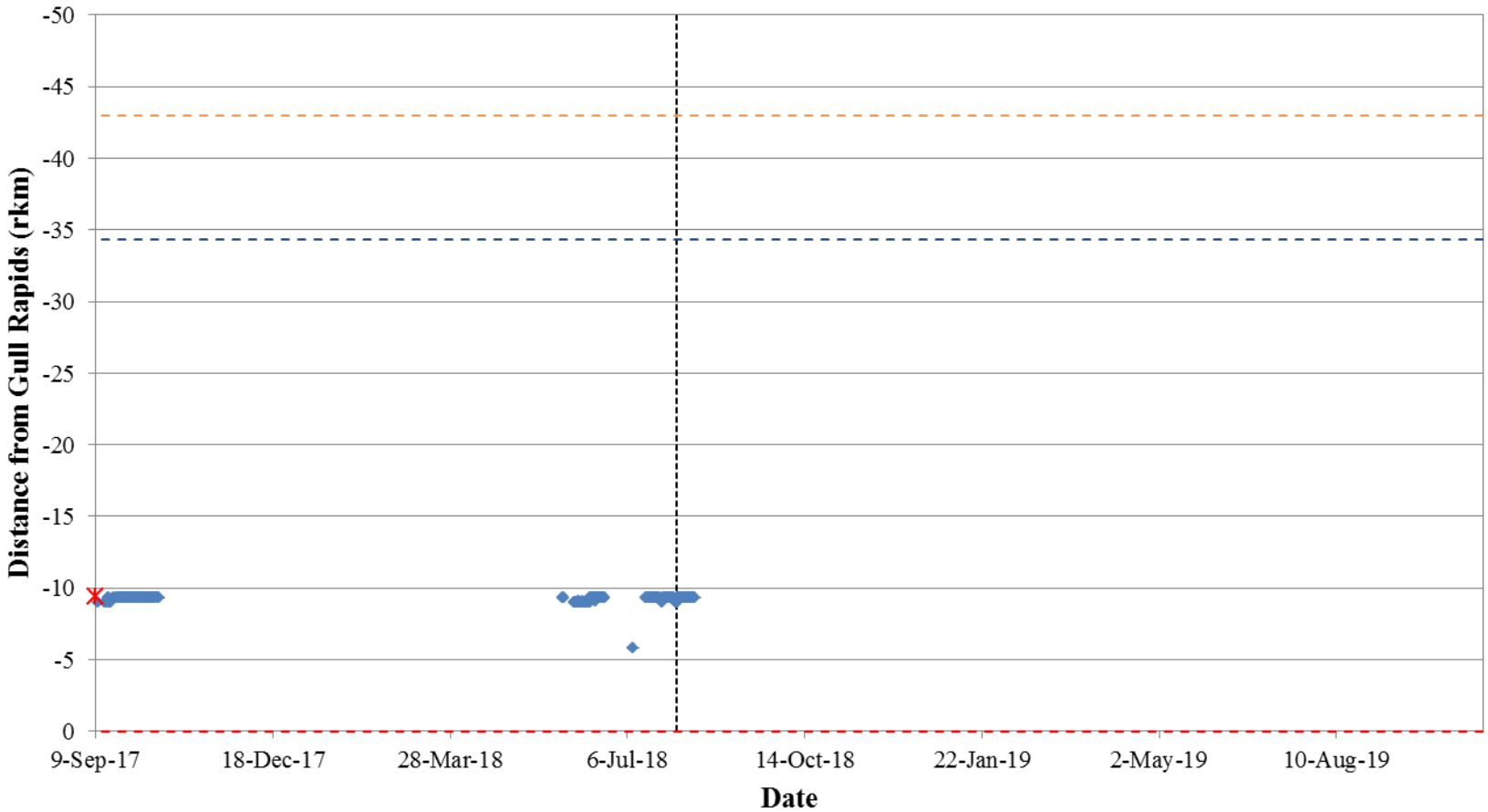


Figure A1-5: Position of a Lake Sturgeon tagged with an acoustic transmitter (code #31687) in Gull Lake in relation to the Keeyask GS (rkm 0), from September 9, 2017 to October 7, 2019. Date and location of tagging is indicated by a red X. Error bars are shown in solid black. Horizontal dashed lines indicate the positions of Keeyask GS (red), Birthday Rapids (blue), and the entrance to Clark Lake (orange). Dashed black vertical line indicates start of spillway operation (Aug 3, 2018).

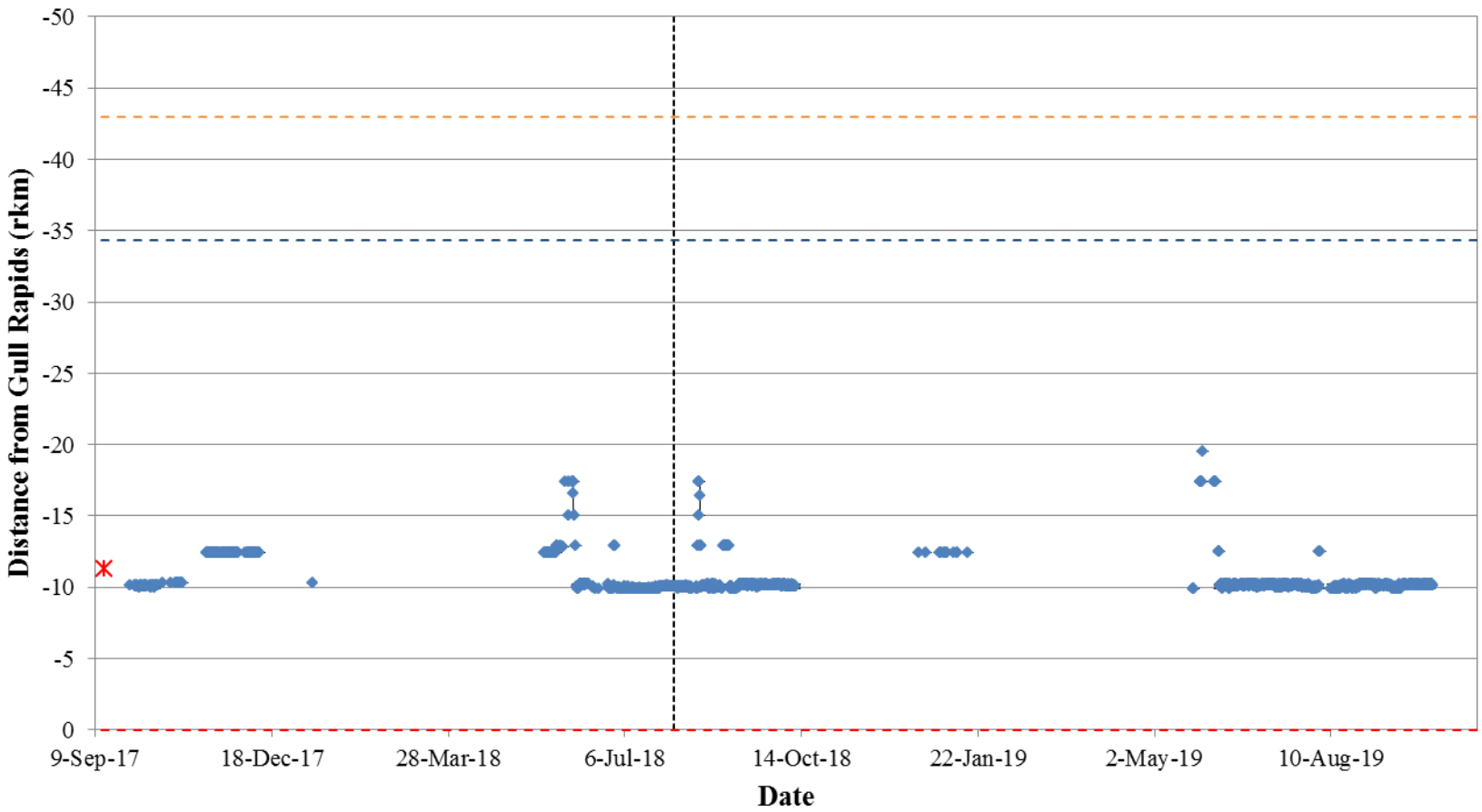


Figure A1-6: Position of a Lake Sturgeon tagged with an acoustic transmitter (code #31768) in Gull Lake in relation to the Keeyask GS (rkm 0), from September 9, 2017 to October 7, 2019. Date and location of tagging is indicated by a red X. Error bars are shown in solid black. Horizontal dashed lines indicate the positions of Keeyask GS (red), Birthday Rapids (blue), and the entrance to Clark Lake (orange). Dashed black vertical line indicates start of spillway operation (Aug 3, 2018).

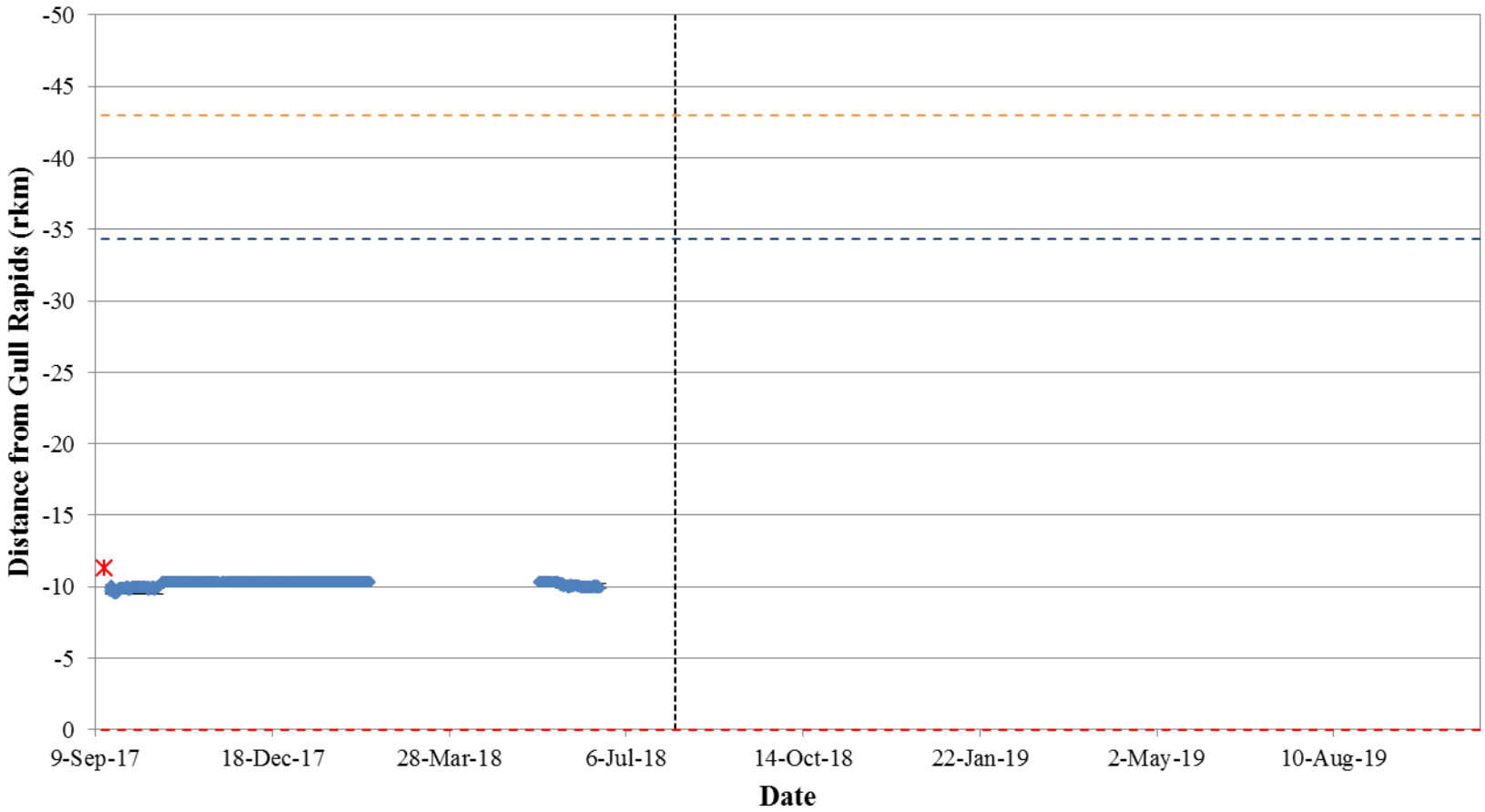


Figure A1-7: Position of a Lake Sturgeon tagged with an acoustic transmitter (code #31769) in Gull Lake in relation to the Keeyask GS (rkm 0), from September 9, 2017 to October 7, 2019. Date and location of tagging is indicated by a red X. Error bars are shown in solid black. Horizontal dashed lines indicate the positions of Keeyask GS (red), Birthday Rapids (blue), and the entrance to Clark Lake (orange). Dashed black vertical line indicates start of spillway operation (Aug 3, 2018).

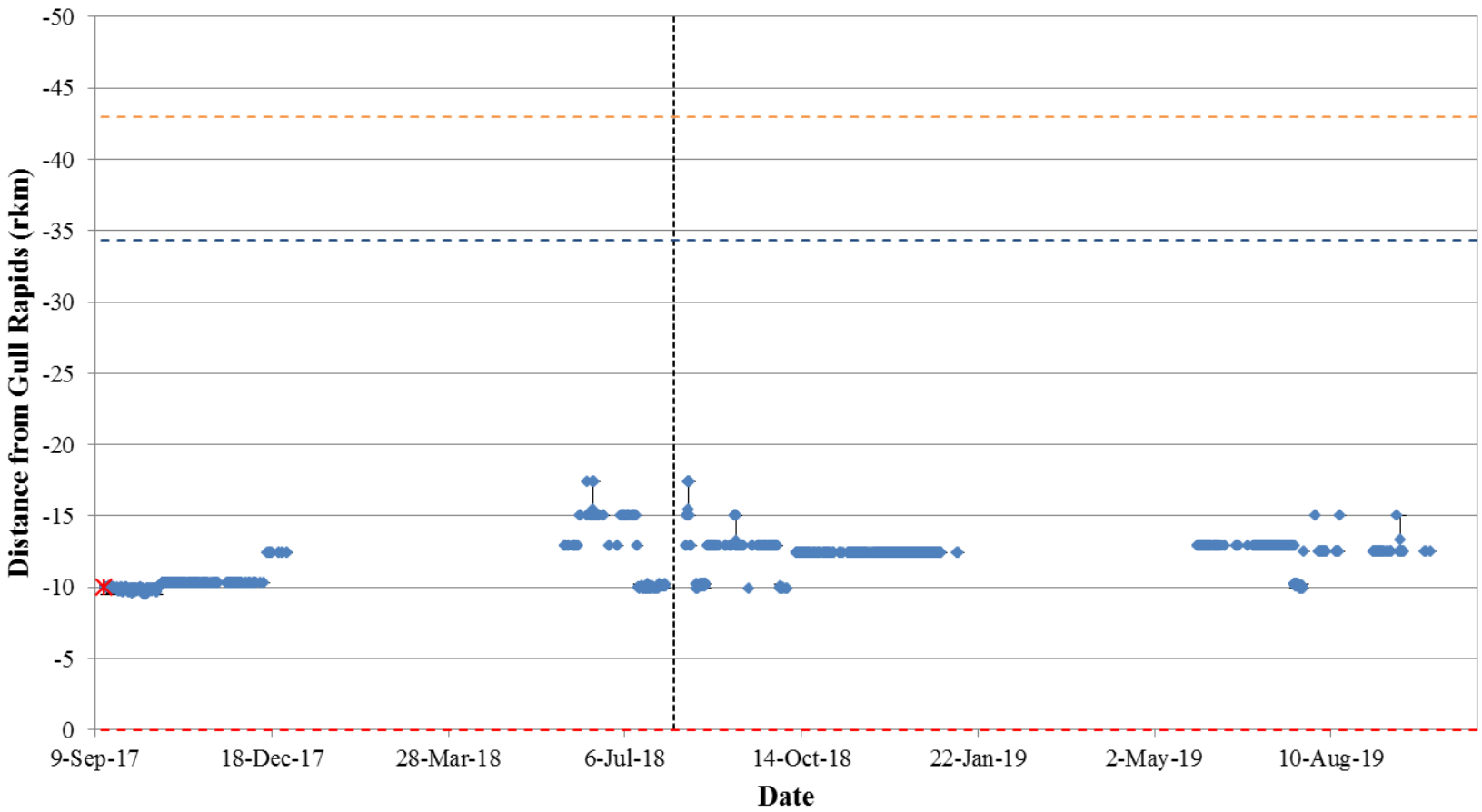


Figure A1-8: Position of a Lake Sturgeon tagged with an acoustic transmitter (code #31770) in Gull Lake in relation to the Keeyask GS (rkm 0), from September 9, 2017 to October 7, 2019. Date and location of tagging is indicated by a red X. Error bars are shown in solid black. Horizontal dashed lines indicate the positions of Keeyask GS (red), Birthday Rapids (blue), and the entrance to Clark Lake (orange). Dashed black vertical line indicates start of spillway operation (Aug 3, 2018).

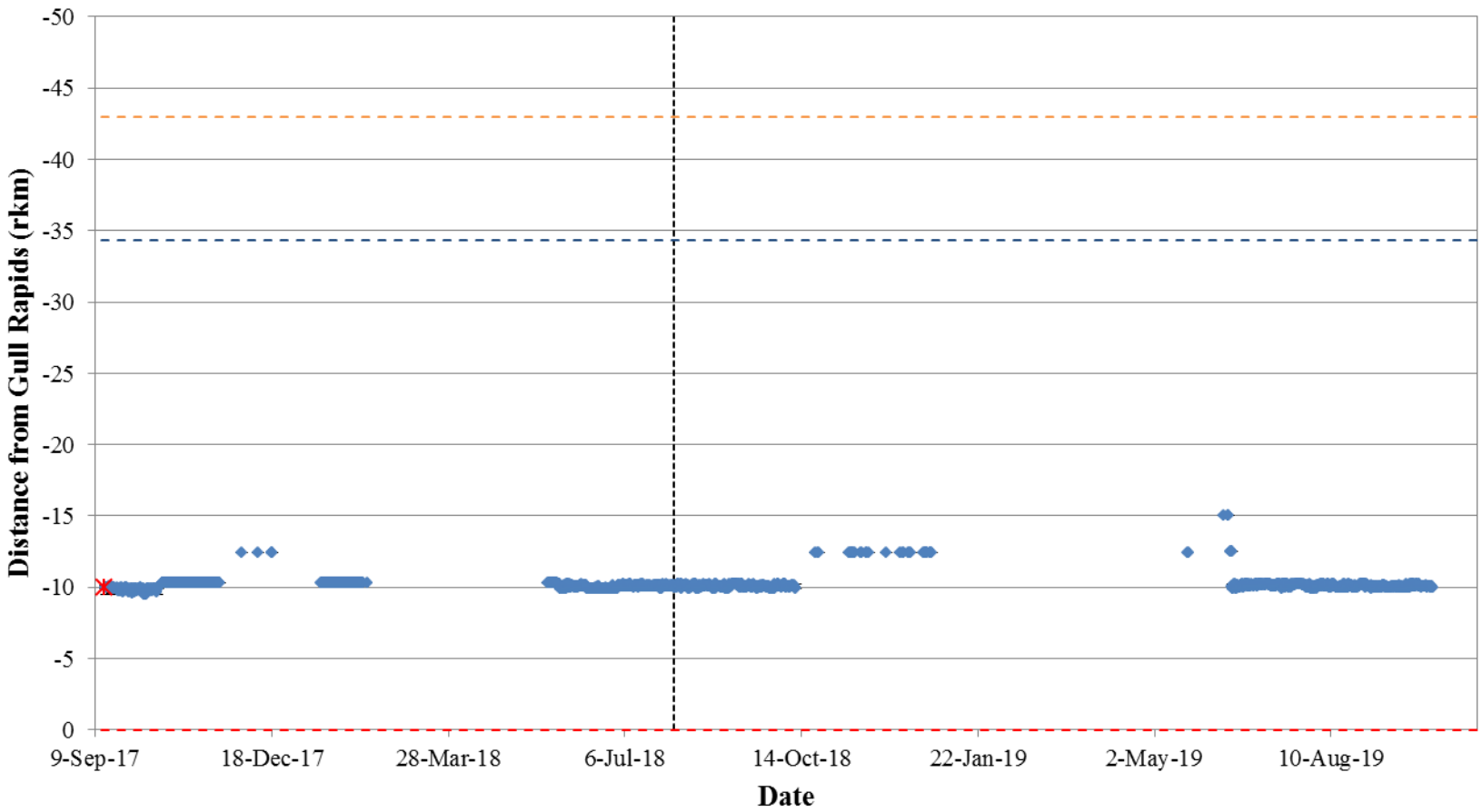


Figure A1-9: Position of a Lake Sturgeon tagged with an acoustic transmitter (code #31771) in Gull Lake in relation to the Keeyask GS (rkm 0), from September 9, 2017 to October 7, 2019. Date and location of tagging is indicated by a red X. Error bars are shown in solid black. Horizontal dashed lines indicate the positions of Keeyask GS (red), Birthday Rapids (blue), and the entrance to Clark Lake (orange). Dashed black vertical line indicates start of spillway operation (Aug 3, 2018).

