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Ministry of Natural Resources

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M.J. Friday

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Front cover photo: Drift nets set in Kaministiquia River below Kakabeka Falls. Courtesy of Mike Friday, Ministry of Natural Resources

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Abstract

At the base of Kakabeka Falls, on the Kaministiquia River, is a historical spawning site for lake sturgeon. However, this site is often dewatered during the spawning period for power production and scenic flows for Kakabeka Falls Provincial Park. Controlled spill flows over the falls were provided by Ontario Power Generation to determine the flows necessary for adult sturgeon to access this site, facilitate successful spawning, hatch, and larval drift. We examined flows of 23 $m^3 \cdot s^{-1}$ (2004 and 2005), 17 $m^3 \cdot s^{-1}$ (2006), "scenic flows" in 2007, uncontrolled flows (2008 and 2009) and 14 $m^3 \cdot s^{-1}$ (2010 and 2011). Scenic flows fluctuate between 0.5 $m^3 \cdot s^{-1}$ (at night), 4.25 $m^3 \cdot s^{-1}$ (on weekdays) and 8.5 $m^3 \cdot s^{-1}$ (on weekends). To monitor sturgeon movements into the spawning area radio telemetry was used. Adult sturgeon were tagged in the lower river (with external radio transmitters) when they were thought to be migrating upstream to spawn. Their movement into the spawning area and migration back downstream was monitored using an Advanced Telemetry Systems data logger. Larval drift netting was carried out to document spawning success under these different flow regimes. During flows of 23 $m^3 \cdot s^{-1}$ and 17 $m^3 \cdot s^{-1}$, access, and successful spawning occurred. While spill flows of 14 $m^3 \cdot s^{-1}$, and scenic flow conditions, resulted in limited access and reduced spawning success.

Acknowledgements

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Disclaimer

The views, conclusions, and recommendations are those of the authors and should not be construed as either policy or endorsement by the Ontario Ministry of Natural Resources.

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Introduction

The Ontario Ministry of Natural Resources (MNR) and Ontario Power Generation (OPG) commenced water management planning for the Kaministiquia River watershed in 2002. The water management plan that was developed included an agreement to study lake sturgeon in the Kaministiquia River (OPG 2005). One component of the agreement was to examine lake sturgeon spawning migrations and reproductive success during controlled flow conditions over Kakabeka Falls.

The river flow upstream of Kakabeka Falls is diverted by a control dam that transfers water (powerflow) through a series of penstocks to a four-unit generating station (GS) located approximately 800 m downstream of Kakabeka Falls. During periods of high river flows that exceed plant capacity (~ 57 $m^3 \cdot s^{-1}$) or when the generating station is shut down, a second dam diverts water away from the station and spills it over the falls (spill flow).

The second dam is also used to divert water over the falls for viewing purposes at Kakabeka Falls Provincial Park. Flow is provided during daylight hours of the tourist season (i.e. Victoria Day weekend in May to Thanksgiving Day weekend in October) at flow rates of 4.25 $m^3 \cdot s^{-1}$ on weekdays and 8.5 $m^3 \cdot s^{-1}$ on weekends and statutory holidays (OPG 2005). These are commonly referred to as scenic flows and represent the minimum flow allowed to pass over the Kakabeka Falls dam. These flow requirements were adopted in 1978 and are a component of the Kaministiquia River Water Management Plan approved in 2005 (OPG 2005). During the overnight hours of the tourism season, leakage through the dam stop logs may provide the only flow over the Falls. Dam leakage was measured at 0.12 $m^3 \cdot s^{-1}$ on July 15, 2009 (downstream of the dam). Spacers were installed, in April 2010, at the Kakabeka dam to provide a minimum flow of 0.5 $m^3 \cdot s^{-1}$.

From 2004 to 2006, flow over the falls was provided to allow sturgeon access to the spawning site at the base of the Falls. Studies conducted in each of these years indicated that adult sturgeon reached the spawning site and spawned successfully during flows of 23 $m^3 \cdot s^{-1}$ (Friday 2004, 2005) and 17 $m^3 \cdot s^{-1}$ (Friday 2006). We examined lake sturgeon movements and reproduction during scenic flows in 2007, and found that sturgeon spawned upstream and downstream of the generating station (Friday 2007). We attempted to examine another flow condition (14 $m^3 \cdot s^{-1}$) in 2008 and 2009, to determine if migration to the base of the falls and successful spawning would occur (Friday 2008, 2009). Due to high water conditions, spill flow, however, could not be controlled at 14 $m^3 \cdot s^{-1}$ during these years. In 2010, we examined lake sturgeon spawning migrations and reproductive success during controlled spill flows of 14 $m^3 \cdot s^{-1}$ and found that sturgeon spawned upstream and downstream of the generating station (Friday 2010). Adult sturgeon reached the spawning site below the falls and spawned successfully during mean daily spill flows of 14.6 $m^3 \cdot s^{-1}$ and 16.6 $m^3 \cdot s^{-1}$ (Friday 2010).

In 2011, we again attempted to examine lake sturgeon spawning migrations and reproductive success during controlled spill flows of 14 $m^3 \cdot s^{-1}$. The objectives of the studies were to:

1. Determine if spawning lake sturgeon can successfully migrate upstream from the generating station to the base of the falls during spill flows of 14 $m^3 \cdot s^{-1}$
2. Determine if spawning lake sturgeon can successfully migrate out of the study area during spill flow conditions of 14 $m^3 \cdot s^{-1}$
3. Determine the length of time spawning adults remain in the study area
4. Determine the approximate date when spawning occurs
5. Determine if the spawning was successful at spill flow rates of 14 $m^3 \cdot s^{-1}$
6. Confirm, through the collection of larval sturgeon, that there are sexually mature adult sturgeon spawning in the study area
7. Determine the timing and duration of downstream dispersal of larval lake sturgeon

Study area

This study focused on an 800-metre stretch of the Kaministiquia River, from the base of Kakabeka Falls downstream to the OPG generating station (Figure 1).

