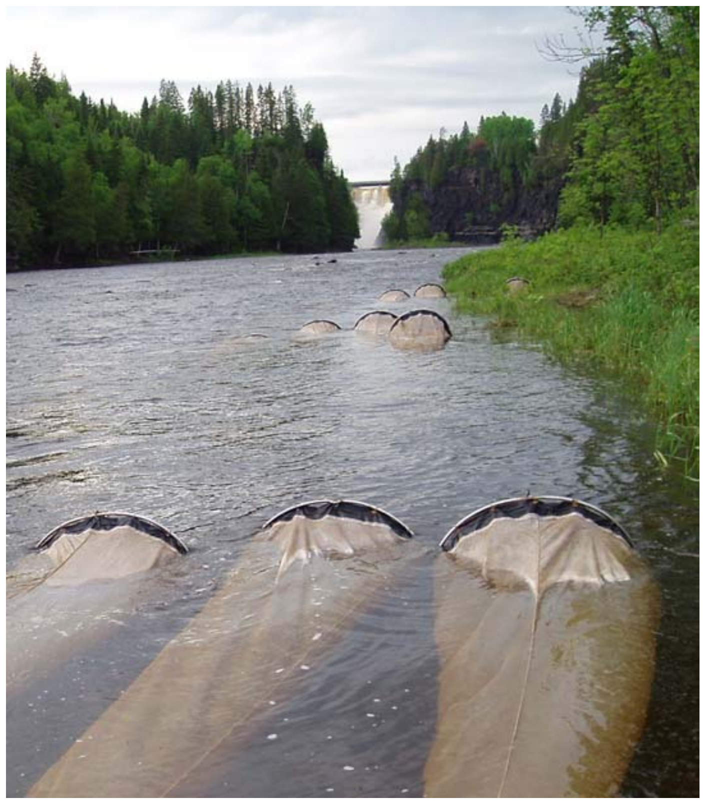
The Migratory and Reproductive Response of Spawning Lake Sturgeon to Controlled Flows over Kakabeka Falls on the Kaministiquia River, 2004



Upper Great Lakes Management Unit

Lake Superior

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Canada-Ontario Agreement
Respecting the Great Lakes Basin Ecosystem

EXECUTIVE SUMMARY

The spawning migration and reproductive success of adult lake sturgeon was examined during controlled "spill" flows over Kakabeka Falls on the Kaministiquia River. An attempt was made to spill 23 $m^3 \cdot s^{-1}$ over the falls from May 15 to June 25 and then reduce flows by 1.5 $m^3 \cdot s^{-1}$ every 12 h until a minimum flow was attained on June 30. A shoreline based data logger was used to track the movements of radio tagged sturgeon as they migrated into and out of the spawning area below Kakabeka Falls. A larval drift netting assessment was carried out to determine if reproduction was successful. This study has shown that (i) sturgeon gained access to and from the spawning area during controlled spill flows of 23 $m^3 \cdot s^{-1}$ (ii) sturgeon remained in the spawning area from two days to 6.5 months (iii) sturgeon spawned successfully on two occasions approximately 37 d apart; and (iv) there were two larval drift events approximately one month apart.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

Kakabeka Falls is a large, 39 metre, waterfall on the Kaministiquia River that is the focal point of a provincial park. It has been suspected that lake sturgeon (*Acipenser fulvescens*) spawn at the base of the falls as that is typical spawning habitat for this species (Harkness and Dymond 1961). Friday and Chase (2005) have documented that sturgeon move to that area of the river each year and the timing of the migrations suggests the rapids at the base of Kakabeka Falls are critical spawning habitat. To meet the goals for rehabilitation of lake sturgeon in the Lake Superior basin known spawning areas should be provided protection (Auer 2003).

Access of adult sturgeon to the base of Kakabeka Falls may be impeded or delayed due to low flow conditions resulting from the operation of a hydroelectric facility located at the falls. The river flow above 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 (Figure 1). During periods of high river flows that exceed plant capacity 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 (LRCA 1990). These are commonly referred to as scenic flows. During the overnight hours of the tourism season leakage through the stop logs provides the only flow over the falls. Outside of the tourism season stop log leakage also accounts for flow over the falls.

Friday and Chase (2005) suggest that scenic flows through the park are insufficient to allow adult sturgeon access to the spawning area at the base of Kakabeka Falls. Radio tagged sturgeon were located in the tailrace of the generating station in 2002 and 2003 where they remained (up to 18 d) until water levels and flows were sufficient to provide access to the upstream reaches. The spawning migration of these fish was delayed and movement to the base of the falls did not occur until flow conditions over the falls reached at least 23 $m^3 \cdot s^{-1}$.

Additional or unexpected increases in the length and timing of migration can deplete already limited energy reserves and exceed the capacity for reproductive success in some fish species (Geen 1975; McKeown 1984). Khoroshko (1972 as reported in Auer 1996) found that the successful fertilization of eggs from Russian sturgeon (*Acipenser guldenstadti*) decreased with the length of time the fish spent in prespawning condition. Preventing a delay or blockage of migratory routes may prove critical to the reproductive success of these fish.

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 activity under controlled flow conditions so that flow regimes over Kakabeka Falls could be renegotiated during future planning. Flow would be controlled from May 15 to June 30, 2004. Within this timeframe a minimum flow of 23 $m^3 \cdot s^{-1}$ would spill over the falls until June 25. Starting on June 26 flow over the falls would be reduced by 1.5 $m^3 \cdot s^{-1}$ every 12 h until scenic flows were attained (June 30).

This report details the results of two studies completed in 2004: a telemetry study to document the spawning migration of sturgeon and a drift net study to assess their spawning success in the Kaministiquia River under controlled flow conditions.

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 controlled spill flows of 23 $m^3 \cdot s^{-1}$;
2. Determine if spawning lake sturgeon can successfully migrate out of the study area during controlled spill flows of 23 $m^3 \cdot s^{-1}$;
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 process was successful at spill flows of 23 $m^3 \cdot s^{-1}$;
6. Confirm, through the collection of larval sturgeon, that there are sexually mature adult sturgeon spawning in the study area;
7. Confirm that previously documented upstream migrations into the study area are primarily spawning migrations and not exploratory movements; and
8. Determine the timing and duration of downstream movement of larval lake sturgeon

STUDY AREA

The Kaministiquia River originates at an elevation of 427 m, approximately 64 km northwest of the City of Thunder Bay and drains an area of about 7730 km^2. Twin tributaries collect the controlled discharges from four reservoirs located at Shebandowan, Kashabowie, Greenwater, and Dog lakes (Figure 2). The river flows southward through power generating facilities at Silver Falls (on Dog Lake) and Kakabeka Falls.

The Kaministiquia River from Lake Superior to rkm 9 (river kilometre 9) has been altered to accommodate commercial marine traffic and has a low degree of channel sinuosity. This section of river is deep (7.8 m median, 11.8 m maximum), with little variation in main channel bathymetry and the substrate is predominantly mud (Figure 3). River kilometer 10 to rkm 20 is meandering, with deep sections on the outer river bends (3.3 m median, 8.9 m maximum) and a range of substrates including sands, pebbles, cobble and rock (Biberhofer and Prokopec 2005) (Figure 4). River kilometre 21 to 31 is meandering with braided sections of exposed gravel bars and large islands, has a maximum depth of 2.19 m and has a range of substrates including boulders, rock and gravel (Figure 5). River kilometre 32 to 37 has a low degree of channel sinuosity, a maximum depth of 2 m with predominantly rubble, gravel and sand substrates (Figure 5).

River kilometer 38 to 47 has a maximum depth of 1.3 m, with some meandering sections, islands and a range of substrates including boulders, rubble, rock, gravel, sand and some bedrock (Cullis *et al*. 1989) (Figure 6).

This study focused on an 800 m stretch of the Kaministiquia River from the base of Kakabeka Falls downstream to the generating station (Figure 7). Over this distance there is a drop in elevation of approximately 3 m. Directly below the falls is a large, deep plunge pool and an island that divides the flow into two channels. The west channel is lower in elevation and concentrates the majority of the flow. There is an elevation drop of approximately 0.96 m over the distance of the west channel (100 m). At higher flows the east channel is also wetted. Approximately 800 m downstream of the falls (i.e. just above the generating station) another set of rapids exists that is characterized by a drop in elevation of approximately 0.90 m over a distance of 120 m (Wayne Burchat unpbl. data). The river bed in the study area consists of shale, rocks, boulders, sections of flat bedrock and pockets of sand and gravel. At flow rates of approximately of 4 $m^3 \cdot s^{-1}$ the wetted perimeter of this stretch of river ranges from 41 to 92 m.

MATERIALS AND METHODS

Radio Tagging

Radio telemetry equipment manufactured by Advanced Telemetry Systems (ATS) was used in this study[1]. Each radio transmitter (n = 15) was identified by a unique frequency between 150.600 – 150.800 MHz. The 20 g transmitters (model F2060) pulsed 55 times per minute and had a battery life of approximately 10 months. Each tag had a 30 cm trailing whip antenna.

To determine the onset of upstream migration we manually tracked the movements of adult sturgeon (n = 19) radio tagged in the fall of 2000 (Friday and Chase 2005). On May 3, 2004 a number of these fish began to migrate, moving 11 km upstream from rkm 9. Water temperature was approximately 8°C. Forty five meters of 254 mm (10”) stretched mesh, multifilament gill net was then set overnight at rkm 19 in approximately 2.5 m of water. Ten sturgeon that had not been previously radio tagged were captured and fitted with external transmitters.