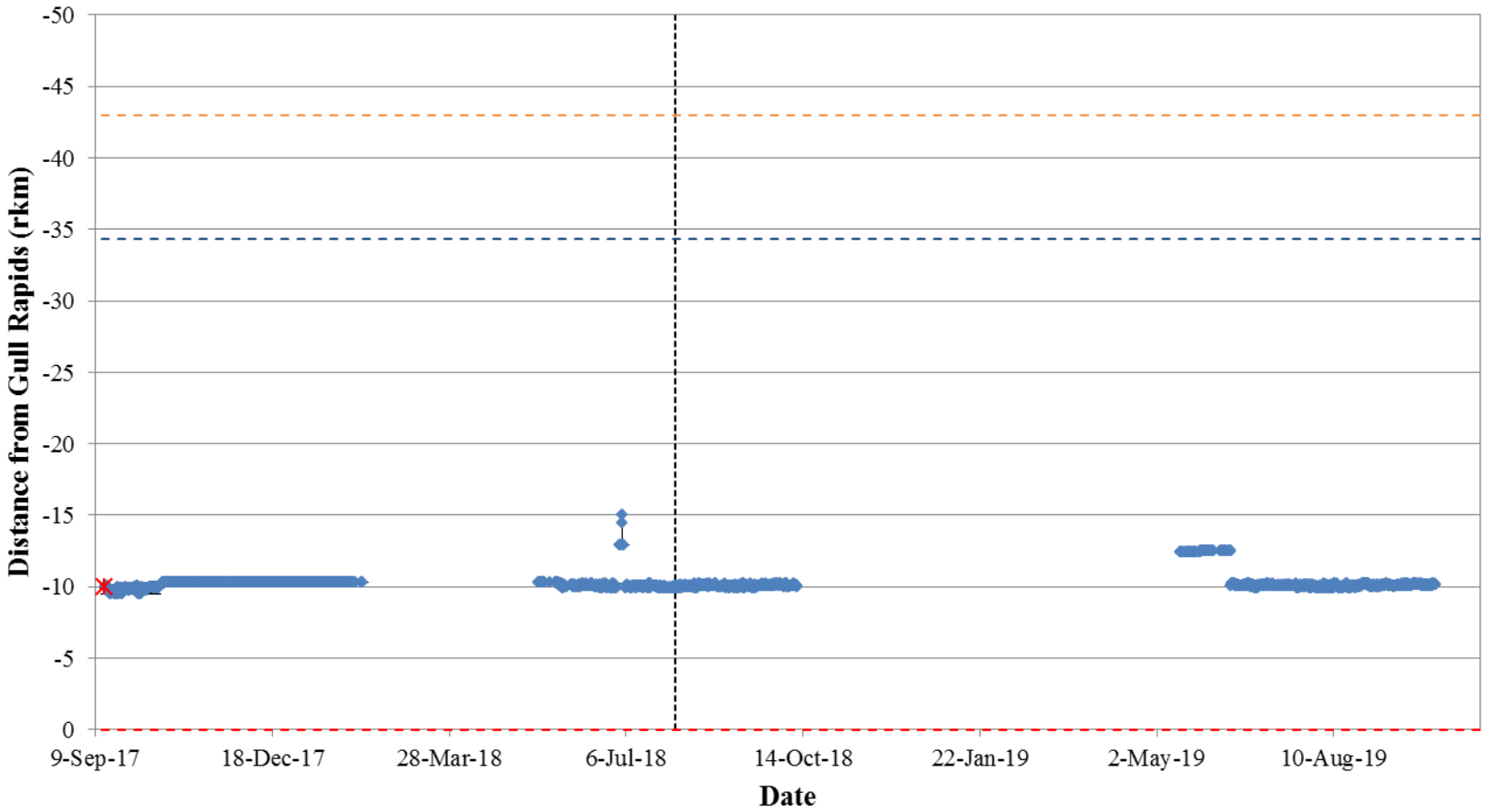


Figure A1-10: Position of a Lake Sturgeon tagged with an acoustic transmitter (code #31772) in Gull Lake in relation to the Keeyask GS (rkm 0), from September 9, 2017 to October 7, 2019. Date and location of tagging is indicated by a red X. Error bars are shown in solid black. Horizontal dashed lines indicate the positions of Keeyask GS (red), Birthday Rapids (blue), and the entrance to Clark Lake (orange). Dashed black vertical line indicates start of spillway operation (Aug 3, 2018).

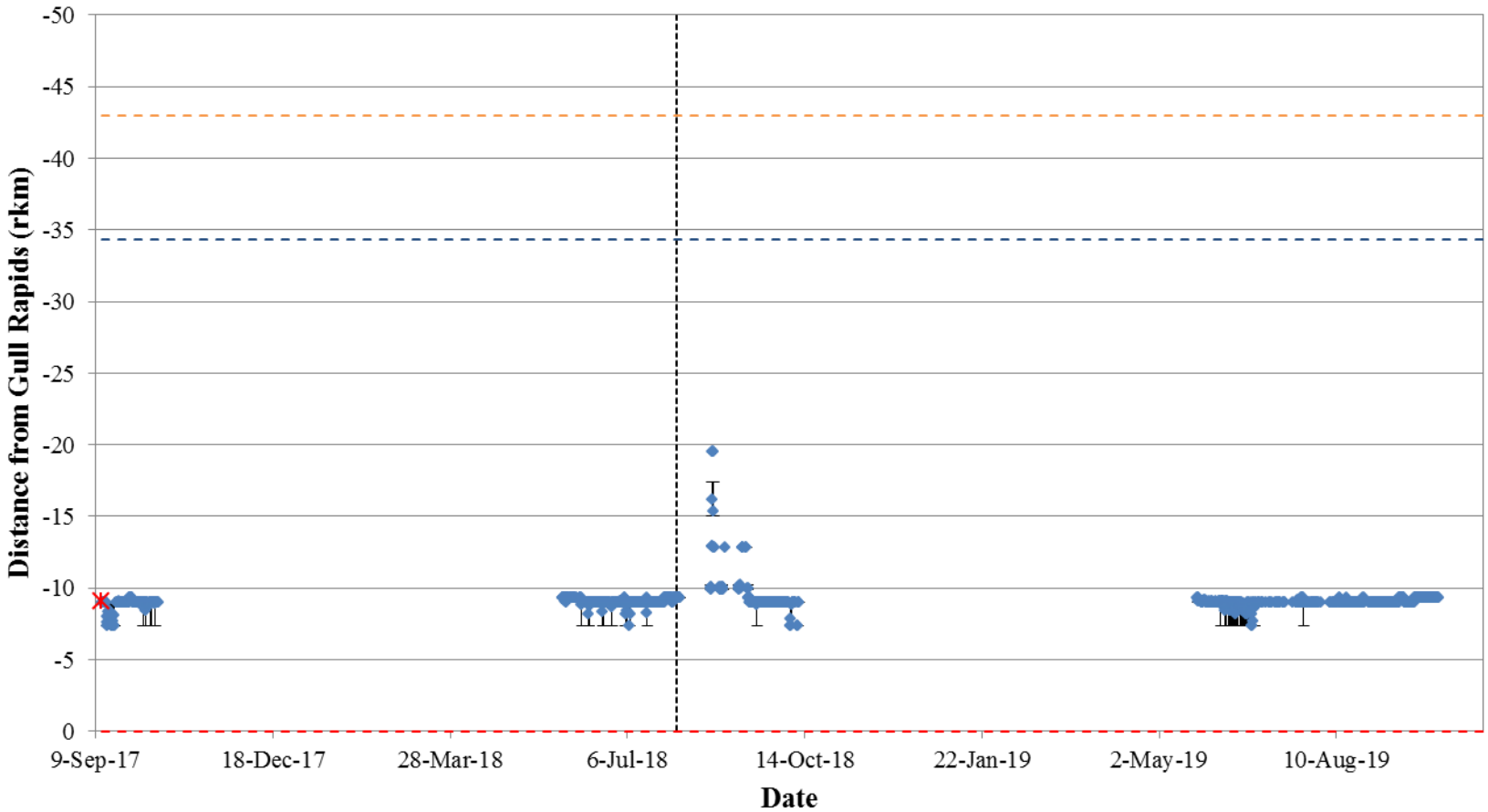


Figure A1-11: Position of a Lake Sturgeon tagged with an acoustic transmitter (code #31773) in Gull Lake in relation to the Keeyask GS (rkm 0), from September 9, 2017 to October 7, 2019. Date and location of tagging is indicated by a red X. Error bars are shown in solid black. Horizontal dashed lines indicate the positions of Keeyask GS (red), Birthday Rapids (blue), and the entrance to Clark Lake (orange). Dashed black vertical line indicates start of spillway operation (Aug 3, 2018).

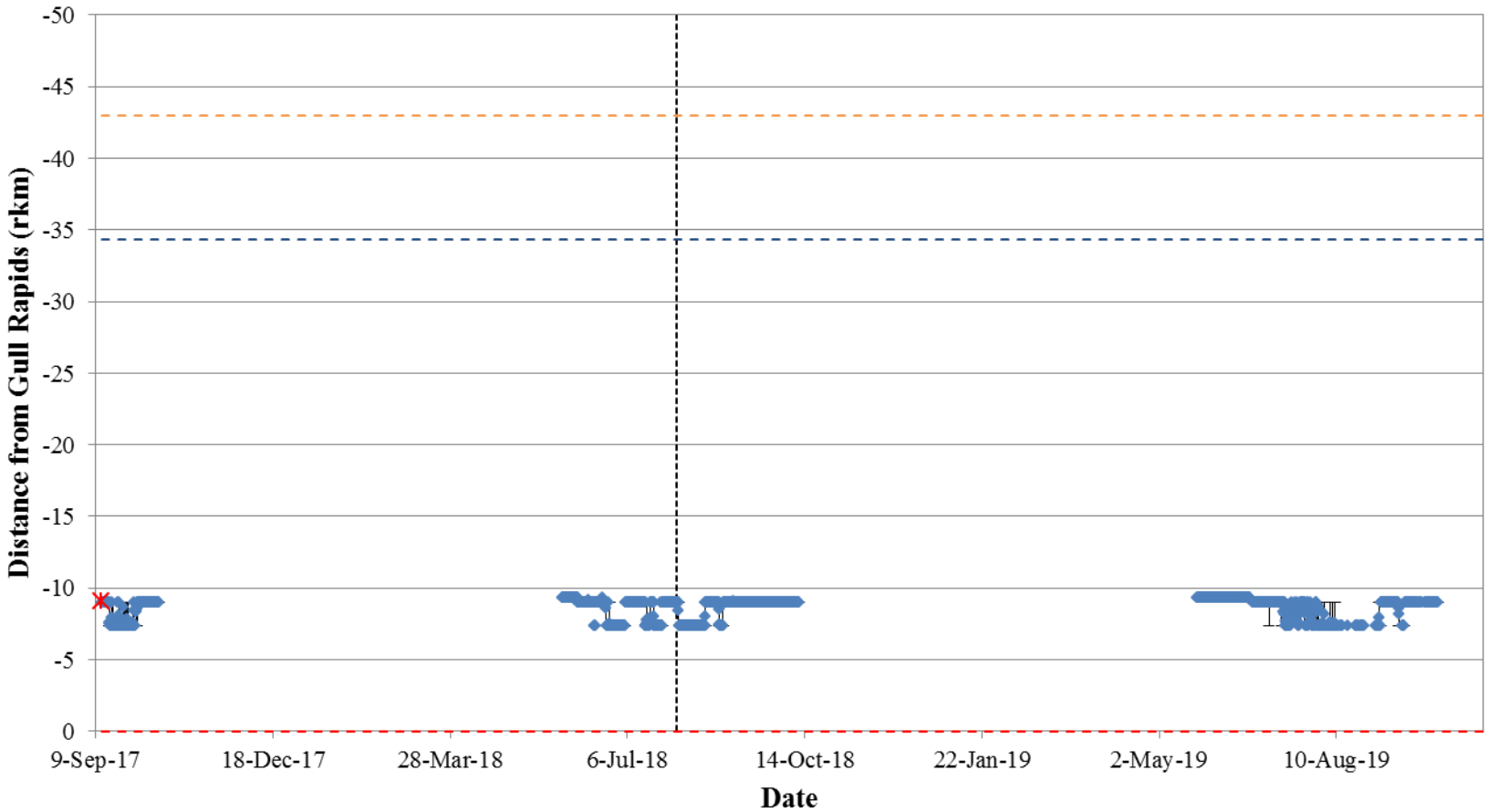


Figure A1-12: Position of a Lake Sturgeon tagged with an acoustic transmitter (code #31774) in Gull Lake in relation to the Keeyask GS (rkm 0), from September 9, 2017 to October 7, 2019. Date and location of tagging is indicated by a red X. Horizontal dashed lines indicate the positions of Keeyask GS (red), Birthday Rapids (blue), and the entrance to Clark Lake (orange). Dashed black vertical line indicates start of spillway operation (Aug 3, 2018).

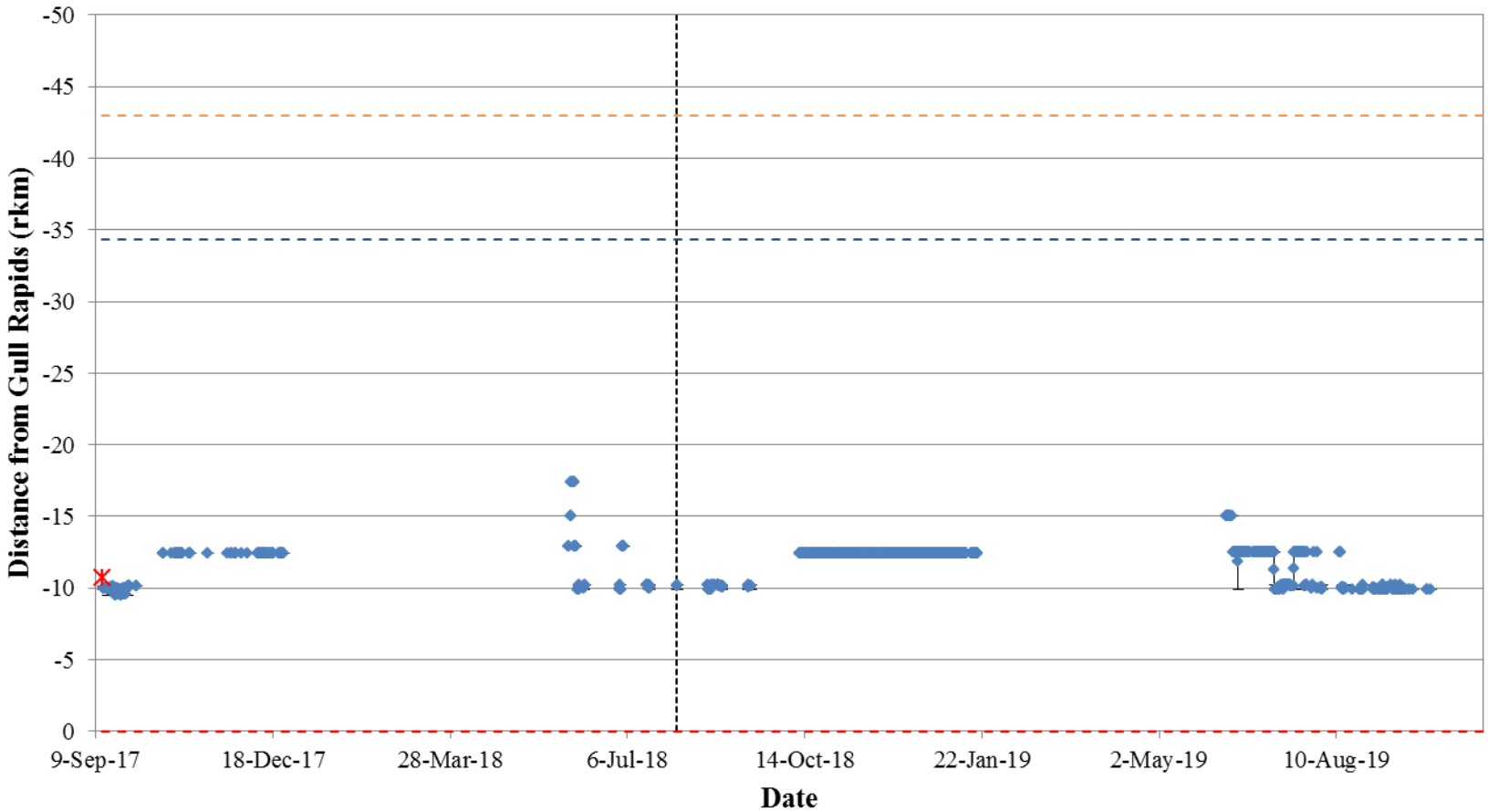


Figure A1-13: Position of a Lake Sturgeon tagged with an acoustic transmitter (code #31775) in Gull Lake in relation to the Keeyask GS (rkm 0), from September 9, 2017 to October 7, 2019. Date and location of tagging is indicated by a red X. Error bars are shown in solid black. Horizontal dashed lines indicate the positions of Keeyask GS (red), Birthday Rapids (blue), and the entrance to Clark Lake (orange). Dashed black vertical line indicates start of spillway operation (Aug 3, 2018).