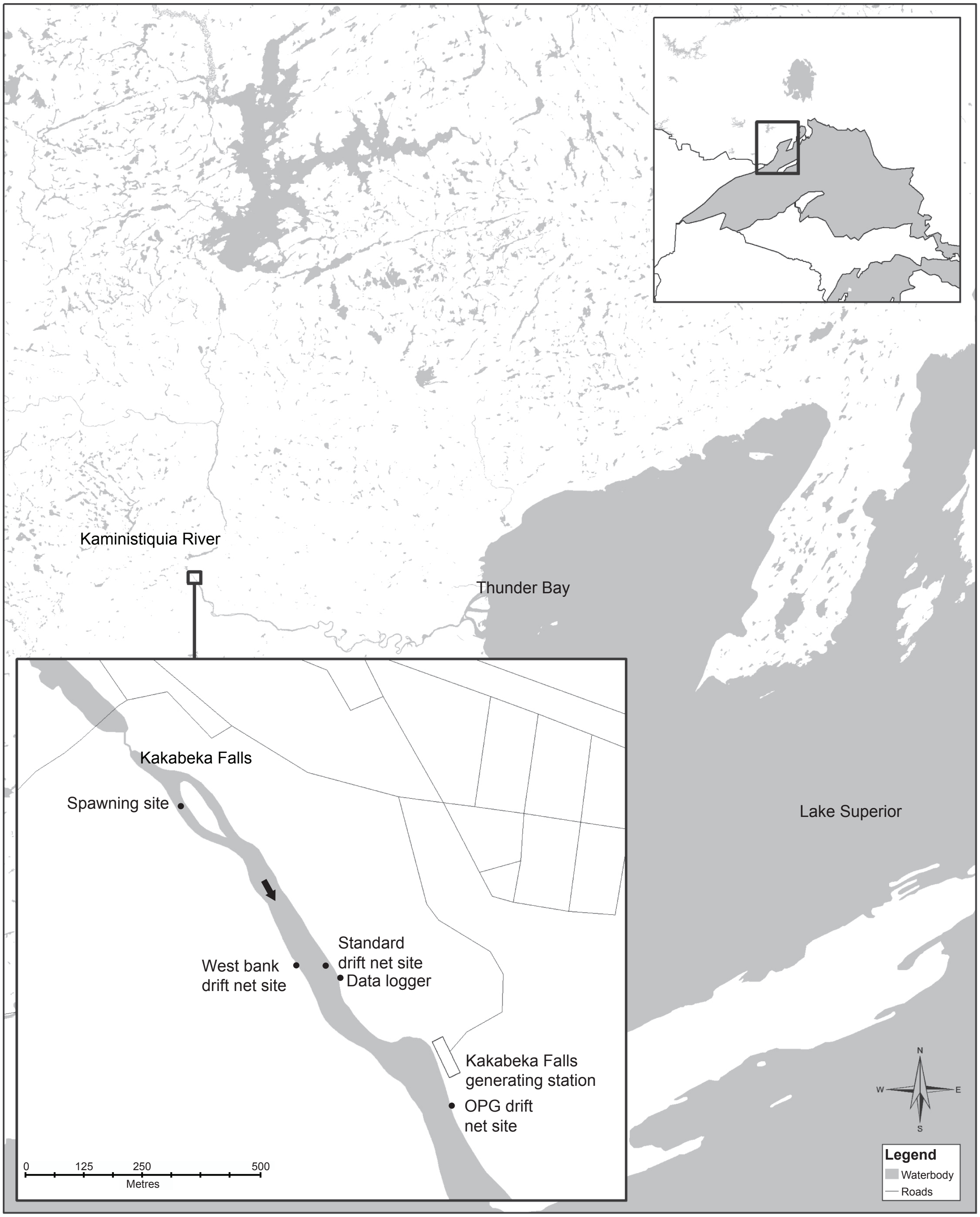

Figure 1. The study area in relation to the Kaministiquia River watershed.

Materials and methods

Radio tagging

Radio telemetry equipment manufactured by Advanced Telemetry Systems (ATS) was used in this study[1]. Each radio transmitter (n=25) was identified by a unique frequency between 150.701 and 151.203 MHz. These 20-gram transmitters (model F2060) pulsed 55 times per minute and had a battery life of approximately 10 months.

From April 28 to May 11, we attempted to radio tag lake sturgeon from river kilometre (rkm) eight to 17 (Figure 2) in the hope that they would migrate upstream to spawn. We set 150 m of 305 mm stretched mesh multifilament gill net overnight (25 sets) during water temperatures that ranged from 5.0 to 10.3°C, and total river flows that ranged from 61.6 to 127.7 $m^3 \cdot s^{-1}$. To attach the transmitters, a hollow bone marrow biopsy needle (#11 Jamshidi) was pushed through the base of the dorsal fin until it exited the other side. One of two attachment wires was then threaded through the hollow needle until it passed through to the opposite side. After the needle was removed, a backing plate and metal crimp were threaded down the wire and slid into position against the base of the dorsal fin. The crimp was securely fastened, excess wire was removed, and the procedure was repeated for the second attachment wire. Anaesthetic was not used during the procedure. All sturgeon were sampled for length (fork, total), weight, girth, body depth, and were tagged with a five-digit orange floy tag applied along the left-hand side of the dorsal fin. A 16-digit passive integrated transponder (PIT tag) was applied under the third dorsal scute (counting back from the head) of each fish. This is a standard PIT tag insertion site for all lake sturgeon tagged in Lake Superior, or its tributaries. A genetic sample was also taken from the leading edge of the left pectoral fin. We attempted to determine fish gender by expressing sexual products from each captured fish.

