# SURVIVAL AND MOVEMENT OF FISH EXPERIMENTALLY PASSED THROUGH A RE-RUNNERED TURBINE AT THE KELSEY GENERATING STATION, 2008

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# SURVIVAL AND MOVEMENT OF FISH EXPERIMENTALLY PASSED THROUGH A RE-RUNNERED TURBINE AT THE KELSEY GENERATING STATION, 2008

A Report Prepared
for
Manitoba Hydro

by

North/South Consultants Inc. and Normandeau Associates Inc.

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# EXECUTIVE SUMMARY

This report presents the results of the second phase of a study investigating short-term (48 h) and long-term (3-4 months) effects of fish passage through turbines at Manitoba Hydro's Kelsey Generation Station (GS). The first phase of the study conducted in June 2006 examined injury, survival, and post-passage movement of three fish species (northern pike, walleye, and lake whitefish) that were passed through one of the original turbines (Unit 2). The present study (2008) examined identical parameters for the same three species upon passage through the re-runnered turbine of Unit 5. Both studies also evaluated long-term (3-4 months) effects of turbine passage on a sub-sample of northern pike and walleye.

Results of the 2008 study indicated that the 48 h survival probability of adult fish introduced into the re-runnered turbine was 87.8% for walleye (compared to 80.4% in 2006) and 75.5% for northern pike (compared to 65.9% in 2006). The mean length of the walleye tested in 2008 (428 mm) was comparable to that tested in 2006 (446 mm). Both small (156-450 mm; "sub-adult") and large (451-769 mm; "adult") pike were tested in 2008 compared to only large (455-1085 mm) pike in 2006. The mean length of the adult pike tested in 2008 was 594 mm compared to 615 mm in 2006. A 48 h survival rate for sub-adult pike could not be calculated because of a high non-passage related mortality rate (40%) of control fish. The 1 h survival rate for sub-adults (88.9%) was higher than the 1 h rate for adults (83.0%). It is likely, that the presence of one less blade (five versus six) for the new runner may account for most of the higher fish survival in the 2008 study.

Acoustic-tracking of more than 100 turbine-passed and control northern pike and walleye for one to four months, and up to two years for some individuals, between June 2006 and October 2008 provides no evidence for substantial long-term mortality attributable to turbine passage. Furthermore, the observed movement patterns of pike and walleye show no clear differences between control and treatment fish, and are largely in agreement with available literature and data obtained from pike and walleye in the Nelson River system, suggesting that turbine passage did not markedly affect subsequent fish movements.

Results of the 2006 and 2008 studies suggest that direct (48 h) mortality of relatively large northern pike and walleye passing through old and re-runnered turbines is in the order of 12-34%, is at the lower end of this range for newly installed propeller-type runners, and does not substantially increase 3-4 months after passage. Considering that turbine passage rates appear relatively low for adult northern pike and walleye in reservoirs in northern Manitoba (Pisiak 2009), it does not appear that such movements have a substantial effect on the

populations of these two predators and probably other large-bodied species in the Nelson River near Kelsey GS.

# TECHNICAL SUMMARY

## Background and Introduction to the Study

Since construction of the first hydroelectric GSs in the 19$^{th}$ century, there have been few studies concerning the effects of turbine passage on non-anadromous boreal fish species. Additionally, little information exists about the frequency with which these fish species naturally pass downstream through hydroelectric GSs. Most studies concerned with fish passage through hydroelectric stations have focused on anadromous species. Two North American studies (Navarro et al. 1996 and Matousek et al. 1994) have looked at fish movements and turbine passage for some of the species of concern in Manitoba; however, the type(s) of turbines examined by these authors are substantially different from those used in Manitoba Hydro plants.

Recent concerns expressed by provincial and federal regulatory agencies and local stakeholders (primarily First Nation communities) regarding the scarcity of information on the fate of fish that pass through Manitoba Hydro's hydroelectric GSs prompted the utility to fund the following studies:

- an assessment of fish movements through Missi Falls Control Structure using hydroacoustic technology (North/South Consultants Inc. and BioSonics, Inc. 2008, 2009);
- the frequency of naturally occurring movements of larger fish through the Limestone GS using acoustic transmitters and receivers (Pisiak 2009); and
- the rate of short-term (≤ 48 h) and long-term (up to three months) injury/mortality of fish as a result of turbine passage using HI-Z tags, and the post-passage movements of these fish using acoustic transmitters and receivers (study at Unit 2 of the Kelsey GS; North/South Consultants Inc. and Normandeau Associates Inc. 2007).

Following the initial study at the Kelsey GS, the retrofitting of the turbines at Kelsey GS has started. The installation of new propeller-type runners has begun, replacing the original (1960s) Kaplan turbines, that were later modified such that they functionally became fixed-blade turbines. In addition to increasing hydraulic efficiency and power output, the expectation was that the new propeller-type runners would result in reduced fish mortalities. To test this assumption on the first re-runnered turbine (Unit 5), Manitoba Hydro contracted North/South Consultants in May 2008 to conduct another fish turbine survival study that included short-term and long-term effects and post-passage movements. As in 2006, North/South Consultants Inc. subcontracted Normandeau Associates Inc. to conduct the short-term turbine passage survival and condition study in June of 2008.

All aspects of the current study were kept very similar to the design and experimental set-up of the 2006 study with the exception of a slight modification to the size range of the northern pike. It was felt that the size distribution of the pike tested in 2006 was at the upper length range of individuals normally encountered in the population and did not include many juvenile fish. Therefore, 30 pike which were smaller than the smallest pike used in the 2006 study (i.e., 455 mm total length) were added to the 2008 study.

The first part of this report documents the results for short-term (≤ 48 h) survival and condition of lake whitefish, northern pike, and walleye, that were passed through the Unit 5 turbine at Kelsey GS. Part 2 reports the results for the long-term (up to 4 months) survival and movement for the subset of fish used in Part 1 that was acoustic-tagged.

**<u>Part 1 – Short-term turbine survival</u>**

The specific objective of Part 1 was to determine the rates of short-term (≤ 48 h) survival and injury/mortality to lake whitefish, pike, and walleye, experimentally passed through the Unit 5 Turbine at Kelsey GS.

A total of 288 fish were used in this study: 121 walleye; 156 northern pike; and 11 lake whitefish. Treatment fish consisted of those fish that were intentionally passed through the newly re-runnered turbine. Control fish consisted of those fish that were released directly into the tailrace downstream of the turbulent eddies below the GS (i.e., fish not passed through the turbine). Treatment fish and control fish were captured and handled using identical techniques prior to their release. “HI-Z” tags and radio tags were attached to all fish to allow for their retrieval and assessment of condition within minutes of their release.

The treatment fish (91 walleye, 116 pike, and 11 lake whitefish) were released at three depths (shallow, mid, and deep) through an induction system into the intake area of the Unit 5 turbine at a discharge of approximately 313.2 $m^3/s$ (11,000 cfs). The study design called for equal numbers of walleye, whitefish, and adult pike and approximately 30 small (<450 mm total length; also referred to as sub-adult) pike to be released through the turbine. Due to the limited availability of whitefish during spring in the vicinity of the Kelsey GS, only 11 whitefish were tested. Average total length for treatment walleye was 428 mm (range 332-

653 mm), 519 mm (105-646 mm) for whitefish, and 553 mm for all pike. The average length of the sub-adult pike was 393 mm (156-450 mm) and 594 mm (452-769 mm) for the adults.

The control fish (30 walleye, 30 adult pike, 10 sub-adult pike, and 0 whitefish) were released through an induction system directly downstream of the tailrace. Mean total length for control walleye was 428 mm (326-562 mm), 361 mm (296-433 mm) for control sub-adult pike, and 599 mm (505-690 mm) for control adult pike.

Recapture rates (physical retrieval of fish following testing) were high for pike (98.1%) and walleye (96.7%), but relatively low for whitefish (81.8%). Retrieval times were short (average <12 min) and comparable to those recorded in 2006. Tag detachment was minimal. Except for acoustic-tagged fish, which were released into the river immediately after inspection, all recaptured treatment and control fish were assessed for injuries or trauma immediately after capture and again after 24 and 48 hours in holding pools, after which all live fish were released into the Nelson River downstream of the GS. None of the control walleye or adult pike died or suffered visible injuries over the 48-hour holding period, indicating that mortality and injury observed was due to passage through the turbine and not other handling associated with the study. However, four of the 10 control sub-adult pike died due to a fungal infection or as a result of fish predation suffered during the time between initial release and recapture.

Survival estimates (≤48 h) for treatment fish across all three entrainment depths were 87.8% (SE = 3.5%) and 75.5% (SE = 4.4%) for walleye and adult pike, respectively. The 1 h survival probability for sub-adult pike was 88.9% (SE = 13.7%), which was higher than the 1 h rate of 83.0% (SE = 3.9%) for adults. A reliable 48 h survival estimate could not be calculated for the sub-adult pike because too many control fish (40%) died of fungus and predation. The mean lengths of those pike and walleye that did not survive turbine passage were similar to their con-specifics that did, indicating that survival was independent of fish size for these two species over the length range tested. Too few whitefish were tested to statistically estimate survival rate. Nine of the 11 lake whitefish were recaptured; the status of two was unknown. Six of the nine recaptured fish survived for 48 h. The status of the three fish that died was one decapitated, one severed, and one died in holding.

Almost all (97.1%) of the walleye and pike released as treatment fish were physically recaptured and available for injury examination. The dominant (30% of recaptured fish) injury type inflicted on turbine passed pike was cuts and/or scrapes on the body or head. Body severance (20%) was the second most common injury. Walleye were inflicted with the same injury types but to a lesser degree: 22% cuts and scrapes, and 10% severed. The probable injury source for almost all fish was mechanical (i.e., contact with structural components of the turbine). The severity of the maladies was nearly equally divided between major and minor, with major maladies being considered life threatening.

Malady-free rates (fish free of visible injuries and/or scale loss, or loss of equilibrium, attributed to turbine passage; also referred to as “clean” fish) of treatment fish showed size and species-specific differences: adult pike malady-free rate was 37.6% compared to 72.2% for their sub-adult con-specifics. Malady rates tended to increase with fish length and for pike the mean length of fish with maladies (555.8 mm) was significantly ($P<0.05$) higher than those that were malady-free (496.8 mm). Walleye malady-free rate was 68.2% and the mean length of walleye with and without maladies was similar (411.6 mm versus 406.3 mm).

Results of the 2008 study indicated that the 48 h survival probability of adult fish introduced into the re-runnered turbine was higher in 2008 than for the old turbine in 2006. The estimate for walleye was 87.8% compared to 80.4% in 2006. The 2008 walleye survival estimate was significantly ($P=0.10$) higher than the 2006 estimate. The total length of the walleye tested in 2008 (332-653 mm, mean 428 mm) was comparable to that tested in 2006 (314-651 mm, mean 446 mm). Both small (156-450 mm; “sub-adult”) and large (452-769 mm; “adult”) pike were tested in 2008 compared to only large (455-1085 mm) fish in 2006. The mean length of the adult pike tested in 2008 was 594 mm compared to 615 mm in 2006. In order to better compare adult pike survival between the 2006 and 2008 study, the 48 h survival probabilities were recalculated for the 2006 study excluding pike >800 mm length. The 48 h survival estimate for adults in 2008 was 75.5% compared to the revised rate of 65.8% in 2006. Although higher in 2008, these values were not significantly different ($P = 0.27$).

Comparison of malady-free rates between the old and the newly re-runnered turbine indicated that the rates were similar for walleye (67% old vs. 68% new) and lower for the re-runnered turbine for similar-sized adult pike (45% old vs. 38% new). These rates were not significantly different for both walleye ($P = 0.98$) and northern pike ($P= 0.41$).

The higher survival of adult walleye and pike in the 2008 study compared to 2006 may have been due to the lower number of blades (five versus six) on the new runner, whereas the lower proportion of clean fish, at least for adult pike, could be related to blade design. The leading edge of the new runner blade has a narrow profile compared to a broader, rounder edge for the old design. Possibly the narrower leading edge has a greater chance of inflicting an injury, particularly on the larger fish, even though they were generally less severe.

## Part 2 – Long-term survival and fish movement

Long-term (up to four months) survival and subsequent movements of treatment and control fish was studied using a sub-sample consisting of 35 walleye (27 treatment and 8 control fish) and 41 northern pike (33 treatment and 8 control fish) surgically implanted with acoustic transmitters. More control fish were acoustic-tagged in 2008 than in 2006 to better establish frequency and patterns of "normal" fish movement after turbine passage. The mean length of acoustic-tagged walleye (440 mm) and pike (600 mm) used as treatment fish was slightly larger than the mean length of all treatment walleye (428 mm) and pike (586 mm). Only pike larger than 431 mm (the length of the smallest acoustic-tagged pike) were considered in this calculation. The mean length of acoustic-tagged control walleye (438 mm) and pike (617 mm) was also slightly larger than the mean of all walleye (428 mm) and pike (593 mm) controls, and was generally similar to the length of their con-specific treatment fish.

Fish locations were monitored from the time of release until removal of stationary receivers on 6 October. Six of these receivers were positioned up to 7.4 km downstream of the Kelsey GS in the two channels of the Nelson River extending towards Split Lake and closer to the GS. Two receivers were lost prior to the first data download. Manual tracking was conducted with mobile receivers on three occasions in June, August, and October.

Of the treatment fish equipped with acoustic transmitters, nine pike (27%) and two walleye (8%) did not survive turbine passage. Additionally, one acoustic-tagged pike released through the turbine was not physically recovered (but subsequent radio and acoustic signals indicated that it was alive). A total of 31 pike, 33 walleye, including all 16 control fish of both species, and one lake whitefish that were acoustic-tagged in 2008 were available for tracking. Except for one control pike for which a signal was never retrieved, the signals of all available fish were tracked for five to 119 days. Both the number of days to last signal reception and the total number of days of tracking did not differ between control and treatment fish for either pike or walleye. However, the number of days with a signal significantly differed between species, for both control (pike 14.3, walleye 22.4 days) and treatment (pike 10.6, walleye 32.5 days) fish.

Mean minimum distance of movement (MDM) for pike was higher for control (18.8 km) than for treatment fish (11.0 km), whereas MDM was higher for treatment walleye (24.8 km) than control walleye (15.9 km). Similarly, mean maximum distance from Kelsey GS (MaxD) was higher for control pike (6.0 km) than for treatment pike (4.9 km), and higher in treatment walleye (5.5 km) than in control walleye (4.5 km). However, these differences were not statistically significant, including any interaction effects between species and experimental group (treatment or control).

The mean MDM and MaxD (24.8 and 5.5 km, respectively) of treatment walleye in 2008 were almost identical to that of treatment walleye in 2006 (23.8 km and 5.6 km, respectively). However, for treatment pike, the MDM of fish tracked in 2008 (11.0 km) was significantly ($P=0.011$) higher than in 2006 (6.8 km), as was the MaxD (2008: 4.9 km; 2006: 3.2 km; $P=0.031$). Greater movement in 2008 is not unexpected, because the approximately one month longer study period compared to 2006 provided additional opportunities for fish movement.

Control and treatment fish also were quite similar in their qualitative patterns of movement, irrespective of species. Relatively few fish remained in the immediate area of the GS, but moved north on the Nelson River, west into the Grass River, or were located in both of these areas. Compared to the pattern observed in 2006, the only difference of note was that more treatment pike moved into the Grass River (but not into the northern Nelson River) in 2008 (48%) than in 2006 (21%), and correspondingly less treatment pike were located only in the Kelsey GS area (9% in 2008 versus 36% in 2006). In terms of the five qualitative movement patterns distinguished in this study that were mainly based on the extent, rate, and location of movement, the seven control pike showed almost all of the patterns that were observed for the 23 treatment pike. The eight control walleye displayed only stationary or extensive movement, whereas the 25 treatment walleye showed all five types of movement.

In addition to the fish that were acoustic-tagged in 2008, six treatment pike and five treatment walleye that had been fitted with acoustic tags in June of 2006 were tracked again in 2008. While some of these tags appeared sedentary and may not have been associated with live fish, one pike and four walleye were almost certainly alive. Three of the walleye showed a similar extensive movement pattern over 3-4 months in 2008 as was observed between June and September of 2006. Thus, five fish documented long-term (>2 years) survival of turbine-passed fish and, of these, three walleye provided evidence that the movements observed in 2006 were not a transient artifact affected by turbine passage, but potentially reflect long-term behavioral patterns of individual fish.

Acoustic-tracking of more than 100 turbine-passed and control northern pike and walleye for one to four months, and up to two years for some individuals, between June 2006 and October 2008, provide no evidence for substantial long-term mortality attributable to turbine passage, including the few acoustic-tagged fish that were injured during turbine passage and released into the river. Furthermore, the observed movement patterns of pike and walleye show no clear differences between control and treatment fish, and are largely in agreement with available literature and data obtained from pike and walleye in the Nelson River system, suggesting that turbine passage did not markedly affect subsequent fish movements. To our knowledge no other studies have documented the long-term survival or movements of pike and walleye (or any non-anadromous species) after turbine passage.

## Conclusions

The results of the 2006 and 2008 studies suggest that large-bodied walleye and northern pike suffer from 12-20% and 24-34%, respectively, direct (48 h) mortality after passage through turbines that are fairly typical for the larger Manitoba Hydro generation stations. Within this range, propeller turbines of modern design seem to result in higher fish survival, but not necessarily lower injury rates. Furthermore, there is no indication that longer-term effects (up to four months) substantially decrease direct survival rates, even among those fish that were injured during turbine passage, or that fish movement is altered by turbine passage in the longer- or long-term (up to two years). Although this study provided no clear evidence that fish survival increases with decreasing body size (over the length range of relatively large pike and walleye tested), injury rates were often positively correlated to fish length. This indicates that the largest and oldest individuals are most vulnerable during turbine passage and that the survival estimated for pike and walleye in this study are likely minimum rates for these species.

Assuming that lower forebays do not provide attractive habitat for walleye and northern pike, and that the frequency of turbine passage is relatively low for adults of these two and some other large-bodied species (Pisiak 2009), all available data suggest that the population effects of turbine passage at the Kelsey GS are relatively minor for pike and walleye.

## NON-TECHNICAL SUMMARY

WHY WAS THIS STUDY DONE?

- This study was done to start to answer three questions:
  - What happens to adult jackfish, pickerel, whitefish, and small jackfish when they move through a newly re-runnered turbine (see Figure 1 for a diagram of a powerhouse, showing a turbine and other components) at the Kelsey GS?
  - Are the results any different from the study that was done two years ago (2006) at the Kelsey GS on a turbine with an older runner?
  - What effect does the movement of adult fish downstream through a typical Manitoba Hydro GS have on numbers of those fish species upstream and downstream of the GS?

WHO DID THE STUDY?

- This study was done for Manitoba Hydro by a large team made up of people from North South Consultants Inc., Normandeau Associates Inc., York Factory First Nation (YFFN), and Tataskweyak Cree Nation (TCN), with help from the Manitoba Hydro staff of the Kelsey Generating Station and several other people from Manitoba Hydro. Ted Bland (YFFN) and Douglas Kitchekeesik (TCN) helped co-ordinate First Nation participation in the study. Isaac Beardy (YFFN), Leslie Flett (TCN), Dean Kitchekeesik (TCN), Keith Kitchekeesik (TCN), Kelvin Kitchekeesik (TCN), Howard Laliberty (YFFN), and Franklin Ponask (YFFN) assisted in the collection of data during the study.

WHERE AND WHEN WAS THE STUDY DONE?

- Most of the study was done at the Kelsey GS during June 2008. Tracking of tagged fish also took place in August and October 2008 between Kelsey GS and Split Lake.

HOW WAS THE STUDY DONE?

- The objectives were: to determine “short-term” (up to 48 hours) survival and injury rates of adult jackfish, pickerel, and whitefish, and small jackfish (less than 18 inches long), passed through the Unit 5 turbine (the one that had its runner replaced); and to assess "longer-term" (up to four months) survival and movement of some of the pickerel and jackfish that were passed through the turbine. Fish were captured downstream of the Kelsey GS (a few whitefish and jackfish were captured upstream of the GS) during June 2008, held in pools for approximately 24 hours, tagged with balloon and radio tags, and released directly into the Unit 5 turbine. These were called treatment fish. Some of the fish were not passed through the turbine, but were tagged the same way and passed through a hose into the water downstream of the GS. These were called control fish. Some of the pickerel and jackfish were also surgically implanted with acoustic tags before being released into the turbine or into the water downstream. Fish were recaptured immediately after passage through the turbine, assessed for turbine related injuries, and released back into the river if acoustic-tagged, or held in pools for an additional assessment after 48 hours. All live fish were released back into the Nelson River following 48 hour assessments.

WHAT WAS FOUND?

- Results of the 2008 study showed that approximately 76% of the adult jackfish and 88% of the pickerel that were introduced directly into the turbine (treatment fish) survived passage. In 2006, approximately 66% of the adult jackfish and 80% of the pickerel survived passage. The average length of the pickerel was about the same in both studies. The adult jackfish tested were bigger in 2006; when only jackfish of similar length are compared, the survival rate of the fish tested in 2006 did not change. It is felt that the presence of one less blade (five versus six) for the new runner may explain most of the higher fish survival in the 2008 study.

- The average lengths of those adult jackfish and pickerel that did not survive turbine passage were about the same as the ones that did survive passage, indicating that fish size did not affect survival rate for the length range tested for jackfish (352-769 mm total length except for two very small fish) and pickerel (332-653 mm). However, injury rates tended to increase with fish length, particularly for jackfish.

- A 48 hour survival rate for small jackfish could not be calculated because too many (40%) of the control fish died due to an infection. The 1 hour survival rate for small jackfish (88.9%) was higher than the 1 hour rate for adult jackfish (83.0%).

- The acoustic-tagged adult jackfish and pickerel that were passed through the turbine continued to do well over the time period that they could be tracked (some left the area). The data from 2006 and 2008 provide no evidence for substantial long-term mortality due to turbine passage. Additionally, the observed movement patterns of jackfish and pickerel showed no clear differences between control and treatment fish, and suggest that turbine passage did not affect subsequent fish movements.

- The studies so far suggest that turbine mortality does not have a large effect on pickerel and jackfish populations in the Nelson River within the sizes of fish tested.

WHAT WILL BE DONE WITH THE INFORMATION?

- Manitoba Hydro will use the information collected in this study, together with information collected in other related studies that looked at numbers of fish naturally moving through Manitoba Hydro facilities, to help try to answer the question of what effect does the movement of adult fish downstream through a typical Manitoba Hydro GS have on numbers of those fish species upstream and downstream of the GS.

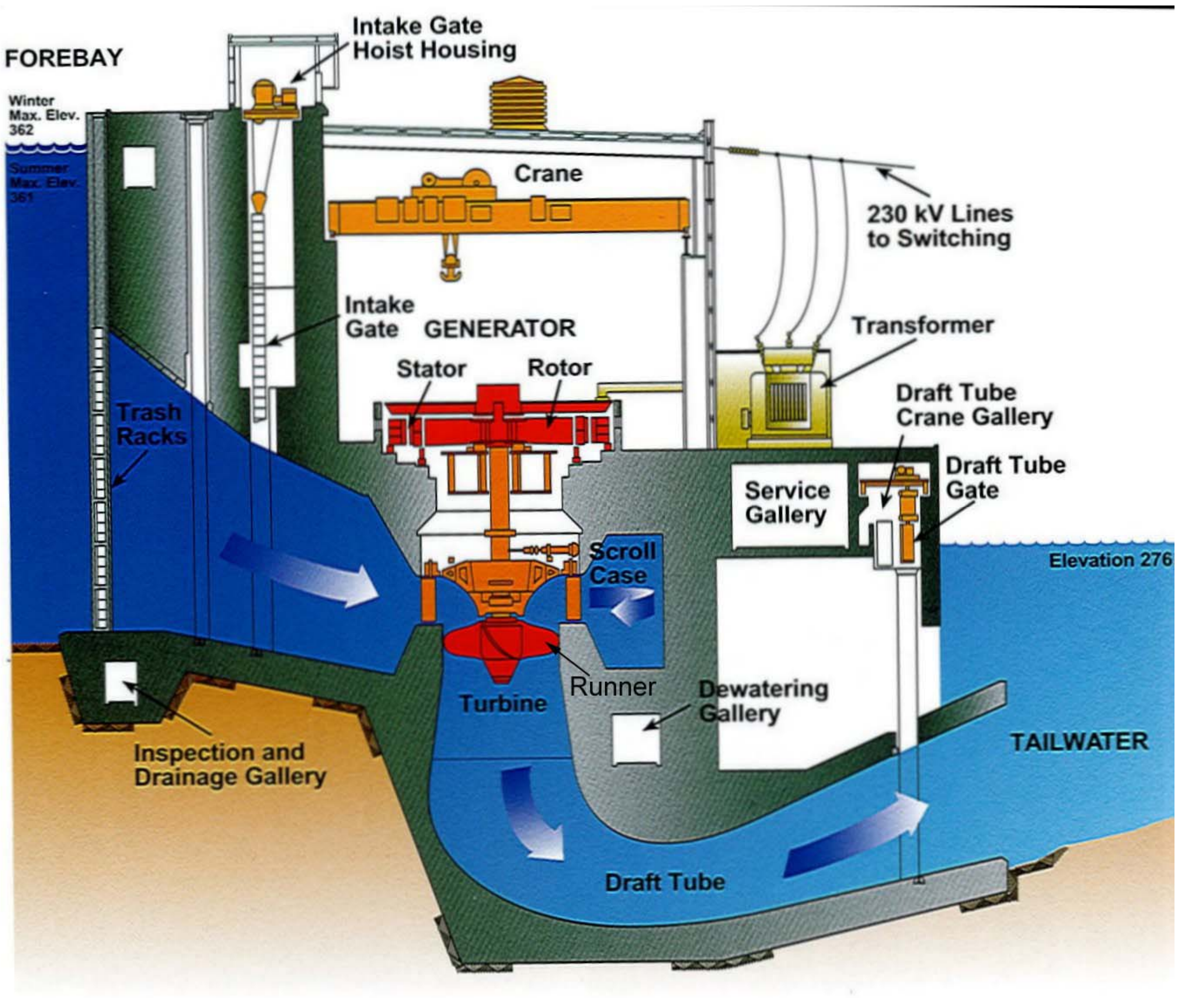


Figure 1. Diagram of a cross-section through the powerhouse of a typical Manitoba Hydro Generation Station showing direction of water flow past the turbine runner.

## ACKNOWLEDGMENTS

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This study was authorized by Manitoba Water Stewardship under terms of Scientific Collection Permit # 34-08.

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## Fish turbine passage through the Kelsey GS, 2008

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# ESTIMATING DIRECT SURVIVAL AND INJURY OF ADULT WALLEYE, NORTHERN PIKE, AND LAKE WHITEFISH THROUGH A RE-RUNNERED TURBINE AT MANITOBA HYDRO'S KELSEY GENERATING STATION

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## 1.0 Introduction

The condition and survival of boreal freshwater fish species of domestic and commercial importance passing through hydroelectric stations was initially examined in 2006 at Unit 2 of Manitoba Hydro's Kelsey Generation Station (GS; North/South Consultants Inc. and Normandeau Associates, Inc. 2007). As a follow-up to this initial study, Manitoba Hydro expressed interest in determining rates of mortality and injury to fish passing through a newly re-runnered turbine (Unit 5) at Kelsey GS and then compare these rates to the 2006 survival/injury estimates from the old turbine of Unit 2. Both the present study and the 2006 study utilized the HI-Z Turb' N Tag (HI-Z) technique to recapture turbine passed fish (Heisey *et al*. 1992, 2008).

The objectives of the 2008 "HI-Z" tag study were: (1) to determine the rates of short term (48 h) survival and injury of turbine passed adult fishes of domestic or commercial interest (i.e., pike, walleye, and lake whitefish); (2) to obtain injury/mortality estimates on smaller (i.e., <450 mm) pike than those used in the 2006 study; and (3) to compare the survival and injury rates between the 2006 and 2008 studies.

## 1.1 Project Description

The Kelsey GS is located on the upper Nelson River in northern Manitoba, at latitude 55° 57' N and longitude 96° 32' W. It is approximately 137 km upstream of the Kettle GS and about 680 km north of Winnipeg (Figure 1-1). The Kelsey GS was built between 1957 and 1961 to supply electricity to the International Nickel Company's mining and smelting operations and also to the City of Thompson. Kelsey's original five turbine generators (units) were expanded to six in 1969 and a seventh unit was added in 1972. They operate with head of approximately 17 m and the current total capacity is 225 MW at a discharge of 1,713 $m^3/s$ (Appendix Table A-1). The original turbines are vertical propeller type with 6 fixed blades, a runner diameter of 7.92 m, and a rotational speed of 102.9 RPM. In 2007, an ALSTOM hydraulic 5 fixed blade propeller type runner was installed in Unit 5 with a rated power of 60500 HP

[45.115 MW]. The present study was conducted in June 2008 to determine the survival and injury rates for the newly re-runnered turbine. The powerhouse was built across a channel of the Nelson River and all generating equipment is housed inside the building, while the transformers are located outside of the generating station on the lower deck (Figure 1-2). The Kelsey GS forebay water level is controlled by a spillway located a short distance east from the powerhouse. The spillway has nine vertical lift sluice gates with a total water discharge capacity of 7,082 $m^3/s$ (approximately 250,000 cfs). The turbine discharge through the test Unit 5 during the time of the study ranged from 312.7-314.7 $m^3/s$ (Appendix Table A-1).

## 2.0 Study Design and Methods

The study was designed to estimate the short-term (48 h) survival and malady-free rates (fish without visible injuries, scale loss < 20% per side, and no loss of equilibrium) of northern pike, walleye, and lake whitefish passed through a newly re-runnered turbine at the Kelsey GS (see Figure 2-1 for a cross-section through a powerhouse). From 9-17 June, 2008, direct effects and indirect effects up to 48 hours post-passage were estimated by introducing HI-Z tagged (Heisey *et al*. 1992) pike, walleye, and whitefish into the Unit 5 turbine (treatment; Figure 2-2) or directly into the tailrace downstream of the turbulent eddies (control; Figure 2-3). Direct effects are manifested immediately after passage (e.g., instantaneous fish mortality, injury, or loss of equilibrium), indirect effects (e.g., predation, disease, or physiological stress) may occur over an extended period or distance after passage. Longer-term (up to four month) indirect effects of turbine passage were also assessed by tracking a sub-sample of fish that were acoustic-tagged (see Part 2).

Fish were released at three entrainment depths in Unit 5: deep (1.5 m above the bottom), shallow (1.5 m below the ceiling), and mid (middle of the turbine intake approximately 5.5 m below ceiling) (Table 2-1; Figure 2-2). Although fish were released at three locations, survival and malady-free rates were estimated for the composite sample. After passage, live and dead fish were enumerated and the condition of each fish examined. Condition was recorded according to coded descriptions (Table 2-2) to help assess the probable causal mechanisms for injury/mortality which may in turn be used to identify potential mitigative measures. Table 2-1 shows the summary of daily fish releases of each species.

## 2.1 Sample Size Calculations

Prior to initiating the study, the sample size requirement was determined to fulfill the primary objective of obtaining survival estimates that would be within a pre-specified precision ($\varepsilon$) level. The sample size is a function of the recapture rate ($P_A$), expected passage survival ( $\hat{\tau}$ ) or mortality (1- $\hat{\tau}$ ), survival of control fish (S), and the desired precision (ε) at a given probability of significance (α). In general, sample size requirements decrease with an increase in control survival and recapture rates (Mathur *et al*. 1996, 2000). Only precision and α levels can be strictly controlled by an investigator. Results of turbine survival experiments from other sites indicate a sample size of approximately 100 (50 treatment and 50 control) fish per species may be sufficient to attain survival estimates within ± 0.10, 90% of the time (Table 2-3). This number assumes close to 100% control survival, a recapture rate of 95% and expected passage survival of > 90% for the study.

Initially, it was proposed that 120 pike, 90 walleye, and 90 lake whitefish (if available) would be released into the intake of Unit 5 turbine at the Kelsey GS and 30 control fish of each of these species would be released into the tailrace (Figure 2-3) to estimate the rate of survival and injury during passage. There was also a desire to obtain preliminary survival and injury estimates on sub-adult pike (fish less than 450 mm total length); therefore 30 of the 120 pike were to be sub-adults. It was determined that fewer controls per species would be needed if all were recaptured free of injuries and survived 48 h. However, it became apparent early in the study that not enough healthy lake whitefish could be captured to meet the sample size requirement for that species, and only 11 treatment and 0 control fish were released during the entire study. The number and location of the fish released during the study are shown in Table 2-1. Appendix A provides data on individual fish and other measured parameters. Appendix B provides statistical output.

## 2.2 Source and Maintenance of Specimens

Fish for this study were obtained between 7 and 16 June, 2008 from locations upstream and downstream of the Kelsey GS. Fish were mainly captured by gill nets that were set in locations that have historically yielded good numbers of fishes and that facilitated rapid transport to the holding facilities at the Station (see below). Fish were also caught by angling and electrofishing in areas around the Kelsey GS. Gill nets were checked at one and two-hour intervals, and fish were removed from the net as soon as possible after capture with minimal handling. Only fish in good physical condition were used. The size range of the pike, walleye, and lake whitefish used in the study largely reflected the size range of captured fish although extra effort was made to acquire sub-adult (<450 mm) pike. Fish were transported by boat to covered soft-walled pools of approximately 5,000 L volume (Figure 2-4) located on the intake deck area of the dam near the Unit 5 turbine release location. In general, enough pools were available to hold fish separately by species and date of capture. The capture location of each fish was recorded and it was individually identified with a number coded Floy-tag before being placed into the holding pool.

A continual supply of ambient river water was supplied to each pool and all fish were held for a minimum of 12-24 h prior to tagging which allowed fish time to recover from initial capture and handling stress. Water temperatures in the holding pools were slightly higher on any given day than river temperatures, which ranged from 12.8 to 13.9° C. River temperature was measured at the cooling water inlet of Unit 1 (Table 2-1).

The total length for all treatment pike ranged from 156-769 mm (mean 553 mm). Pike were segregated into sub-adult (156-450 mm) and adult (452-769 mm) fish for testing. The average length of the sub-adults was 393 mm and 594 mm for the adults, respectively. Control sub-adult and adult pike measured 296-433 mm (mean 361) and 505-690 mm (mean 599), respectively (Figure 2-5). Walleye mean total length was 428 mm (range 332-653 mm) for treatment fish and 428 mm (range 326-562 mm) for controls. Lake whitefish total length ranged from 105-646 mm with a mean of 519 mm (Figure 2-6).

## 2.3 Tagging and Release

Due to the different species composition and the relative large size of the test fish, fish handling, tagging, and recapture techniques that were developed for adult salmon and American shad (Normandeau Associates, Inc. and Mid Columbia Consulting 2003, Heisey *et al*. 2008) were adapted specifically for this study and the previous HI-Z tag study at the Kelsey Station (North/South Consultants, Inc. and Normandeau Associates, Inc. 2007). In order to bring large fish to the surface for rapid recapture, as many as six HI-Z balloon tags (typically 4) were attached with a small cable tie through the musculature beneath the pelvic, pectoral and dorsal fins via a curved canula needle (Figures 2-7 and 2-8). The conventional method of attaching HI-Z tags with a small stainless steel pin was used to attach tags at the base of the walleye's pelvic fins. Radio tags were attached in combination with one of the HI-Z balloon tags to aid in tracking released fish. Specially designed fish restraint devices were developed and built by Normandeau to aid in tagging test fish (Figures 2-7 and 2-8). Acoustic tags were surgically implanted in a sub-sample of the treatment and control fish (see Part 2 of this report).