Individual sturgeon were removed from the gill net and placed in a large holding tank for tag attachment and biological measurements. 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. No anaesthetic was used during the procedure. All sturgeon were sampled for length (fork, total, legal), weight, girth and were tagged with a five digit orange floy tag applied along the left hand side of the dorsal fin.

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

The location of these fish was monitored by boat every day. Once the tagged fish moved upstream from the capture location the 254 mm (10”) gill net was reset at rkm 19 and another 305 mm (12”) net was set at rkm 41 near the mouth of the Whitefish River. Four additional sturgeon captured at rkm 41 were equipped with external radio transmitters and one other was tagged at rkm 19. These fish had not been previously radio tagged.

Tracking

A shoreline based data logger (model R4500) was installed upstream of the generating station (Figure 7) in early May to track the movements of radio tagged sturgeon as they migrated into and out of the study area. The system consisted of a switch box, two directional antennae, a 12-volt deep cycle marine battery and a solar panel. The two antennae 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).

A reference transmitter (150.474 MHz) was placed in the river above the GS to provide a known signal strength from a fixed position (Figure 7). Radio tagged fish were determined to be upstream of the GS (in the study area) when the signal strength of their transmitter matched, or was close to, the reference tag signal strength. Fish were considered to be in the plunge pool when the logged signal strength associated with the upstream facing antenna was low (<100) and there was no signal strength being recorded from the downstream facing antenna.

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 stationary logger and as a backup in case of logger malfunction or vandalism. A number of road accessible sections of the river; rkm 27 at Highway 130, rkm 38 at Davis Point, rkm 40 at Highway 588 and rkm 41- 42 at Harstone Road were monitored to track the upstream and downstream progression of radio tagged fish.

Drift Netting

Drift netting took place approximately 400 m downstream of the suspected spawning site. 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 a detachable collection container. Two different mesh sized collection containers were used (950 and 1600 µm). Effort was concentrated at one site located on the east shore of the river in an easily accessible area (Figure 7).

Drift nets were held in place by attaching a 4.5 kg fishing anchor to each frame. To sample, 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 sturgeon 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. Drift netting commenced on May 26 and terminated on July 22. Nets were not set during extreme spill conditions (50 -150 $m^3 \cdot s^{-1}$) encountered from June 1 to 4 and the evenings of June 25, 26, 30 and July 1 to 5 were not sampled because of logistical issues.

Drift netting was carried out at night to sample the period when larval drift is known to occur (Kempinger 1988). During the first seven evenings of the drift netting program three sampling methods were tested until a suitable protocol was established.

1. Six nets were set at dusk and allowed to fish for an hour before lifting. This cycle was repeated two more times throughout the night (May 27, 28);

2. Six nets were set at dusk and allowed to fish for an hour before lifting. The nets were then reset and allowed to fish overnight (May 29, 30 June 6); and

3. Six nets were set overnight and lifted the following morning (June 7).

On June 8, all drift nets (n = 11) were deployed at dusk and lifted the following morning. This method was used to maximize effort since previous attempts to catch larvae were unsuccessful. This method was used for the remainder of the project.

Water Temperature, Velocity and Depth

Water temperature in the study area was recorded using a Vemco Minilog- T data logger. The logger was located approximately 500 m above the GS in 0.5 m of water. Temperature was recorded hourly from April 26 to November 2, 2004. Water velocity ($m \cdot s^{-1}$; Marsh McBirney Flo-Mate) was measured at one site upon drift net deployment. Water depth (cm) was measured at the opening of each drift net upon deployment.

RESULTS AND DISCUSSION

Radio Tagging

Fifteen lake sturgeon were fitted with external transmitters. These fish ranged from 121.5 to 149.7 cm in total length and weighed 10.25 to 20.22 kg (Table 1).
It was not possible to determine the sex of radio tagged fish based on external characteristics. All fish survived the tag attachment procedure and continued on their upstream spawning migration to Kakabeka Falls. Fish 614 lost its tag in the plunge pool at the base of the falls sometime after arriving on May 19.

Spill Flows

Water spilled over Kakabeka Falls increased from 1 $m^3 \cdot s^{-1}$ to 47.9 $m^3 \cdot s^{-1}$ as a result of a transformer failure at the GS on May 12, 2004 and subsequent plant shutdown. When the plant was brought back on-line on May 13 spill was decreased to 23 $m^3 \cdot s^{-1}$ and the study started a day earlier than scheduled. Controlled flows (23 $m^3 \cdot s^{-1}$) were maintained until May 31 when significant rainfall throughout the watershed increased flows in the upper Kaministiquia River beyond the plant capacity (Figure 8). Uncontrolled spill flows peaked at 150 $m^3 \cdot s^{-1}$ on June 1 and did not return to 23 $m^3 \cdot s^{-1}$ until June 23. At the end of June an effort was made to decrease spill to prescribed scenic flows. Spill reached a low of 7.3 $m^3 \cdot s^{-1}$ on July 2 but significant rainfall again increased upstream flows beyond plant capacity, thereby exceeding scenic flows until July 23.

Migration
Individual fish moved into the study area between May 16 and June 20 (Figure 9). The majority of fish (n = 14) arrived on May 19 and 20 when water temperature averaged 12.4°C (Figure 10). The latest arrival to the study area was an individual tagged in 2000 (fish 095) that arrived on June 20 during uncontrolled spill conditions of 29 $m^3 \cdot s^{-1}$ and water temperature of 15.1°C.

Eighteen radio tagged sturgeon accessed the study area. Fifteen were individuals tagged in the spring of 2004 and three were tagged in the fall of 2000. Two of the three fish tagged in 2000 have a history of spawning migrations to Kakabeka Falls. Fish 254 migrated into the study area in the spring of 2001. Fish 233 migrated into the study area in the spring of 2001 and 2002. These periodic spawning forays are consistent with the intermittent spawning behaviour of lake sturgeon. Work by Lyons and Kempinger (1992) in the Lake Winnebago system, indicates that male lake sturgeon may spawn annually or biennially and females every three to four years. Fish 095 moved to the base of the falls for the first time in 2004 since being tagged in 2000.

Sixteen of the 18 fish moved into the study area during the initial 18 d of 23 $m^3 \cdot s^{-1}$ spill. One fish moved up to the base of the falls when uncontrolled spill flows reached 125 $m^3 \cdot s^{-1}$ and the last fish moved up under flow rates of 29 $m^3 \cdot s^{-1}$ (Figure 9). All fish were able to navigate the entire length of the study area when spill flows were controlled at 23 $m^3 \cdot s^{-1}$ and congregated in the plunge pool at the base of Kakabeka Falls. During spill flows of 23 $m^3 \cdot s^{-1}$ it took approximately one to ten hours for radio tagged fish to move upstream from the reference transmitter to the plunge pool at the base of the falls. Harkness and Dymond (1961) also chronicle accounts of sturgeon "congregating in a pool or hole after reaching the vicinity of the spawning site and remaining there until certain temperature and perhaps other conditions are suitable". This behaviour was also noted in previous study years when flow conditions were suitable for access to the base of the falls (Friday and Chase 2005). The fish in this study seem to utilize the plunge pool as a refuge area and it is suspected they drop back into the rapids of the west channel to spawn.

Spawning Events
Four types of behaviour (A, B, C and D) were evident based on the timing of spawning migrations and the length of time that fish stayed in the study area (Figure 9 and 10). Group A (10 fish) participated in the first spawning event only, spent two to 12 days in the study area and subsequently migrated downstream to rkm 9. It is likely that spawning occurred somewhere between May 20 and May 22 when water temperatures averaged 12.7°C and peaked at 14°C (Figure 8). Kempinger (1988) noted the peak spawning period would usually last one day and only occasionally for three to six days. He also found that water temperatures strongly influenced the spawning of lake sturgeon with a peak in spawning generally occurring between 10 and 14°C. Scott and Crossman (1973) reported optimum spawning temperatures between 13 and 18°C. Our observations regarding duration of spawning and associated water temperatures, although at the low end of the range noted by Scott and Crossman, are consistent with these findings.

Group B (two fish) only participated in the second spawning event, arriving in the study area after the fish from Group A had dispersed. The second spawning event occurred some time in late June but these fish remained in the study area for 28 and 32 d respectively. Water temperatures increased slowly throughout the month of June and reached a mean daily high of 16.7°C. Kempinger (1988) and Auer and Baker (2002) have also observed two peaks in spawning activity, the second of which was characterized by water temperatures between 13 and 21°C and occurred two to three weeks after the initial spawn.

Group C (three fish) were in the study area during both spawning events. These fish (704, 633, and 233) made two distinct forays into the study area (Figure 10, Group C) separated by a nine day absence. After spending four to five days in the study area these fish along with eight others from Group A left on May 24 and 25. Water temperatures prior to departure dropped from 14 to 10.8°C. Kempinger (1988) noted that a slight drop in water temperature (1.5 – 3°C) would cause spawning sturgeon to disperse. During the nine day interval away from the study site, one fish was located nine kilometres downstream at rkm 38 and two fish were at rkm 40. A dramatic increase in total river flows (> 200 $m^3 \cdot s^{-1}$) that commenced on May 31 may have prompted the collective movement of these fish back into the study area on June 1 and 2.

Group D (two fish) were in the study area during both spawning events but spent considerable amount of time in the plunge pool at the base of the falls after the conclusion of spawning. Fish 724 remained in the plunge pool for approximately 6.5 months and migrated downstream on November 2 during uncontrolled spill flows of 16.4 $m^3 \cdot s^{-1}$. Fish 623 remained in the plunge pool for 3.5 months and migrated downstream sometime between August 27 and 30. Spill flow rates for this period ranged from 3.4 - 20 $m^3 \cdot s^{-1}$.