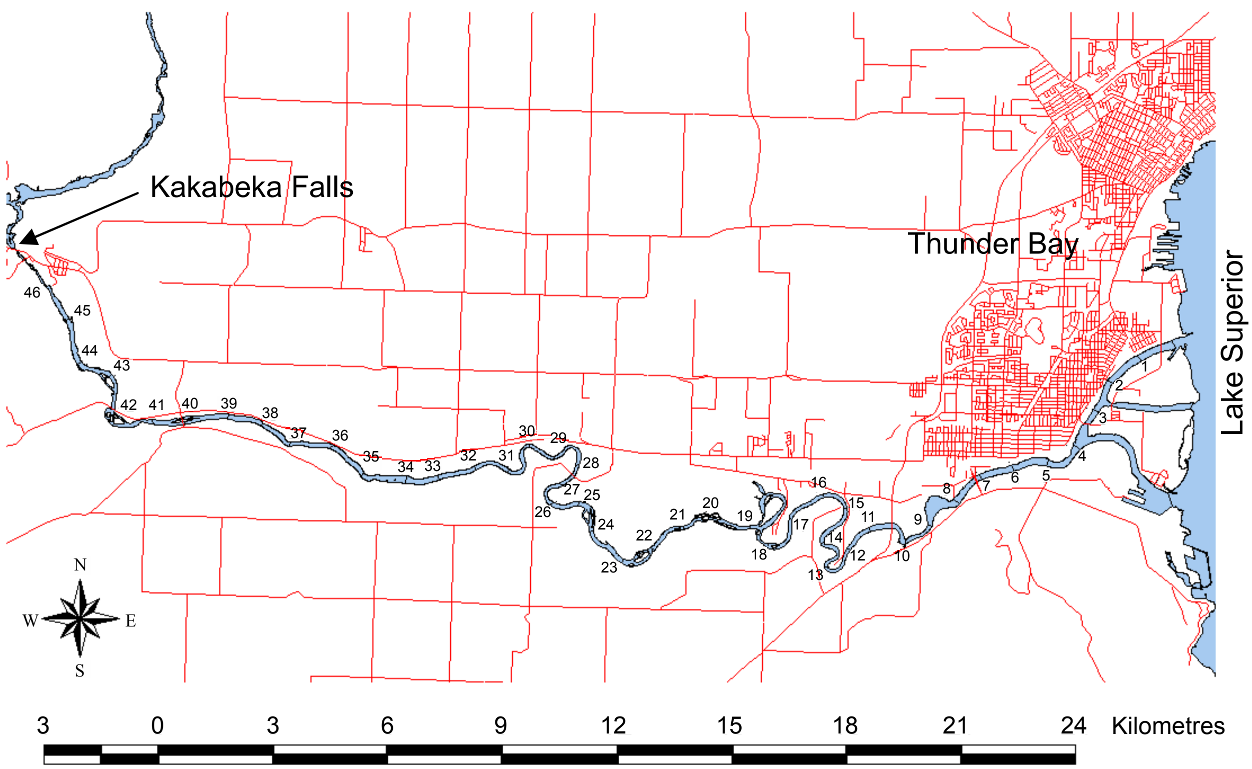

Figure 2. The location of Kakabeka Falls and sturgeon tagging area on the Kaministiquia River.

[1]Reference to trademark names does not imply endorsement by the Ontario government.

Tracking

A shoreline-based data logger (model R4500) was installed upstream of the generating station (Figure 1) in mid-April to track the movements of radio-tagged sturgeon as they migrated to the study area. A two-antenna system was used to interpret the direction of fish movement as one antenna was facing upstream (toward the falls), and the other was facing downstream (toward the generating station). The logger operated from April 23 to September 1.

A reference transmitter (150.893 MHz) was placed in the river upstream of the generating station and was logged every six hours to provide a known signal strength (average strength=150) from a fixed position. If radio-tagged sturgeon were detected by the shoreline-based data logger, their approximate position could be determined by comparing the signal strength of their transmitter to the reference tag signal strength.

Manual tracking in the study area was conducted using a portable receiver and hand-held antenna. This was done to validate data being collected by the data logger and as a backup in case of logger malfunction or vandalism. A number of road accessible sections of the river were monitored to track the upstream and downstream progression of radio-tagged fish.

Drift netting

Drift netting took place at the standard site (12 nets) established in 2004, approximately 400 m downstream of Kakabeka Falls on the east shore of the river. We also set four nets (400 m downstream of Kakabeka Falls) on the west side of the river to examine drift within the main river channel where the majority of the flow over the falls was concentrated during these study flow conditions (Figure 1). All 16 nets were set from June 3 to 30.

At all locations, stainless steel D-frame drift nets were used that measured 0.76 m across the base, 0.53 m high, and had a 3.6-metre tapered mesh bag that terminates at a collection container with filtering holes covered by 1,000 µm mesh.

Drift nets were held in place by attaching a 4.5 kg fishing anchor to the bridle of each frame. To sample the catch, the cod end was lifted from the water and the collection container was detached and rinsed in a shallow white pan for examination. All sturgeon were removed, counted, and measured, and live sturgeons were released downstream. Dead specimens were placed in glass vials and preserved in 70 percent ethanol. Other larval fish species captured were also preserved and later identified in the laboratory.

Drift netting was also carried out by Northern Bioscience for OPG downstream of the generating station from June 7 to June 24. Nets were set in the same sites sampled in 2007 and 2009 (Site 1) on the east bank of the river approximately 300 m downstream from the generating station (Foster and Harris 2010) (Figure 1).

Water temperature, velocity, and depth

Water temperature in the study area was recorded using a Vemco Minilog-T data logger. The logger was located on the east side of the river, approximately 500 m upstream of the generating station in 0.5 m of water. Temperature was recorded hourly from April 15 to September 15. Real-time water temperature information from the tailwater of the generating station was recorded by OPG with a permanently installed RBR data logger and was available via web link. Water velocity ($m \cdot s^{-1}$) and depth (cm) was measured at the opening of each drift net upon deployment.

Study flow plan

The MNR and OPG planned to examine lake sturgeon access to the base of Kakabeka Falls and reproduction during spill flows of approximately 14 $m^3 \cdot s^{-1}$ (from May 15 to June 25 with a four-day taper to scenic flows).

Results

Radio tagging

External radio transmitters were attached to 25 lake sturgeon that ranged in total length from 115.5 to 162.0 cm and weighed 8 to 24.5 kg (Table 1). Fish gender could not be determined.

Table 1. Fish attribute information and migration results for 25 adult lake sturgeon radio-tagged in 2011.

Tagging date (D-M-Y)	Flen (cm)	Tlen (cm)	Girth (cm)	Rwt (kg)	Freq.	Migrated upstream of GS	Remained in the lower river
29-Apr-11	117.0	129.0	48.0	11.5	151.123	X	
10-May-11	122.0	130.0	57.0	16.5	150.882	X	
29-Apr-11	119.0	130.0	49.5	13.5	150.701		X
03-May-11	119.0	130.5	55.0	15.0	150.902		X
03-May-11	120.0	123.5	46.0	10.5	150.801		X
04-May-11	110.0	122.0	46.0	10.5	150.922		X
04-May-11	119.0	131.5	52.5	13.0	150.742		X
04-May-11	110.0	120.5	47.5	11.0	150.781		X
04-May-11	108.0	117.5	45.0	10.0	151.163		X
04-May-11	107.0	118.0	43.0	9.0	151.203		X
06-May-11	128.0	140.0	52.0	16.0	150.822		X
06-May-11	115.0	129.0	49.0	12.5	151.142		X
06-May-11	133.0	146.0	59.0	20.0	150.982		X
06-May-11	132.0	146.5	55.0	18.0	150.723		X
06-May-11	128.0	140.5	47.0	13.5	151.065		X
06-May-11	133.0	142.0	52.0	17.0	151.085		X
06-May-11	117.0	127.5	54.0	14.0	150.762		X
06-May-11	130.0	143.5	54.0	17.0	151.183		X
06-May-11	138.0	153.0	55.0	20.0	151.044		X
06-May-11	115.0	128.5	51.0	14.0	150.862		X
06-May-11	149.0	162.0	59.0	24.5	151.002		X
10-May-11	103.5	115.5	42.0	8.0	151.103		X
10-May-11	133.5	143.5	55.0	18.0	151.022		X
11-May-11	125.0	136.0	46.0	15.5	150.962		X
11-May-11	134.0	146.5	54.0	18.0	150.943		X

Spill flow

River flow was in excess of generating station capacity (57 $m^3 \cdot s^{-1}$) prior to the study start date (May 15). Surplus water was therefore spilled over Kakabeka Falls, but was controlled at approximately 14 $m^3 \cdot s^{-1}$ for the duration of the study period. There were no significant rain events that caused spill over Kakabeka Falls in excess of study flows (Figures 3 and 4).