HI-Z tags were activated by injecting a small amount of water into the balloons which caused the tag to inflate in approximately 2 to 4 minutes. All treatment fish were released through an induction apparatus (Figure 2-9) that consisted of a holding basin attached to a 20.32 cm (8 inch) diameter flexible hose which led to a rigid 20.32 cm (8 inch) PVC pipe. This pipe was U-bolted onto a steel frame that could be raised or lowered to the desired release depth (Figure 2-10). The release hose was continuously supplied with river water to ensure fish were transported quickly to the desired release point. Control fish were released through the same induction apparatus attached to a 20.32 cm (8 inch) diameter flexible hose approximately 15 m (50 ft) long that released fish into the tailrace downstream of the turbulent eddies (Figure 2-3). Treatment fish were introduced into Unit 5 turbine at 3 depths, shallow (1.5 m below ceiling), mid (middle of turbine intake approximately 5.5 m below ceiling) and deep (1.5 m above the bottom) (Figure 2-2).

Procedures for handling, tagging, release and recapture of fish were similar for treatment and control groups. Fish were randomly selected from the holding pools, using small seines and dip nets. Fish were handled using wool gloves. All fish releases were made during daylight hours.

## 2.4 Fish Recapture Methods

After release (either as treatment or control), fish were tracked and retrieved when they buoyed to the surface downstream of the Kelsey GS by one of three recapture boat crews (Figure 2-11). Boat crews were notified of the radio tag frequency of each fish upon its release. Only crew members trained in fish handling were used to retrieve tagged fish. To minimize crew bias, no crew was specifically assigned to retrieve either control or treatment fish.

Radio signals were received on a 5-element Yagi antenna or Loop antenna coupled to an Advanced Telemetry System receiver. The radio signal transmission enabled the boat crews to follow the movement of each fish after passage and position the boats downstream for retrieval when fish buoyed to the surface (Figure 2-11).

Active radio tags which failed to surface were tracked for a minimum of 30 minutes and then periodically thereafter to determine whether the fish appeared to be alive (moving around) or whether the tag broke loose (stationary signal). Recaptured fish were placed into an on-board holding facility and tags were removed. Each fish was immediately examined for maladies consisting of visible injuries, descaling, and loss of equilibrium and assigned appropriate condition codes, per the descriptions presented in Table 2-2. Tagging and data recording personnel were notified via a two-way radio system of each fish's recovery time and condition. Appendix Table C provides data on disposition of individual fish.

After recapturing an acoustically tagged fish, the fish was assessed for condition and any turbine related injuries. If no or only minor (*i.e.*, small scrape, bruise) injuries were present, all HI-Z tags were removed and the fish was released back into the river for subsequent monitoring of movements. Any acoustically tagged fish that were recaptured injured were held in 5,000 liter holding pools and monitored during the 48 h delayed assessment period. If injuries were not life-threatening, and the fish was alive at 48 h, the fish was released into the river. The results of the acoustic tag study are reported in Part 2 of this report.

## 2.5 Assessment of Fish Injuries

All recaptured fish, dead or alive, were examined for types of external injuries. Dead fish were also examined for internal injuries when there were no apparent external injuries. Visible injuries and scale loss were assigned a likely causal mechanism. Controlled laboratory experiments (Neitzel *et al*. 2000; PNNL *et al*. 2001) to replicate and correlate injury type and characteristic to a specific causative mechanism provides some indication of the cause of observed injuries in the field. Some injury symptoms can be manifested by two different sources which may lessen the probability of accurate delineation of a cause and effect relationship in the field (Eicher Associates 1987).

Injury and descaling were categorized by type, extent, and area of body. Fish without visible injuries that were not actively swimming or swimming erratically at recapture were classified as "loss of equilibrium". This condition has been noted in most past studies and often disappears within 10 to 15 min after recapture if the fish is not injured (Normandeau Associates *et al*. 1996, 2000, 2003). Visible injuries, scale loss, and loss of equilibrium (LOE) were also categorized as minor or major. The criteria for this determination are based on laboratory studies by PNNL *et al.* (2001) and Normandeau personnel field observations (Table 2-4).

A malady classification was established to include fish with visible injuries, scale loss (≥20% on either side), or LOE. Fish without maladies were designated "malady-free". The malady-free metric was established to provide a standard way to depict a specific passage route's effects on the condition of entrained fish (Normandeau and Skalski 2006). The malady-free metric is based solely on fish physically recaptured and examined. Additionally, the malady-free metric in concert with site-specific hydraulic and physical data may provide insight into what passage conditions present safer fish passage. Daily tag-recapture and daily malady data are presented in Appendix Table D-2.

## 2.6 Classification of Recaptured Fish

As in previous investigations (Mathur *et al*. 1996, 2000; Normandeau and Skalski 2006; North/South Consultants Inc. and Normandeau Associates Inc. 2007), the immediate post-passage status of an individual recaptured fish and recovery of inflated tags dislodged from fish was designated as alive, dead, tag and pin recovered, or unknown. The following criteria have been established to make these designations: (1) alive—recaptured alive and remaining so for 1 h; (2) alive—fish does not surface but radio signals indicate movement patterns; (3) dead—recaptured dead or dead within 1 h of release; (4) dead—only inflated dislodged tag(s) are recovered, and telemetric tracking or the manner in which inflated tags surfaced is not indicative of a live fish; and (5) unknown—no fish or dislodged tags are recaptured, or radio signals are received only briefly, and the subsequent status cannot be ascertained.

Each fish recaptured alive (except acoustically tagged) was immediately transferred to 5,000 liter holding pools (see section 2.2) on the lower deck for assessment of delayed effects (48 h). Each pool was continuously supplied with ambient river water and shielded to prevent potential fish escape and predation (otters, bears, *etc*.).

Mortalities of recaptured fish occurring after 1 h were assigned 48 h post-passage effects although fish were observed at approximately 12 h intervals. Dead fish were examined for descaling and injury, and those that died without obvious injuries were necropsied to determine the probable cause of death. Additionally, all specimens alive at 48 h were closely examined for injury and descaling. The initial examination allows detection of some injuries, such as bleeding and minor bruising that may not be evident after 48 h due to natural healing processes (Normandeau Associates *et al*. 1996).

## 2.7 Acoustically Tagged fish

Generally, recaptured fish are held in pools for 48 h to assess any post-passage effects and thereby are included in the 48 h survival/injury probabilities (Heisey *et al*. 1992 and 2008; Mathur *et al*. 1996 and 2000). However, the acoustic-tagged fish that were recaptured and released back into the Nelson River (minus HI-Z tags and radio tag) were included in the 48 h survival calculation after determining the post-recapture condition of the fish (North/South Consultants Inc. and Normandeau Associates Inc. 2007). Information from acoustically tracked fish (see Section 2.6 and Part 2 of this report) was considered in the final classification of fish that were not immediately recaptured and their status could not be assessed based on radio signals. This included one pike of initially "unknown" status that was subsequently assigned "alive" status (after 48 h) because the acoustic data indicated that this fish was actively moving over several months.

## 2.8 Survival and Malady-Free Estimation

Separate survival probabilities (1 and 48 h) and malady-free rates and their associated standard errors were estimated for pike and walleye using the likelihood model given in Mathur *et al*. (1996) and Normandeau Associates *et al*. (2000). To determine if survival or injury was related to fish length, the mean length of fish that did not survive turbine passage or that suffered an injury in the process was compared to those surviving and to "clean" fish, respectively, using a t-test. Significance was assigned at $P \leq 0.10$ for all statistical tests reported in this report. The model outputs along with results of other statistical analyses are provided in Appendix B.

## 3.0 Results

### 3.1 Recapture Rates

The HI-Z tag recapture technique performed satisfactorily with generally high recapture rates (physical retrieval of live and dead fish). The recapture rate for treatment pike adults was 98.9% and 95.2% for sub-adults. The recapture rate for treatment walleye was 96.7% and for lake whitefish 81.8%. All control pike and walleye were recaptured (Table 3-1 and Appendix Table A-2).

### 3.2 Retrieval Times

Retrieval times (the interval between fish release through the induction system and physical retrieval) were generally short for pike treatment fish and ranged from 4-116 minutes (average 11.5 minutes) for sub-adults to 3-11 minutes (average 6.3 minutes) for adults. The average retrieval times for control sub-adult and adult pike were 5.5 and 6.3 minutes, respectively (Figure 3-1). Average retrieval time for walleye was 5.5 minutes for controls and 7.6 minutes for treatment fish. The mean retrieval time was 7.6 minutes for lake whitefish (Figure 3-2).

### 3.3 Survival Estimates

Estimated 1 h and 48 h direct survival estimates were calculated for walleye and adult and sub-adult pike (Table 3-2 and 3-3). Survival estimate (1 h) for walleye across all release locations (shallow, mid and deep) was 87.8% (SE = 3.5%) and 48 h estimated survival was identical to 1 h. For adult pike, the 1 h survival estimate was 83.0% (SE = 3.9%) and the 48 h estimate was 75.5% (SE = 4.4%) across all entrainment depths. For sub-adult pike, the 1 h survival estimate was 88.9% (SE = 13.7%). A 48 h estimate could not be calculated because of unacceptable (40%) control mortality (Ruggles 1992). One control fish died immediately (1 h) due to predation, and another within 48 h due to predation. Two fish died within 48 h from fungal infection Lake whitefish survival probabilities were not calculated because of the low sample size and absence of controls. However, six of nine recaptured whitefish survived 48 hours.

No significant influence of fish length on survival was detected for either walleye or adult pike. The mean lengths of dead and alive pike (t =-1.22, P=0.2239) and walleye (t =-0.80, P=0.4409) were similar. This lack of a strong relationship between survival and fish size over the size range tested for pike (151-800 mm) or walleye (301-700 mm) was also evident when survival rate was plotted for fish grouped into 50 mm length intervals (Figure 3-3).

### 3.4 Injury/Malady Types, Causes, and Rates

All but eight of the 218 (3.7%) treatment fish were examined for visible injuries, loss of equilibrium, and scale loss (Table 3-4). Of these 210 fish, 96 (45.7%) had maladies. All but one of the maladies was a visible injury. One fish had only loss of equilibrium; none of the fish had only scale loss. The dominant injury type for adult pike was cuts and/or scrapes on the body and head (Table 3-5). Overall, 33% of the pike displayed these injuries. Adult pike from the deep release were most prone to these injuries with 15 of 35 fish (43%) recaptured with cuts and/or scrapes. Body severance (approximately 20%) was the second most observed injury to adult pike. Body laceration/cuts (15%) and severance (15%) were the injuries most observed on sub-adult pike. The walleye were inflicted primarily by the same types of injuries observed on the pike, but to a lesser degree (Table 3-5). Some 22% of the walleye were recaptured with cuts and scrapes to the head and body, and 10% were severed. Mid-depth released walleye incurred the highest injury rate (approximately 47%), and 12 of the 31 fish (40%) examined had cuts and/or scrapes to the head or body. The few whitefish available for post-turbine passage examination indicated that body severance (2 of 9 fish) was the primary injury type for this species.

The incidence of maladies differed substantially between adult pike (62%) and sub-adult pike (35%), walleye (32%) and whitefish (33%). All maladies were not severe or lethal (Table 3-6) and were approximately equally distributed between minor and major maladies.

Injury rate tended to increase with fish length in pike and walleye (Figure 3-4). However, only the mean length of injured pike (555.8 mm) was significantly ($P<0.05$) different from the mean length of their uninjured conspecifics (496.8 mm).The mean length of injured (411.6 mm) and uninjured (406.3 mm) walleye were similar. Furthermore, the mean length of injured pike was significantly ($P<0.0001$) higher compared to the mean length of injured walleye.

Probable sources of observed maladies for all species were almost exclusively mechanical (Table 3-6). Among treatment fish, all injuries observed in sub-adult pike, walleye, and whitefish were mechanically induced. Only the cause of LOE in one adult pike seemed to be non-mechanical in nature.

## 3.5 Malady-Free Estimates (MFE)

Malady-free estimates (MFE) (i.e., fish free of passage-related maladies) are presented in Tables 3-3 and 3-7. MFE rates were adjusted by any maladies incurred by control fish. MFE estimates differed between species. The MFE for adult and sub-adult pike was 37.6% (SE = 5.0%) and 72.2% (SE = 14.1%), respectively. The MFE for walleye was 68.2% (SE = 5.0%). Release depth appeared to affect MFE rates (Table 3-7); however, the sample size was not deemed adequate for further statistical analysis.

## 3.6 Comparison of Old and New Runner Design

The effect of passage through the re-runnered turbine on survival and condition of adult walleye and pike was compared to the Unit 2 turbine with an old runner. Although the two turbines were tested in different years (2006 and 2008, respectively) and for different units (5 vs. 2), it is likely the results are quite comparable for several reasons: study design, general methodology, and fish capture and handling were identical except for the Floy-tagging of all fish (and not just the acoustic-tagged fish) in 2008 (see

North/South Consultants, Inc. and Normandeau Associates, Inc. 2007). Both studies were conducted in the beginning of June at similar water temperatures and both units were operated near hydraulic capacity. Walleye tested in 2006 (314-651 mm, mean 459 mm) were similar in size to those tested in 2008 (332-653 mm, mean 430 mm). To account for the testing of larger pike (up to 1085 mm) in 2006, pike >800 mm were removed from the 2006 data set for the comparison between turbines. The resulting mean total length of treatment adult pike was 615 mm (range 455-765 mm) compared to the 2008 mean of 594 mm (range 452-769 mm). The 48 h survival of walleye passing through the new design was 87.8% (SE = 3.5%) compared to 80.4% (SE = 4.0%) for the old design. The 48 h survival rate of adult pike introduced into the re-runnered turbine was 75.5% (SE = 4.4%) compared to 65.8% (SE = 5.4%) for the old turbine (Table 3-8). The 48 h survival rates for the old design and re-runnered turbine were compared using a two-tailed Z test. There were no statistical differences between the pike survival rates ($Z = 1.10$, $P = 0.27$); however, there was a statistical difference between the walleye rates ($Z = 1.64$, $P = 0.10$).

Although walleye and pike survival was approximately 10 percentage points higher for the re-runnered turbine, malady-free estimates were lower for pike. Adult pike had a malady-free rate of 38% (SE = 5.0%) in 2008 compared to 45% (SE = 5.8%) in 2006. However, these estimates were not significantly different ($Z = 0.03$, $P = 0.98$, $\alpha = 0.10$). The percentage of the pike maladies that were classified as “major” was less (53%) for the re-runnered turbine than for the old turbine (78%; Table 3-8). The malady-free rates for walleye were similar for the re-runnered turbine and the old turbine with respective rates of 68% (SE = 5.0%) and 67% (SE = 4.8%).

One possible reason for the (nominally) lower malady-free rate observed for pike when passing the re-runnered turbine is runner design. The leading edge of the new runner has a narrower profile as compared to the broader, rounder edge of the old runner (Figure 3-5). This narrow edge likely has a greater chance for causing injury when fish and blade contact.

## 4.0 Principal Findings and Discussion

The primary objectives of the study were largely met. Estimation of survival of adults of three species of domestic or commercial interest within ± 0.10, 90% of the time was successfully achieved for pike and walleye; however, because of the difficulties in obtaining healthy lake whitefish at the time of treatment or control release and the consequently small sample size of 11 treatment whitefish, survival rate for this species could not be estimated. The precision (ε) on survival estimates of pike and walleye was within the desired criteria of ± 0.10, 90% of the time. The 48 h direct survival estimate for walleye passed through the Unit 5 turbine was 87.8% (SE = 3.5%). The 48 h direct survival estimate of adult pike was 75.5% (SE = 4.4%). A secondary objective of obtaining preliminary survival estimates on sub-adult pike was partially achieved. The 1 h survival rate was 88.9% (SE = 13.7%); however, the 48 h rate could not be established because of high control fish mortality during the delayed assessment period.

A literature review (EPRI 1992, 1996; Franke *et al*. 1997) indicates that scant information exists on survival rates of fish larger than 300 mm in passage through relatively large Kaplan and propeller type turbines such as at Kelsey. In particular, comparable data for the two species and sizes tested herein in passage through turbines with characteristics similar to Kelsey GS are unavailable to provide a perspective on the results obtained herein. Although survival estimates have been reported for walleye of lengths up to > 300 mm (Navarro *et al*. 1996), and for pike of up to 456 mm length (Matousek *et al*. 1994), these are not deemed comparable to the results from the present study because they were obtained at Francis and Sampson type turbines. In general, the available data for Kaplan turbines are that fish size and shape (rather than species *per se*), number of runner blades, runner diameter, and runner blade rotational speed affect survival rates.

Survival rates for large-sized American shad (424 to 560 mm), somewhat similar in size and shape to walleye, in passage through Kaplan type turbines reported in the literature (Bell and Kynard 1985; Franke *et al.* 1997; Heisey *et al*. 2008) are available for comparisons. Bell and Kynard (1985) reported a survival rate (2-4 h) of 78.2% for radio-tagged American shad (average length 560 mm) in passage through a Kaplan turbine at the Hadley Falls Station on the Connecticut River. Heisey *et al*. (2008) reported a survival rate (48 h) of 86% for post-spawned American shad (average length 424 mm) in passage through Kaplan type turbines at the Safe Harbor Station on the Susquehanna River. The 48 h survival rate (87.8%) for walleye with an average length of 430 mm found in the present study is relatively similar to that reported for American shad, particularly at Hadley Falls. Kelsey GS has several similar structural characteristics with both the Hadley Falls and Safe Harbor Stations (5 to 7 runner blades and runner speeds of 78 to 128 RPM), although with 750 cm the runner diameter is larger than at the two US stations (432-566 cm).

Even though literature is scant on survival of larger sized fish (>300 mm) evidence is emerging that when turbine characteristics are similar, survival may be more a function of fish size than species *per se* (Normandeau Associates 1997; Skalski *et al*. 2002). In studies of juvenile (≤150 mm) and post-spawned American shad (average length 424 mm) in passage through Kaplan type turbines at Safe Harbor Hydroelectric Station, survival for juveniles was reported at >97% and for adults at about 86% (Heisey *et al*. 1992 and 2008; Normandeau Associates 1997). A retrospective analysis of survival data on several species by Skalski *et al*. (2002) showed fish length to be an important variable affecting survival more than other variables tested. Results from both the 2006 and present studies at the Kelsey GS suggest that both size and species can affect survival and/or injury at this station. Adult walleye that were smaller than the adult pike tested in both 2006 and 2008 (Table 3-8) had higher survival rates. During the earlier study, walleye with a mean length of 459 mm had a 48 h survival of 80.4% compared to 65.8% for pike with a mean length of 615 mm. The same trend held for the present study where walleye of 430 mm length had a 48 h survival of 87.8% compared to 75.5% for pike of 594 mm length. There was also an increasing trend in malady-free rates with decreasing fish length in both studies at Kelsey. The malady-free rate for the walleye (459 mm mean length) in 2006 was 67.4% compared to 45.2% for the pike (615 mm mean length). For the present study, the malady-free rates for the walleye (430 mm mean length) was 68.2% versus 37.6% for the pike (594 mm mean length).

The higher survival of pike and walleye for the re-runnered turbine with 5 blades compared to the 2006 study for the old turbine with 6 runner blades does support the contention that the number of runner blades affects direct survival.

The species composition and size of the fish naturally passing through the Kelsey GS is unknown and it is difficult to predict the extent to which present survival estimates for pike and walleye apply to the fish community at large. However, the present study does indicate that the new turbine design should result in higher survival for fish entrained at the Kelsey GS.

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# TABLES

**Table 2-1.**

**Daily schedule of releases for adult (> 450 mm) and sub-adult (<451 mm) northern pike, walleye and lake whitefish passed through the Unit 5 turbine at Kelsey GS in June 2008. Fish were released at three locations (shallow, mid and deep) in front of the turbine intake. Control fish were released into the tailrace.**

| | | Treatment | | | | | | | | | | Control | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Northern Pike | | | | | Walleye | | | Lake Whitefish | | Northern Pike | | Walleye | |
| | River | Deep | Mid | | Shallow | | Deep | Mid | Shallow | Deep | Shallow | | | | |
| | Temp. | adult | adult | sub-adult | adult | sub-adult | | | | | | adult | sub-adult | | Fish |
| **Date** | **(˚C)** | | | | | | | | | | | | | | **Total** |
| 9-Jun | 12.8 | 5 | | | | | | | | | | | | | **5** |
| 10-Jun | 13.1 | 25 | | | | | | | | | | 15 | | | **40** |
| 11-Jun | 13.3 | 5 | | | | | 30 | | | 1 | | | | 15 | **51** |
| 12-Jun | 13.9 | | 28 | 2 | | | | 31 | | | | | | | **61** |
| 14-Jun | 13.3 | | 2 | 9 | 30 | | | | | | 2 | 15 | | | **58** |
| 16-Jun | 13.9 | | | | | | | | 30 | | 7 | | | 15 | **52** |
| 17-Jun | 13.9 | | | | | 10 | | | | | 1 | | 10 | | **21** |
| **Total** | | **35** | **30** | **11** | **30** | **10** | **30** | **31** | **30** | **1** | **10** | **30** | **10** | **30** | **288** |

**Table 2-2.**

**Condition codes assigned to fish and dislodged balloon tags for fish passage survival studies.**

| Status Codes | Description | | |
|---|---|---|---|
| * | Turbine/passage-related malady | | |
| 4 | Damaged gill(s): hemorrhaged, torn or inverted | | |
| 5 | Major scale loss, > 20% | | |
| 6 | Severed body or nearly severed | | |
| 7 | Decapitated or nearly decapitated | | |
| 8 | Damaged eye(s): hemorrhaged, bulged, ruptured or missing | | |
| 9 | Damaged operculum: torn, bent | | |
| A | No visible marks on fish | | |
| B | Flesh tear at tag site(s) | | |
| C | Minor scale loss, < 20% | | |
| E | Laceration(s): tear(s) on body or head (not severed) | | |
| F | Torn isthmus | | |
| G | Hemorrhaged, bruised head or body | | |
| H | Loss of equilibrium (LOE) | | |
| K | Failed to enter system | | |
| L | Fish likely preyed on (telemetry, circumstances relative to recapture) | | |
| M | Substantial bleeding at tag site | | |
| P | Predator marks | | |
| Q | Other information | | |
| R | Replaced due to unrecoverable conditions | | |
| S | Acoustic-tagged fish - Kelsey Station only | | |
| T | Trapped inside tunnel/gate well | | |
| V | Fins displaced, or hemorrhaged (ripped, torn, or pulled) from origin | | |
| W | Abrasion / Scrape | | |
| **Survival Codes** | | | |
| 1 | Recovered alive | | |
| 2 | Recovered dead | | |
| 3 | Unrecovered – tag & pin only | | |
| 4 | Unrecovered – no information or brief radio telemetry signal | | |
| 5 | Unrecovered – trackable radio telemetry signal or other information | | |
| **Dissection Codes** | | | |
| 1 | Shear | F | Hemorrhaged internally |
| 2 | Mechanical | J | Major |
| 3 | Pressure | L | Organ displacement |
| 4 | Undetermined | M | Minor |
| 5 | Mechanical/Shear | N | Heart damage, rupture, hemorrhaged |
| 6 | Mechanical/Pressure | O | Liver damage, rupture, hemorrhaged |
| 7 | Shear/Pressure | R | Necropsied, no obvious injuries |
| B | Swim bladder ruptured or expanded | S | Necropsied, internal injuries |
| D | Kidneys damaged (hemorrhaged) | T | Tagging/Release |
| E | Broken bones obvious | W | Head removed; i.e., otolith |

**Table 2-3.**

**Required sample sizes for treatment and control fish releases for various combinations of control survival (S), recapture probability ($P_A$), and turbine related mortality ($\tau$) to obtain a precision ($\varepsilon$) of $\leq \pm 0.10$ at $1-\alpha = 0.90$.**

| | | Turbine Mortality | |
|---|---|---|---|
| Control Survival (S) | Recapture Rate ($P_A$) | ($1-\tau$) | Number of Fish |
| 1.00 | 0.99 | 0.05 | 18 |
| | | 0.10 | 29 |
| | | 0.15 | 39 |
| | 0.95 | 0.05 | 39 |
| | | 0.10 | 49 |
| | | 0.15 | 57 |
| | 0.9 | 0.05 | 69 |
| | | 0.10 | 76 |
| | | 0.15 | 82 |
| 0.95 | 0.99 | 0.05 | 45 |
| | | 0.10 | 54 |
| | | 0.15 | 61 |
| | 0.95 | 0.05 | 67 |
| | | 0.10 | 74 |
| | | 0.15 | 80 |
| | 0.90 | 0.05 | 98 |
| | | 0.10 | 103 |
| | | 0.15 | 107 |
| 0.90 | 0.99 | 0.05 | 74 |
| | | 0.10 | 81 |
| | | 0.15 | 87 |
| | 0.95 | 0.05 | 98 |
| | | 0.10 | 103 |
| | | 0.15 | 107 |
| | 0.90 | 0.05 | 130 |
| | | 0.10 | 133 |
| | | 0.15 | 134 |

**Table 2-4**

**Criteria for assigning severity of maladies observed for recaptured turbine and spillway passed fish.**

- A fish with only LOE is classified as major if the fish dies within 1 h; if it survives or dies beyond 1 h, it is classified as minor.
- A fish with no visible internal or external maladies is classified as a passage-related major injury if the fish dies within 1 h; if it dies beyond 1 h, it is classified as a non-passage-related minor injury.
- Any minor injury that leads to death within 1 h is classified as a major injury; if it lives or dies after 1 h, it remains a minor injury.
- Hemorrhaged eye: minor if less than 50%; major if 50% or more.
- Deformed pupil(s): major.
- Bulged eye: major unless only slightly bulged; minor if slight bulge.
- Bruises (size-dependent): major if 10% or more of fish body per side; otherwise minor.
- Inverted or bleeding gills or gill arches: major.
- Operculum tear at dorsal insertion: major if 5 mm or greater; otherwise minor.
- Operculum folded under or torn off: major.
- Scale loss: major if 20% or more of fish per side; otherwise minor.
- Scraping (damage to epidermis): major if 10% or more per side of fish; otherwise minor.
- Cuts and lacerations: generally classified as major. Small flaps of skin or skinned snouts: minor.
- Internal hemorrhage or rupture of kidney, heart or other internal organs and/or damaged spinal column resulting in death at 1 to 48 h: major.
- Multiple injuries: use worst injury.

**Table 3-1.**

**Summary tag-recapture data for adult (> 450 mm) and sub-adult (<451 mm) northern pike, walleye and lake whitefish passed through the Unit 5 turbine at Kelsey GS in June 2008. Fish were released at three locations (shallow, mid and deep) in front of the turbine intake. Control fish were released into the tailrace. Proportions are given in parentheses.**

| | Northern pike | | | | | | |
|---|---|---|---|---|---|---|---|
| | Treatment | | | | | | |
| **Operational Level** | **Deep** | **Mid** | | **Shallow** | | **Combined** | |
| | **adult** | **adult** | **sub-adult** | **adult** | **sub-adult** | **adult** | **sub-adult** |
| Number released | 35 | 30 | 11 | 30 | 10 | 95 | 21 |
| Number alive | 28 (0.800) | 25 (0.833) | 7 (0.636) | 25[a] (0.833) | 9 (0.900) | 78 (0.821) | 16 (0.762) |
| Number recovered dead | 7 (0.200) | 5 (0.167) | 3 (0.273) | 4 (0.133) | 1 (0.100) | 16 (0.168) | 4 (0.190) |
| Assigned dead* | 0 (0.000) | 0 (0.000) | 0 (0.000) | 0 (0.000) | 0 (0.000) | 0 (0.000) | 0 (0.000) |
| Dislodged tags | 0 (0.000) | 0 (0.000) | 0 (0.000) | 0 (0.000) | 0 (0.000) | 0 (0.000) | 0 (0.000) |
| Stationary radio signals | 0 (0.000) | 0 (0.000) | 0 (0.000) | 0 (0.000) | 0 (0.000) | 0 (0.000) | 0 (0.000) |
| Undetermined | 0 (0.000) | 0 (0.000) | 1 (0.091) | 1 (0.033) | 0 (0.000) | 1 (0.011) | 1 (0.048) |
| Held[b] | 28 (0.800) | 25 (0.833) | 7 (0.636) | 24 (0.800) | 9 (1.000) | 77 (0.811) | 16 (0.762) |
| Alive 48 h | 26 (0.743) | 23 (0.767) | 4 (0.364) | 21 (0.700) | 9 (1.000) | 70 (0.737) | 13 (0.619) |
| | **Controls** | | | | | | |
| | **adult** | **sub-adult** | | **Combined** | | | |
| Number released | 30 | 10 | | 40 | | | |
| Number alive | 30 (1.000) | 9 (0.900) | | 39 (0.975) | | | |
| Number recovered dead | 0 (0.000) | 1 (0.100) | | 1 (0.025) | | | |
| Assigned dead* | 0 (0.000) | 0 (0.000) | | 0 (0.000) | | | |
| Dislodged tags | 0 (0.000) | 0 (0.000) | | 0 (0.000) | | | |
| Stationary radio signals | 0 (0.000) | 0 (0.000) | | 0 (0.000) | | | |
| Undetermined | 0 (0.000) | 0 (0.000) | | 0 (0.000) | | | |
| Held[b] | 30 (1.000) | 9 (0.900) | | 39 (0.975) | | | |
| Alive 48 h | 30 (1.000) | 6 (0.600) | | 36 (0.900) | | | |

[a] 1fish counted as alive based on telemetry data; fish was not physically recovered

**Table 3-1**

## Continued.

| | Walleye | | | | |
|---|---|---|---|---|---|
| | Treatment | | | | Control |
| Operational Level | Deep | Mid | Shallow | Combined | Combined |
| Number released | 30 | 31 | 30 | 91 | 30 |
| Number alive | 26 (0.867) | 28 (0.903) | 25 (0.833) | 79 (0.868) | 30 (1.000) |
| Number recovered dead | 3 (0.100) | 2 (0.065) | 4 (0.133) | 9 (0.099) | 0 (0.000) |
| Assigned dead* | 1 (0.033) | 1 (0.032) | 0 (0.000) | 2 (0.022) | 0 (0.000) |
| Dislodged tags | 0 (0.000) | 0 (0.000) | 0 (0.000) | 0 (0.000) | 0 (0.000) |
| Stationary radio signals | 1 (0.033) | 1 (0.032) | 0 (0.000) | 2 (0.022) | 0 (0.000) |
| Undetermined | 0 (0.000) | 0 (0.000) | 1 (0.033) | 1 (0.011) | 0 (0.000) |
| Held[b] | 26 (0.867) | 28 (0.903) | 25 (0.833) | 79 (0.868) | 30 (1.000) |
| Alive 48 h | 26 (0.867) | 28 (0.903) | 25 (0.833) | 79 (0.868) | 30 (1.000) |

| | Lake Whitefish | | |
|---|---|---|---|
| | Treatment | | |
| Operation Level | Deep | Shallow | Combined |
| Number released | 1 | 10 | 11 |
| Number alive | 0 (0.000) | 7 (0.700) | 7 (0.636) |
| Number recovered dead | 0 (0.000) | 2 (0.200) | 2 (0.182) |
| Assigned dead* | 0 (0.000) | 0 (0.000) | 0 (0.000) |
| Dislodged tags | 0 (0.000) | 0 (0.000) | 0 (0.000) |
| Stationary radio signals | 0 (0.000) | 0 (0.000) | 0 (0.000) |
| Undetermined | 1 (1.000) | 1 (0.100) | 2 (0.182) |
| Held[b] | 0 (0.000) | 7 (0.700) | 7 (0.636) |
| Alive 48 h | 0 (0.000) | 6 (0.600) | 6 (0.545) |

*Primarily fish where balloon tag(s) were recaptured
[b] Most acoustically tagged fish not held but included in total

**Table 3-2.**

**Estimated 1 h and 48 h direct survival estimates and standard errors (SE) for northern pike (adult > 450 mm and sub-adult < 451 mm), walleye and lake whitefish passed through Unit 5 intake at 313.7 $m^3/s$ (approximately 11,000 cfs) and released at 3 locations (shallow, mid and deep). Control fish released into the tailrace at Kelsey Generating Station, June 2008.**

**Northern Pike**

| | Treatment | | | | | Controls | |
|---|---|---|---|---|---|---|---|
| | sub-adult | adult | | adult | | sub-adult | adult |
| | Combined Release Levels | | Shallow | Mid | Deep | | |
| Number released | 21 | 95 | 30 | 30 | 35 | 10 | 30 |
| Number recaptured alive | 16 | 78* | 25* | 25 | 28 | 9 | 30 |
| Number recaptured dead | 4 | 16 | 4 | 5 | 7 | 1 | 0 |
| Number assigned dead | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Number unknown | 1 | 1 | 1 | 0 | 0 | 0 | 0 |
| 1 h survival | 88.9% | 83.0% | 86.2% | 83.3% | 80.0% | | |
| SE[1] | 13.7% | 3.9% | 6.4% | 6.8% | 6.8% | | |
| Number died in holding | 3 | 7 | 3 | 2 | 2 | 4 | 0 |
| 48 h survival | 88.9% ** | 75.5% | 75.9% | 76.7% | 74.3% | | |
| SE[1] | N/A | 4.4% | 8.0% | 7.7% | 7.4% | | |

* 1 fish counted as alive based on telemetry actually not recovered

** calculated rate is 100%, but rate established at 1 h because survival should not increase with time

**Walleye**

| | Treatment | | | | Controls |
|---|---|---|---|---|---|
| | Combined Release Levels | Shallow | Mid | Deep | Combined Release Levels |
| Number released | 91 | 30 | 31 | 30 | 30 |
| Number recaptured alive | 79 | 25 | 28 | 26 | 30 |
| Number recaptured dead | 9 | 4 | 2 | 3 | 0 |
| Number assigned dead | 2 | 0 | 1 | 1 | 0 |
| Number unknown | 1 | 1 | 0 | 0 | 0 |
| 1 h survival | 87.8% | 86.2% | 90.3% | 86.7% | |
| SE[1] | 3.5% | 6.4% | 5.3% | 6.2% | |
| Number died in holding | 0 | 0 | 0 | 0 | 0 |
| 48 h survival | 87.8% | 86.2% | 90.3% | 86.7% | |
| SE[1] | 3.5% | 6.4% | 5.3% | 6.2% | |

**Table 3-2**

**Continued.**

| | Lake Whitefish Treatment Combined Release Levels |
|---|---|
| Number released | 11 |
| Number recaptured alive | 7 |
| Number recaptured dead | 2 |
| Number assigned dead | 0 |
| Number unknown | 2 |
| 1 h survival | N/A |
| SE[1] | N/A |
| Number died in holding | 1 |
| 48 h survival | N/A |
| SE[1] | N/A |

[1] Multiply standard errors (SE) by 1.645 to obtain 90% confidence intervals.

**Table 3-3.**

**Summary of direct survival (1 and 48 h) and malady-free estimates for northern pike and walleye released into Unit 5 intake at 313.7 m ³/s (approximately 11,000 cfs). Control fish released into the tailrace at Kelsey Generating Station, June 2008.**

| | Northern Pike | | Walleye |
|---|---|---|---|
| | sub-adult | adult | |
| **Survival** | | | |
| 1 h survival | 88.9% | 83.0%* | 87.8% |
| SE*** | 13.7% | 3.9% | 3.5% |
| 48 h survival | N/A** | 75.5% | 87.8% |
| SE*** | N/A** | 4.4% | 3.5% |
| **Malady-Free** | | | |
| Estimate | 72.2% | 37.6% | 68.2% |
| SE*** | 14.1% | 5.0% | 5.0% |

* 1 fish counted as alive based on telemetry actually not recovered
** Reliable estimate could not be calculated because of high (40%) control mortality
*** Multiply standard errors (SE) by 1.645 to obtain 90% confidence intervals.

