A DESCRIPTION AND ASSESSMENT OF THE ATLANTIC SALMON (*SALMO SALAR*) FALL PRE-SMOLT MIGRATION IN RELATION TO THE TOBIQUE NARROWS HYDROELECTRIC FACILITY, TOBIQUE RIVER, NEW BRUNSWICK USING RADIO TELEMETRY

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During the fall of 2006, 77 migrating wild Atlantic salmon (*Salmo salar*) pre-smolts from the Tobique River, New Brunswick were tagged and released with individually coded radio transmitters to monitor their downstream movements and behaviour in relation to a hydroelectric generating facility at Tobique Narrows. Fifty-seven of the tagged pre-smolts approached and descended the dam. Of those passing the dam, little delay was observed, as the mean time from first detection at the dam to confirmation downstream was 1 day 15 hours, with 65% descending the dam within two hours. Twenty of the tagged pre-smolts never reached the Tobique Narrows Dam either because they overwintered in the Tobique Narrows Headpond (n = 13), were post surgery mortalities, or had been predated upon and not detected after their release (n = 7).

The majority of pre-smolts (96%) approached the dam on the turbine side and 79% used one of two functioning turbine units as their route of passage – principally because there was no concurrent spilling. During spill from November 13 to November 26, 2006, 12 of 15 pre-smolts used spill gates to descend the dam. Spilling of a similar or greater magnitude and duration as in 2006 has only occurred three times since 1994, and is therefore infrequently available for passage. Mortality resultant of passage through turbines and spill gates was estimated to range from 8% to 28%.

The estimated population of wild and hatchery pre-smolts in the Tobique River in 2006 was 19,040. Using the radio tagged pre-smolts as indicators of the fate of the population, 4,945 pre-smolts stayed in the Tobique River while the remaining 14,095 descended the Tobique Narrows Dam. The number of pre-smolt mortalities, using the combined turbine and spill mortality rates at the Tobique Narrows Dam; were estimated to be between 1,128 (8%) and 3,947 (28%).

Résumé

Jones, R.A. and J.J. Flanagan. 2007. A description and assessment of the Atlantic salmon (*Salmo salar*) fall pre-smolt migration in relation to the Tobique Narrows hydroelectric facility, Tobique River, New Brunswick using radio telemetry. Can. Tech. Rep. Fish. Aquat. Sci. 2735: ix + 41 p.

En automne 2006, 77 saumons atlantiques (*Salmo salar*) sauvages en voie de smoltification qui descendaient la rivière Tobique, au Nouveau-Brunswick, ont été interceptés et munis, avant d’être remis à l’eau, d’un émetteur radio à code individuel permettant de suivre leur avalaison et leur comportement à la centrale hydroélectrique de Tobique Narrows. Cinquante-sept d’entre eux ont atteint le barrage et l’ont franchi. On a constaté que peu de temps s’écoulait entre leur arrivée au barrage et la descente de celui-ci. En effet, le laps de temps moyen entre le moment où ils détectaient le barrage pour la première fois et la confirmation de leur arrivée en aval était de 1 journée et 15 heures, mais 65 % d’entre eux franchissaient le barrage dans les deux heures. Vingt des 77 porteurs d’émetteur n’ont pas atteint le barrage de Tobique Narrows, soit qu’ils ont passé l’hiver dans le réservoir du barrage (n = 13), qu’ils sont morts après l’intervention ou encore qu’ils ont été victimes de prédation et n’ont pas été détectés après leur remise à l’eau (n = 7).

La majorité des saumons considérés (96 %) ont approché le barrage du côté des turbines et 79 % d’entre eux l’ont franchi en passant par une des deux turbines en fonctionnement, principalement en raison de l’absence de flot déversant simultané. Du 13 au 26 novembre 2006, en période de flot déversant, 12 saumons sur 15 ont utilisé les vannes d’évacuation pour franchir le barrage. Il n’y a eu que trois fois depuis 1994 un flot égalant ou surpassant en intensé celui de 2006. On estime que la mortalité résultant du passage par les turbines et les vannes d’évacuation est de l’ordre de 8 % à 28 %.

En 2006, on a estimée à 19 040 l’effectif des saumons sauvages et d’élevage au stade préalable à la smoltification dans la rivière Tobique. Si ceux du groupe qui ont été munis d’émetteurs sont des indicateurs du sort de cette population, 4 945 de ces 19 040 saumons seraient demeurés dans la rivière Tobique, tandis que les 14 095 autres seraient passés en aval du barrage de Tobique Narrows. D’après les taux combinés de mortalité aux turbines et aux vannes d’évacuation, la mortalité parmi ces saumons se serait située entre 1 128 et 3 947 individus, soit entre 8 et 28 % .

Introduction

Atlantic salmon (*Salmo salar*) smolts typically migrate to the ocean in the spring after two to four years in freshwater. However, in some rivers there is a component of the population that begins migration in the fall (Ruggles 1980). These fish commonly termed “pre-smolts” do not complete their migration to the ocean in the fall, but instead remain in freshwater, closer to the marine environment, until the following spring when they complete their migration (Buck and Youngson 1982). It is thought that such behaviour may benefit juveniles especially from more upstream tributaries by combining their eventual seaward out migration in the spring with other members of the same cohort from lower tributaries, increasing the overall number of smolts and helping to minimize predator mortality (Riddell and Leggett 1981) which is often high during this time (Elson 1962). Riddell and Leggett (1981) suggested that fall migration to more downstream areas also provides relief from potentially harsh overwintering areas in more upstream natal rivers.

The Tobique River is the largest salmon producing tributary of the Saint John River, upstream of the Mactaquac Dam (Marshall et al. 1998; Figure 1). A wild pre-smolt component of the Atlantic salmon population in this river has been identified (Semple 1971) and was estimated in 2001 to comprise 64% of the total juvenile salmon contributing to the 2002 smolt class (Jones et al. 2004). Tobique origin salmon face many challenges which are largely related to three hydroelectric facilities located at Tobique Narrows, Beechwood and Mactaquac (Figure 1) that are without safe downstream passage. Artificial flow and water temperature regimes (Flanagan 2003), headponds and developing communities of invasive predators, such as muskellunge, smallmouth bass and rainbow trout, pose additional challenges (Jones et al. 2006).

A coded-wire tag study by the Department of Fisheries and Oceans (DFO) indicated that smolts released upriver of the Tobique Narrows Dam returned as adult salmon at half the rate of smolts released downriver of Mactaquac Dam (Carr 2001, AMEC 2005). The wild and hatchery one-sea-winter (1SW) and multi-sea-winter (MSW) salmon returns upriver of Mactaquac Dam (which includes Tobique origin salmon) have declined significantly since 1985; the last year in which the conservation requirement was achieved (Jones et al. 2006). Since 2002, salmon returns released upriver of Mactaquac Dam have been less than 13% of the conservation requirement and were less than 7% in three of those years. Most of the salmon populations in the Maritimes have declined since the 1980’s, but the salmon population upriver of Mactaquac Dam has shown one of the greatest declines (Gibson et al. 2006). Turbine-related mortality at the Tobique Narrows Dam was as much as 16.5% – 23.7% (MacEachern 1959, 1960). This mortality, combined with the inferred mortality and headpond delays from other generating facilities at Beechwood and Mactaquac (Lindroth 1967) are believed to account for the difference between the Mactaquac and Tobique smolt-to-adult return rates. Moreover, an Expert Opinion (DFO 2006) revealed that the low freshwater production on the Tobique River and the low marine survival, combined with the mortality of downstream migrating smolts, increases the risk of decline to this population. Supplementation of Atlantic salmon from the Mactaquac Biodiversity Facility at all life stages to the Tobique River reduces the risk of decline. Supplementation programs that maximize exposure to the wild environment are preferred, and currently, the release of captive-reared adults raised from smolt captured in the Tobique River is the preferred supportive rearing method (DFO 2006).

Downstream passage was identified as an important initiative in a report[1] commissioned by DFO, New Brunswick Power Commission (NBPC), First Nations and local conservation groups for the long-term sustainability of salmon populations on the Saint John River. The New Brunswick Salmon Council in 2001 established the Saint John River Salmon Recovery Committee with a primary objective of improving downstream passage for juvenile salmon on the Saint John River. Among other initiatives, the committee has facilitated site visits by US fish passage experts and contracted the AMEC (2005) report "Conceptual Facility to Bypass Atlantic Salmon Smolts at the Tobique Narrows Dam". After a review (DFO 2006) of the AMEC (2005) report, which examined three options for bypassing smolts, NBPC and DFO determined that it was important to understand the pre-smolt migration behaviour at or in the vicinity of the Tobique Narrows Dam.

In the fall 2006, a collaborative research project between NBPC, DFO, Atlantic Salmon Federation (ASF), University of New Brunswick (UNB) and the Tobique Salmon Protective Association (TSPA) was conducted using radio telemetry to study the spatial and temporal movements of fall migrating, wild Atlantic salmon pre-smolts in the upstream and downstream vicinities of the Tobique Narrows Dam. Rotary screw traps (RST), and a mark recapture method were also used to provide an estimation of the fall pre-smolt population migrating from the Tobique River. It was anticipated that the results from this radio tagging experiment and earlier works by Carr (1999) would contribute to establishing effective downstream fish passage and/or collection strategies for juvenile salmon.

Materials & Methods

Study Area

The Tobique River is located in north-western New Brunswick, Canada (46° 46' N, 67° 42' W) and is 148 km long. The Tobique Narrows Dam is located 1.5 km upriver of the Tobique rivers confluence with the Saint John River (Figure 1). The study area covered about 120 km between the communities of Plaster Rock and Woodstock (Figure 2). Besides the hydroelectric dams, other points of interest included the RST/tagging location at Three Brooks, the Arthurette Bridge, and the Perth-Andover Bridge located about 5 km downstream of the Tobique Narrows Dam (Figure 2).

Tobique Narrows Dam

The Tobique Narrows Dam was completed in 1953 near the mouth of the Tobique River (Smith 1969). Operated by the NBPC, the power station has a generation capacity of 20 megawatts and is a barrier to migratory fishes such as Atlantic salmon. Upstream fish passage is provided by a pool and weir fishway (Smith 1979); there is no downstream passage except for the turbines or spill gates of the dam. The dam has four large spill gates (12.2 m wide, 8.0 m deep at a headpond level of 93.6 m), one smaller regulation gate (4.9 m wide, 4.6m deep at headpond level of 93.6 m) and two turbine units with openings 6.3 m deep at a depth of 8.1 m at a headpond level of 93.6 m (AMEC 2005). All spill gates open from the bottom. The forebay is considered the area of the headpond closest to the five spill gates and two turbine units. The tailrace is described as the immediate (<200 m) downstream area of the spill gates and turbine units.

[1] Fisheries and Oceans Canada, 1993. "A New Strategy for Conservation and Development of Saint John River Atlantic Salmon above Mactaquac," Amended July 26, 1993.

Catches and Estimates

Wild pre-smolts for radio tagging were captured from the Tobique River using RSTs operated at Three Brooks in the fall 2006 (Figure 2). This was done in conjunction with a pre-smolt collection and monitoring program previously described by Jones et al. (2004). Three 1.52 m RSTs (EG Solutions Inc., http://www.screwtraps.com) were operated simultaneously in series to capture downstream migrating wild and hatchery (released as age-0+ adipose-clipped parr during the fall in previous years and in 2006; see Jones et al. 2006) origin pre-smolts for the captive-reared program at the Mactaquac Biodiversity Facility which is described in detail in Jones et al. (2004). Chaput and Jones (2004) gave details on the type of RST used, site characteristics and the various species captured in the RSTs at Three Brooks. A mark-recapture study was also implemented, whereby a portion of the daily catch of wild and hatchery pre-smolts were tagged with a numerical streamer tag and 'recycled' 3.5 km upriver. All pre-smolts were enumerated and those recaptured helped provide estimates of the wild and hatchery pre-smolt populations in the Tobique River. Mark-recapture data were used in a Bayesian estimation procedure described by Gazey and Staley (1986) to determine the most probable estimate. These methods were similar to those used in the spring of 2004 as described in Jones et al. (2006).

RSTs were usually checked once daily in the morning from September 25 to December 1, 2006. During days in which high water conditions prevailed, monitoring was more frequent during daylight hours. The RSTs did not operate from November 14-19, 2006 due to high flows.

In-river water temperatures were taken during each RST check and with a real-time temperature data logger[2] (hourly mean) installed near Arthurette (Figure 2). Environment Canada recorded discharge data at a gauging station located in Riley Brook. Discharge is affected by water storage facilities on four tributaries upriver of the Riley Brook gauging station. Discharge data and operating conditions at the Tobique Narrows and Beechwood dams were provided by NBPC.

Radio Tagging

All pre-smolts obtained for the radio-tagging study were first measured for fork length and weighed. Pre-smolts less than 24.0 g were not selected for tagging to assure the tag weight (mean = 1.2 g) did not exceed 5% of the weight of the fish. Tag weight of less than 8% of the fishes body weight has been shown to have less effect on the swimming behaviour of tagged Atlantic salmon smolts (Lacroix et al. 2004). Pre-smolts were anaesthetized with clove oil (0.1 ml [95% oil / 5% ethanol]:1L water) for approximately 3.5 minutes (mean = 3:44; minutes : seconds). Overall surgical procedure time was 3:23 (n = 77) on average, while time to recovery (i.e. returned to equilibrium) averaged 6:31 in oxygenated, ambient river water. Tagged pre-smolts were held in the recovery water for a minimum of one hour before being released downriver of the RSTs.

Activated, individually coded radio-tags (Lotek Wireless[3], nanotag NC-3-2, Figure 3) with a burst rate ranging from 4.8 to 5.2 seconds, a frequency of 150.5 mega-hertz and a life expectancy of 53 days, were surgically implanted in the ventral area of the body cavity, one centimetre posterior of the pectoral fins (Figure 4). Once implanted, the incision was closed with two sutures and the antenna was left exposed externally via an opening made with an 18-

[2] Vemco Ltd. Shad Bay, Nova Scotia, Canada
[3] Lotek Wireless, Fish and Wildlife Monitoring, Newmarket, Ontario, L3Y 7B5

gauge needle (Figure 4). A sub-sample of 20 pre-smolts (every fifth fish) was also subjected to the same procedures as the radio-tagged fish, but kept in a local rearing tank as a control group to monitor possible long-term effects of tagging. These fish were surgically implanted with non-transmitting or "dummy" tags and were subsequently brought to the Mactaquac Biodiversity Facility at the completion of the study.

Between October 21 and November 1, 2006, 97 of the wild pre-smolts captured in the RSTs were surgically implanted with radio tags.

Date	Time of release	Number of pre-smolts tagged	
		Released	Controls
21-Oct	18:00	10	2
23-Oct	17:00	12	3
24-Oct	14:00	12	3
25-Oct	13:00	4	1
26-Oct	17:00	4	1
27-Oct	17:15	8	2
30-Oct	17:30	12	3
31-Oct	18:00	12	3
1-Nov	15:40	3	2
Total:		**77**	**20**

The mean fork length for all radio tagged pre-smolts was 15.7 cm (SD = 0.8) (Table 1) with the shortest fish being 14.4 cm and the longest 17.5 cm. Weights of the tagged pre-smolts ranged from 29.4 to 57.1 g with an overall mean weight of 39.7 g (SD = 6.5) (Table 1). Considering the mean tag weight of 1.2 g, the tags accounted for 2-4% (mean = 3%) the weight of the tagged pre-smolts. The mean size of the pre-smolts released with activated tags was slightly larger than the mean values for the randomly chosen 'control' pre-smolts (Table 1).

The fate of radio tagged pre-smolts that descended the Tobique Narrows Dam were assigned to one of the following four categories; 1) alive 2) mortality 3) delayed mortality or overwintering and 4) unknown, based on the following conditions or criteria:

Status	Condition or Criteria
Alive	-detected in the main Saint John River at or downriver of the Perth-Andover Bridge
Mortality	-detected in tailrace at the end of the study and for more than 3 weeks after first detection at the Tobique Narrows forebay
Delayed mortality or overwintering	-detected in the main Saint John River between the confluence of the Tobique River and the Perth-Andover Bridge and did not display upstream movement
Unknown	-not detected after exiting the tailrace area

Knowing the number of tagged pre-smolts that approached the dam and the fates of those that descended the dam, it was possible to apply the relative proportions of tagged pre-smolts to the estimated number leaving the Tobique River. This permitted a more thorough description and assessment of the overall fall pre-smolt migration in relation to the Tobique Narrows dam in 2006.

Fixed Radio Receivers

An SRX 400 data receiver (Lotek Wireless[3]) and fixed antenna (4-element yagi) were installed near the Arthurette Bridge to log real time data of passing pre-smolts at a point approximately 11 km downriver of the release location and 1 km upriver of the Tobique Headpond (Figure 5). This station operated daily from the first day pre-smolts were tagged and released until the completion of the project, with the exception of a 34 hour period on October 22-23 when the receiver was not appropriately set to store data. Pre-study testing revealed a detection range that covered a complete cross-section of the river and upriver to the bridge.