Migration

Only two of 25 radio-tagged sturgeon migrated to Kakabeka in 2011.

Kakabeka data logger

Radio-tagged sturgeon arrived at Kakabeka between May 15 (14.7°C) and May 18 (14.8°C) during total river flows that ranged from 32 to 58 $m^3 \cdot s^{-1}$. Frequency 150.822 (130 cm, 16.5 kg) was initially detected by the data logger on May 15 and took approximately 15 hours to access the plunge pool at the base of the falls during controlled spill of 14.7 $m^3 \cdot s^{-1}$ (Appendix 1). It migrated back downstream on May 17 during controlled spill of 16.3 $m^3 \cdot s^{-1}$. Frequency 151.123 (129 cm, 11.5 kg) was initially detected by the data logger on May 18 and took approximately four hours to reach the plunge pool at the base of the falls during controlled spill of 14.8 $m^3 \cdot s^{-1}$ (Appendix 1). It migrated back downstream on June 7 during controlled spill of 14.5 $m^3 \cdot s^{-1}$.

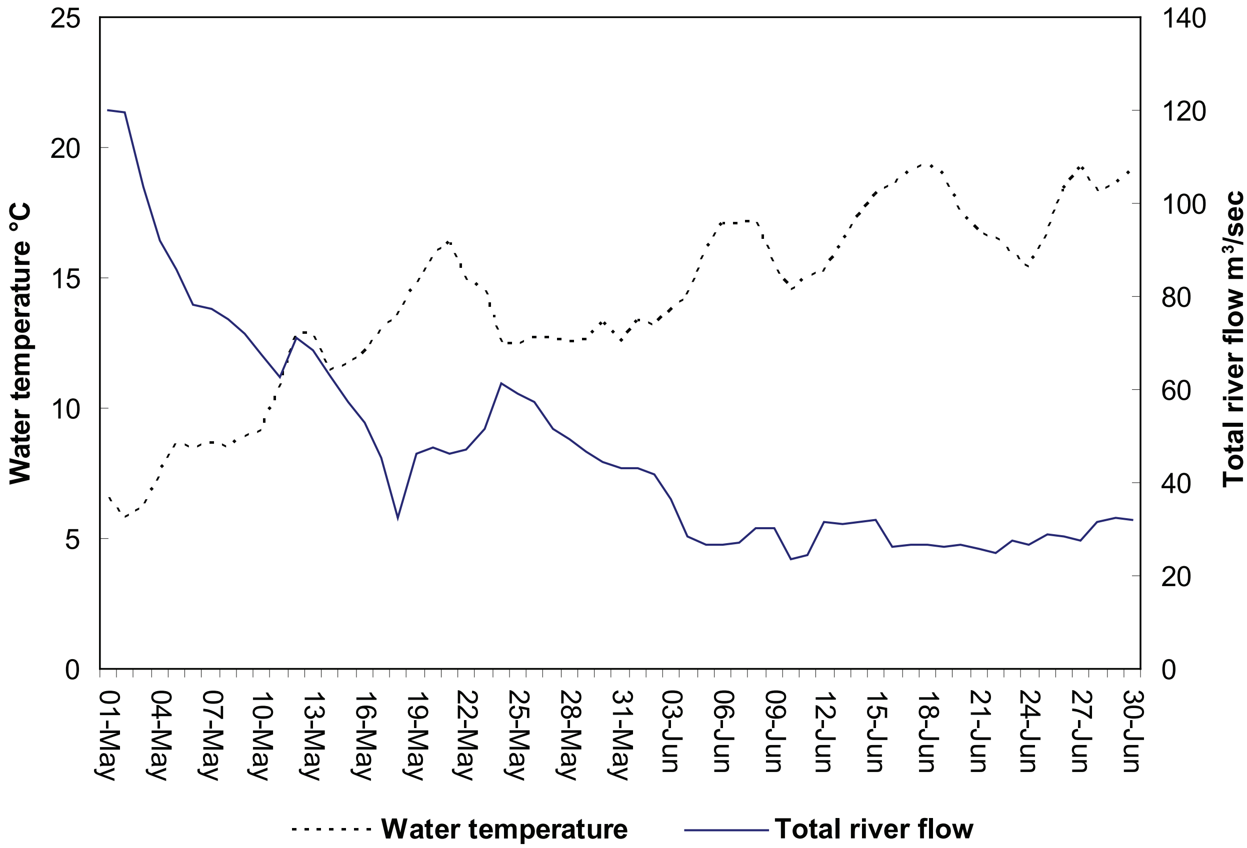

Figure 3. Water temperature and total river flow from May 1 to June 30, 2011.