**Table 3-4.**

**Summary malady data for northern pike (adult > 450 mm and sub-adult < 451 mm), walleye and lake whitefish passed through Unit 5 intake at 313.7 m ³/s (approximately 11,000 cfs) and released at 3 locations (deep, mid, and shallow). Control fish released into the tailrace at Kelsey Generating Station, June 2008. Proportions given in parentheses.**

| | Northern Pike | | | | | Walleye | | | Lake Whitefish | | Control | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Operation Level** | **Deep** | **Mid** | | **Shallow** | | **Deep** | **Mid** | **Shallow** | **Deep** | **Shallow** | **Northern Pike** | | **Walleye** | |
| | | **adult** | **sub-adult** | **adult** | **sub-adult** | | | | | | **adult** | **sub-adult** | | |
| Number released | 35 | 30 | 11 | 30 | 10 | 30 | 31 | 30 | 1 | 10 | 30 | 10 | 30 | ***288*** |
| Number examined | 35 | 30 | 10 | 28 | 10 | 29 | 30 | 29 | 0 | 9 | 30 | 10 | 30 | ***280*** |
| Passage related maladies | 25 | 18 | 5 | 15 | 2 | 7 | 14 | 7 | 0 | 3 | 0 | 1 | 0 | ***97*** |
| Visible injuries | 24 | 18 | 5 | 15 | 2 | 7 | 14 | 7 | 0 | 3 | 0 | 1 | 0 | ***96*** |
| Loss of equilibrium only | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | ***1*** |
| Scale loss only | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | ***0*** |
| Without maladies | 10 | 12 | 5 | 13 | 8 | 22 | 16 | 22 | 0 | 6 | 30 | 9 | 30 | ***183*** |
| Without maladies that died | 0 | 0 | 3 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 4 | 0 | ***9*** |

| | **Treatment** | | | | | | **Control** | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Northern Pike** | | **Walleye** | | **Lake Whitefish** | | **Northern Pike** | | **Walleye** | | **Total** |
| Number released | 116 | | 91 | | 11 | | 40 | | 30 | | ***288*** |
| Number examined | 113 | (0.974) | 88 | (0.967) | 9 | (0.818) | 40 | (1.000) | 30 | (1.000) | ***280*** |
| Passage related maladies | 65 | (0.575) | 28 | (0.318) | 3 | (0.333) | 1 | (0.025) | 0 | (0.000) | ***97*** |
| Visible injuries | 64 | (0.566) | 28 | (0.318) | 3 | (0.333) | 1 | (0.025) | 0 | (0.000) | ***96*** |
| Loss of equilibrium only | 1 | (0.009) | 0 | (0.000) | 0 | (0.000) | 0 | (0.000) | 0 | (0.000) | ***1*** |
| Scale loss only | 0 | (0.000) | 0 | (0.000) | 0 | (0.000) | 0 | (0.000) | 0 | (0.000) | ***0*** |
| Without maladies | 48 | (0.425) | 60 | (0.682) | 6 | (0.667) | 39 | (0.975) | 30 | (1.000) | ***183*** |
| Without maladies that died | 4 | (0.035) | 0 | (0.000) | 1 | (0.111) | 4 | (0.100) | 0 | (0.000) | ***9*** |

## Table 3-5.

**Summary of visible injury types (passage induced) and injury rates observed on recaptured northern pike (adult > 450 mm and sub-adult < 451 mm), walleye and lake whitefish passed through Unit 5 intake at 313.7 m ³/s (approximately 11,000 cfs) and released at 3 locations (deep, mid, and shallow). Control fish released into the tailrace at Kelsey Generating Station, June 2008. Proportions are given in parentheses.**

| Operational Level | No. Released | No. Examined | Passage Related Visibly Injured No. of fish | Injury Type: Eye(s) Hemorrhaged Bulged, Ruptured | Injury Type: Operculum/ Gills Torn, Scraped, Hemorrhaged | Injury Type: Body/Head Laceration Scraped | Injury Type: Body/Head Hemorrhaged, Bruised | Injury Type: Missing Body Parts, Severed, Decapitated | Injury Type: Internal Injury |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | **Northern Pike** | | | | |
| Deep adult | 35 | 35 (1.000) | 25 (0.714) | 1 (0.029) | 3 (0.086) | 15 (0.429) | 3 (0.086) | 8 (0.229) | 0 (0.000) |
| Mid adult | 30 | 30 (1.000) | 18 (0.600) | 0 (0.000) | 1 (0.033) | 8 (0.267) | 8 (0.267) | 6 (0.200) | 1 (0.033) |
| Shallow adult | 30 | 28 (0.933) | 15 (0.536) | 0 (0.000) | 0 (0.000) | 8 (0.286) | 2 (0.071) | 5 (0.179) | 2 (0.071) |
| ***Total Treatment*** | ***95*** | ***93 (0.979)*** | ***58 (0.624)*** | ***1 (0.011)*** | ***4 (0.043)*** | ***31 (0.333)*** | ***13 (0.140)*** | ***19 (0.204)*** | ***3 (0.032)*** |
| Mid sub-adult | 11 | 10 (0.909) | 5 (0.500) | 0 (0.000) | 1 (0.100) | 2 (0.200) | 1 (0.100) | 2 (0.200) | 0 (0.000) |
| Shallow sub-adult | 10 | 10 (1.000) | 2 (0.200) | 0 (0.000) | 0 (0.000) | 1 (0.100) | 0 (0.000) | 1 (0.100) | 0 (0.000) |
| ***Total Treatment*** | ***21*** | ***20 (0.952)*** | ***7 (0.350)*** | ***0 (0.000)*** | ***1 (0.050)*** | ***3 (0.150)*** | ***1 (0.050)*** | ***3 (0.150)*** | ***0 (0.000)*** |
| | | | | | **Walleye** | | | | |
| Deep | 30 | 29 (0.967) | 7 (0.241) | 0 (0.000) | 0 (0.000) | 3 (0.103) | 1 (0.034) | 3 (0.103) | 0 (0.000) |
| Mid | 31 | 30 (0.968) | 14 (0.467) | 0 (0.000) | 1 (0.033) | 12 (0.400) | 0 (0.000) | 2 (0.067) | 0 (0.000) |
| Shallow | 30 | 29 (0.967) | 7 (0.241) | 1 (0.034) | 0 (0.000) | 4 (0.138) | 0 (0.000) | 4 (0.138) | 0 (0.000) |
| ***Total Treatment*** | ***91*** | ***88 (0.967)*** | ***28 (0.318)*** | ***1 (0.011)*** | ***1 (0.011)*** | ***19 (0.216)*** | ***1 (0.011)*** | ***9 (0.102)*** | ***0 (0.000)*** |
| | | | | | **Lake Whitefish** | | | | |
| Deep | 1 | 0 (0.000) | 0 (0.000) | 0 (0.000) | 0 (0.000) | 0 (0.000) | 0 (0.000) | 0 (0.000) | 0 (0.000) |
| Shallow | 10 | 9 (0.900) | 3 (0.333) | 0 (0.000) | 0 (0.000) | 1 (0.111) | 0 (0.000) | 2 (0.222) | 0 (0.000) |
| ***Total Treatment*** | ***11*** | ***9 (0.818)*** | ***3 (0.333)*** | ***0 (0.000)*** | ***0 (0.000)*** | ***1 (0.111)*** | ***0 (0.000)*** | ***2 (0.222)*** | ***0 (0.000)*** |
| | | | | | **Control** | | | | |
| | | | | | **Northern Pike** | | | | |
| Control sub-adult | 10 | 10 (1.000) | 1 (0.100) | 0 (0.000) | 0 (0.000) | 0 (0.000) | 1 (0.100) | 0 (0.000) | 0 (0.000) |
| Control adult | 30 | 30 (1.000) | 0 (0.000) | 0 (0.000) | 0 (0.000) | 0 (0.000) | 0 (0.000) | 0 (0.000) | 0 (0.000) |
| ***Total Control*** | ***40*** | ***40 (1.000)*** | ***1 (0.025)*** | ***0 (0.000)*** | ***0 (0.000)*** | ***0 (0.000)*** | ***1 (0.025)*** | ***0 (0.000)*** | ***0 (0.000)*** |
| | | | | | **Walleye** | | | | |
| Control | 30 | 30 (1.000) | 0 (0.000) | 0 (0.000) | 0 (0.000) | 0 (0.000) | 0 (0.000) | 0 (0.000) | 0 (0.000) |

* Some fish had multiple injuries

**Table 3-6.**

**Probable sources of visibly observed injuries, and scale loss (≥ 20% per side) observed on recaptured northern pike (adult > 450 mm and sub-adult < 451 mm), walleye and lake whitefish passed through Unit 5 intake at 313.7 m ³/s (approximately 11,000 cfs) and released at 3 locations (deep, mid, and shallow). Control fish released into the tailrace at Kelsey Generating Station, June 2008. Proportions given in parentheses.**

| Operational Level | No. of Fish Examined | Total With Passage Related Maladies | | Probable Injury Source: Mechanical | | Probable Injury Source: Undetermined | | Severity: Minor | | Severity: Major | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | **Northern Pike** | | | | | | | |
| Deep adult | 35 | 25 | (0.714) | 24 | (0.686) | 1 | (0.029) | 11 | (0.314) | 14 | (0.400) |
| Mid adult | 30 | 18 | (0.600) | 18 | (0.600) | 0 | (0.000) | 10 | (0.333) | 8 | (0.267) |
| Shallow adult | 28 | 15 | (0.536) | 15 | (0.536) | 0 | (0.000) | 6 | (0.214) | 9 | (0.321) |
| ***Total*** | ***93*** | ***58*** | ***(0.624)*** | ***57*** | ***(0.613)*** | ***1*** | ***(0.011)*** | ***27*** | ***(0.290)*** | ***31*** | ***(0.333)*** |
| Mid sub-adult | 10 | 5 | (0.500) | 5 | (0.500) | 0 | (0.000) | 2 | (0.200) | 3 | (0.300) |
| Shallow sub-adult | 10 | 2 | (0.200) | 2 | (0.200) | 0 | (0.000) | 1 | (0.100) | 1 | (0.100) |
| ***Total*** | ***20*** | ***7*** | ***(0.350)*** | ***7*** | ***(0.350)*** | ***0*** | ***(0.000)*** | ***3*** | ***(0.150)*** | ***4*** | ***(0.200)*** |
| | | | | **Walleye** | | | | | | | |
| Deep | 29 | 7 | (0.241) | 7 | (0.241) | 0 | (0.000) | 3 | (0.103) | 4 | (0.138) |
| Mid | 30 | 14 | (0.467) | 14 | (0.467) | 0 | (0.000) | 9 | (0.300) | 5 | (0.167) |
| Shallow | 29 | 7 | (0.241) | 7 | (0.241) | 0 | (0.000) | 1 | (0.034) | 6 | (0.207) |
| ***Total*** | ***88*** | ***28*** | ***(0.318)*** | ***28*** | ***(0.318)*** | ***0*** | ***(0.000)*** | ***13*** | ***(0.148)*** | ***15*** | ***(0.170)*** |
| | | | | **Lake Whitefish** | | | | | | | |
| Deep | 0 | 0 | (0.000) | 0 | (0.000) | 0 | (0.000) | 0 | (0.000) | 0 | (0.000) |
| Shallow | 9 | 2 | (0.222) | 3 | (0.333) | 0 | (0.000) | 0 | (0.000) | 3 | (0.333) |
| ***Total*** | ***9*** | ***3*** | ***(0.333)*** | ***3*** | ***(0.333)*** | ***0*** | ***(0.000)*** | ***0*** | ***(0.000)*** | ***3*** | ***(0.333)*** |

## Table 3-6

## Continued.

| Operational Level | No. of Fish Examined | Total With Passage Related Maladies | | Probable Injury Source: Mechanism: Mechanical | | Undetermined | | Severity: Minor | | Major | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | **Control** | | | | | | | |
| | | | | **Northern Pike** | | | | | | | |
| Control sub-adult | 10 | 1 | (0.100) | 0 | (0.000) | 1 | (0.100) | 1 | (0.100) | 0 | (0.000) |
| Control adult | 30 | 0 | (0.000) | 0 | (0.000) | 0 | (0.000) | 0 | (0.000) | 0 | (0.000) |
| ***Total*** | ***40*** | ***1*** | ***(0.025)*** | ***0*** | ***(0.000)*** | ***1*** | ***(0.025)*** | ***1*** | ***(0.025)*** | ***0*** | ***(0.000)*** |
| | | | | **Walleye** | | | | | | | |
| Control | 30 | 0 | (0.000) | 0 | (0.000) | 0 | (0.000) | 0 | (0.000) | 0 | (0.000) |

**Table 3-7.**

**Malady-free rates for northern pike (adult > 450 mm and sub-adult < 451 mm), walleye and lake whitefish passed through Unit 5 intake at 313.7 $m^3/s$ (approximately 11,000 cfs) and released at 3 locations (shallow, mid and deep). Control fish released into the tailrace at Kelsey Generating Station, June 2008.**

| | Northern Pike | | | | | | |
|---|---|---|---|---|---|---|---|
| | Treatment | | | | | Controls | |
| | subadult | adult | | adult | | subadult | adult |
| | Combine Release Levels | | Shallow | Mid | Deep | | |
| Number released | 21 | 95 | 30 | 30 | 35 | 10 | 30 |
| Number recaptured alive | 16 | 78* | 25* | 25 | 28 | 9 | 30 |
| Number recaptured dead | 4 | 16 | 4 | 5 | 7 | 1 | 0 |
| Number assigned dead | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Number unknown | 1 | 1 | 1 | 0 | 0 | 0 | 0 |
| Number examined for maladies | 20 | 93 | 28 | 30 | 35 | 10 | 30 |
| Number without maladies | 13 | 35 | 13 | 12 | 10 | 9 | 30 |
| Number with passage related maladies | 7 | 58 | 15 | 18 | 25 | 1 | 0 |
| Number died, no visible passage related malady (i.e. predation/fungus) | 3 | 1 | 1 | 0 | 0 | 4 | 0 |
| Malady-free rate | 0.722 | 0.376 | 0.464 | 0.400 | 0.286 | | |
| SE[1] | 0.141 | 0.050 | 0.094 | 0.089 | 0.076 | | |

* 1 fish counted as alive based on telemetry actually not recovered

## Table 3-7

## Continued.

| | Walleye | | | | |
|---|---|---|---|---|---|
| | Treatment | | | | Controls |
| | Combined Release Levels | Shallow | Mid | Deep | Combined Release Levels |
| Number released | 91 | 30 | 31 | 30 | 30 |
| Number recaptured alive | 79 | 25 | 28 | 26 | 30 |
| Number recaptured dead | 9 | 4 | 2 | 3 | 0 |
| Number assigned dead | 2 | 0 | 1 | 1 | 0 |
| Number unknown | 1 | 1 | 0 | 0 | 0 |
| Number examined for maladies | 88 | 29 | 30 | 29 | 30 |
| Number without maladies | 60 | 22 | 16 | 22 | 30 |
| Number with passage related maladies | 28 | 7 | 14 | 7 | 0 |
| Number died, no visible passage related malady (i.e. predation/fungus) | 0 | 0 | 0 | 0 | 0 |
| Malady-free rate | 0.682 | 0.759 | 0.533 | 0.759 | |
| SE[1] | 0.050 | 0.080 | 0.091 | 0.080 | |

| | Lake Whitefish |
|---|---|
| | Treatment |
| | Combined Release Levels |
| Number released | 11 |
| Number recaptured alive | 7 |
| Number recaptured dead | 2 |
| Number assigned dead | 0 |
| Number unknown | 2 |
| Number examined for maladies | 9 |
| Number without maladies | 6 |
| Number with passage related maladies | 3 |
| Number died, no visible passage related malady (i.e. predation/fungus) | 1 |
| Malady-free rate | N/A |
| SE[1] | N/A |

[1] Multiply standard errors (SE) by 1.645 to obtain 90% confidence intervals.

## Table 3-8.

**Comparison of 48 h survival probabilities and malady-free rates for adult (> 450 mm) northern pike and walleye passed through turbine Unit 5 in June 2008 and turbine Unit 2 at Kelsey GS in June 2006. The number of fish with major maladies is provided in brackets.**

| | 2006 | 2008 |
|---|---|---|
| **Walleye** | | |
| **48 h survival probability** | | |
| No. released | 99 | 91 |
| No. alive fish | 77 | 79 |
| No. dead or assigned dead | 20 | 11 |
| Total length range (mm) | 314 - 651 | 332 - 653 |
| Mean length (mm) | 459 | 430 |
| Survival probability | 0.804 | 0.878** |
| SE* | 0.040 | 0.035 |
| **Malady-free rate** | | |
| No. examined | 95 | 88 |
| No. malady-free | 66 | 60 |
| No. with maladies | 29 (19) | 28 (15) |
| Malady-free rate | 0.674 | 0.682 |
| SE* | 0.048 | 0.050 |
| **Northern Pike** | | |
| **48 h survival probability** | | |
| No. released | 76 | 95 |
| No. alive fish | 50 | 71 |
| No. dead or assigned dead | 26 | 23 |
| Total length range (mm) | 455 - 765 | 452 -769 |
| Mean length (mm) | 615 | 594 |
| Survival probability | 0.658 | 0.755 |
| SE* | 0.054 | 0.044 |
| **Malady-free rate** | | |
| No. examined | 73 | 93 |
| No. malady-free | 33 | 35 |
| No. with maladies | 40 (31 major) | 58 (31 major) |
| Malady-free rate | 0.452 | 0.376 |
| SE* | 0.058 | 0.05 |

* Multiply standard errors (SE) by 1.645 to obtain 90% confidence intervals.
** Significantly higher than 2006 estimate at α = 0.10.

# FIGURES

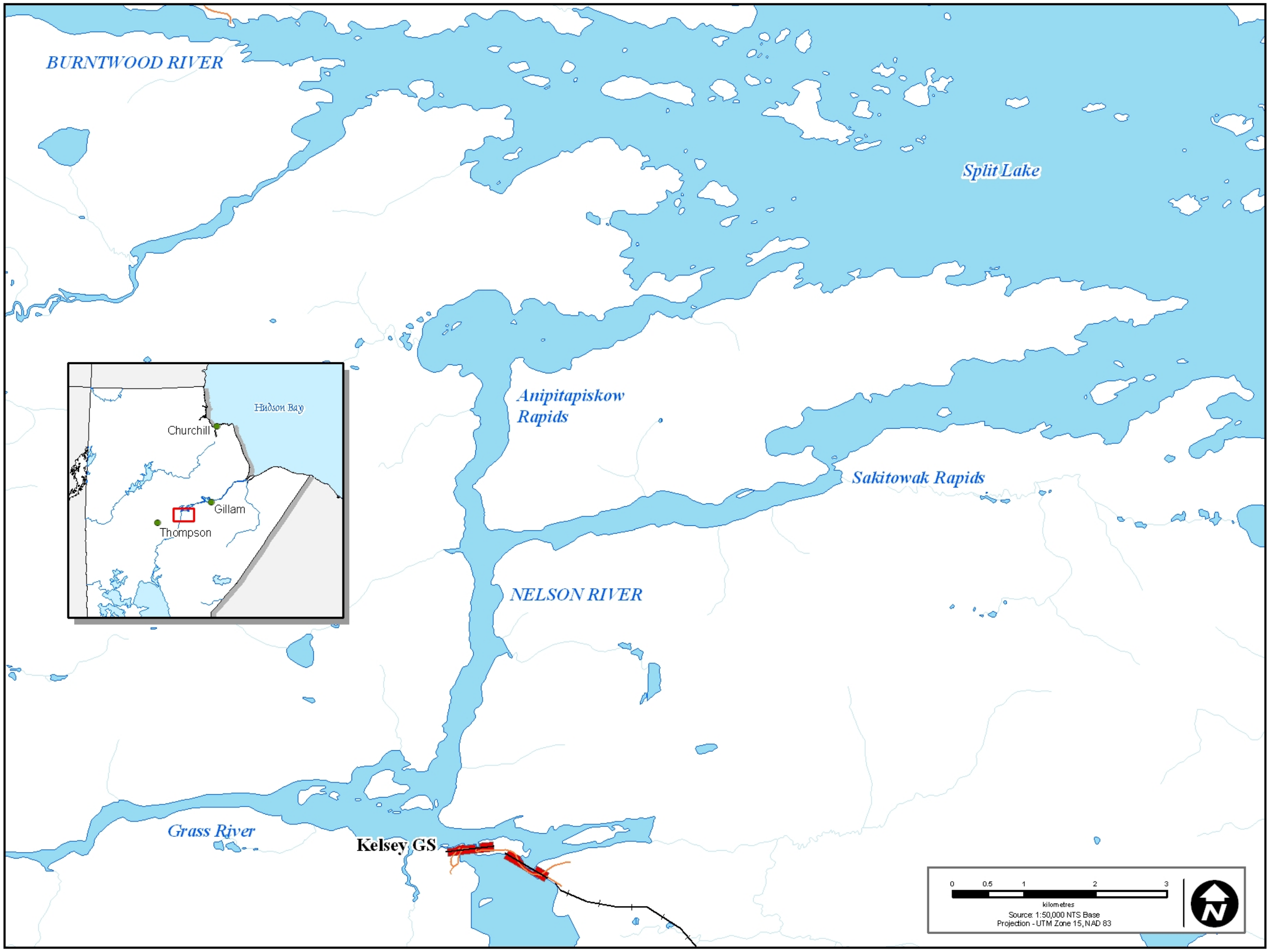



**Figure 1-1. Location of Kelsey GS in northern Manitoba.**


**Figure 1-2. Nelson River with Kelsey GS powerhouse; view from south.**

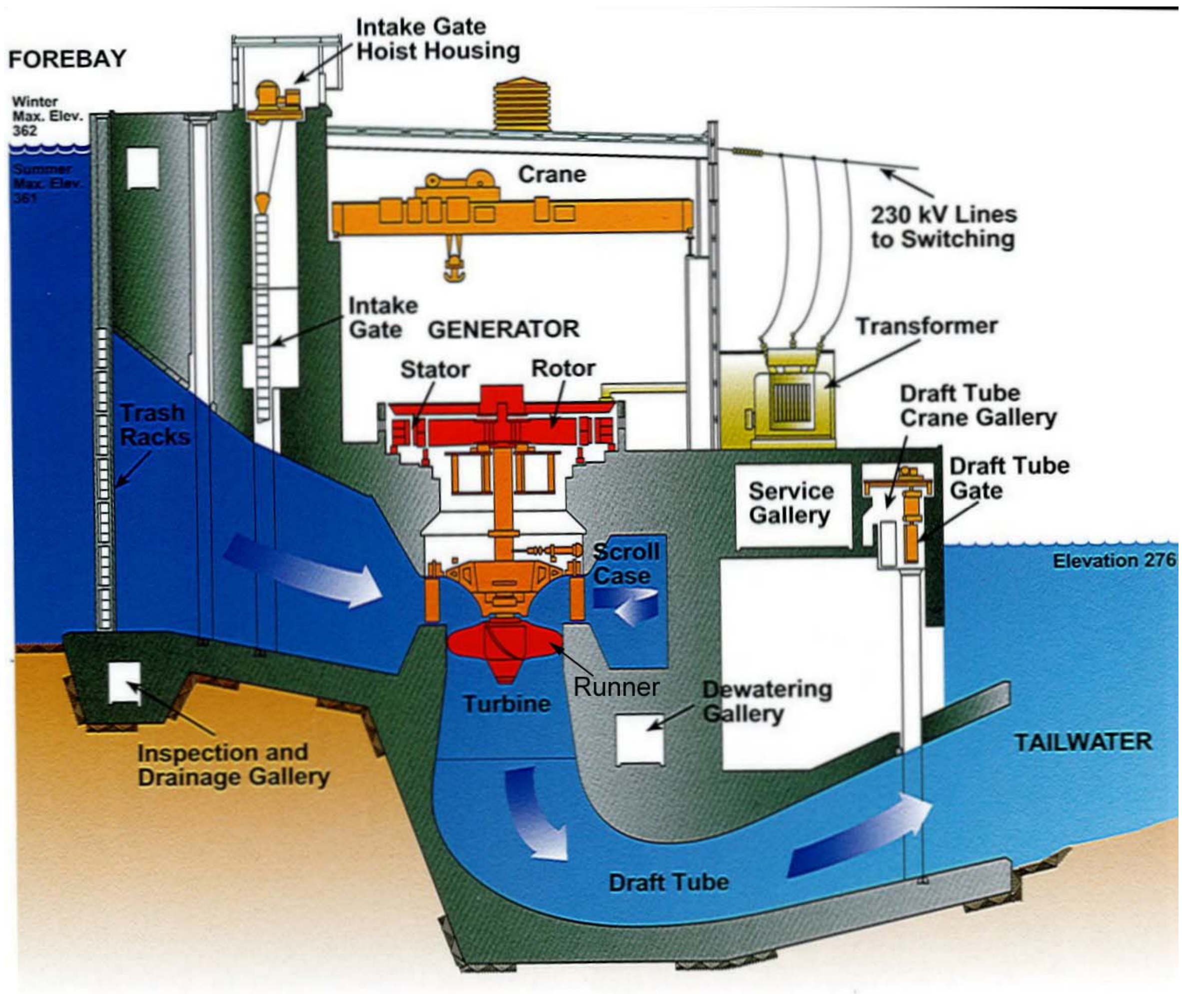



**Figure 2-1. Schematic drawing of a cross-section through the powerhouse of a typical Manitoba Hydro Generation Station showing direction of water flow past the turbine runner.**

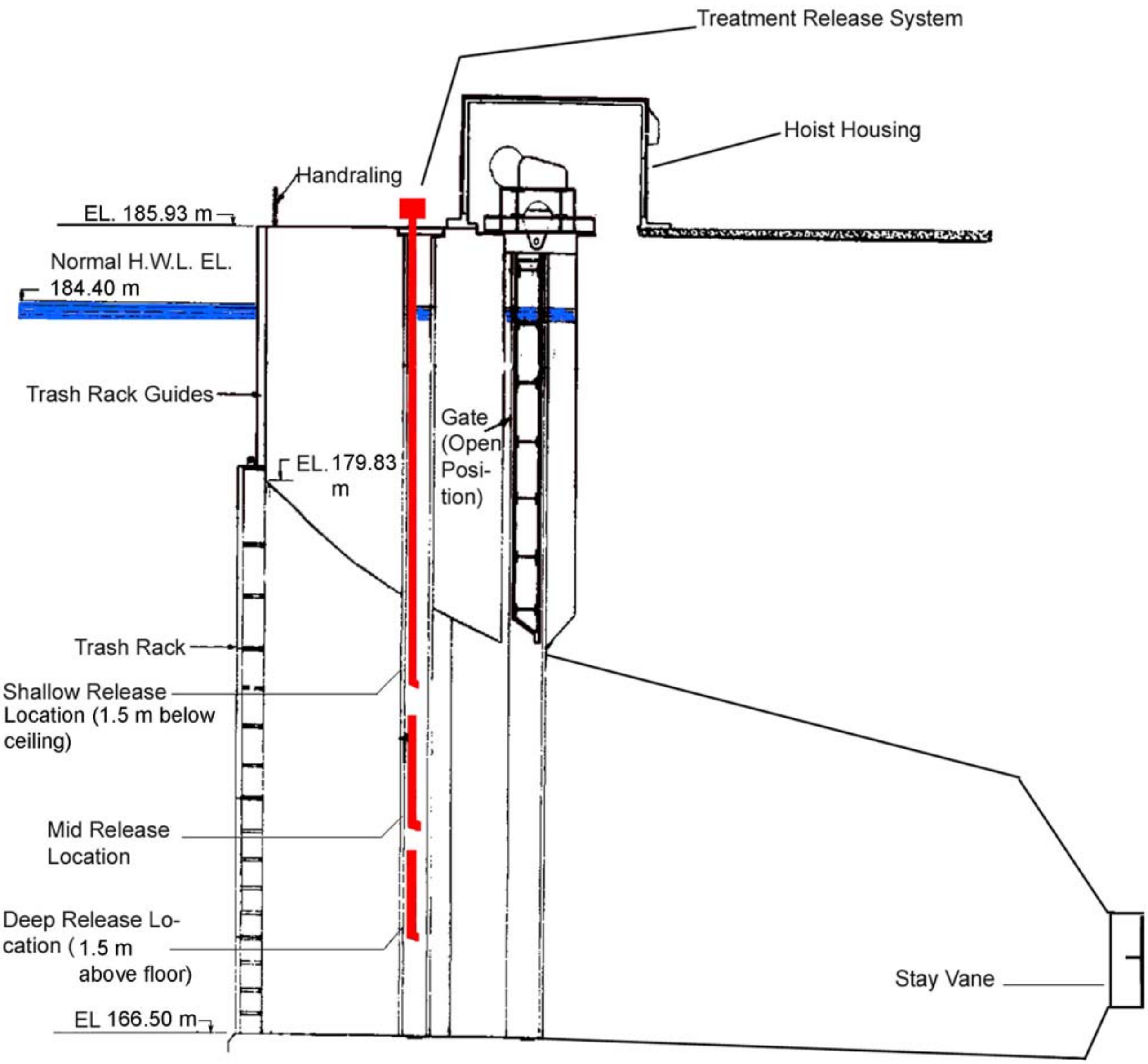
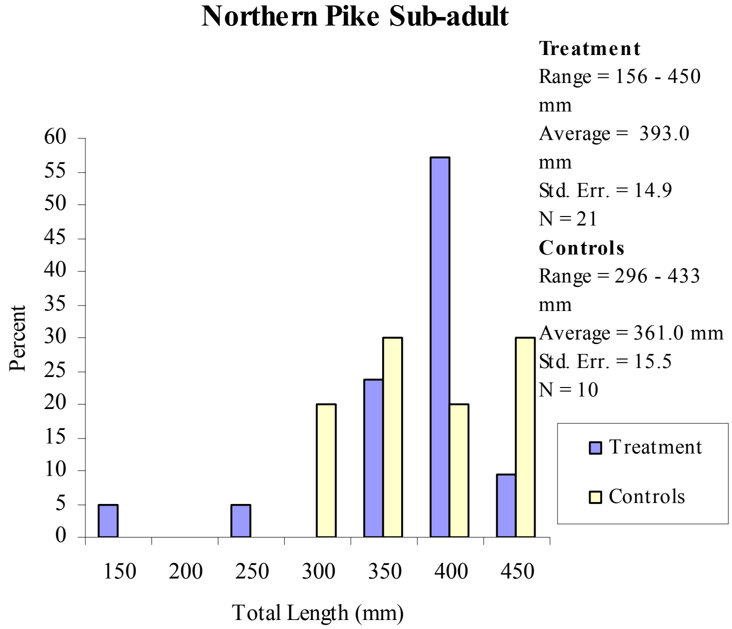



**Figure 2-2. Cross-section of the Kelsey GS head works and turbine intake, showing position of fish release pipe (red) at the three release locations.**


**Figure 2-3. Control site with induction apparatus and release hose extending into Nelson River.**


**Figure 2-4. Fish holding pools on forebay deck.**



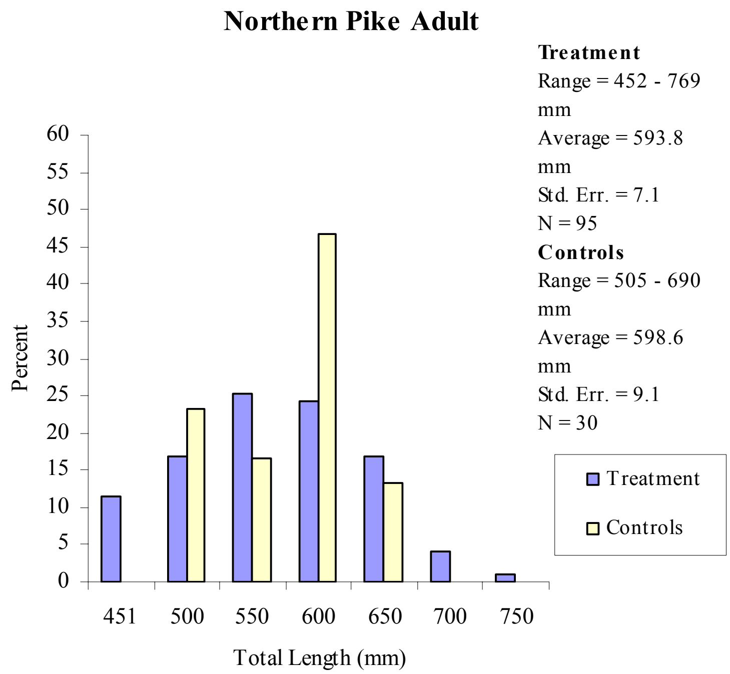
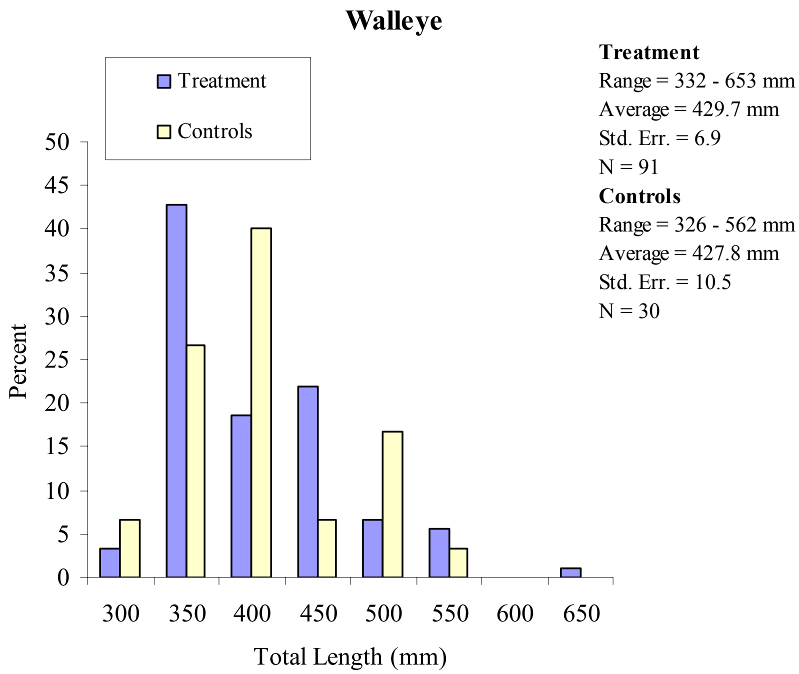




**Figure 2-5. Total length (mm) frequency distribution of all treatment and control recaptured northern pike passed through Unit 5 at approximately 314 cms and released at three locations (shallow, mid, and deep) at Kelsey Generating Station, June 2008. Sub-adults were not released at deep location. Controls released into the tailrace.**



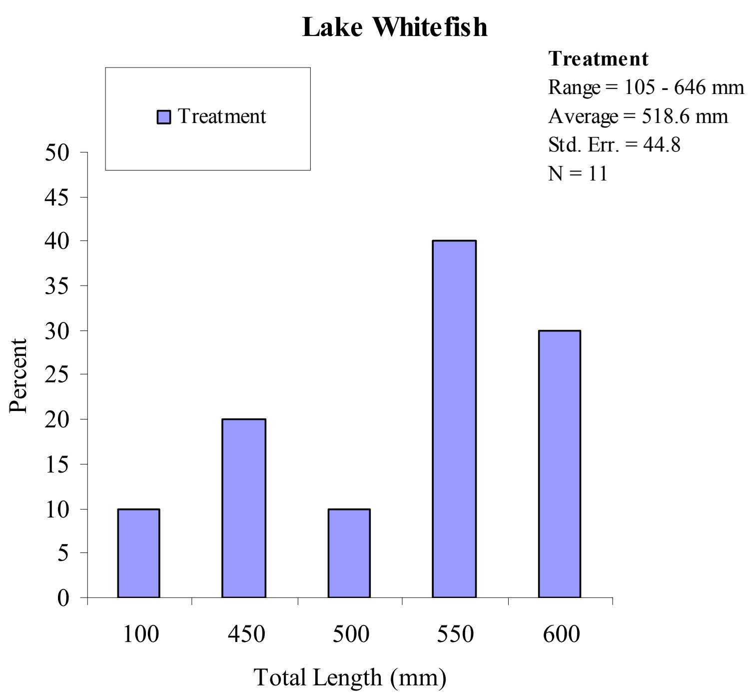




**Figure 2-6. Total length (mm) frequency distribution of all treatment and control recaptured walleye and lake whitefish passed through Unit 5 at approximately 314 cms and released at three locations (shallow, mid and deep) at Kelsey Generating Station, June 2008. Controls released into the tailrace.**

