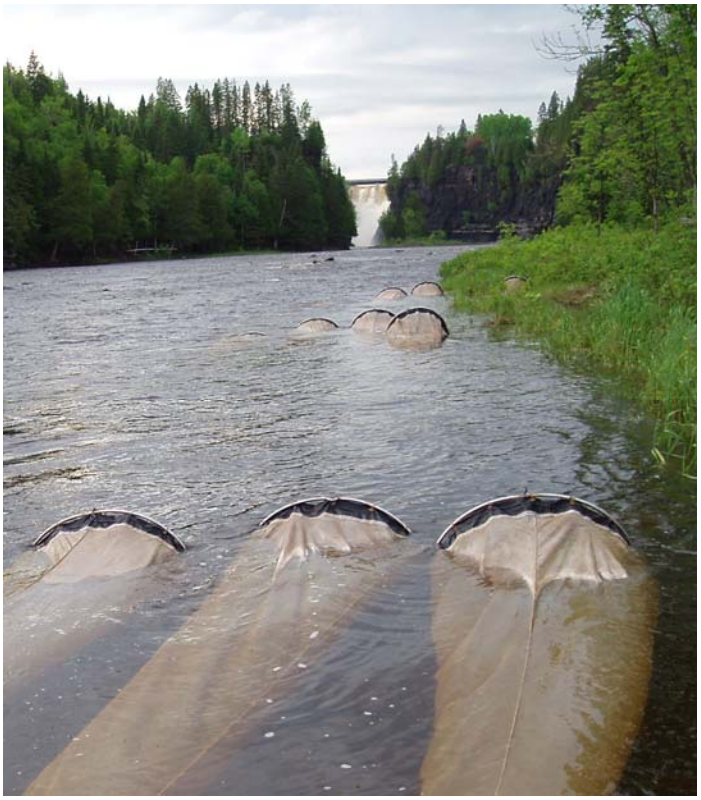
The Migratory and Reproductive Response of Spawning Lake Sturgeon to Controlled Flows over Kakabeka Falls on the Kaministiquia River, 2008



Upper Great Lakes Management Unit

Lake Superior

Technical Report 2008 - 01

M.J. Friday

Ontario

TABLE OF CONTENTS

List of Tables ……. i

List of Figures ……. ii

List of Appendices ……. ii

Introduction …… 1

Study Area ……. 2

Materials and Methods ……. 3
- Radio Tagging …… 3
- Tracking …… 4
- Drift Netting …….. 5
- Water Temperature, Velocity and Depth ……..…… 5
- Study Flow Plan …….. 5

Results …….. 6
- Spill Flows…… 6
- Water Temperature…….. 6
- Radio Tagging…….. 6
- Migration …….. 7
  - Harstone Logger…….. 7
  - Kakabeka Logger…… 8
- Spawning Events ……. 8
  - Telemetry…….. 8
  - Water Temperature …… 9
  - Drift Netting …… 9
  - Cumulative Thermal Units ……. 10

Summary……. 11
- Telemetry…….. 11
- Drift Netting…… 11
- Spawning Events …… 12

Glossary ……. 12

Acknowledgements …….. 13

References …….. 13

LIST OF TABLES

Table		Pg.
1	Fish attribute information for 4 adult sturgeon radio tagged in 2008 and two tagged in 2007 and one tagged in 2000.	21
2	The drift netting incidental catch.	21

LIST OF FIGURES

Figure		Pg.
1	The Kaministiquia River watershed and major reservoirs.	14
2	The study area from Kakabeka Falls downstream to the OPG generating station.	15
3	The Kaministiquia River from Kakabeka Falls downstream to Lake Superior.	16
4	Water temperature and mean daily spill flow over Kakabeka Falls from April 28 to August 14, 2008.	17
5	Mean daily spill flow over Kakabeka Falls and total river flow from April 28 to August 14, 2008.	17
6	Mean daily water temperature for May (2004 to 2008).	18
7	The migration of radio tagged sturgeon to the Harstone and Kakabeka loggers in relation to mean daily total river flows and water temperature.	19
8	Kakabeka Falls spill flow in relation to approximate spawning date and catches of downstream drifting larvae.	20
9	Mean daily water temperature in relation to approximate spawning date and catches of downstream drifting larvae.	20

LIST OF APPENDICES

App.		Pg.
1	Cumulative daily thermal units (CTU's) calculated for the time period from first spawning to the start of larval drift in the Kaministiquia River.	22
2	Cumulative daily thermal units (CTU's) calculated for the time period from second spawning to the start of larval drift in the Kaministiquia River.	22

INTRODUCTION

In 2002, the Ontario Ministry of Natural Resources (OMNR) and Ontario Power Generation (OPG) commenced water management planning for the Kaministiquia River watershed. 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 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.

The second dam is also utilized 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 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. It was measured at 0.34 $m^3 \cdot s^{-1}$ on May 5, 2006.

From 2004 to 2006 flow over the Falls was provided to allow sturgeon access to the holding pool and 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 and 2005) and 17 $m^3 \cdot s^{-1}$ (Friday 2006). In 2007 we examined lake sturgeon movements and reproduction during scenic flows and found that sturgeon spawned upstream and downstream of the GS (Friday 2007). In 2008, we proposed to re-examine the flow condition of 17 $m^3 \cdot s^{-1}$, to determine if migration to the base of the Falls and successful spawning would occur.

This report details the fifth year of research examining lake sturgeon spawning migrations and reproductive success.

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 17 $m^3 \cdot s^{-1}$;
2. Determine if spawning lake sturgeon can successfully migrate out of the study area during spill flows of 17 $m^3 \cdot s^{-1}$;
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 during spill flows of 17 $m^3 \cdot s^{-1}$;
6. Determine the timing and duration of downstream movement of larval lake sturgeon.

STUDY AREA

These studies focused on an 800 m stretch of the Kaministiquia River from the base of Kakabeka Falls downstream to the GS (Figure 1 and 2).

MATERIALS AND METHODS

Radio Tagging

Radio telemetry equipment manufactured by Advanced Telemetry Systems (ATS) was used in this study[1]. Each external radio transmitter (n = 20) was identified by a unique frequency between 150.503 – 151.452 MHz. The 20 g transmitters (model F2060) pulsed 55 times per minute and had a battery life of approximately 10 months.