Fixed antennae (4-element yagi) were installed at the forebay area on the turbine (TY) and spill gate (SY) sides of the Tobique Narrows Dam (Figure 6). Antennae were directed upriver towards the Tobique headpond area, and were strategically placed to help differentiate which side of the headpond pre-smolts used as they approached the dam. Antenna orientation was tested prior to the release of tagged pre-smolts and it was determined that each antenna adequately covered their respective side of the headpond, with some detection overlap at mid-channel and upstream to a point about 0.5 km from the dam. Eight underwater antennae (approximate depth of 4.25 m) with a detection range of 4.5 m each, were also placed at an angle on the gate abutments to cover each of the five spill gates (two antennae on spill gate #4) and one in front of each turbine unit facing directly upriver (Figure 6). The antennae at the dam forebay were grouped according to their location, whether on the turbine or spill gate side. Each arrangement was logged to a separate SRX 600 receiver and was combined with a separate ASP-8 (see Lotek Wireless; http://www.lotek.com) which permits continuous scanning, in this case 5.5 seconds per antenna, of multiple antennae on a single receiver. This assured the detection of activated tags (when in the detection range) with minimal time lapse between port scans and served to more accurately monitor fish passage during all operating conditions, as well as possible movements in front of the dam prior to passing. On November 14, antennae on Gates #1, #2 and #3 were removed from the spill side configuration because headpond spilling was more likely to be through Gates #4 and #5. This reduced the full cycle scan time on the spill side receiver because there were fewer antennae connected to the ASP-8 and receiver combination. In addition, antennae (one 6-element yagi and one 4-element yagi) were combined and connected to a SRX 400 receiver placed in the tailrace area of the Tobique Narrows Dam to confirm passage and movements of tagged pre-smolts downriver of the dam (Figure 6). The tailrace receiver also operated continuously during the experiment except from November 30 at 04h00 to December 4 at 19h00 when the power supply to the receiver was dislodged during the data downloads. Data downloads from this receiver were generally done during daylight hours and would last from one to four hours depending on the time and date of the previous download. Lastly, two 6-element yagi antennae were installed at the Beechwood Dam, one directed upriver and one downriver (Figure 1). These two antennae were connected to an ASP-8, SRX 600 receiver combination from November 3 to December 14 to monitor potential movements of tagged pre-smolts past Beechwood. Because only two antennae were used at the Beechwood Dam, coverage was minimal and it was possible that some tagged pre-smolts descended the dam undetected via the furthermost spill gates.

Searches

Along with the fixed receivers at Arthurette, and the Tobique Narrows and Beechwood dams, searches for radio tagged pre-smolts were also conducted periodically by boat, helicopter and vehicle during the project (Table 2). The search setup for the boat and vehicle consisted of a 4-element yagi antenna attached to a 1.5 m pole positioned upright at the bow of the boat, antenna facing forward and connected to a SRX 400 or SRX 600 receiver. For boat searches in the Tobique headpond, a zigzag pattern moving upriver or downriver was used and covered the greatest possible area along the river. Searches by boat in the Saint John River were in one direction on one side of the river and in the opposite direction on the other side of the river. The vehicle search was done by towing the boat behind a truck with the antenna directed perpendicular to the river flow and following a road along the river. This search method was not 100% efficient as the river was not always in view from the road. This greatly reduced the likelihood of detecting a tagged fish in these areas. For the helicopter search a dual element antenna was attached to each skid, directed downward at an angle to the left and right of the helicopter. The two antennae were combined to form one and were connected to a SRX 600 receiver. In situ testing determined that radio tags were detected while flying at a speed of approximately 80 km per hr at a height of 60 m. The helicopter flew a path that followed the center of the river. The areas covered included the Tobique River and Tobique Narrows Headpond from the release location at Three Brooks to the Tobique Narrows Dam, the Saint John River from Tobique Narrows Dam to Beechwood Dam and from Beechwood Dam to Woodstock (by helicopter and vehicle only).

For all fixed receiver and search antennae, the maximum signal strength recorded from a tag was 255 (i.e., the tag is closest to or virtually in the same location as the antenna, best possible scenario). A combination of high signal strength and a greater incidence of repeated detections for a specifically coded tag, was used to determine the presence and relative location of a tagged pre-smolt in relation to an antenna (see Appendix i for example). During all search events, a GPS coordinate was taken at the point of the largest signal strength displayed on the manual receiver.

Results

Catches and Estimates

Total catches at the Three Brooks RSTs numbered 917 wild (60.7%) and 593 hatchery pre-smolts (Table 3). Daily combined catches (wild and hatchery) were greater than or equal to 100 pre-smolts on three occasions; October 8 (100), October 30 (138) and October 31 (141) with 1.5 times more wild than hatchery pre-smolts caught overall. The first pre-smolts were captured on September 27 and the last on December 1. Overall distribution appeared bi-modal and peak catches were moderately associated with increased flows. There did not appear to be any association between water temperature and pre-smolt catches (Figure 7). While the date on which 50% of the wild and hatchery pre-smolts were captured was similar to previous years, the overall distribution of the run seemed longer with the timing extending later into the season in 2006 (Figure 8).

There was virtually no difference between capture efficiencies for wild and hatchery tagged pre-smolts (wild = 7.93% and hatchery = 7.92%) as determined from the mark-recapture experiment. Sixty-eight of the 858 streamer tagged pre-smolts that were recycled upriver, were recaptured and the combined efficiency for wild and hatchery pre-smolts was 7.93%. Applying this capture efficiency to the catch (n = 1,510) resulted in an estimate of 19,040 pre-smolts

(15,465 - 24,760; 2.5 and 97.5 percentiles) or 11,560 wild and 7,480 hatchery pre-smolts, for the Tobique River in 2006 (Figure 9).

Migration to Arthurette

Seventy of the 77 radio tagged pre-smolts were confirmed to have passed the first fixed receiver near Arthurette. However, six of the 70 that were tagged and released on October 21, 2006 likely were not detected at Arthurette because the receiver was not logging data from 08h00 on October 22 until 18h30 on October 23 (Table 4). All six of these pre-smolts were later detected on receivers at the Tobique Narrows Dam or during searches within the Tobique Headpond. The mean travel time for the 64 pre-smolts released at Three Brooks and detected at Arthurette was 1 day and 17 hours (SD = 2 days 23 hours, Table 5). The fastest pre-smolt took 1 hour and 41 minutes to travel the approximately 11 km from the release location at Three Brooks. The slowest fish took more than 20 days (Table 5), but most (76%) of the radio tagged pre-smolts were detected at Arthurette within 2 days (Figure 10). Using hour of day of first detection at Arthurette as a proxy, most of the pre-smolt movement occurred during the hours of darkness from 18h00-07h00, and peak movements occurred between 20h00 and 22h00 (Figure 11).

Two of the seven pre-smolts that were not detected at Arthurette were located during searches between Three Brooks and Arthurette on November 8 and/or November 22 (Figure 12). The remaining five pre-smolts were never detected during searches and may have died as a result of the surgery and/or had been predated upon. If these five pre-smolts, representing 7% of the total fish tagged and released, were mortalities as a result of surgery, then the percentage would be similar to the 5% observed for the control group. One control fish tagged on October 25, 2006 died within two days in the holding tank. The high number of detections for each of the 64 pre-smolts detected at the Arthurette receiver suggests it was unlikely that any of the seven tagged pre-smolts, categorized as not having passed the receiver, had gone by undetected (Table 4).

Migration to Tobique Narrows Dam

Fifty-seven of the radio tagged presmolts passed the Tobique Narrows Dam, representing 81% of the tagged pre-smolts known to have passed the Arthurette receiver. Two of the 57 pre-smolts descended the Tobique Narrows Dam undetected on the antenna/receiver setup at the hydroelectric facility. These two undetected pre-smolts were later detected at least twice on separate searches downriver of the Tobique Narrows Dam. It is likely that these two pre-smolts passed during a time when water levels in the Tobique River were high and the corresponding turbidity and high discharge through the spill gates probably reduced the efficiency of the antennae setup. Eleven of the 13 pre-smolts that passed Arthurette, but did not migrate as far as the Tobique Narrows Dam, were last detected by boat searches in the Tobique Narrows Headpond (Figure 12). Seven of these 11 radio tagged pre-smolts were last detected and assumed to be overwintering in the lower 8 km of the Tobique Narrows Headpond.

Mean travel time from Three Brooks until first detection at the Tobique Narrows Dam forebay was 11 days 21 hours (SD = 5 days 3 hours; n = 55) and ranged from 4 days 13 hours to 24 days 2 hours (Table 5). Twenty-one or 38% of the pre-smolts reached the Tobique Narrows Dam within eight days of release from Three Brooks and 85% had been detected at the dam within 16 days (Figure 10). Using hour of first detection as an indication of migration time within the day, the majority of the pre-smolt movement near the vicinity of the dam occurred during darkness (Figure 11). The majority of the first detections occurred between 18h00 and 20h00; about two hours earlier than at Arthurette.

All 55 pre-smolts that were detected in the Tobique Narrows forebay descended the dam. The majority of the radio tagged pre-smolts migrating downstream approached the forebay on the turbine side, as 96% were first detected on the turbine yagi (TY) antenna (Figure 6). The total number of detections on each antenna also confirmed that the pre-smolt movement was predominantly on the turbine side of the forebay area (Figure 13). Upon arrival in the forebay area, pre-smolts were generally quick to descend the dam. In all, 40 of the 55 (73%) detected pre-smolts descended the dam within 1 day of arrival and 36 of these passed within 2 hours of first detection (Figure 14). On average, radio tagged pre-smolts spent 1 day 15 hours (SD = 4 days 13 hours) in the forebay area before moving past the dam (Table 5). Six pre-smolts spent more than 3 days in the forebay or headpond area before descending the dam and one pre-smolt was detected continuously for 28 days in the forebay area.

Operating Conditions at Tobique Narrows Dam

Spilling at the Tobique Narrows Dam occurred mostly from November 13 to 26, 2006, with the bulk of spilling through gates #4 and #5 (Figure 15). Rarely have any of the remaining gates been opened during the fall (September 25 to November 30) according to the time series of discharge data (1994-2006). In 2006, the overall open gate height in the fall was slightly less for gate #4 (mean = 0.15m) than gate #5 (mean = 0.17m), although given the larger width of gate #4 the volume of water it passed was greater (Figure 15). Volume and velocity through the gates during spilling was not estimated in this study. The greatest number of spilling events occurred in 2005 and acute, sustained periods (4 to 8 days) of spilling >100 m^3/s only occurred in 1996, 2003, 2005 and 2006, with the latter showing the longest sustained period of 8 days (Figure 16).

Pre-smolt Passage Route - Turbines versus Spill Gates

The underwater antenna showing the last detection and corresponding signal strength were used to determine the passage route through the turbines or spill gates of the migrating pre-smolts (Appendix i). Forty-five radio tagged pre-smolts were last detected on at least one of the underwater antennae mounted in front of the turbine intakes (Table 6; Figure 6). This represented 79% of the 57 pre-smolts that passed the Tobique Narrows Dam and overall an equal number of radio tagged pre-smolts passed each turbine unit (#1 and #2). The remaining 12 pre-smolts descended the dam via the spill gates (Table 6). Few detections and weak signal strengths due to the high flows, turbid water and debris in the forebay created some uncertainty in determining which spill gate the pre-smolts used to descend the dam. During a high water period when spilling and maximum generation occurred at the dam, November 13-26, 12 pre-smolts passed through the spill gates and three others used the turbines (Table 6, Figure 17).

Pre-smolt Fate after Passage – Turbine versus Spill Gate

Seven of the 57 tagged pre-smolts that passed the Tobique Narrows Dam were classified as ‘unknown’ because these fish were not detected during any boat, helicopter or truck searches after leaving the tailrace area (Table 7). Of the remaining 50 pre-smolts that passed the Tobique Narrows Dam 72% were classified as “alive”. These fish were typically detected by searches a number of times or at different locations downstream of the Tobique Narrows Dam, beyond the Perth-Andover Bridge (Appendix ii, Figure 2). Of the pre-smolts classified as “alive”, 27 used the turbines and nine used the spill gates (Table 7).

Four pre-smolts were classified as "mortality" due to their prolonged duration and continual detection at the dam (Table 7). Three of these pre-smolts were detected in the tailrace area at the end of the study and more than 36 days after passing through the turbines (Appendix ii). The fourth mortality was detected in the forebay area for 28 days before being detected below the dam on December 10. A search from the road way or parking area near the Tobique Narrows Dam on December 19, 2006 detected all four mortalities in the tailrace area after passing through the turbines (Figure 18). Another suspected mortality was also in the tailrace area for more than 28 days, but was undetected after November 29, 2006 and therefore was one of the seven pre-smolts classified as "unknown" (Appendix ii).

Two pre-smolts that used the spill gates and eight pre-smolts that used the turbines for passage at the Tobique Narrows Dam were classified as "delayed mortality" or "overwintering" (Table 7, Appendix ii). These ten pre-smolts moved from the tailrace area within one day of passing the dam and were detected at the end of the study in the main Saint John River between the confluence of the Tobique River and the Perth-Andover Bridge (Figure 18).

Overall, mortality at the Tobique Narrows Dam ranged from 8% – 28% when combining pre-smolts that used the spill gates and turbines (Table 7). However when treated separately, the survival of pre-smolts that used the spill gates was between 82% and 100% and for those that used the turbines was between 69% and 90%, although given the limited availability of spill gate openings (November 13 – 26, 2006) the majority of presmolts had no choice but to use the turbines as their passage route.

<u>Estimated Numbers of Pre-smolts Up River and Down River of the Tobique Narrows Dam</u>

Using the radio tagged pre-smolts as an index of the population and considering that 74% approached and descended the Tobique Narrows Dam, it was estimated that 14,095 (11,448 to 18,329, 2.5 and 97.5 percentiles) would have passed (Table 8). Using the combined spill and turbine mortality rates, the estimated loss of pre-smolts at the Tobique Narrows Dam in 2006, was between 1,128 and 3,947 (Table 8). From this it was determined that the number of pre-smolts estimated to have survived passage through the dam was between 10,148 and 12,967 fish.

<u>Migration to Beechwood Dam</u>

Fifteen of 57 pre-smolts that passed the Tobique Narrows Dam were confirmed to have descended the Beechwood Dam as well. Nine were detected at the dam while the remaining six passed the dam undetected, but were observed downriver during searches from helicopter or vehicle (Figure 18).

Discussion

The daily distribution of RST catches of downstream migrating wild and hatchery pre-smolts in the Tobique River have been relatively similar during each of the six years of pre-smolt monitoring, i.e., 50% of the catch generally occurred during the last two weeks of October and first two weeks of November (Figure 8). The extended migration of wild and hatchery pre-smolt through the later part of November in 2006 was likely because of the milder water temperatures in late November.

In all, 77 wild pre-smolts were radio tagged and released from October 21 to November 1, 2006. Of these, 74% (57) passed the Tobique Narrows Dam, 1.5 times greater than what was found in similar studies in 1996 and 1997 by Carr (1999) using acoustic tagged pre-smolts. The smaller number of acoustic tagged fish and tags themselves may have contributed to the lower percentage that migrated to the dam (~50%) determined by Carr (Carr op. cit.). The acoustic tags used by Carr (1999) were much larger and heavier in comparison to the radio tags used here, and possibly affected overall pre-smolt swimming behavior. Also, the detection and tag position accuracy of acoustic tags are impacted by noise (Ehrenberg and Steig 2002) possibly like that emanating from working turbines and spilling water.

It has largely been accepted that the migration of spring smolts usually occurs at night (McCormick et al. 1998) but very little has been documented on the hours that pre-smolts migrate. Based on the first detections for each of the tagged pre-smolts that passed the Arthurette receiver, the majority (87%) migrated during the hours of darkness, while at the Tobique Narrows Dam this proportion had decreased to 72%. This might imply a difference in pre-smolt migratory behavior in the Tobique River as a result of moving from a fast flowing river at Arthurette, to a slower headpond environment at Tobique Narrows Dam (Figure 11). However, it should be noted that spring smolt movements during the day have been shown to increase later in the migration period and the same might be possible here (Moore et al. 1995; Russell et al. 1998; also see Osterdahl 1969 and Thorpe and Morgan 1978 cited in McCormick et al. 1998).

In this study, Tobique River pre-smolts showed little delay in moving past the dam after their first detection. Of the 55 radio tagged pre-smolts that were detected in the forebay area of the dam, 65% descended the dam in less than two hours. It was not possible to distinguish between an active (i.e., diving or sounding) versus a passive descent (i.e., drawn by increased flow) through the dam. Eventually, all 55 pre-smolts passed the dam with 96% approaching on the turbine side and 79% moving past the dam via one of the two turbines. Clearly, the preference of pre-smolts was to approach the dam on the turbine side. This was likely associated with the natural thalweig of the former river (pre-headpond) or the ‘draw’ from the turbines. Therefore any fish passage or collection strategy would be most effective if located on the turbine side of the forebay. Only one of the six pre-smolts that spent more than 2d in the forebay area demonstrated a searching behavior by swimming back and forth across the entire face of the dam. Most of our data, instead, suggested localized movements in front of one of the two turbines and that pre-smolts were more likely entrained, possibly in the intake gatewells. Radio tagged pre-smolts were present in the forebay area of the Tobique Narrows Dam from October 25 until December 10.

The option to use spill gates as a means to pass pre-smolts at Tobique Narrows Dam was only possible from November 13, 2006 until November 26, 2006 and although five gates are present, typically only one or two gates are partially open at one time. During spilling, 15 radio tagged pre-smolts descended the dam and it was determined that 12 passed via the spill gates during spill gate discharges ranging from 26% to 82% of the total discharge (median value of 71%). Three pre-smolts used the turbines as their route of passage despite flows through the spill gates that represented 25, 21, and 78% of the dam’s total discharge during their presence (Table 6). Assuming a similar gate opening strategy to that used in 2006 (Figure 15), flows through the spill gates greater than 50% of the total discharge would be necessary to ‘draw’ the majority of pre-smolts through the spill gates. This is unlikely to occur given the historical operating conditions at the dam during the fall migration period on the Tobique River. Spilling of a similar or greater magnitude to that observed in 2006 has only occurred on three occasions since 1994 (Figure 16).