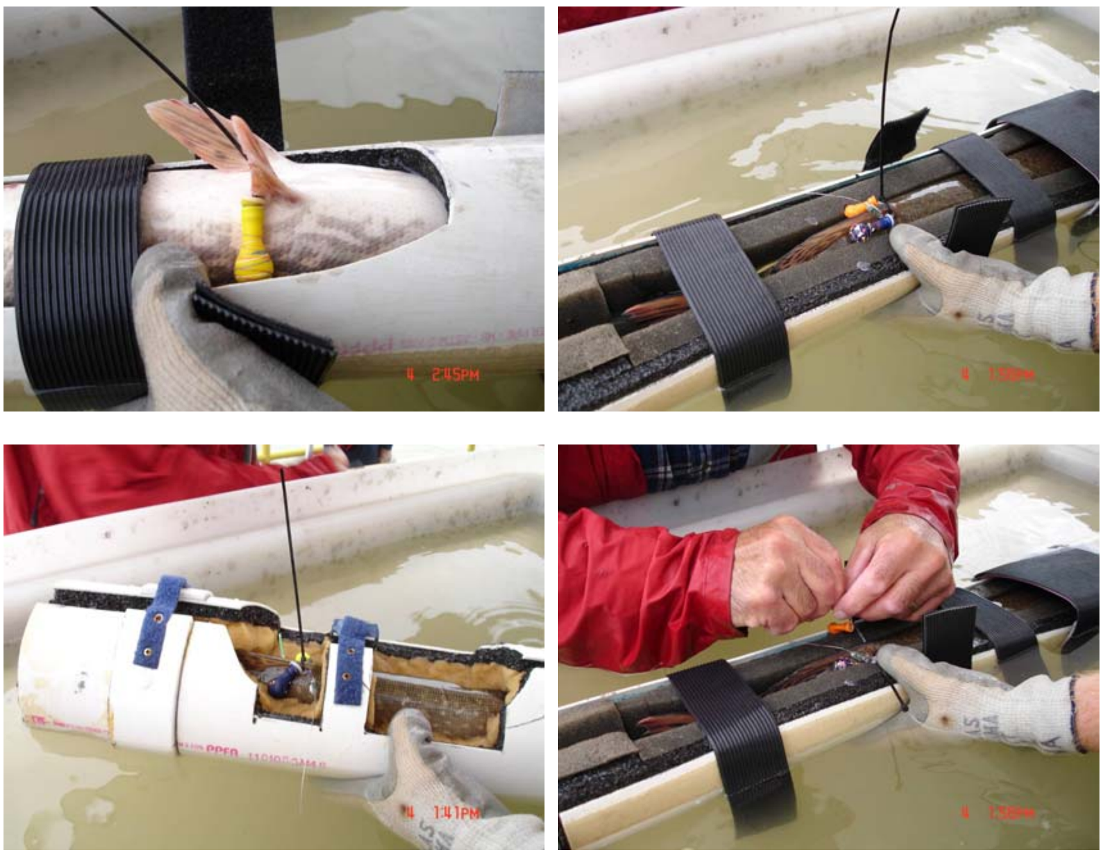


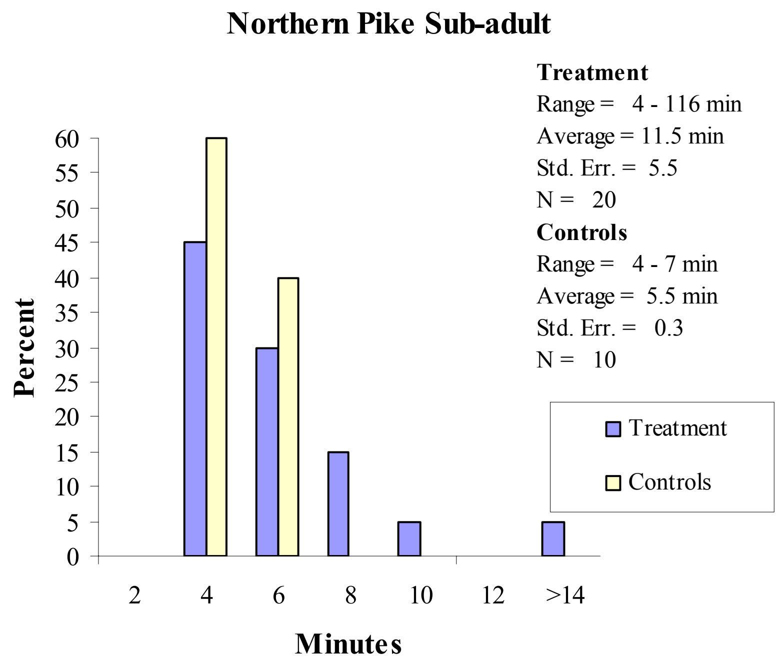
**Figure 2-7. HI-Z tag attachment to adult fish while inside a restraining device.**

**Figure 2-8. HI-Z balloon tagged fish. Upper photo uninflated; lower photo inflated balloons.**


**Figure 2-9 Induction apparatus (upper photo) and release pipe (lower photo) for introducing fish into Unit 5 Turbine intake at the Kelsey GS.**

**Figure 2-10. Steel support frame and lower section of the 20 cm diameter PVC release pipe used to release fish into Unit 2 intake at the Kelsey GS (2006 photo).**

**Figure 2-11. Top photo: Retrieving a HI-Z tagged fish. Bottom photo: Tracking radio tagged fish with a loop antenna.**



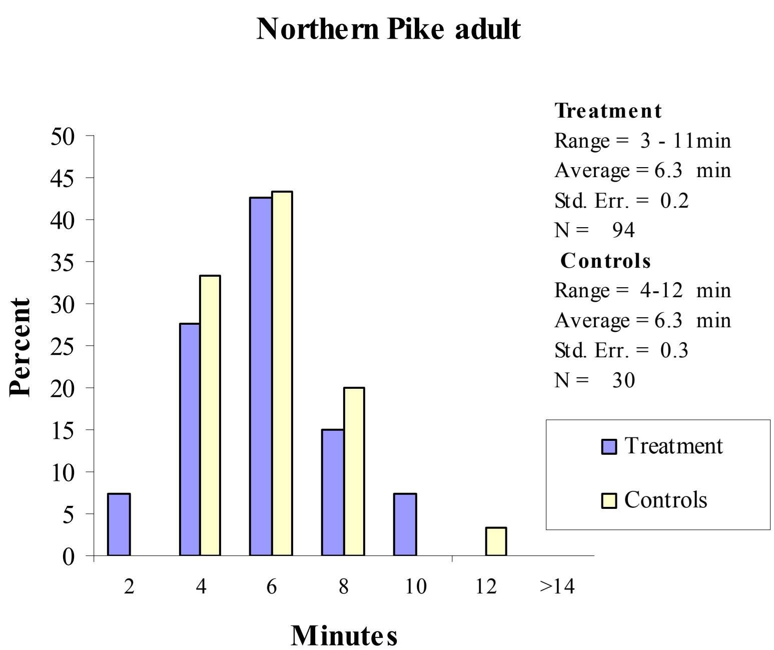
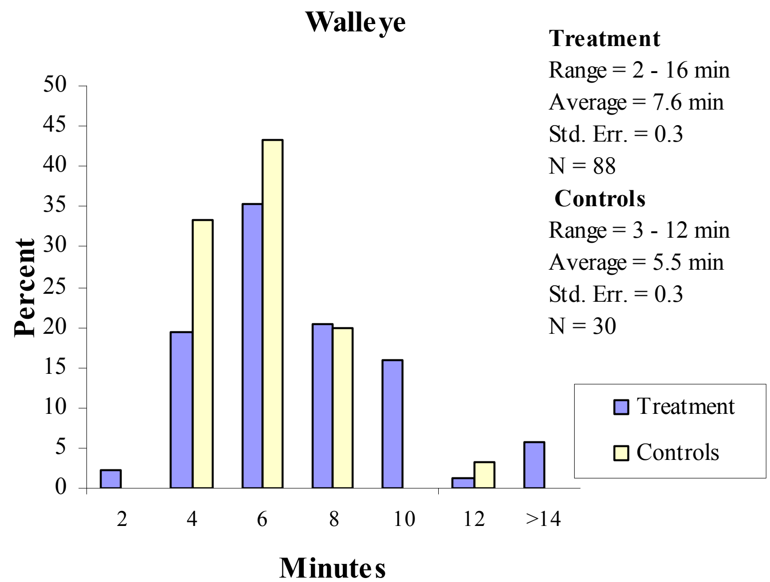




**Figure 3-1. Frequency distribution of retrieval times (minutes) of all treatment and controls on recaptured northern pike passed through Unit 5 at approximately 314 cms and released at three locations (shallow, mid and deep) at Kelsey Generating Station, June 2008. Sub-adults were not released at deep location. Controls released into the tailrace.**



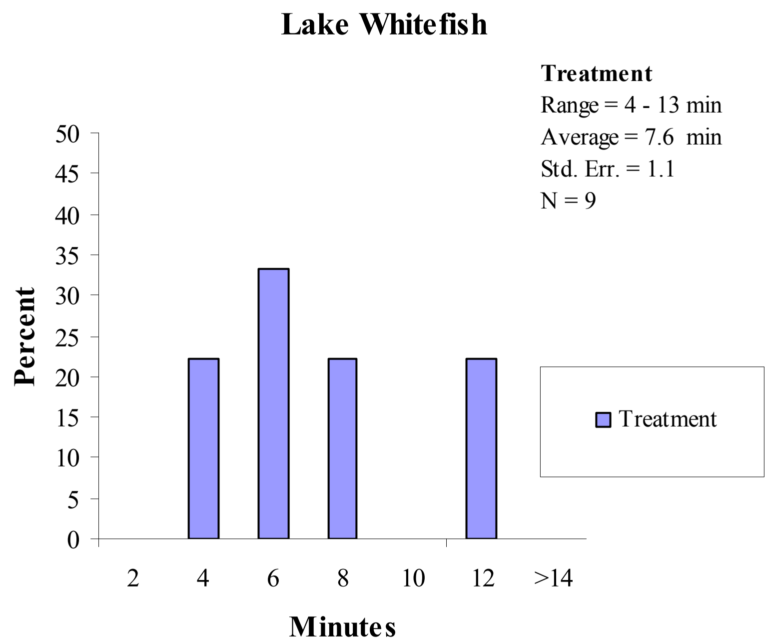
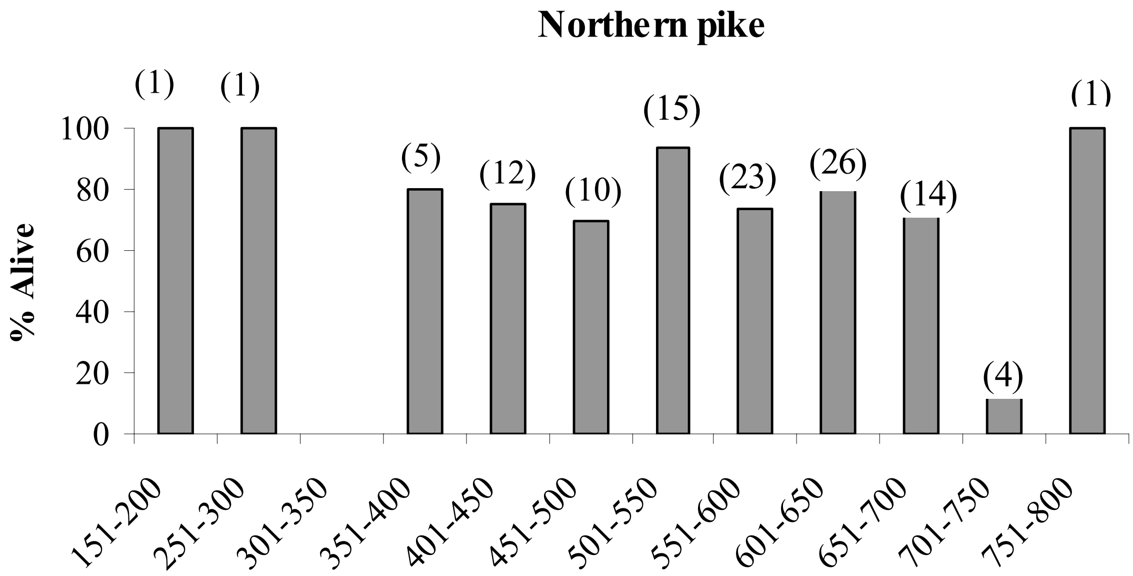




**Figure 3-2. Frequency distribution of retrieval times (minutes) of all treatment and controls on recaptured walleye and lake whitefish passed through Unit 5 at approximately 314 cms and released at three locations (shallow, mid and deep) at Kelsey Generating Station, June 2008. Controls released into the tailrace.**



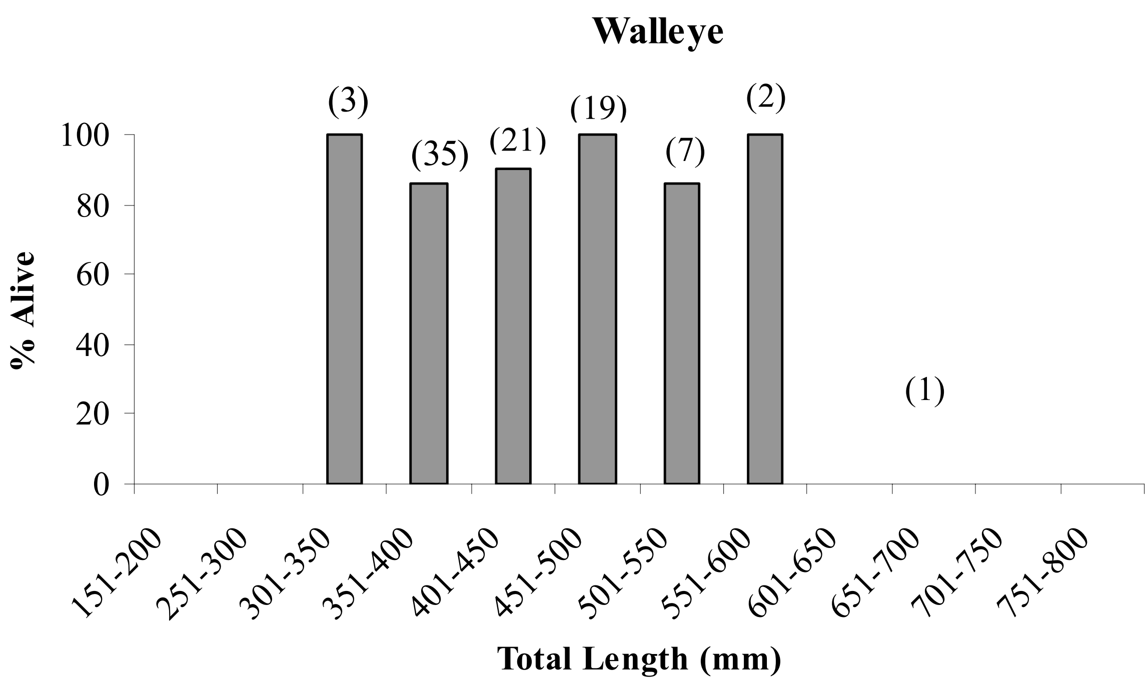




**Figure 3-3. Relationship of turbine passed alive fish versus total length of northern pike and walleye in passage through Unit 5 of the Kelsey GS, June 2008. Number of fish examined post-passage in each length group is given in parentheses.**

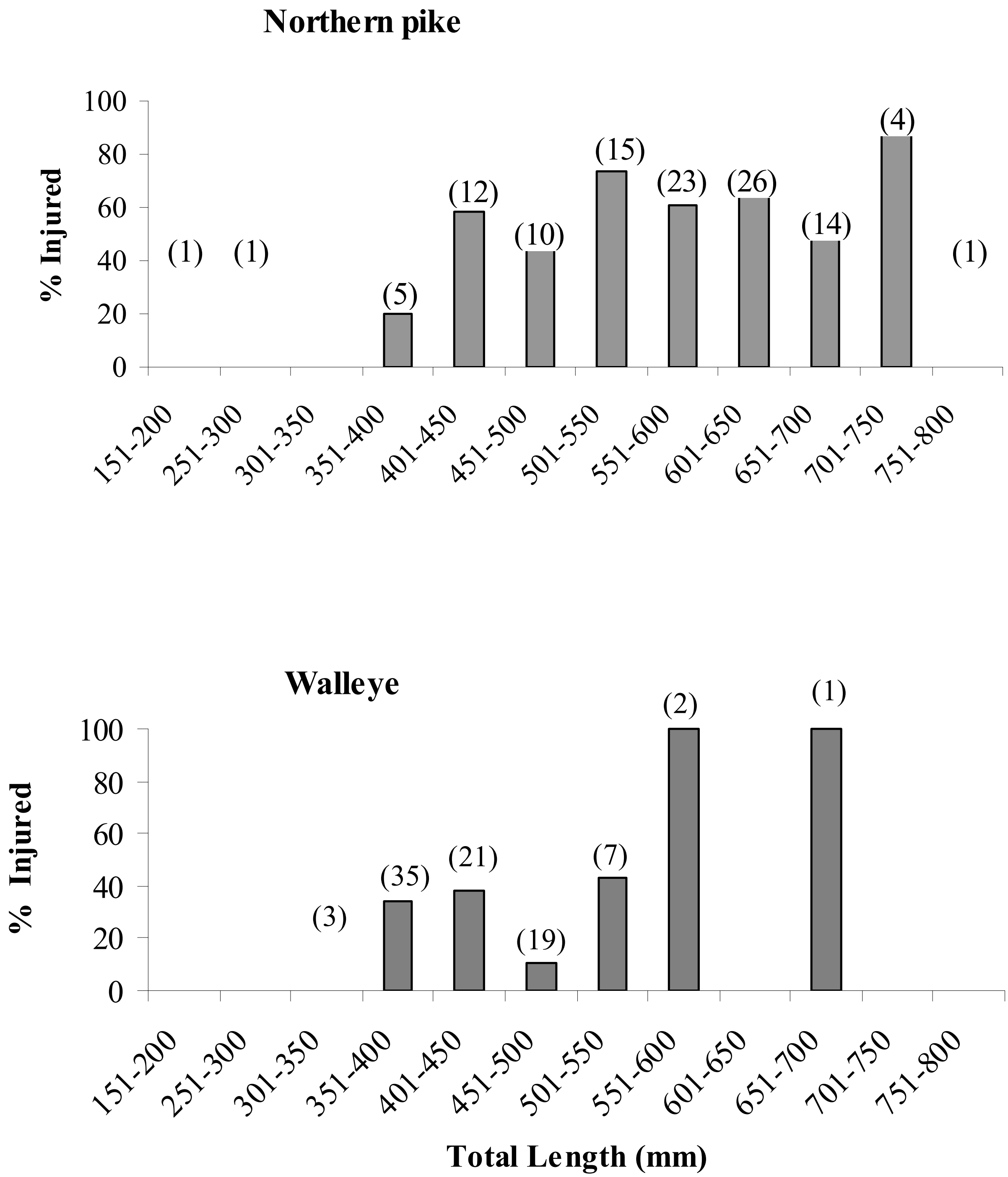



**Figure 3-4. Relationship of turbine passage related injury versus total length of northern pike and walleye in passage through the Kelsey GS, June 2008. Number of fish examined post-passage in each length group is given in parentheses.**


**Figure 3-5. Old turbine blade (top picture) and new turbine blade (bottom picture), showing leading edge.**

# APPENDIX TABLE A

# PHYSICAL PARAMETERS AND DAILY TAG RECAPTURE DATA

**Appendix Table A-1**

**Number of northern pike, walleye, and lake whitefish released and hydrological parameters (averages for each scenario) for the turbine survival study conducted at Kelsey GS in June 2008. Treatment fish were released at three locations (deep, mid, and shallow) in front of the turbine intake of Unit 5. Control fish (northern pike and walleye only) were released into the tailrace.**

| Release Location | Fish released (n) | Forebay Elevation (m) | Tailwater Elevation (m) | Head (m) | Discharge Unit 5 (cms) | Discharge Total (cms) |
|---|---|---|---|---|---|---|
| | | | **Northern Pike** | | | |
| **Deep** | 35 | 184.2 | 167.6 | 16.6 | 313.3 | 1493.6 |
| **Mid** | 41 | 184.3 | 167.4 | 16.9 | 313.5 | 1460.1 |
| **Shallow** | 40 | 184.4 | 167.7 | 16.7 | 312.7 | 1477.9 |
| **Controls** | 40 | 184.3 | 167.7 | 16.6 | 314.7 | 1488.6 |
| | | | **Walleye** | | | |
| **Deep** | 30 | 184.3 | 167.6 | 16.7 | 314.3 | 1483.9 |
| **Mid** | 31 | 184.3 | 167.4 | 16.9 | 313.5 | 1484.1 |
| **Shallow** | 30 | 184.3 | 167.7 | 16.6 | 313.7 | 1477.6 |
| **Controls** | 30 | 184.3 | 167.6 | 16.7 | 314.2 | 1495.0 |
| | | | **Lake Whitefish** | | | |
| **Deep** | 1 | 184.3 | 167.3 | 17.0 | 314.1 | 1489.1 |
| **Shallow** | 10 | 184.3 | 167.8 | 16.5 | 314.2 | 1487.4 |

**Appendix Table A-2**

**Daily tag-recapture data for adult (> 450 mm) and sub-adult (<451 mm) northern pike, walleye, and lake whitefish passed through the Unit 5 turbine at Kelsey GS in June 2008. Fish were released at three locations (shallow, mid and deep) in front of the turbine intake. Control fish were released into the tailrace.**

| Date | 9-Jun | 10-Jun | 11-Jun | 12-Jun | 14-Jun | 16-Jun | 17-Jun | Totals |
|---|---|---|---|---|---|---|---|---|
| **Northern Pike adult - Deep** | | | | | | | | |
| Number released | 5 | 25 | 5 | | | | | **35** |
| Number alive | 5 | 20 | 3 | | | | | **28** |
| Number recovered dead | 0 | 5 | 2 | | | | | **7** |
| Assigned dead* | 0 | 0 | 0 | | | | | **0** |
| Dislodged tags | | | | | | | | **0** |
| Stationary radio signals | | | | | | | | **0** |
| Undetermined | 0 | 0 | 0 | | | | | **0** |
| Held and Alive 1 h | 5 | 20 | 3 | | | | | **28** |
| Alive 24 h | 5 | 18 | 3 | | | | | **26** |
| Alive 48 h | 5 | 18 | 3 | | | | | **26** |
| **Northern Pike adult - Mid** | | | | | | | | |
| Number released | | | | 28 | 2 | | | **30** |
| Number alive | | | | 24 | 1 | | | **25** |
| Number recovered dead | | | | 4 | 1 | | | **5** |
| Assigned dead* | | | | 0 | 0 | | | **0** |
| Dislodged tags | | | | | | | | **0** |
| Stationary radio signals | | | | | | | | **0** |
| Undetermined | | | | 0 | 0 | | | **0** |
| Held and Alive 1 h | | | | 24 | 1 | | | **25** |
| Alive 24 h | | | | 23 | 1 | | | **24** |
| Alive 48 h | | | | 22 | 1 | | | **23** |
| **Northern Pike adult - Shallow** | | | | | | | | |
| Number released | | | | | 30 | | | **30** |
| Number alive | | | | | 25* | | | **25** |
| Number recovered dead | | | | | 4 | | | **4** |
| Assigned dead* | | | | | 0 | | | **0** |
| Dislodged tags | | | | | | | | **0** |
| Stationary radio signals | | | | | | | | **0** |
| Undetermined | | | | | 1 | | | **1** |
| Held and Alive 1 h | | | | | 24 | | | **24** |
| Alive 24 h | | | | | 23 | | | **23** |
| Alive 48 h | | | | | 21 | | | **21** |

* 1 fish counted as alive based on telemetry actually not recovered

**Appendix Table A-2**

**Continued.**

| | 6/9 | 6/10 | 6/11 | 6/12 | 6/14 | 6/16 | 6/17 | Totals |
|---|---|---|---|---|---|---|---|---|
| | | | | **Northern Pike - sub-adult - Mid** | | | | |
| Number released | | | | 2 | 9 | | | **11** |
| Number alive | | | | 2 | 5 | | | **7** |
| Number recovered dead | | | | 0 | 3 | | | **3** |
| Assigned dead* | | | | 0 | 0 | | | **0** |
| Dislodged tags | | | | | | | | **0** |
| Stationary radio signals | | | | | | | | **0** |
| Undetermined | | | | 0 | 1 | | | **1** |
| Held and Alive 1 h | | | | 2 | 5 | | | **7** |
| Alive 24 h | | | | 2 | 4 | | | **6** |
| Alive 48 h | | | | 2 | 2 | | | **4** |
| | | | | **Northern Pike - sub-adult - Shallow** | | | | |
| Number released | | | | | | | 10 | **10** |
| Number alive | | | | | | | 9 | **9** |
| Number recovered dead | | | | | | | 1 | **1** |
| Assigned dead* | | | | | | | 0 | **0** |
| Dislodged tags | | | | | | | | **0** |
| Stationary radio signals | | | | | | | | **0** |
| Undetermined | | | | | | | 0 | **0** |
| Held and Alive 1 h | | | | | | | 9 | **9** |
| Alive 24 h | | | | | | | 9 | **9** |
| Alive 48 h | | | | | | | 9 | **9** |
| | | | | **Walleye - Deep** | | | | |
| Number released | | | 30 | | | | | **30** |
| Number alive | | | 26 | | | | | **26** |
| Number recovered dead | | | 3 | | | | | **3** |
| Assigned dead* | | | 1 | | | | | **1** |
| Dislodged tags | | | | | | | | **0** |
| Stationary radio signals | | | 1 | | | | | **1** |
| Undetermined | | | 0 | | | | | **0** |
| Held and Alive 1 h | | | 26 | | | | | **26** |
| Alive 24 h | | | 26 | | | | | **26** |
| Alive 48 h | | | 26 | | | | | **26** |

**Appendix Table A-2**

**Continued.**

| | 6/9 | 6/10 | 6/11 | 6/12 | 6/14 | 6/16 | 6/17 | Totals |
|---|---|---|---|---|---|---|---|---|
| | | | | **Walleye - Mid** | | | | |
| Number released | | | | 31 | | | | **31** |
| Number alive | | | | 28 | | | | **28** |
| Number recovered dead | | | | 2 | | | | **2** |
| Assigned dead* | | | | 1 | | | | **1** |
| Dislodged tags | | | | | | | | **0** |
| Stationary radio signals | | | | 1 | | | | **1** |
| Undetermined | | | | 0 | | | | **0** |
| Held and Alive 1 h | | | | 28 | | | | **28** |
| Alive 24 h | | | | 28 | | | | **28** |
| Alive 48 h | | | | 28 | | | | **28** |
| | | | | **Walleye - Shallow** | | | | |
| Number released | | | | | | 30 | | **30** |
| Number alive | | | | | | 25 | | **25** |
| Number recovered dead | | | | | | 4 | | **4** |
| Assigned dead* | | | | | | 0 | | **0** |
| Dislodged tags | | | | | | | | **0** |
| Stationary radio signals | | | | | | | | **0** |
| Undetermined | | | | | | 1 | | **1** |
| Held and Alive 1 h | | | | | | 25 | | **25** |
| Alive 24 h | | | | | | 25 | | **25** |
| Alive 48 h | | | | | | 25 | | **25** |
| | | | | **Lake Whitefish - Deep** | | | | |
| Number released | | | 1 | | | | | **1** |
| Number alive | | | 0 | | | | | **0** |
| Number recovered dead | | | 0 | | | | | **0** |
| Assigned dead* | | | 0 | | | | | **0** |
| Dislodged tags | | | | | | | | **0** |
| Stationary radio signals | | | | | | | | **0** |
| Undetermined | | | 1 | | | | | **1** |
| Held and Alive 1 h | | | 0 | | | | | **0** |
| Alive 24 h | | | 0 | | | | | **0** |
| Alive 48 h | | | 0 | | | | | **0** |

**Appendix Table A-2**

**Continued.**

| | 6/9 | 6/10 | 6/11 | 6/12 | 6/14 | 6/16 | 6/17 | Totals |
|---|---|---|---|---|---|---|---|---|
| | | | | **Lake Whitefish - Shallow** | | | | |
| Number released | | | | | 2 | 7 | 1 | **10** |
| Number alive | | | | | 2 | 4 | 1 | **7** |
| Number recovered dead | | | | | 0 | 2 | 0 | **2** |
| Assigned dead* | | | | | 0 | 0 | 0 | **0** |
| Dislodged tags | | | | | | | | **0** |
| Stationary radio signals | | | | | | | | **0** |
| Undetermined | | | | | 0 | 1 | 0 | **1** |
| Held and Alive 1 h | | | | | 2 | 4 | 1 | **7** |
| Alive 24 h | | | | | 2 | 4 | 1 | **7** |
| Alive 48 h | | | | | 2 | 3 | 1 | **6** |
| | | | | **Northern Pike - adult - Control** | | | | |
| Number released | | 15 | | | 15 | | | **30** |
| Number alive | | 15 | | | 15 | | | **30** |
| Number recovered dead | | 0 | | | 0 | | | **0** |
| Assigned dead* | | 0 | | | 0 | | | **0** |
| Dislodged tags | | | | | | | | **0** |
| Stationary radio signals | | | | | | | | **0** |
| Undetermined | | 0 | | | 0 | | | **0** |
| Held and Alive 1 h | | 15 | | | 15 | | | **30** |
| Alive 24 h | | 15 | | | 15 | | | **30** |
| Alive 48 h | | 15 | | | 15 | | | **30** |
| | | | | **Northern Pike - sub-adult - Control** | | | | |
| Number released | | | | | | | 10 | **10** |
| Number alive | | | | | | | 9 | **9** |
| Number recovered dead | | | | | | | 1 | **1** |
| Assigned dead* | | | | | | | 0 | **0** |
| Dislodged tags | | | | | | | | **0** |
| Stationary radio signals | | | | | | | | **0** |
| Undetermined | | | | | | | 0 | **0** |
| Held and Alive 1 h | | | | | | | 9 | **9** |
| Alive 24 h | | | | | | | 9 | **9** |
| Alive 48 h | | | | | | | 6 | **6** |

**Appendix Table A-2**

**Continued.**

| | 6/9 | 6/10 | 6/11 | 6/12 | 6/14 | 6/16 | 6/17 | Totals |
|---|---|---|---|---|---|---|---|---|
| | | | **Walleye - Control** | | | | | |
| Number released | | | 15 | | | 15 | | **30** |
| Number alive | | | 15 | | | 15 | | **30** |
| Number recovered dead | | | 0 | | | 0 | | **0** |
| Assigned dead* | | | 0 | | | 0 | | **0** |
| Dislodged tags | | | | | | | | **0** |
| Stationary radio signals | | | | | | | | **0** |
| Undetermined | | | 0 | | | 0 | | **0** |
| Held and Alive 1 h | | | 15 | | | 15 | | **30** |
| Alive 24 h | | | 15 | | | 15 | | **30** |
| Alive 48 h | | | 15 | | | 15 | | **30** |

*Primarily fish where balloon tag(s) were recaptured

# APPENDIX TABLE B

# STATISTICAL OUTPUTS

**Appendix B**

**Forty-eight hour survival estimates for northern pike adult (> 450 mm) released into Unit 5 intake at 313.7 m $^3$/s (approximately 11,000 cfs) at two release locations, shallow, and mid. Control fish released into the tailrace at Kelsey Generation Station, Nelson River, Manitoba, Canada, June 2008. Control fish released 30, 30 alive and 0 dead; Shallow: 30 released, 22 alive and 7 assigned dead; Mid: 30 released, 23 alive and 7 assigned dead.**

---

RESULTS FOR REDUCED MODEL (EQUAL LIVE/DEAD RECOVERY)

| | estim. | std.err. | |
|---|---|---|---|
| S1 = | 1.0 | N/A | Control group survival* |
| Pa = Pd | 0.9889 | (0.0110) | Recovery probability |
| S2 = | 0.7586 | (0.0795) | Shallow survival |
| S3 = | 0.7667 | (0.0772) | Mid survival |

* -- Because of constraints in the data set, this probability is assumed equal to 1.0; not estimated.
log-likelihood : -37.8197

**Tau = 0.7586 (0.0795) Shallow/Control ratio**
**Tau = 0.7667 (0.0772) Mid/Control ratio**

Z statistic for the equality of equal turbine survivals: 0.0726

Compare with quantiles of the normal distribution:

| | 1-tailed | 2-tailed |
|---|---|---|
| For significance level 0.10: | 1.2816 | 1.6449 |
| For significance level 0.05: | 1.6449 | 1.9600 |
| For significance level 0.01: | 2.3263 | 2.5758 |

Variance-Covariance matrix for estimated probabilities:

| | | | |
|---|---|---|---|
| 0.00000000 | 0.00000000 | 0.00000000 | 0.00000000 |
| 0.00000000 | 0.00012209 | 0.00000000 | 0.00000000 |
| 0.00000000 | 0.00000000 | 0.00631432 | 0.00000000 |
| 0.00000000 | 0.00000000 | 0.00000000 | 0.00596297 |

Confidence intervals:

| | Shallow Tau | Mid Tau |
|---|---|---|
| 90 percent: | (0.6279, 0.8893) | (0.6396, 0.8937) |
| 95 percent: | (0.6029, 0.9144) | (0.6153, 0.9180) |
| 99 percent: | (0.5540, 0.9632) | (0.5678, 0.9655) |

==================================================

Likelihood ratio statistic for equality of recovery probabilities: 0.9002
Compare with quantiles of the chi-squared distribution with 1 d.f.:
For significance level 0.10: 2.706
For significance level 0.05: 3.841
For significance level 0.01: 6.635

---

**Appendix B**

**One and forty-eight hour survival estimates for walleye released into Unit 5 intake at 313.7 m $^3$/s (approximately 11,000 cfs) at two release locations, shallow, and deep . Control fish released into the tailrace at Kelsey Generation Station, Nelson River, Manitoba, Canada, June 2008. Control fish released 30, 30 alive and 0 dead; Shallow: 30 released, 25 alive and 4 assigned dead; Deep: 30 released, 26 alive and 4 assigned dead.**

---

RESULTS FOR REDUCED MODEL (EQUAL LIVE/DEAD RECOVERY)

| | estim. | std.err. | |
|---|---|---|---|
| S1 = | 1.0 | N/A | Control group survival* |
| Pa = Pd | 0.9889 | (0.0110) | Recovery probability |
| S2 = | 0.8621 | (0.0640) | shallow survival |
| S3 = | 0.8667 | (0.0621) | deep survival |

* -- Because of constraints in the data set, this probability is assumed equal to 1.0; not estimated.
log-likelihood : -28.9090

**Tau = 0.8621 (0.0640) shallow/Control ratio**
**Tau = 0.8667 (0.0621) deep/Control ratio**

Z statistic for the equality of equal turbine survivals: 0.0516

| | | 1-tailed | 2-tailed |
|---|---|---|---|
| For significance level | 0.10: | 1.2816 | 1.6449 |
| For significance level | 0.05: | 1.6449 | 1.9600 |
| For significance level | 0.01: | 2.3263 | 2.5758 |