To catch sturgeon for tag attachment, 46 m of 305 mm (12”) and 254 mm (10”) stretched mesh multifilament gill net was set overnight at river kilometre (rkm) 19 (Figure 3). Netting was carried out from May 14 to May 28 (15 net sets) during water temperatures that ranged from 7.45 to 12.6 °C and total river flows from 80 to 159 $m^3 \cdot s^{-1}$. To attach the transmitter, 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. No anaesthetic was 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 sixteen digit passive integrated transponder (PIT tag) was applied under the third dorsal scute of each fish (counting back from the head). This is a standard PIT tag insertion site for all lake sturgeon tagged in Lake Superior and its tributaries. A genetic sample was also taken from the leading edge of the left pectoral fin. We attempted to determine fish gender by forcing eggs or milt from the genital opening.

[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 GS (Figure 2) 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 GS). The logger operated from May 5 to June 6 (permanently damaged in a high water event on June 6th) and was replaced with a back up unit on June 10 which operated to October 12.

A reference transmitter (150.893 MHz) was placed in the river upstream of the GS and was logged every six hours to provide a known signal strength 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.

An additional shoreline based data logger was set up approximately 6.5 rkm downstream of Kakabeka Falls on Harstone Drive (Harstone logger) to monitor the upstream and downstream movements of migrating sturgeon. This data logger was situated where, in previous study years, sturgeon were often located before migrating to the Falls (Figure 3). This logger operated from May 5 to June 6th. It was permanently damaged in the June 6th high water event and was not replaced.

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 loggers 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 on the east shore of the river approximately 400 m downstream of Kakabeka Falls (Figure 2). Nets were set from June 23 to August 1 inclusive and from August 4 to 15 inclusive. Although in previous years we set 12 nets to monitor drift, high flows and excessive amounts of debris made this difficult and time consuming. We modified the protocol and set 8 nets from June 23 to 25, 12 nets from June 26 to 28 and 8 nets from June 29 to August 15.

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 m tapered mesh bag that terminated at collection container with filtering holes covered by 1000 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. Live sturgeons were released downstream. Dead specimens were placed in glass vials and preserved in 70% ethanol. Other larval fish species captured were also preserved and later identified in the laboratory.

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 GS in 0.5 m of water. Temperature was recorded hourly from April 28 to October 23. Water velocity was recorded using a Marsh McBirney Flo-Mate ($m \cdot s^{-1}$) and depth (cm) was measured daily at the opening of each drift net when setting.

Study Flow Plan

From May 15 to June 25, 2008 the study plan was to provide 17 $m^3 \cdot s^{-1}$ over the falls (inflows permitting). Starting on June 26 flow over the Falls would be

reduced by 3 $m^3 \cdot s^{-1}$ and continue every 24 h until scenic flows were attained (June 30).

RESULTS

Spill Flows

As a result of high river flows prior to the study start date (spring freshet) and heavy rainfall throughout the Kaministiquia watershed, flow over the falls could not be controlled at 17 $m^3 \cdot s^{-1}$ within the study period. A major rain event on June 6th increased flow over Kakabeka Falls from 106 $m^3 \cdot s^{-1}$ on June 6 to a maximum mean daily uncontrolled flow of 369 $m^3 \cdot s^{-1}$ on June 7 (Figure 4 and 5). The greatest mean hourly flow recorded was 545 $m^3 \cdot s^{-1}$on June 7.

Flow over the falls remained uncontrolled until approximately July 10th. At that time, due to continued uncertainty over a potential late larval drift period, and to accommodate the overall study objectives, OPG agreed to continue to provide a minimum continuous flow over Kakabeka Falls until August 15. The minimum spill target during this period was decreased to 12 $m^3 \cdot s^{-1}$ from the original study flow of 17 $m^3 \cdot s^{-1}$. The actual spill flow ranged from 13 to 32 $m^3 \cdot s^{-1}$.

Water Temperature

The mean daily water temperature in May of 2008 (8.3 °C) was the coldest recorded since these studies began in 2004. The rate of river warming to the initial spawning temperature of approximately 13°C was slower than in all previous years, and the major storm event on June 6 may have further delayed warming by several days (Figure 6).

Radio Tagging

External radio transmitters were attached to four lake sturgeon in the spring of 2008. These fish ranged from 111 to 159 cm in total length and weighed 9.5 to 19.5 kg (Table 1). Gill netting was not as effective as in previous years due to excessive river flows (80 to 159 $m^3 \cdot s^{-1}$).

Migration

Four radio tagged sturgeon migrated to the base of Kakabeka Falls in 2008 (frequencies 522, 624, 794 and 095). One was radio tagged in the present study (522), two were tagged during a similar study in 2007 (624 and 794) and one was internally tagged (095) in the fall of 2000. Of the fish that were externally radio tagged in 2007, only one fish (794) migrated to the base of the Falls in that year. Fish 095 migrated to the base of the Falls in 2004.

The three fish (tagged in 2008) that did not migrate to Kakabeka Falls did not migrate upstream of the tagging site. All three were located on August 13 in the "turning basin", approximately 9 kilometres from the confluence with Lake Superior (Figure 3).

Harstone Logger

The first upstream migrating sturgeon detected by the Harstone logger (frequency 794) arrived on May 10 (8.4°C). This fish was logged for approximately 1 hr as it migrated upstream. It was detected by the Kakabeka logger 24 hours later and moved approximately .27 km/hr. During this 24 hour period of upstream migration, the mean daily total river flows ranged from 92.3 to 121 $m^3 \cdot s^{-1}$ and water temperature was 8.2°C. This fish was also detected moving back downstream on May 23 during mean daily total river flows of 80 $m^3 \cdot s^{-1}$ and water temperature of 10.8°C (Figure 7).

The second upstream migrating sturgeon detected by the Harstone logger (Frequency 624) arrived on May 18 (9.8°C) and was detected for 15 minutes as it migrated upstream. It was detected by the Kakabeka logger 21 hours later and moved approximately .3 km/hr. During this 21 hour period of upstream migration, the mean daily total river flows ranged from 103 to 114 $m^3 \cdot s^{-1}$ and water temperature was 9.8°C (Figure 7).