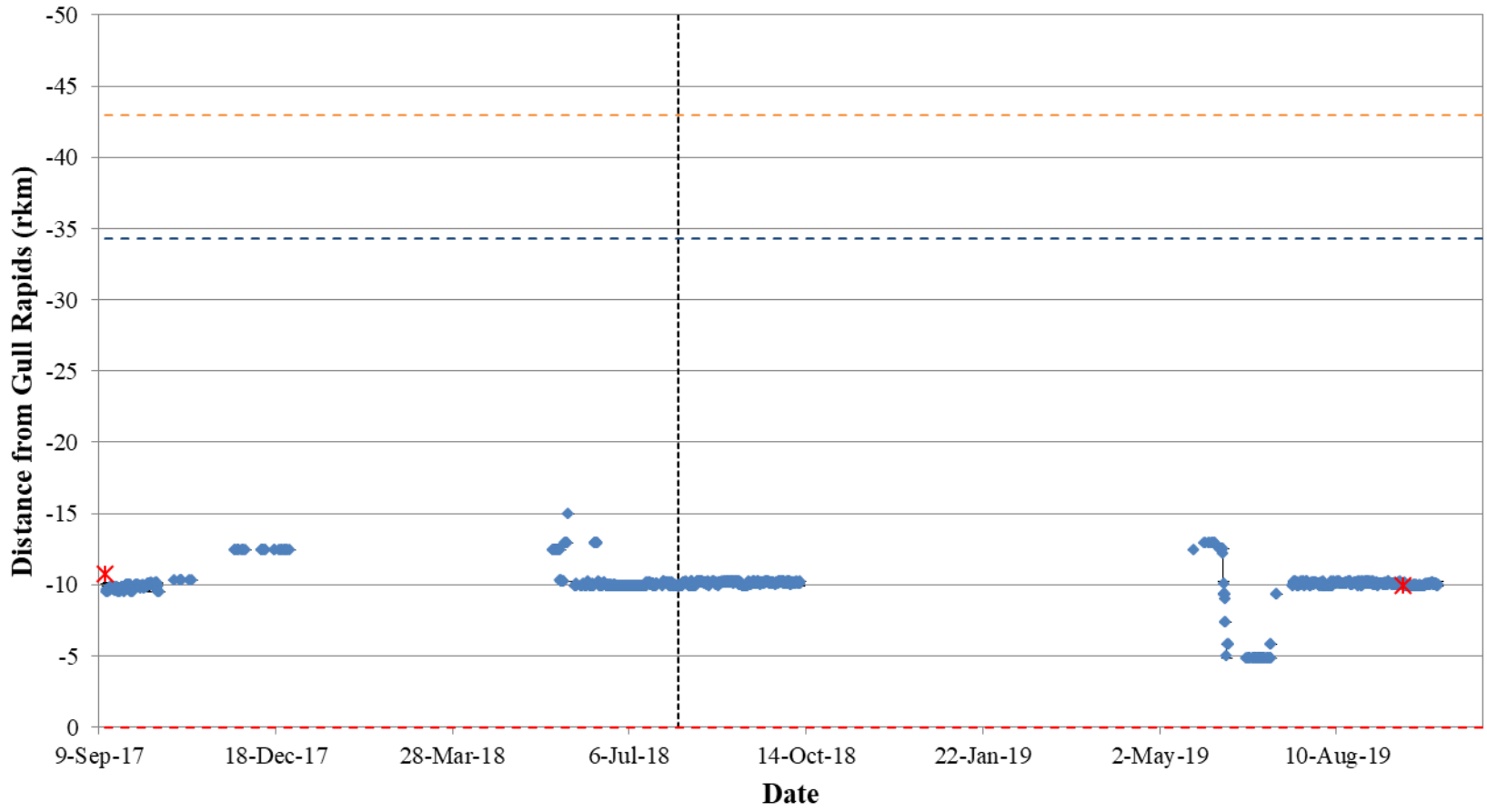


Figure A1-14: Position of a Lake Sturgeon tagged with an acoustic transmitter (code #31776) in Gull Lake in relation to the Keeyask GS (rkm 0), from September 9, 2017 to October 7, 2019. Date and location of tagging and subsequent recapture are indicated by a red X. Error bars are shown in solid black. Horizontal dashed lines indicate the positions of Keeyask GS (red), Birthday Rapids (blue), and the entrance to Clark Lake (orange). Dashed black vertical line indicates start of spillway operation (Aug 3, 2018).

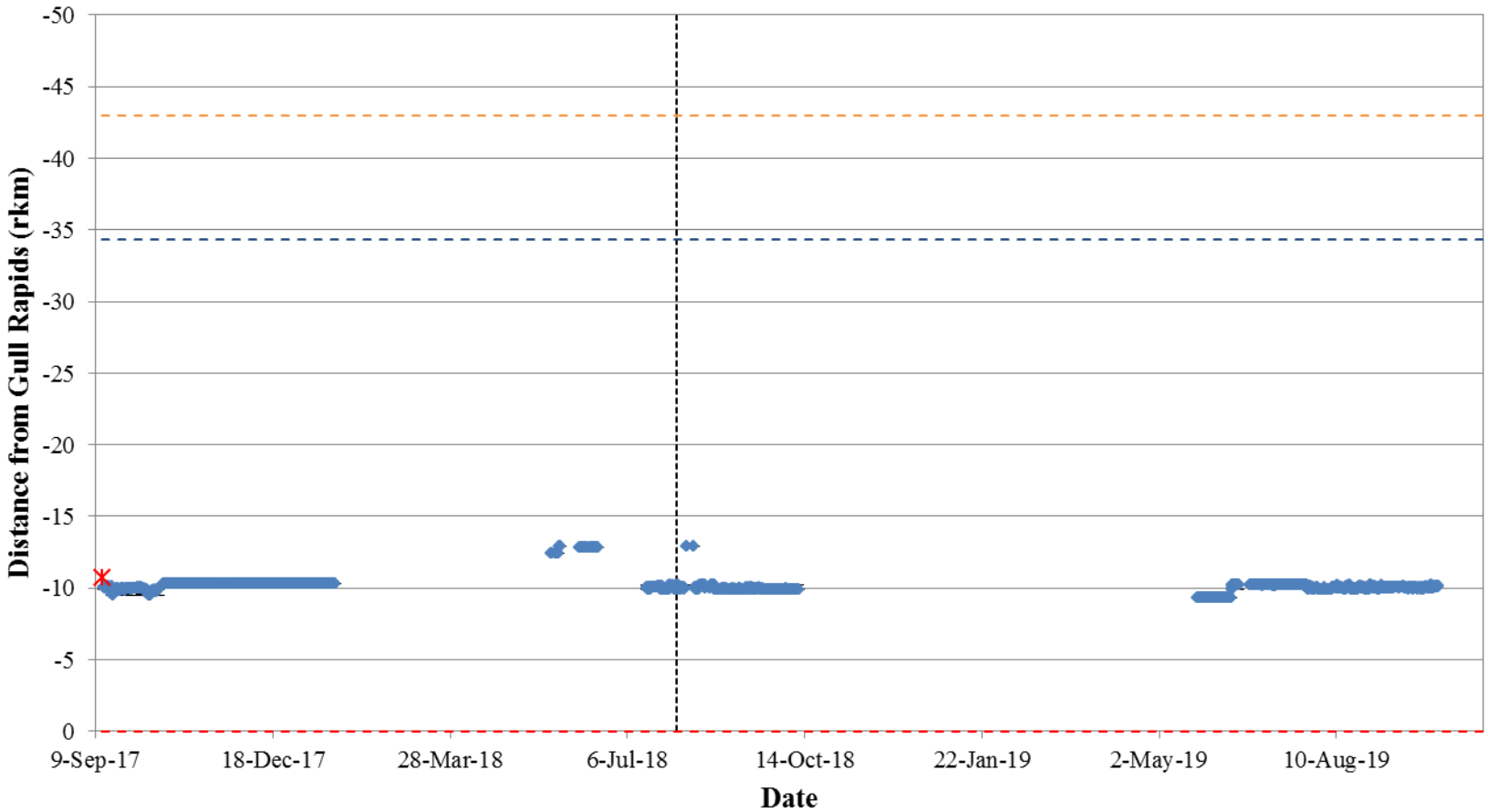


Figure A1-15: Position of a Lake Sturgeon tagged with an acoustic transmitter (code #31777) in Gull Lake in relation to the Keeyask GS (rkm 0), from September 9, 2017 to October 7, 2019. Date and location of tagging is indicated by a red X. Error bars are shown in solid black. Horizontal dashed lines indicate the positions of Keeyask GS (red), Birthday Rapids (blue), and the entrance to Clark Lake (orange). Dashed black vertical line indicates start of spillway operation (Aug 3, 2018).

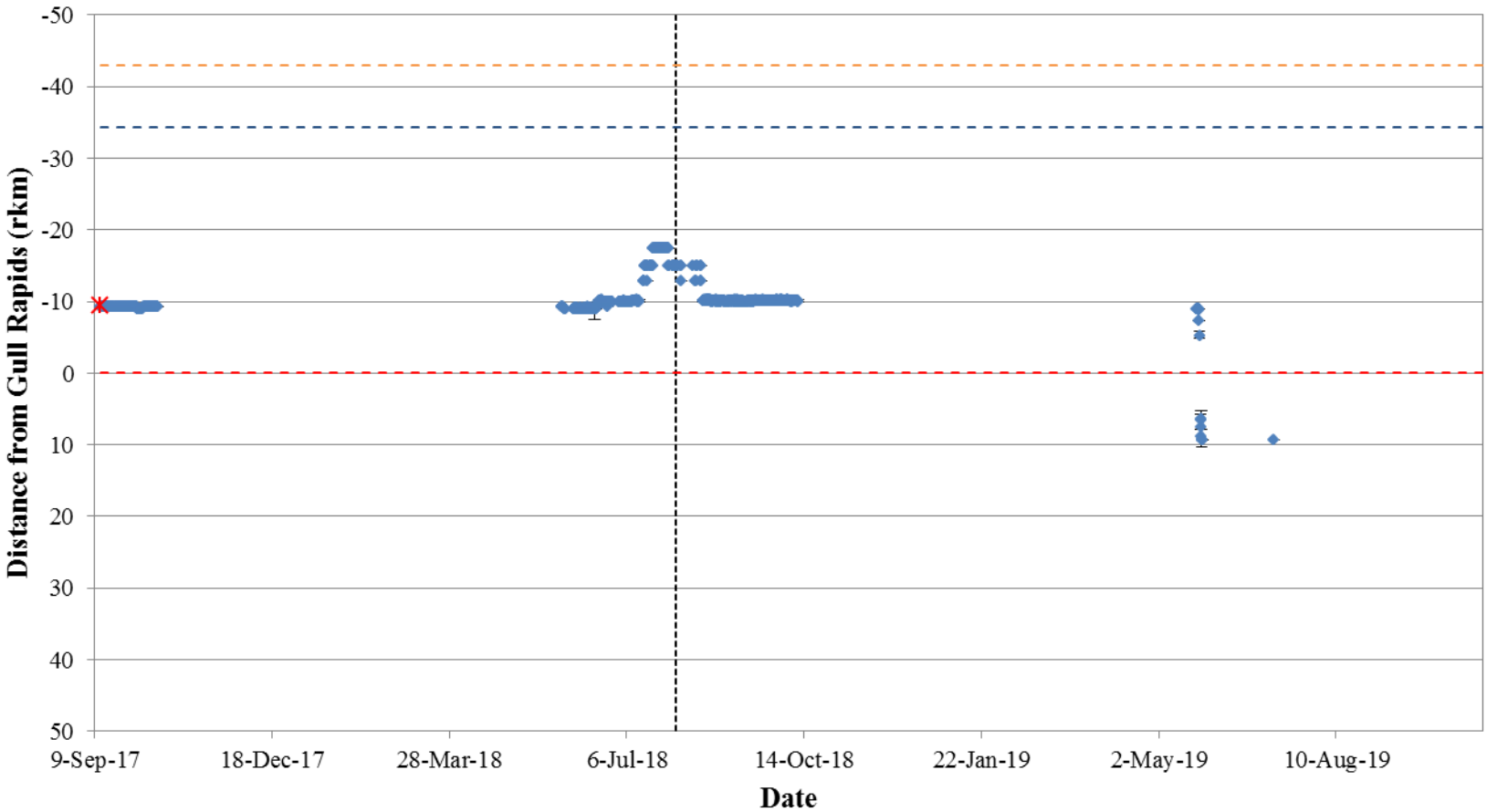


Figure A1-16: Position of a Lake Sturgeon tagged with an acoustic transmitter (code #31778) in Gull Lake in relation to the Keeyask GS (rkm 0), from September 9, 2017 to October 7, 2019. Date and location of tagging is indicated by a red X. Error bars are shown in solid black. Horizontal dashed lines indicate the positions of Keeyask GS (red), Birthday Rapids (blue), and the entrance to Clark Lake (orange). Dashed black vertical line indicates start of spillway operation (Aug 3, 2018).

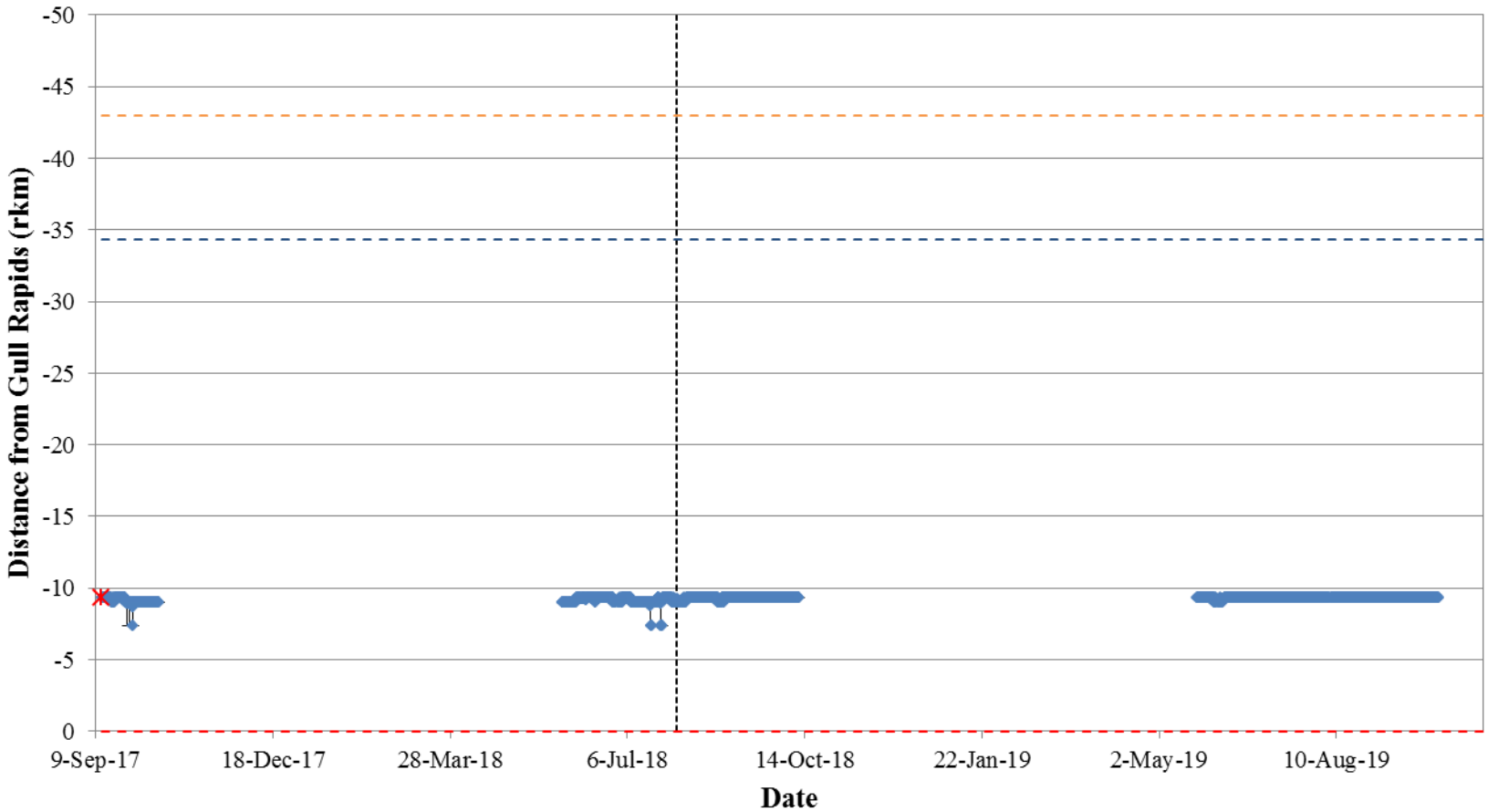


Figure A1-17: Position of a Lake Sturgeon tagged with an acoustic transmitter (code #31779) in Gull Lake in relation to the Keeyask GS (rkm 0), from September 9, 2017 to October 7, 2019. Date and location of tagging is indicated by a red X. Error bars are shown in solid black. Horizontal dashed lines indicate the positions of Keeyask GS (red), Birthday Rapids (blue), and the entrance to Clark Lake (orange). Dashed black vertical line indicates start of spillway operation (Aug 3, 2018).