Very little is known of the type and location of the overwintering habitat for Tobique origin pre-smolts. It was therefore difficult to classify a pre-smolt that was categorized as a delayed mortality versus one that may have been overwintering. Mortality estimates therefore, were potentially high based on the underlying assumptions used to define pre-smolt fate, and are instead presented as a range from 8% to 28% overall (turbine and spill gates combined). Using these estimated mortality rates there were possibly between 1,128 and 3,946 pre-smolts mortalities attributed to the hydroelectric dam operation. Notwithstanding, the majority of pre-smolts had to use the turbines for passage, and therefore the mortality range which better represents the population that migrated past the Tobique Narrows Dam was 10% to 31%. There was no evidence of mortality from the radio tagged pre-smolts that passed through the spill gates, although 18% were assigned to the delayed mortality category and would represent the upper end of mortality associated with the spill gates. A similar study with spring smolts would potentially help clarify the issue of overwintering and delayed mortality in pre-smolts.

Based on the location of last detection for all 77 radio tagged pre-smolts (unadjusted for possible mortalities) overwintering locations for Tobique origin pre-smolts (and their respective percentage) were suggested to be; downriver of Beechwood Dam (19%) between Beechwood Dam and Tobique Narrows Dam (55%) and, upriver of the Tobique Narrows Dam (26%) (Appendix iii). The search from helicopter revealed the location of five pre-smolts that would have otherwise been categorized as unknown (i.e. undetected after leaving Tobique tailrace). These pre-smolts were detected in the ice-free river section between Beechwood Dam and the community of Hartland (Figure 2, Figure 18). The search by helicopter was for the most part unable to detect pre-smolts in the ice-covered river sections, in particular from Beechwood Dam to the Perth-Andover Bridge and upriver of Tobique Narrows Dam. The search completed by vehicle from the adjacent river road after all fixed receivers were removed on December 19, 2006, revealed one pre-smolt downriver of Beechwood Dam that had not been detected during the search from the helicopter. This search also confirmed most of the helicopter detections. The searches from helicopter and vehicle detected pre-smolts that were otherwise categorized as “unknown” or “delayed mortality/overwintering”, in new locations and permitted their re-categorization to the “alive” category.

Recommendations

Any fish passage or collection strategies that are proposed should take into consideration the following;

- the mid October - early December migration period in which pre-smolts are present at the Tobique Narrows Dam
- peak pre-smolt activity between 5pm and 8am (some daylight activity during the latter part of the migration period)
- predominant downstream approaches to the dam are in the area of the turbines
- that significant flow (potentially 50% of the total discharge) would appear to be required for an extended period to ‘draw’ the majority of the pre-smolts to descend the dam through the spill gates.

Considerations for Future Evaluations or Research

Any future studies on the migration behavior of pre-smolts in the vicinity of the Tobique Narrows Dam should take into consideration the following;

- release of headpond captured and radio tagged pre-smolts ‘controls’ to the tailrace of the Tobique Narrows Dam so as to elucidate by comparison, the ‘effects’ of passage through spill gates or turbines on subsequent downstream migration
- searches by helicopter prior to ice formation and extended use of vehicles in searching for tagged pre-smolts in river sections that parallel roads
- establishment of an additional receiver and antenna in the tailrace to monitor suspected mortalities. When more than three tags were in the tailrace area, the number of collisions and/or false detections increased and thereby reduced the opportunity for detecting other passing tagged pre-smolts (Gord Carl - Lotek, pers. comm.)
- acquisition of tags that would continue functioning into the spring smolt migration and that could be used in conjunction with 2 to 3 arrays of fixed receivers operated between the Tobique Narrows and Beechwood dams throughout the winter and spring. This would provide information with regards to overwintering mortality, and help distinguish between the delayed mortality and overwintering pre-smolts
- tagging of sacrificed pre-smolts for release both upriver to simulate a fish that died prior to passing the dam, and downriver to simulate a fish that died immediately upon passing the dam (Skalski et al. 2001). This would provide insight on the transportability and end resting places of dead pre-smolts
- study of the behaviour of active and passive descending fish at the dam to identify opportunities for enhancement / prevention of one or the other descent opportunities.

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References

AMEC. 2005. Conceptual Facility to Bypass Atlantic Salmon Smolts at the Tobique Narrows Dam: Final Report. Report to the Saint John Salmon Recovery Committee of the New Brunswick Salmon Council. AMEC Earth and Environmental, Fredericton, New Brunswick. iii + 44p + appendices.

Buck, R.J.G. and A.F. Youngson. 1982. The downstream migration of precociously mature Atlantic salmon, *Salmo salar* L, parr in autumn; its relation to the spawning migration of mature adult fish. J. Fish. Biol. 20: 279-288.

Carr, J. 1999. Atlantic salmon (*Salmo salar*) smolt migration patterns in the dam-impacted St. John River system. pp 217-227 *In* Advances in Fish Telemetry, Proceedings of the Third Conference on Fish Telemetry in Europe, Norwich, England, 20-25 June 1999..

Carr, J. 2001. A review of downstream movements of juvenile Atlantic salmon (*Salmo salar*) in the dam-impacted Saint John River drainage. Can. Man. Rep. Fish. Aquat. Sci. 2573: 76p.

Chaput, G.J., and R.A. Jones. 2004. Catches of downstream migrating fish in fast-flowing rivers using rotary screw traps. Can. Man. Rep. Fish. Aquat. Sci. 2688: v + 14p.

Gibson, J., B. Hubley, G. Chaput, J. B. Dempson, F. Caron, and P. Amiro. 2006. Summary of status and abundance trends for eastern Canadian Atlantic salmon (*Salmo salar*) populations. Can. Sci. Advis. Sec. Res. Doc. 2006/026. vi + 31p.

DFO. 2006. Science Expert Opinion on conceptual facility to bypass Atlantic salmon smolts at the Tobique Narrows Dam. Maritimes Region, Expert Opinion 2006/02: 29p.

Ehrenberg, J.E., and T.W. Steig. 2002. A method for estimating the “position accuracy” of acoustic fish tags. ICES J. Mar. Sci. 59: 140-149.

Elson, P.F. 1962. Predator-prey relationships between fish-eating birds and Atlantic salmon. Bull. Fish. Res. Board Can. 133: 87p.

Flanagan, J. 2003. The impacts of fine sediments and variable flow regimes on the habitat and survival of Atlantic salmon (*Salmon salar*) eggs. University of New Brunswick, Department of Biology. MSc. Thesis. xii + 122p.

Gazey, W.J. and M.J. Staley. 1986. Population estimation from mark-recapture experiments using a sequential Bayes algorithm. Ecology 67: 941-952.

Jones, R.A., L. Anderson, and T. Goff. 2004. Assessments of Atlantic salmon stocks in southwest New Brunswick, an update to 2003. Can. Sci. Advis. Sec. Res. Doc. 2004/019. ii + 70p.

Jones, R.A., L. Anderson, J.J. Flanagan, and T. Goff. 2006. Assessments of Atlantic salmon stocks in southern and western New Brunswick (SFA 23), an update to 2005. Can. Sci. Advis. Sec. Res. Doc. 2006/025. ii + 82p.

Lacroix, G.L., D. Knox, and P. McCurdy. 2004. Effects of implanted dummy acoustic transmitters on juvenile Atlantic salmon. Trans. Am. Fish. Soc. 133: 211-220.

Lindroth, A. 1967. Mactaquac project and Saint John River salmon. Draft Report for N.B. Power Electric Commission.

MacEachern, N. 1959. Mortality Tests – Tobique Narrows Dam, 1959. Unpubl. Rep. Fish Culture Develop. Maritimes Area, Halifax, Nova Scotia.

MacEachern, N. 1960. Mortality Tests – Tobique Narrows Dam, 1960. Can. Fish. Service. (Maritimes Region), Resource Development Branch. Man. Rep. 60-12. 24p.

Marshall, T.L., C.J. Harvie, and R.A. Jones. 1998. Status of Atlantic salmon stocks of southwest New Brunswick. 1997. Can. Sci. Advis. Sec. Res. Doc. 98/30. iii + 60p.

McCormick, S.D., L.P. Hansen, T.P. Quinn, and R.L. Saunders. 1998. Movement, migration, and smolting of Atlantic salmon (*Salmo salar*). Can. J. Fish. Aquat. Sci. 55 (Suppl. 1): 77-92.

Moore, A., E.C.E. Potter, N.J. Milner, and S. Bamber. 1995. The migratory behaviour of wild Atlantic salmon (*Salmo salar*) smolt in the estuary of the River Conwy, North Wales. Can. J. Fish. Aquat. Sci. 52: 1923-1935.

Osterdahl, L. 1969. The smolt run of a small Swedish river. pp. 205-215 *In* Symposium on salmon and trout in streams. H.R. MacMillan Lectures in Fisheries, Univ. of British Columbia,.

Riddell, B.E. and W.C. Leggett. 1981. Evidence of an adaptive basis for geographic variation in body morphology and time of downstream migration of juvenile Atlantic salmon (*Salmo salar*). Can. J. Fish. Aquat. Sci. 38: 308-320.

Ruggles, C.P. 1980. A review of the downstream migration of Atlantic salmon. Can. Tech. Rep. Fish. Aquat. Sci. 952: 39p.

Russell, I.C., A. Moore, S. Ives, L.T. Kell, M.J. Ives, and R.O. Stonehewer. 1998. The migratory behaviour of juvenile and adult salmonids in relation to an estuarine barrage. Hydrobiologia 371/372: 321-333.

Semple, J.R. 1971. Fisheries investigations in the Saint John River drainage emphasizing juvenile Atlantic salmon, 1970. Resource Development Branch, Department of Fisheries and Forestry, Fisheries Service, Maritime Region, Halifax, NS 75p.

Skalski, J.R., J. Lady, R. Townsend, A.E. Giorgi, J.R. Stevenson, C.M. Peven, and R.D. McDonald. 2001. Estimating in-river survival of migrating salmonid smolts using radiotelemetry. Can. J. Fish. Aquat. Sci. 58: 1987-1997.

Smith, K.E. 1969. Compendium Saint John River system, N.B. Fisheries Service (Maritimes Region), Resource Development Branch. Man. Rep. 69-6. 238p.

Smith, K.E.H. 1979. Capture and distribution of all fish species at Saint John River power dams, New Brunswick, from construction years to 1971. Can. Data Rep. Fish. Aquat. Sci. 171: viii + 55p.

Thorpe, J.E., and R.I.G. Morgan. 1978. Periodicity in Atlantic salmon *Salmo salar* L. smolt migration. J. Fish. Biol. 12: 541-548.

Table 1. Summary of biological characteristics for all radio tagged pre-smolts from the Tobique River, 2006. “Controls” are pre-smolts tagged with a “dummy” transmitter to assess surgical mortality.

Pre-smolts		Fork length (cm)	Weight (grams)
Controls	Number	20	20
	Minimum	14.4	30.0
	Maximum	17.1	49.6
	Mean	15.4	37.1
	Standard Deviation	0.8	0.8
Radio-tagged	Number	77	77
	Minimum	14.4	29.4
	Maximum	17.5	57.1
	Mean	15.8	40.3
	Standard Deviation	0.9	0.9
Combined	Number	97	97
	Minimum	14.4	29.4
	Maximum	17.5	57.1
	Mean	15.7	39.7
	Standard Deviation	0.8	0.8

Table 2. Searches (including method, area and direction) for radio tagged Tobique River pre-smolts, October – December, 2006.

Date	Method	Area covered
25-Oct	boat	- Three Brooks to Tobique Narrows Dam (downstream)
26-Oct	boat	- Tobique Narrows Dam to Arthurette (upstream)
2-Nov	boat	- Arthurette to Tobique Narrows Dam (downstream), and - Tobique Narrows Dam to Inman (downstream/upstream)
3-Nov	boat	- Tobique Narrows Dam to Inman (downstream/upstream)
6-Nov	boat	- Tobique Narrows Dam to Inman (downstream/upstream)
7-Nov	boat	- Beechwood Dam to Perth (upstream)
8-Nov	boat	- Three Brooks to Tobique Narrows Dam (downstream)
9-Nov	boat	- Beechwood Dam to Inman (upstream/downstream)
10-Nov	boat	- Tobique Narrows Dam to Inman (downstream/upstream)
20-Nov	boat	- Tobique Narrows Dam to Inman (downstream/upstream)
21-Nov	boat	- Beechwood Dam to Inman (upstream/downstream)
22-Nov	boat	- Three Brooks to Tobique Narrows Dam (downstream)
28-Nov	boat	- Tobique Narrows Dam to Inman (downstream/upstream)
30-Nov	boat	- Beechwood Dam to Inman (upstream/downstream) - Tobique Narrows Dam to Pokiok (upstream)
13-Dec	helicopter	- Woodstock to Beechwood Dam to Tobique Narrows Dam to Grand Falls (upstream) - Tobique Dam to Three Brooks (upstream)
19-Dec	truck	- Tobique Narrows Dam to Beechwood Dam downstream to Woodstock (downstream)

Notes:
- downstream/upstream (or vice-versa) tracking was typically near one river bank in one direction and near the opposite bank on return.
- Distances:
  - Arthurette to Tobique Narrows Dam = 19.2 km
  - Beechwood Dam to Perth = 24.5 km
  - Beechwood Dam to Inman = 18.5 km
  - Three Brooks to Tobique Narrows Dam = 30.5 km
  - Tobique Narrows Dam to Inman = 12.0 km
  - Tobique Narrows Dam to Pokiok = 6.1 km

Table 3. Counts and status of Atlantic salmon pre-smolts captured in rotary screw traps operated near Three Brooks, in the Tobique River, 2006. "Captive reared" were wild pre-smolts removed and transported to Mactaquac Biodiversity Facility for the broodstock program.

	Pre-smolt		
Status	**Wild**	**Hatchery**	**Total**
Released	18	47	65
Mortality	4	1	5
Lethal Sample		2	2
Captive Reared [a]	483		483
Recycled	315	543	858
Radio Tagged	97		97
Total	917	593	1,510

[a] - excludes 17 recaptured wild pre-smolts kept for captive reared program.

Table 4. Date of release at Three Brooks, date and time of first and last detections and total number of detections at the Arthurette receiver for individually coded radio tags in the Tobique River, 2006.

		First Detect		Last Detect		
Tag	Date Released	Date (dd-mmm)	Time (hh:mm:ss)	Date (dd-mmm)	Time (hh:mm:ss)	No. Detections
11	21-Oct	n/a	n/a	n/a	n/a	
12	21-Oct	n/a	n/a	n/a	n/a	
27	21-Oct	n/a	n/a	n/a	n/a	
28	21-Oct	n/a	n/a	n/a	n/a	
43	21-Oct	22-Oct	0:25:57	22-Oct	3:01:38	1,722
44	21-Oct	n/a	n/a	n/a	n/a	
59	21-Oct	21-Oct	22:24:30	21-Oct	22:39:43	123
60	21-Oct	24-Oct	7:37:20	24-Oct	18:50:09	3,725
75	21-Oct	21-Oct	21:53:42	21-Oct	22:09:18	92
76	21-Oct	n/a	n/a	n/a	n/a	
13	23-Oct	23-Oct	20:25:25	23-Oct	20:35:06	96
14	23-Oct	23-Oct	22:03:58	23-Oct	22:16:07	67
15	23-Oct	24-Oct	19:17:14	24-Oct	19:20:40	53
29	23-Oct	23-Oct	20:59:50	23-Oct	21:05:13	114
30	23-Oct	24-Oct	18:22:55	24-Oct	19:27:15	460
31	23-Oct	23-Oct	20:51:38	23-Oct	21:06:04	82
45	23-Oct	23-Oct	20:05:47	23-Oct	20:14:57	120
46	23-Oct	23-Oct	21:51:03	23-Oct	21:55:33	115
61	23-Oct	24-Oct	8:22:03	24-Oct	21:00:46	2,735
62	23-Oct	23-Oct	20:49:31	23-Oct	20:55:12	75
77	23-Oct	25-Oct	19:19:55	25-Oct	19:31:11	80
78	23-Oct	23-Oct	22:01:56	23-Oct	22:15:53	76
16	24-Oct	25-Oct	19:32:29	26-Oct	3:39:35	3,202
17	24-Oct	25-Oct	23:05:45	26-Oct	19:25:54	3,920
32	24-Oct					
33	24-Oct	26-Oct	20:09:03	13-Nov	17:46:02	149,604
47	24-Oct	27-Oct	23:08:18	27-Oct	23:16:12	16
48	24-Oct	24-Oct	22:19:46	24-Oct	22:30:05	83
49	24-Oct	29-Oct	6:34:21	29-Oct	17:44:47	1,477
63	24-Oct	26-Oct	1:43:17	14-Nov	8:48:48	179,025
64	24-Oct	29-Oct	7:07:03	29-Oct	7:12:50	41
65	24-Oct	25-Oct	20:47:17	25-Oct	21:10:29	59
79	24-Oct	30-Oct	18:54:24	30-Oct	18:55:01	32
80	24-Oct	25-Oct	20:00:08	25-Oct	20:11:23	73
18	25-Oct	29-Oct	22:53:13	29-Oct	22:56:40	42
34	25-Oct					
66	25-Oct	28-Oct	0:32:12	31-Oct	18:44:36	9,525
81	25-Oct	29-Oct	22:06:40	29-Oct	22:16:01	26
19	26-Oct	29-Oct	6:52:48	29-Oct	18:06:26	2,921
35	26-Oct	26-Oct	22:39:18	27-Oct	16:46:00	4,431
67	26-Oct	26-Oct	22:00:37	26-Oct	22:06:13	75
82	26-Oct	27-Oct	6:37:25	27-Oct	6:53:11	26
20	27-Oct	28-Oct	20:43:00	28-Oct	20:50:44	36
21	27-Oct	27-Oct	22:23:44	27-Oct	22:36:22	65
36	27-Oct	28-Oct	4:23:30	30-Oct	6:57:49	21,376
37	27-Oct					
52	27-Oct	27-Oct	22:57:27	27-Oct	23:06:22	188
68	27-Oct	28-Oct	0:11:28	28-Oct	3:52:37	199
83	27-Oct	16-Nov	9:02:40	16-Nov	9:03:01	55
84	27-Oct	1-Nov	19:01:36	2-Nov	7:26:16	64
22	30-Oct	30-Oct	21:20:38	30-Oct	21:24:57	43
23	30-Oct					
38	30-Oct	30-Oct	19:11:31	4-Nov	15:48:00	43
39	30-Oct	3-Nov	21:46:34	6-Nov	15:30:51	11,572
53	30-Oct	30-Oct	21:48:00	30-Oct	21:56:35	53
54	30-Oct	3-Nov	22:54:15	4-Nov	2:08:49	395
55	30-Oct	30-Oct	23:50:45	8-Nov	9:16:01	71,044
69	30-Oct	30-Oct	22:51:29	11-Nov	16:26:29	9,816
70	30-Oct	30-Oct	20:55:50	30-Oct	21:04:14	59
71	30-Oct	30-Oct	22:09:55	30-Oct	22:15:41	47
85	30-Oct	3-Nov	20:32:31	4-Nov	7:18:57	219
86	30-Oct	30-Oct	21:14:00	30-Oct	21:15:17	40
24	31-Oct	1-Nov	21:31:40	1-Nov	21:41:15	34
25	31-Oct	31-Oct	23:58:50	1-Nov	0:04:16	33
26	31-Oct	31-Oct	22:39:24	31-Oct	22:44:41	41
40	31-Oct	31-Oct	21:31:17	31-Oct	21:34:03	24
41	31-Oct					
56	31-Oct	31-Oct	21:24:19	31-Oct	21:35:14	61
57	31-Oct	31-Oct	21:34:30	31-Oct	21:43:40	31
72	31-Oct	31-Oct	21:31:45	31-Oct	21:43:54	47
73	31-Oct	31-Oct	22:21:37	31-Oct	22:24:00	16
87	31-Oct	1-Nov	2:14:01	1-Nov	2:24:51	40
88	31-Oct	31-Oct	23:05:49	31-Oct	23:15:52	26
89	31-Oct	31-Oct	22:34:08	31-Oct	22:43:55	39
42	1-Nov					
58	1-Nov	1-Nov	21:08:02	1-Nov	21:35:36	38
74	1-Nov					