Kakabeka Logger

Radio tagged sturgeon arrived at Kakabeka between May 11 (7.9°C) and June 27 (17.9°C) during spill flows that ranged from 40.6 to 292.4 $m^3 \cdot s^{-1}$. One fish (624) migrated into the study area on two separate occasions (May 19 and June 25) and was downstream of Kakabeka for approximately 20 d (Figure 7). A similar pattern of behaviour has been noted in each of the other study years. In 2004 and 2007, after initially moving into the study area, some sturgeon (2 in 2007 and 3 in 2004) migrated downstream approximately 6.5 rkm before migrating back to Kakabeka Falls at a later date (Friday 2004 and 2007). The duration of these downstream movements from the spawning site has ranged from 1 to 20 d and in 2004 may have been associated with a drop in water temperature.

The logger recorded three fish moving out of the study area between May 22 and July 23 (Figure 5) during spill flows that ranged from 27.5 to 105.6 $m^3 \cdot s^{-1}$ (Figure 7). The downstream migration of the fourth fish (095) occurred some time after the data logger had been removed (October 12). This fish was manually tracked in the plunge pool at the base of the falls on November 7 but was not located during a subsequent tracking effort on November 21. Spill flows from November 7 to 21 ranged from 0 to 187 $m^3 \cdot s^{-1}$.

Spawning Events

Telemetry

In previous study years we determined the approximate date of spawning and the number of spawning events that may have occurred by observing when groups of radio tagged fish migrated downstream from the spawning site. With so few radio tagged fish at Kakabeka (n=4) this was not a reliable method to predict the date of spawning. Frequency 794 did however; depart the study area on May 22 which is during the time period when spawning activity has been previously documented.

Water Temperature

We relied on water temperatures associated with the first and second spawning events (approximately 13 and 16°C respectively) from previous years to predict when spawning had occurred. From these data, we assumed that the first spawning event may have occurred on June 7 when the mean daily water temperature was 12.9°C and mean flow over Kakabeka Falls was 368 $m^3 \cdot s^{-1}$.

A second spawning may have occurred on June 20 when the mean daily water temperature was 15.1°C and mean daily flow over Kakabeka Falls was 89 $m^3 \cdot s^{-1}$.

Although 794 left the study area during the time period when spawning activity has been previously documented (May 22), the mean daily water temperature (10.2°C) does not seem to support the possibility that there was a spawning event on that date.

Drift Netting

During 47 sampling events from June 23 to August 15 (8986 sample hrs), 78 larval lake sturgeon were captured. The catch per unit effort was .008 larvae/hour. The incidental catch of other fish species was 4407, of which 1907 were identified to the species level and 2500 specimens were grouped by family (Table 2).

The first larval sturgeon (20 mm) was captured on June 26 which seems to support the conclusion that there was likely a spawning event around June 7 when the mean daily water temperature was 12.9°C. The duration of the downstream movement of larvae from the spawning site was approximately 18 d (June 26 to July 13) (Figure 8 and 9). Larval sturgeons ranging in length from 18 to 26 mm were captured. During the period of larval drift, mean daily spill flows ranged from 21.2 to 177 $m^3 \cdot s^{-1}$, water velocity ranged from 0.01 to 0.63 $m \cdot s^{-1}$ and water depth at the drift net site ranged from 11 to 99 cm. The mean daily water temperature from the suspected spawning date (June 7) to the date when the

first larva was collected was 13.8 °C. The mean daily water temperature during the period of larval drift was 17.2 °C (Figure 9).

Cumulative Thermal Units

Kempinger (1988) developed an equation to determine approximate hatching dates based on cumulative daily water temperature units (CTU). Using this equation, for data on the Kaministiquia River, we know that it takes approximately 150 CTU's to accumulate before larvae will start to drift after the first spawning event (Appendix 1). When daily CTU values are back-calculated from the date when the first larva was captured (June 26) to June 7, the accumulated CTU value (159) is within the typical range for first spawnings (Appendix 1). This seems to support the conclusion that there was a spawning event around June 7.

It is difficult to assess whether there were spawning events on May 22 and June 20 using the telemetry and drift netting data alone. Using Kempinger's equation, we know that it takes approximately 183 CTU's to accumulate before larvae will start to drift after a second spawning event (Appendix 2). If spawning did occur on June 20, we would anticipate larval drift to commence around July 6th when 185 CTU's had accumulated and last for 5 to 10 d. While a few more larvae were caught (7) from July 9 -13, this could be the tail end of the drift event from the June 7 spawning; rather than larvae from a June 20th spawning.

Additionally, the CTU requirement from first spawn to drift also seems to indicate that there was likely not a spawning event on May 22. If spawning had occurred, drift catches would have commenced around June 18, when ~ 155 CTU's had accumulated, and should have been detected during our first few lift days (June 24 -25).

SUMMARY

TELEMETRY

1. One radio tagged sturgeon (794) migrated into the study area prior to the study start date during mean spill flows of 40.6 $m^3 \cdot s^{-1}$ and mean daily water temperature of 9.4 °C.
2. With so few radio tagged fish in the study area (n=4) it was more difficult to predict the date of spawning by observing when groups of radio tagged fish migrated downstream.
3. Spill flows during migration into the study area ranged from 40.6 to 292.4 $m^3 \cdot s^{-1}$.
4. Spill flows during movement from the study area ranged from 27.5 to 105.6 $m^3 \cdot s^{-1}$.
5. The last radio tagged sturgeon to migrate from the study area occurred between November 7 and November 21 during spill flows that ranged from 0 to 187 $m^3 \cdot s^{-1}$.

DRIFT NETTING

1. Despite high flows and cold water temperatures, sturgeon spawned successfully in the study area.
2. There was one period (18 days) when larvae were captured as they drifted downstream from the spawning site (June 26 to July 13).
3. Larval drift occurred during mean daily spill flows ranging from 21.2 to 177 $m^3 \cdot s^{-1}$.
4. Drift occurred outside of the timeframe in which flows were intended to be controlled (until June 25) and lasted until July 13.

SPAWNING EVENTS

1. Spawning was likely delayed by an extended period of low water temperatures.
2. Based on the CTU data for this river and back-calculating from the onset of larval drift, we concluded that there was probably one spawning event sometime around June 7 during mean daily flows of 368 $m^3 \cdot s^{-1}$.

The 2008 study year was characterized by extremely high flows and low water temperatures. As a result, small samples sizes were evident in all elements of this study. This made data interpretation more difficult than it has been in the past. Despite these extreme environmental conditions, spawning migrations and successful reproduction were documented.