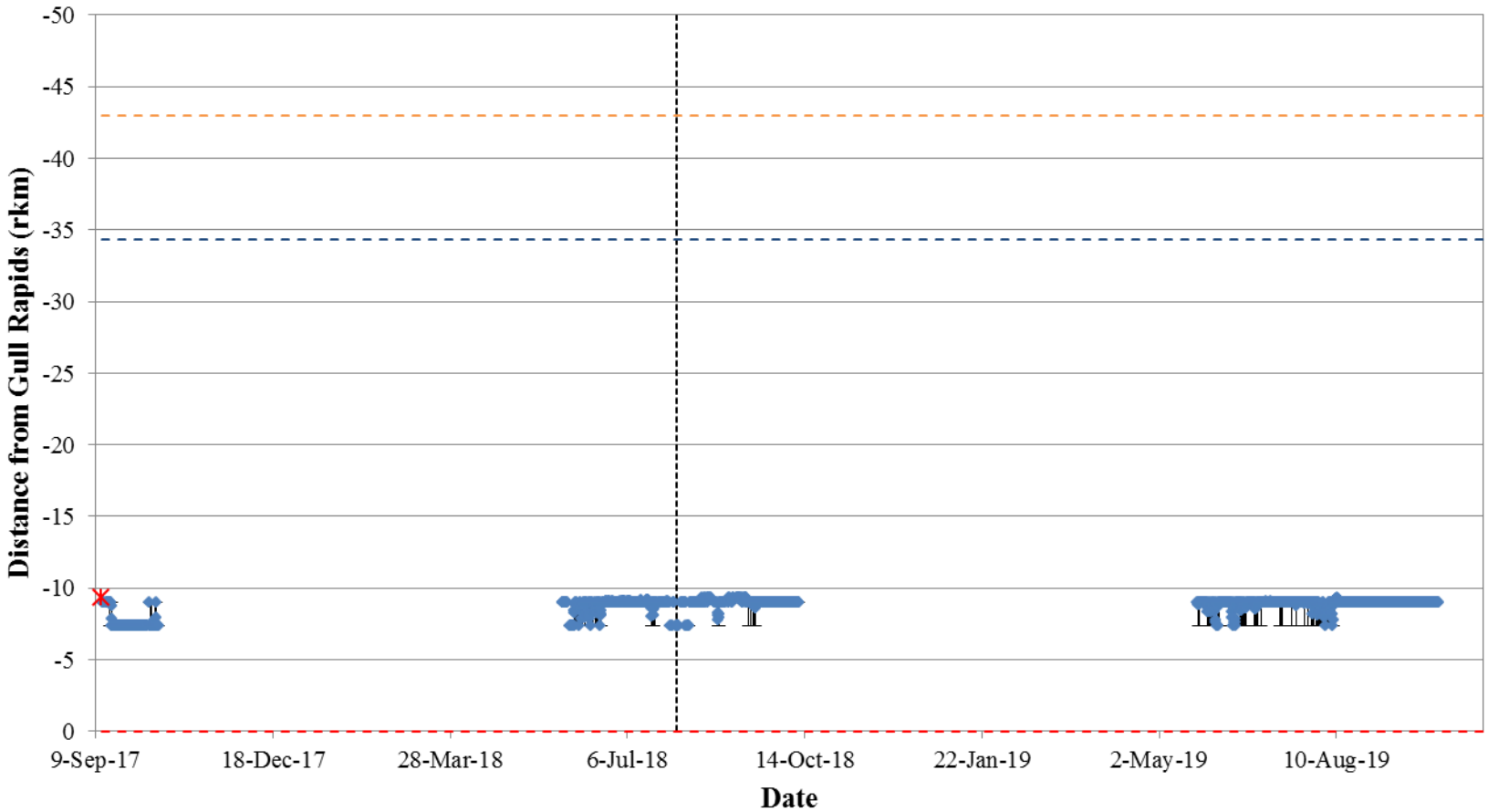


Figure A1-18: Position of a Lake Sturgeon tagged with an acoustic transmitter (code #31780) in Gull Lake in relation to the Keeyask GS (rkm 0), from September 9, 2017 to October 7, 2019. Date and location of tagging is indicated by a red X. Error bars are shown in solid black. Horizontal dashed lines indicate the positions of Keeyask GS (red), Birthday Rapids (blue), and the entrance to Clark Lake (orange). Dashed black vertical line indicates start of spillway operation (Aug 3, 2018).

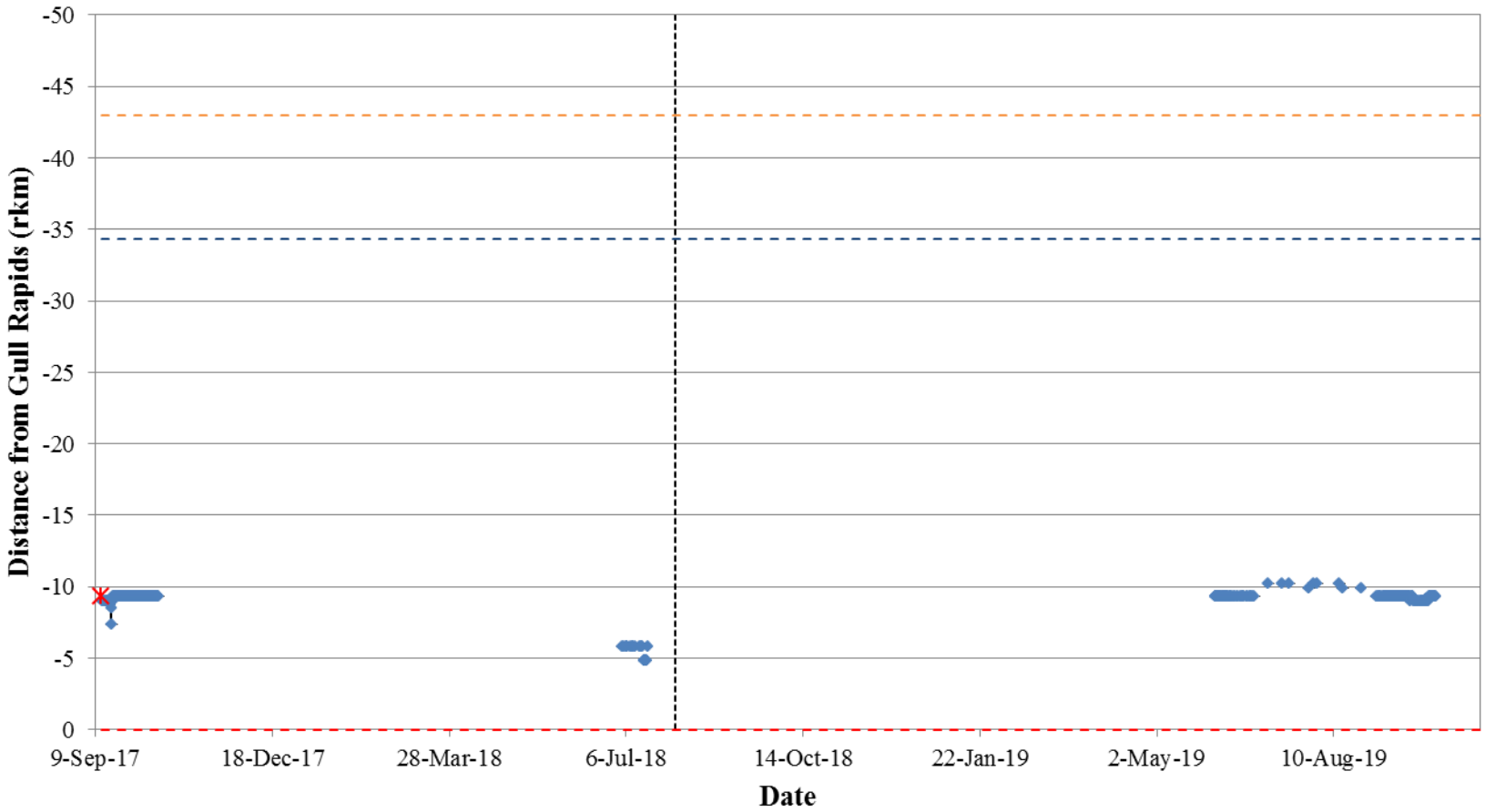


Figure A1-19: Position of a Lake Sturgeon tagged with an acoustic transmitter (code #31781) in Gull Lake in relation to the Keeyask GS (rkm 0), from September 9, 2017 to October 7, 2019. Date and location of tagging is indicated by a red X. Error bars are shown in solid black. Horizontal dashed lines indicate the positions of Keeyask GS (red), Birthday Rapids (blue), and the entrance to Clark Lake (orange). Dashed black vertical line indicates start of spillway operation (Aug 3, 2018).

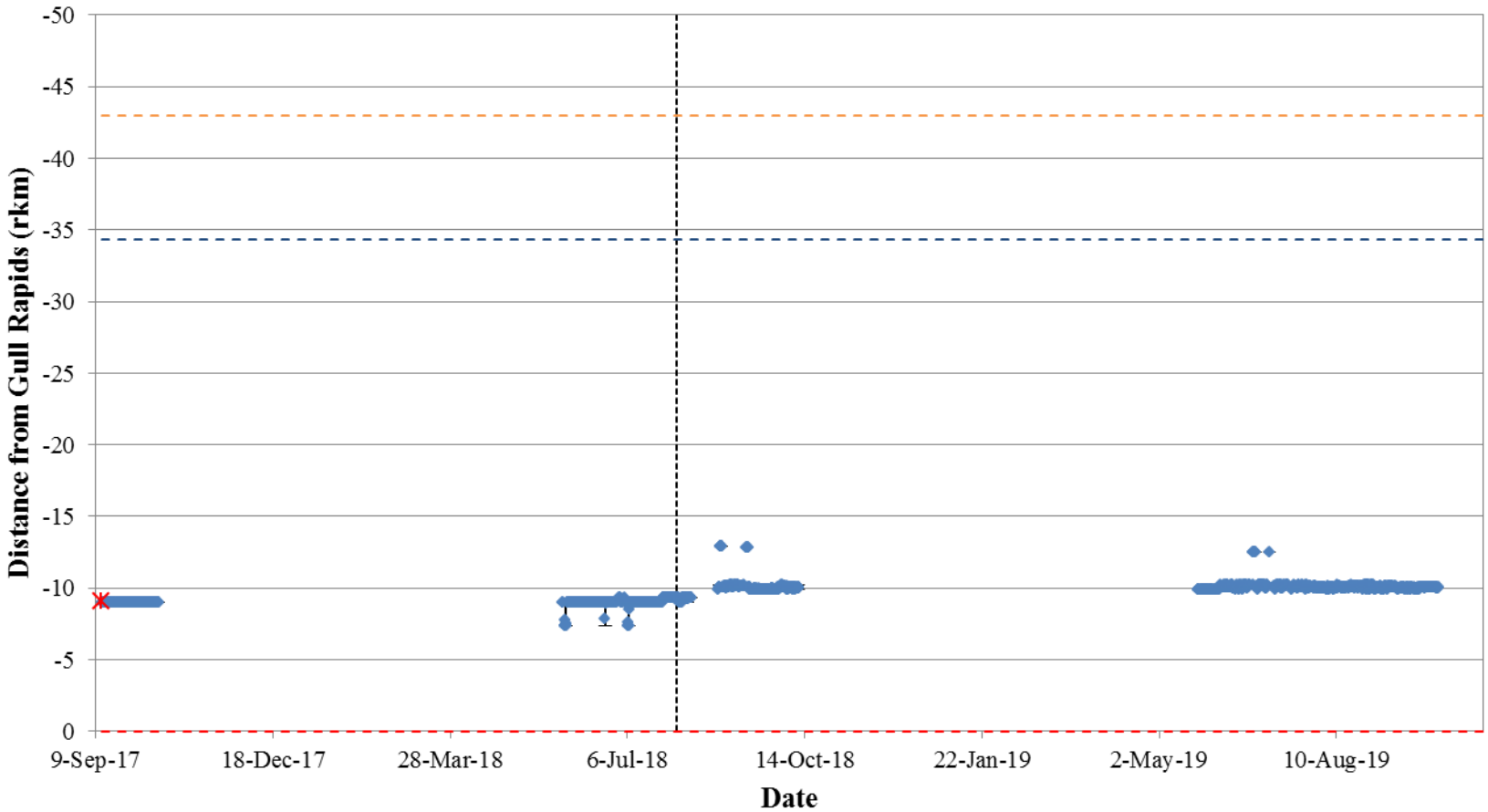


Figure A1-20: Position of a Lake Sturgeon tagged with an acoustic transmitter (code #31782) in Gull Lake in relation to the Keeyask GS (rkm 0), from September 9, 2017 to October 7, 2019. Date and location of tagging is indicated by a red X. Error bars are shown in solid black. Horizontal dashed lines indicate the positions of Keeyask GS (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 THE KEEYASK GS, SEPTEMBER 2017 TO OCTOBER 2019

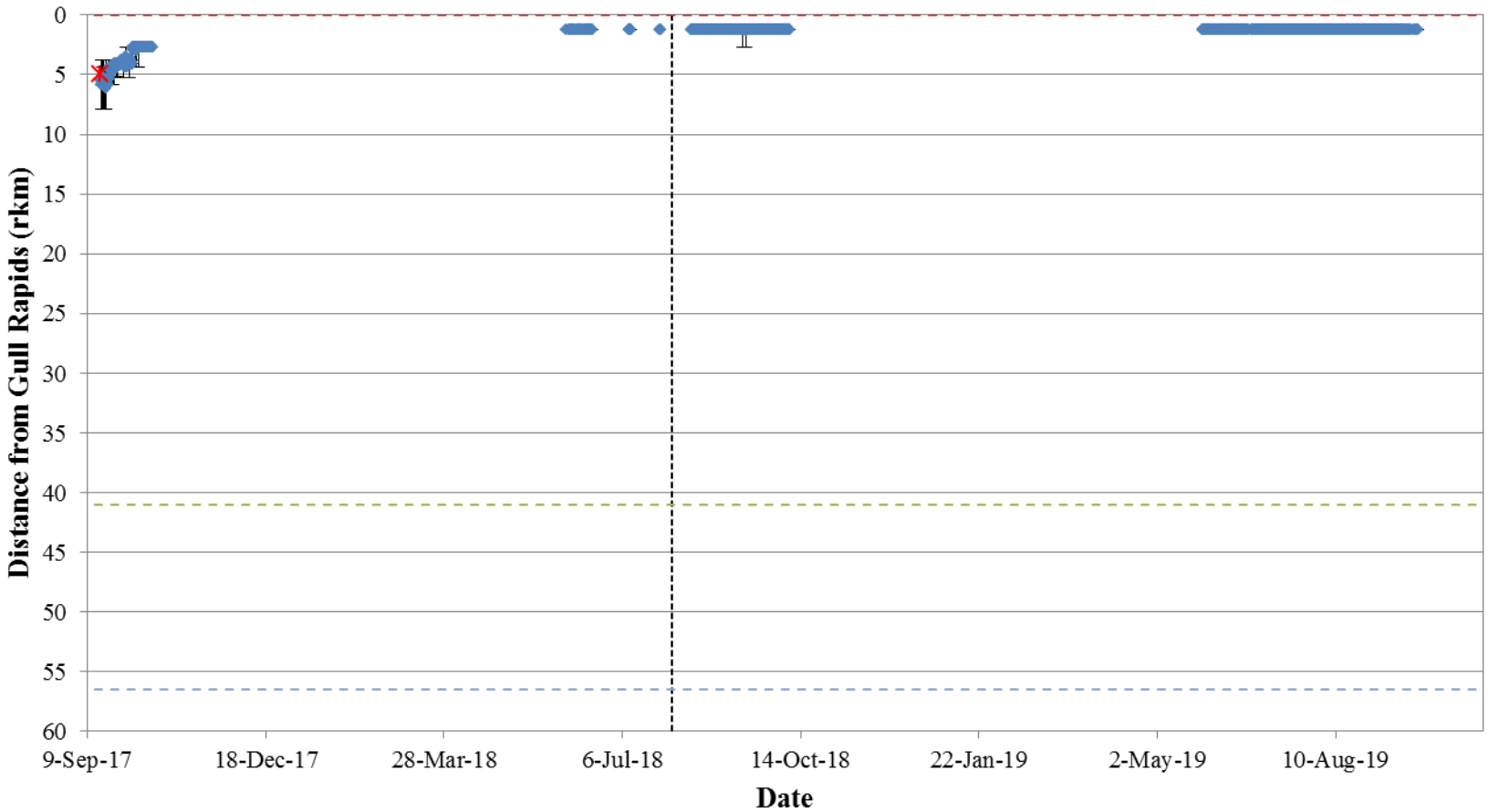


Figure A2-1: Position of a Lake Sturgeon tagged with an acoustic transmitter (code #31668) in Stephens Lake in relation to the Keeyask GS (rkm 0), 9 September 2017 to 7 October, 2019. Date and location of tagging is indicated in red. Error bars are shown in solid black. Horizontal dashed lines indicate the positions of Keeyask GS (red), Kettle GS (green), and Long Spruce GS (blue). Dashed black vertical line indicates start of spillway operation (Aug 3, 2018).

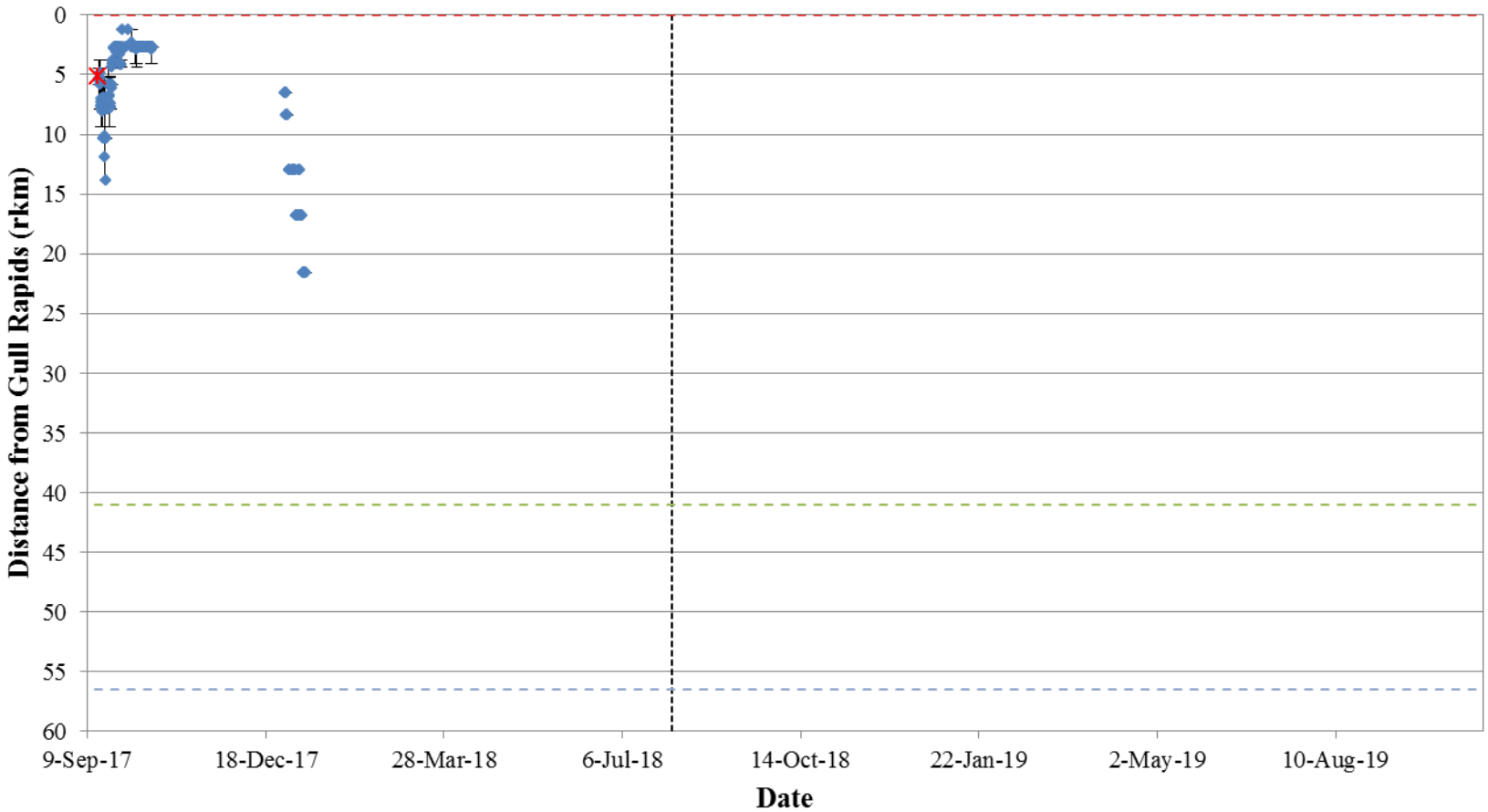


Figure A2-2: Position of a Lake Sturgeon tagged with an acoustic transmitter (code #31689) in Stephens Lake in relation to the Keeyask GS (rkm 0), from September 9, 2017 to October 7, 2019. Date and location of tagging is indicated in red. Error bars are shown in solid black. Horizontal dashed lines indicate the positions of Keeyask GS (red), Kettle GS (green), and Long Spruce GS (purple). Dashed black vertical line indicates start of spillway operation (Aug 3, 2018).