Variance-Covariance matrix for estimated probabilities:

| | | | |
|---|---|---|---|
| 0.00000000 | 0.00000000 | 0.00000000 | 0.00000000 |
| 0.00000000 | 0.00012209 | 0.00000000 | 0.00000000 |
| 0.00000000 | 0.00000000 | 0.00410021 | 0.00000000 |
| 0.00000000 | 0.00000000 | 0.00000000 | 0.00385186 |

Confidence intervals:

| | shallow Tau | deep Tau |
|---|---|---|
| 90 percent: | (0.7567, 0.9674) | (0.7646, 0.9688) |
| 95 percent: | (0.7366, 0.9876) | (0.7450, 0.9883) |
| 99 percent: | (0.6972, 1.0270) | (0.7069, 1.0265) |

=====================================================

Likelihood ratio statistic for equality of recovery probabilities: 0.9448
Compare with quantiles of the chi-squared distribution with 1 d.f.:
For significance level 0.10: 2.706
For significance level 0.05: 3.841
For significance level 0.01: 6.635

---

**Appendix B**

**One and forty-eight hour survival estimates for walleye released into Unit 5 intake at 313.7 m ³/s (approximately 11,000 cfs) at two release locations, shallow, and mid . Control fish released into the tailrace at Kelsey Generation Station, Nelson River, Manitoba, Canada, June 2008.**
**Control fish released 30, 30 alive and 0 dead; Shallow: 30 released, 25 alive and 4 assigned dead; Mid: 31 released, 28 alive and 3 assigned dead.**

---

RESULTS FOR REDUCED MODEL (EQUAL LIVE/DEAD RECOVERY)
estim. std.err.
S1 = 1.0 N/A Control group survival*
Pa = Pd 0.9890 (0.0109) Recovery probability
S2 = 0.8621 (0.0640) shallow survival
S3 = 0.9032 (0.0531) mid survival

* -- Because of constraints in the data set, this probability is assumed equal to 1.0; not estimated.
log-likelihood : -26.9959

Tau = 0.8621 (0.0640) shallow/Control ratio
Tau = 0.9032 (0.0531) mid/Control ratio

Z statistic for the equality of equal turbine survivals: 0.4948

Compare with quantiles of the normal distribution:

| | 1-tailed | 2-tailed |
|---|---|---|
| For significance level 0.10: | 1.2816 | 1.6449 |
| For significance level 0.05: | 1.6449 | 1.9600 |
| For significance level 0.01: | 2.3263 | 2.5758 |

Variance-Covariance matrix for estimated probabilities:

| | | | |
|---|---|---|---|
| 0.00000000 | 0.00000000 | 0.00000000 | 0.00000000 |
| 0.00000000 | 0.00011943 | 0.00000000 | 0.00000000 |
| 0.00000000 | 0.00000000 | 0.00410021 | 0.00000000 |
| 0.00000000 | 0.00000000 | 0.00000000 | 0.00281964 |

Confidence intervals:

| | Shallow Tau | Mid Tau |
|---|---|---|
| 90 percent: | (0.7567, 0.9674) | (0.8159, 0.9906) |
| 95 percent: | (0.7366, 0.9876) | (0.7991, 1.0073) |
| 99 percent: | (0.6972, 1.0270) | (0.7665, 1.0400) |

=====================================================

Likelihood ratio statistic for equality of recovery probabilities: 1.2177
Compare with quantiles of the chi-squared distribution with 1 d.f.:
For significance level 0.10: 2.706
For significance level 0.05: 3.841
For significance level 0.01: 6.635

---

**Appendix B**

**One hour combined survival estimates for northern pike adult (> 450 mm) released into Unit 5 intake at 313.7 m ³/s (approximately 11,000 cfs) at three release locations, shallow, mid and deep. Control fish released into the tailrace at Kelsey Generation Station, Nelson River, Manitoba, Canada, June 2008. Control fish released 30, 30 alive and 0 dead; Treatment: 95 released, 78 alive and 16 assigned dead.**

---

```
RESULTS FOR REDUCED MODEL (EQUAL LIVE/DEAD RECOVERY)
      estim. std.err.
S =      1.0    N/A      Control group survival*
Pa = Pd  0.9920 (0.0080)   Recovery probability

Tau =    0.8298 (0.0388)   Treatment survival
1-Tau =  0.1702 (0.0388)   Treatment mortality

* --  Because of constraints in the data set, this probability is assumed equal to 1.0; not estimated.
         log-likelihood : -48.709305

         Variance-Covariance matrix for estimated probabilities:
         0.00006  0.00000
         0.00000  0.00150

Profile likelihood intervals:
                         Treatment survival    Treatment mortality
         90 percent:     (0.7601, 0.8870)        (0.1130, 0.2399)
         95 percent:     (0.7455, 0.8964)        (0.1036, 0.2545)
         99 percent:     (0.7159, 0.9133)        (0.0867, 0.2841)
         ===============================================================


         Likelihood ratio statistic for equality of recovery probabilities:          0.551416
         Compare with quantiles of the chi-squared distribution with 1 d.f.:
           For significance level 0.10:  2.706
           For significance level 0.05:  3.841
           For significance level 0.01:  6.635
```

---

**Appendix B**

**One hour combined survival estimates for northern pike sub-adult (< 451 mm) released into Unit 5 intake at 313.7 m ³/s (approximately 11,000 cfs) at three release locations, shallow, mid and deep. Control fish released into the tailrace at Kelsey Generation Station, Nelson River, Manitoba, Canada, June 2008. Control fish released 10, 9 alive and 1 dead; Treatment: 21 released, 16 alive and 4 assigned dead.**

---

RESULTS FOR REDUCED MODEL (EQUAL LIVE/DEAD RECOVERY)
estim. std.err.
S = 0.9000 (0.0949) Control group survival
Pa = Pd 0.9677 (0.0317) Recovery probability

**Tau = 0.8889 (0.1366) Treatment survival**
1-Tau = 0.1111 (0.1366) Treatment mortality

log-likelihood : -17.676560
.
Variance-Covariance matrix for estimated probabilities:

| | | |
|---|---|---|
| 0.00900 | 0.00000 | -0.00889 |
| 0.00000 | 0.00101 | 0.00000 |
| -0.00889 | 0.00000 | 0.01866 |

Profile likelihood intervals:

| | Treatment survival | Treatment mortality |
|---|---|---|
| 90 percent: | (0.6791, 1.0000) | (0.0000, 0.3209) |
| 95 percent: | (0.6390, 1.0000) | (0.0000, 0.3610) |
| 99 percent: | (0.5607, 1.0000) | (0.0000, 0.4393) |

==========================================================

Likelihood ratio statistic for equality of recovery probabilities: 0.392002
Compare with quantiles of the chi-squared distribution with 1 d.f.:
For significance level 0.10: 2.706
For significance level 0.05: 3.841
For significance level 0.01: 6.635
==========================================================

**Appendix B**

**One hour survival estimates for northern pike adult (> 450 mm) released into Unit 5 intake at 313.7 m ³/s (approximately 11,000 cfs) at two release locations, shallow, and deep. Control fish released into the tailrace at Kelsey Generation Station, Nelson River, Manitoba, Canada, June 2008. Control fish released 30, 30 alive and 0 dead; Shallow: 30 released, 25 alive and 4 assigned dead; Deep: 35 released, 28 alive and 7 assigned dead.**

---

RESULTS FOR REDUCED MODEL (EQUAL LIVE/DEAD RECOVERY)

```
                    estim.  std.err.
S1 =      1.0      N/A       Control group survival*
Pa = Pd   0.9895 (0.0105)    Recovery probability
S2 =      0.8621 (0.0640)    Shallow survival
S3 =      0.8000 (0.0676)    Deep survival
```

* -- Because of constraints in the data set, this probability is assumed equal to 1.0; not estimated.
log-likelihood : -34.6972

**Tau = 0.8621 (0.0640) Shallow/Control ratio**
**Tau = 0.8000 (0.0676) Deep/Control ratio**

Z statistic for the equality of equal turbine survivals: 0.6665

Compare with quantiles of the normal distribution:

| | 1-tailed | 2-tailed |
|---|---|---|
| For significance level 0.10: | 1.2816 | 1.6449 |
| For significance level 0.05: | 1.6449 | 1.9600 |
| For significance level 0.01: | 2.3263 | 2.5758 |

Variance-Covariance matrix for estimated probabilities:

| | | | |
|---|---|---|---|
| 0.00000000 | 0.00000000 | 0.00000000 | 0.00000000 |
| 0.00000000 | 0.00010964 | 0.00000000 | 0.00000000 |
| 0.00000000 | 0.00000000 | 0.00410021 | 0.00000000 |
| 0.00000000 | 0.00000000 | 0.00000000 | 0.00457143 |

Confidence intervals:

| | Shallow Tau | Deep Tau |
|---|---|---|
| 90 percent: | (0.7567, 0.9674) | (0.6888, 0.9112) |
| 95 percent: | (0.7366, 0.9876) | (0.6675, 0.9325) |
| 99 percent: | (0.6972, 1.0270) | (0.6259, 0.9741) |

=====================================================

Likelihood ratio statistic for equality of recovery probabilities: 0.4485
Compare with quantiles of the chi-squared distribution with 1 d.f.:
For significance level 0.10: 2.706
For significance level 0.05: 3.841
For significance level 0.01: 6.635

---

**Appendix B**

**One hour survival estimates for northern pike adult (> 450 mm) released into Unit 5 intake at 313.7 m ³/s (approximately 11,000 cfs) at two release locations, shallow, and mid. Control fish released into the tailrace at Kelsey Generation Station, Nelson River, Manitoba, Canada, June 2008. Control fish released 30, 30 alive and 0 dead; Shallow: 30 released, 25 alive and 4 assigned dead; Mid: 30 released, 25 alive and 5 assigned dead.**

---

RESULTS FOR REDUCED MODEL (EQUAL LIVE/DEAD RECOVERY)

| | estim. | std.err. | |
|---|---|---|---|
| S1 = | 1.0 | N/A | Control group survival* |
| Pa = Pd | 0.9889 | (0.0110) | Recovery probability |
| S2 = | 0.8621 | (0.0640) | Shallow survival |
| S3 = | 0.8333 | (0.0680) | Mid survival |

* -- Because of constraints in the data set, this probability is assumed equal to 1.0; not estimated.
log-likelihood : -30.6456

Tau = 0.8621 (0.0640) Shallow/Control ratio
Tau = 0.8333 (0.0680) Mid/Control ratio

Z statistic for the equality of equal turbine survivals: 0.3076

Compare with quantiles of the normal distribution:

| | 1-tailed | 2-tailed |
|---|---|---|
| For significance level 0.10: | 1.2816 | 1.6449 |
| For significance level 0.05: | 1.6449 | 1.9600 |
| For significance level 0.01: | 2.3263 | 2.5758 |

Variance-Covariance matrix for estimated probabilities:

| | | | |
|---|---|---|---|
| 0.00000000 | 0.00000000 | 0.00000000 | 0.00000000 |
| 0.00000000 | 0.00012208 | 0.00000000 | 0.00000000 |
| 0.00000000 | 0.00000000 | 0.00410021 | 0.00000000 |
| 0.00000000 | 0.00000000 | 0.00000000 | 0.00462963 |

Confidence intervals:

| | Shallow Tau | Mid Tau |
|---|---|---|
| 90 percent: | (0.7567, 0.9674) | (0.7214, 0.9453) |
| 95 percent: | (0.7366, 0.9876) | (0.7000, 0.9667) |
| 99 percent: | (0.6972, 1.0270) | (0.6581, 1.0085) |

Likelihood ratio statistic for equality of recovery probabilities: 0.7221
Compare with quantiles of the chi-squared distribution with 1 d.f.:
For significance level 0.10: 2.706
For significance level 0.05: 3.841
For significance level 0.01: 6.635

---

**Appendix B**

**Forty-eight hour combined survival estimates** for northern pike sub-adult (< 451 mm) released into Unit 5 intake at 313.7 m ³/s (approximately 11,000 cfs) at three release locations, shallow, mid and deep. Control fish released into the tailrace at Kelsey Generation Station, Nelson River, Manitoba, Canada, June 2008. Control fish released 10, 6 alive and 4 dead; Treatment: 21 released, 13 alive and 7 assigned dead.**

---

RESULTS FOR REDUCED MODEL (EQUAL LIVE/DEAD RECOVERY)

| | estim. | std.err. | |
|---|---|---|---|
| S = | 0.6333 | (0.0880) | Control group survival |
| Pa = Pd | 0.9677 | (0.0317) | Recovery probability |
| **Tau =** | **1.0** | **N/A** | **Treatment survival*** |
| 1-Tau = | 1.0 | N/A | Treatment mortality* |

* -- Because of constraints in the data set, this probability is assumed equal to 1.0; not estimated.
log-likelihood : -24.132415

Variance-Covariance matrix for estimated probabilities:
0.00774 0.00000
0.00000 0.00101

Profile likelihood intervals:

| | Treatment survival | Treatment mortality |
|---|---|---|
| 90 percent: | (0.6742, 1.0000) | (0.0000, 0.3258) |
| 95 percent: | (0.6165, 1.0000) | (0.0000, 0.3835) |
| 99 percent: | (0.5130, 1.0000) | (0.0000, 0.4870) |

==================================================

Likelihood ratio statistic for equality of recovery probabilities: 8.835364
Compare with quantiles of the chi-squared distribution with 1 d.f.:
For significance level 0.10: 2.706
For significance level 0.05: 3.841
For significance level 0.01: 6.635

** Must use output from one hour survival

**Appendix B**

**Forty-eight hour combined survival estimates for northern pike adult (> 450 mm) released into Unit 5 intake at 313.7 m ³/s (approximately 11,000 cfs) at three release locations, shallow, mid and deep. Control fish released into the tailrace at Kelsey Generation Station, Nelson River, Manitoba, Canada, June 2008. Control fish released 30, 30 alive and 0 dead; Treatment: 95 released, 71 alive and 23 assigned dead.**

---

RESULTS FOR REDUCED MODEL (EQUAL LIVE/DEAD RECOVERY)
estim. std.err.
S = 1.0 N/A Control group survival*
Pa = Pd 0.9920 (0.0080) Recovery probability

**Tau = 0.7553 (0.0443) Treatment survival**
1-Tau = 0.2447 (0.0443) Treatment mortality

* -- Because of constraints in the data set, this probability is assumed equal to 1.0; not estimated.
log-likelihood : -58.127374

Variance-Covariance matrix for estimated probabilities:
0.00006 0.00000
0.00000 0.00197

Profile likelihood intervals:

| | Treatment survival | Treatment mortality |
|---|---|---|
| 90 percent: | (0.6780, 0.8230) | (0.1770, 0.3220) |
| 95 percent: | (0.6623, 0.8346) | (0.1654, 0.3377) |
| 99 percent: | (0.6310, 0.8561) | (0.1439, 0.3690) |

==================================================

Likelihood ratio statistic for equality of recovery probabilities: 0.551416
Compare with quantiles of the chi-squared distribution with 1 d.f.:
For significance level 0.10: 2.706
For significance level 0.05: 3.841
For significance level 0.01: 6.635

---

**Appendix B**

**Forty-eight hour survival estimates for northern pike adult (> 450 mm) released into Unit 5 intake at 313.7 m ³/s (approximately 11,000 cfs) at two release locations, shallow, and deep. Control fish released into the tailrace at Kelsey Generation Station, Nelson River, Manitoba, Canada, June 2008. Control fish released 30, 30 alive and 0 dead; Shallow: 30 released, 22 alive and 7 assigned dead; Deep: 35 released, 26 alive and 9 assigned dead.**

---

RESULTS FOR REDUCED MODEL (EQUAL LIVE/DEAD RECOVERY)

| | estim. | std.err. | |
|---|---|---|---|
| S1 = | 1.0 | N/A | Control group survival* |
| Pa = Pd | 0.9895 | (0.0105) | Recovery probability |
| S2 = | 0.7586 | (0.0795) | Shallow survival |
| S3 = | 0.7429 | (0.0739) | Deep survival |

* -- Because of constraints in the data set, this probability is assumed equal to 1.0; not estimated.
log-likelihood : -41.5275

**Tau = 0.7586 (0.0795) Shallow/Control ratio**
**Tau = 0.7429 (0.0739) Deep/Control ratio**

Z statistic for the equality of equal turbine survivals: 0.1453

Compare with quantiles of the normal distribution:

| | 1-tailed | 2-tailed |
|---|---|---|
| For significance level 0.10: | 1.2816 | 1.6449 |
| For significance level 0.05: | 1.6449 | 1.9600 |
| For significance level 0.01: | 2.3263 | 2.5758 |

Variance-Covariance matrix for estimated probabilities:

| | | | |
|---|---|---|---|
| 0.00000000 | 0.00000000 | 0.00000000 | 0.00000000 |
| 0.00000000 | 0.00010964 | 0.00000000 | 0.00000000 |
| 0.00000000 | 0.00000000 | 0.00631432 | 0.00000000 |
| 0.00000000 | 0.00000000 | 0.00000000 | 0.00545773 |

Confidence intervals:

| | Shallow Tau | Deep Tau |
|---|---|---|
| 90 percent: | (0.6279, 0.8893) | (0.6213, 0.8644) |
| 95 percent: | (0.6029, 0.9144) | (0.5981, 0.8877) |
| 99 percent: | (0.5540, 0.9632) | (0.5526, 0.9331) |

=====================================================

Likelihood ratio statistic for equality of recovery probabilities: 0.7504
Compare with quantiles of the chi-squared distribution with 1 d.f.:
For significance level 0.10: 2.706
For significance level 0.05: 3.841
For significance level 0.01: 6.635

---

**Appendix B**

**Combined one and forty-eight hour survival estimates for walleye released into Unit 5 intake at 313.7 m $^3$/s (approximately 11,000 cfs) at three release locations, shallow, mid and deep . Control fish released into the tailrace at Kelsey Generation Station, Nelson River, Manitoba, Canada, June 2008. Control fish released 30, 30 alive and 0 dead; Combine treatment: 91 released, 79 alive and 11 assigned dead.**

---

```
====================================================
RESULTS FOR REDUCED MODEL (EQUAL LIVE/DEAD RECOVERY)
        estim. std.err.
S =      1.0     N/A       Control group survival*
Pa = Pd  0.9917 (0.0082)   Recovery probability

Tau =    0.8778 (0.0345)   Combine survival
1-Tau =  0.1222 (0.0345)   combine mortality
```

* -- Because of constraints in the data set, this probability is assumed equal to 1.0; not estimated.
log-likelihood : -39.211289

```
            Variance-Covariance matrix for estimated probabilities:
            0.00007  0.00000
            0.00000  0.00119

Profile likelihood intervals:
                             combine survival    combine mortality
            90 percent:      (0.8137, 0.9269)    (0.0731, 0.1863)
            95 percent:      (0.7998, 0.9346)    (0.0654, 0.2002)
            99 percent:      (0.7714, 0.9480)    (0.0520, 0.2286)
            ====================================================

            Likelihood ratio statistic for equality of recovery probabilities:     0.572604
            Compare with quantiles of the chi-squared distribution with 1 d.f.:
             For significance level 0.10:  2.706
             For significance level 0.05:  3.841
             For significance level 0.01:  6.635
```

---

**Appendix B**

**Malady-free rates for northern pike adult (> 450 mm) released into Unit 5 intake at 313.7 m $^3$/s (approximately 11,000 cfs) at two release locations, shallow, and deep. Control fish released into the tailrace at Kelsey Generation Station, Nelson River, Manitoba, Canada, June 2008. Control fish released: 30, 30 alive no maladies and 0 with maladies; shallow: 28 released, 13 alive no maladies and 15 with maladies; deep: 35 released, 10 alive no maladies and 25 with maladies.**

---

RESULTS FOR REDUCED MODEL (EQUAL LIVE/DEAD RECOVERY)

| | estim. | std.err. | |
|---|---|---|---|
| S1 = | 1.0 | N/A | Control group malady free rate* |
| Pa = Pd | 1.0 | N/A | Recovery probability* |
| S2 = | 0.4643 | (0.0942) | shallow malady free rate |
| S3 = | 0.2857 | (0.0764) | deep malady free rate |

* -- Because of constraints in the data set, this probability is assumed equal to 1.0; not estimated.
log-likelihood : -40.2761

**Tau = 0.4643 (0.0942) shallow/Control ratio**
**Tau = 0.2857 (0.0764) deep/Control ratio**

Z statistic for the equality of malady free rates: 1.4721
Compare with quantiles of the normal distribution:

| | 1-tailed | 2-tailed |
|---|---|---|
| For significance level 0.10: | 1.2816 | 1.6449 |
| For significance level 0.05: | 1.6449 | 1.9600 |
| For significance level 0.01: | 2.3263 | 2.5758 |

Variance-Covariance matrix for estimated probabilities:

| | | | |
|---|---|---|---|
| 0.00000000 | 0.00000000 | 0.00000000 | 0.00000000 |
| 0.00000000 | 0.00000000 | 0.00000000 | 0.00000000 |
| 0.00000000 | 0.00000000 | 0.00888302 | 0.00000000 |
| 0.00000000 | 0.00000000 | 0.00000000 | 0.00583094 |

Confidence intervals:

| | shallow Tau | deep Tau |
|---|---|---|
| 90 percent: | (0.3092, 0.6193) | (0.1601, 0.4113) |
| 95 percent: | (0.2796, 0.6490) | (0.1361, 0.4354) |
| 99 percent: | (0.2216, 0.7070) | (0.0891, 0.4823) |

==================================================

Likelihood ratio statistic for equality of recovery probabilities: 0.0000
Compare with quantiles of the chi-squared distribution with 1 d.f.:
For significance level 0.10: 2.706
For significance level 0.05: 3.841
For significance level 0.01: 6.635

---

* includes Loss of Equilibrium and Major Scale Loss

**Appendix B**

**Combined malady-free rates for northern pike adult (> 450 mm) released into Unit 5 intake at 313.7 m ³/s (approximately 11,000 cfs) at three release locations, shallow, mid and deep. Control fish released into the tailrace at Kelsey Generation Station, Nelson River, Manitoba, Canada, June 2008. Combined Control fish released: 30, 30 alive no maladies and 0 with maladies; treatment: 93 released, 35 alive no maladies and 58 with maladies.**

---

RESULTS FOR REDUCED MODEL (EQUAL LIVE/DEAD RECOVERY)

| | estim. | std.err. | |
|---|---|---|---|
| S = | 1.0 | N/A | Control group malady free rate* |
| Pa = Pd | 1.0 | N/A | Recovery probability* |

Tau = 0.3763 (0.0502) treatment malady free rate
1-Tau = 0.6237 (0.0502) treatment mortality

* -- Because of constraints in the data set, this probability is assumed equal to 1.0; not estimated.
log-likelihood : -61.588876

Variance-Covariance matrix for estimated probabilities: 0.00252

Profile likelihood intervals:

| | treatment malady free rate | treatment mortality |
|---|---|---|
| 90 percent: | (0.3646, 1.0000) | (0.0000, 0.6354) |
| 95 percent: | (0.0000, 1.0000) | (0.0000, 1.0000) |
| 99 percent: | (0.0000, 1.0000) | (0.0000, 1.0000) |

====================================================

Likelihood ratio statistic for equality of recovery probabilities: 0.000000
Compare with quantiles of the chi-squared distribution with 1 d.f.:
For significance level 0.10: 2.706
For significance level 0.05: 3.841
For significance level 0.01: 6.635

---

* includes Loss of Equilibrium and Major Scale Loss

**Appendix B**

**Combined malady-free rates for northern pike sub adult (< 451 mm) released into Unit 5 intake at 313.7 m ³/s (approximately 11,000 cfs) at three release locations, shallow, mid and deep. Control fish released into the tailrace at Kelsey Generation Station, Nelson River, Manitoba, Canada, June 2008. Combined control fish released: 10, 9 alive no maladies and 1 with maladies; treatment: 20 released, 13 alive no maladies and 7 with maladies.**

---

RESULTS FOR REDUCED MODEL (EQUAL LIVE/DEAD RECOVERY)
estim. std.err.
S = 0.9000 (0.0949) Control group malady free rate
Pa = Pd 1.0 N/A Recovery probability*

**Tau = 0.7222 (0.1409) treatment malady free rate**
1-Tau = 0.2778 (0.1409) treatment mortality

* -- Because of constraints in the data set, this probability is assumed equal to 1.0; not estimated.
log-likelihood : -16.199763

Variance-Covariance matrix for estimated probabilities:
0.00900 -0.00722
-0.00722 0.01984
Profile likelihood intervals:

| | treatment malady free rate | treatment mortality |
|---|---|---|
| 90 percent: | (0.5058, 1.0000) | (0.0000, 0.4942) |
| 95 percent: | (0.4668, 1.0000) | (0.0000, 0.5332) |
| 99 percent: | (0.3938, 1.0000) | (0.0000, 0.6062) |

=====================================================
Likelihood ratio statistic for equality of recovery probabilities: 0.000000
Compare with quantiles of the chi-squared distribution with 1 d.f.:
For significance level 0.10: 2.706
For significance level 0.05: 3.841
For significance level 0.01: 6.635

---

* includes Loss of Equilibrium and Major Scale Loss

## Appendix B

**Malady-free rates for northern pike adult (> 450 mm) released into Unit 5 intake at 313.7 m $^3$/s (approximately 11,000 cfs) at two release locations, shallow, and mid. Control fish released into the tailrace at Kelsey Generation Station, Nelson River, Manitoba, Canada, June 2008. Control fish released: 30, 30 alive no maladies and 0 with maladies; shallow: 28 released, 13 alive no maladies and 15 with maladies; mid: 30 released, 12 alive no maladies and 18 with maladies.**

---

```
RESULTS FOR REDUCED MODEL (EQUAL LIVE/DEAD RECOVERY)
        estim. std.err.
S1 =     1.0     N/A      Control group malady free rate*
Pa = Pd  1.0     N/A      Recovery probability*
S2 =     0.4643 (0.0943)  shallow malady free rate
S3 =     0.4000 (0.0894)  mid malady free rate
* --  Because of constraints in the data set, this probability is assumed equal to 1.0; not estimated.
 log-likelihood : -39.5270
```

**Tau = 0.4643 (0.0943) shallow/Control ratio**
**Tau = 0.4000 (0.0894) mid/Control ratio**

```
Z statistic for the equality of  malady free rates:              0.4948

            Compare with quantiles of the normal distribution:
                                    1-tailed   2-tailed
For significance level 0.10:        1.2816     1.6449
For significance level 0.05:        1.6449     1.9600
For significance level 0.01:        2.3263     2.5758

Variance-Covariance matrix for estimated probabilities:
0.00000000  0.00000000  0.00000000  0.00000000
0.00000000  0.00000000  0.00000000  0.00000000
0.00000000  0.00000000  0.00888307  0.00000000
0.00000000  0.00000000  0.00000000  0.00800000

Confidence intervals:
                  shallow Tau            mid Tau
90 percent:       (0.3092, 0.6193)  (0.2529, 0.5471)
95 percent:       (0.2796, 0.6490)  (0.2247, 0.5753)
99 percent:       (0.2216, 0.7070)  (0.1697, 0.6303)
=====================================================
Likelihood ratio statistic for equality of recovery probabilities:        0.0000
Compare with quantiles of the chi-squared distribution with 1 d.f.:
  For significance level 0.10:  2.706
  For significance level 0.05:  3.841
  For significance level 0.01:  6.635
```

---

* includes Loss of Equilibrium and Major Scale Loss

**Appendix B**

**Combined malady-free rates for walleye released into Unit 5 intake at 313.7 m $^3$/s (approximately 11,000 cfs) at three release locations, shallow, mid and deep. Control fish released into the tailrace at Kelsey Generation Station, Nelson River, Manitoba, Canada, June 2008. Combined Control fish released: 30, 30 alive no maladies and 0 with maladies; treatment: 88 released, 60 alive no maladies and 28 with maladies.**

---

RESULTS FOR REDUCED MODEL (EQUAL LIVE/DEAD RECOVERY)
estim. std.err.
S = 1.0 N/A Control group malady free rates*
Pa = Pd 1.0 N/A Recovery probability*

**Tau = 0.6818 (0.0497) Treatment malady free rates**
1-Tau = 0.3182 (0.0497) Treatment mortality

* -- Because of constraints in the data set, this probability is assumed equal to 1.0; not estimated.
log-likelihood : -55.043240

Variance-Covariance matrix for estimated probabilities: 0.00247
Profile likelihood intervals:

| | Treatment malady free rates | Treatment mortality |
|---|---|---|
| 90 percent: | (0.0000, 1.0000) | (0.0000, 1.0000) |
| 95 percent: | (0.0000, 1.0000) | (0.0000, 1.0000) |
| 99 percent: | (0.0000, 1.0000) | (0.0000, 1.0000) |

=====================================================

Likelihood ratio statistic for equality of recovery probabilities: 0.000000
Compare with quantiles of the chi-squared distribution with 1 d.f.:
For significance level 0.10: 2.706
For significance level 0.05: 3.841
For significance level 0.01: 6.635

---

* includes Loss of Equilibrium and Major Scale Loss

**Appendix B**

**Malady-free rates for walleye released into Unit 5 intake at 313.7 m ³/s (approximately 11,000 cfs) at two release locations, shallow, and deep. Control fish released into the tailrace at Kelsey Generation Station, Nelson River, Manitoba, Canada, June 2008. Control fish released: 30, 30 alive no maladies and 0 with maladies; shallow: 29 released, 22 alive no maladies and 7 with maladies; deep: 29 released, 22 alive no maladies and 7 with maladies.**

---

RESULTS FOR REDUCED MODEL (EQUAL LIVE/DEAD RECOVERY)
estim. std.err.
S1 = 1.0 N/A Control group malady free rate*
Pa = Pd 1.0 N/A Recovery probability*
S2 = 0.7586 (0.0795) shallow malady free rate
S3 = 0.7586 (0.0795) deep malady free rate
* -- Because of constraints in the data set, this probability is assumed equal to 1.0; not estimated.
log-likelihood : -32.0545

Tau = 0.7586 (0.0795) shallow/Control ratio
Tau = 0.7586 (0.0795) deep/Control ratio

Z statistic for the equality of malady free rates: 0.0000

Compare with quantiles of the normal distribution:

| | 1-tailed | 2-tailed |
|---|---|---|
| For significance level 0.10: | 1.2816 | 1.6449 |
| For significance level 0.05: | 1.6449 | 1.9600 |
| For significance level 0.01: | 2.3263 | 2.5758 |

Variance-Covariance matrix for estimated probabilities:

| | | | |
|---|---|---|---|
| 0.00000000 | 0.00000000 | 0.00000000 | 0.00000000 |
| 0.00000000 | 0.00000000 | 0.00000000 | 0.00000000 |
| 0.00000000 | 0.00000000 | 0.00631430 | 0.00000000 |
| 0.00000000 | 0.00000000 | 0.00000000 | 0.00631434 |

Confidence intervals:

| | Turbine 1 Tau | Turbine 2 Tau |
|---|---|---|
| 90 percent: | (0.6279, 0.8893) | (0.6279, 0.8893) |
| 95 percent: | (0.6029, 0.9144) | (0.6029, 0.9144) |
| 99 percent: | (0.5540, 0.9632) | (0.5540, 0.9632) |

=====================================================

Likelihood ratio statistic for equality of recovery probabilities: 0.0000
Compare with quantiles of the chi-squared distribution with 1 d.f.:
For significance level 0.10: 2.706
For significance level 0.05: 3.841
For significance level 0.01: 6.635

---

* includes Loss of Equilibrium and Major Scale Loss

## Appendix B

**Malady-free rates for walleye released into Unit 5 intake at 313.7 m ³/s (approximately 11,000 cfs) at two release locations, shallow, and mid. Control fish released into the tailrace at Kelsey Generation Station, Nelson River, Manitoba, Canada, June 2008. Control fish released: 30, 30 alive no maladies and 0 with maladies; shallow: 29 released, 22 alive no maladies and 7 with maladies; mid: 30 released, 16 alive no maladies and 14 with maladies.**

---

RESULTS FOR REDUCED MODEL (EQUAL LIVE/DEAD RECOVERY)

| | estim. | std.err. | |
|---|---|---|---|
| S1 = | 1.0 | N/A | Control group malady free rate* |
| Pa = Pd | 1.0 | N/A | Recovery probability* |
| S2 = | 0.7586 | (0.0795) | shallow malady free rate |
| S3 = | 0.5333 | (0.0911) | mid malady free rate |

* -- Because of constraints in the data set, this probability is assumed equal to 1.0; not estimated.
log-likelihood : -36.7550

Tau = 0.7586 (0.0795) Shallow/Control ratio
Tau = 0.5333 (0.0911) Mid/Control ratio

Z statistic for the equality of malady free rates: 1.8639

Compare with quantiles of the normal distribution:

| | 1-tailed | 2-tailed |
|---|---|---|
| For significance level 0.10: | 1.2816 | 1.6449 |
| For significance level 0.05: | 1.6449 | 1.9600 |
| For significance level 0.01: | 2.3263 | 2.5758 |

Variance-Covariance matrix for estimated probabilities:

| | | | |
|---|---|---|---|
| 0.00000000 | 0.00000000 | 0.00000000 | 0.00000000 |
| 0.00000000 | 0.00000000 | 0.00000000 | 0.00000000 |
| 0.00000000 | 0.00000000 | 0.00631429 | 0.00000000 |
| 0.00000000 | 0.00000000 | 0.00000000 | 0.00829629 |

Confidence intervals:

| | Shallow Tau | Deep Tau |
|---|---|---|
| 90 percent: | (0.6279, 0.8893) | (0.3835, 0.6832) |
| 95 percent: | (0.6029, 0.9144) | (0.3548, 0.7119) |
| 99 percent: | (0.5540, 0.9632) | (0.2988, 0.7679) |

=====================================================

Likelihood ratio statistic for equality of recovery probabilities: 0.0000
Compare with quantiles of the chi-squared distribution with 1 d.f.:
For significance level 0.10: 2.706
For significance level 0.05: 3.841
For significance level 0.01: 6.635

---

* includes Loss of Equilibrium and Major Scale Loss

# APPENDIX TABLE C

# SHORT-TERM PASSAGE SURVIVAL DATA

## APPENDIX TABLE C

**Release and recovery information for individual northern pike, walleye and lake whitefish released as treatment (deep, mid, and shallow release locations) or control fish at Kelsey GS in June 2008.**