GLOSSARY

Leakage - Water that seeps through the gaps between dam stop logs. During the overnight hours of the tourism season (Victoria Day weekend in May to Thanksgiving Day weekend in Oct.) leakage through the stop logs (.34 $m^3 \cdot s^{-1}$) provides the only flow over the falls. Outside of the tourism season stop log leakage also accounts for flow over the falls.

Drift event – The period of time (days) during which larval sturgeon drift downstream from the spawning site.

Scenic flows - Flow 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.

Uncontrolled flow – Flow over Kakabeka Falls in excess of study flows.

ACKNOWLEDGEMENTS

This study was funded by the Canada Ontario Agreement respecting the Great Lakes Basin Ecosystem. The contributions of OMNR staff including Karen Schmidt (technical expertise), Kim Ahola (data entry) and Kim Armstrong (report review) and the assistance of summer field staff are greatly appreciated. I would also like to thank Ontario Power Generation for monitoring spill flows, providing spill reports, assisting with logistical aspects of the project and report review. Thanks to Ontario Parks for allowing us to carry out this research in the park and Grant Majala for the use of his property for the Harstone telemetry data logger.

REFERENCES

Friday, M. 2004. The Migratory and Reproductive Response of Spawning Lake Sturgeon to Controlled Flows over Kakabeka Falls on the Kaministiquia River, 2004. Min. Nat. Res. Upper Great Lakes Management Unit – Lake Superior Technical Report 06.01. 27 p.

Friday, M. 2005. The Migratory and Reproductive Response of Spawning Lake Sturgeon to Controlled Flows over Kakabeka Falls on the Kaministiquia River, 2005. Min. Nat. Res. Upper Great Lakes Management Unit – Lake Superior QUIK Report 05.01. 16 p.

Friday, M. 2006. The Migratory and Reproductive Response of Spawning Lake Sturgeon to Controlled Flows over Kakabeka Falls on the Kaministiquia River, 2006. Min. Nat. Res. Upper Great Lakes Management Unit – Lake Superior QUIK Report 06.02. 13 p

Friday, M. 2007. The Migratory and Reproductive Response of Spawning Lake Sturgeon to Controlled Flows over Kakabeka Falls on the Kaministiquia River, 2007. Min. Nat. Res. Upper Great Lakes Management Unit – Lake Superior Technical Report 2007.01. 18 p

Kempinger, J. J., 1988. Spawning and early life history of the lake sturgeon in the Lake Winnebago system, Wisconsin. N. Am. J. Fish Manage. 16, 102-114.

Ontario Power Generation, 2005. Kaministiquia River System Water Management Plan 323 p.

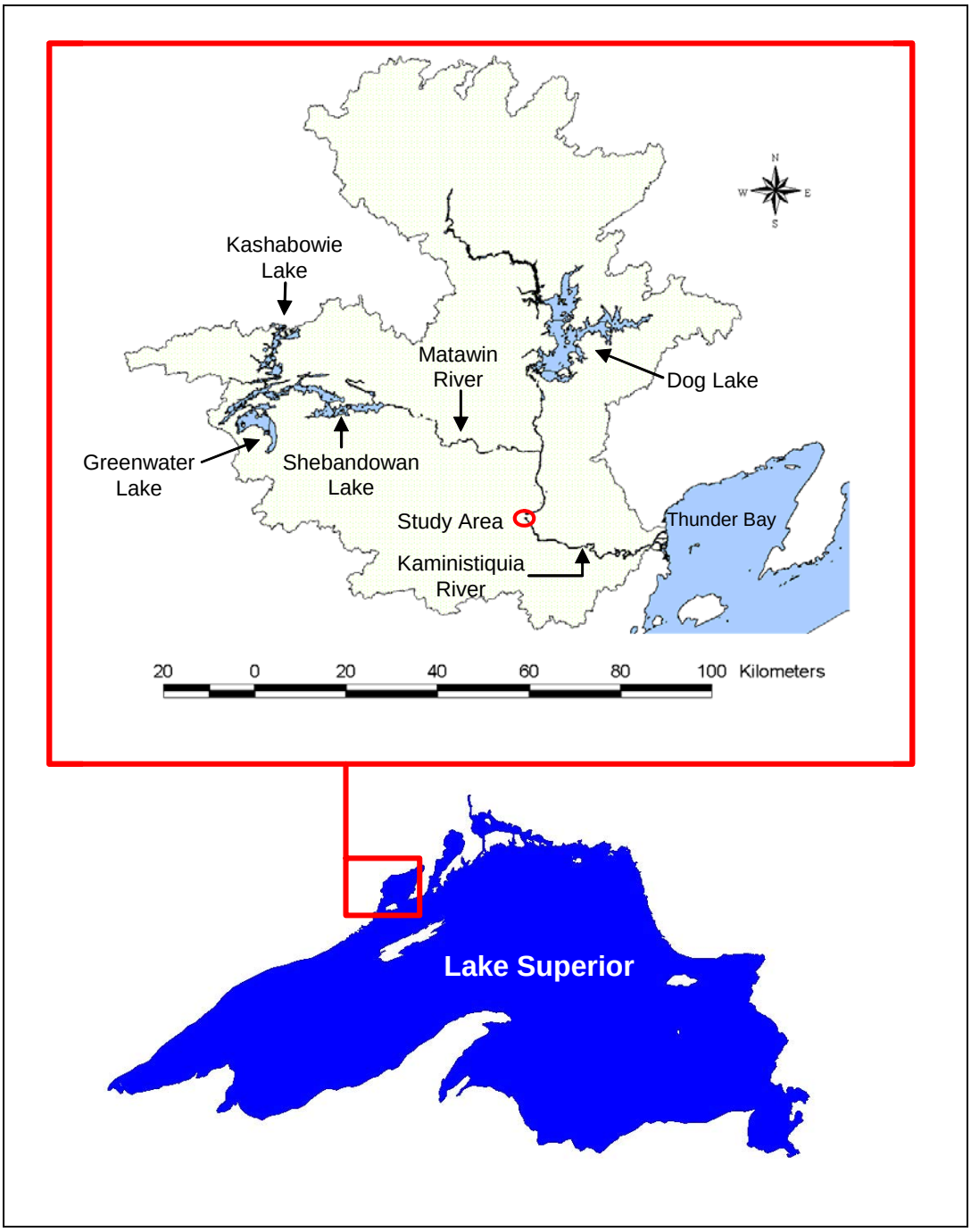


Figure 1. The Kaministiquia River watershed and major reservoirs.