Individual fish moved out of the study area between May 23 and November 2 (Figure 9). The majority of fish (n = 12) left between May 23 and May 27 when spill flows were controlled at 23 $m^3 \cdot s^{-1}$.

Drift Netting

During 38 sampling events (6890.6 sample hrs), 445 larval lake sturgeon were captured resulting in a catch per unit effort of 0.06 larvae/hour. The incidental catch was 3408 larval fish, of which 1057 were identified to the species level and 2351 specimens were grouped by family (Table 2). There were two periods, approximately one month apart, when larval sturgeon were captured as they drifted downstream (Figure 11). The first larval sturgeon (18 mm) was captured on June 10. The duration of the first downstream movement of larvae from the spawning site (drift event) was 18 d. Over this period, 234 larval sturgeon ranging in length from 18 to 25 mm were captured (Figure 12). The June catch per unit effort was 0.07 (3232.1 sample hours).

The mean daily water temperature from the suspected spawning date (May 21) to the time when the first larva was collected (June 10) was 12.7 °C. The mean daily spill flows during the 18 d of larval drift ranged from 19 to 69.9 $m^3 \cdot s^{-1}$. Water velocity at the drift net site averaged 0.40 $m \cdot s^{-1}$ and ranged from 0.26 to 0.51 $m \cdot s^{-1}$. Water depth at the opening of the drift nets averaged 46 cm and ranged from 26 to 71 cm.

The second downstream movement of larvae started on July 12 with the capture of an 18 mm sturgeon. Over the next eight days, 211 larval sturgeon ranging in length from 18 to 26 mm were captured (Figure 12). The catch per unit effort was 0.06 (3658.5 sample hours). The mean daily spill flows over the nine days of larval drift ranged from 16.7 to 31.3 $m^3 \cdot s^{-1}$. Water velocity at the drift net site averaged 0.69 $m \cdot s^{-1}$ and ranged from 0.39 to 0.82 $m \cdot s^{-1}$. Water depth at the opening of the drift nets averaged 48 cm and ranged from 27 to 63 cm.

The only yolk sac (i.e. newly hatched) larvae were captured on July 6, 7 and 8, prior to the start of second drift event (Figure 13). One specimen was caught on each of these days and ranged in length from 7 to 8 mm. The capture of the yolk sac larvae coincided with a significant increase in spill flows that commenced on July 4 (Figure 11).

Using similar drift netting methods (i.e. overnight sets), Auer and Baker (2002) reported catch per unit effort (CPUE) values of 0.15 in 1992 and 0.26 in 1993 when nets were set 14 to 61 km downstream from the spawning site on the Sturgeon River, MI. In the present study, the catch per unit effort was significantly lower (0.06), even though nets were set in close proximity to the spawning site (400 m downstream). The low CPUE value may be due to a small spawning population or the fact that that drift is not uniform in space (Auer and Baker 2002). Although CPUE values from two different systems are not directly comparable, it provides some perspective related to the effort expended on the Kaministiquia River.

This study showed that sturgeon spawned below Kakabeka Falls on two separate occasions (Figure 13) and supports the inference from the telemetry portion of the project. The first spawning event (~May 21) and subsequent 18 d of larval drift occurred within the intended timeframe of controlled flows (May 15 to June 30). Although controlled flows (23 $m^3 \cdot s^{-1}$) could only be maintained for the first 18 d of the study, successful reproduction occurred at this flow and the larval specimens collected survived uncontrolled spill conditions that exceeded 150 $m^3 \cdot s^{-1}$.

In June, larval lake sturgeon started to drift approximately 20 d after the suspected spawning date. In July, larval drift started approximately 15 d after the suspected spawning date. Increased water temperatures in July likely contributed to shorter incubation times. These observations are similar to results documented by LaHaye et al. (1992) in the Des Prairies River, Quebec, who found that larvae began drifting from the spawning grounds 18 d after peak spawning.

The date of the second spawning event can only be estimated by back calculating from the capture of the first yolk sac larva. Based on its size (7 mm) and developmental characteristics (Auer 1982; Kempinger 1988) the specimen was estimated to be less than 1 d post hatch and may have emerged on July 5. Wang et al. (1985) developed an equation for lake sturgeon describing the relationship between developmental time of early life stages and water temperature. Although the equation is based on laboratory experiments using constant incubation temperatures, it provides insight into determining the age of the first yolk sac larva. Using this equation, and substituting an incubation temperature of 16°C (i.e., the 10 d average water temperature prior July 6), the first yolk sac larva collected was approximately eight days old, making the fertilization date around June 27 when flows were approximately 20 $m^3 \cdot s^{-1}$.

Although the second spawning event likely occurred within the intended timeframe of controlled flows (i.e. prior to June 30), the length of time required for egg incubation, hatch and downstream movement of larvae from the spawning site (~15 d) put the second drift event beyond the time frame when spill was being deliberately provided. Significant rainfall, however, caused uncontrolled spill conditions throughout most of July and may have contributed to a successful second drift of larvae from the area. This may not have been the case if scenic flow regimes had been maintained throughout July. Typically, spill that is provided during daylight hours is reduced to leakage (1 $m \cdot s^{-1}$) from 21:00 to 06:00, precisely the time when larval sturgeon drift from the spawning grounds. Kempinger (1988), Quinlan (2000) and Auer and Baker (2002) have documented nocturnal drifting and found the peak in drift to occur between 21:00 to 04:00. In the Kaministiquia River larval sturgeon would be vulnerable to overnight changes in flows that are typical in the study area. Protection of these young as they move downstream is important for the recovery and restoration of lake sturgeon populations throughout the Great Lakes region (Auer and Baker 2002).

Even though the duration of the second drift event was shorter (9 d) than the first event (18 d) the total number of larvae caught, represented 47% of the total catch (211 of 445). This suggests that the second spawning event may have been equally important to larval production as the first spawning event. Other researchers have documented the occurrence of multiple spawning events (Kempinger 1988; LaHaye et al. 1992; Auer and Baker 2002) but the contribution of each event to total larval production has not been evaluated.

Kempinger (1988) found that spawning activity would cease when water temperatures dropped 1.5 to 3.0°C and would resume only when temperatures increased. He documented the days between multiple spawning events on the Wolf River, WI between 12 and 21 d. In the present study, the gap between spawning events was much longer (~37 d). It is not clear, however, if the gap is related to a cessation and resumption in spawning associated with temperature or a response to some other reproductive cue. Although water temperature dropped after the first spawning event and adults dispersed, the temperature rose to optimal levels well before the date of the second spawn. Additionally, one sturgeon (095) that was radio tagged in 2000 did not arrive at the study area until June 20, 2004. This suggests that the drop in water temperature may not have been a contributing factor to the multiple spawning events.

SUMMARY

TELEMETRY

1. Sturgeon gained access to and from the study area during controlled spill flows of 23 $m^3 \cdot s^{-1}$.
2. There appeared to be two spawning events approximately one month apart.
3. There were four distinct movement behaviours through this period

   Group A (10 fish) participated in the first spawning event only and spent two to twelve days in the study area.

   Group B (2 fish) participated in the second spawning event only and remained in the study area for 28 and 32 d.

   Group C (3 fish) were in the study area during both spawning events and made two distinct forays into the study area.

   Group D (2 fish) were in the study area during both spawning events but spent approximately 3.5 and 6.5 months at the base of the falls.
4. Two fish remained in the plunge pool for approximately 3.5 and 6.5 months. Scenic flows may be insufficient to permit adult sturgeon migration out of the study area.

DRIFT NETTING

1. Sturgeon spawned successfully in the study area.
2. There were two spawning events approximately 37 d apart and two larval drift events, approximately one month apart.
3. The first drift event was in June and lasted 18 d. The second drift event was in July, lasted 9 d and occurred outside the timeframe of controlled flows. Larval sturgeon would be vulnerable to overnight changes in flows that are typical in the study area after June 30.
4. In this spawning year (2004), the second spawning event may have been equally important to larval production as the first spawning event.