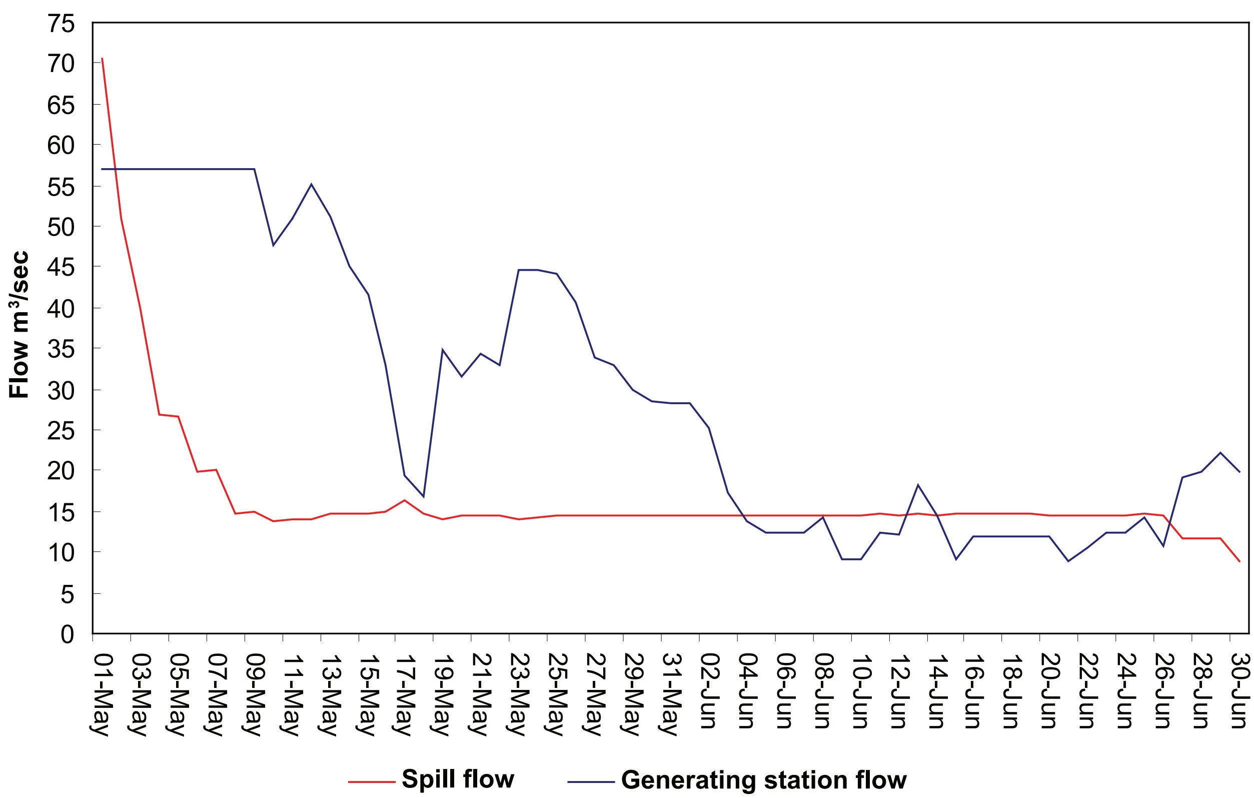

Figure 4. Mean daily spill flow over Kakabeka Falls and generating station flow from May 1 to June 30, 2011.

Spawning events

Telemetry

The first spawning event likely occurred on May 18 (13.5°C) when one radio-tagged fish migrated from the base of Kakabeka Falls back downstream. The spill flow was 14.8 $m^3 \cdot s^{-1}$ (Figure 5).

The second spawning event likely occurred on June 7 (17.1°C) when one radio-tagged fish migrated from the base of Kakabeka Falls back downstream. The spill flow was 14.5 $m^3 \cdot s^{-1}$ (Figure 5).

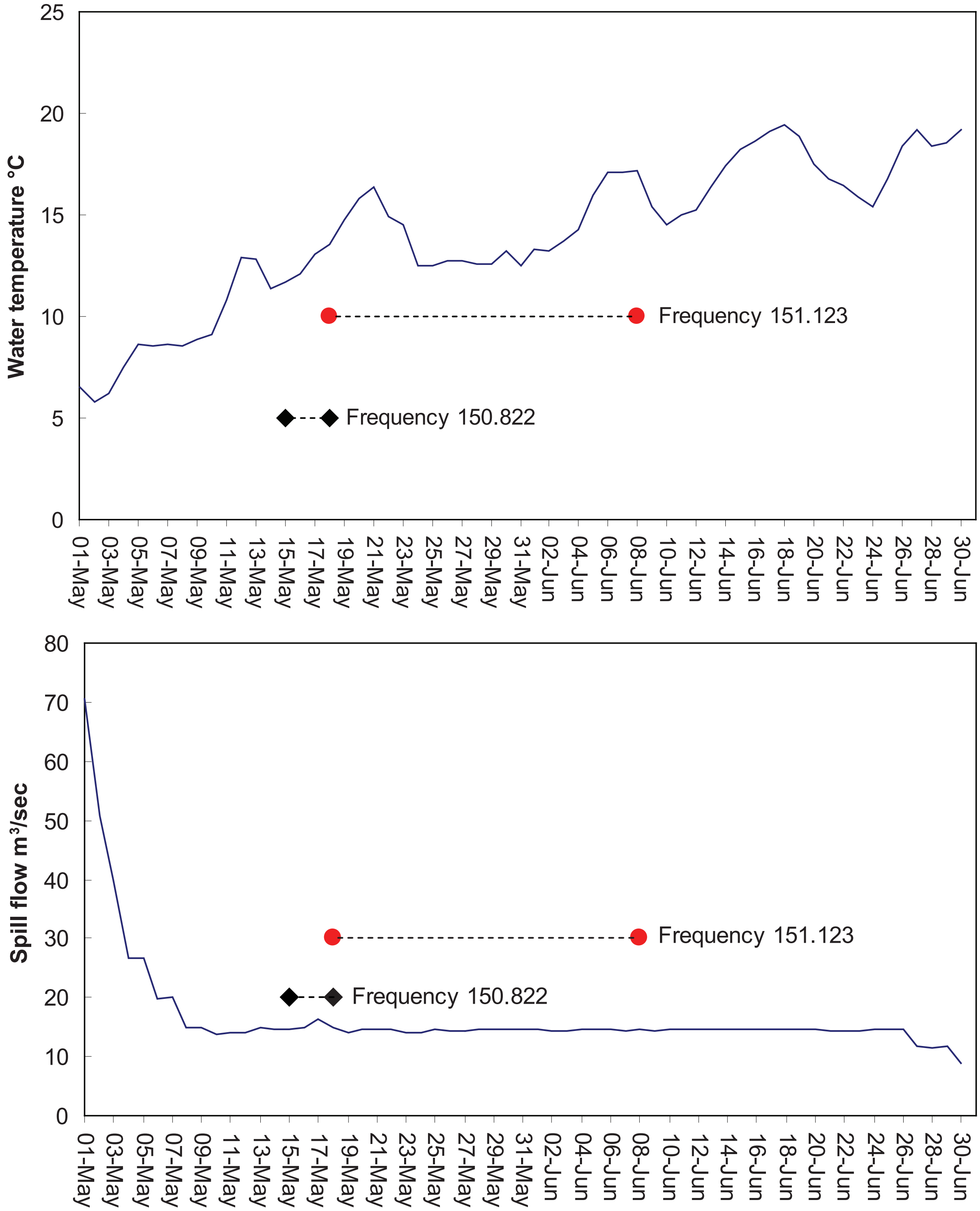

Figure 5. The migration of radio-tagged lake sturgeon to the Kakabeka logger in relation to water temperature and mean daily spill flows from May 1 to June 30, 2011.

Drift netting

Two separate larval drift events were documented upstream of the generating station confirming that there were two separate spawning events.

MNR sampling upstream of generating station

Standard site (east bank)

During 30 overnight sampling events (June 1 to June 30 with 12 nets) at the standard site upstream of the generating station, 1,155 larval lake sturgeon were captured (Figures 6 and 7). The catch per unit effort was 0.16 larvae/hour (7,177 sample hours) (Table 2).