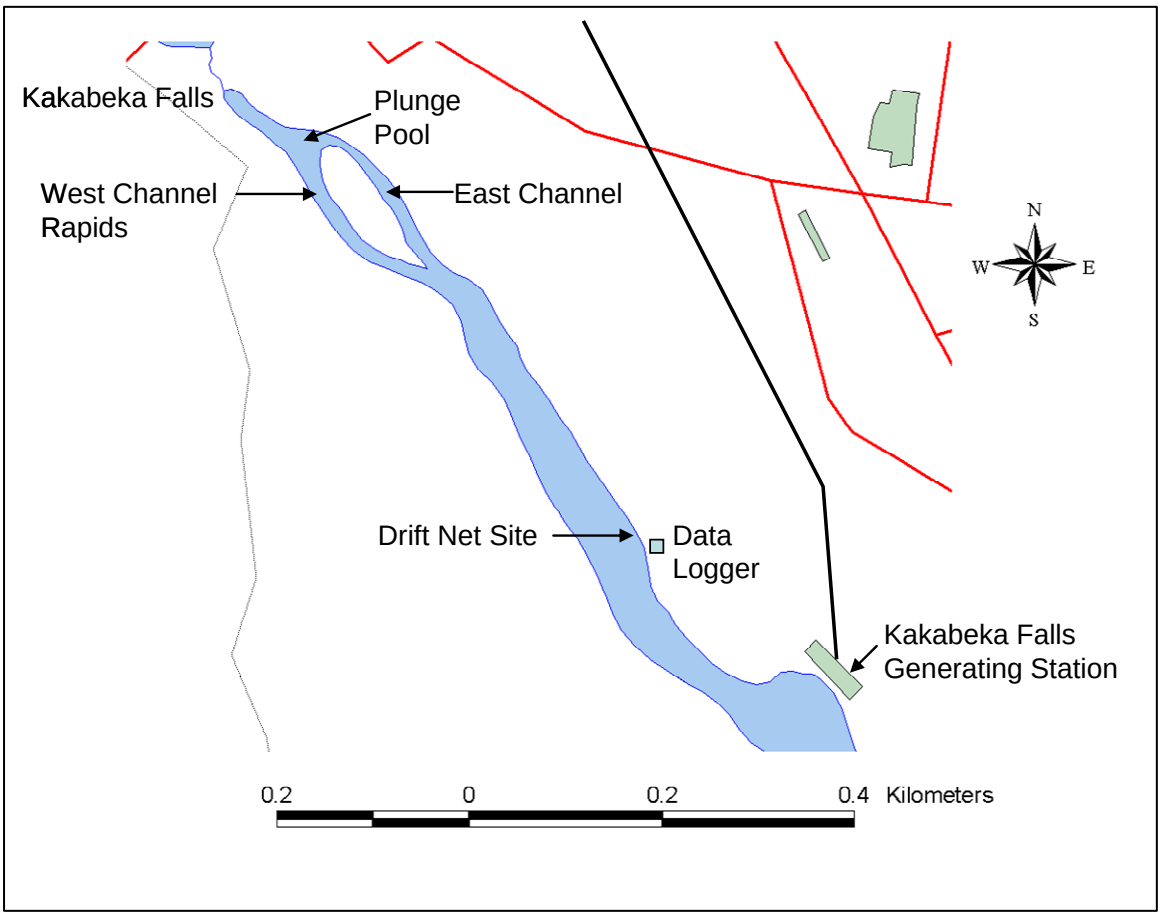


Figure 2. The study area from Kakabeka Falls downstream to the OPG generating station.

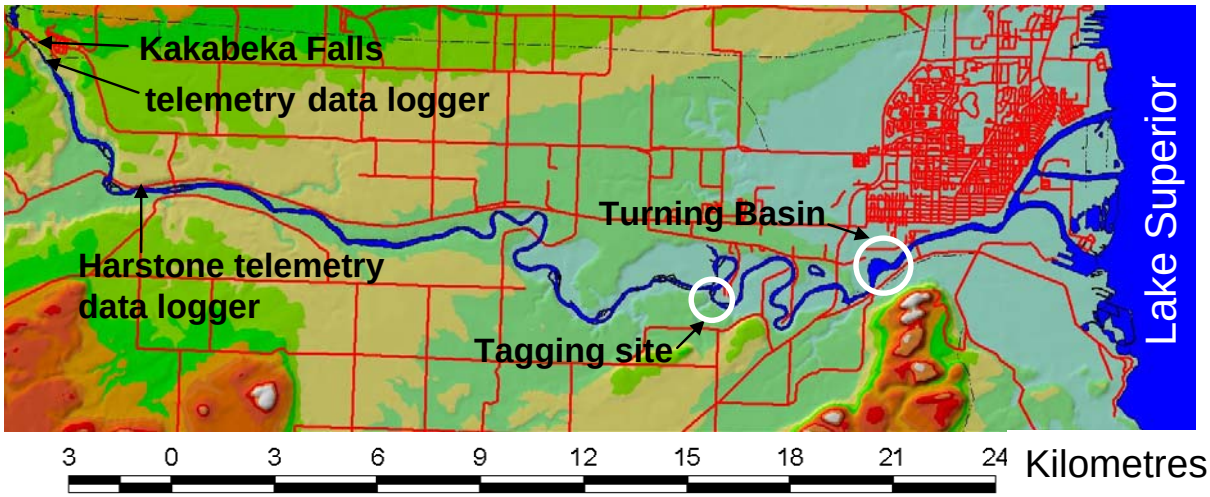


Figure 3. The Kaministiquia River from Kakabeka Falls downstream to Lake Superior.