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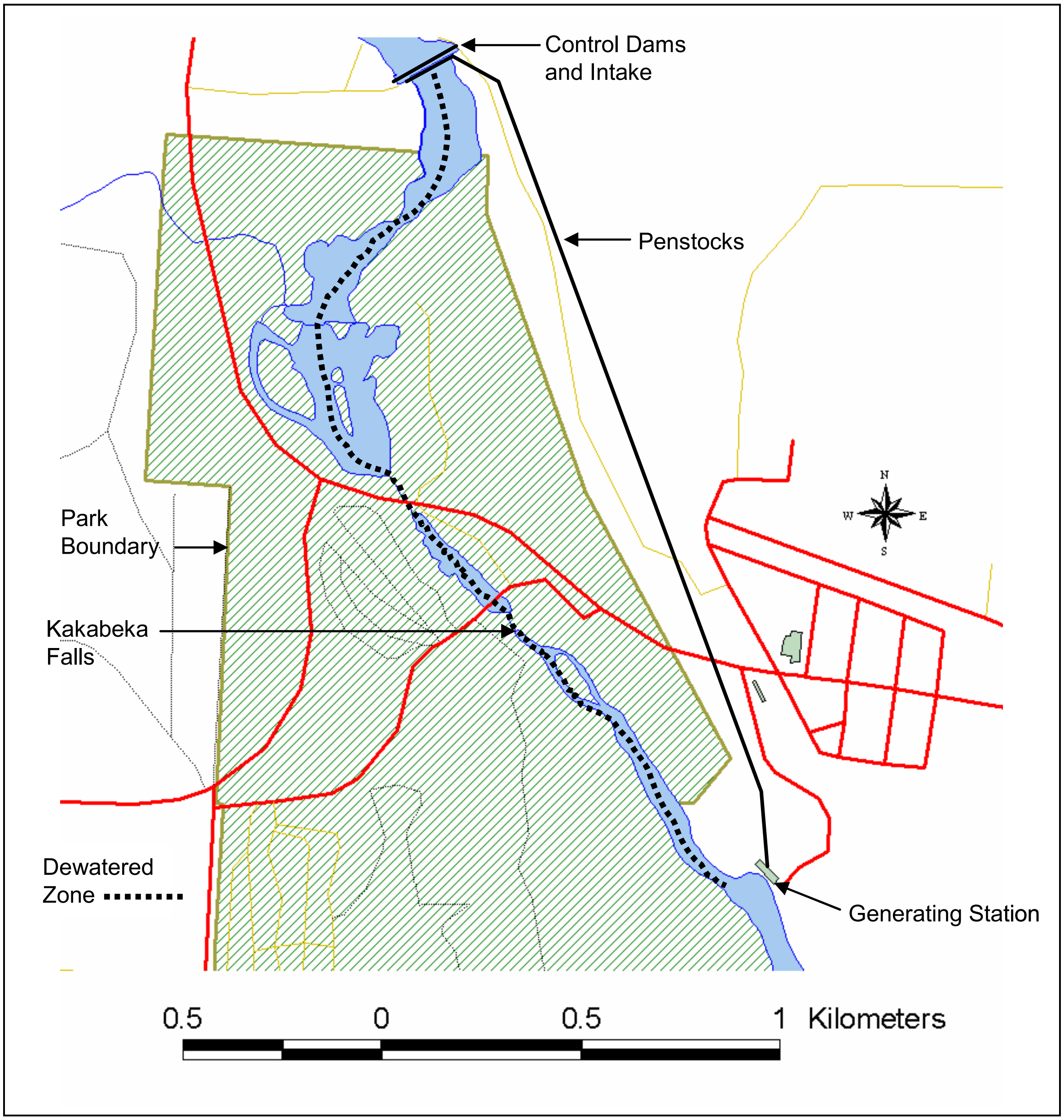


Figure 1. Location of Kakabeka Falls Provincial Park, the OPG generating station, control dams, penstocks and the area of the Kaministiquia River that is subject to dewatering.

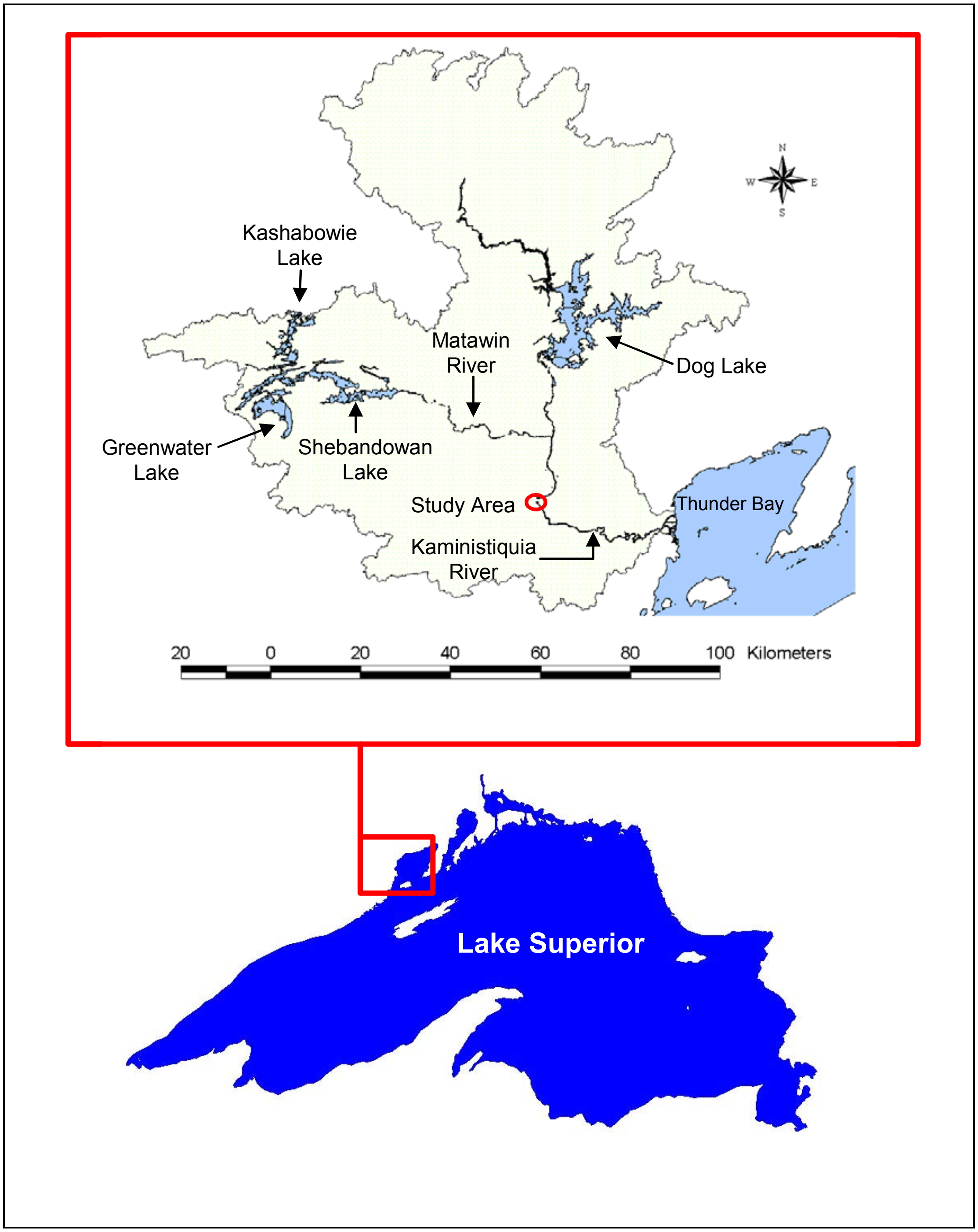


Figure 2. The Kaministiquia River watershed, major reservoirs and location of study area.

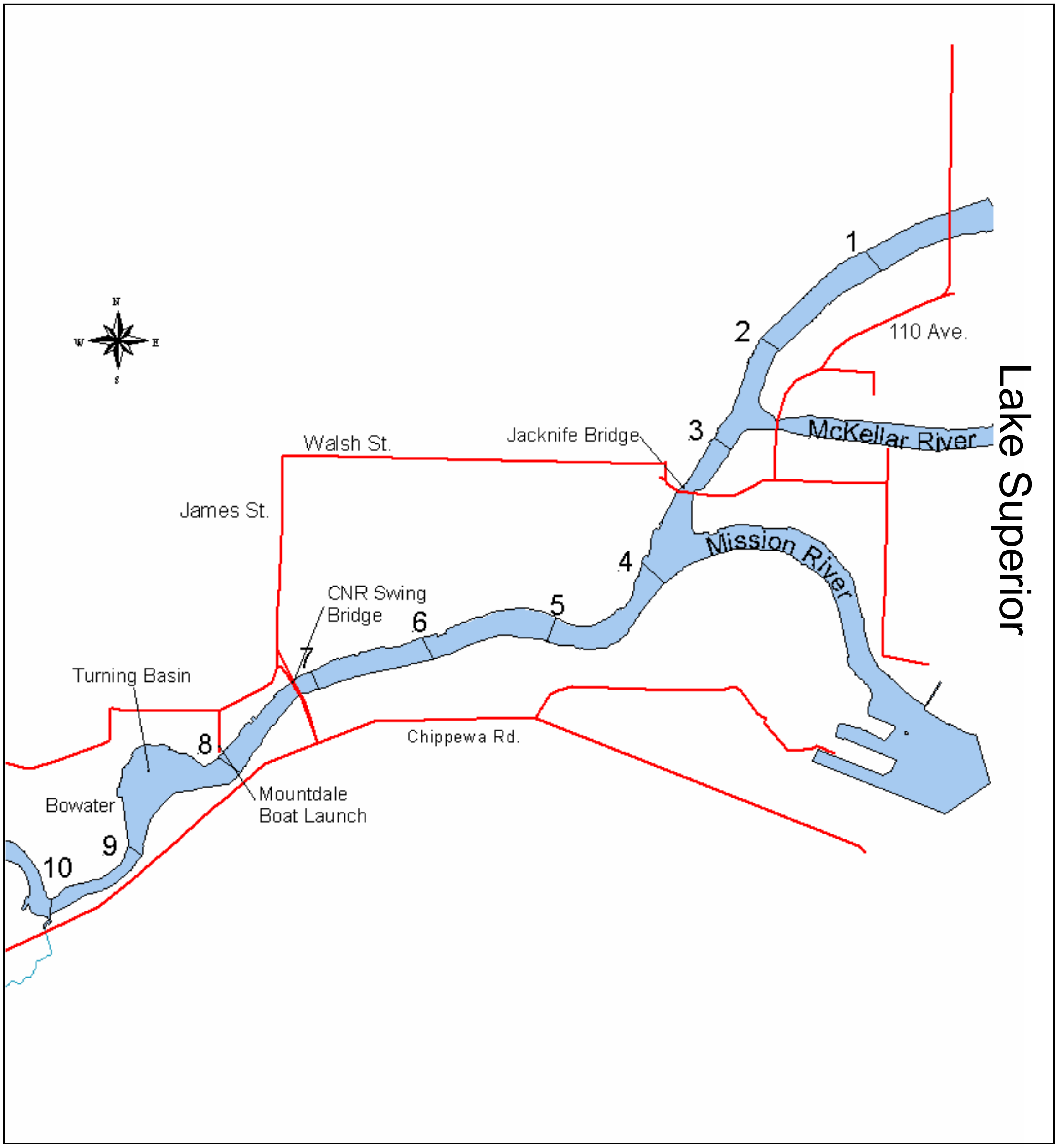


Figure 3. The Kaministiquia River from Lake Superior to river kilometre (rkm) 10.