Notes: - Arthurette receiver did not log data from October 22 at 08h00 to October 23 18h30.
- blank cells signify pre-smolts undected at the Arthruette receiver.
- "n/a" represents pre-smolts that passed the receiver when it wasn't logging data.

Table 5. Travel time (min, max, mean and standard deviation) for radio tagged pre-smolts from the release site at Three Brooks to the fixed receiver locations downstream in the Tobique River, 2006.

Points of reference	Number of pre-smolts	Days:Hours:Minutes Minimum	Maximum	Mean	Standard Deviation
Three Brooks to Arthurette	64 [a]	00:01:41	20:15:47	01:17:12	02:22:48
Three Brooks to Tobique forebay	55	04:13:10	24:02:38	11:21:36	05:03:10
First detection at Tobique forebay to Last dectection in Tobique forebay	55	00:00:00 [b]	28:02:49	01:15:17	04:13:43

[a] - 6 pre-smolts passed Arthurette receiver undetected and are not included here.
[b] - 0:00:00 because that pre-smolt was only detected once, the second quickest (minimum) was 0:04:33.

Table 6. Date, time, passage route and discharge conditions (m^3/s) for individually coded, radio tagged pre-smolts at the Tobique Narrows Dam, 2006.

Last Detection on Forebay			Specific Route	Discharge (m^3/s) Conditions at Tobique Dam			
Tag	Date	Time	Passage	Gate	% Gate	Turbine	Total
75	25-Oct	7:47:36	Turbine 1 or 2 [a]	-	0%	54	54
43	27-Oct	22:54:53	Turbine 1	-	0%	115	115
76	29-Oct	3:17:38	Turbine 1	-	0%	114	114
59	29-Oct	4:50:12	Turbine 1	-	0%	114	114
28	30-Oct	4:33:56	Turbine 1	-	0%	115	115
29	30-Oct	9:38:58	Turbine 1	-	0%	116	116
14	30-Oct	17:31:42	Turbine 2	-	0%	116	116
62	30-Oct	18:09:03	Turbine 2	-	0%	117	117
48	1-Nov	22:38:19	Turbine 1	-	0%	57	57
67	1-Nov	23:15:24	Turbine 1	-	0%	59	59
80	1-Nov	23:54:29	Turbine 2	-	0%	59	59
30	2-Nov	22:34:29	Turbine 1	-	0%	112	112
31	3-Nov	7:28:43	Turbine 1	-	0%	109	109
45	3-Nov	8:21:49	Turbine 2	-	0%	111	111
47	3-Nov	16:40:10	Turbine 2	-	0%	59	59
36	3-Nov	17:26:04	Turbine 1 or 2 [a]	-	0%	103	103
18	3-Nov	18:44:57	Turbine 2	-	0%	116	116
13	3-Nov	19:14:36	Turbine 2	-	0%	62	62
46	3-Nov	19:19:44	Turbine 2	-	0%	62	62
68	4-Nov	8:13:11	Turbine 1	-	0%	56	56
21	4-Nov	17:59:24	Turbine 1	-	0%	111	111
44	4-Nov	20:37:01	Turbine 2	-	0%	63	63
77	5-Nov	18:54:05	Turbine 2	-	0%	106	106
88	5-Nov	22:51:48	Turbine 1	-	0%	118	118
71	6-Nov	7:17:09	Turbine 1	-	0%	57	57
70	6-Nov	7:49:20	Turbine 1	-	0%	57	57
60	6-Nov	19:30:55	Turbine 1	-	0%	120	120
64	6-Nov	22:21:56	Turbine 1	-	0%	108	108
38	8-Nov	6:21:05	Turbine 1	-	0%	27	27
25	8-Nov	8:06:13	Turbine 1	-	0%	76	76
53	8-Nov	20:08:39	Turbine 2	-	0%	105	105
65	8-Nov	20:27:35	Turbine 1	-	0%	105	105
22	8-Nov	20:41:46	Turbine 2	-	0%	105	105
20	8-Nov	20:53:07	Turbine 2	-	0%	105	105
40	9-Nov	0:35:09	Turbine 2	-	0%	54	54
61	10-Nov	0:53:33	Turbine 2	-	0%	14	14
58	12-Nov	11:46:27	Turbine 1	-	0%	120	120
56	12-Nov	21:05:13	Turbine 1	-	0%	121	121
89	12-Nov	21:18:25	Turbine 2	-	0%	121	121
26	13-Nov	4:10:54	Turbine 2	-	0%	118	118
66	13-Nov	5:23:16	Turbine 2	-	0%	118	118
72	14-Nov	4:25:02	Turbine 2	39	25%	117	156
24	14-Nov	8:19:29	Turbine 2	31	21%	117	147
86	14-Nov	19:27:15	Spill 4 or 5 [a]	214	65%	117	331
73	15-Nov	10:29:17	Spill 4 or 5 [a]	487	81%	112	600
11	15-Nov	12:46:24	Spill 4 or 5 [a]	469	81%	113	581
35	15-Nov	15:47:18	Turbine 1	409	78%	115	524
33	15-Nov	18:47:14	Spill 4 or 5 [a]	514	82%	113	627
82	16-Nov	10:30:18	Spill 4	289	72%	113	402
52	17-Nov	20:22:27	Spill 4	249	69%	113	361
27	19-Nov	8:48:53	Spill 4 or 5 [a]	192	63%	112	305
19	19-Nov	19:42:52	Spill 4 or 5 [a]	154	58%	113	267
83	20-Nov	19:57:22	Spill 4	164	59%	112	276
49	23-Nov	20:59:26	Spill 5	41	26%	121	162
63	unk[b]	unk[b]	Spill 4 or 5 [a]	unk	unk	unk	unk
85	unk[b]	unk[b]	Spill 4 or 5 [a]	unk	unk	unk	unk
57	10-Dec	11:33:18	Turbine 2	-	0%	33	33

[a] actual turbine unit or spill gate could not be determined based on data

[b] likely passed undetected during spilling period between Nov. 13 and 26, 2006

Table 7. Fate of pre-smolts (number and percentage) after descending the spill gates or turbines at the Tobique Narrows Dam, 2006.

	Spill		Turbine		Total	
Fate	**No.**	**%**	**No.**	**%**	**No.**	**%**
Alive	9	82%	27	69%	36	72%
Mortality	0	0%	4	10%	4	8%
Delayed Mortality or overwintering	2	18%	8	21%	10	20%
Sub-total	11	100%	39	100%	50	100%
Unknown	1		6		7	
Total	**12**		**45**		**57**	

Table 8. Pre-smolt population estimates upriver and downriver of the Tobique Narrows Dam. Estimates are based on the proportion of tagged pre-smolts that approached and passed the dam, and the estimated mortality associated with the different passage routes at the dam in 2006.

	percentage [a]	**estimate**	**range (2.5 to 97.5 percentile)**
Tobique River at RST (Three Brooks)		19,040	15,465 to 24,760
Overwinter in Tobique River and Headpond	26%	4,945	4,017 to 6,431
Passed Tobique Narrows Dam	74%	14,095	11,448 to 18,329
Passed via Turbines	79%	11,128	9,038 to 14,470
Passed via Spill Gates	21%	2,967	2,410 to 3,859
Pre-smolt loses - turbine (8%) + spill mortality (0%)	8% [b]	1,128	916 to 1,466
Pre-smolt loses - turbine (8%) + delayed mortality (20%)	28% [b]	3,946	3,205 to 5,132

[a] based on the different fates of radio tagged pre-smolts

[b] percentages shown are mortality estimates (Table 7)

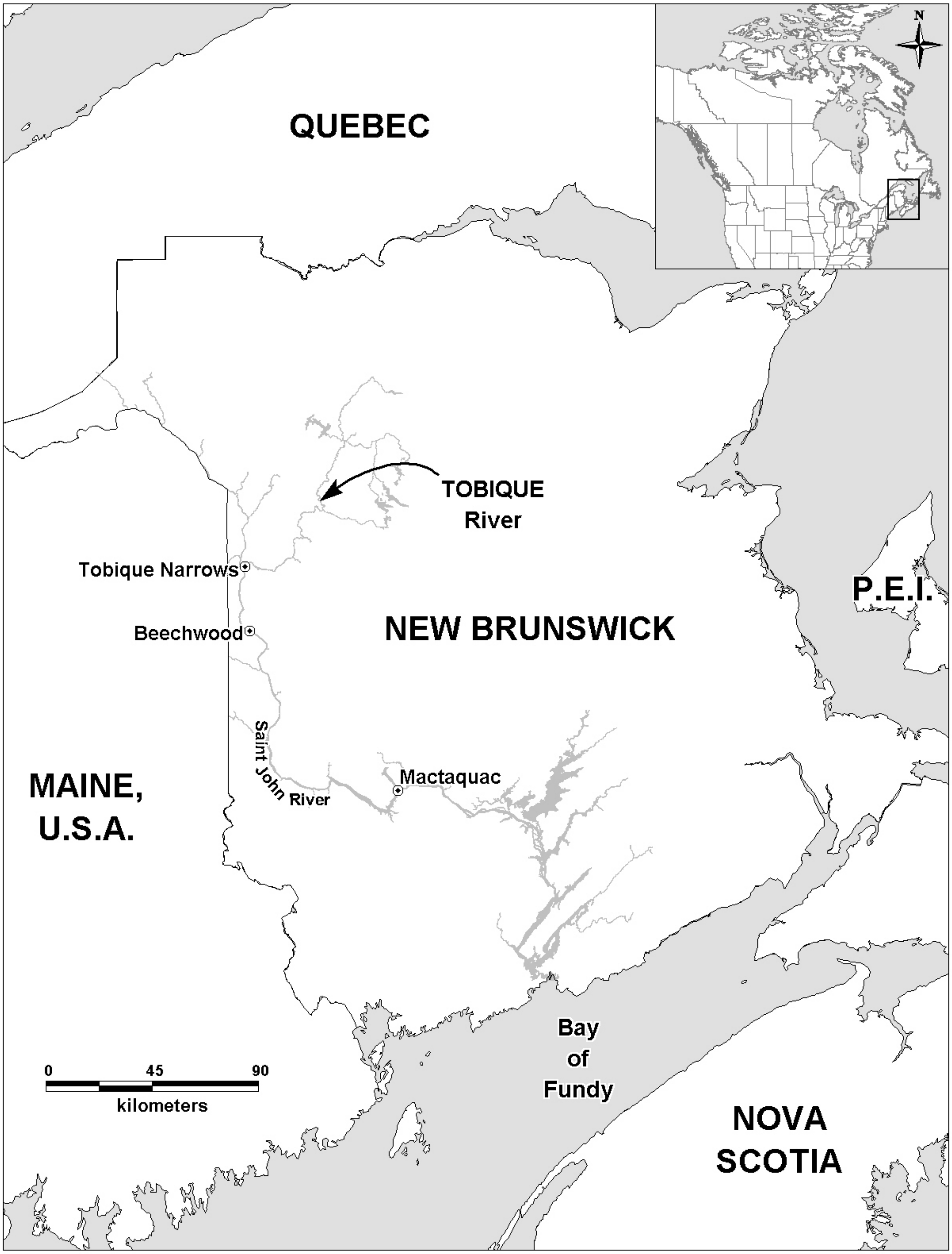


Figure 1. Map showing the Tobique River and the location of three major hydroelectric dams (Mactaquac, Beechwood and Tobique Narrows) on the Saint John River.

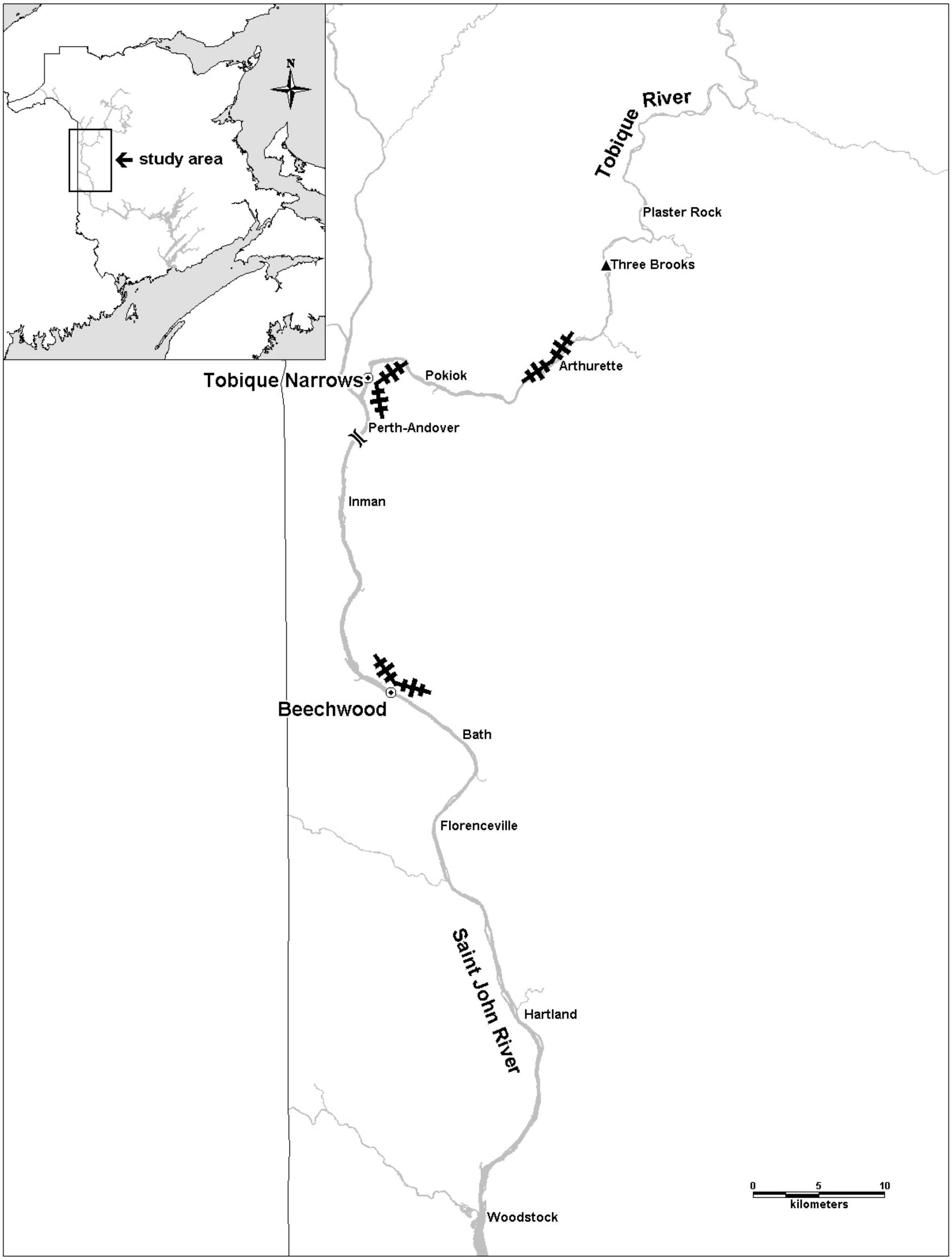


Figure 2. Map showing the location of the rotary screw traps and release site at Three Brooks for the radio tagged pre-smolts (triangle), location of fixed receivers (hatched-bars), Perth-Andover Bridge, Tobique Narrows and Beechwood dams (circle in circle).