**For descriptions of codes see Table 2-2; details on injured fish are presented in Appendix Table D-2.**

| Fish ID | Total Length (mm) | Time: Released | Time: Recovered | Time: Minutes at large | No. HI-Z tags recovered | Survival Code | Status Codes: 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|---|---|---|---|---|
| **9-Jun-08** | | | | | **Water temp = 12.8 °C** | | | | | |
| | | **Northern Pike** | | | | | | | | |
| | | **Deep** | | | | | | | | |
| 906 | 575 | 16:22 | 16:27 | 5 | 2 | 1 | A | | | |
| 678 | 620 | 16:37 | 16:48 | 11 | 4 | 1 | A | | | |
| 698 | 565 | 16:49 | 16:59 | 10 | 4 | 1 | A | | | |
| 693 | 660 | 17:04 | 17:11 | 7 | 4 | 1 | W | * | | |
| 904 | 575 | 17:17 | 17:23 | 6 | 3 | 1 | A | | | |
| **10-Jun-08** | | | | | **Water temp = 13.1 °C** | | | | | |
| | | **Northern Pike** | | | | | | | | |
| | | **Deep** | | | | | | | | |
| 923 | 549 | 8:06 | 8:11 | 5 | 4 | 1 | * | H | E | |
| 660 | 537 | 8:15 | 8:18 | 3 | 4 | 1 | * | 8 | W | |
| 658 | 649 | 8:22 | 8:27 | 5 | 4 | 1 | * | V | E | G |
| 908 | 625 | 8:29 | 8:35 | 6 | 4 | 1 | A | | | |
| 925 | 601 | 8:36 | 8:45 | 9 | 4 | 1 | * | W | | S |
| 915 | 710 | 8:46 | 8:54 | 8 | 2 | 1 | * | H | | S |
| 914 | 660 | 8:53 | 9:02 | 9 | 4 | 1 | * | | W | S |
| 684 | 588 | 9:00 | 9:06 | 6 | 3 | 2 | * | 6 | | |
| 921 | 614 | 9:08 | 9:16 | 8 | 3 | 2 | * | 7 | | S |
| 917 | 588 | 9:15 | 9:18 | 3 | 2 | 2 | * | 6 | | |
| 907 | 641 | 10:01 | 10:05 | 4 | 4 | 1 | * | V | H | |
| 905 | 531 | 10:11 | 10:18 | 7 | 3 | 1 | * | 9 | | |
| 687 | 720 | 10:25 | 10:31 | 6 | 5 | 1 | * | W | | |
| 911 | 692 | 10:32 | 10:37 | 5 | 5 | 2 | * | 7 | | S |
| 659 | 630 | 10:39 | 10:46 | 7 | 4 | 1 | A | | | |
| 913 | 559 | 9:22 | 9:25 | 3 | 4 | 2 | * | 6 | | |
| 922 | 560 | 9:28 | 9:37 | 9 | 3 | 1 | * | W | | |
| 677 | 476 | 9:34 | 9:44 | 10 | 4 | 1 | A | | | |
| 910 | 546 | 9:46 | 9:51 | 5 | 3 | 1 | * | 9 | W | H |
| 685 | 658 | 9:54 | 10:03 | 9 | 3 | 1 | A | | | |
| 924 | 637 | 10:46 | 10:52 | 6 | 4 | 1 | * | G | V | S |
| 652 | 573 | 10:53 | 10:58 | 5 | 4 | 1 | A | | | S |
| 691 | 639 | 11:04 | 11:14 | 10 | 4 | 1 | * | E | | |
| 916 | 555 | 11:13 | 11:18 | 5 | 4 | 1 | * | W | | |
| 694 | 597 | 11:20 | 11:25 | 5 | 4 | 1 | * | W | | |

**APPENDIX C**

**Continued.**

| Fish ID | Total Length (mm) | Time: Release | Time: Recovered | Time: Minutes at large | No. HI-Z tags recovered | Survival Code | Status Codes 1 | Status Codes 2 | Status Codes 3 | Status Codes 4 |
|---|---|---|---|---|---|---|---|---|---|---|
| **10-Jun-08** | | | | | **Water temp = 13.1 °C** | | | | | |
| | | **Northern Pike** | | | | | | | | |
| | | **Control** | | | | | | | | |
| 563 | 668 | 13:00 | 13:05 | *5* | 4 | 1 | A | | | |
| 564 | 620 | 13:07 | 13:12 | *5* | 4 | 1 | A | | | |
| 560 | 536 | 13:15 | 13:20 | *5* | 4 | 1 | A | | | |
| 562 | 682 | 13:23 | 13:29 | *6* | 4 | 1 | A | | | |
| 557 | 644 | 13:30 | 13:36 | *6* | 4 | 1 | A | | | |
| 558 | 632 | 13:39 | 13:44 | *5* | 4 | 1 | A | | | |
| 579 | 622 | 13:44 | 13:49 | *5* | 4 | 1 | A | | | |
| 553 | 618 | 13:53 | 13:58 | *5* | 4 | 1 | A | | | |
| 554 | 505 | 13:59 | 14:05 | *6* | 4 | 1 | A | | | |
| 581 | 567 | 14:16 | 14:22 | *6* | 4 | 1 | A | | | |
| 565 | 548 | 14:22 | 14:28 | *6* | 4 | 1 | A | | | |
| 552 | 537 | 14:28 | 14:34 | *6* | 4 | 1 | A | | | |
| 555 | 605 | 14:34 | 14:42 | *8* | 4 | 1 | A | | | |
| 590 | 659 | 14:41 | 14:47 | *6* | 4 | 1 | A | | | |
| 578 | 602 | 14:48 | 14:54 | *6* | 4 | 1 | A | | | |
| **11-Jun-08** | | | | | **Water temp = 13.3 °C** | | | | | |
| | | **Walleye** | | | | | | | | |
| | | **Deep** | | | | | | | | |
| 569 | 474 | 8:02 | 8:08 | *6* | 4 | 1 | A | | | S |
| 584 | 491 | 8:13 | 8:24 | *11* | 4 | 1 | A | | | |
| 477 | 539 | 8:19 | 8:34 | *15* | 4 | 1 | A | | | |
| 679 | 387 | 8:26 | 8:31 | *5* | 4 | 1 | A | | | |
| 653 | 428 | 8:31 | 8:38 | *7* | 4 | 1 | A | | | |
| 690 | 494 | 8:37 | 8:52 | *15* | 4 | 1 | A | | | |
| 568 | 466 | 8:44 | 8:56 | *12* | 5 | 1 | * | G | | S |
| 585 | 394 | 8:50 | 8:56 | *6* | 4 | 1 | * | H | E | |
| 683 | 497 | 9:04 | 9:11 | *7* | 4 | 1 | A | | | S |
| 680 | 417 | 9:09 | 9:19 | *10* | 2 | 2 | * | 6 | | |
| 657 | 550 | 9:17 | 9:33 | *16* | 5 | 1 | A | | | S |
| 695 | 338 | 9:22 | 9:29 | *7* | 3 | 1 | A | | | |
| 570 | 445 | 9:28 | 9:38 | *10* | 4 | 1 | * | A | | |
| 580 | 445 | 9:34 | 9:41 | *7* | 4 | 1 | A | | | |
| 566 | 492 | 9:38 | 9:46 | *8* | 4 | 1 | A | | | S |
| 681 | 388 | 9:43 | 9:50 | *7* | 4 | 1 | A | | | |
| 583 | 362 | 9:48 | 9:54 | *6* | 3 | 1 | A | | | |
| 698 | 412 | 9:53 | 10:02 | *9* | 4 | 1 | A | | | |
| 682 | 456 | 9:59 | 10:10 | *11* | 4 | 1 | A | | | S |

**APPENDIX C**

**Continued.**

| Fish ID | Total Length (mm) | Time: Release | Time: Recovered | Time: Minutes at large | No. HI-Z tags recovered | Survival Code | Status Codes 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|---|---|---|---|---|
| 586 | 374 | 10:03 | 10:07 | *4* | 4 | 2 | * | 6 | H | |
| 697 | 481 | 10:10 | 10:19 | *9* | 4 | 1 | A | | | |
| 654 | 420 | 10:17 | | | 0 | 5 | | | | |
| 592 | 424 | 10:22 | 10:27 | *5* | 4 | 1 | * | A | | |
| 574 | 356 | 10:27 | 10:36 | *9* | 2 | 2 | * | 6 | | |
| 593 | 361 | 10:33 | 10:38 | *5* | 4 | 1 | A | | | |
| 696 | 432 | 10:41 | 10:50 | *9* | 4 | 1 | A | | | |
| 567 | 456 | 10:48 | 10:58 | *10* | 4 | 1 | A | | | S |
| 587 | 498 | 10:55 | 11:00 | *5* | 5 | 1 | A | | | |
| 656 | 372 | 11:02 | 11:06 | *4* | 4 | 1 | A | | | |
| 572 | 351 | 11:06 | 11:09 | *3* | 4 | 1 | A | | | |
| **11-Jun-08** | | | | | **Water temp = 13.3 °C** | | | | | |
| | | **Walleye** | | | | | | | | |
| | | **Control** | | | | | | | | |
| 655 | 379 | 13:50 | 13:54 | *4* | 4 | 1 | A | | | |
| 571 | 418 | 13:55 | 13:59 | *4* | 4 | 1 | A | | | |
| 476 | 473 | 14:03 | 14:09 | *6* | 4 | 1 | A | | | |
| 479 | 430 | 14:09 | 14:16 | *7* | 4 | 1 | A | | | |
| 575 | 420 | 14:15 | 14:20 | *5* | 4 | 1 | A | | | |
| 489 | 465 | 14:34 | 14:39 | *5* | 4 | 1 | A | | | |
| 497 | 431 | 14:38 | 14:44 | *6* | 4 | 1 | A | | | |
| 498 | 409 | 14:43 | 14:49 | *6* | 4 | 1 | A | | | |
| 818 | 326 | 14:47 | 14:51 | *4* | 4 | 1 | A | | | |
| 488 | 336 | 14:53 | 14:57 | *4* | 3 | 1 | A | | | |
| 500 | 430 | 15:07 | 15:12 | *5* | 4 | 1 | A | | | |
| 493 | 387 | 15:11 | 15:17 | *6* | 4 | 1 | A | | | |
| 803 | 368 | 15:15 | 15:21 | *6* | 4 | 1 | A | | | |
| 813 | 562 | 15:22 | 15:28 | *6* | 5 | 1 | A | | | |
| 825 | 390 | 15:28 | 15:33 | *5* | 4 | 1 | A | | | |
| **11-Jun-08** | | | | | **Water temp = 13.3 °C** | | | | | |
| | | **Northern Pike** | | | | | | | | |
| | | **Deep** | | | | | | | | |
| 588 | 609 | 11:42 | 11:47 | *5* | 4 | 2 | * | 7 | | S |
| 591 | 506 | 11:50 | 11:55 | *5* | 4 | 1 | * | G | | S |
| 559 | 612 | 11:57 | 12:03 | *6* | 4 | 2 | * | 9 | W | S |
| 556 | 515 | 12:04 | 12:10 | *6* | 4 | 1 | A | | | S |
| 576 | 641 | 12:10 | 12:16 | *6* | 4 | 1 | * | W | | S |

**APPENDIX C**

**Continued.**

| Fish ID | Total Length (mm) | Time: Release | Time: Recovered | Time: Minutes at large | No. HI-Z tags recovered | Survival Code | Status Codes 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|---|---|---|---|---|
| **11-Jun-08** | | | | | **Water temp = 13.3 °C** | | | | | |
| | | **Lake Whitefish** | | | | | | | | |
| | | **Deep** | | | | | | | | |
| 599 | 608 | 11:23 | | | 0 | 4 | | | | |
| **12-Jun-08** | | | | | **Water temp = 13.9 °C** | | | | | |
| | | **Walleye** | | | | | | | | |
| | | **Mid** | | | | | | | | |
| 492 | 379 | 9:20 | 9:26 | *6* | 4 | 1 | A | | | |
| 821 | 448 | 9:25 | 9:31 | *6* | 4 | 1 | A | | | |
| 802 | 494 | 9:31 | 9:41 | *10* | 5 | 1 | A | | | |
| 806 | 377 | 9:36 | 9:42 | *6* | 4 | 1 | A | | | |
| 495 | 416 | 9:40 | 9:47 | *7* | 4 | 1 | * | A | | |
| 814 | 370 | 9:44 | 9:49 | *5* | 4 | 1 | * | E | | |
| 496 | 381 | 9:50 | 9:56 | *6* | 4 | 1 | A | | | |
| 822 | 396 | 9:54 | 10:01 | *7* | 4 | 1 | * | H | W | |
| 824 | 362 | 9:59 | 10:03 | *4* | 4 | 1 | A | | | |
| 491 | 418 | 10:05 | 10:11 | *6* | 4 | 1 | * | A | | |
| 823 | 430 | 10:08 | 10:13 | *5* | 4 | 1 | * | E | 4 | |
| 494 | 432 | 10:12 | 10:22 | *10* | 4 | 1 | * | E | | |
| 801 | 560 | 10:19 | 10:26 | *7* | 6 | 1 | * | G | W | H |
| 483 | 394 | 10:27 | 10:35 | *8* | 4 | 1 | A | | | |
| 816 | 363 | 10:32 | 10:38 | *6* | 4 | 1 | * | E | | |
| 820 | 377 | 10:36 | 10:41 | *5* | 4 | 2 | 6 | * | | |
| 819 | 367 | 10:41 | 10:48 | *7* | 4 | 1 | A | | | |
| 484 | 465 | 10:47 | 10:55 | *8* | 4 | 1 | * | E | | |
| 486 | 377 | 10:54 | 11:00 | *6* | 4 | 1 | A | | | S |
| 700 | 358 | 10:59 | 11:04 | *5* | 4 | 1 | * | F | | |
| 809 | 457 | 11:06 | 11:13 | *7* | 4 | 1 | A | | | S |
| 485 | 332 | 11:10 | 11:15 | *5* | 4 | 1 | A | | | S |
| 656 | 458 | 11:17 | | | 0 | 5 | | | | |
| 804 | 365 | 11:22 | 11:27 | *5* | 4 | 1 | A | | | S |
| 812 | 540 | 11:30 | 11:35 | *5* | 5 | 2 | * | 6 | | S |
| 654 | 365 | 11:34 | 11:42 | *8* | 4 | 1 | A | | | |
| 651 | 371 | 11:40 | 11:48 | *8* | 4 | 1 | A | | | |
| 805 | 382 | 11:48 | 11:52 | *4* | 2 | 1 | * | W | E | S |
| 810 | 387 | 11:52 | 11:59 | *7* | 4 | 1 | A | | | S |
| 487 | 387 | 11:57 | 12:02 | *5* | 4 | 1 | * | 9 | | S |
| 815 | 388 | 12:14 | 12:22 | *8* | 2 | 1 | A | | | S |

**APPENDIX C**

**Continued.**

| Fish ID | Total Length (mm) | Time: Release | Time: Recovered | Time: Minutes at large | No. HI-Z tags recovered | Survival Code | Status Codes 1 | Status Codes 2 | Status Codes 3 | Status Codes 4 |
|---|---|---|---|---|---|---|---|---|---|---|
| **12-Jun-08** | | | | | **Water temp = 13.9 °C** | | | | | |
| | | **Northern Pike** | | | | | | | | |
| | | **Mid** | | | | | | | | |
| 826 | 664 | 13:34 | 13:40 | *6* | 3 | 2 | * | 6 | | |
| 480 | 658 | 13:41 | 13:44 | *3* | 4 | 1 | A | | | |
| 482 | 423 | 13:47 | 13:53 | *6* | 1 | 1 | A | | | S |
| 577 | 544 | 13:53 | 13:59 | *6* | 4 | 1 | * | G | W | S |
| 596 | 735 | 14:00 | 14:05 | *5* | 6 | 2 | * | 7 | | |
| 912 | 625 | 14:09 | 14:15 | *6* | 4 | 1 | * | W | G | |
| 682 | 578 | 14:21 | 14:29 | *8* | 4 | 1 | A | | | |
| 687 | 555 | 14:27 | 14:33 | *6* | 4 | 1 | * | 9 | G | E |
| 693 | 466 | 14:33 | 14:38 | *5* | 4 | 1 | A | | | |
| 830 | 769 | 14:40 | 14:46 | *6* | 6 | 1 | A | | | |
| 589 | 560 | 14:46 | 14:51 | *5* | 4 | 2 | * | 7 | | S |
| 807 | 645 | 14:52 | 14:58 | *6* | 3 | 1 | A | | | S |
| 808 | 452 | 15:01 | 15:08 | *7* | 4 | 1 | A | | | S |
| 685 | 638 | 15:07 | 15:16 | *9* | 5 | 1 | A | | | |
| 681 | 629 | 15:13 | 15:19 | *6* | 4 | 1 | * | | E | |
| 697 | 651 | 15:20 | 15:26 | *6* | 4 | 1 | A | | | |
| 849 | 583 | 15:25 | 15:30 | *5* | 4 | 1 | * | | W | |
| 598 | 684 | 15:36 | 15:42 | *6* | 3 | 2 | * | 6 | | S |
| 817 | 645 | 15:43 | 15:51 | *8* | 5 | 1 | A | | | S |
| 595 | 691 | 15:50 | 15:57 | *7* | 5 | 1 | A | | | S |
| 688 | 608 | 15:57 | 16:03 | *6* | 4 | 1 | * | E | | |
| 828 | 629 | 16:04 | 16:12 | *8* | 4 | 1 | * | W | H | |
| 684 | 597 | 16:10 | 16:17 | *7* | 4 | 1 | * | W | G | |
| 582 | 675 | 16:16 | 16:27 | *11* | 5 | 1 | A | | | S |
| 689 | 561 | 16:23 | 16:29 | *6* | 4 | 1 | * | W | | G |
| 691 | 573 | 16:38 | 16:41 | *3* | 4 | 1 | A | | | |
| 676 | 583 | 16:43 | 16:50 | *7* | 4 | 1 | * | G | | |
| 694 | 489 | 16:52 | 16:55 | *3* | 4 | 1 | * | W | | |
| 696 | 470 | 16:57 | 17:01 | *4* | 3 | 1 | * | H | G | |
| 592 | 424 | 17:02 | 17:07 | *5* | 3 | 1 | A | | | |
| **14-Jun-08** | | | | | **Water temp = 13.3 °C** | | | | | |
| | | **Northern Pike** | | | | | | | | |
| | | **Control** | | | | | | | | |
| 683 | 620 | 11:01 | 11:05 | *4* | 4 | 1 | A | | | S |
| 200 | 630 | 11:06 | 11:18 | *12* | 4 | 1 | A | | | S |
| 677 | 690 | 11:12 | 11:18 | *6* | 4 | 1 | A | | | S |
| 752 | 606 | 11:17 | 11:24 | *7* | 4 | 1 | A | | | S |

**APPENDIX C**

**Continued.**

| Fish ID | Total Length (mm) | Time: Release | Time: Recovered | Time: Minutes at large | No. HI-Z tags recovered | Survival Code | Status Codes 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|---|---|---|---|---|
| 686 | 637 | 11:24 | 11:30 | *6* | 4 | 1 | A | | | S |
| 833 | 571 | 11:31 | 11:35 | *4* | 4 | 1 | A | | | S |
| 161 | 603 | 11:36 | 11:44 | *8* | 4 | 1 | A | | | S |
| 850 | 580 | 11:41 | 11:49 | *8* | 4 | 1 | A | | | S |
| 174 | 601 | 11:46 | 11:53 | *7* | 4 | 1 | A | | | |
| 170 | 538 | 11:51 | 11:59 | *8* | 4 | 1 | A | | | |
| 177 | 530 | 11:56 | 12:04 | *8* | 3 | 1 | A | | | |
| 160 | 596 | 12:02 | 12:11 | *9* | 4 | 1 | A | | | |
| 168 | 510 | 13:14 | 13:20 | *6* | 4 | 1 | A | | | |
| 157 | 555 | 13:21 | 13:26 | *5* | 4 | 1 | A | | | |
| 159 | 645 | 13:27 | 13:32 | *5* | 4 | 1 | A | | | |
| **14-Jun-08** | | | | | **Water temp = 13.3 °C** | | | | | |
| | | **Northern Pike Shallow** | | | | | | | | |
| 178 | 555 | 13:55 | 14:04 | *9* | 4 | 1 | A | | | S |
| 481 | 689 | 14:01 | 14:08 | *7* | 2 | 1 | A | | | S |
| 664 | 541 | 14:07 | 14:13 | *6* | 4 | 1 | * | G | | S |
| 456 | 546 | 14:14 | 14:19 | *5* | 4 | 1 | * | G | | |
| 764 | 541 | 14:20 | 14:28 | *8* | 4 | 1 | A | | | |
| 187 | 629 | 14:27 | 14:32 | *5* | 4 | 1 | * | W | | |
| 460 | 499 | 14:32 | 14:38 | *6* | 2 | 2 | * | 6 | | |
| 663 | 547 | 14:39 | 14:44 | *5* | 4 | 1 | A | | | S |
| 690 | 510 | 14:44 | 14:49 | *5* | 4 | 1 | * | W | | S |
| 665 | 532 | 14:49 | 14:54 | *5* | 4 | 1 | A | | | S |
| 458 | 492 | 14:57 | 15:03 | *6* | 4 | 2 | * | 6 | | |
| 772 | 486 | 15:03 | 15:08 | *5* | 3 | 1 | A | | | |
| 476 | 654 | 15:09 | 15:16 | *7* | 4 | 1 | * | E | | |
| 761 | 529 | 15:15 | 15:21 | *6* | 4 | 1 | * | A | | |
| 757 | 682 | 15:22 | | | 0 | 4 | | | | S |
| 811 | 650 | 15:29 | 15:38 | *9* | 5 | 1 | * | E | V | S |
| 199 | 580 | 15:35 | 15:41 | *6* | 4 | 1 | A | | | S |
| 768 | 620 | 15:50 | 15:57 | *7* | 4 | 1 | * | H | E | |
| 770 | 646 | 15:56 | 16:07 | *11* | 4 | 1 | Q | | | |
| 766 | 626 | 16:02 | 16:12 | *10* | 4 | 2 | * | 9 | W | H |
| 771 | 585 | 16:08 | 16:15 | *7* | 4 | 1 | * | G | | |
| 666 | 667 | 16:15 | 16:20 | *5* | 5 | 1 | A | | | |
| 675 | 578 | 16:20 | 16:27 | *7* | 4 | 1 | A | | | |
| 760 | 550 | 16:26 | 16:32 | *6* | 4 | 1 | A | | | |
| 167 | 530 | 16:32 | 16:37 | *5* | 4 | 1 | A | | | |

**APPENDIX C**

**Continued.**

| Fish ID | Total Length (mm) | Time: Release | Time: Recovered | Time: Minutes at large | No. HI-Z tags recovered | Survival Code | Status Codes 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|---|---|---|---|---|
| 763 | 536 | 16:37 | 16:42 | *5* | 3 | 1 | * | G | H | W |
| 765 | 462 | 16:44 | 16:52 | *8* | 3 | 1 | A | | | |
| 695 | 570 | 16:54 | 17:01 | *7* | 4 | 1 | * | A | | S |
| 165 | 496 | 17:00 | 17:06 | *6* | 4 | 1 | A | | | S |
| 672 | 745 | 17:06 | 17:09 | *3* | 6 | 2 | * | 6 | | S |
| **14-Jun-08** | | **Northern Pike Mid** | | | **Water temp = 13.3 °C** | | | | | |
| 451 | 419 | 8:21 | 8:25 | *4* | 3 | 1 | A | | | |
| 182 | 445 | 8:25 | 8:35 | *10* | 1 | 2 | * | 6 | | |
| 461 | 419 | 8:30 | 10:26 | *116* | 1 | 2 | * | 7 | | |
| 188 | 389 | 8:38 | 8:43 | *5* | 4 | 1 | A | | | |
| 183 | 404 | 8:45 | 8:50 | *5* | 4 | 1 | * | G | | |
| 453 | 381 | 9:09 | 9:14 | *5* | 4 | 1 | A | | | |
| 181 | 492 | 9:20 | 9:27 | *7* | 4 | 1 | * | G | | |
| 190 | 675 | 9:27 | 9:31 | *4* | 4 | 2 | * | 6 | | |
| 454 | 356 | 9:44 | 9:48 | *4* | 3 | 1 | * | W | | |
| 758 | 450 | 9:51 | | | | 4 | | | | |
| 452 | 430 | 10:03 | 10:09 | *6* | 3 | 2 | * | W | 9 | |
| **14-Jun-08** | | **Lake Whitefish Shallow** | | | **Water temp = 13.3 °C** | | | | | |
| 462 | 472 | 17:20 | 17:28 | *8* | 6 | 1 | A | | | |
| 469 | 560 | 17:27 | 17:33 | *6* | 6 | 1 | A | | | |
| **16-Jun-08** | | **Walleye Shallow** | | | **Water temp = 13.9 °C** | | | | | |
| 845 | 374 | 8:08 | 8:15 | *7* | 4 | 1 | A | | | |
| 657 | 430 | 8:13 | 8:21 | *8* | 2 | 2 | * | 6 | | |
| 846 | 356 | 8:18 | 8:23 | *5* | 4 | 1 | A | | | |
| 660 | 383 | 8:23 | 8:30 | *7* | 4 | 1 | A | | | |
| 835 | 382 | 8:28 | 8:34 | *6* | 4 | 1 | A | | | |
| 678 | 388 | 8:32 | 8:38 | *6* | 4 | 2 | * | 7 | | S |
| 834 | 391 | 8:37 | 8:44 | *7* | 4 | 1 | A | | | S |
| 841 | 512 | 8:43 | 8:49 | *6* | 4 | 1 | A | | | S |
| 679 | 463 | 8:49 | 8:59 | *10* | 4 | 1 | A | | | S |
| 659 | 387 | 8:54 | 9:04 | *10* | 4 | 1 | A | | | |

**APPENDIX C**

**Continued.**

| Fish ID | Total Length (mm) | Time: Release | Time: Recovered | Time: Minutes at large | No. HI-Z tags recovered | Survival Code | Status Codes: 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|---|---|---|---|---|
| 652 | 375 | 8:59 | 9:07 | *8* | 4 | 1 | A | | | |
| 698 | 391 | 9:05 | 9:14 | *9* | 4 | 1 | A | | | S |
| 775 | 334 | 9:10 | 9:17 | *7* | 4 | 1 | A | | | |
| 664 | 587 | 9:16 | | | 0 | 4 | | | | |
| 166 | 510 | 9:23 | 9:37 | *14* | 5 | 1 | * | G | W | |
| 744 | 398 | 9:29 | 9:31 | *2* | 4 | 2 | * | 6 | | |
| 680 | 451 | 9:45 | 9:56 | *11* | 4 | 1 | A | | | S |
| 837 | 463 | 9:53 | 10:03 | *10* | 4 | 1 | A | | | S |
| 838 | 497 | 10:19 | 10:29 | *10* | 5 | 1 | A | | | S |
| 653 | 428 | 10:24 | 10:31 | *7* | 4 | 1 | A | | | S |
| 745 | 465 | 10:29 | 10:38 | *9* | 5 | 1 | | | A | |
| 663 | 458 | 10:35 | 10:44 | *9* | 5 | 1 | A | | | S |
| 754 | 568 | 10:43 | 10:50 | *7* | 6 | 1 | * | E | | |
| 671 | 653 | 15:37 | 15:48 | *11* | 4 | 2 | * | 6 | | |
| 759 | 546 | 15:28 | 15:42 | *14* | 5 | 1 | A | | | |
| 836 | 421 | 15:42 | 15:50 | *8* | 4 | 1 | A | | | S |
| 665 | 530 | 15:53 | 16:03 | *10* | 5 | 1 | * | H | V | |
| 773 | 445 | 15:58 | 16:06 | *8* | 5 | 1 | A | | | |
| 760 | 425 | 16:02 | 16:09 | *7* | 4 | 1 | A | | | |
| 774 | 372 | 16:08 | 16:16 | *8* | 4 | 1 | A | | | |
| **16-Jun-08** | | | | | **Water temp = 13.9 °C** | | | | | |
| | | **Walleye Control** | | | | | | | | |
| 490 | 371 | 13:25 | 13:29 | *4* | 4 | 1 | A | | | S |
| 843 | 420 | 13:29 | 13:34 | *5* | 4 | 1 | A | | | S |
| 184 | 501 | 13:36 | 13:43 | *7* | 5 | 1 | A | | | |
| 732 | 441 | 13:40 | 13:45 | *5* | 4 | 1 | A | | | |
| 655 | 431 | 13:44 | 13:50 | *6* | 4 | 1 | A | | | S |
| 173 | 505 | 14:01 | 14:06 | *5* | 4 | 1 | A | | | |
| 658 | 530 | 14:06 | 14:12 | *6* | 4 | 1 | A | | | S |
| 840 | 522 | 14:11 | 14:17 | *6* | 4 | 1 | A | | | S |
| 848 | 406 | 14:16 | 14:28 | *12* | 4 | 1 | A | | | S |
| 455 | 366 | 14:20 | 14:24 | *4* | 4 | 1 | A | | | |
| 842 | 422 | 14:42 | 14:49 | *7* | 4 | 1 | A | | | S |
| 731 | 389 | 14:47 | 14:52 | *5* | 4 | 1 | A | | | |
| 699 | 405 | 14:51 | 14:55 | *4* | 4 | 1 | A | | | S |
| 185 | 398 | 14:56 | 14:59 | *3* | 4 | 1 | A | | | |
| 746 | 503 | 15:01 | 15:08 | *7* | 4 | 1 | A | | | |

**APPENDIX C**

**Continued.**

| Fish ID | Total Length (mm) | Time: Release | Time: Recovered | Time: Minutes at large | No. HI-Z tags recovered | Survival Code | Status Codes 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|---|---|---|---|---|
| **16-Jun-08** | | | | | **Water temp = 13.9 °C** | | | | | |
| | | **Lake Whitefish** | | | | | | | | |
| | | **Shallow** | | | | | | | | |
| 750 | 539 | 16:25 | 16:31 | *6* | 5 | 1 | A | | | |
| 749 | 458 | 16:22 | 16:35 | *13* | 4 | 1 | E | * | | |
| 666 | 646 | 16:22 | 16:35 | *13* | 4 | 2 | * | 7 | | |
| 668 | 550 | 16:50 | 16:54 | *4* | 6 | 1 | A | | | |
| 672 | 579 | 16:59 | 17:05 | *6* | 6 | 2 | * | 6 | | |
| 739 | 568 | 17:07 | 17:11 | *4* | 5 | 1 | A | | | |
| 1 | 105 | 17:20 | | | 0 | 4 | | | | |
| **17-Jun-08** | | | | | **Water temp = 13.9 °C** | | | | | |
| | | **Northern Pike** | | | | | | | | |
| | | **Shallow** | | | | | | | | |
| 741 | 450 | 9:19 | 9:27 | *8* | 3 | 1 | A | | | |
| 639 | 426 | 9:21 | 9:28 | *7* | 3 | 1 | A | | | |
| 643 | 422 | 9:29 | 9:35 | *6* | 3 | 1 | A | | | |
| 627 | 402 | 9:33 | 9:38 | *5* | 3 | 1 | A | | | |
| 626 | 402 | 9:36 | 9:44 | *8* | 3 | 1 | A | | | |
| 158 | 445 | 9:43 | 9:48 | *5* | 3 | 1 | * | A | | |
| 736 | 380 | 9:50 | 9:58 | *8* | 1 | 2 | * | 6 | | |
| 743 | 352 | 10:00 | 10:06 | *6* | 3 | 1 | A | | | |
| 470 | 272 | 9:54 | 10:01 | *7* | 3 | 1 | A | | | |
| 1 | 156 | 10:02 | 10:06 | *4* | 2 | 1 | A | | | |
| **17-Jun-08** | | | | | **Water temp = 13.9 °C** | | | | | |
| | | **Northern Pike** | | | | | | | | |
| | | **Control** | | | | | | | | |
| 662 | 369 | 11:26 | 11:32 | *6* | 3 | 1 | A | | | |
| 628 | 391 | 11:03 | 11:08 | *5* | 3 | 1 | A | | | |
| 748 | 329 | 11:21 | 11:28 | *7* | 3 | 1 | P | | | |
| 471 | 296 | 11:07 | 11:13 | *6* | 3 | 1 | A | | | |
| 661 | 300 | 11:23 | 11:30 | *7* | 3 | 2 | P | | | |
| 644 | 433 | 11:10 | 11:15 | *5* | 4 | 1 | * | A | | |
| 673 | 347 | 11:30 | 11:34 | *4* | 3 | 1 | A | | | |
| 640 | 324 | 11:05 | 11:10 | *5* | 3 | 1 | A | | | |
| 671 | 412 | 11:14 | 11:19 | *5* | 3 | 1 | A | | | |
| 737 | 409 | 11:17 | 11:22 | *5* | 3 | 1 | A | | | |

**APPENDIX C**

**Continued.**

| Fish ID | Total Length (mm) | Time: Release | Time: Recovered | Minutes at large | No. HI-Z tags recovered | Survival Code | Status Codes 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|---|---|---|---|---|
| **17-Jun-08** | | | | | **Water temp = 13.9 °C** | | | | | |
| | | **Lake Whitefish Shallow** | | | | | | | | |
| 642 | 620 | 8:59 | 9:07 | *8* | 6 | 1 | A | | | S |

# APPENDIX TABLE D

# DAILY MALADY DATA AND INCIDENCE OF MALADIES

**Appendix Table D-1**

**Daily malady data for adult (>450 mm) and sub-adult (<451 mm) northern pike, walleye, and lake whitefish passed as treatment fish through Unit 5 at three release locations (deep, mid, and shallow) or as control fish into the tailrace of Kelsey Generating Station in June 2008.**

| | 9-Jun | 10-Jun | 11-Jun | 12-Jun | 14-Jun | 16-Jun | 17-Jun | Totals |
|---|---|---|---|---|---|---|---|---|
| **Northern Pike - adult - Deep** | | | | | | | | |
| Number released | 5 | 25 | 5 | | | | | **35** |
| Number examined | 5 | 25 | 5 | | | | | **35** |
| Passage related maladies | 1 | 19 | 5 | | | | | **25** |
| Visible injuries | 1 | 18 | 5 | | | | | **24** |
| Loss of equilibrium only | | 1 | | | | | | **1** |
| Scale loss only | | | | | | | | **0** |
| Without maladies | 4 | 6 | 0 | | | | | **10** |
| Without maladies that died | 0 | 0 | 0 | | | | | **0** |
| **Northern Pike - adult -Mid** | | | | | | | | |
| Number released | | | | 28 | 2 | | | **30** |
| Number examined | | | | 28 | 2 | | | **30** |
| Passage related maladies | | | | 16 | 2 | | | **18** |
| Visible injuries | | | | 16 | 2 | | | **18** |
| Loss of equilibrium only | | | | | | | | **0** |
| Scale loss only | | | | | | | | **0** |
| Without maladies | | | | 12 | 0 | | | **12** |
| Without maladies that died | | | | 0 | 0 | | | **0** |
| **Northern Pike - adult - Shallow** | | | | | | | | |
| Number released | | | | | 30 | | | **30** |
| Number examined | | | | | 28 | | | **28** |
| Passage related maladies | | | | | 15 | | | **15** |
| Visible injuries | | | | | 15 | | | **15** |
| Loss of equilibrium only | | | | | | | | **0** |
| Scale loss only | | | | | | | | **0** |
| Without maladies | | | | | 13 | | | **13** |
| Without maladies that died | | | | | 1 | | | **1** |

**Appendix Table D-1**

| | 9-Jun | 10-Jun | 11-Jun | 12-Jun | 14-Jun | 16-Jun | 17-Jun | Totals |
|---|---|---|---|---|---|---|---|---|
| | | | | **Northern Pike - sub-adult - Mid** | | | | |
| Number released | | | | 2 | 9 | | | **11** |
| Number examined | | | | 2 | 8 | | | **10** |
| Passage related maladies | | | | 0 | 5 | | | **5** |
| Visible injuries | | | | 0 | 5 | | | **5** |
| Loss of equilibrium only | | | | | | | | **0** |
| Scale loss only | | | | | | | | **0** |
| Without maladies | | | | 0 | 3 | | | **3** |
| Without maladies that died | | | | 0 | 3 | | | **3** |

**Appendix Table D-1**

**Continued.**

| | 6/9 | 6/10 | 6/11 | 6/12 | 6/14 | 6/16 | 6/17 | Totals |
|---|---|---|---|---|---|---|---|---|
| | | | | **Northern Pike - sub-adult - Shallow** | | | | |
| Number released | | | | | | | 10 | **10** |
| Number examined | | | | | | | 10 | **10** |
| Passage related maladies | | | | | | | 2 | **2** |
| Visible injuries | | | | | | | 2 | **2** |
| Loss of equilibrium only | | | | | | | | **0** |
| Scale loss only | | | | | | | | **0** |
| Without maladies | | | | | | | 8 | **8** |
| Without maladies that died | | | | | | | 0 | **0** |
| | | | | **Walleye - Deep** | | | | |
| Number released | | | 30 | | | | | **30** |
| Number examined | | | 29 | | | | | **29** |
| Passage related maladies | | | 7 | | | | | **7** |
| Visible injuries | | | 7 | | | | | **7** |
| Loss of equilibrium only | | | | | | | | **0** |
| Scale loss only | | | | | | | | **0** |
| Without maladies | | | 22 | | | | | **22** |
| Without maladies that died | | | 0 | | | | | **0** |