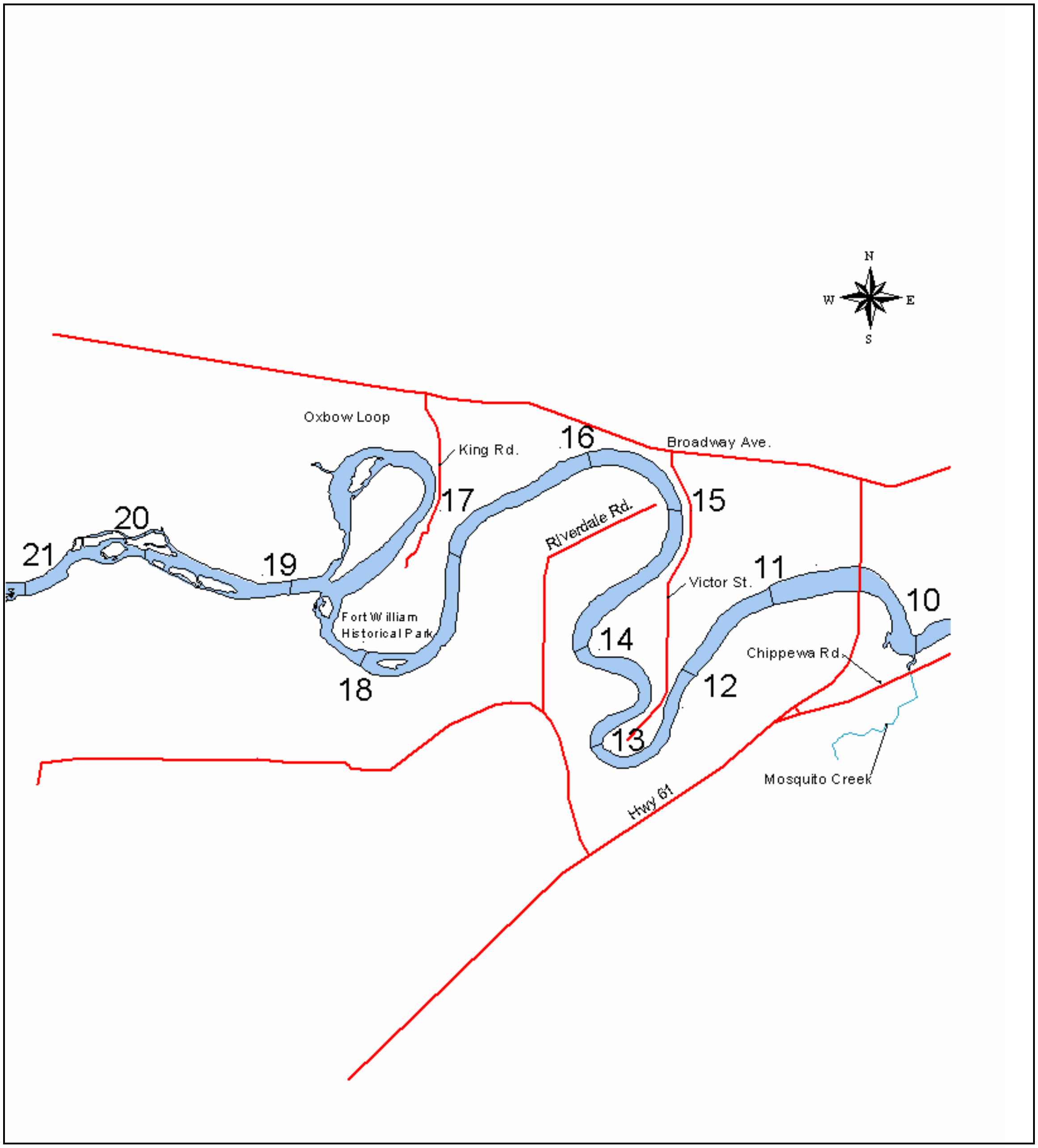


Figure 4. The Kaministiquia River from rkm 10 to rkm 21.

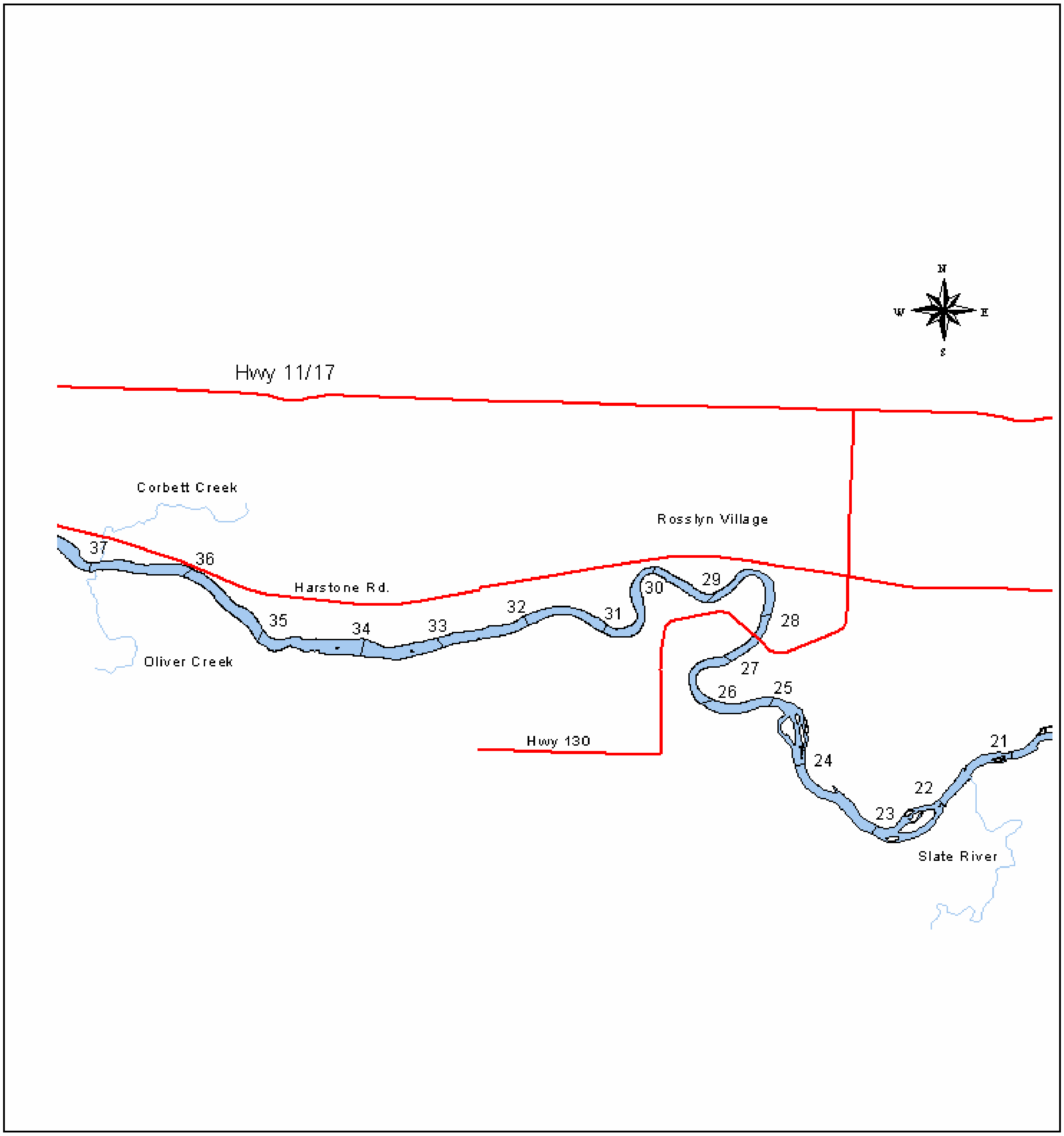


Figure 5. The Kaministiquia River from rkm 21 to rkm 37.