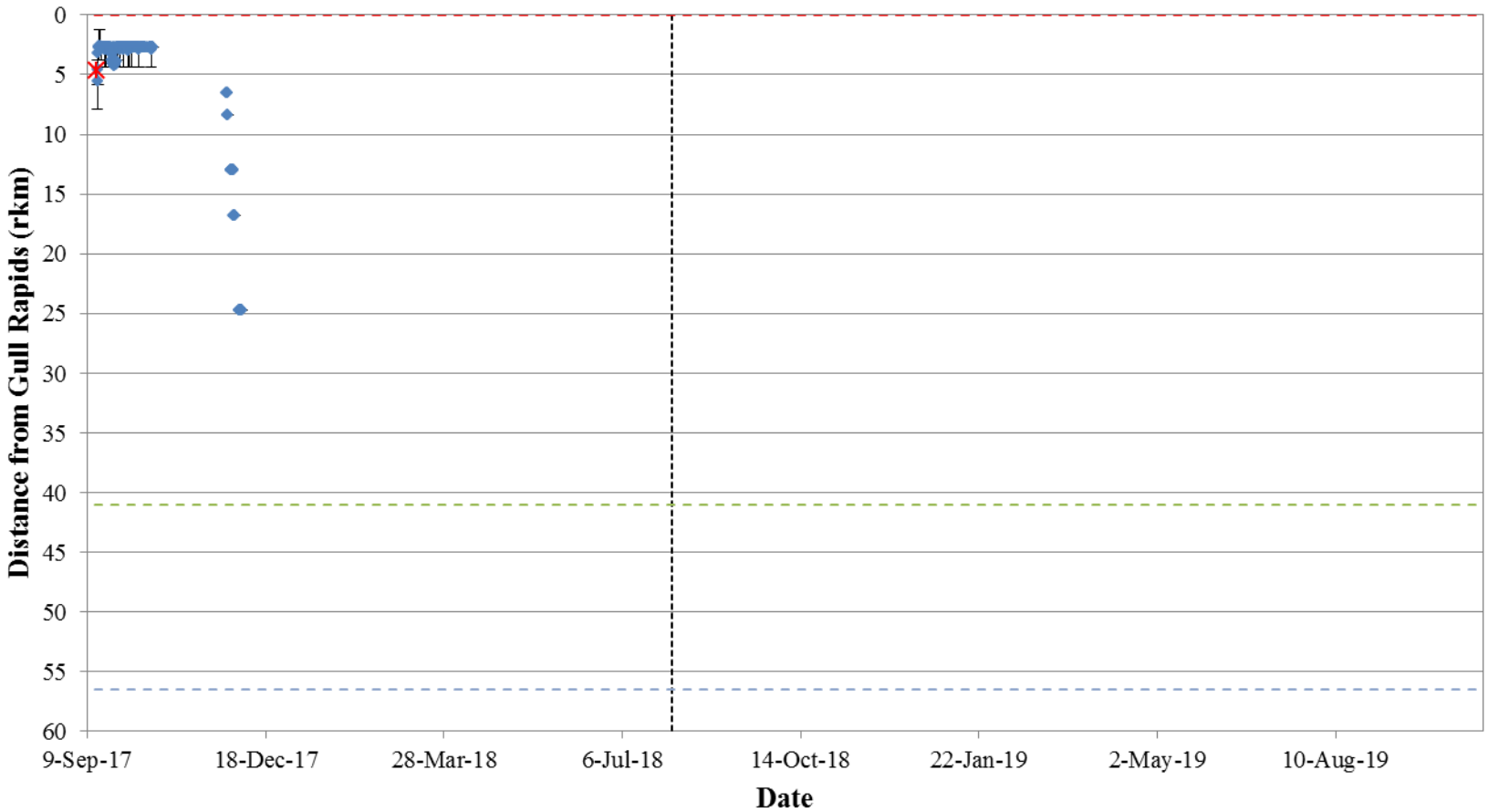


Figure A2-3: Position of a Lake Sturgeon tagged with an acoustic transmitter (code #31690) in Stephens Lake in relation to the Keeyask GS (rkm 0), from September 9, 2017 to October 7, 2019. Date and location of tagging is indicated in red. Error bars are shown in solid black. Horizontal dashed lines indicate the positions of Keeyask GS (red), Kettle GS (green), and Long Spruce GS (purple). Dashed black vertical line indicates start of spillway operation (Aug 3, 2018).

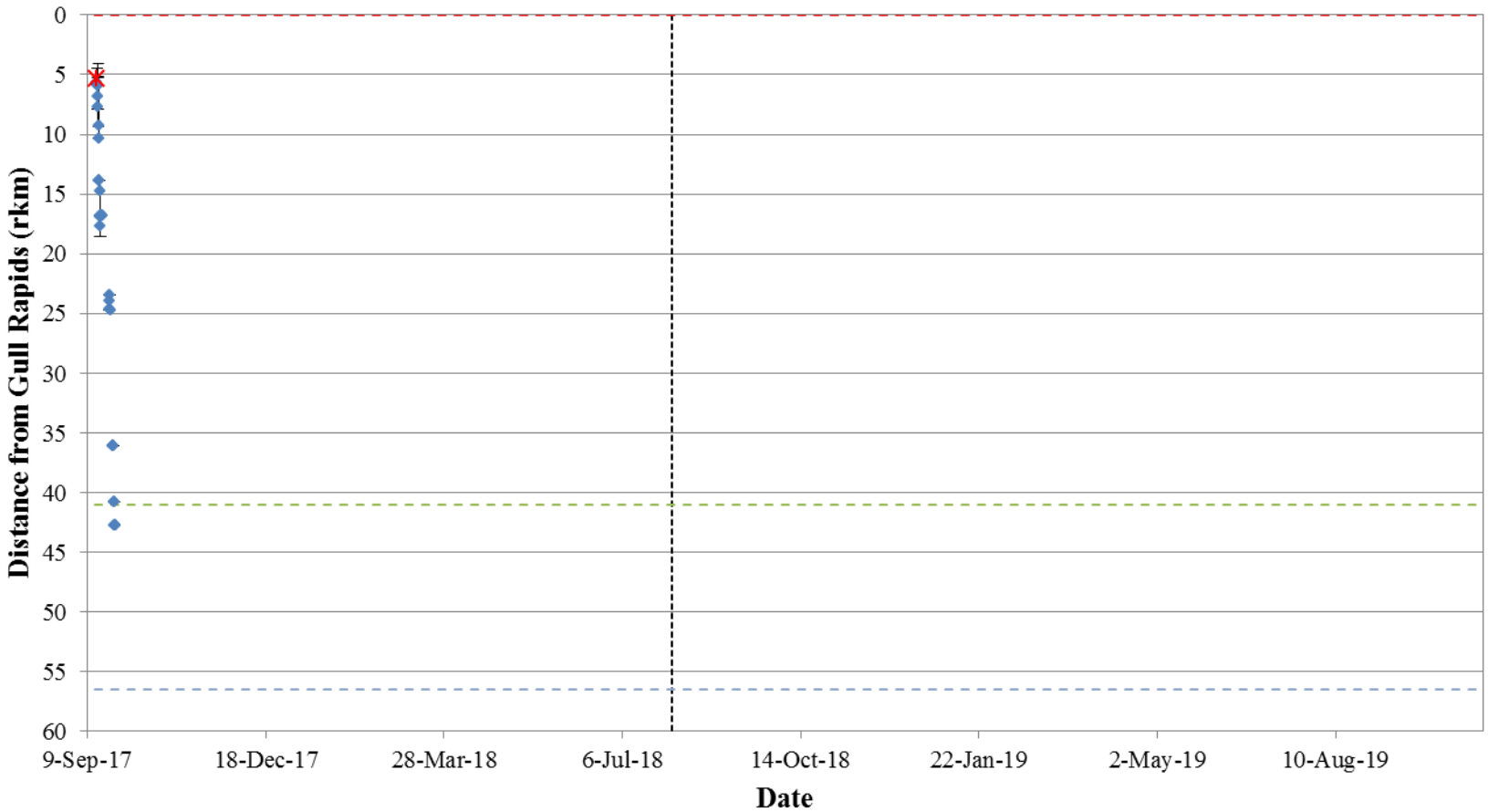


Figure A2-4: Position of a Lake Sturgeon tagged with an acoustic transmitter (code #31691) in Stephens Lake in relation to the Keeyask GS (rkm 0), from September 9, 2017 to October 7, 2019. Date and location of tagging is indicated in red. Error bars are shown in solid black. Horizontal dashed lines indicate the positions of Keeyask GS (red), Kettle GS (green), and Long Spruce GS (purple). Dashed black vertical line indicates start of spillway operation (Aug 3, 2018).

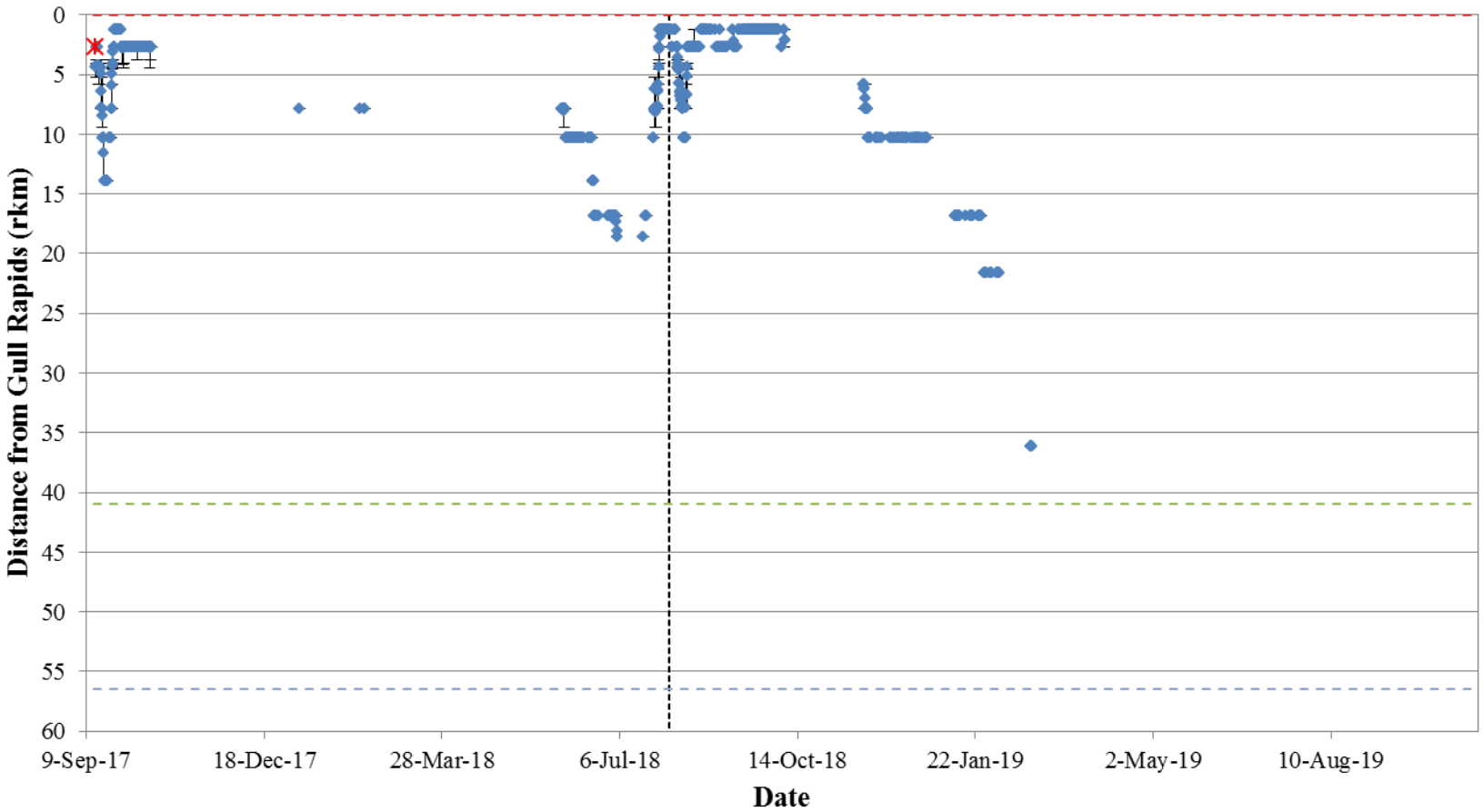


Figure A2-5: Position of a Lake Sturgeon tagged with an acoustic transmitter (code #31692) in Stephens Lake in relation to the Keeyask GS (rkm 0), from September 9, 2017 to October 7, 2019. Date and location of tagging is indicated in red. Error bars are shown in solid black. Horizontal dashed lines indicate the positions of Keeyask GS (red), Kettle GS (green), and Long Spruce GS (purple). Dashed black vertical line indicates start of spillway operation (Aug 3, 2018).

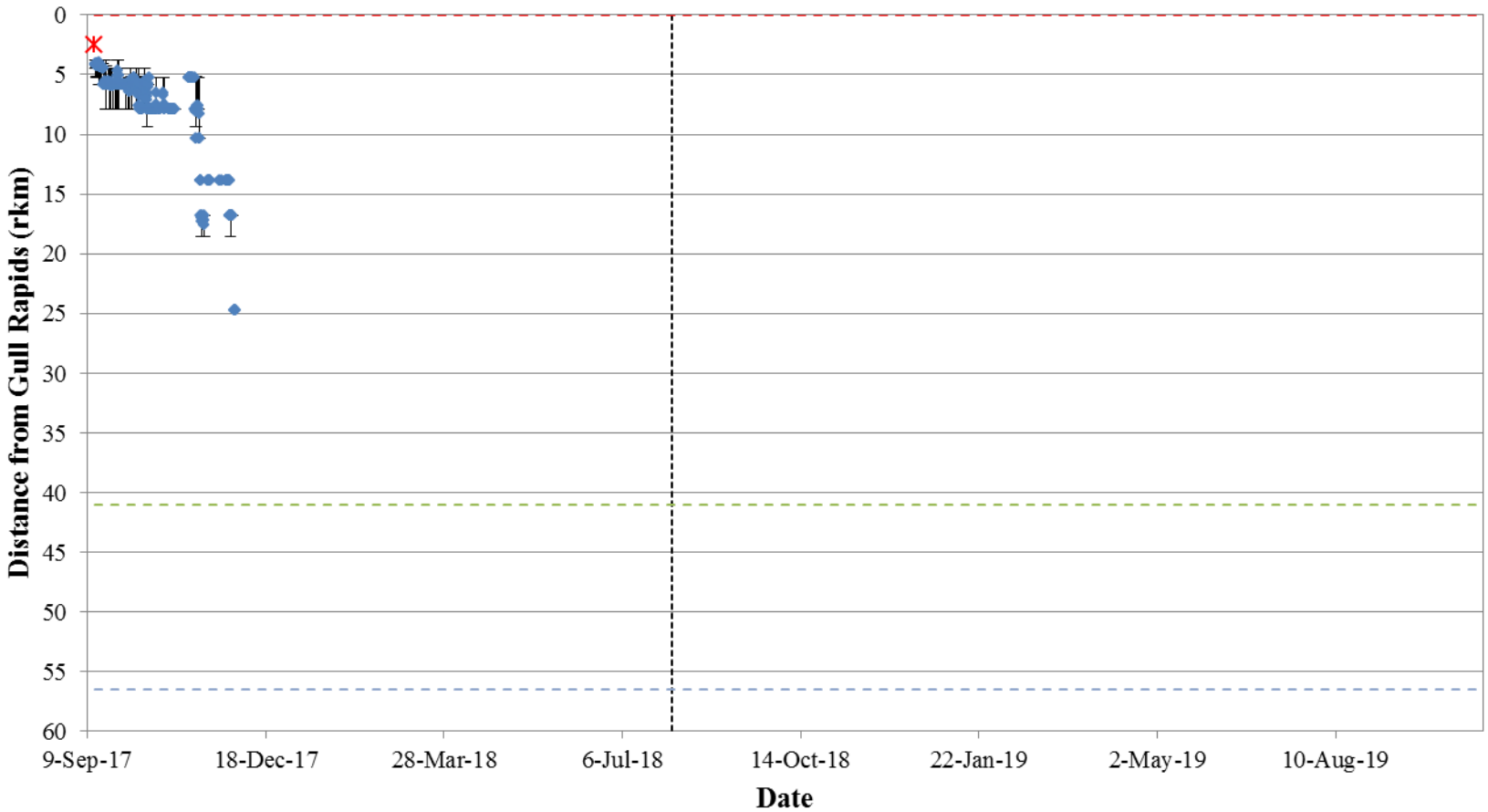


Figure A2-6: Position of a Lake Sturgeon tagged with an acoustic transmitter (code #31693) in Stephens Lake in relation to the Keeyask GS (rkm 0), from September 9, 2017 to October 7, 2019. Date and location of tagging is indicated in red. Error bars are shown in solid black. Horizontal dashed lines indicate the positions of Keeyask GS (red), Kettle GS (green), and Long Spruce GS (purple). Dashed black vertical line indicates start of spillway operation (Aug 3, 2018).