**Appendix Table D-1**

| | 9-Jun | 10-Jun | 11-Jun | 12-Jun | 14-Jun | 16-Jun | 17-Jun | Totals |
|---|---|---|---|---|---|---|---|---|
| **Walleye - Mid** | | | | | | | | |
| Number released | | | | 31 | | | | **31** |
| Number examined | | | | 30 | | | | **30** |
| Passage related maladies | | | | 14 | | | | **14** |
| Visible injuries | | | | 14 | | | | **14** |
| Loss of equilibrium only | | | | | | | | **0** |
| Scale loss only | | | | | | | | **0** |
| Without maladies | | | | 16 | | | | **16** |
| Without maladies that died | | | | 0 | | | | **0** |
| **Walleye - Shallow** | | | | | | | | |
| Number released | | | | | | 30 | | **30** |
| Number examined | | | | | | 29 | | **29** |
| Passage related maladies | | | | | | 7 | | **7** |
| Visible injuries | | | | | | 7 | | **7** |
| Loss of equilibrium only | | | | | | | | **0** |
| Scale loss only | | | | | | | | **0** |
| Without maladies | | | | | | 22 | | **22** |
| Without maladies that died | | | | | | 0 | | **0** |

**Appendix Table D-1**

**Continued.**

| | 6/9 | 6/10 | 6/11 | 6/12 | 6/14 | 6/16 | 6/17 | Totals |
|---|---|---|---|---|---|---|---|---|
| **Lake Whitefish - Deep** | | | | | | | | |
| Number released | | | 1 | | | | | **1** |
| Number examined | | | 0 | | | | | **0** |
| Passage related maladies | | | 0 | | | | | **0** |
| Visible injuries | | | 0 | | | | | **0** |
| Loss of equilibrium only | | | | | | | | **0** |
| Scale loss only | | | | | | | | **0** |
| Without maladies | | | 0 | | | | | **0** |
| Without maladies that died | | | 0 | | | | | **0** |

**Appendix Table D-1**

| | 9-Jun | 10-Jun | 11-Jun | 12-Jun | 14-Jun | 16-Jun | 17-Jun | Totals |
|---|---|---|---|---|---|---|---|---|
| **Lake Whitefish - Shallow** | | | | | | | | |
| Number released | | | | | 2 | 7 | 1 | **10** |
| Number examined | | | | | 2 | 6 | 1 | **9** |
| Passage related maladies | | | | | 0 | 3 | 0 | **3** |
| Visible injuries | | | | | | 3 | 0 | **3** |
| Loss of equilibrium only | | | | | | | | **0** |
| Scale loss only | | | | | | | | **0** |
| Without maladies | | | | | 2 | 3 | 1 | **6** |
| Without maladies that died | | | | | 0 | 1 | 0 | **1** |
| **Northern Pike - adult - Control** | | | | | | | | |
| Number released subadult | | 15 | | | 15 | | | **30** |
| Number examined | | 15 | | | 15 | | | **30** |
| Passage related maladies | | 0 | | | 0 | | | **0** |
| Visible injuries | | | | | | | | **0** |
| Loss of equilibrium only | | | | | | | | **0** |
| Scale loss only | | | | | | | | **0** |
| Without maladies | | 15 | | | 15 | | | **30** |
| Without maladies that died | | 0 | | | 0 | | | **0** |
| **Northern Pike - sub-adult - Control** | | | | | | | | |
| Number released | | | | | | | 10 | **10** |
| Number examined | | | | | | | 10 | **10** |
| Passage related maladies | | | | | | | 1 | **1** |
| Visible injuries | | | | | | | | **0** |
| Loss of equilibrium only | | | | | | | | **0** |
| Scale loss only | | | | | | | | **0** |
| Without maladies | | | | | | | 9 | **9** |
| Without maladies that died | | | | | | | 4* | **4** |

*2 fish died due to predation; 2 fish died due to fungus

**Appendix Table D-1**

| | 9-Jun | 10-Jun | 11-Jun | 12-Jun | 14-Jun | 16-Jun | 17-Jun | Totals |
|---|---|---|---|---|---|---|---|---|
| | | | | **Walleye - Control** | | | | |
| Number released | | | 15 | | | 15 | | **30** |
| Number examined | | | 15 | | | 15 | | **30** |
| Passage related maladies | | | 0 | | | 0 | | **0** |
| Visible injuries | | | | | | | | **0** |
| Loss of equilibrium only | | | | | | | | **0** |
| Scale loss only | | | | | | | | **0** |
| Without maladies | | | 15 | | | 15 | | **30** |
| Without maladies that died | | | 0 | | | 0 | | **0** |

**Appendix Table D-2**

**Incidence of maladies, including injury, scale loss, and temporary loss of equilibrium (LOE) observed on recaptured adult (>450 mm) and subadult (<451 mm) northern pike, walleye and lake whitefish passed as treatment fish through Unit 5 at three release locations (deep, mid, and shallow) or as control fish into the tailrace of Kelsey Generating Station in June 2008.**

| | Date | Test Lot | Fish VI | Live / Dead | | Maladies | Passage Malady | Photo taken | Probable Cause | Status |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | **Northern Pike Control** | | | | |
| * | 6/17/08 | 7 | 661 | dead | 1h | Predator marks | No | Yes | Predation | Major |
| * | 6/17/08 | 7 | 640 | dead | 48h | Fungus on body; No visible passage related marks on fish | No | Yes | Tagging/ Release | Minor |
| * | 6/17/08 | 7 | 644 | alive | 48h | Bruised behind head | Yes | Yes | Tagging/ Release | Minor |
| * | 6/17/08 | 7 | 671 | dead | 48h | Fungus on body; No visible passage related marks on fish | No | Yes | Tagging/ Release | Minor |
| * | 6/17/08 | 7 | 748 | dead | 48h | Predator marks | No | Yes | Predation | Major |
| | | | | | | **Northern Pike Deep** | | | | |
| | 6/09/08 | 1 | 693 | alive | 48h | Scraped 1 X 3" right side | Yes | Yes | Mechanical | Minor |
| | 6/10/08 | 2 | 925 | alive | 48h | Acoustic tagged; Minor scrape | Yes | No | Mechanical | Minor |
| | 6/10/08 | 2 | 924 | alive | 48h | Acoustic tagged; Bruised upper jaw; Torn caudal fin | Yes | No | Mechanical | Minor |
| | 6/10/08 | 2 | 905 | alive | 48h | Damaged right operculum: scraped | Yes | No | Mechanical | Minor |
| | 6/10/08 | 2 | 914 | alive | 48h | Acoustic tagged; Scrape right side (2") | Yes | No | Mechanical | Minor |
| | 6/10/08 | 2 | 687 | alive | 48h | Abrasion on back | Yes | No | Mechanical | Minor |
| | 6/10/08 | 2 | 694 | alive | 48h | Scraped right side and lower jaw | Yes | No | Mechanical | Minor |
| | 6/10/08 | 2 | 684 | dead | 1h | Severed body at anal vent | Yes | Yes | Mechanical | Major |
| | 6/10/08 | 2 | 911 | dead | 1h | Acoustic tagged; Decapitated | Yes | Yes | Mechanical | Major |

**Appendix Table D-2**

**Continued.**

| Date | Test Lot | Fish VI | Live / Dead | | Maladies | Passage Malady | Photo taken | Probable Cause | Status |
|---|---|---|---|---|---|---|---|---|---|
| 6/10/08 | 2 | 913 | dead | 1h | Severed behind dorsal fin | Yes | Yes | Mechanical | Major |
| 6/10/08 | 2 | 917 | dead | 1h | Severed at back end | Yes | Yes | Mechanical | Major |
| 6/10/08 | 2 | 921 | dead | 1h | Acoustic tagged; Decapitated | Yes | Yes | Mechanical | Major |
| 6/10/08 | 2 | 658 | dead | 24h | Fins displaced: caudal fin missing; Bruised near top of mouth | Yes | Yes | Mechanical | Major |
| 6/10/08 | 2 | 915 | dead | 24h | Acoustic tagged; LOE; Necropsied, no obvious passage related injuries | Yes | No | Undetermined | Minor |
| 6/10/08 | 2 | 660 | alive | 48h | Damaged right eye: hemorrhaged; Scrape on left side of head; Laceration: tear on lower jaw, right side | Yes | Yes | Mechanical | Major |
| 6/10/08 | 2 | 691 | alive | 48h | Laceration: split upper jaw | Yes | Yes | Mechanical | Major |
| 6/10/08 | 2 | 907 | alive | 48h | Fins displaced: 90% of caudal fin missing; LOE | Yes | Yes | Mechanical | Major |
| 6/10/08 | 2 | 910 | alive | 48h | Damaged right operculum: slashed; Scrape on right flank; LOE | Yes | Yes | Mechanical | Major |
| 6/10/08 | 2 | 916 | alive | 48h | Scraped behind pectoral fin, left side (2 X 1") | Yes | Yes | Mechanical | Minor |
| 6/10/08 | 2 | 922 | alive | 48h | Scraped behind pectoral fin, left side (2 X 1") | Yes | Yes | Mechanical | Minor |
| 6/11/08 | 3 | 923 | alive | 48h | LOE; Laceration: split upper jaw | Yes | Yes | Mechanical | Major |
| 6/11/08 | 3 | 591 | alive | 48h | Acoustic tagged; Bruised randomly on body | Yes | No | Mechanical | Minor |
| 6/11/08 | 3 | 576 | alive | 48h | Acoustic tagged; Scrape (large) at anal fin | Yes | No | Mechanical | Major |
| 6/11/08 | 3 | 559 | dead | 1h | Acoustic tagged; Damaged both operculum: torn; Scraped left side | Yes | Yes | Mechanical | Major |
| 6/11/08 | 3 | 588 | dead | 1h | Acoustic tagged; Decapitated | Yes | Yes | Mechanical | Major |

**Appendix Table D-2**

**Continued.**

| | Date | Test Lot | Fish VI | Live / Dead | | Maladies | Passage Malady | Photo taken | Probable Cause | Status |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | **Northern Pike Mid** | | | | |
| | 6/12/08 | 4 | 912 | alive | 48h | Scraped 1 X 1½" left side; Bruised left side of body | Yes | No | Mechanical | Minor |
| | 6/12/08 | 4 | 577 | alive | 48h | Acoustic tagged; Bruised left side of body; Vertical scrape left side (2 X 1") | Yes | No | Mechanical | Minor |
| | 6/12/08 | 4 | 694 | alive | 48h | Scrape (small) left side | Yes | No | Mechanical | Minor |
| | 6/12/08 | 4 | 689 | alive | 48h | Scraped on head (1½" long); Bruised lower jaw | Yes | No | Mechanical | Minor |
| | 6/12/08 | 4 | 676 | alive | 48h | Bruised on back | Yes | No | Mechanical | Minor |
| | 6/12/08 | 4 | 589 | dead | 1h | Acoustic tagged; Decapitated | Yes | Yes | Mechanical | Major |
| | 6/12/08 | 4 | 596 | dead | 1h | Decapitated | Yes | Yes | Mechanical | Major |
| | 6/12/08 | 4 | 598 | dead | 1h | Acoustic tagged; Severed body | Yes | Yes | Mechanical | Major |
| | 6/12/08 | 4 | 826 | dead | 1h | Severed body | Yes | Yes | Mechanical | Major |
| | 6/12/08 | 4 | 687 | dead | 24h | Damaged operculum: bent; Bruised head and belly; Hemorrhaged internally above swim bladder- kidneys | Yes | No | Mechanical | Major |
| | 6/12/08 | 4 | 681 | alive | 48h | Laceration: tear on upper jaw | Yes | No | Mechanical | Minor |
| | 6/12/08 | 4 | 684 | alive | 48h | Abrasion left side (2 X 2"); Bruised behind head | Yes | Yes | Mechanical | Minor |
| | 6/12/08 | 4 | 688 | alive | 48h | Fins displaced: caudal fin 90% missing | Yes | Yes | Mechanical | Major |
| | 6/12/08 | 4 | 696 | dead | 48h | LOE; Bruised on back | Yes | Yes | Mechanical | Major |
| | 6/12/08 | 4 | 828 | alive | 48h | LOE; Scraped left side (2 X 1½") | Yes | Yes | Mechanical | Minor |
| | 6/12/08 | 4 | 849 | alive | 48h | Scraped left side (1 X 1½") | Yes | Yes | Mechanical | Minor |
| * | 6/14/08 | 5 | 183 | alive | 48h | Bruised body | Yes | No | Mechanical | Minor |
| | 6/14/08 | 5 | 181 | alive | 48h | Bruised body | Yes | No | Mechanical | Minor |
| * | 6/14/08 | 5 | 454 | alive | 48h | Scrapes on body | Yes | No | Mechanical | Minor |

**Appendix Table D-2**

**Continued.**

| | Date | Test Lot | Fish VI | Live / Dead | | Maladies | Passage Malady | Photo taken | Probable Cause | Status |
|---|---|---|---|---|---|---|---|---|---|---|
| * | 6/14/08 | 5 | 182 | dead | 1h | Severed body | Yes | Yes | Mechanical | Major |
| | 6/14/08 | 5 | 190 | dead | 1h | Severed body | Yes | Yes | Mechanical | Major |
| * | 6/14/08 | 5 | 452 | dead | 1h | Abrasions and scrapes on left side above operculum; Damaged right operculum: torn | Yes | Yes | Mechanical | Major |
| * | 6/14/08 | 5 | 461 | dead | 1h | Decapitated | Yes | Yes | Mechanical | Major |
| * | 6/14/08 | 5 | 188 | dead | 24h | Necropsied, no obvious passage related injuries | No | Yes | Tagging/ Release | Minor |
| * | 6/14/08 | 5 | 451 | dead | 48h | Fungus on body; No visible passage related marks on fish | No | Yes | Tagging/ Release | Minor |
| * | 6/14/08 | 5 | 453 | dead | 48h | Fungus on body; No visible passage related marks on fish | No | No | Tagging/ Release | Minor |
| | | | | | | **Northern Pike Shallow** | | | | |
| | 6/14/08 | 5 | 771 | alive | 48h | Bruised left side of body (1") | Yes | No | Mechanical | Minor |
| | 6/14/08 | 5 | 456 | alive | 48h | Bruised left side of body (small) | Yes | No | Mechanical | Minor |
| | 6/14/08 | 5 | 664 | alive | 48h | Acoustic tagged; Bruised on back | Yes | No | Mechanical | Minor |
| | 6/14/08 | 5 | 690 | alive | 48h | Acoustic tagged; Small scrape left side | Yes | No | Mechanical | Minor |
| | 6/14/08 | 5 | 768 | alive | 48h | LOE; Laceration: torn caudal fin | Yes | No | Mechanical | Minor |
| | 6/14/08 | 5 | 187 | alive | 48h | Scraped right side (1 X 1") | Yes | No | Mechanical | Minor |
| | 6/14/08 | 5 | 458 | dead | 1h | Severed body | Yes | Yes | Mechanical | Major |
| | 6/14/08 | 5 | 460 | dead | 1h | Severed body | Yes | Yes | Mechanical | Major |
| | 6/14/08 | 5 | 672 | dead | 1h | Acoustic tagged; Severed body | Yes | Yes | Mechanical | Major |
| | 6/14/08 | 5 | 766 | dead | 1h | Laceration: left side of head missing | Yes | Yes | Mechanical | Major |
| | 6/14/08 | 5 | 695 | dead | 24h | Acoustic tagged; Scrape on left side 1" x 2"; Bruised internally | Yes | Yes | Mechanical | Major |

**Appendix Table D-2**

**Continued.**

| | Date | Test Lot | Fish VI | Live / Dead | | Maladies | Passage Malady | Photo taken | Probable Cause | Status |
|---|---|---|---|---|---|---|---|---|---|---|
| | 6/14/08 | 5 | 476 | alive | 48h | Laceration: torn upper jaw (2 to 3" long) | Yes | Yes | Mechanical | Major |
| | 6/14/08 | 5 | 760 | dead | 48h | Necropsied, no obvious passage related injuries | No | No | Undetermined | Minor |
| | 6/14/08 | 5 | 761 | alive | 48h | Scraped left side(1 X 4"); Fins displaced: lower caudal fin missing | Yes | Yes | Mechanical | Major |
| | 6/14/08 | 5 | 763 | dead | 48h | LOE; Scraped both sides (1 X 3" and 2 X 3'); Hemorrhaged internally | Yes | Yes | Mechanical | Major |
| | 6/14/08 | 5 | 811 | alive | 48h | Acoustic tagged; LOE; Fins displaced: lower caudal fin missing | Yes | Yes | Mechanical | Major |
| * | 6/17/08 | 7 | 736 | dead | 1h | Severed body | Yes | Yes | Mechanical | Major |
| * | 6/17/08 | 7 | 158 | alive | 48h | Scraped left side (1 X 2") | Yes | Yes | Mechanical | Minor |
| | | | | | | **Walleye Deep** | | | | |
| | 6/11/08 | 3 | 568 | alive | 48h | Acoustic tagged; Bruised near caudal and dorsal fins | Yes | No | Mechanical | Minor |
| | 6/11/08 | 3 | 574 | dead | 1h | Severed body | Yes | Yes | Mechanical | Major |
| | 6/11/08 | 3 | 586 | dead | 1h | Severed body | Yes | Yes | Mechanical | Major |
| | 6/11/08 | 3 | 680 | dead | 1h | Severed body | Yes | Yes | Mechanical | Major |
| | 6/11/08 | 3 | 570 | alive | 48h | Laceration: small split to upper jaw | Yes | No | Mechanical | Minor |
| | 6/11/08 | 3 | 585 | alive | 48h | LOE; Laceration: torn upper jaw | Yes | Yes | Mechanical | Major |
| | 6/11/08 | 3 | 592 | alive | 48h | Laceration: small split to upper jaw | Yes | No | Mechanical | Minor |
| | | | | | | **Walleye Mid** | | | | |
| | 6/12/08 | 4 | 816 | alive | 48h | Laceration: torn flap of skin on mouth | Yes | No | Mechanical | Minor |
| | 6/12/08 | 4 | 484 | alive | 48h | Laceration: torn flap of skin on mouth | Yes | No | Mechanical | Minor |

**Appendix Table D-2**

**Continued.**

| Date | Test Lot | Fish VI | Live / Dead | | Maladies | Passage Malady | Photo taken | Probable Cause | Status |
|---|---|---|---|---|---|---|---|---|---|
| 6/12/08 | 4 | 487 | alive | 48h | Acoustic tagged; Damaged right operculum: bent | Yes | No | Mechanical | Minor |
| 6/12/08 | 4 | 812 | dead | 1h | Acoustic tagged; Severed body | Yes | Yes | Mechanical | Major |
| 6/12/08 | 4 | 820 | dead | 1h | Severed body | Yes | Yes | Mechanical | Major |
| 6/12/08 | 4 | 491 | alive | 48h | Laceration: small tear to jaw | Yes | No | Mechanical | Minor |
| 6/12/08 | 4 | 494 | alive | 48h | Laceration: small tears on upper and lower jaws | Yes | No | Mechanical | Minor |
| 6/12/08 | 4 | 495 | alive | 48h | Laceration: split upper jaw | Yes | No | Mechanical | Minor |
| 6/12/08 | 4 | 700 | alive | 48h | Torn isthmus; Laceration: split upper jaw | Yes | No | Mechanical | Minor |
| 6/12/08 | 4 | 801 | alive | 48h | LOE; Laceration: tear on upper and lower jaw | Yes | Yes | Mechanical | Minor |
| 6/12/08 | 4 | 805 | alive | 48h | Acoustic tagged; Laceration: tear on upper jaw | Yes | No | Mechanical | Major |
| 6/12/08 | 4 | 814 | alive | 48h | Laceration: split upper jaw | Yes | Yes | Mechanical | Major |
| 6/12/08 | 4 | 822 | alive | 48h | LOE; Laceration: torn flap of skin on lower jaw | Yes | No | Mechanical | Minor |
| 6/12/08 | 4 | 823 | alive | 48h | Laceration: torn upper jaw | Yes | Yes | Mechanical | Major |
| | | | | | **Walleye Shallow** | | | | |
| 6/16/08 | 6 | 657 | dead | 1h | Severed body | Yes | Yes | Mechanical | Major |
| 6/16/08 | 6 | 671 | dead | 1h | Severed body | Yes | Yes | Mechanical | Major |
| 6/16/08 | 6 | 678 | dead | 1h | Acoustic tagged; Decapitated | Yes | Yes | Mechanical | Major |
| 6/16/08 | 6 | 744 | dead | 1h | Severed body | Yes | Yes | Mechanical | Major |
| 6/16/08 | 6 | 166 | alive | 48h | Laceration: torn upper mandible (1") | Yes | Yes | Mechanical | Minor |
| 6/16/08 | 6 | 665 | alive | 48h | LOE; Laceration: torn flap of skin lower jaw, upper jaw compacted back to eyes | Yes | Yes | Mechanical | Major |
| 6/16/08 | 6 | 754 | alive | 48h | Laceration: torn tip of jaw; Upper left jaw torn to eye; Damaged left eye: out of socket | Yes | Yes | Mechanical | Major |

**Appendix Table D-2**

**Continued.**

| Date | Test Lot | Fish VI | Live / Dead | | Maladies | Passage Malady | Photo taken | Probable Cause | Status |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | **Lake Whitefish - Shallow** | | | | |
| 6/14/08 | 5 | 462 | alive | 48h | Fungus on body just behind head at gill net mark, No visible passage related marks on fish | No | Yes | Tagging/ Release | Minor |
| 6/16/08 | 6 | 666 | dead | 1h | Decapitated | Yes | Yes | Mechanical | Major |
| 6/16/08 | 6 | 672 | dead | 1h | Severed in 3 parts | Yes | Yes | Mechanical | Major |
| 6/16/08 | 6 | 749 | alive | 48h | Laceration: tear at anal fin | Yes | Yes | Mechanical | Major |
| 6/16/08 | 6 | 750 | dead | 48h | Fungus on body, No visible passage related marks on fish | No | Yes | Tagging/ release | Minor |

* Denotes fish lengths < 451mm

# LONG-TERM SURVIVAL AND MOVEMENT OF ACOUSTIC-TAGGED FISH FOLLOWING PASSAGE THROUGH A RE-RUNNERED TURBINE AT THE KELSEY GENERATING STATION, 2008

A Report Prepared

for

Manitoba Hydro

by

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May 2009

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# 1.0 INTRODUCTION

Since the first hydroelectric generating stations (GSs) were constructed in the 19th century, concerns have been expressed about the impact that dam construction and operation has on fish. Since then much more is known about the magnitude of fish movements through hydroelectric stations and the associated rate of injury/mortality. However, most studies on downstream fish passage through hydroelectric plants to date have focused on **anadromous*** species, such as salmon, trout, char, shad, and alewife, and **catadromous** species such as eels (see review by Cada 2001). These studies have, in most cases, been carried out in the United States and Europe and largely involve either **smolts** or adult salmon during their spawning migration. Information on the fate of **potamodromous** species (Lucas and Baras 2001), or so called "resident" fish populations, when passing hydroelectric generating stations is largely absent. There is virtually no information regarding species of concern from reservoirs in boreal North America. Two North American studies (Navarro et al. 1996 and Matousek et al. 1994) have looked at fish movements and turbine passage for some cool, freshwater species; however, the type(s) of turbines examined by these authors were substantially different from those used in Manitoba Hydro plants. Furthermore, injury and mortality studies at hydroelectric GSs have mainly considered a time period of 48 hours or less after turbine passage. However, it has been recently shown that, at least for radio- and PIT-tagged juvenile Pacific salmon, delayed mortality (mainly due to predation) of successfully passed fish can be much higher than the direct turbine mortality rates as estimated by HI-Z tags (Ferguson et al. 2006). Similar direct assessments of the longer-term survival of turbine-passed fish and the potential effects of turbine passage on fish movements are lacking for larger individuals and for boreal species.

In June of 2006 (North/South Consultants Inc. and Normandeau Associates Inc. 2007) and 2008, at the request of Manitoba Hydro, North/South Consultants Inc. and Normandeau Associates Inc. collaborated to investigate fish injury and/or mortality due to passage through turbines at the Kelsey GS on the lower Nelson River. Injury rates and rates of short term (up to 48 hours) survival after turbine passage were estimated using "HI-Z" tags (see Part 1 of this study and Normandeau Associates, Inc. 2007). In 2006, information on the long-term survival (up to three months) and the post-passage movement of a relatively small sub-sample of HI-Z-tagged northern pike (*Esox lucius*) and walleye (*Sander vitreus*), was obtained from internally implanted acoustic transmitters. This second part of the report

**** for definitions of terms see glossary in section 6.0***

summarizes results on the long-term survival (up to four months) and the post-passage movement of a larger sub-sample of HI-Z-tagged northern pike and walleye and of one lake whitefish (*Coregonus clupeaformis*) that were acoustic-tagged in 2008. The 2008 study also included a larger (compared to 2006) proportion of control fish to better assess the effect of turbine passage on fish movements. Finally, this part presents data on a few pike and walleye tagged in 2006 that were tracked in 2008, and thus provides information on survival and movements of fish more than two years after turbine passage.

# 2.0 STUDY AREA

The Kelsey GS is located on the upper Nelson River in northern Manitoba, at latitude 55° 57' N and longitude 96° 32' W. The station lies 137 km upstream of the Kettle GS and approximately 680 km north of Winnipeg. Kelsey GS was the first hydroelectric station built on the Nelson River. Construction of Kelsey GS commenced in 1957 and was completed in 1961 with five turbine generators (units), each producing 30 MW for a combined capacity of 160 MW. Additional units were added in 1969 and 1972 bringing the total capacity up to 211 MW. Kelsey GS was originally built to supply power to the International Nickel Company's (INCO) mining and smelting operations in the area and also to the City of Thompson. Kelsey also supplies the northern communities of Split Lake, Gillam, Ilford, and Churchill and nine communities on the east side of Lake Winnipeg (Manitoba Hydro 2002).

Just downstream of the Kelsey GS the Nelson River is joined by the Grass River from the west (Figure 1). Past the confluence, the Nelson River flows north for approximately 5 km until it splits into two channels, one channel continues north around a large island and the other flows east around the island. Both channels have a set of rapids before they enter into Split Lake where they are joined by water from the Burntwood River. The aquatic habitat within the area downstream of Kelsey ranges from a low velocity, relatively high water clarity riverine environment in the Grass River to a medium to high velocity, low water clarity riverine environment in the upstream portion of the Nelson River. Lower velocity conditions start to exist past the two set of rapids on the Nelson River at the eastern edge of the Study Area (Figure 1) and lacustrine conditions are encountered as the river enters Split Lake. Aquatic macrophytes are frequently found in the Grass River and two larger tributaries entering the Nelson River and the Grass River within the Study Area, but are not prominent along the shoreline of the Nelson River in the vicinity of Kelsey GS.

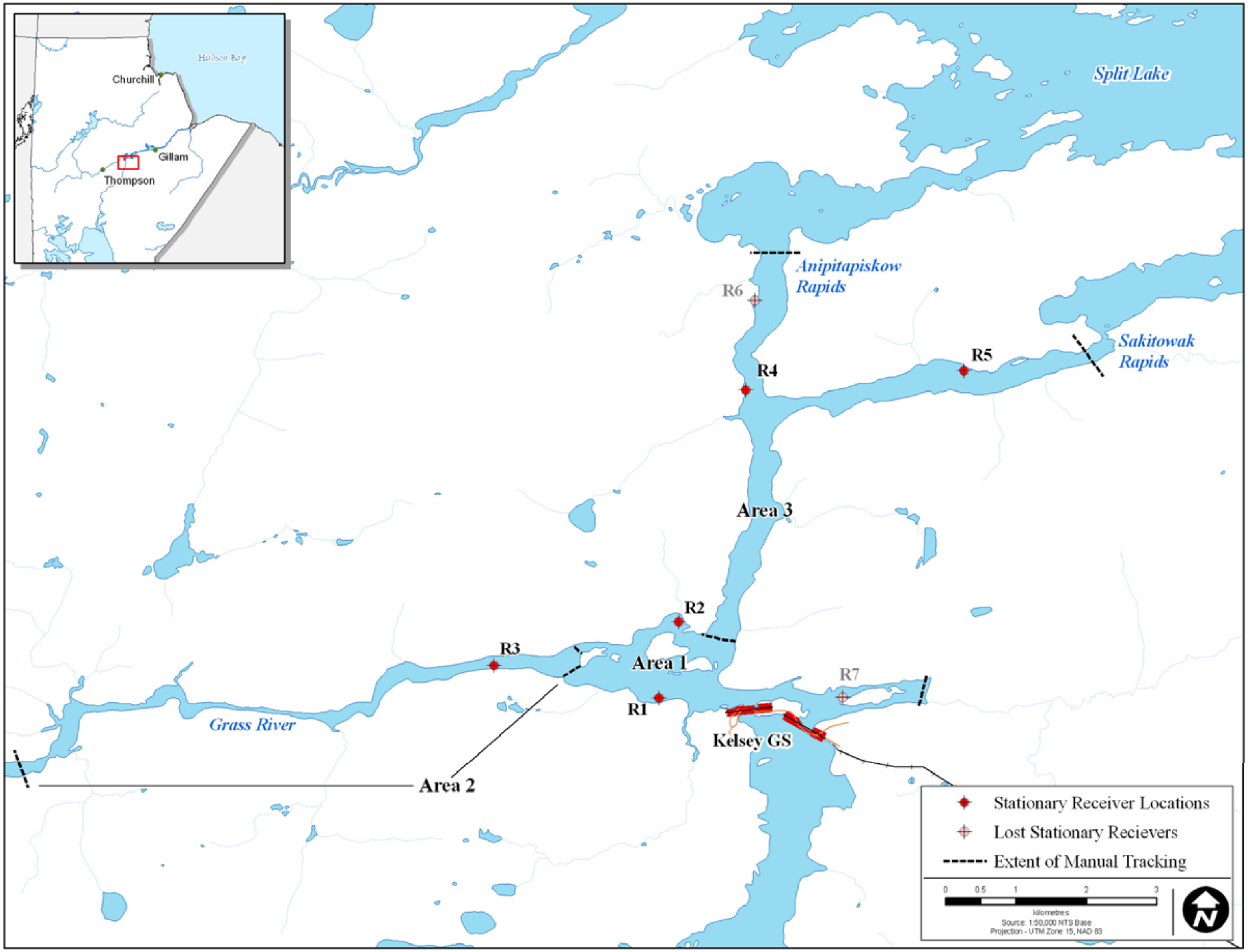


Figure 1. Overview of the Kelsey GS Study Area with locations of stationary acoustic receivers, the three areas considered to describe qualitative fish movement, and the approximate extent of manual tracking in June-October 2008.

# 3.0 METHODS

## 3.1 FISH CAPTURE AND HANDLING

Northern pike, walleye, and the one lake whitefish used in this study were captured from several locations (Figure 2) downstream and upstream of Kelsey GS by gillnetting (Figure 3), boat electrofishing (Figure 4), and angling. Figure 2 identifies only those locations from which fish were captured that were acoustic-tagged and released back into the river (see Appendix 1).

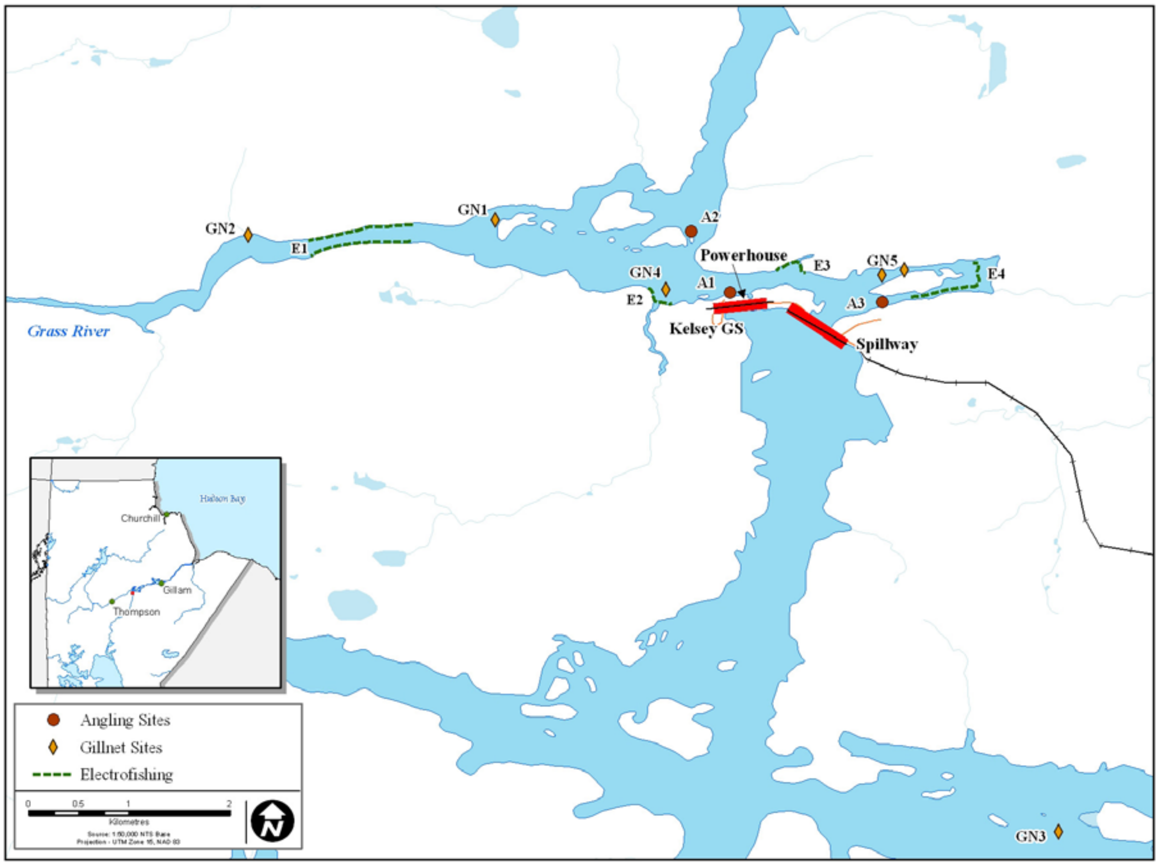


Figure 2. Locations where fish for the Turbine Passage Study were captured by either gillnetting, electrofishing, or angling from 8-14 June, 2008.

Captured fish were immediately placed in tubs of fresh water and transported to the Kelsey GS where they were measured for total length and fork length (± 1 mm), and individually marked with a green, numbered Floy-tag (FD-94 T-bar anchor tags) before being transferred to soft-walled pools of approximately 5000 L volume (see Part 1). Floy-tags were inserted at the base of the dorsal fin between the posterior basal pterygiophores with a Denison Mark II tagging gun (Figure 5). Usually, fish remained in the pools for a 24-hour monitoring period before acoustic transmitters were surgically implanted (see Section 3.2), but occasionally surgery was performed earlier. Fish were monitored for 12-24 hours post-surgery before being released either as treatment or control fish (see Part 1 of the study). Prior to release, each fish was externally fitted with a radio transmitter and "HI-Z Turb'N" tags to enable its relocation after turbine passage (see Part 1).

Figure 3. Gillnet capture of experimental fish.

Figure 4. Capture of experimental fish by electrofishing.