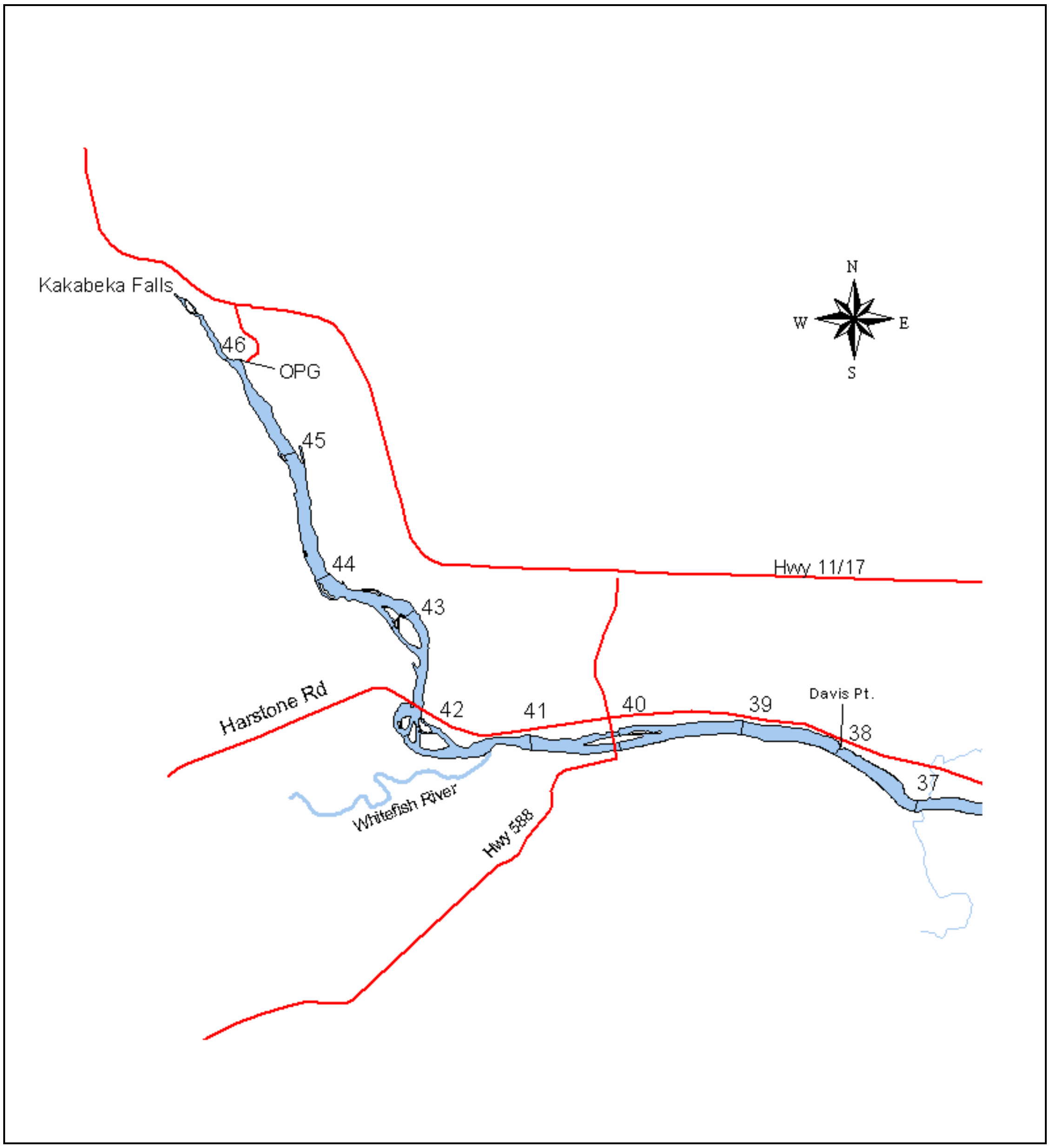


Figure 6. The Kaministiquia River from rkm 38 at Davis Point to rkm 47 at Kakabeka Falls.

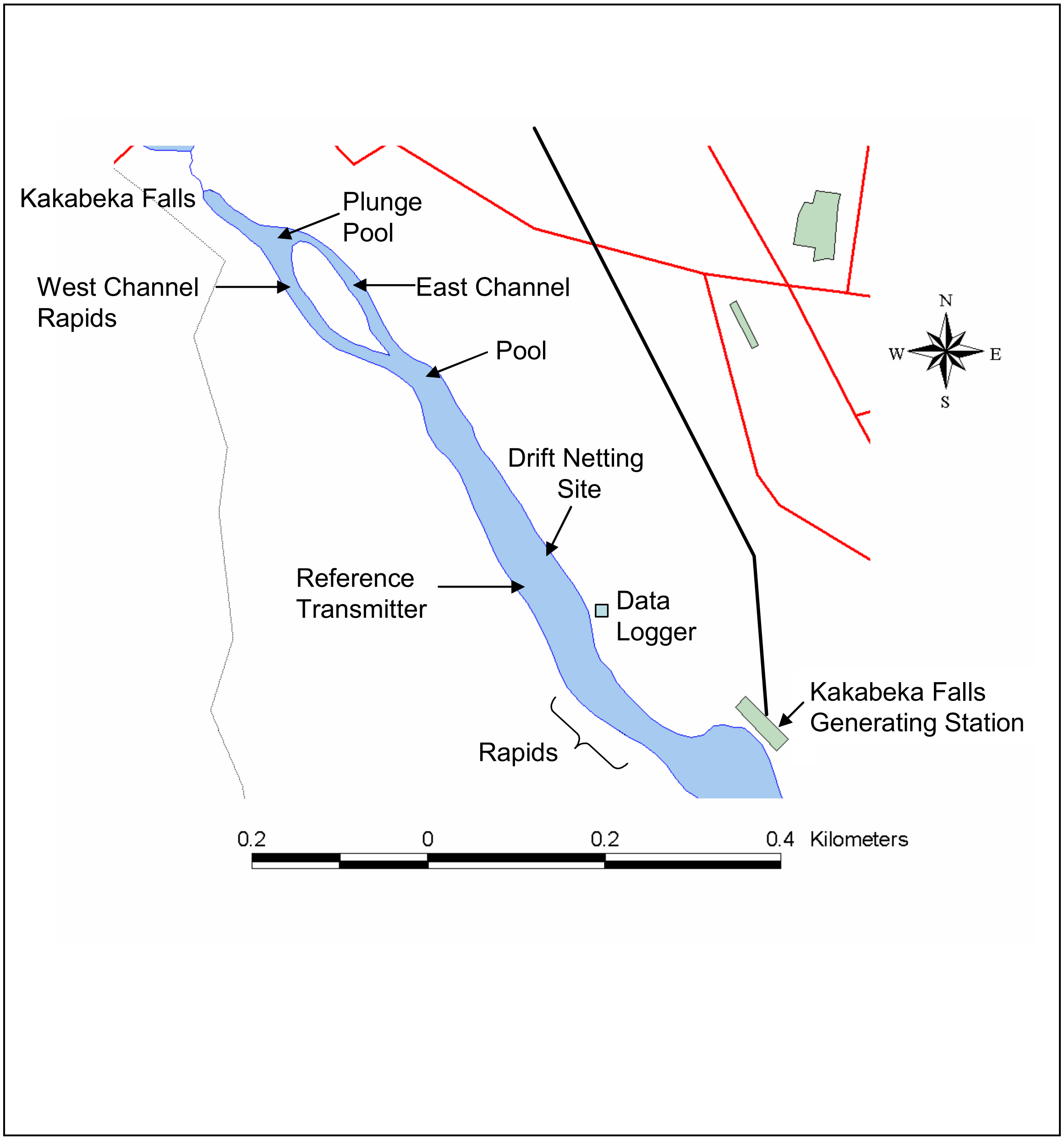


Figure 7. The study area from Kakabeka Falls downstream to the OPG generating station.

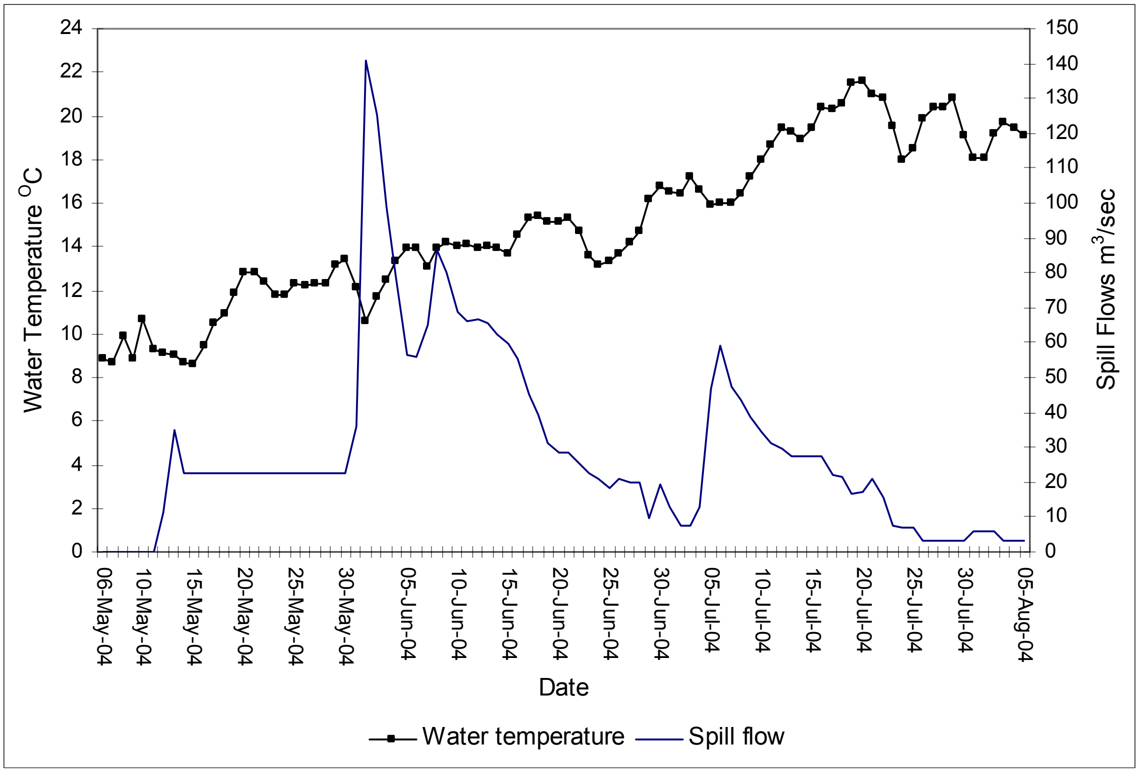
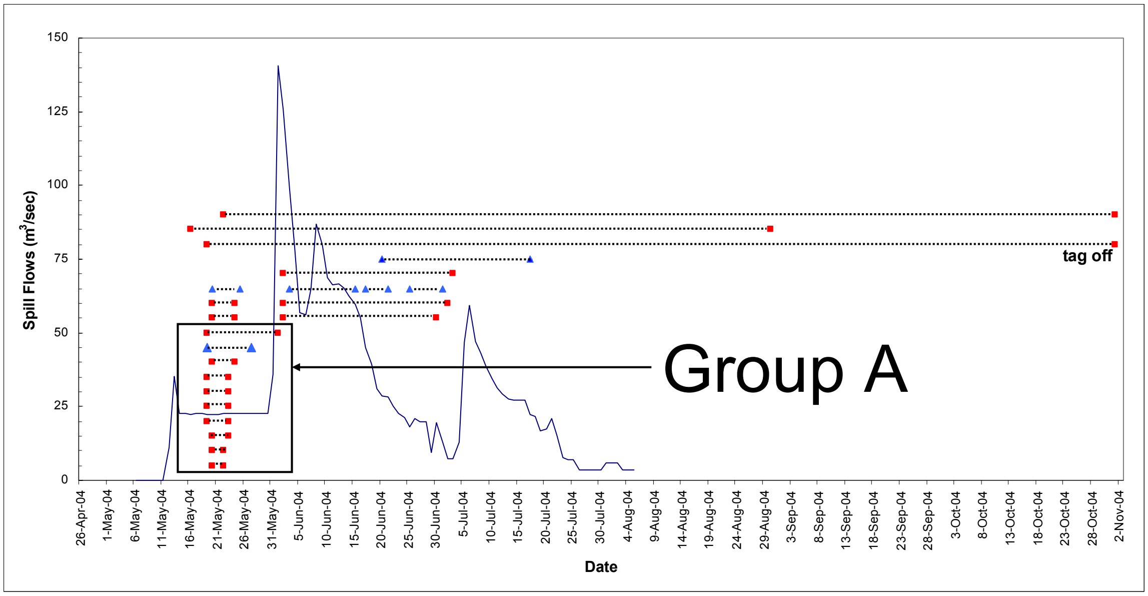