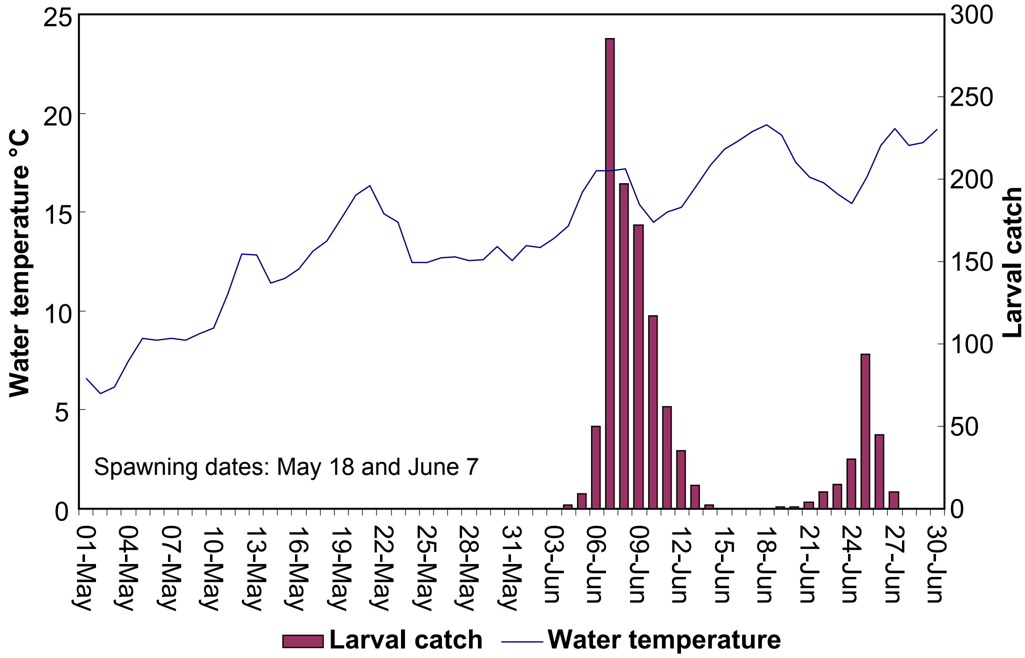

Figure 6. Mean daily water temperature and larval catch at the standard site upstream of the generating station, 2011.

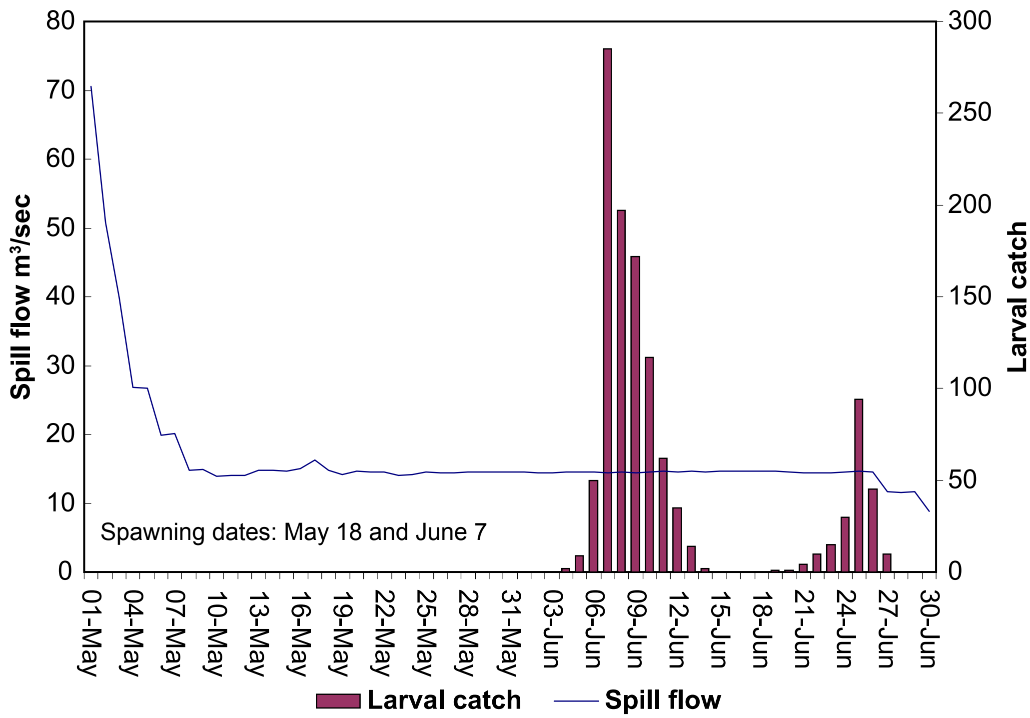

Figure 7. Mean daily spill flow and larval catch at the standard site upstream of the generating station, 2011.

Table 2. Lake sturgeon larval catch summary from MNR and OPG sampling sites.

Date (D-M-Y)	MNR west bank (4 nets)	MNR east bank (12 nets)	OPG east bank (6 nets)*
01-Jun-11			
02-Jun-11			
03-Jun-11			
04-Jun-11	3	2	
05-Jun-11	45	9	
06-Jun-11	99	50	
07-Jun-11	512	285	2
08-Jun-11	459	197	4
09-Jun-11	372	172	1
10-Jun-11	64	117	5
11-Jun-11	142	62	
12-Jun-11	21	35	
13-Jun-11	15	14	
14-Jun-11	7	2	
15-Jun-11	0	0	
16-Jun-11	0	0	
17-Jun-11	0	0	
18-Jun-11	0	0	
19-Jun-11	0	1	
20-Jun-11	1	1	
21-Jun-11	16	4	
22-Jun-11	52	10	
23-Jun-11	no lift	15	
24-Jun-11	29	30	
25-Jun-11	8	94	
26-Jun-11	11	45	
27-Jun-11	6	10	
28-Jun-11	0	0	
29-Jun-11	0	0	
30-Jun-11	0	0	

*Only 3 nets were used below the generating station after July 22.

There were two periods, approximately four days apart, when larval sturgeon were captured as they drifted downstream from the spawning site (Figure 6 and 7). The first larval sturgeon (17 mm) was captured on June 4, approximately 17 days after the suspected spawning date (May 18). The duration of the first downstream movement of larvae from the spawning site was approximately 11 days (June 4 to June 14). Over this period, 945 larval sturgeon ranging in length from 16 to 26 mm were captured. The mean daily spill flows over the eleven days of larval drift was 14.5 $m^3 \cdot s^{-1}$. Water velocity at the drift net site averaged 0.69 $m \cdot s^{-1}$ and ranged from 0.40 to 0.59 $m \cdot s^{-1}$. Water depth at the opening of the drift nets averaged 36 cm and ranged from 22 to 47 cm.

The second downstream movement of larvae started on June 19 and lasted nine days. Over this period, 210 larval sturgeon ranging in length from 18 to 25 mm were captured (Figure 6 and 7). The mean daily spill flows over the nine days of larval drift ranged 11.6 to 14.7 $m^3 \cdot s^{-1}$. Water velocity at the drift net site averaged 0.28 $m \cdot s^{-1}$ and ranged from 0.40 to 0.57 $m \cdot s^{-1}$. Water depth at the opening of the drift nets averaged 48 cm and ranged from 22 to 46 cm.