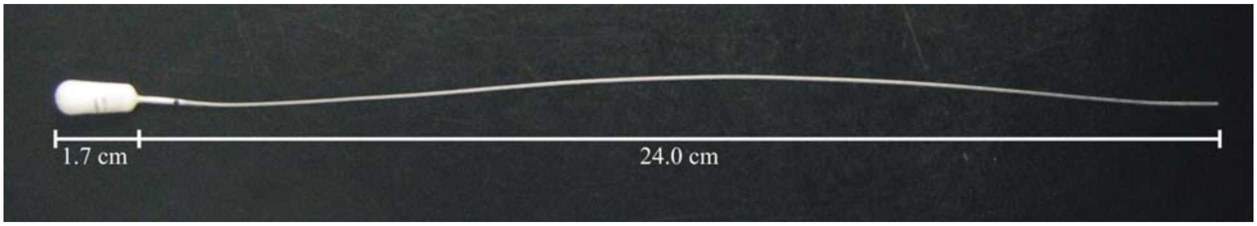


Figure 3. Radio tag used in the Tobique River pre-smolt tracking study, 2006.

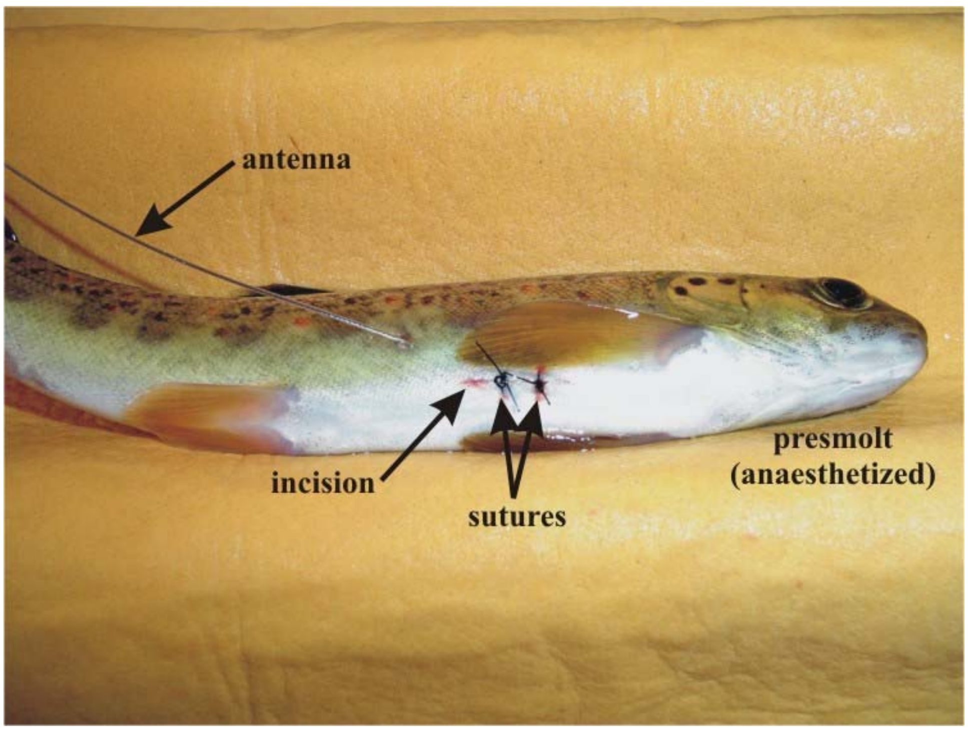


Figure 4. Photo showing anaesthetized Atlantic salmon pre-smolt post surgery.

Figure 5. Photo showing typical installation of antenna connected to receiver (Arthurette location).

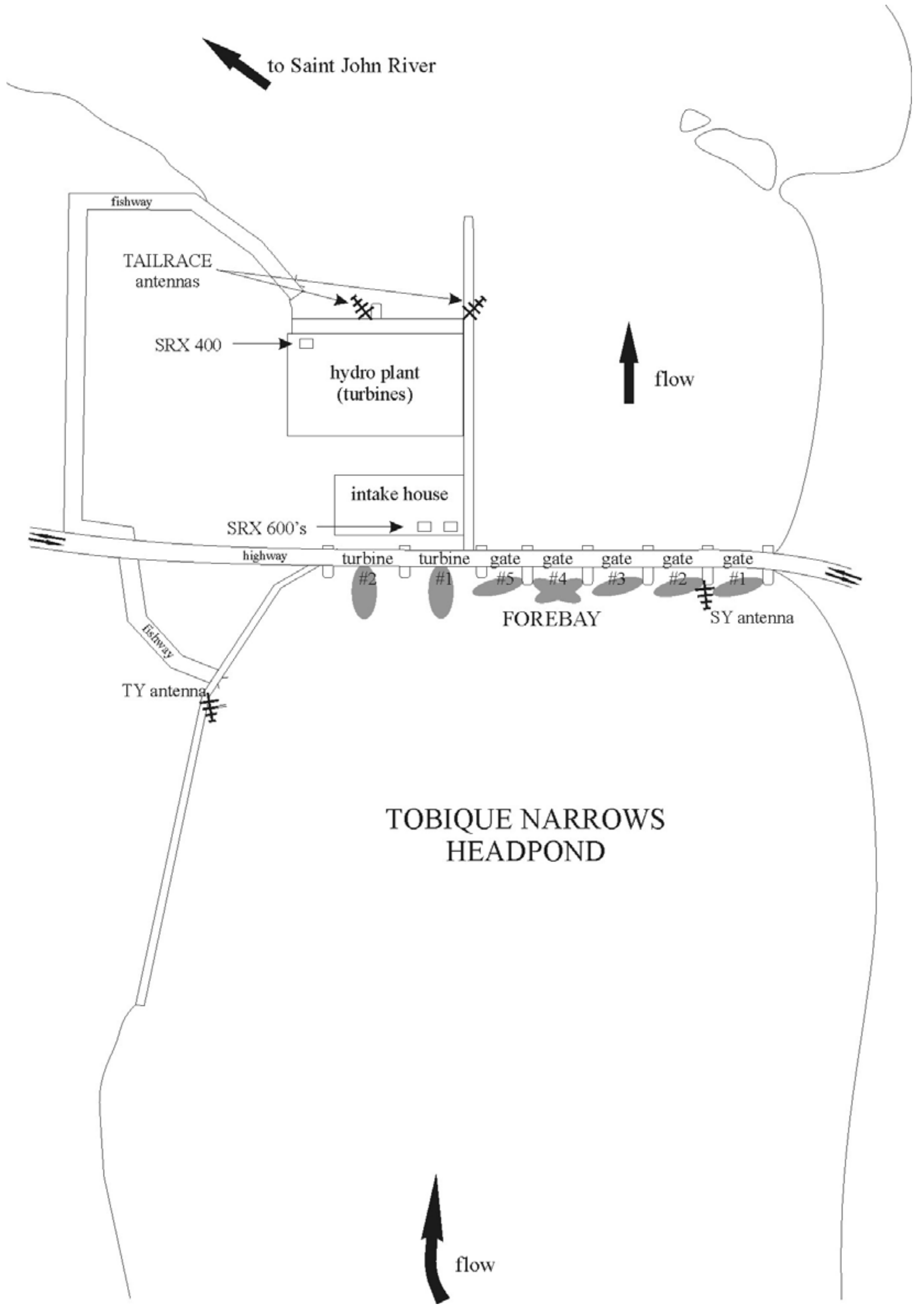
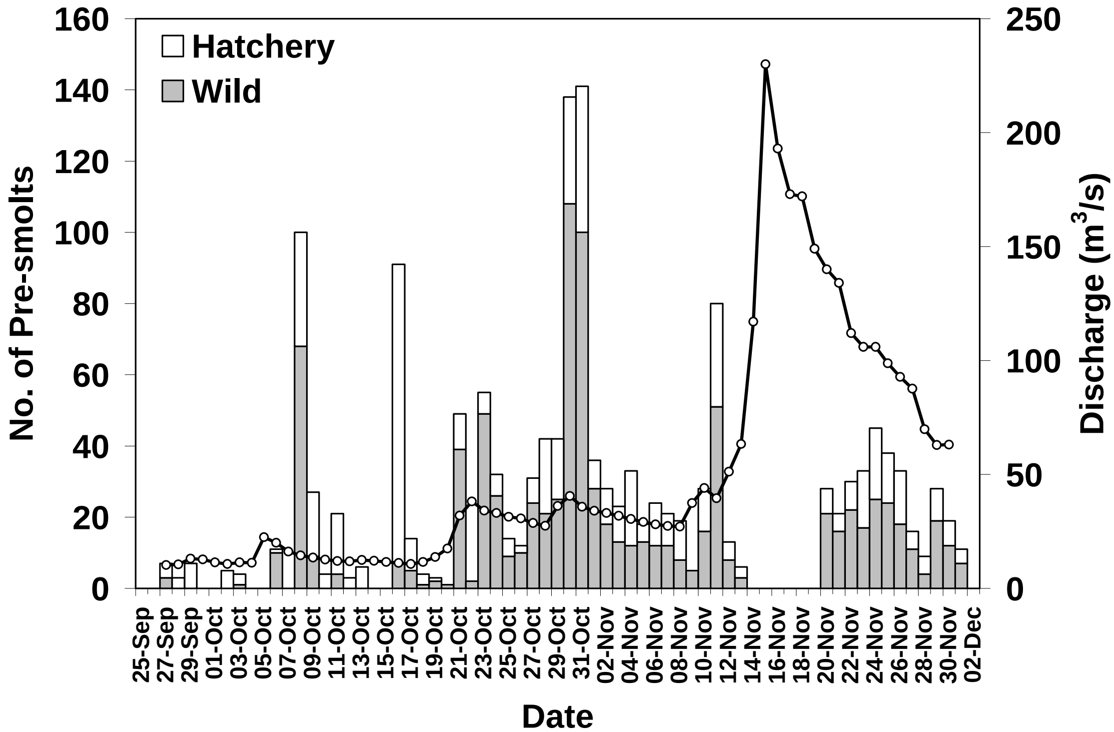


Figure 6. Conceptual diagram showing the locations of the turbine and spill gate underwater antennae at the Tobique Narrows Dam. Shaded circles represent hypothetical areas of detection for underwater antennae at each spill gate and/or turbine unit. Location of turbine antenna (TY), spill gate antenna (SY), and tailrace antennae are also shown. Diagram is not to scale.



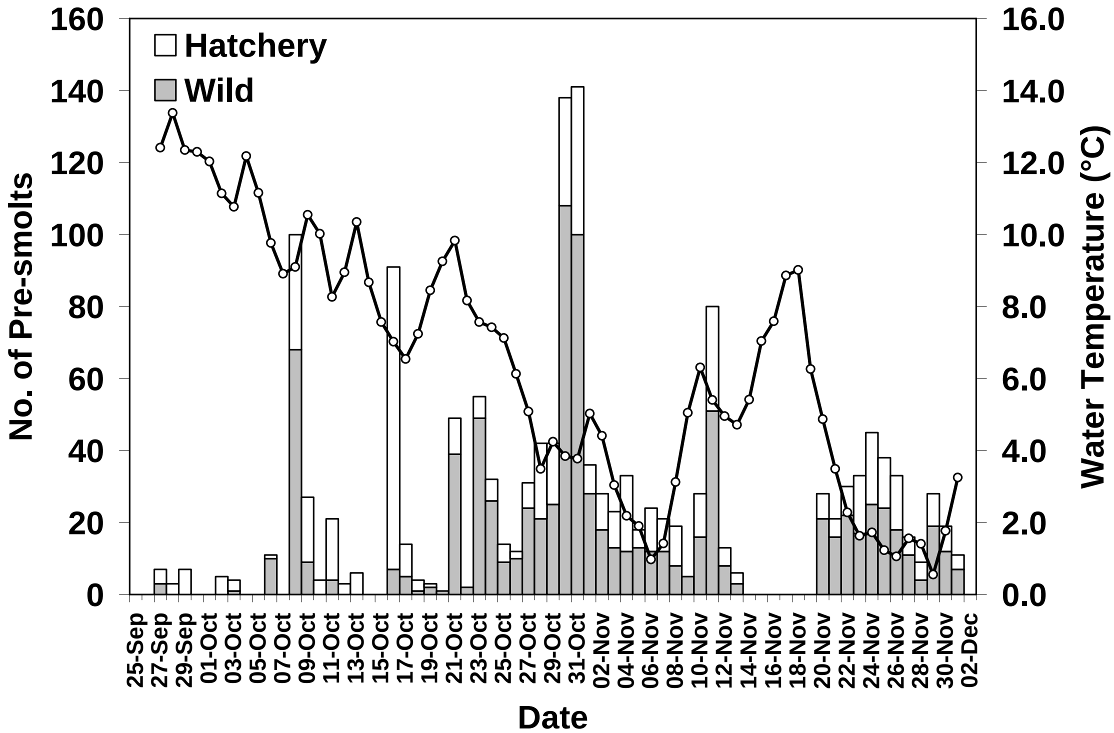


Figure 7. Mean daily discharge at Riley Brook (upper) and mean daily temperature at Arthurette (lower) with daily wild and hatchery Atlantic salmon pre-smolt captures at the Three Brooks RSTs on the Tobique River, 2006.

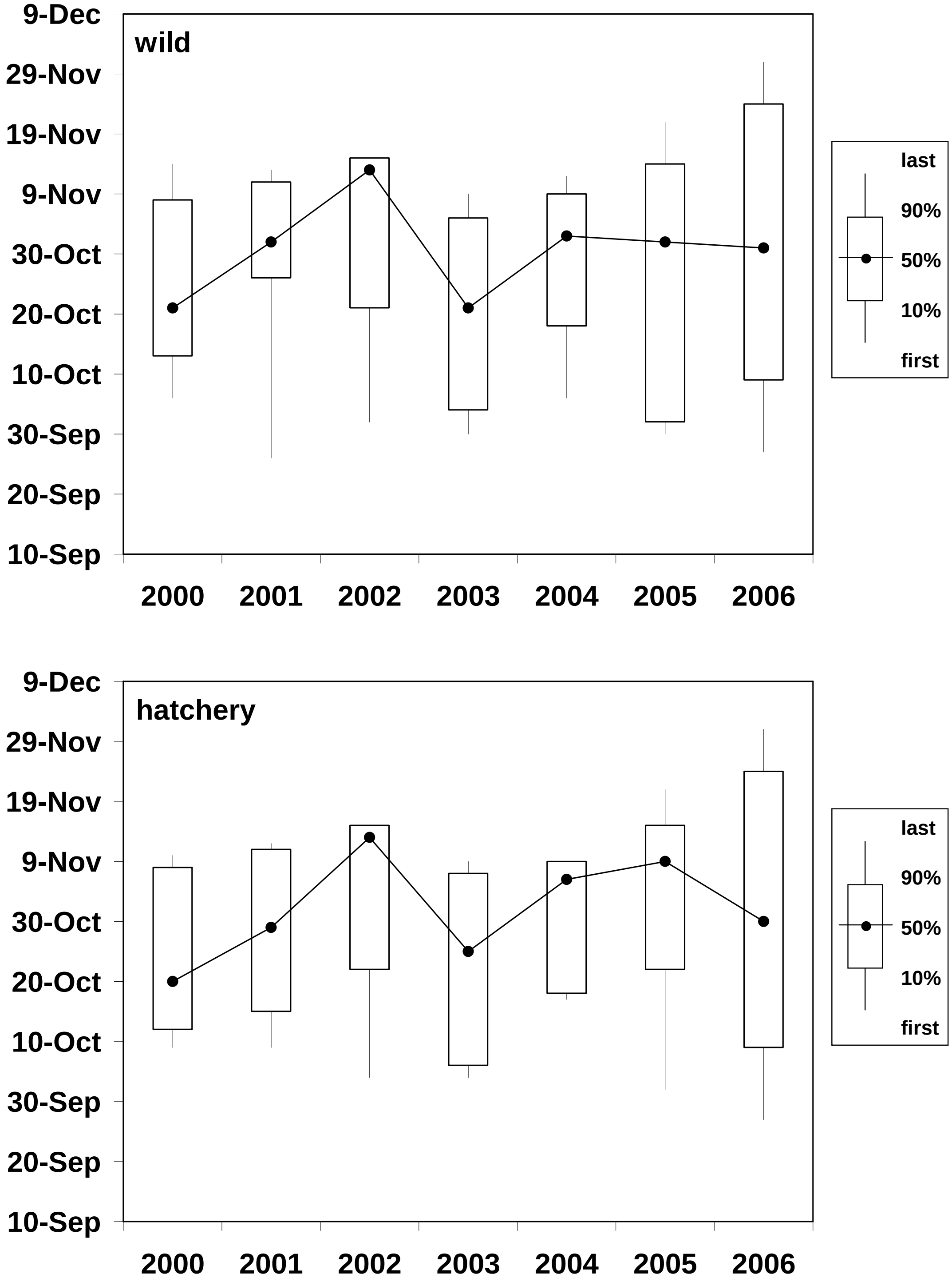


Figure 8. Dates of the first, last, and cumulative proportions (10%, 50% and 90%) of the catch for wild and hatchery pre-smolt at the Three Brooks RSTs on the Tobique River, 2000-2006.