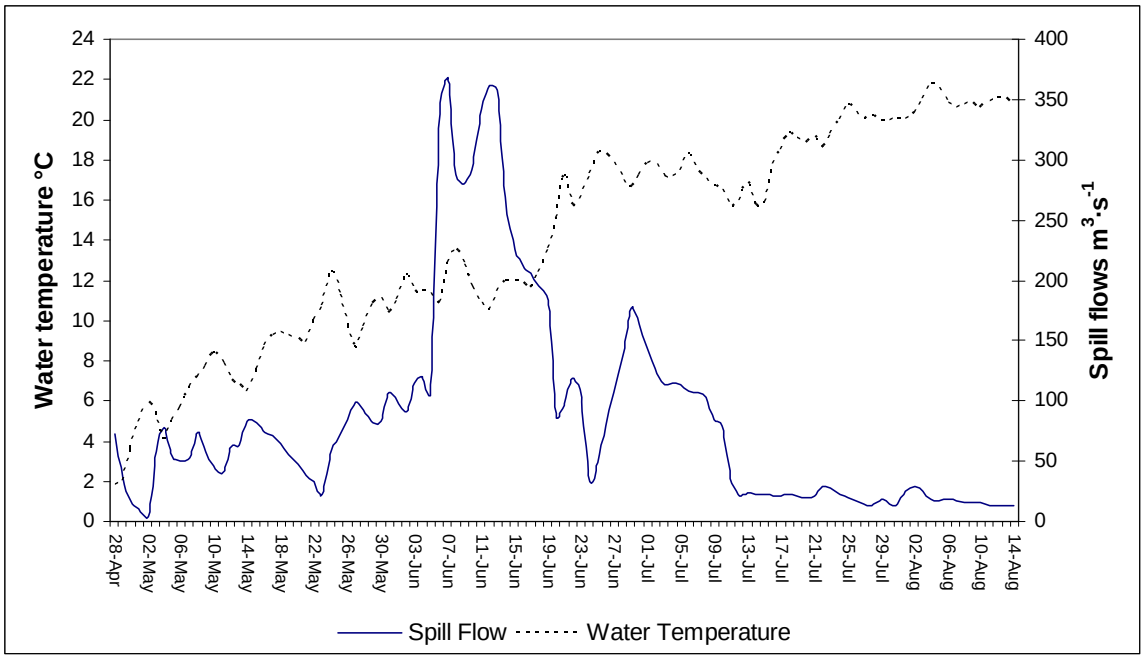


Figure 4. Water temperature and mean daily spill flow over Kakabeka Falls from April 28 to August 14, 2008.

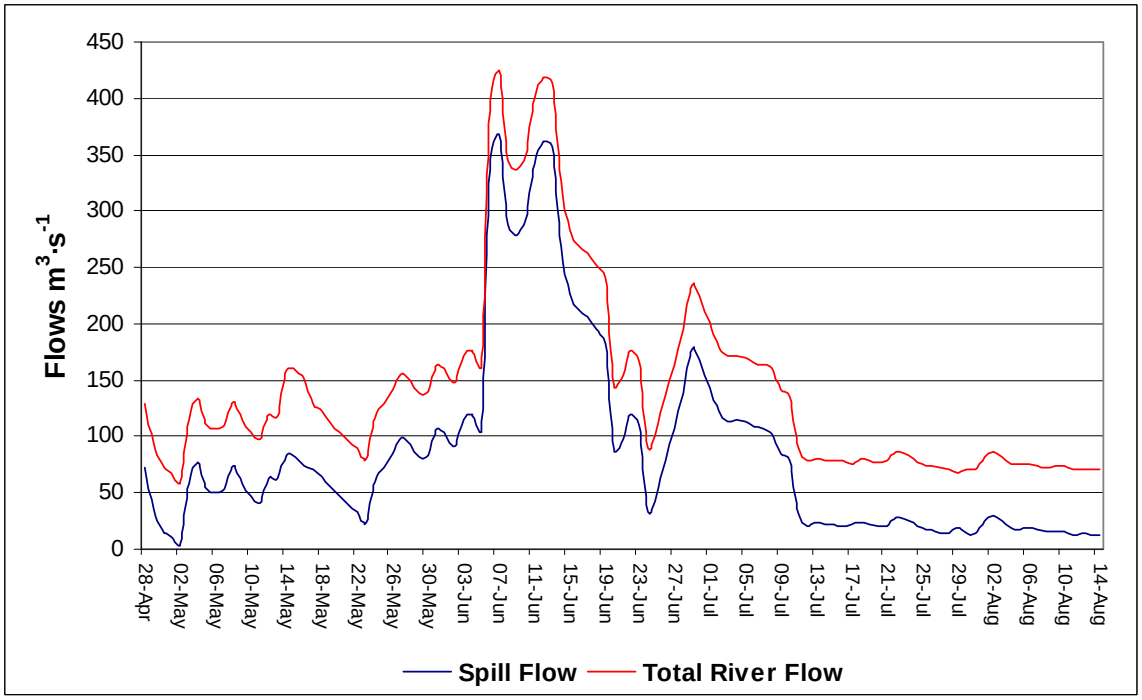


Figure 5. Mean daily spill flow over Kakabeka Falls and total river flow from April 28 to August 14, 2008.

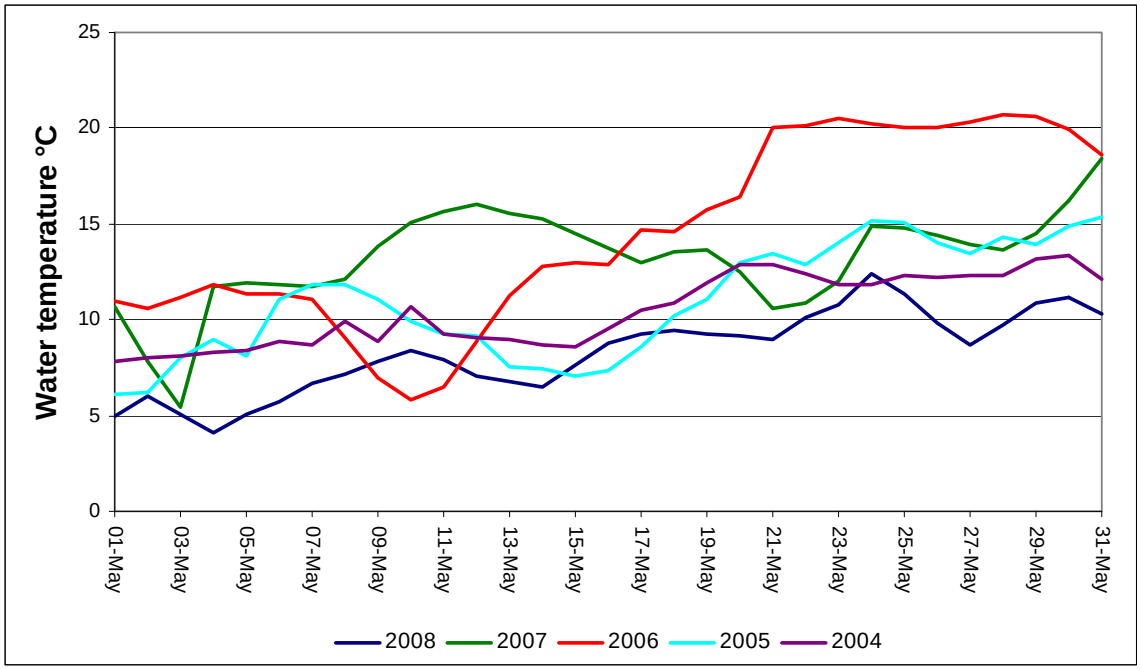


Figure 6. Mean daily water temperature for May (2004 to 2008).