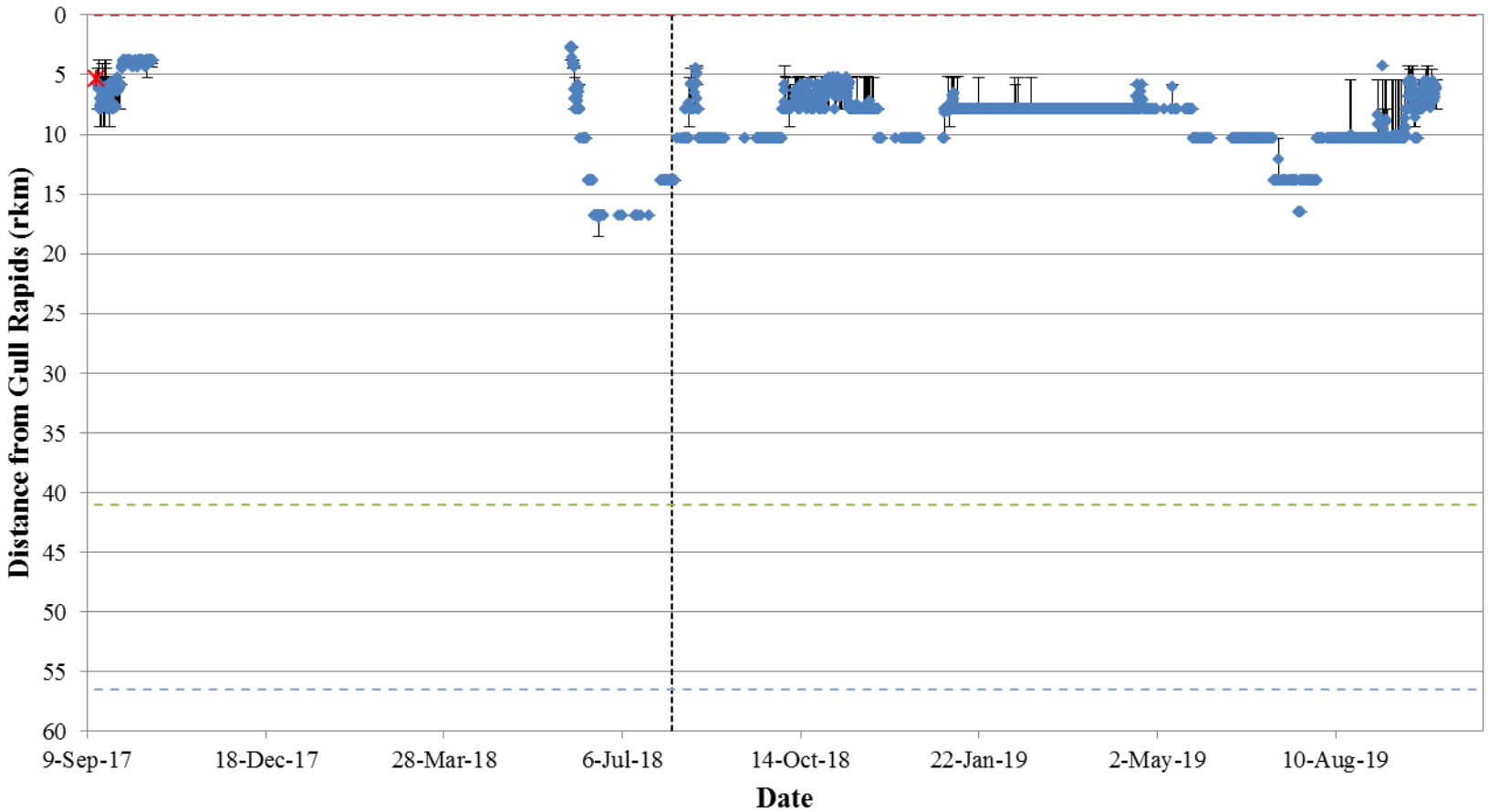


Figure A2-7: Position of a Lake Sturgeon tagged with an acoustic transmitter (code #31694) in Stephens Lake in relation to the Keeyask GS (rkm 0), from September 9, 2017 to October 7, 2019. Date and location of tagging is indicated in red. Error bars are shown in solid black. Horizontal dashed lines indicate the positions of Keeyask GS (red), Kettle GS (green), and Long Spruce GS (purple). Dashed black vertical line indicates start of spillway operation (Aug 3, 2018).

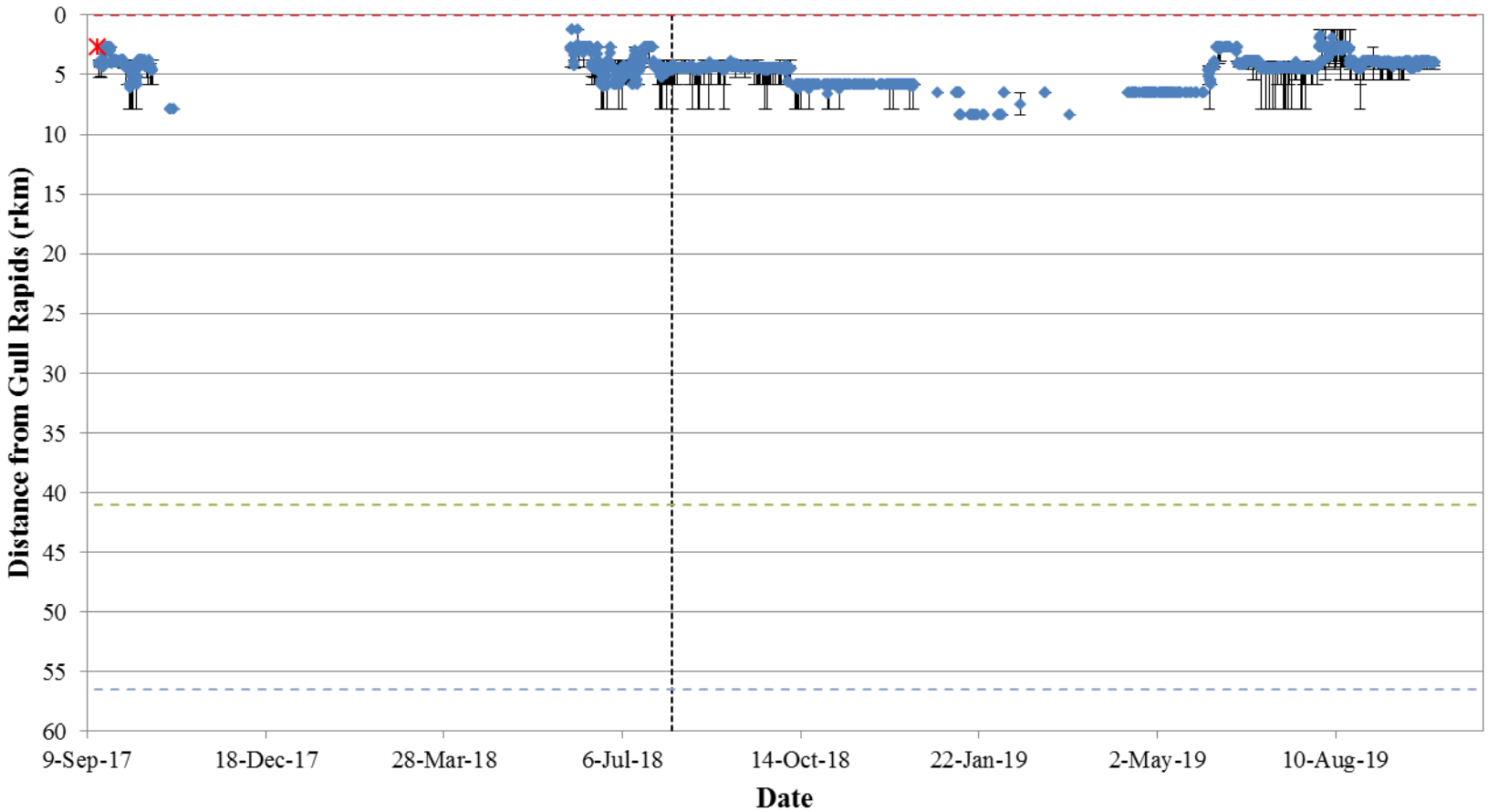


Figure A2-8: Position of a Lake Sturgeon tagged with an acoustic transmitter (code #31695) in Stephens Lake in relation to the Keeyask GS (rkm 0), from September 9, 2017 to October 7, 2019. Date and location of tagging is indicated in red. Error bars are shown in solid black. Horizontal dashed lines indicate the positions of Keeyask GS (red), Kettle GS (green), and Long Spruce GS (purple). Dashed black vertical line indicates start of spillway operation (Aug 3, 2018).

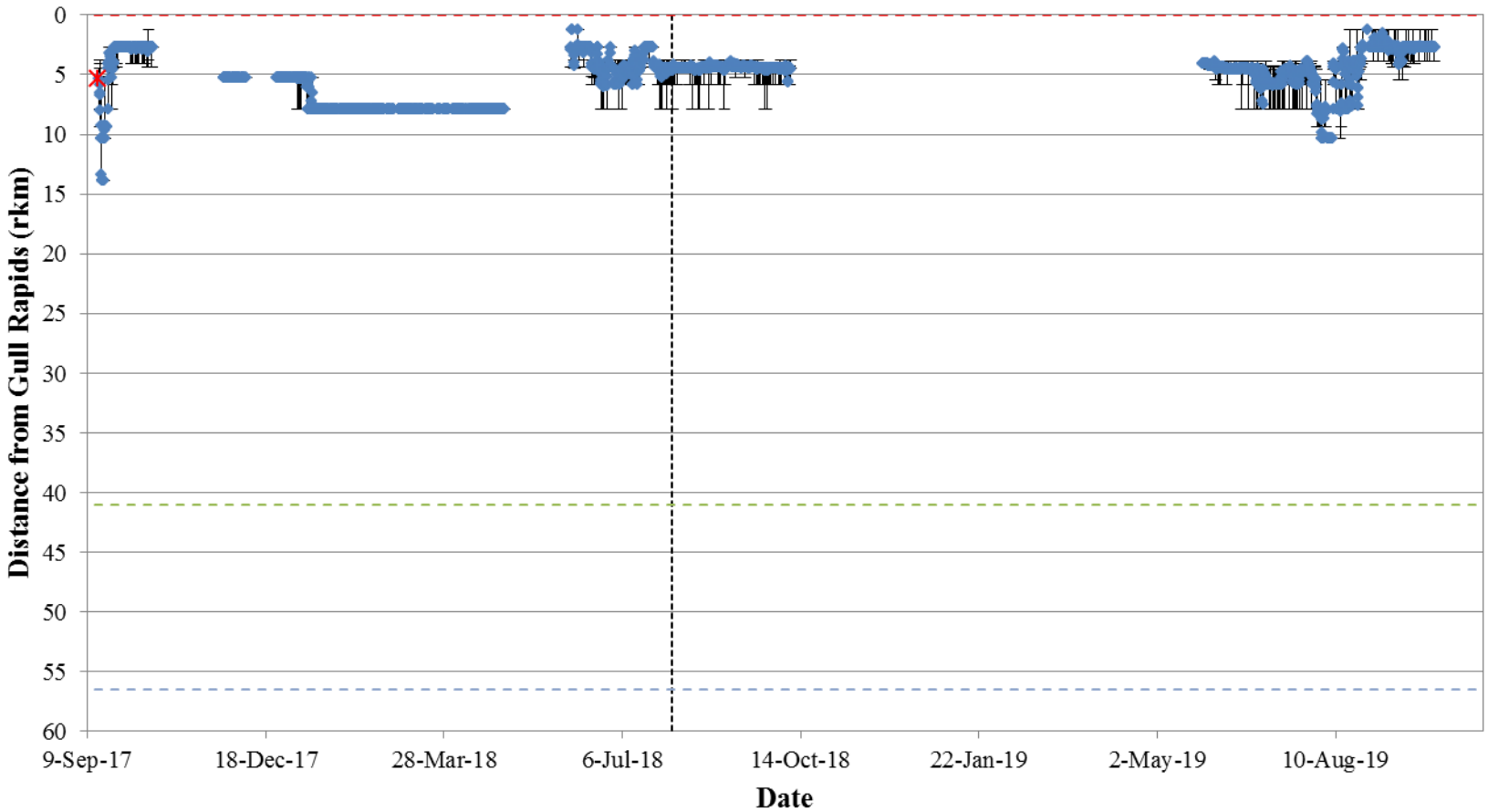


Figure A2-9: Position of a Lake Sturgeon tagged with an acoustic transmitter (code #31696) in Stephens Lake in relation to the Keeyask GS (rkm 0), from September 9, 2017 to October 7, 2019. Date and location of tagging is indicated in red. Error bars are shown in solid black. Horizontal dashed lines indicate the positions of Keeyask GS (red), Kettle GS (green), and Long Spruce GS (purple). Dashed black vertical line indicates start of spillway operation (Aug 3, 2018).

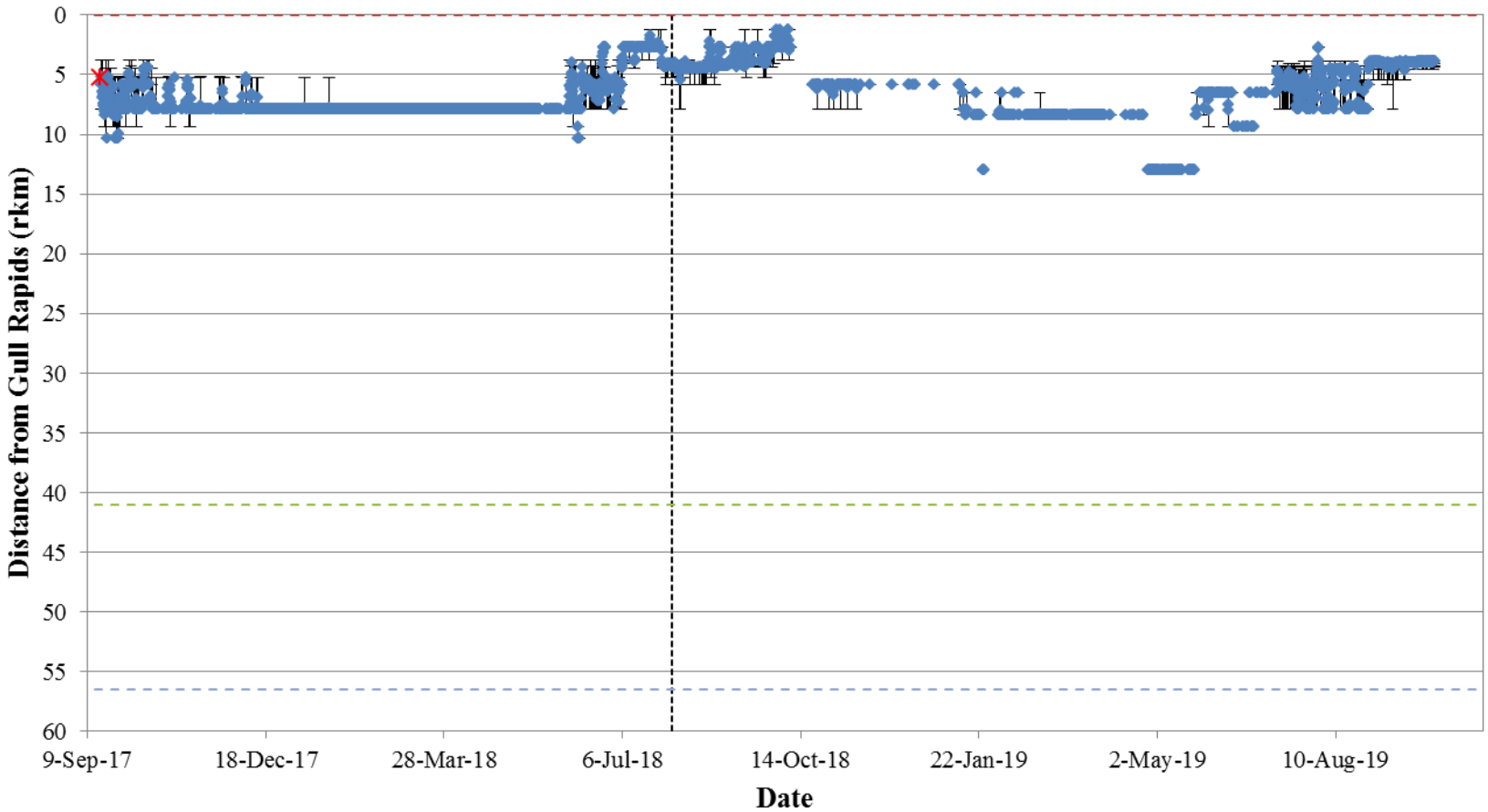


Figure A2-10: Position of a Lake Sturgeon tagged with an acoustic transmitter (code #31697) in Stephens Lake in relation to the Keeyask GS (rkm 0), from September 9, 2017 to October 7, 2019. Date and location of tagging is indicated in red. Error bars are shown in solid black. Horizontal dashed lines indicate the positions of Keeyask GS (red), Kettle GS (green), and Long Spruce GS (purple). Dashed black vertical line indicates start of spillway operation (Aug 3, 2018).

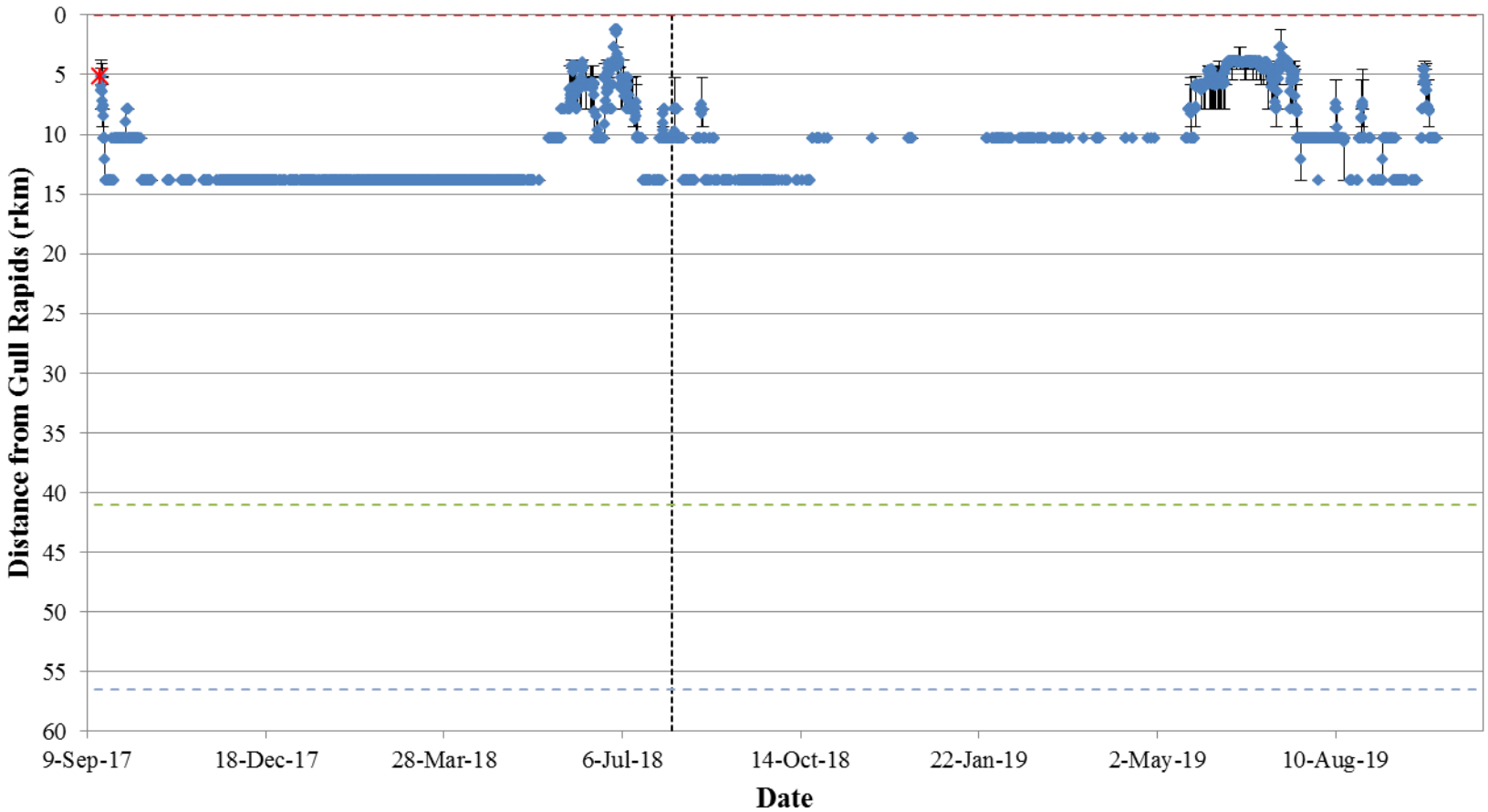


Figure A2-11: Position of a Lake Sturgeon tagged with an acoustic transmitter (code #31758) in Stephens Lake in relation to the Keeyask GS (rkm 0), from September 9, 2017 to October 7, 2019. Date and location of tagging is indicated in red. Error bars are shown in solid black. Horizontal dashed lines indicate the positions of Keeyask GS (red), Kettle GS (green), and Long Spruce GS (purple). Dashed black vertical line indicates start of spillway operation (Aug 3, 2018).