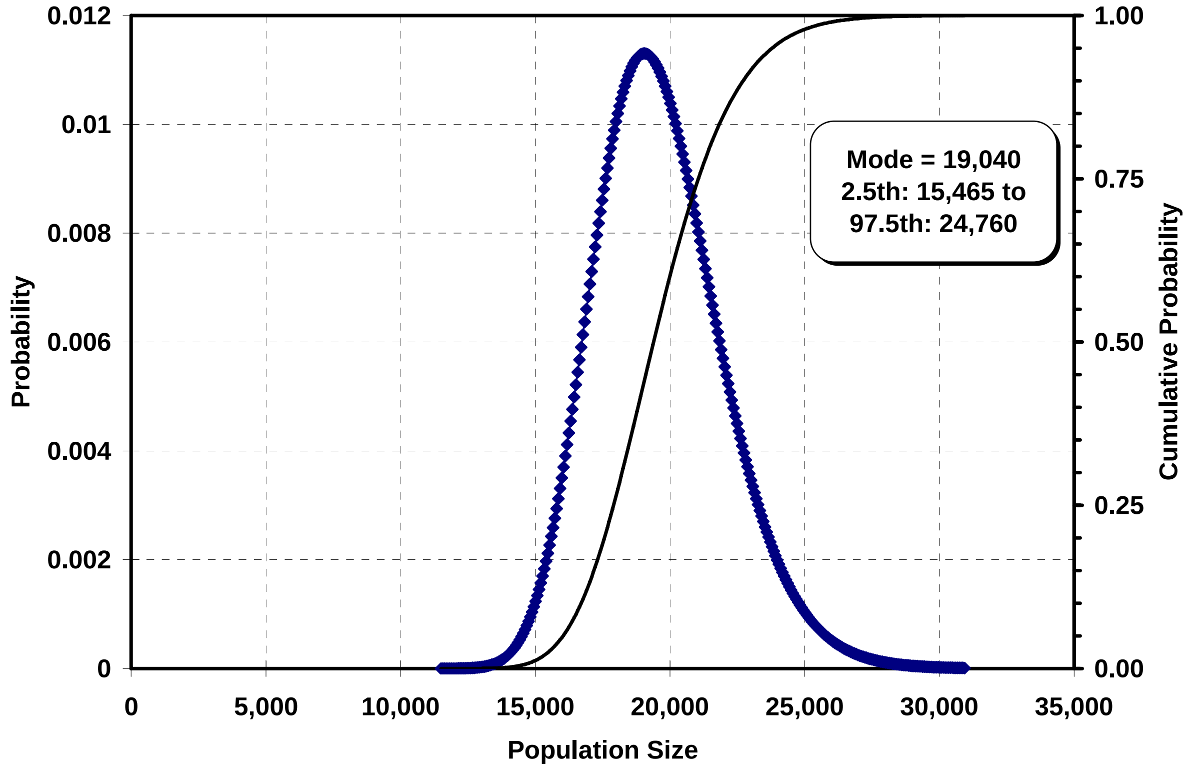
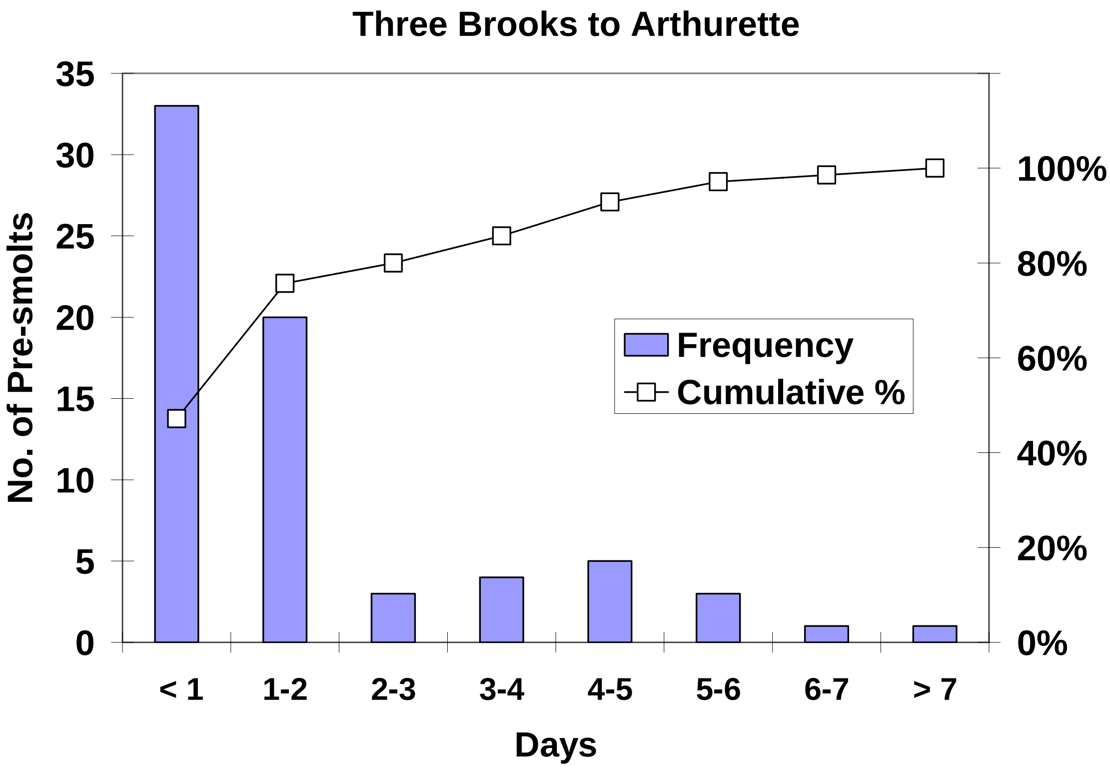


Figure 9. Estimated number (mode, 2.5 and 97.5 percentiles) of wild and hatchery pre-smolts migrating downstream at Three Brooks on the Tobique River, 2006.



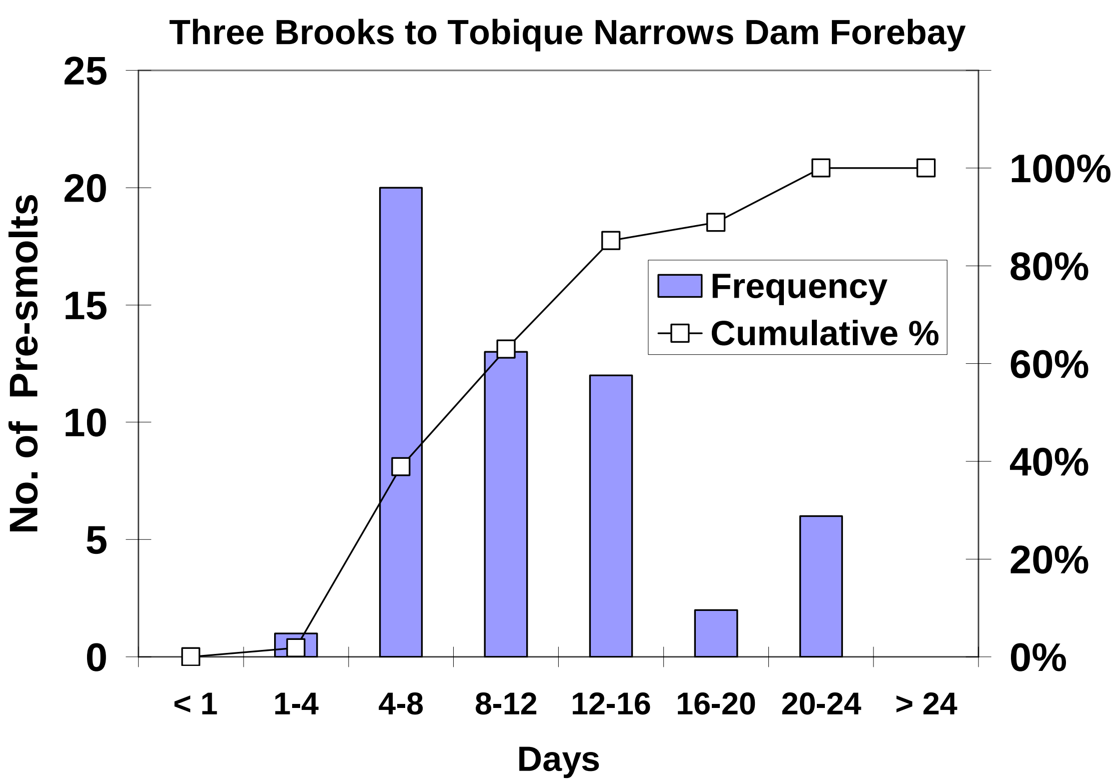


Figure 10. Frequency distribution of the travel time (days) from Three Brooks to Arthurette (upper) and the Tobique Narrows Dam (lower) for radio tagged pre-smolts, 2006.

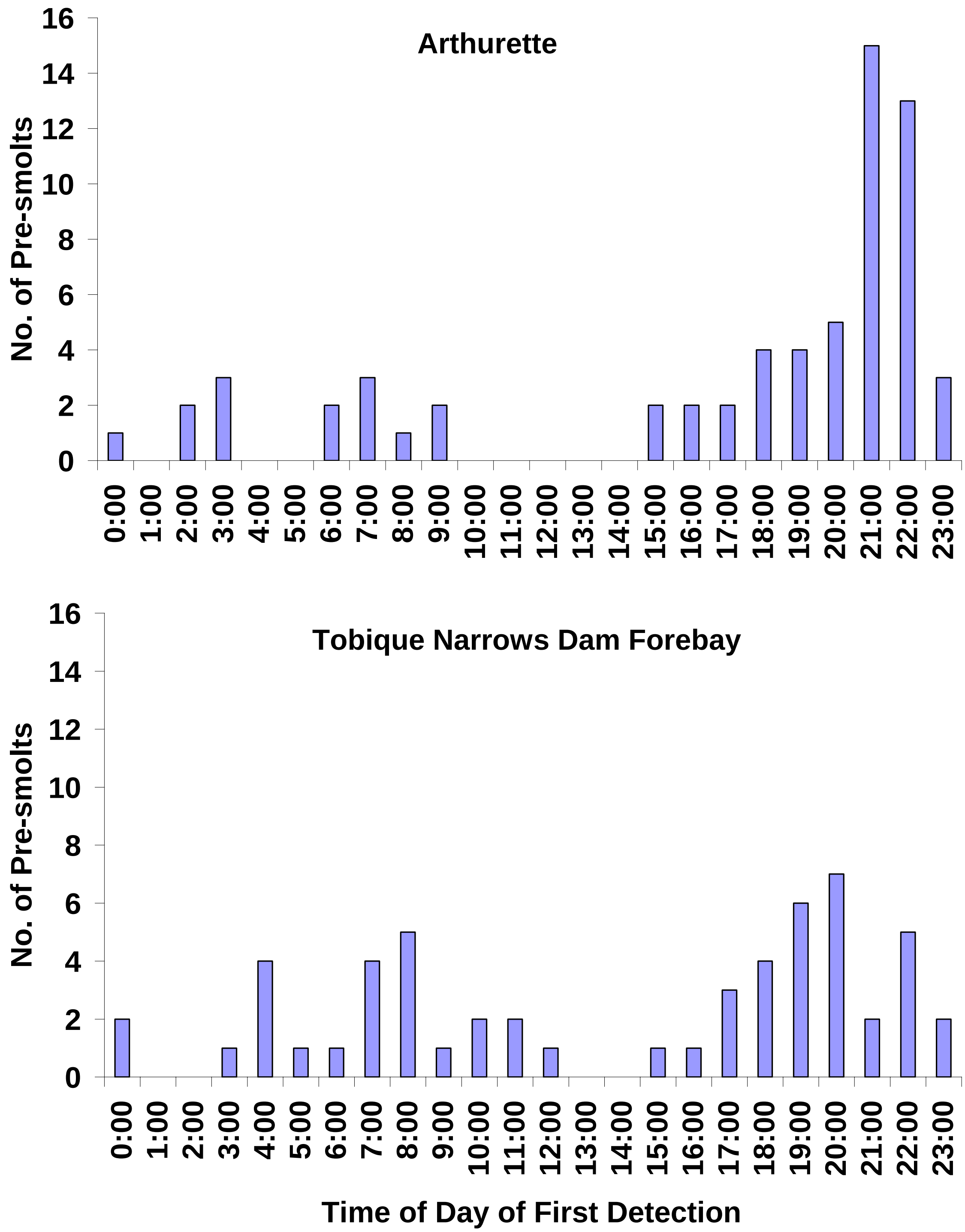


Figure 11. Frequency distribution of time of day (hour) of first detection for radio tagged pre-smolts at the Arthurette and Tobique Narrows Dam receivers, 2006.

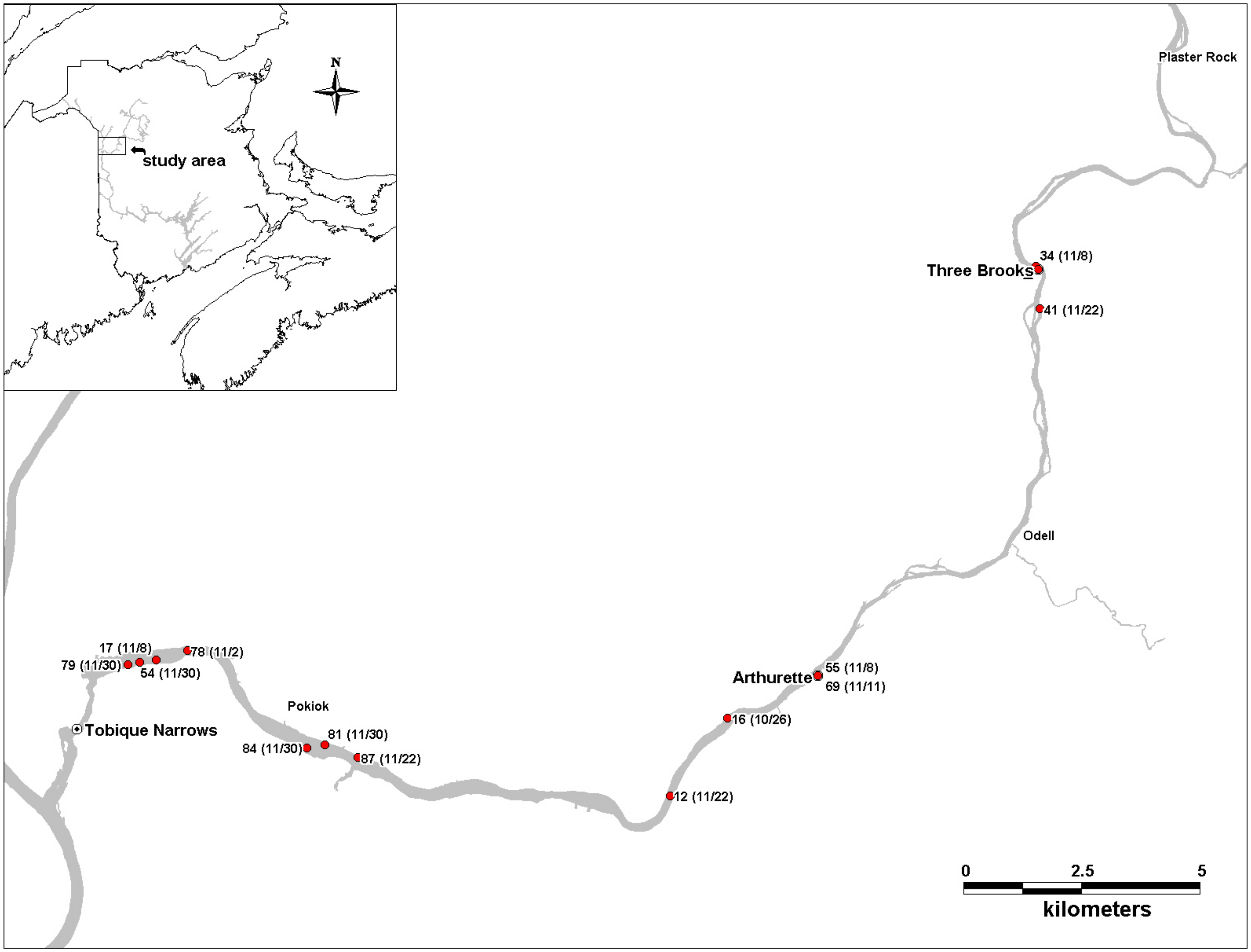


Figure 12. Map of the Tobique River showing the location, pre-smolt radio tag ID number and date in brackets (month/day) of last detection during boat searches for pre-smolts that did not descend the Tobique Narrows Dam.