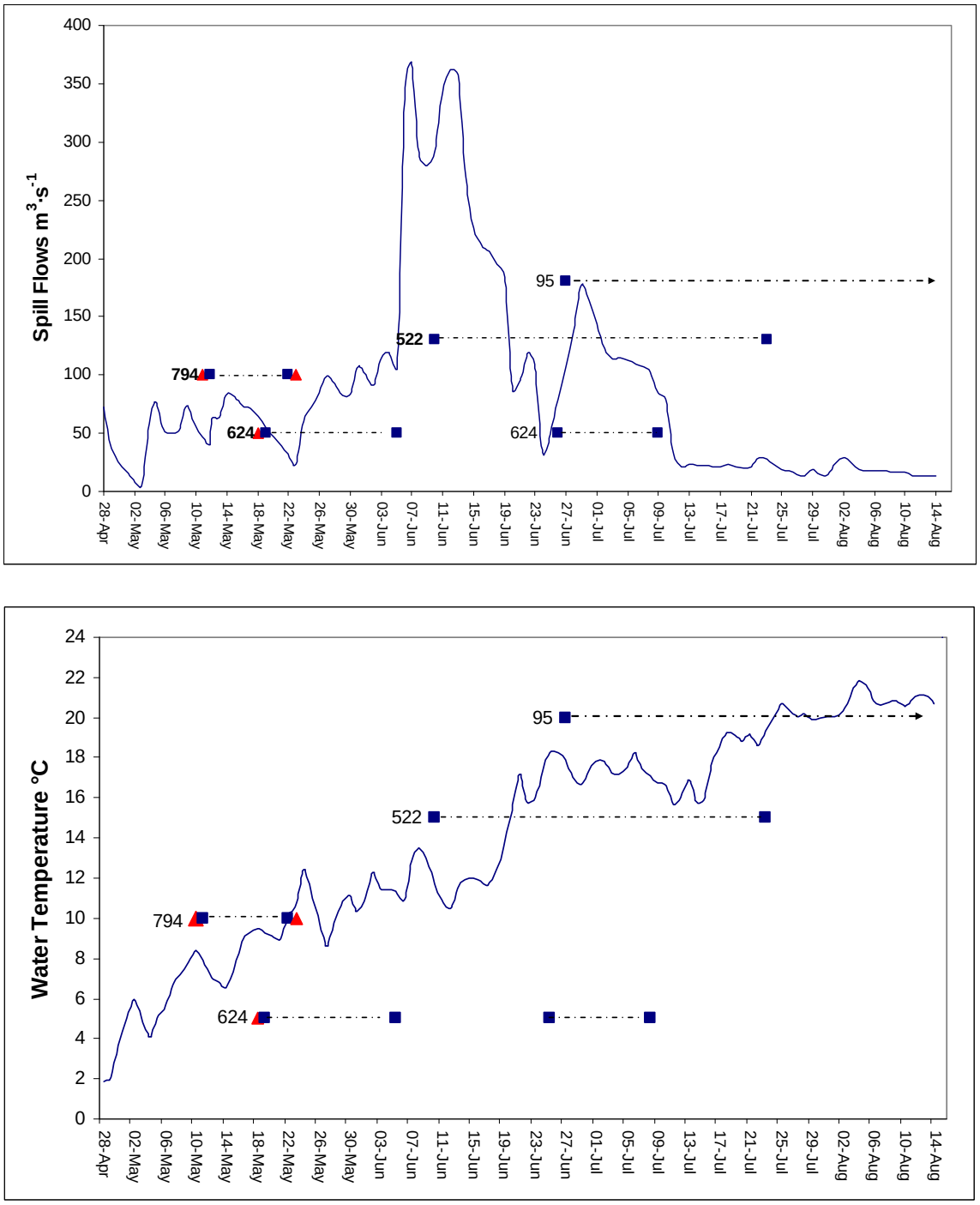


Figure 7. The migration of radio tagged sturgeon to the Harstone (red triangles) and Kakabeka (blue squares) loggers in relation to mean daily total river flows and water temperature. Dashed lines indicate duration of time within the study area.

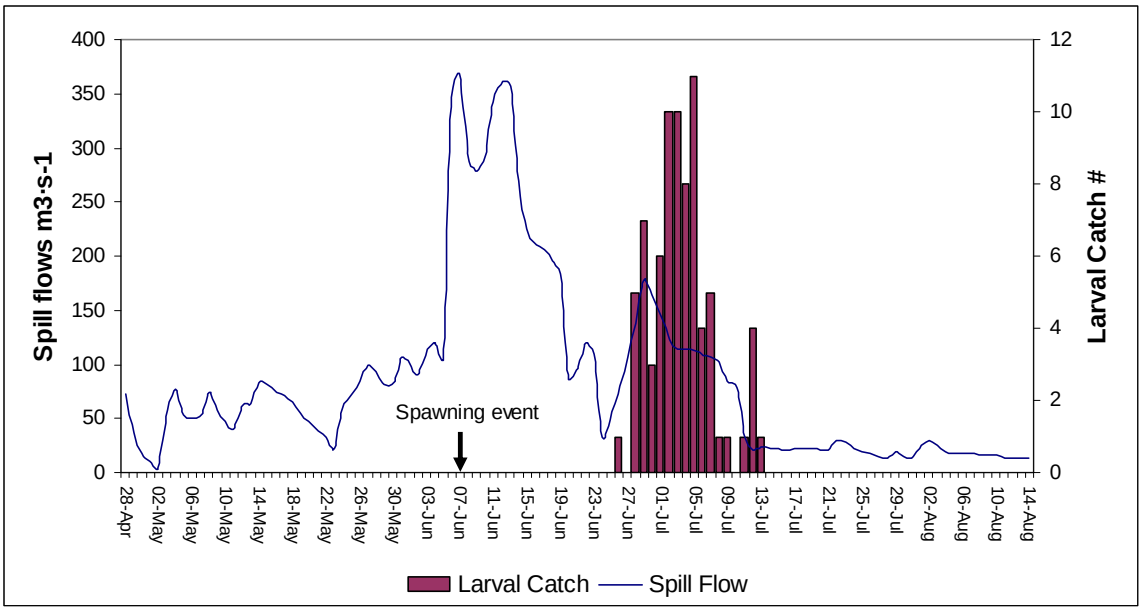


Figure 8. Kakabeka Falls spill flow in relation to approximate spawning date and catches of downstream drifting larvae.