Additional site (west bank)

During 29 overnight sampling events (June 1 to June 30 with 4 nets) at the west bank site where flows and depth are greatest, 1,862 larval lake sturgeon were captured (Table 2). The catch per unit effort was 0.91 larvae/hour (2,051 sample hours).

Similar to the standard site, there were two periods when larvae were captured drifting downstream from the spawning site. During the first period of downstream drift the mean hourly spill flows averaged 14.5 $m^3 \cdot s^{-1}$, water velocity at the opening of each net ranged from 0.21 to 0.94 $m \cdot s^{-1}$ and water depth at the drift net site ranged from 43 to 65 cm. During the second period of downstream drift the mean daily spill flows over the eight days of larval drift ranged 11.6 to 14.7 $m^3 \cdot s^{-1}$, water velocity at the opening of each net ranged from 0.22 to 0.75 $m \cdot s^{-1}$ and water depth at the drift net site ranged from 49 to 70 cm.

The incidental catch (from all sites sampled upstream of the generating station) of other species was 415 larval fish, all of which were identified to the species level (Table 3).

Table 3. The drift netting incidental catch.

Common name	Scientific name	Catch
Burbot	*Lota lota*	4
Chinook salmon	*Oncorhynchus tshawytscha*	1
Johnny darter	*Etheostoma olmstedi*	3
Lake whitefish	*Coregonus clupeaformis*	87
Longnose dace	*Rhinichthys cataractae*	32
Northern pike	*Esox lucius*	69
Pink salmon	*Oncorhynchus gorbuscha*	10
Rainbow smelt	*Osmerus mordax*	1
Rock bass	*Ambloplites rupestris*	2
Sculpin family	*Cottidae*	5
Smallmouth bass	*Mocropterus dolomieu*	3
Spottail shiner	*Notropis hudsonius*	4
Trout perch	*Percopsis omiscomaycus*	54
Walleye	*Sander vitreus*	140

OPG sampling downstream of generating station

Northern Bioscience set a total of 66 nets in the Kaministiquia River downstream of the Kakabeka Falls generating station. Drift nets were set from June 6 to 12, and again from June 19 to 23, during the period that larval drift was occurring upstream of the generating station.

Twelve larval lake sturgeon were caught downstream of the generating station, when the first drift event was occurring upstream of the generating station (Table 2). Greater numbers of larval lake sturgeon were generally found in the nets set further from shore.

Based on visual observations, it appears there was incomplete separation of spill and power flows in 2011 when the total river flow was equally split between station (~14 $m^3 \cdot s^{-1}$) and spill (~14 $m^3 \cdot s^{-1}$). Based on this and the fact that the larval lake sturgeon were mostly caught in the outermost nets, it was concluded that these likely drifted from a hatch above the generating station rather than a spawning event downstream of the generating station (Foster and Harris 2011).

No larval lake sturgeon were caught downstream of the generating station when the second drift event was occurring upstream of the generating station.

Cumulative temperature units

Kempinger (1988) developed an equation to determine approximate hatching dates based on cumulative daily water temperature units (CTU). Using this equation for drift data acquired on the Kaministiquia River (2004 to 2010), we know that it takes approximately 150 CTU to accumulate before larvae will start to drift after the first spawning event (Table 4). If we assume that spawning occurred on May 18, 142 CTU had accumulated when the first larva was captured (June 4), which is consistent with previous study years.

We also know that it takes approximately 142 CTU to accumulate from the date of spawning before larvae will start to drift after the second spawning event (Table 4). If we assume, from the telemetry and temperature data, that spawning occurred upstream of the generating station on June 7, 142 CTU had accumulated by the time the first larvae was captured. This is consistent with other study years.

Summary

Telemetry

1. Radio-tagged sturgeon (n=2) migrated into the study area on May 15 and 18 during mean spill flows of 14.5 $m^3 \cdot s^{-1}$. It took them from four to 15 hours to move upstream from the generating station to the base of the falls.
2. The first spawning event may have occurred around May 18 when one radio-tagged sturgeon departed the study area.
3. The second spawning event may have occurred around June 7 when one radio-tagged sturgeon departed the study area.
4. Migration from the study area occurred during mean spill flows of 14.6 $m^3 \cdot s^{-1}$.

Drift netting

1. Sturgeon spawned successfully in the study area. A total of 1,155 larvae were captured at the standard index site.
2. There were two periods when larvae were captured as they drifted downstream from the spawning site (June 4 to 14, and June 19 to 27).
3. Larval drift was documented at the standard index site during mean daily spill flows of 14.5 $m^3 \cdot s^{-1}$.
4. An additional 1,862 larvae were captured at the west bank site where water velocity and depths were the greatest.
5. Spawning did not occur downstream of the generating station.

Table 4. Cumulative daily thermal units (CTU) for the time period from first spawning event and second spawning event to the start and end of larval drift in the Kaministiquia River.

Cumulative temperature units associated with first spawning events.

Year	Date of spawning	Incubation period (date)	CTU for incubation	Duration of drift (days)	Days to end of drift (date)	CTU to end of drift
2004	21-May	21 (10-June)	145.9	19	39 (28-June)	299.2
2005	22-May	17 (7-June)	154.2	12	28 (18-June)	266.4
2006	21-May	12 (1-June)	130.5	16	27 (16-June)	332.0
2007	24-May	15 (7-June)	162.7	7	23 (15-June)	263.0
2008	7-June	20 (26-June)	159.3	18	37 (13-July)	351.9
2009	21-May	25 (15-June)	152.2	19	44 (3-July)	352.2
2010	19-May	10 (29-May)	146.9	11	21 (8-June)	275.8
2011	18-May	18 (4-June)	141.8	11	27 (14-June)	237.5
Mean CTU			**149.2**			**297.3**

Cumulative temperature units associated with second spawning events.

Year	Date of spawning	Incubation period (date)	CTU for incubation	Duration of drift (days)	Days to end of drift (date)	CTU to end of drift
2004	27-June	23 (20-July)	173.3	8	23 (20-July)	289.0
2005	31-May	20 (19-June)	203.7	7	26 (25-June)	291.0
2006						
2007	31-May	15 (14-June)	169.7	5	19 (18-June)	250.0
2008						
2009	5-June	20 (24-June)	176.9	10	29 (3-July)	279.8
2010	22-May	10 (31-May)	142.3	10	21 (9-June)	277.0
2011	7-June	13 (19-June)	147.1	9	21 (27-June)	249.7
Mean CTU			**168.8**			**272.8**

Cumulative temperature units

1. If we assume from the telemetry data, that there was a spawning event on May 18, 142 CTU had accumulated when the first larva was captured on June 4, which is consistent with previous study years.
2. If we assume from the telemetry data, that there was a spawning event on June 7, 147 CTU had accumulated when the first larva was captured on June 19, which is consistent with previous study years.