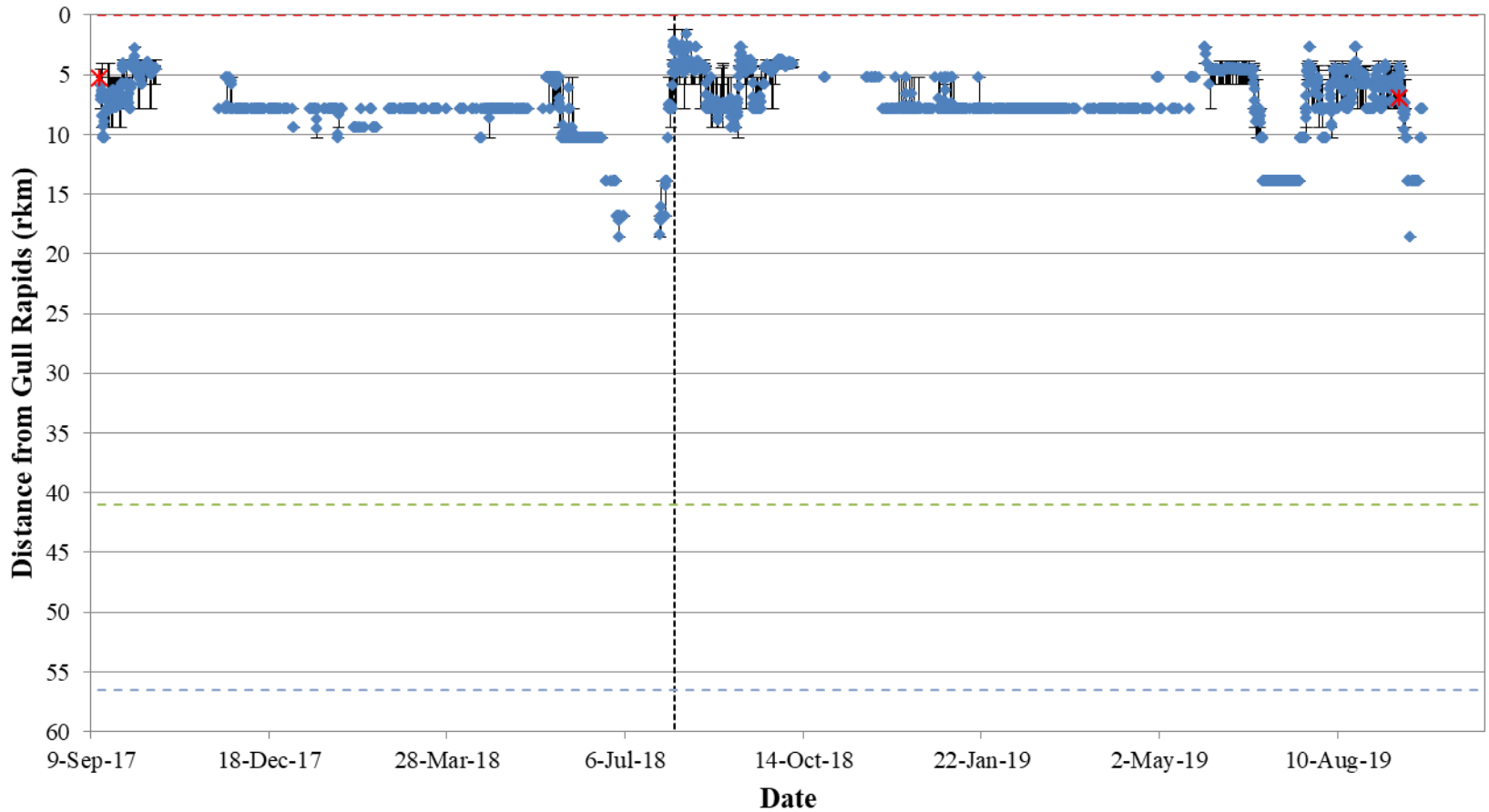


Figure A2-12: Position of a Lake Sturgeon tagged with an acoustic transmitter (code #31759) in Stephens Lake in relation to the Keeyask GS (rkm 0), from September 9, 2017 to October 7, 2019. Date and location of tagging and recapture is indicated in red. Error bars are shown in solid black. Horizontal dashed lines indicate the positions of Keeyask GS (red), Kettle GS (green), and Long Spruce GS (purple). Dashed black vertical line indicates start of spillway operation (Aug 3, 2018).

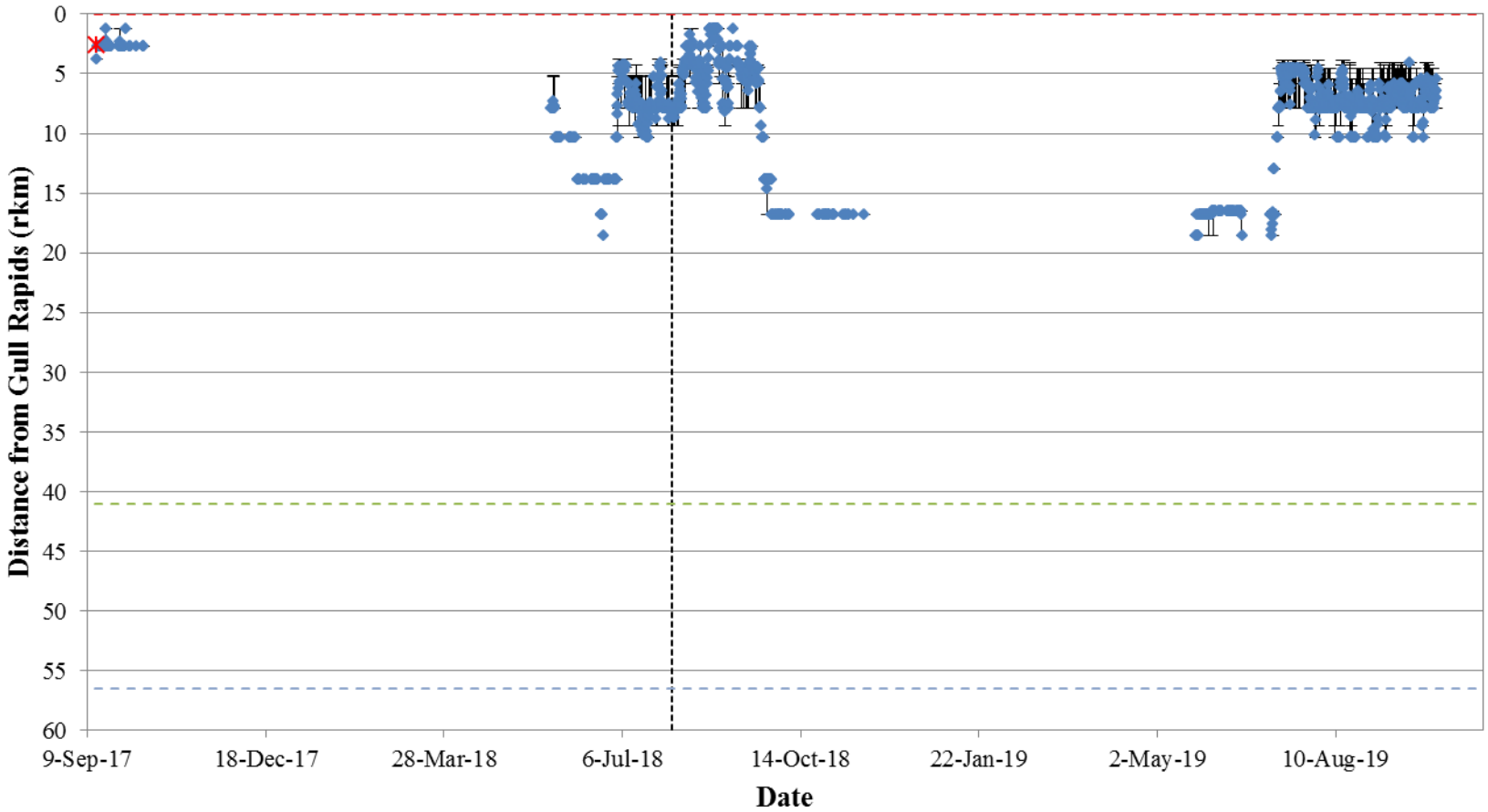


Figure A2-13: Position of a Lake Sturgeon tagged with an acoustic transmitter (code #31760) in Stephens Lake in relation to the Keeyask GS (rkm 0), from September 9, 2017 to October 7, 2019. Date and location of tagging is indicated in red. Error bars are shown in solid black. Horizontal dashed lines indicate the positions of Keeyask GS (red), Kettle GS (green), and Long Spruce GS (purple). Dashed black vertical line indicates start of spillway operation (Aug 3, 2018).

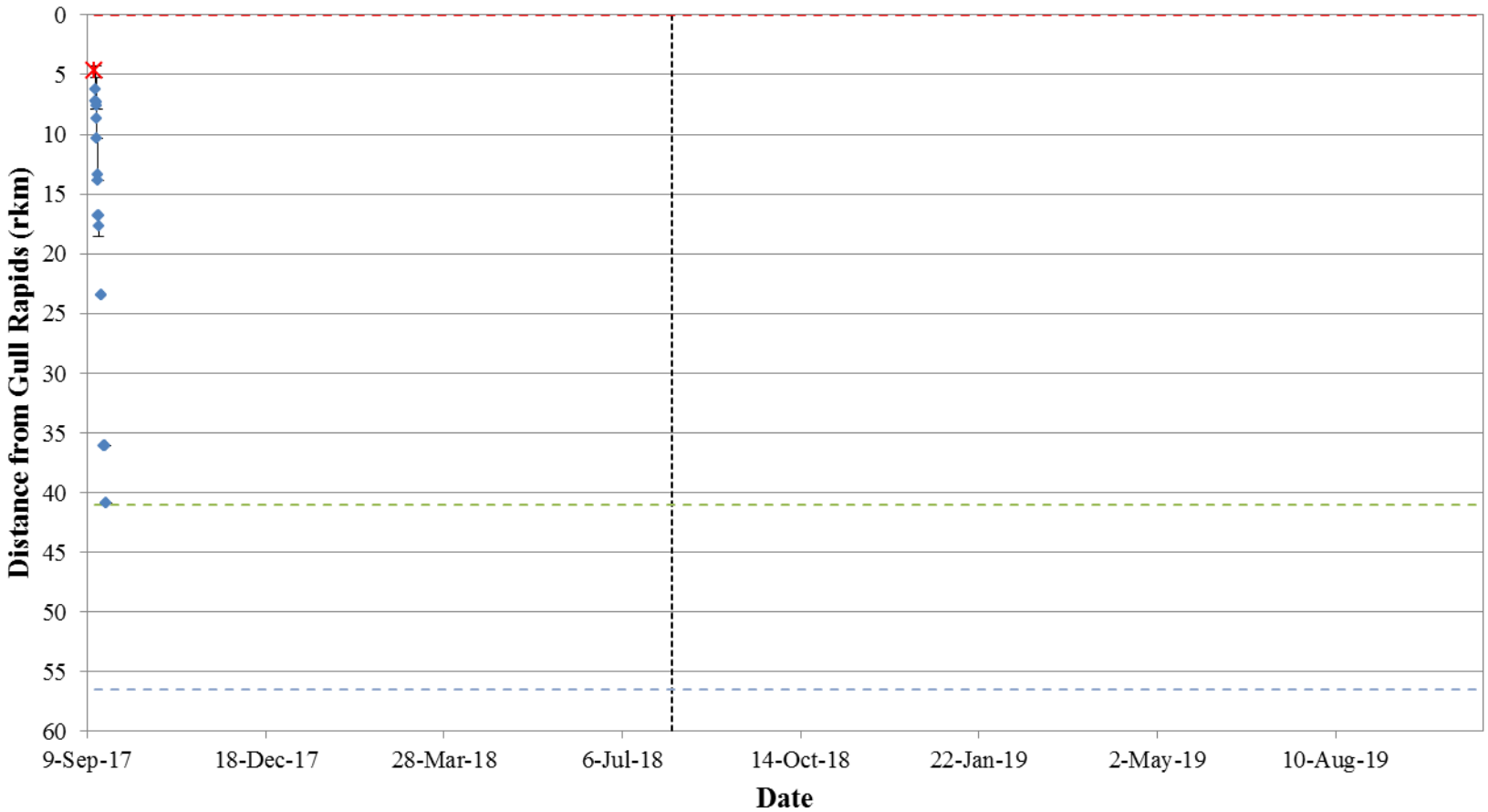


Figure A2-14: Position of a Lake Sturgeon tagged with an acoustic transmitter (code #31761) in Stephens Lake in relation to the Keeyask GS (rkm 0), from September 9, 2017 to October 7, 2019. Date and location of tagging is indicated in red. Error bars are shown in solid black. Horizontal dashed lines indicate the positions of Keeyask GS (red), Kettle GS (green), and Long Spruce GS (purple). Dashed black vertical line indicates start of spillway operation (Aug 3, 2018).

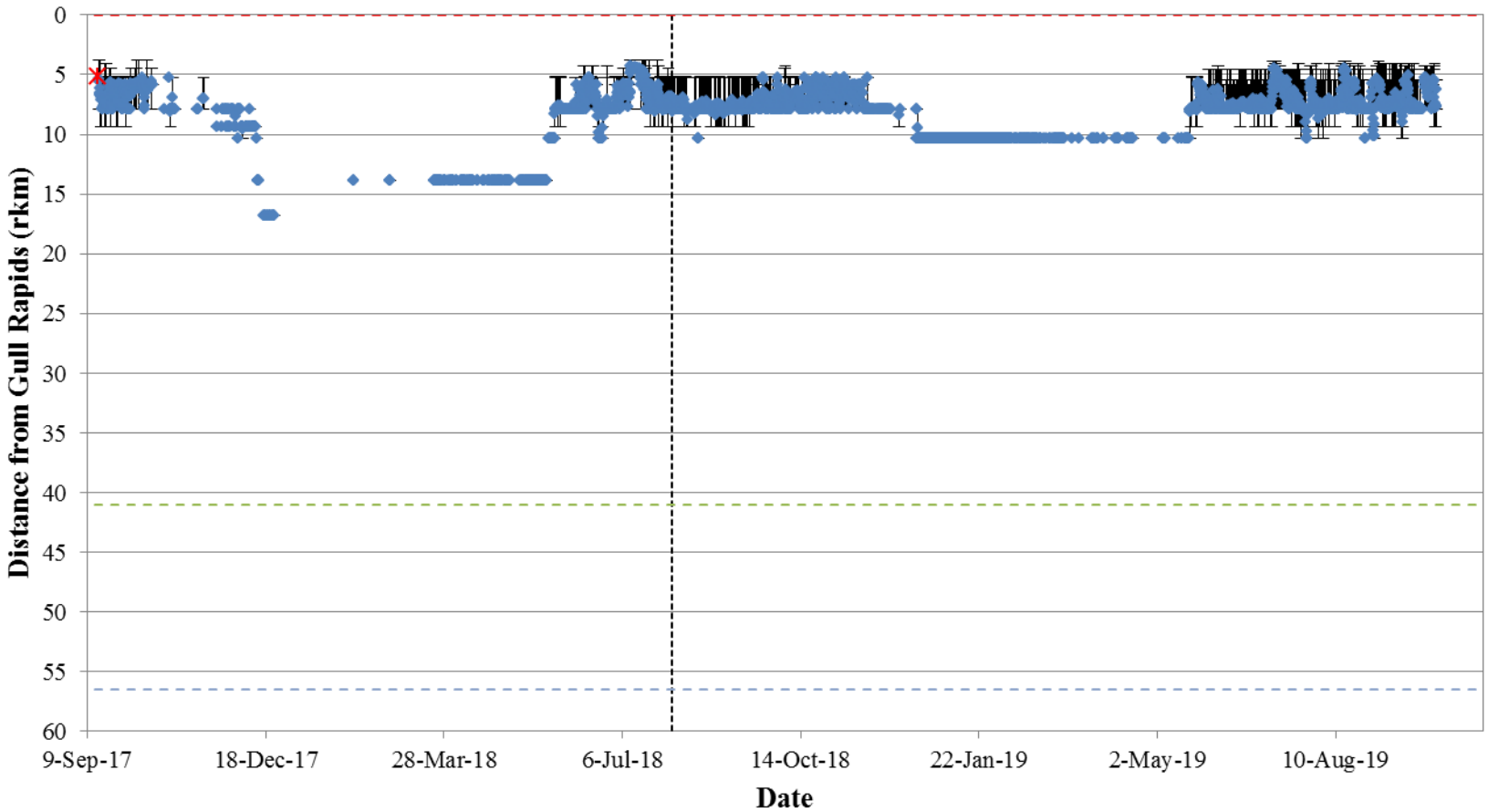


Figure A2-15: Position of a Lake Sturgeon tagged with an acoustic transmitter (code #31762) in Stephens Lake in relation to the Keeyask GS (rkm 0), from September 9, 2017 to October 7, 2019. Date and location of tagging is indicated in red. Error bars are shown in solid black. Horizontal dashed lines indicate the positions of Keeyask GS (red), Kettle GS (green), and Long Spruce GS (purple). Dashed black vertical line indicates start of spillway operation (Aug 3, 2018).