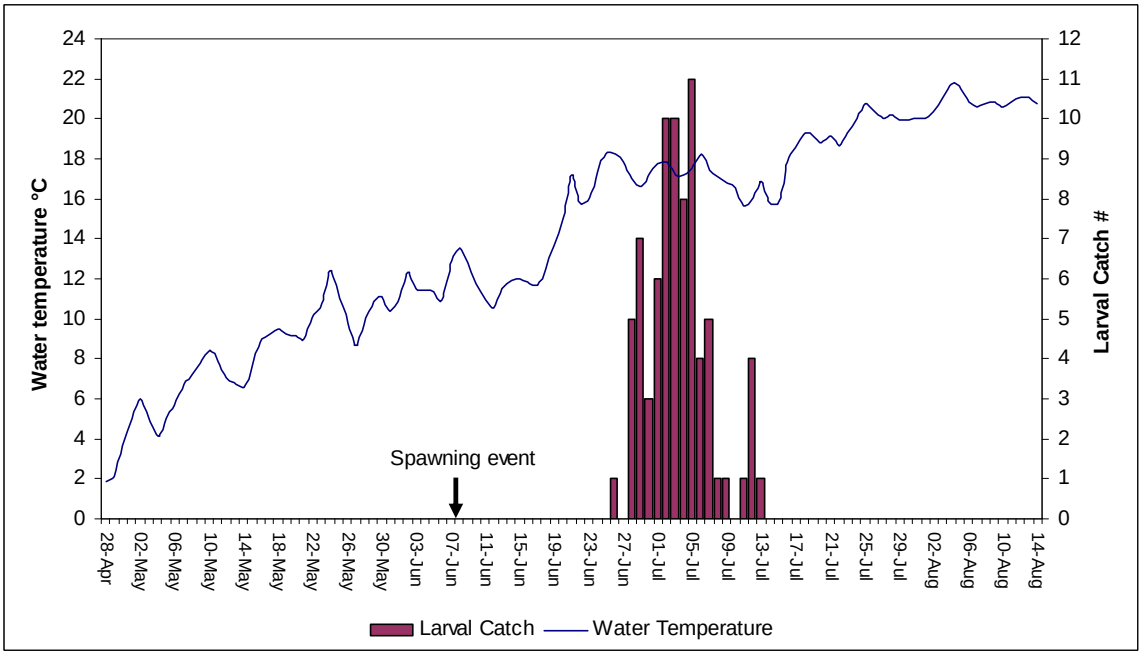


Figure 9. Mean daily water temperature in relation to approximate spawning date and catches of downstream drifting larvae.

Table 1. Fish attribute information for 4 adult sturgeon radio tagged in 2008, two tagged in 2007 and one tagged in 2000.

Tagging Date	Fork Length (mm)	Total Length (mm)	Girth (mm)	Weight (kg)	Sex	Frequency	Did fish migrate to spawning site in 2008?
24-May-08	1440	1590	520	19.5	?	545	no
24-May-08	1205	1340	460	12.5	?	522	yes
24-May-08	995	1110	410	9.5	?	273	no
24-May-08	1040	1160	405	10	?	584	no
06-Sep-00	1120	1189		10.9	?	95	yes
27-Apr-07	965	1070	420	9.5	?	624	yes
28-Apr-07	1220	1310	510	16	?	794	yes

Table 2. The drift netting incidental catch.

Common name	**Scientific name**	**Catch**
Blacknose dace	*Rhinichthys atratulus*	12
Brook stickleback	*Culaea inconstans*	2
Burbot	*Lota lota*	18
Central mudminnow	*Umbra limi*	75
Fathead minnow	*Pimephales promelas*	2
Finescale dace	*Chrosomus neogaeus*	5
Whitefish / herring	*Coregonus*	7
Longnose dace	*Rhinichthys cataractae*	4
Minnow family	*Cyprinidae*	124
Ninespine stickleback	*Pungitius pungitius*	209
Northern pike	*Esox lucius*	48
Pink salmon	*Oncorhynchus gorbuscha*	40
Rainbow smelt	*Osmerus mordax*	395
Sculpin family	*Cottidae*	38
Smallmouth bass	*Micropterus dolomieui*	203
Spottail shiner	*Notropis hudsonuis*	3
Sucker family	*Catostomidae*	2331
Trout perch	*Percopsis omiscomaycus*	18
Walleye	*Sander vitreus*	873

Appendix 1. Cumulative daily thermal units (CTU's) calculated for the time period from first spawning to the start of larval drift in the Kaministiquia River.

YEAR	Date of first spawn	Drift start date	Days (d) from spawn to drift	**CTU's from spawning to start of drift**	Duration of drift
2004	21-May-04	10-Jun-04	21 d	**145.9**	19 d
2005	22-May-05	07-Jun-05	17 d	**154.2**	12 d
2006	21-May-06	01-Jun-06	12 d	**130.5**	16 d
2007	24-May-07	07-Jun-07	15 d	**162.7**	7 d
2008	7-Jun-08	26-Jun-08	20 d	**159.3**	18 d
Average CTU				**150.5**	

Appendix 2. Cumulative daily thermal units (CTU's) calculated for the time period from second spawning to the start of larval drift in the Kaministiquia River.

YEAR	Date of second spawn	Drift start date	Days (d) from spawn to drift	**CTU's from spawning to start of drift**	Duration of drift
2004	27-Jun-04	20-Jul-04	23 d	**173.3**	8 d
2005	31-May-05	19-Jun-05	20 d	**203.7**	7 d
2006					
2007	31-May-07	14-Jun-07	15 d	**169.7**	5 d
2008					
Average CTU				**182.2**	