Figure 8. Mean daily water temperature and spill flow over Kakabeka Falls from May 6 to August 5, 2004.



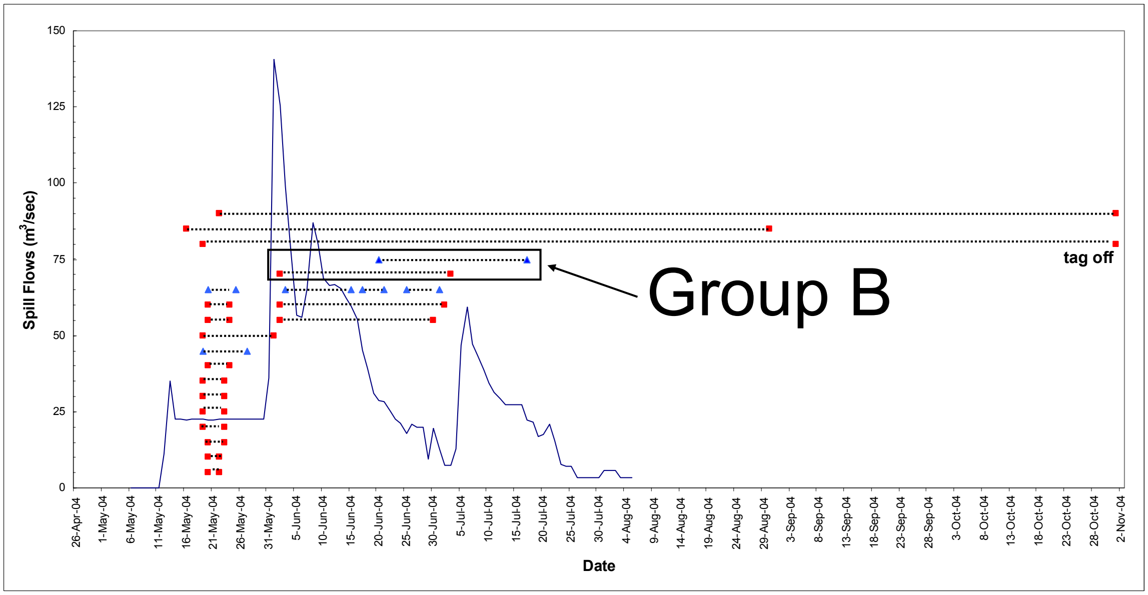


Figure 9. The migratory behaviour of spawning group A and B. Paired symbols (square = tagged in 2004, triangle = tagged in 2000) represent the arrival and departure date of individual fish to and from the study area.

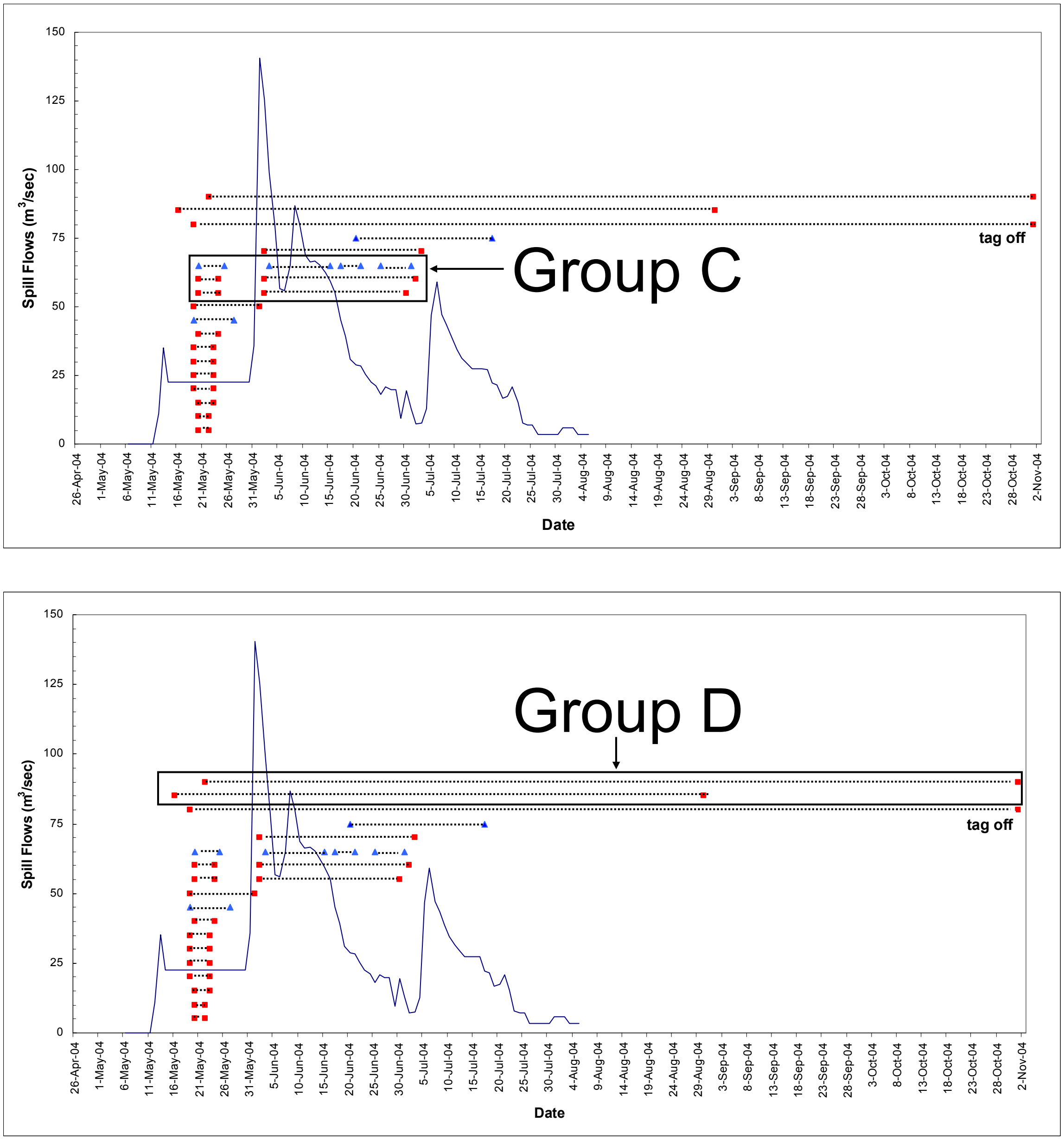


Figure 10. The migratory behaviour of spawning group C and D. Paired symbols (square = tagged in 2004, triangle = tagged in 2000) represent the arrival and departure date of individual fish to and from the study area.