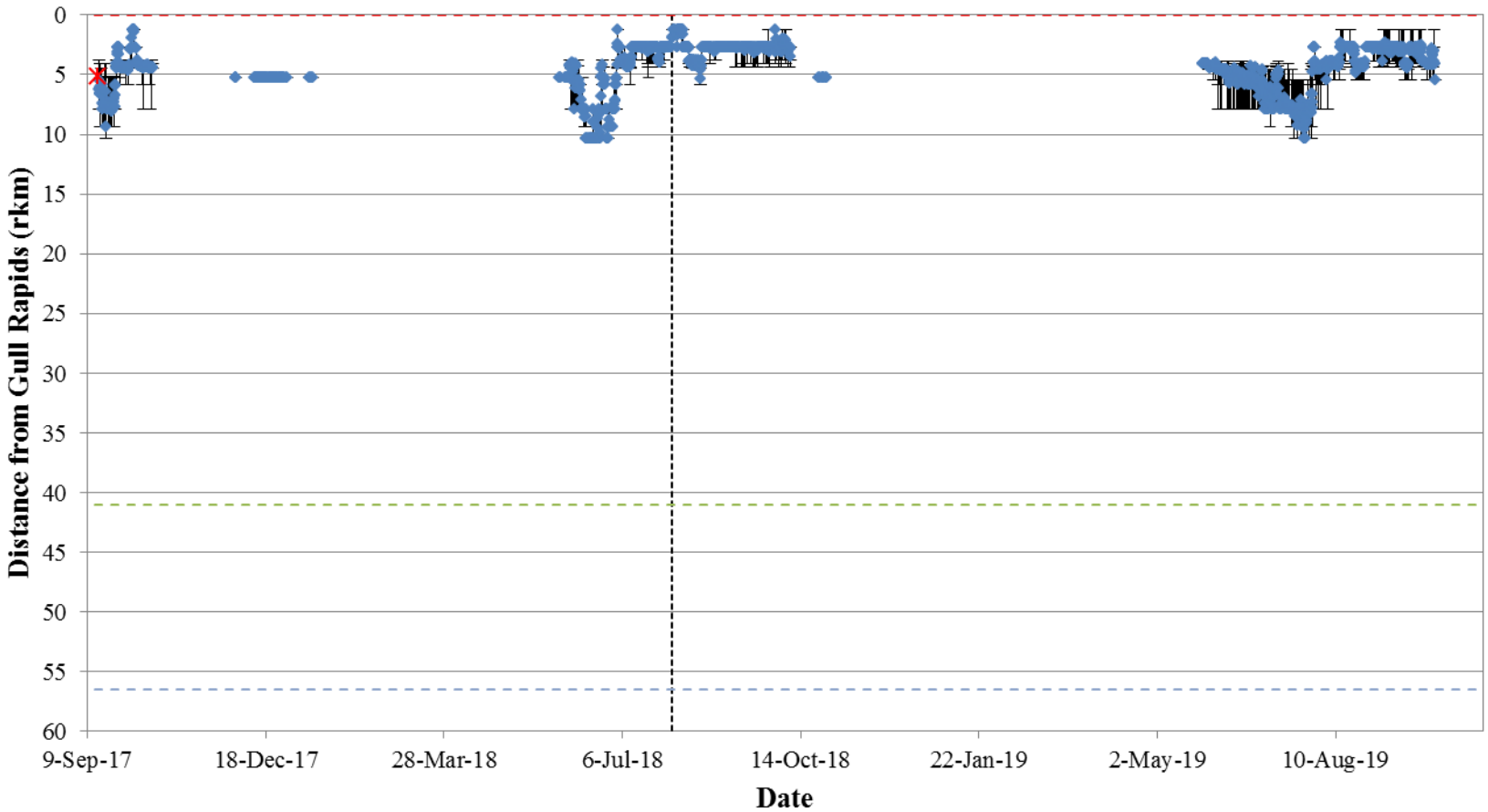


Figure A2-16: Position of a Lake Sturgeon tagged with an acoustic transmitter (code #31763) in Stephens Lake in relation to the Keeyask GS (rkm 0), from September 9, 2017 to October 7, 2019. Date and location of tagging is indicated in red. Error bars are shown in solid black. Horizontal dashed lines indicate the positions of Keeyask GS (red), Kettle GS (green), and Long Spruce GS (purple). Dashed black vertical line indicates start of spillway operation (Aug 3, 2018).

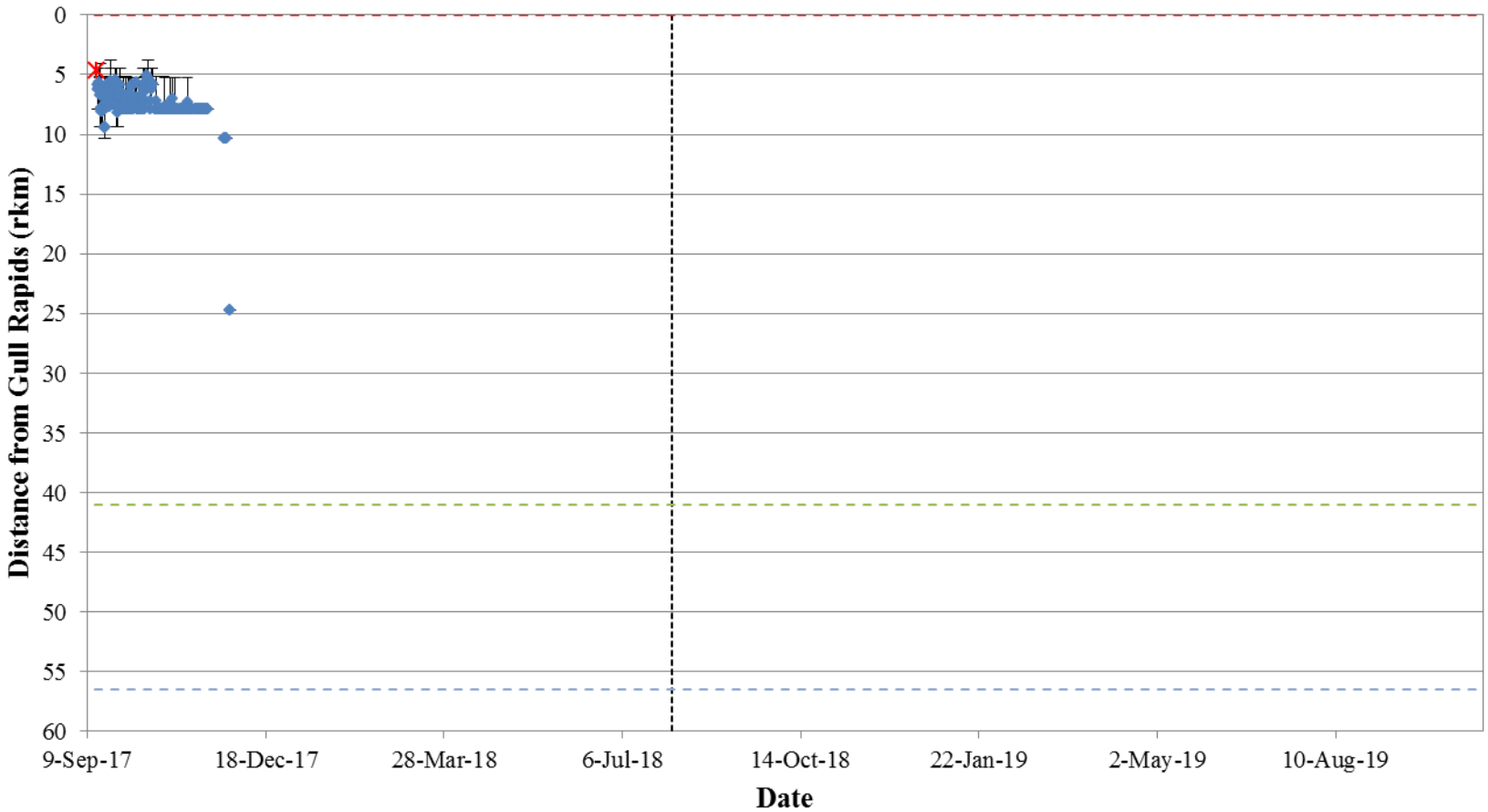


Figure A2-17: Position of a Lake Sturgeon tagged with an acoustic transmitter (code #31764) in Stephens Lake in relation to the Keeyask GS (rkm 0), from September 9, 2017 to October 7, 2019. Date and location of tagging is indicated in red. Error bars are shown in solid black. Horizontal dashed lines indicate the positions of Keeyask GS (red), Kettle GS (green), and Long Spruce GS (purple). Dashed black vertical line indicates start of spillway operation (Aug 3, 2018).

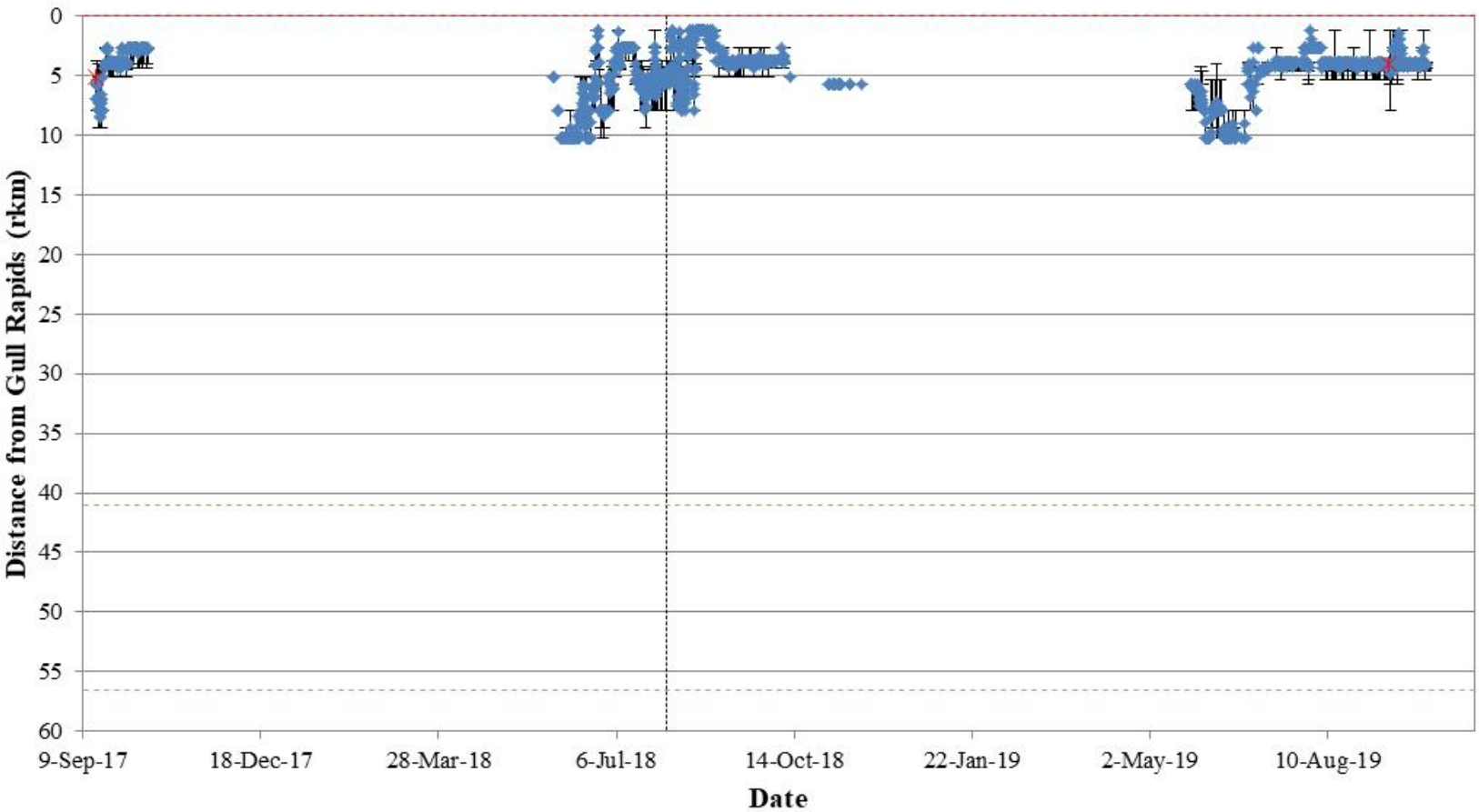


Figure A2-18: Position of a Lake Sturgeon tagged with an acoustic transmitter (code #31765) in Stephens Lake in relation to the Keeyask GS (rkm 0), from September 9, 2017 to October 7, 2019. Date and location of tagging and recapture is indicated in red. Error bars are shown in solid black. Horizontal dashed lines indicate the positions of Keeyask GS (red), Kettle GS (green), and Long Spruce GS (purple). Dashed black vertical line indicates start of spillway operation (Aug 3, 2018).

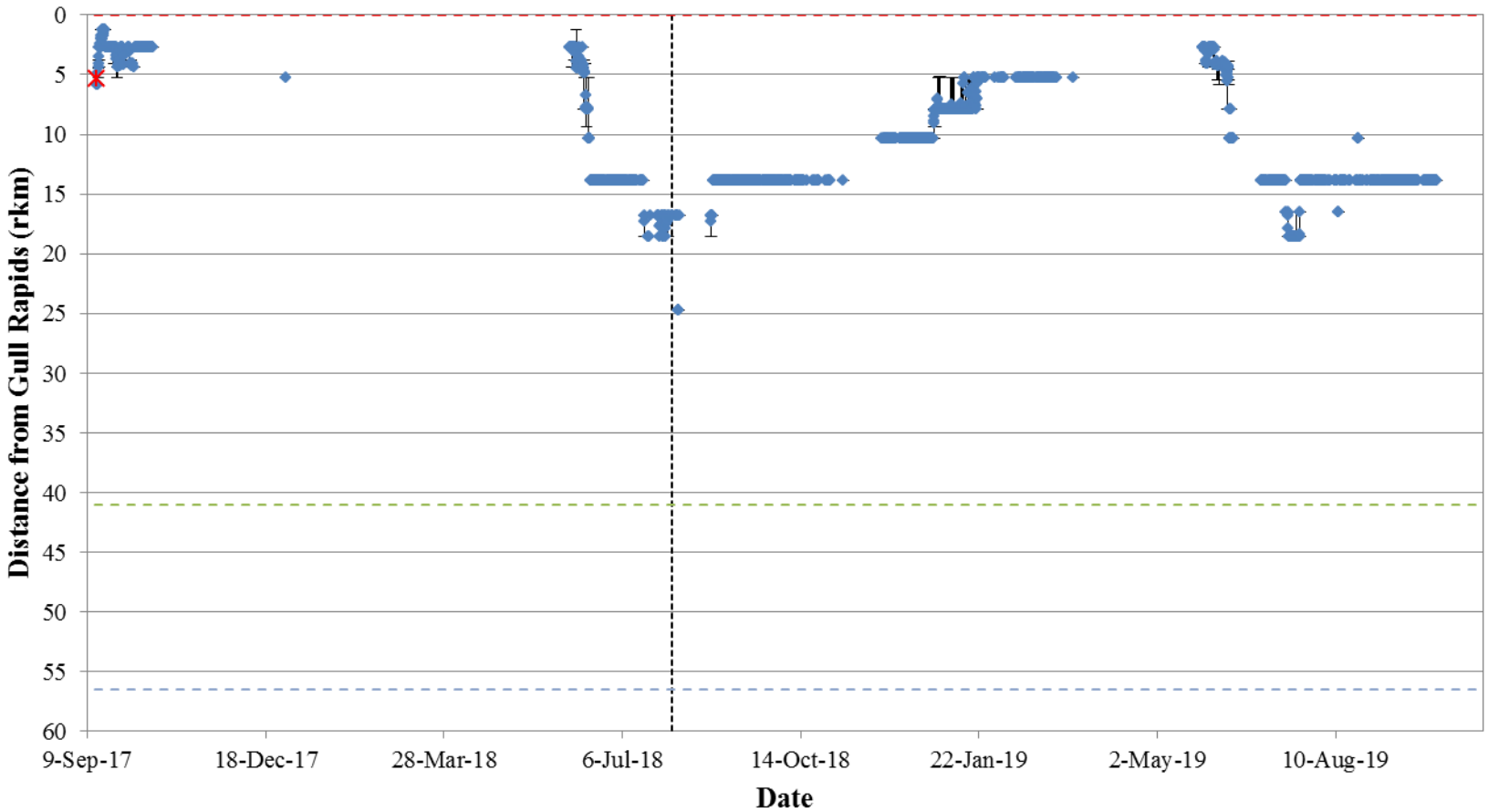


Figure A2-19 Position of a Lake Sturgeon tagged with an acoustic transmitter (code #31766) in Stephens Lake in relation to the Keeyask GS (rkm 0), from September 9, 2017 to October 7, 2019. Date and location of tagging is indicated in red. Error bars are shown in solid black. Horizontal dashed lines indicate the positions of Keeyask GS (red), Kettle GS (green), and Long Spruce GS (purple). Dashed black vertical line indicates start of spillway operation (Aug 3, 2018).

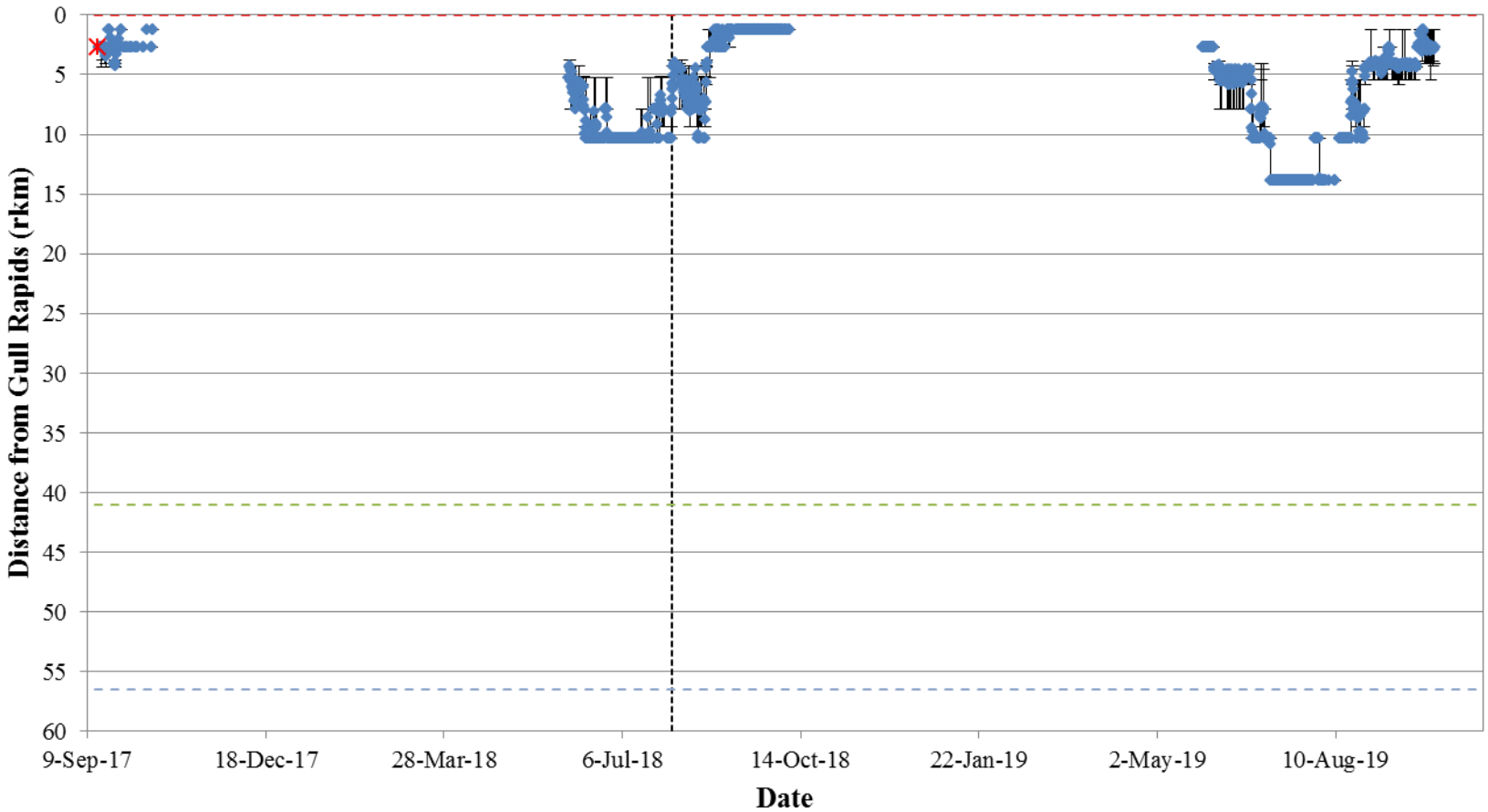


Figure A2-20: Position of a Lake Sturgeon tagged with an acoustic transmitter (code #31767) in Stephens Lake in relation to the Keeyask GS (rkm 0), from September 9, 2017 to October 7, 2019.Date and location of tagging is indicated in red. Error bars are shown in solid black. Horizontal dashed lines indicate the positions of Keeyask GS (red), Kettle GS (green), and Long Spruce GS (purple). Dashed black vertical line indicates start of spillway operation (Aug 3, 2018).