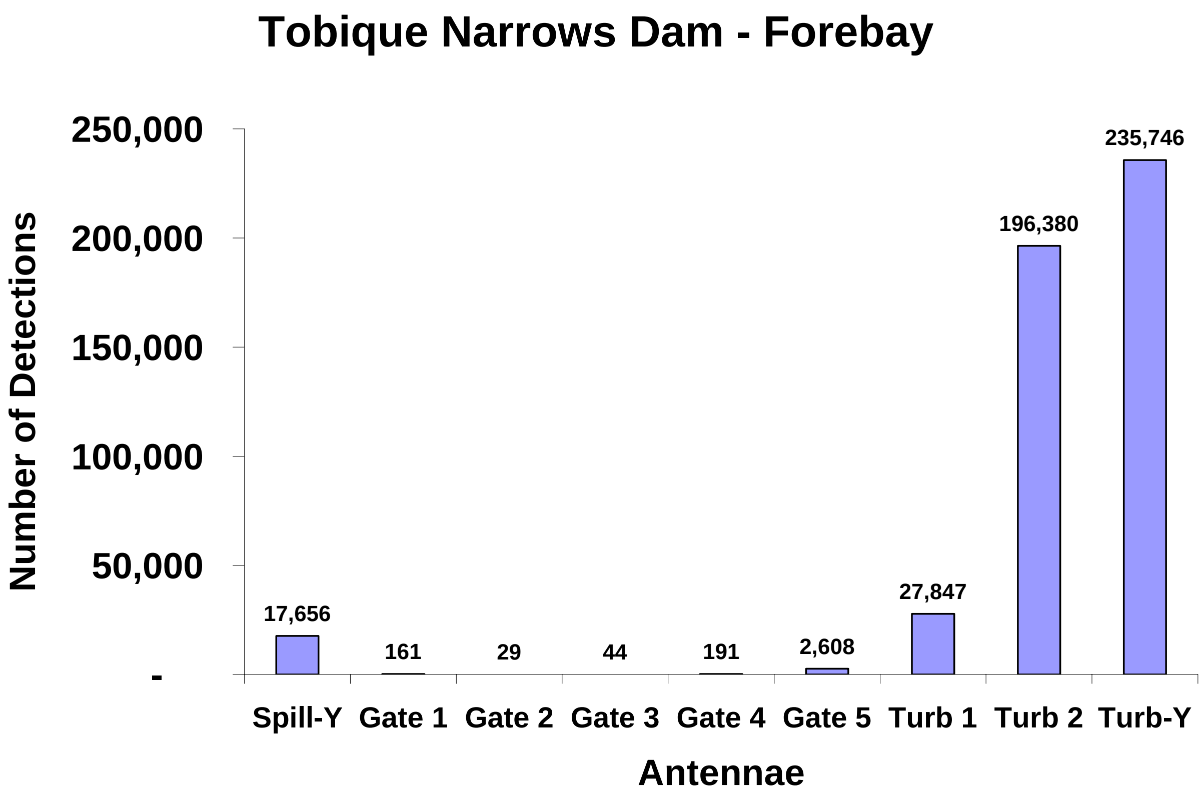
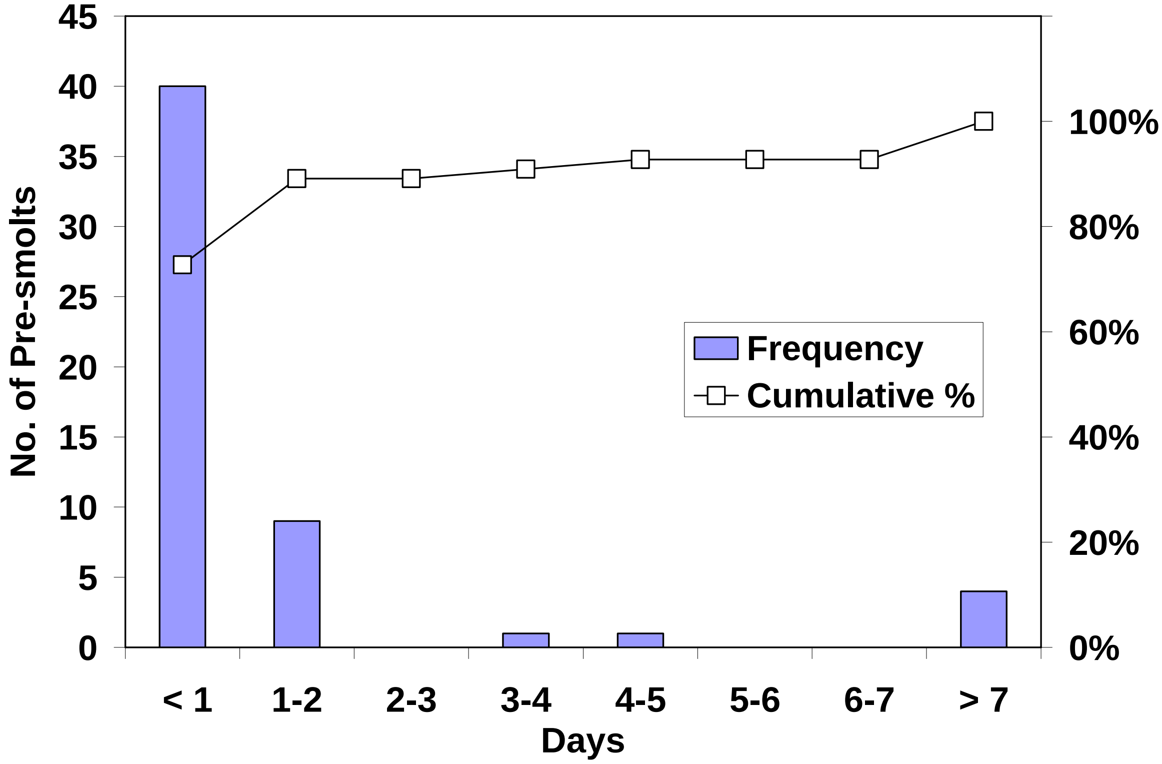


Figure 13. Total number of detections of radio tagged pre-smolts on antennae installed in the forebay area at the Tobique Narrows Dam.



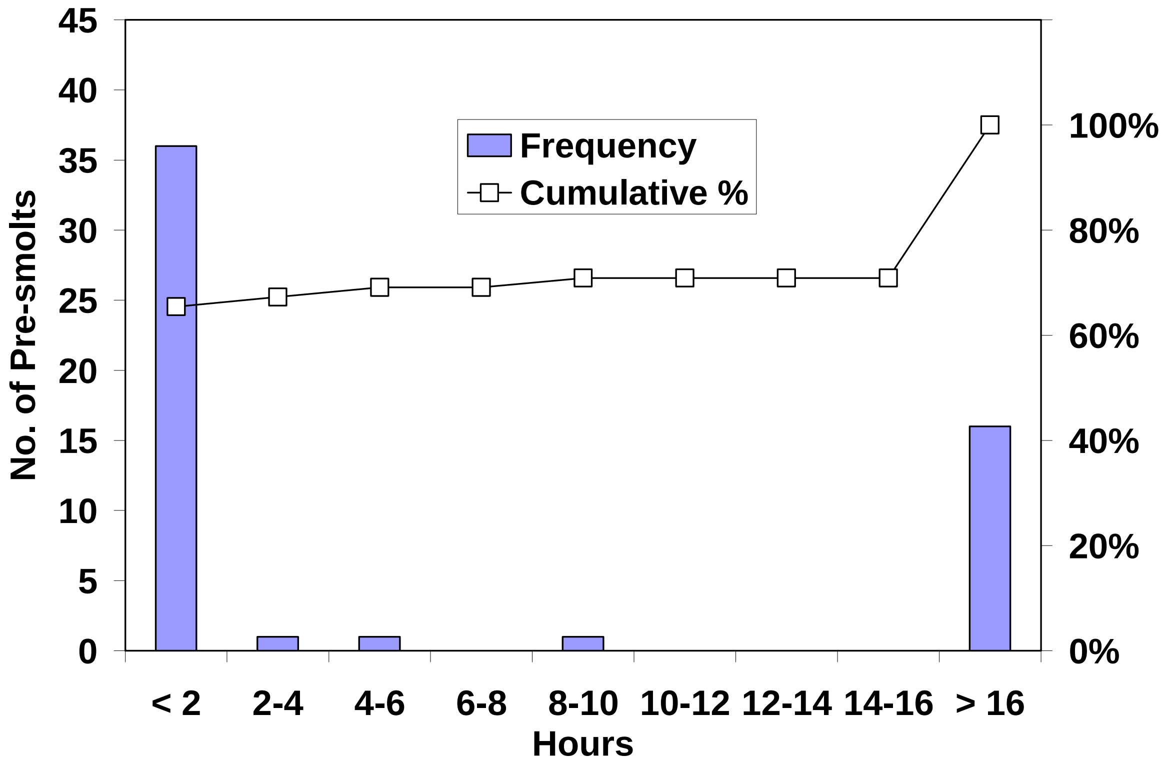


Figure 14. Frequency distribution of the time in days (upper) and hours (lower) between the first and last detection in the Tobique Narrows Dam forebay area for radio tagged pre-smolts, 2006.

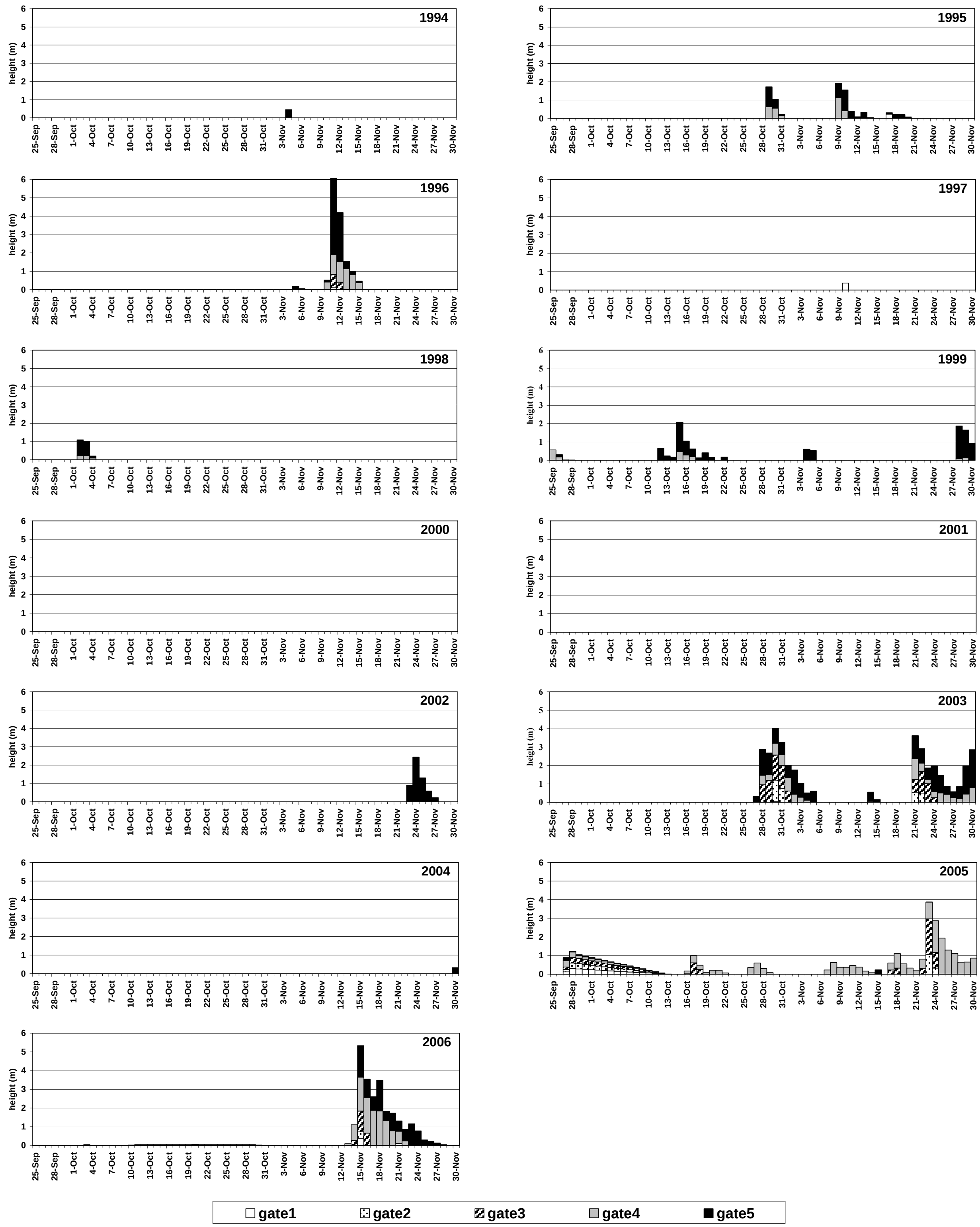


Figure 15. Mean daily gate height (m) for all spill gates at the Tobique Narrows Dam, from September 25 to November 30, 1994-2006.

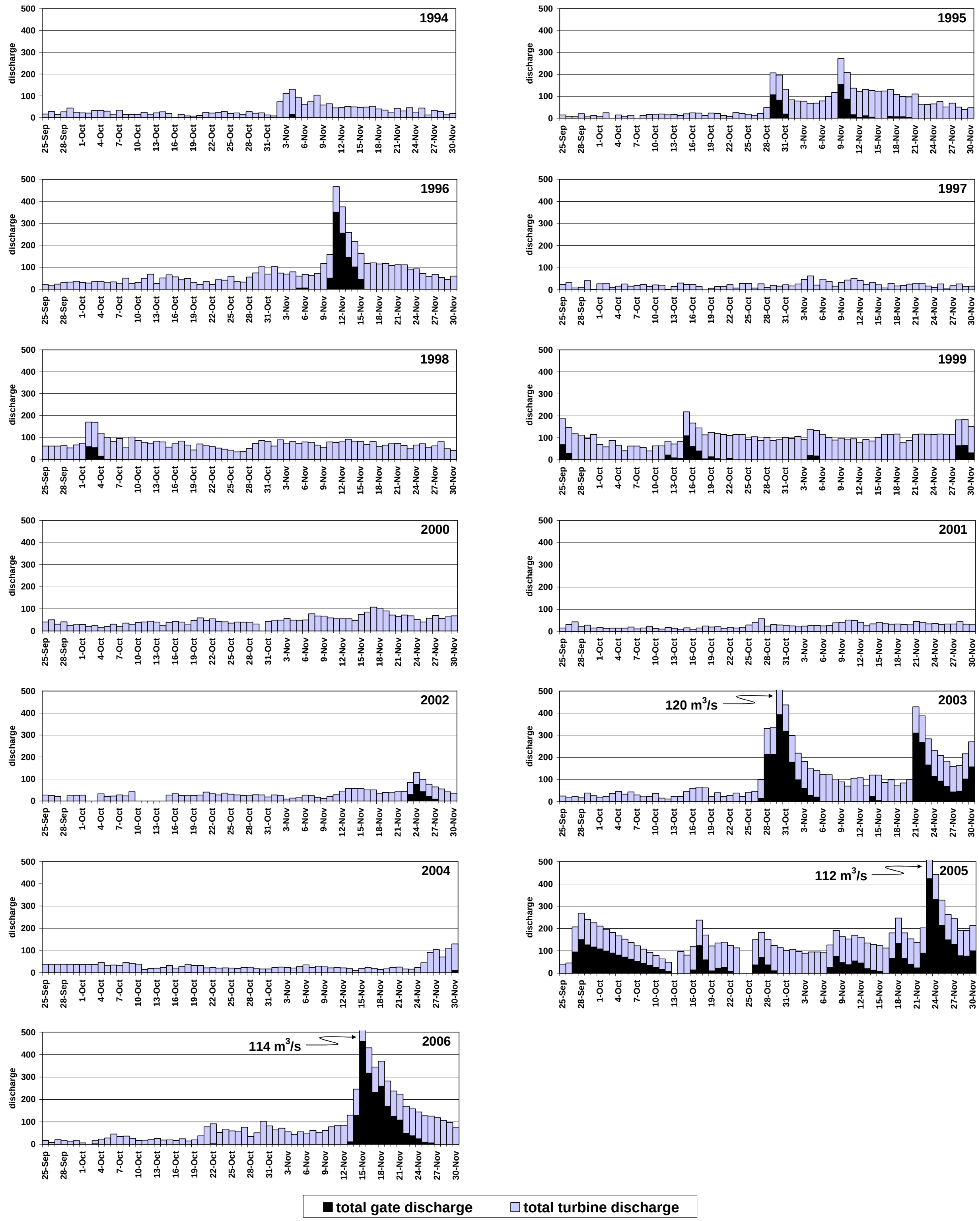


Figure 16. Mean daily discharge (m^3/s) for the five spill gates (combined) and two turbines (combined) at the Tobique Narrows Dam, from September 25 to November 30, 1994-2006.