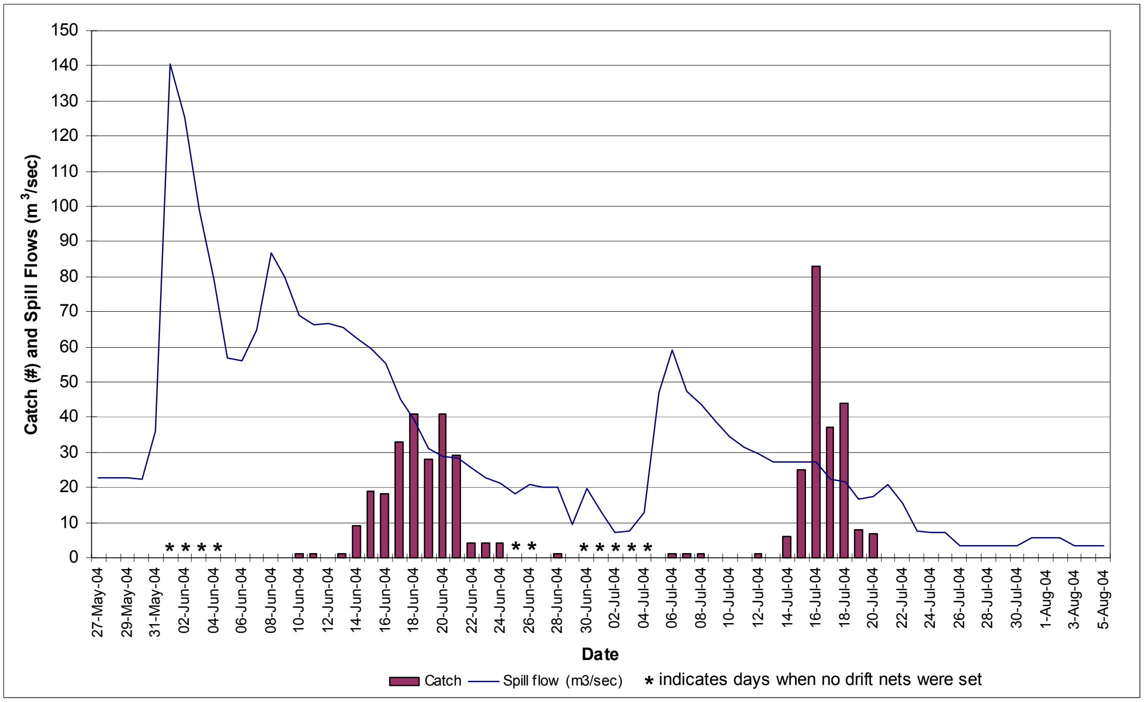


Figure 11. Mean daily spill flow over Kakabeka Falls in relation to June and July catches of downstream drifting larvae.

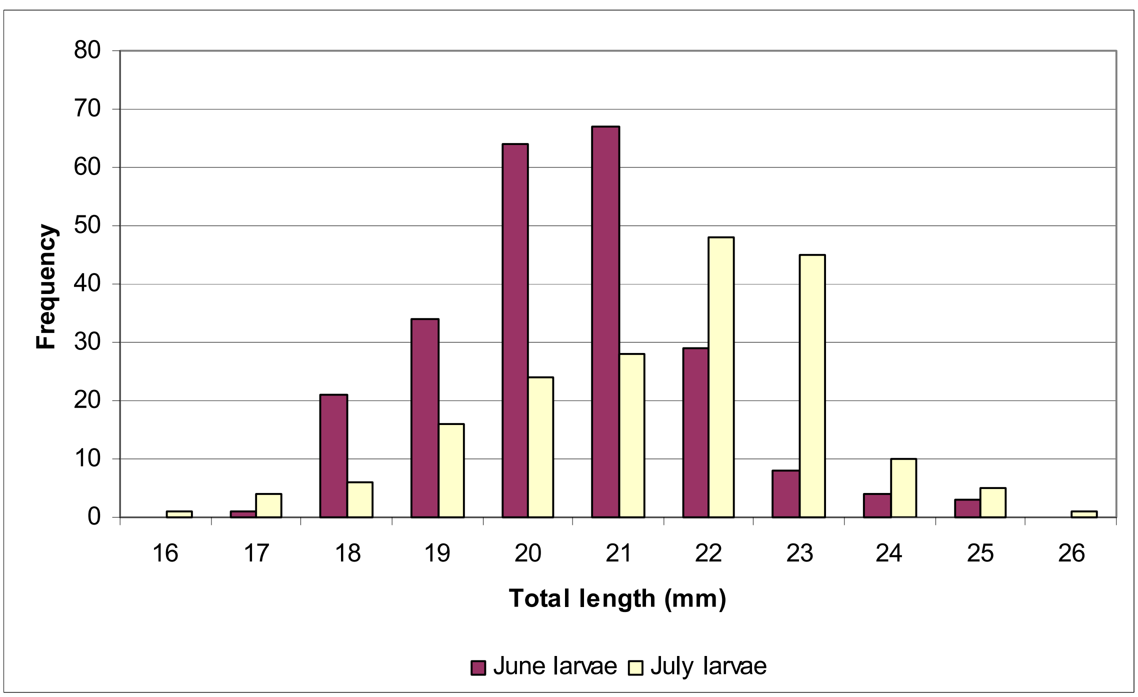


Figure 12. Total length distribution of lake sturgeon larvae collected below Kakabeka Falls in 2004.

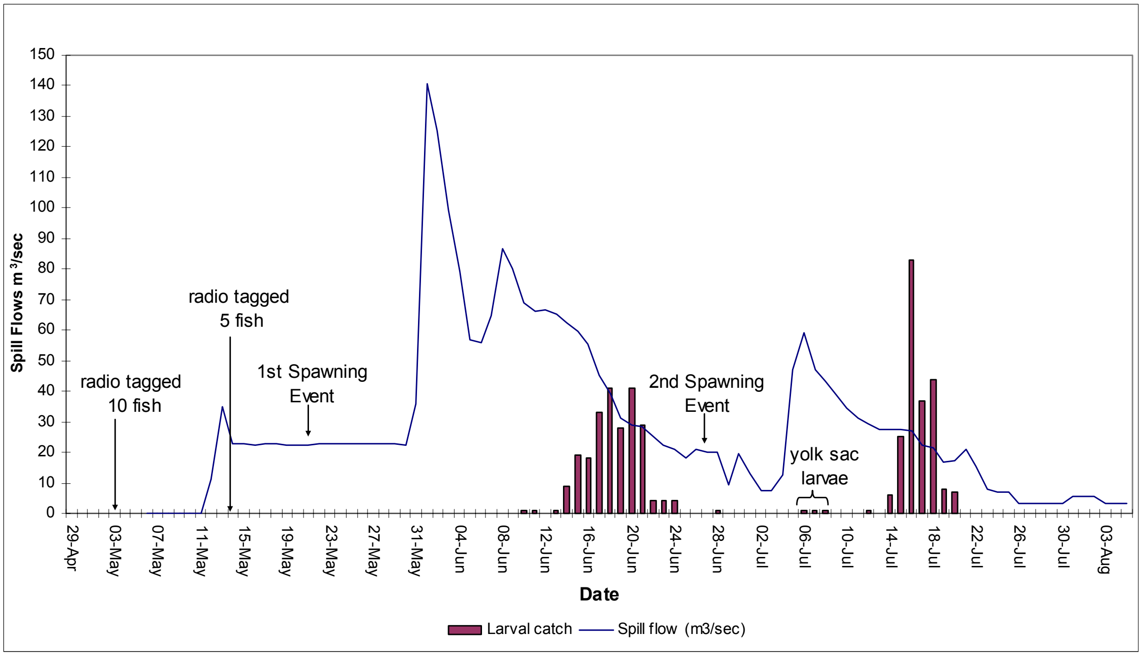


Figure 13. Mean daily spill flow over Kakabeka Falls in relation to radio tagging dates, approximate spawning dates, and catches of downstream drifting larvae.

Table 1. Fish attribute information for 15 adult sturgeon radio tagged in 2004 and three radio tagged in 2000.

Radio Tag Frequency	Fork Length (mm)	Total Length (mm)	Girth (mm)	Weight (kg)	Gill to dorsal fin Length (mm)	Tagging Date	Tagging Location (km number)
724	1150	1260	475	12.06	725	04-May-04	Km 19
704	1145	1225	454	11.61	710	04-May-04	Km 19
693	1210	1340	485	12.97	750	04-May-04	Km 19
614	1190	1290	486	12.97	760	04-May-04	Km 19
743	1140	1225	455	10.25	725	04-May-04	Km 19
672	1415	1497	585	20.22	885	04-May-04	Km 19
663	1160	1255	445	10.25	710	04-May-04	Km 19
602	1160	1300	450	11.15	750	04-May-04	Km 19
623	1150	1250	485	12.06	715	04-May-04	Km 19
644	1170	1215	462	11.15	763	04-May-04	Km 19
633	1150	1240	450	10.25	720	14-May-04	Km 41
653	1185	1265	720	12.06	720	14-May-04	Km 41
683	1165	1290	760	11.15	760	14-May-04	Km 41
733	1160	1250	715	10.25	715	14-May-04	Km 41
714	1140	1220	445	10.25	715	14-May-04	Km 19
254	1239	1345		13.4	781	06-Sep-00	Km 14
233	1142	1205		13.9	745	06-Sep-00	Km 14
095	1120	1189		10.9	720	06-Sep-00	Km 14

Table 2. The June and July drift netting incidental catch.

Species or Family	Number caught
Pink salmon	56
Brook trout	65
Lake whitefish	30
Rainbow smelt	9
Northern pike	43
Central mudminnow	16
Longnose sucker	13
Silver redhorse	2
Spottail shiner	12
Fathead minnow	2
Blacknose dace	5
Longnose dace	56
Pearl dace	1
Burbot	7
Ninespine stickleback	3
Trout perch	1
Rock bass	1
Smallmouth bass	6
Walleye	715
Johnny darter	7
Log perch	7
Cyprinidae	97
Cottidae	261
Catostomidae	1993