Glossary

dam leakage
Refers to flow that is passed through spacers between the Kakabeka dam stop logs (0.5 $m^3 \cdot s^{-1}$).

drift event
The period of time (days) during which larval sturgeon are captured as they drift downstream from the spawning site.

PIT tag
passive integrated responder: an internal tag inserted under the third dorsal scute (counting back from the head) of the sturgeon

plunge pool
Refers to the large pool at the base of Kakabeka Falls where sturgeon congregate during spawning.

power flows
Refers to flow that originates from the generating station.

reference tag
Refers to the radio tag that is situated within the study area to determine sturgeon location and verify logger function.

scenic flow
Water flowing over the falls that is provided (for Kakabeka Falls Provincial Park) during daylight hours of the tourist season (i.e. Victoria Day weekend in May to Thanksgiving Day weekend in October) at flow rates of 4.25 $m^3 \cdot s^{-1}$ on weekdays and 8.5 $m^3 \cdot s^{-1}$ on weekends and statutory holidays.

spill flow
Flow over Kakabeka Falls that is in excess of scenic flows or dam leakage.

study area
Refers to the portion of the Kaministiquia River from Kakabeka Falls downstream to the generating station.

tailwater
Refers to waters located immediately downstream from the generating station.

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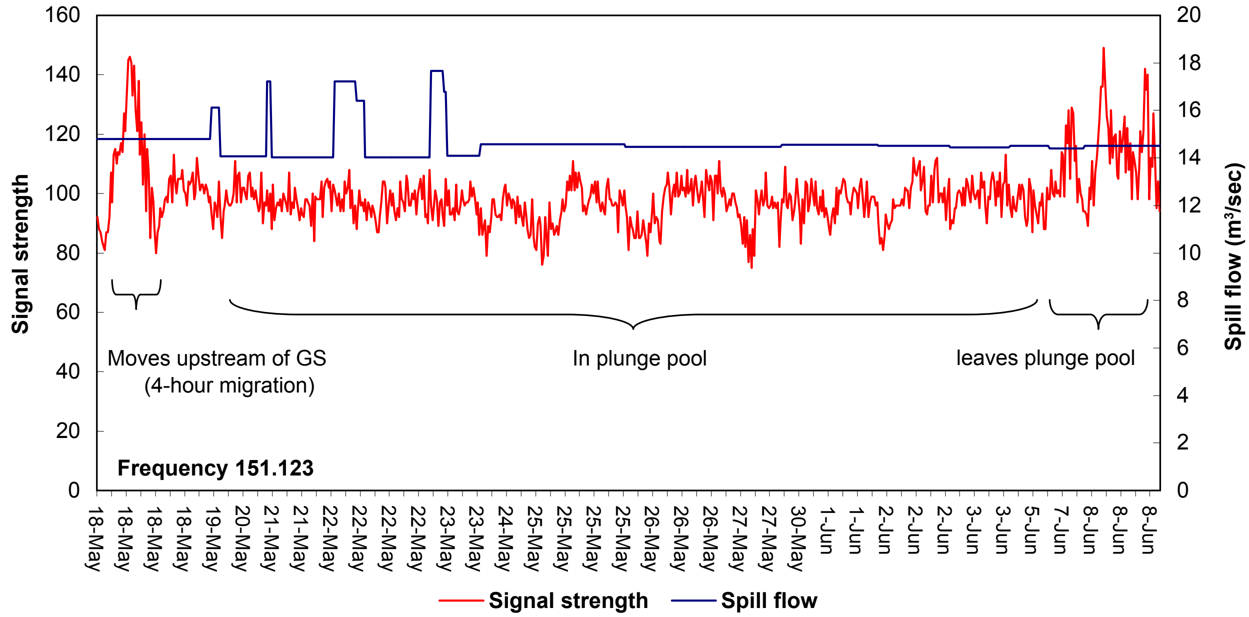
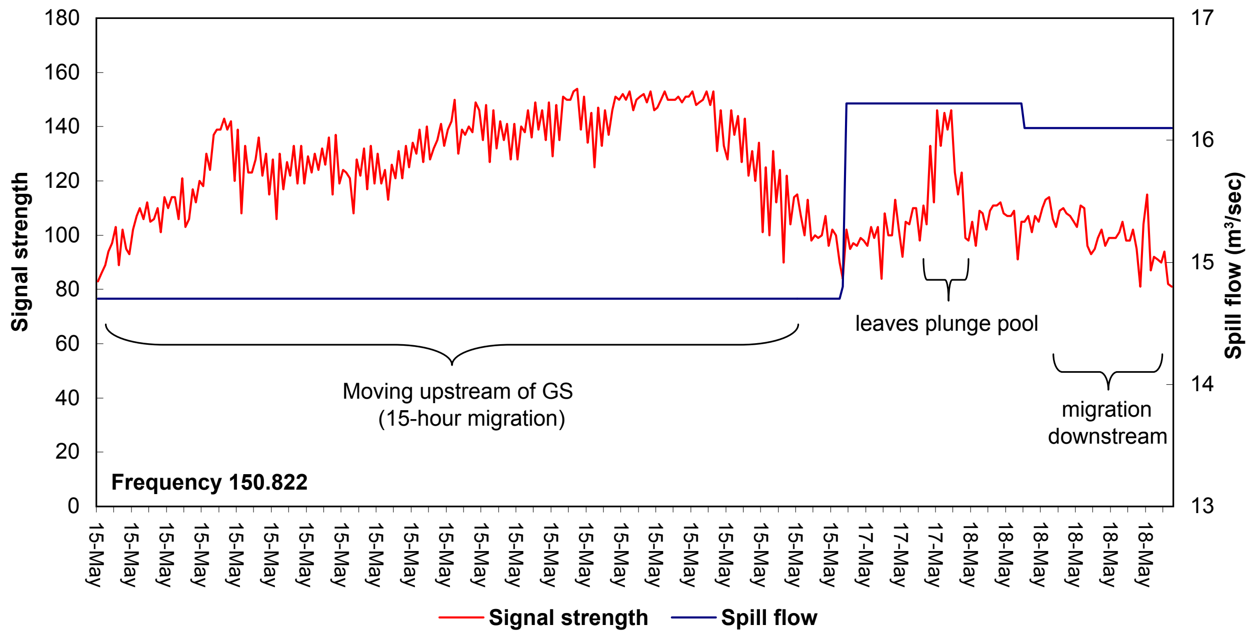
Appendices

Appendix 1

Detailed movement of two radio-tagged sturgeon into the study area upstream of the generating station.





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