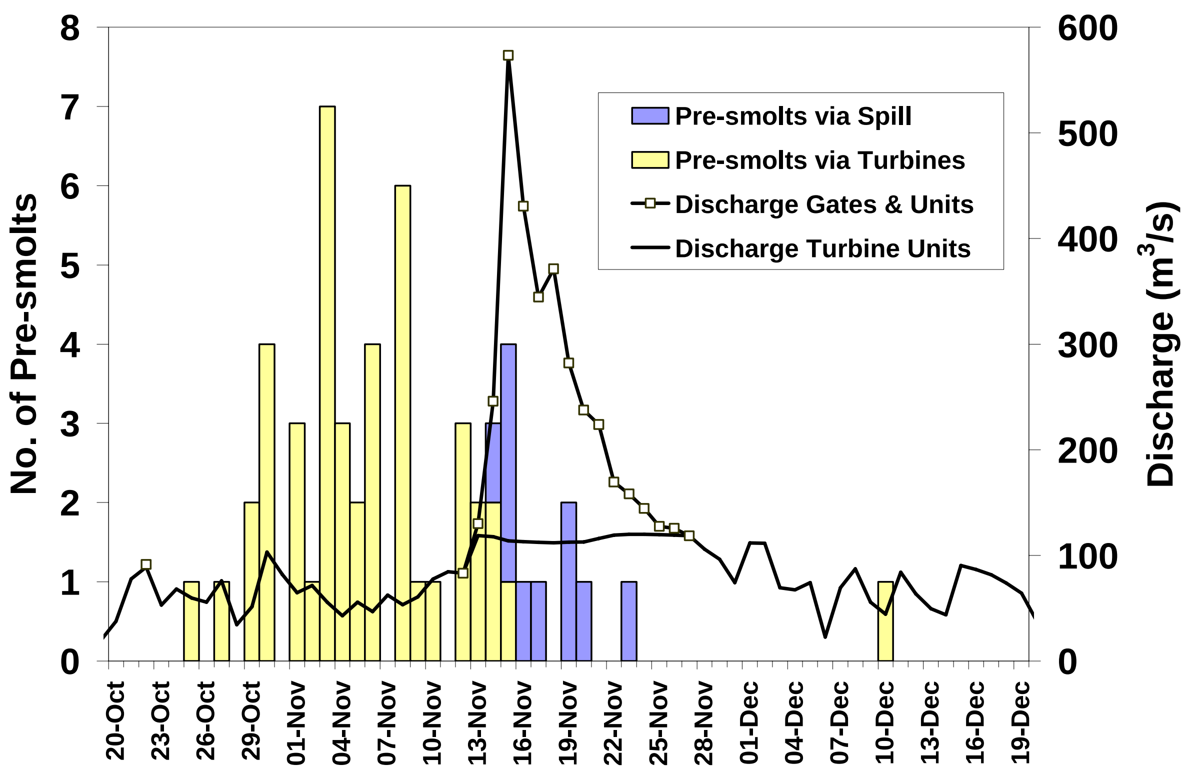


Figure 17. Date of passage of radio tagged pre-smolts below Tobique Narrows Dam and mean daily discharge (m^3/s) of the turbine units and spill gates at the facility, 2006.

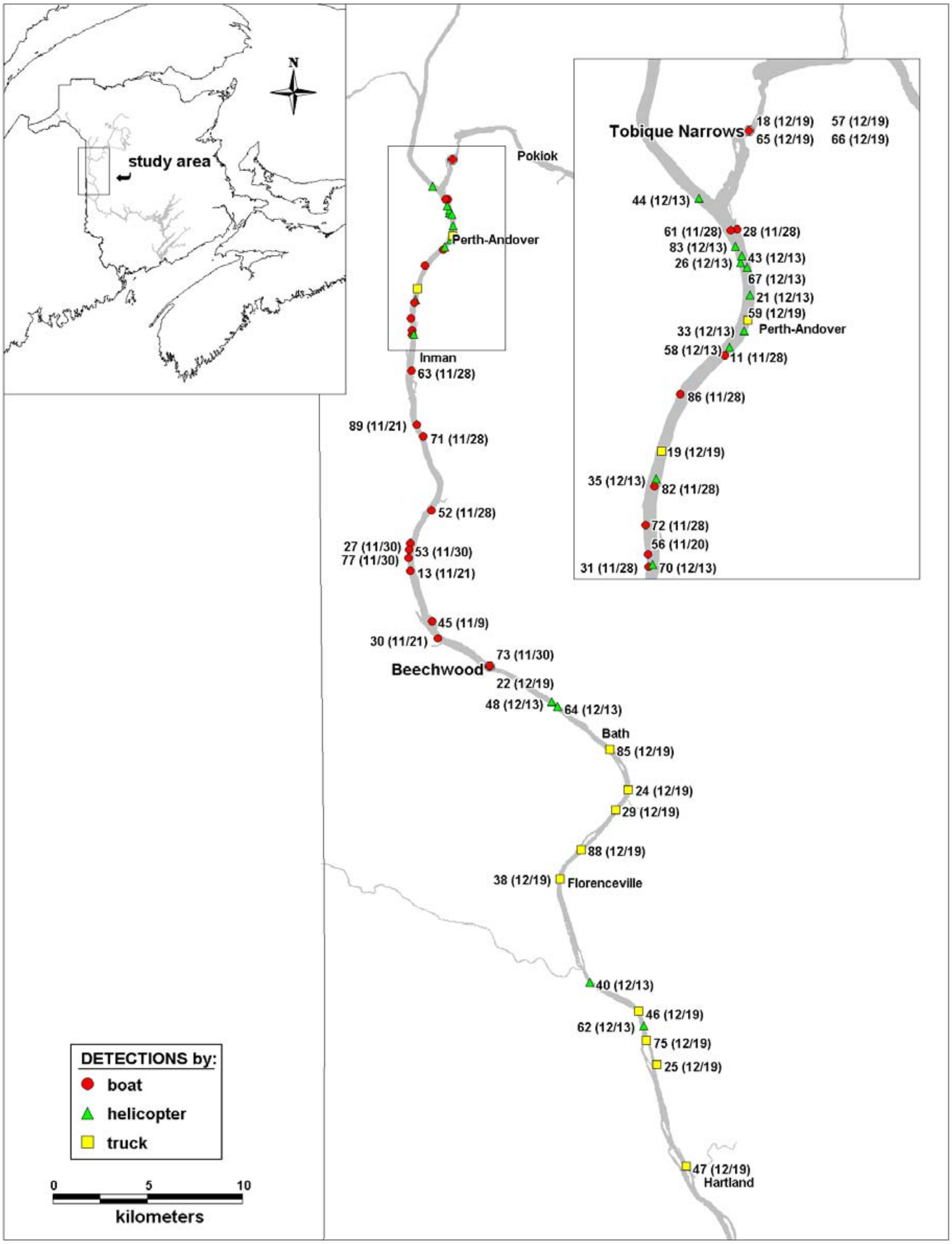


Figure 18. Map of the main Saint John River (confluence of the Tobique River to Hartland) showing the location and date in brackets (month/day) of last detection during searches for pre-smolts that descended the Tobique Narrows Dam.

Appendix i. Example of a detection pattern for an individual (no. 64) radio tagged pre-smolt, showing date, time, antennae and signal strength of detections. Yagi is the antenna.

Date	Time	Spill Yagi	Spill Gate #1	Spill Gate #2	Spill Gate #3	Spill Gate #4	Spill Gate #5	Turbine Unit #1	Turbine Unit #2	Turbine Yagi	Tailrace Yagi	Beechwood Yagi (forebay)	Beechwood Yagi (tailrace)	Comments
6-Nov	21:33:35									133				first detection at forebay
6-Nov	21:34:11									124				
6-Nov	21:42:04									81				
6-Nov	21:44:07									103				
*	*	*	*	*	*	*	*	*	*	*	*	*	*	see footnote
6-Nov	22:19:06									211				
6-Nov	22:19:11									203				
6-Nov	22:19:27									200				
6-Nov	22:19:43									222				
6-Nov	22:20:04									210				
6-Nov	22:20:08								84					
6-Nov	22:20:13							73						
6-Nov	22:20:19									225				
6-Nov	22:20:28							90						
6-Nov	22:20:35									213				
6-Nov	22:20:39								107					
6-Nov	22:20:44							179						
6-Nov	22:20:49							213						
6-Nov	22:20:54									224				
6-Nov	22:21:00								145					movements at forebay
6-Nov	22:21:04							251						
6-Nov	22:21:09									165				
6-Nov	22:21:15								116					
6-Nov	22:21:18							254						
6-Nov	22:21:25									164				
6-Nov	22:21:31								115					
6-Nov	22:21:40							255						
6-Nov	22:21:45									205				
6-Nov	22:21:50								178					
6-Nov	22:21:56							255						last detection in forebay
6-Nov	22:23:15										47			first detection in tailrace
6-Nov	22:23:33										60			
6-Nov	22:23:50										158			
6-Nov	22:24:00										148			
6-Nov	22:24:18										41			
6-Nov	22:24:27										75			
6-Nov	22:24:38										141			
6-Nov	22:24:48										25			
6-Nov	22:24:58										24			
6-Nov	22:25:10										31			
6-Nov	22:25:19										115			
6-Nov	22:25:38										80			
6-Nov	22:25:56										61			
6-Nov	22:26:47										53			
6-Nov	22:26:55										78			
6-Nov	22:27:12										124			
6-Nov	22:27:21										126			
6-Nov	22:27:31										17			
6-Nov	22:28:00										27			
6-Nov	22:28:51										56			
6-Nov	22:30:36										22			
10-Nov	0:16:39											44		first detection at Beechwood
10-Nov	0:17:00											61		(forebay)
10-Nov	0:17:15											69		
10-Nov	0:17:35											36		
10-Nov	0:17:46											33		
10-Nov	0:18:01											49		
10-Nov	0:18:11											77		
10-Nov	0:18:20											72		
10-Nov	0:18:32											101		
10-Nov	0:18:47											94		
10-Nov	0:18:57											107		
10-Nov	0:19:07											169		
10-Nov	0:19:16											158		
10-Nov	0:19:28											138		
10-Nov	0:19:33											117		
10-Nov	0:19:43											95		
10-Nov	0:19:53											70		
10-Nov	0:20:03											103		
10-Nov	0:20:13											101		
10-Nov	0:20:24											55		
10-Nov	0:20:29											85		
10-Nov	0:20:39											121		
10-Nov	0:20:48											129		
10-Nov	0:20:59											124		
10-Nov	0:21:15											71		
10-Nov	0:21:25											76		
10-Nov	0:21:35											111		
10-Nov	0:21:44											48		
10-Nov	0:22:56											71		
10-Nov	0:23:07											73		
10-Nov	0:23:17											77		
10-Nov	0:24:28											40		
10-Nov	0:24:49											27		
10-Nov	0:24:59											138		
10-Nov	0:25:14											63		
10-Nov	0:25:25											123		
10-Nov	0:27:01												114	first detection at Beechwood
10-Nov	0:27:12												74	(tailrace)
10-Nov	0:27:32												88	
10-Nov	0:27:37												82	
10-Nov	0:27:46												118	
10-Nov	0:28:18												112	
10-Nov	0:31:01												48	

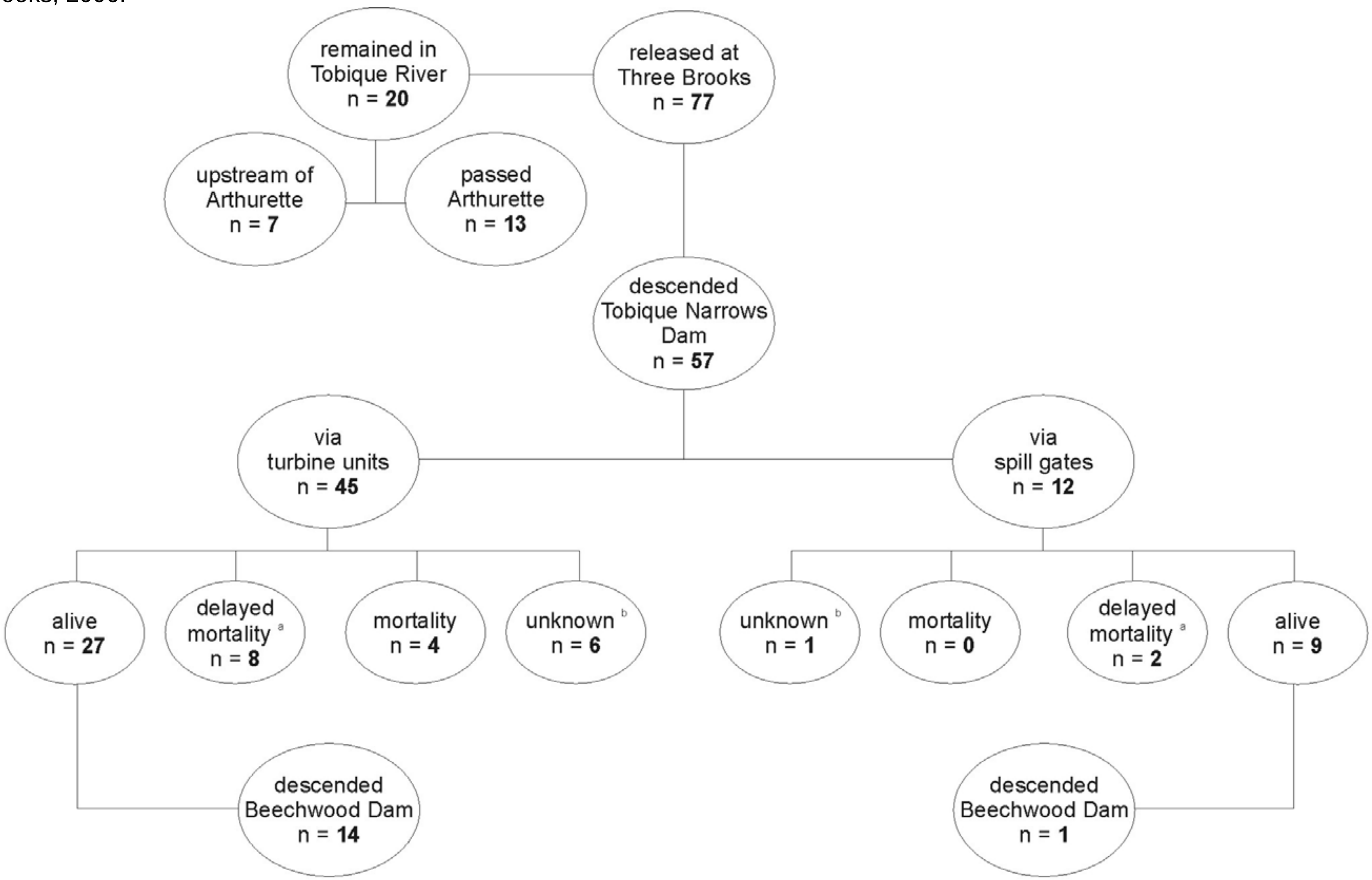
Notes:

* break in Turbine Yagi data from Nov-06 at 21:44:42 to Nov-06 at 22:18:52. A total of 117 'hits' with a range in signal strength between 59 and 222 were removed.

Appendix ii. Checklist used to determine fate, i.e. alive (A), mortality (M), delayed mortality (DM) or overwintering (OM), and unknown (UN) for pre-smolts that descended the Tobique Narrows Dam.

			Time in Tailrace			ALIVE (A)				MORTALITY (M)		(DM / OW)	UNKNOWN (UN)	
Fish No.	Passage Route	Tag No.	Days	Hours	Mins	Detected in main SJR below the Perth-Andover Bridge	Detected in main SJR at or below Beechwood Dam	Detected at multiple locations (>1km apart) in main SJR	Displayed upstream movement	Detected in Tobique Tailrace at end of study	Detected in Tobique HP > 21 days	Detected in main SJR above Perth-Andover Bridge	Undetected after leaving tailrace area	FINAL STATUS
1	Spill	19	2	22	31	Y		Y						A
2		52	4	1	10	Y								A
3		27	1	9	14	Y								A
4		63	n/d	n/d	n/d	Y								A
5		82	0	0	9	Y								A
6		85	n/d	n/d	n/d	Y	Y	Y						A
7		86	0	0	27	Y								A
8		73	0	0	5	Y								A
9		11	4	21	38	Y		Y						A
10		33	0	0	0							Y		DM / OW
11		83	0	12	47							Y		DM / OW
12		49	0	1	9								Y	UN
1	Turbine	13	1	14	24	Y		Y						A
2		24	0	0	45	Y	Y	Y						A
3		25	0	9	27	Y	Y	Y						A
4		29	0	0	32	Y	Y	Y	Y					A
5		30	0	9	20	Y		Y						A
6		38	0	1	3	Y	Y	Y						A
7		40	0	0	5	Y	Y	Y						A
8		45	0	0	20	Y								A
9		48	0	0	21	Y	Y							A
10		56	0	0	6	Y								A
11		58	0	7	3	Y			Y					A
12		64	0	0	7	Y	Y	Y						A
13		75	0	11	15	Y	Y							A
14		77	0	3	4	Y		Y						A
15		89	0	0	4	Y								A
16		20	0	0	4	Y	Y	Y						A
17		31	0	11	3	Y		Y	Y					A
18		35	0	0	2	Y								A
19		46	0	0	18	Y	Y							A
20		47	1	2	40	Y	Y							A
21		53	1	0	31	Y		Y						A
22		70	0	12	4	Y								A
23		71	0	1	1	Y		Y	Y					A
24		72	0	2	2	Y		Y						A
25		88	0	20	38	Y	Y	Y						A
26		22	0	0	26	Y	Y	Y						A
27		62	0	0	48	Y	Y		Y					A
28		43	0	19	31							Y		DM / OW
29		44	0	23	55							Y		DM / OW
30		21	0	1	58							Y		DM / OW
31		26	0	2	28							Y		DM / OW
32		28	0	2	25							Y		DM / OW
33		59	0	0	19							Y		DM / OW
34		61	0	0	57							Y		DM / OW
35		67	0	0	19							Y		DM / OW
36		57	9	2	48					Y	Y			M
37		18	45	19	39					Y				M
38		65	41	17	56					Y				M
39		66	36	6	54					Y				M
40		14	28	7	54								Y	UN
41		36	0	0	0								Y	UN
42		60	0	1	7								Y	UN
43		68	0	0	42								Y	UN
44		76	0	16	7								Y	UN
45		80	0	9	28								Y	UN

Appendix iii. Flow chart summarizing the final status of the 77 radio tagged pre-smolts released in the Tobique River near Three Brooks, 2006.



[a] Impossible to determine whether "delayed mortality" or just over-wintering.
[b] Never detected in mobile searches after passed Tobique Narrows Dam.