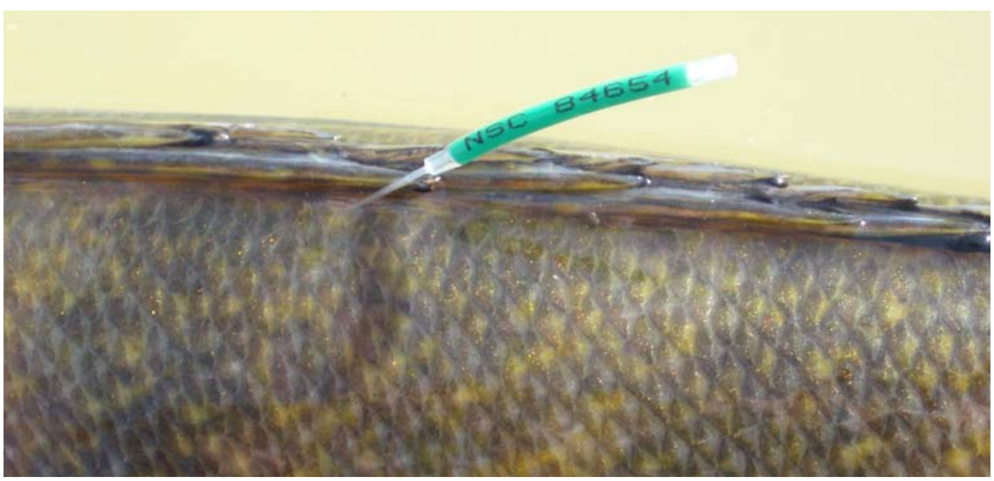


Figure 5. Walleye tagged with Floy-tag NSC 84654 in the dorsal musculature.

Fish that were physically recovered after turbine passage were placed into on-board holding tanks, where the radio transmitter and balloon tags were removed and the physical condition of the fish was assessed (see Part 1 of the study). Any injuries or mortalities were recorded and if a fish was in good enough condition it was released into the river. One acoustic-tagged pike and walleye each with substantial injuries were kept and transferred to a pool on the tailrace deck of the powerhouse to monitor survival for 48 hours. At that time, both fish were alive and behaved normally, and were released into the river.

## 3.2 ACOUSTIC TRANSMITTER IMPLANTATION

Strong and healthy fish selected for acoustic tagging were measured for fork length and total length (± 1 mm) and round weight (± 25 g; pan balance) prior to transmitter implantation. Fish were anaesthetized in a solution of clove oil and ethanol as described by Peake (1999). Clove oil was first dissolved in ethanol at a ratio of 1:10 (approximately 3 mL clove oil: 27 mL ethanol). This solution was mixed into approximately 30 L of river water. Fish were placed into the anaesthetic solution until immobile, then transferred to a V-shaped surgical table, ventral side up (Figures 6 and 7). As anaesthetized fish are unable to ventilate on their own, fresh water was continually pumped over the gills during the surgical procedure (Figure 6).

A mid-ventral incision, approximately 2 cm in length, was made through the body wall of the fish using a sterilized 30 mm long scalpel. The acoustic transmitter, sterilized in alcohol, was inserted into the body cavity of the fish (Figure 6), and gently pushed forward to avoid stressing the incision after closure. The incision was closed using chromic #2 gut sutures


Figure 6. Surgical implantation of an acoustic transmitter into a walleye.

Figure 7. Suturing and gill irrigation of a walleye after implantation of an acoustic transmitter.

(Figure 7). Fish were placed into a small enclosure formed by 5 mm mesh soft netting inside the recovery pool, and were monitored until they were able to maintain equilibrium and had regained mobility before being released into the main body of the pool.

## 3.3 ACOUSTIC TELEMETRY

### 3.3.1 Acoustic transmitters and receivers

Fish were implanted with individually coded pinger V9-2H (n=60) and V16-4H (n=12) acoustic transmitters (VEMCO Ltd.; Figure 6). The V9-2H transmitters measure 29 mm in length by 9 mm in diameter, weigh 2.9 g in water, and have a battery life expectancy of 140 days. These transmitters emit a pulse train every 50-130 seconds to minimize simultaneous pulse train transmissions by other acoustic transmitters in the immediate area. The V16-4H transmitters measure 68 mm in length by 16 mm in diameter, weigh 11 g in water, and have a battery life expectancy of 570 days. The V16-4H transmitters emit a pulse train every 20-69 seconds. All transmitters operate on the same frequency (69 kHz), with each one transmitting a unique pulse train that can be recognized by either a submersible, stationary VR2 receiver (Figure 8), or a portable ultrasonic receiver connected to a VH65 omni-directional hydrophone. In 2008, a portable VR-60 (VEMCO Ltd.; Figure 9) receiver was used for manual tracking in June and August, and a newer model VR-100 receiver (Figure 10) was used in October.

Figure 8. Deployment of a stationary VR-2 receiver, also showing steel cable and float.

Stationary receivers operate with a built-in omni-directional hydrophone and an internal data logger. The omni-directional hydrophones of both the stationary and the portable receiver detect the pulse train transmitted from active transmitters within its range of detection, which may vary depending on environmental conditions (i.e., range of detection decreases with decreasing depths, increasing water velocity and turbulence or other “noise”). Based on preliminary field testing in the Study Area and on experience from other acoustic tagging studies (e.g., Pisiak and Barth 2006), the range of detection for all stationary receivers in this study was estimated at 500 m.

Figure 9. VR-60 acoustic receiver used for manual tracking of fish in June and August.

Figure 10. VR-100 acoustic receiver used for manual tracking of fish in October (from http://www.vemco.com).

It should be noted that although transmitters emit pulse trains at variable intervals, the possibility exists of simultaneous transmissions reaching a receiver when a number of acoustic-tagged fish are within a receiver's range of detection. Receivers positioned in close proximity to the tagging / release sites are particularly susceptible to this. As such, receivers cannot distinguish individual signals and the possibility exists that signals were missed by stationary receivers.

At each stationary receiver location, a coated steel cable attached to a king anchor was held vertically in the water column by a large float (Figure 11). Stationary receivers were attached via steel brackets to the cable and lowered into the water using a second float line (Figure 8). A U-bolt attached to the cable approximately 2 m off the river bottom served as a stopper. Tests performed for similar studies (e.g., Pisiak and Barth 2006) have shown that receivers positioned near the river bottom had a higher range of detection than those placed near the surface. This set-up allowed each receiver to be held vertically in the water column and allowed for the receivers to be pulled up along the anchor cable with relative ease while eliminating the need to pull the anchor. This also ensured that following each download, receivers would be repositioned in the same location and at the same depth. Stationary receivers recorded the transmitter code number, date, and time of detection in an internal data logger until downloaded by an IBM/PC/AT computer. A VR2PC computer interface (VEMCO Ltd.) was used to transfer data between receiver and computer.

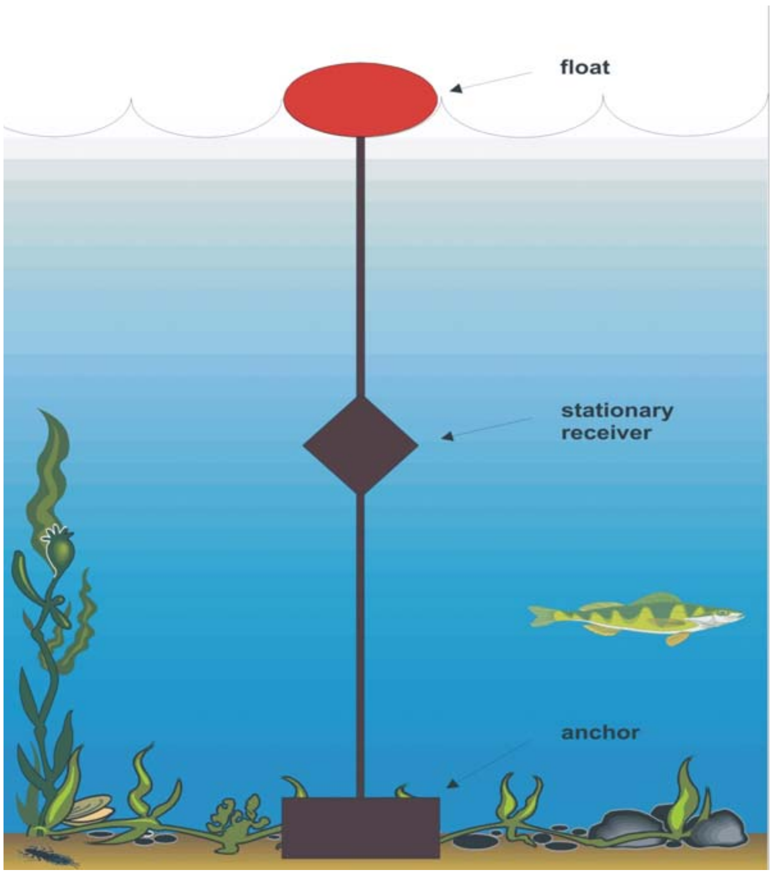


Figure 11. Schematic presentation of a deployed stationary acoustic receiver with anchor and float.

### 3.3.2 Fish tracking

Seven stationary VR2 receivers were installed downstream of Kelsey GS and tested for signal detection on 8 June, 2008 (Figure 1). A list of receiver locations with UTM coordinates and the periods of deployment is provided in Table 1. Locations were selected based partially on the experience of the 2006 study. However, water levels and velocities within the Nelson River did not allow safe navigation through Anipitapiskow Rapids, requiring receiver R6 to be installed south of location R1 from 2006. Furthermore, receivers R6 and R7 were lost prior to the first data download (see below) on 6 August due to rapidly rising water levels and thus provided no records of fish movements. VR2 receivers were downloaded a second time prior to their removal from the Nelson River on 6 October, 2008.

In addition to the stationary receivers, fish movements were monitored by manual tracking from a boat with a portable VR-60 receiver on 13 and 17 June, 6 and 7 August, and a portable VR-100 receiver on 6 October. For each of the five tracking runs, the boat followed a regular path within the boundaries of the tracking area (Figure 1), stopping every 300-500 m at waypoints established during the first run to check for acoustic signals. Because safe navigation through Anipitapiskow and Sakitowak rapids was not possible, these two features marked the downstream extent of the manual tracking study area (see Figure 1). At each waypoint the hydrophone was lowered 1-2 m into the water and held there for approximately 3-5 minutes. If a number of signals were detected in the area, the hydrophone was held in the water for a longer period of time to ensure all signals in the area were detected. If a weak signal was detected, the boat was maneuvered into the immediate area and acoustic readings were taken at shorter distances following a path of increasing signal strength until transmitter identification was obtained or could not be achieved. The time and location of tag identification was recorded. Although the actual position of the manual receiver at the time of transmitter identification sometimes differed by a couple hundred meters between relocations on different days of a tracking period, or the signal for the same fish was sometimes received from several locations within a 30-45 min time span, it was assumed that the fish had remained ‘stationary’ between such relocations. A total of 65 distinct manual tracking locations were assigned, 41 of which provided fish signals (Figures 12-14; Appendix 2).

Manual tracking effort and the extent of the tracking area differed between tracking periods. The two tracking runs on 13 and 17 June, during and immediately after the days of fish release through the turbine, focused on areas closer to the GS, extending north only as far as receiver location R4, east only 500 m into the southern arm of the Nelson River to location VR46 (Figure 13), and west to location VR18 in the Grass River. In August, heavy spill at the GS prevented tracking at locations east of the powerhouse. In October, the entire tracking area was covered, but waypoints were only visited once. Thus, the area west of the Kelsey GS to the narrows of the Grass River and extending north to approximately location VR 46 was searched for acoustic signals during every day of manual tracking, the westernmost part of the Grass River and the area east of location VR 39 and north of R4 was searched three times, and the area east of the powerhouse and the two arms of the Nelson River extending north and east from stationary receiver location R4 and location VR46 were searched twice.

In Part 1 of this report, acoustic-tagged fish are identified by their Floy-tag number. To allow cross identification of fish between the two parts of the report, text references to individual fish in this part of the report also use their Floy-tag number.

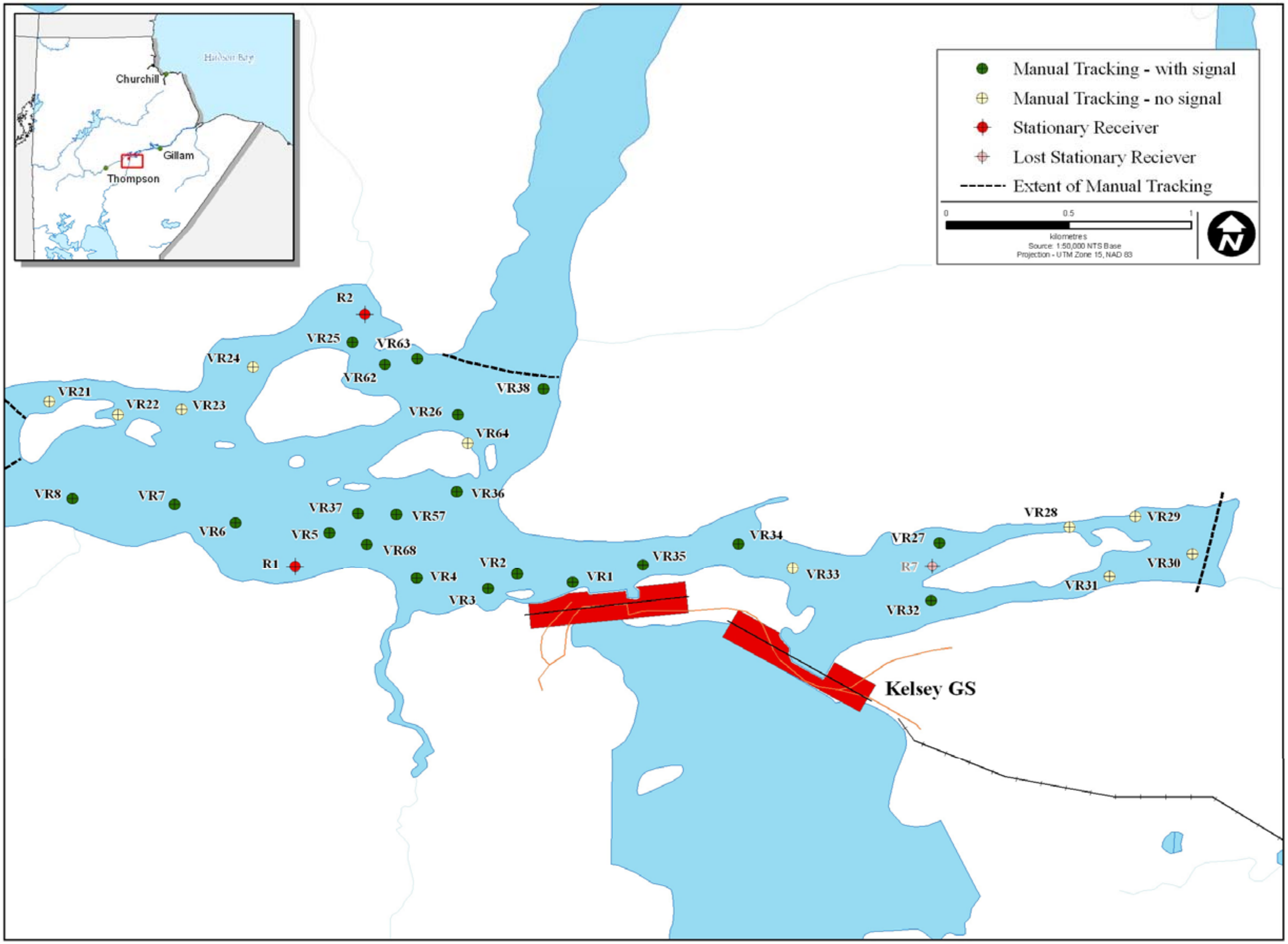


Figure 12. Sites with fish relocation(s) from manual tracking in the area near the Kelsey GS, June-October 2008.

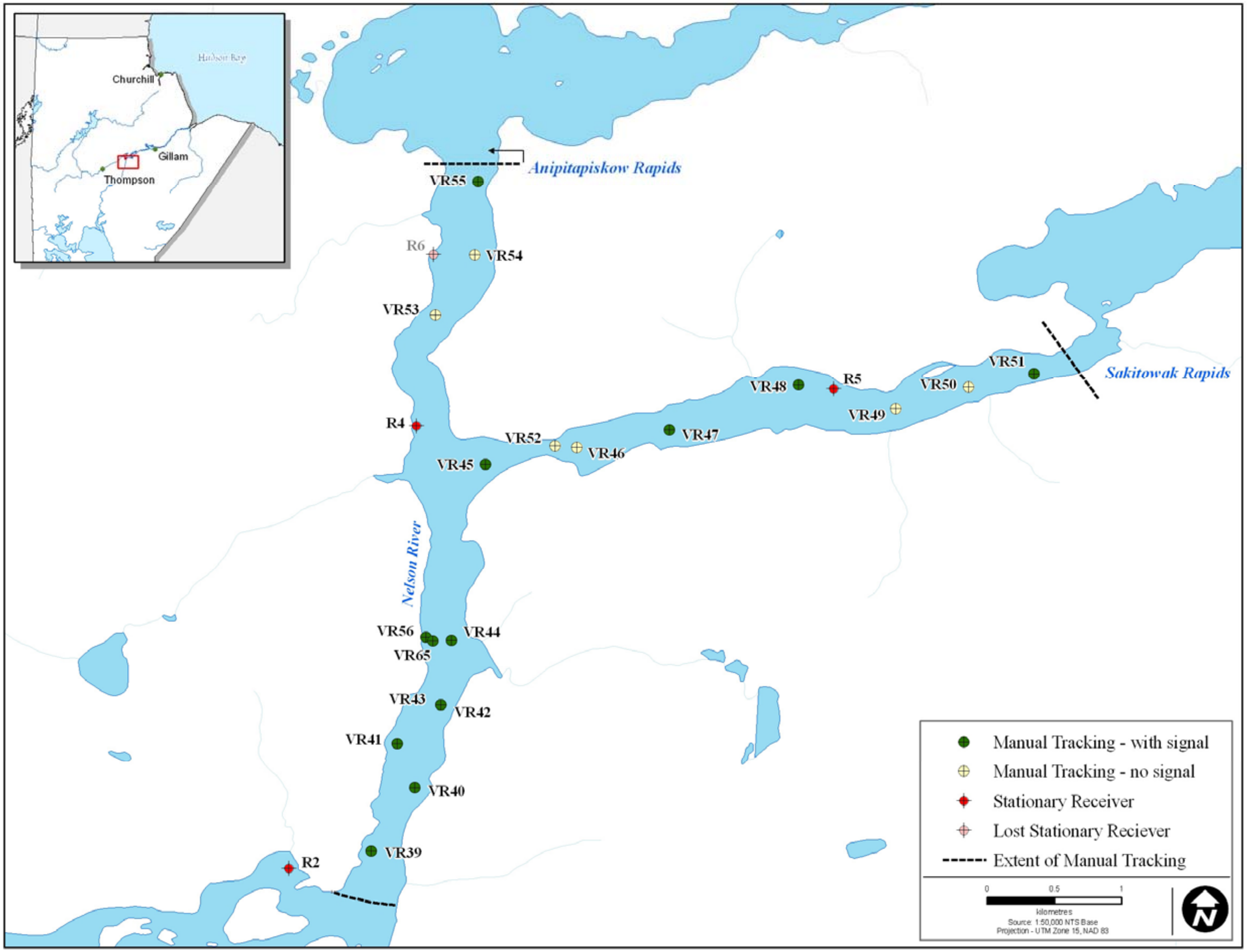


Figure 13. Sites with fish relocations from manual tracking in the area north of the Kelsey GS, June-October 2008.

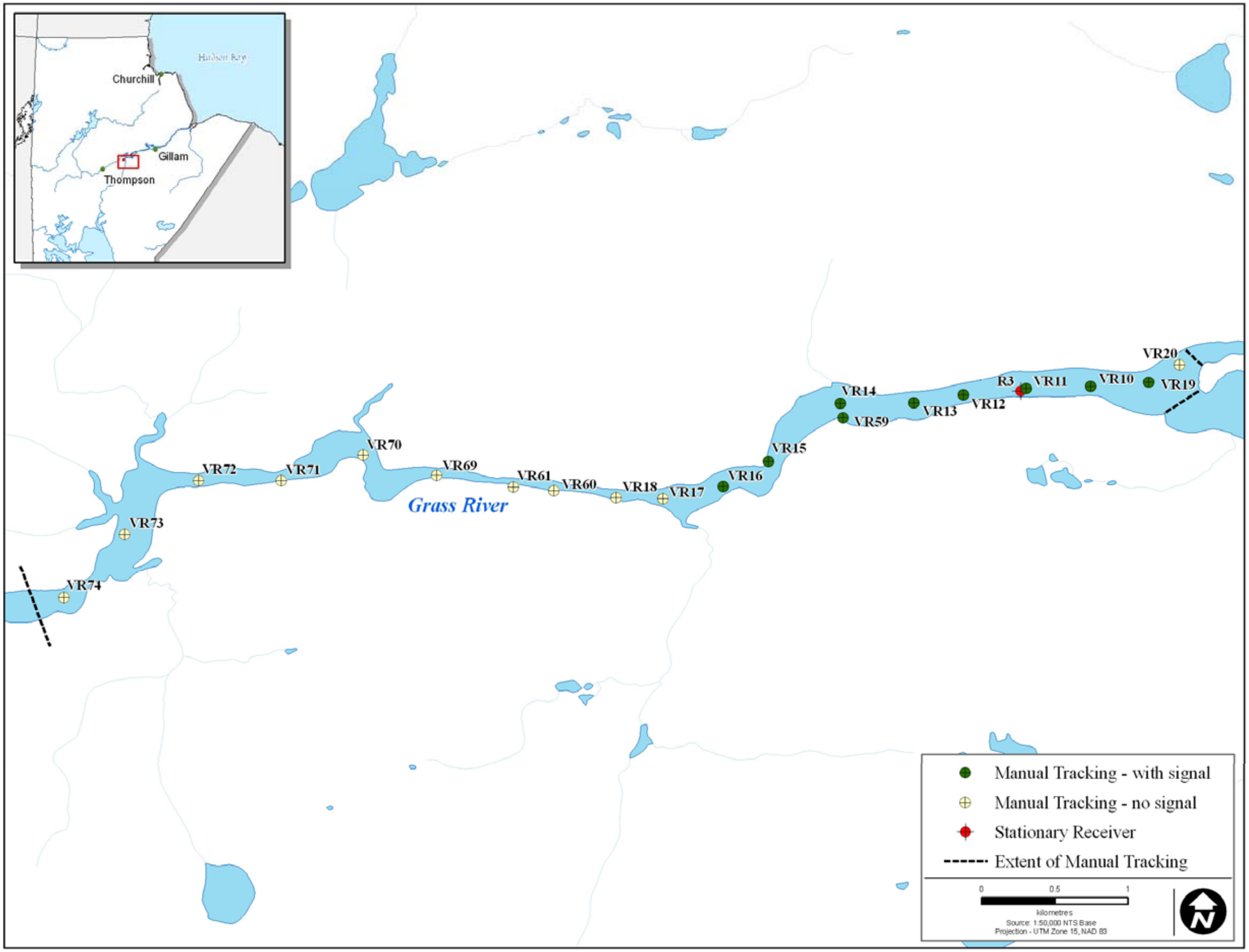


Figure 14. Sites with fish relocation(s) from manual tracking in the area west of the Kelsey GS, June-October 2008.

## 3.4 DATA ANALYSIS

A conservative measure of the extent of movements of acoustic-tagged fish over the study period was calculated as the minimum distance of movement (MDM). The MDM was calculated by adding the distances between the downstream exit of turbine Unit 5 and all subsequent relocations to the nearest 100 metres. On those few occasions when signals from the same fish were recorded repeatedly by stationary receivers R1 and R2 just 0.5-2 minutes apart, the distance (1.3 km) between the receivers (Table 1) was not applied in the calculation of the MDM, because it was assumed that the fish was stationary near the midpoint between the two receivers. Since both the time period and the frequency of relocations sometimes differed substantially between individuals, MDM has to be used with caution when comparing movements between individual fish. Another metric that was calculated to quantify fish movements was the maximum distance from the Kelsey GS that a fish was relocated (MaxD). Categories were established for both MDM (<6, 6-20, >20-50, >50 km) and MaxD (<4, 4-7, >7 km) to classify movement distances. These distance categories were arbitrary and were based on the distribution of the data.

In addition to the above quantitative analysis, fish movements were also assessed qualitatively. For this, the entire Study Area was split up into three sub-areas that differed in their distance from Kelsey GS and also in their physical characteristics and general habitat. Area 1 is the region bordered by the Kelsey GS in the south, extending west to locations VR9 and VR21, north to location VR38, and east to location VR30 in the section of the Nelson River east of the spillway, hereafter referred to as “East Bay” (Figures 1 and 12). This area is mainly characterized by relatively shallow (<10 m depth), turbid waters over bedrock/boulder/hard mud substrate with a number of bays that feature some macrophyte growth and/or coarse woody debris including deadfalls. Area 2 includes the Grass River from location VR74 downstream to the limits of its plume as it extends into the Nelson River just north of location VR20 (Figures 1 and 14). In contrast to 2006, this area did not include the unnamed tributary of the Nelson River south of E2 (Figure 2) because water levels were too low to navigate safely into the creek. Area 2 is characterized by generally shallow (<5 m), relatively clear but **DOC**-rich waters indicating bog influence (see Figure 15). Sediments consist mainly of sand or mud with local accumulations of organic debris and stands of submerged and/or emergent macrophytes. Water velocities are generally low (estimated at <0.4 m/s), typically the lowest of all three areas. Area 3 is the Nelson River mainstem just south of location VR39 to the northern extent of the Study Area (Figures 1 and 13). This area features a variety of habitats, but mainly has moderate to fast flowing (≥ 1.0 m/s), deep (up to 30 m), mainstem waters. The water is turbid and bottom substrates mainly consist of bedrock or boulders (overlain by compacted mud in places) with a few sandy shoreline areas within bays. Macrophyte growth is local (e.g., bays near VR41 and VR44; Figure 13) and sparse.

Apart from an assessment of the use of the three broad geographical areas, a second qualitative measure of fish movement, mainly related to speed and frequency of movement, was categorized. Six categories were recognized: Short = signal was received only for a few days, no pattern was assessed; Fast and Distant (FD) = fast movement to a distant location and out of the Study Area; Extensive= generally wider ranging movements between several locations over at least a one month period; Stationary (Stat) = little movement limited to the area near Kelsey GS (including location R3); Foray = mainly stationary near the Kelsey GS (including location R3) with one foray to location R4 or R5; Grass River = movement into the Grass River (location R3 or further west) and loss of signal soon after.

Differences in mean MDM and MaxD between control and treatment fish and between northern pike and walleye were ascertained employing one-way or two-way analysis of variance (ANOVA). If the distribution of the MDM and MaxD data could not be normalized by transformation or tests for equal variances failed, an ANOVA on ranks according to Kruskal-Wallis was performed. Statistical analyses were run using Sigma Stat V. 3.0 (SPSS 2003) software.

# 4.0 RESULTS AND DISCUSSION

## 4.1 STUDY LIMITATIONS AND DIFFERENCES TO 2006

One major objective of the 2008 study was to compare post-release movements of control and treatment fish based on a somewhat larger sample size than used in 2006. A total of eight control pike and eight control walleye were acoustic-tagged in 2008 (compared to four pike and two walleye in 2006). No acoustic signal was recorded for fish #75161, reducing the number of control pike for movement analysis to seven.

Only one walleye (#86683) and one pike (#75690) were found east of the spillway flows. This information is based on only three days of mobile tracking on 13 and 17 June and 6 October as one stationary receiver installed in this area was lost. Due to the relatively simple morphometry of the river channel east of the spillway, it is unlikely that acoustic signals of resident fish in the above area would have been missed by the receiver. However, because of the long time period between the two tracking events in the Nelson River east of the spillway, and because the unnamed tributary flowing into the east end of East Bay could not be accessed for acoustic tracking in June and October due to low water levels, the possibility cannot be excluded that some of the acoustic-tagged fish moved outside of the tracking area . Persistent low water levels also prevented both fish capture and meaningful manual tracking in the tributary of the Nelson River entering Cabin Bay (south of site E2 in Figure 2). As evidenced during the 2006 study when at least one fish swam into this tributary, it represents another potential habitat into which fish could have moved and escaped, at least temporarily, acoustic-tracking in 2008.

Considering these limitations and the slight differences from the 2006 study, the focus of the following sections will be the survival of treatment fish and the comparison of movements of control and treatment fish for pike and walleye in 2008. In addition, some comparisons will be made between the movements of treatment fish in 2006 and 2008, and an update will be provided on fish that were acoustic-tagged in 2006 and tracked in 2008.

## 4.2 SURVIVAL OF ACOUSTIC-TAGGED FISH

Acoustic transmitters were implanted into 33 of the 95 adult (>450 mm total length) northern pike (34.7%), 27 of the 91 walleye (29.7%), and one of the 11 lake whitefish (9.1%) that were used as treatment fish in the Turbine Passage Study (see Part 1 of this report). Because some of the acoustic-tagged fish did not survive turbine passage, or were not recovered after passage (1 pike), 23 treatment pike and 25 treatment walleye were available for tracking (Table 2, Appendix 1). Approximately equal numbers of pike and walleye were passed through the turbine at all three release depths between 10 and 16 June (Table 3). The single whitefish was a shallow release. In addition to the treatment fish, eight each of the 30 pike and 30 walleye (26.7%) used as control fish were acoustic-tagged, resulting in a total count of 65 fish that were available for tracking.

The acoustic-tagged treatment pike had a mean total length of 583 mm and a mean weight of 1,246 g, almost identical to the mean length of 586 mm for all treatment pike (Table 4). The eight control pike that were fitted with acoustic transmitters had a mean length of 617 mm and a mean weight of 1,406 g, slightly larger than the mean length of 593 mm of all control pike (Table 4). The mean length of acoustic-tagged walleye that were either treatment fish (435 mm) or control fish (438 mm) were slightly larger compared to all walleye within those two groups of fish (430 and 428 mm, respectively). Treatment and control walleye that were acoustic-tagged weighed on average 915 g and 931 g, respectively (Table 4). The one treatment whitefish measured 620 mm and weighed 3,600 g and was the second largest of the 11 treatment whitefish that measured from 108-646 mm.

All 16 acoustic-tagged control fish survived and were released into the Nelson River with their radio tag and HI-Z balloons removed. Of the 60 acoustic-tagged pike and walleye that were released through the turbine, nine pike (27.3 % of the pike) and two walleye (7.7% of the walleye) did not survive the turbine passage or died within 48 hours (Table 2). These mortality rates were slightly higher compared to those observed for treatment pike >430 mm length that were not acoustic-tagged (21.2%; based on column "survival code" of Appendix C of Part 1), and were slightly lower for non acoustic-tagged treatment walleye (11.1%). Of the remaining 24 pike and 25 walleye that were acoustic-tagged treatment fish, one pike (#74757) was not physically recovered after turbine passage (Table 2: Appendix 2) and, consequently, its radio tag and HI-Z balloons were not removed. Acoustic signals were obtained for this pike from several locations until 3 October, 2008, indicating that this fish was alive after turbine passage (Appendix 1). Because the possibility cannot be excluded that the attached HI-Z balloons (they usually deflate within 6-24 hours without being punctured; Paul Heisey, Normandeau Associates, pers. comm.), cable ties, and the radio tag with antenna affected fish locomotion, pike #74757 was not considered in the quantitative analyses of fish movements. This treatment of unrecovered fish was more conservative than in the 2006 study, for which two unrecovered pike and walleye each were included in the calculations of MDM and MaxD.

Of the 65 fish that were available for tracking only one fish never had its signal recorded. This individual was pike #75161, which had been released as a control fish on 14 June. All of the remaining 64 acoustic-tagged fish were considered to be alive over the time period of their tracking. This assessment was based on the temporal and spatial pattern of signal reception, and included the two pike (#86576 and #86811) and one walleye (#86805) that were released with what was assessed a major injury (see Appendix Table D-2 of Part 1; the numbers in column VI represent the last three digits of the tag number).

The number of tracked fish decreased with time post-release (Table 5): 63 fish were tracked during the time period of turbine passage and the release of control fish (i.e., 10-17 June, Period 1); the signal of 59 fish was received during tracking Period 2 (18 June-7 August), and 32 fish were relocated during Period 3 (8 August-6 October). More than one third (n=24) of the 65 fish available for acoustic tracking were detected (and very likely alive) between 20 September and 6 October, approximately 13-15 weeks after passing through the turbine (n=18) or being released as control fish (n=6; Appendix 1). Twenty of the 24 fish were acoustic-tracked during the last three days before the receivers were removed from the water.

For the vast majority of fish (92.2%), an acoustic signal was received at least 14 days after their release into the river (Table 6). All of the three pike and two walleye that were acoustic-tracked for less than 12 days were treatment fish. These results are somewhat different from comparable data for the 2006 study (Jansen and Murray 2007). In that year, exactly one third (including one of the five control fish) of the 39 acoustic-tracked pike and walleye could no longer be detected after day 10 post-release. In addition, 43.8% (or 42.9%, if the one whitefish is excluded) of the fish had a signal recorded for at least 85 days post-release in 2008. This proportion was higher than the 38.5% observed in 2006. Consequently, the mean number of days to last signal reception of pike and walleye (because of the different lengths of the studies all days >91 in 2008 were set to 91 for the calculation) was higher (56.0 days) in 2008 than in 2006 (49.3 days).

An assessment of the longer-term (3-4 months) survival of those fish that were tracked for only a relatively short period of time soon after turbine passage or control release is often difficult and can only be inferred based on the temporal and spatial pattern of relocations together with our knowledge about the ‘normal’ behaviour of the study species. Such an approach indicates that almost half of the 20 fish that were tracked for less than 26 days (the time period was extended beyond the two week limit used in 2006 to increase sample size; see above) likely moved north-east on the Nelson River outside of the Study Area soon after being released (see movement pattern "FD" in Appendix 1 and Section 4.3.3.3). For nine of the 20 fish (two controls and seven treatment fish), or approximately 14% of all acoustic-tracked pike and walleye, the last signals at the end of their tracking were stationary and the possibility exists that some of these individuals died with a delayed effect of turbine passage or handling/tagging stress being a contributing factor. However, equally likely, these fish did not die but rapidly moved out of the range of the receivers or otherwise avoided signal detection, or if they died, their death was unrelated to the turbine passage. Fish handling and surgery for transmitter implantation is unlikely to have contributed to mortality of acoustic-tagged fish, because fish movement studies unrelated to turbine passage performed by the study team indicate approximately 100% survival of fish equipped with acoustic tags (Murray et al. 2005; Pisiak and Barth 2006). The relatively small proportion of fish for which an assessment of longer-term (3-4 months) survival is uncertain, is almost identical to the corresponding value (15%) for pike and walleye in the 2006 study (Jansen and Murray 2007).

Some of the fish acoustic-tagged in June of 2006 were confirmed to be alive in the Study Area during the 2008 tracking period, indicating that at least some pike and walleye may live for >2 years after turbine passage (for details see Section 4.3.3.4).

## 4.3 FISH MOVEMENT AND BEHAVIOUR

### 4.3.1 Stationary receivers versus mobile tracking

For the three assigned tracking periods, manual tracking over 1-2 days supplemented the information obtained from the stationary receivers. During periods 1 and 3, the signal of 3 and 5 fish, respectively, was only recorded from manual tracking. However, overall, the stationary receivers detected the signal of all 64 fish that were acoustic-tracked, whereas manual tracking provided acoustic information on 44 fish, 21 pike and 23 walleye (Table 5).

### 4.3.2 Effect of capture location

Because all fish used in this study were individually identified and the approximate capture location recorded, it was possible to compare the post-release movement pattern of treatment and control fish to the location and the habitat at the time of their capture. For most of the fish captured near the GS in the Nelson River (excluding the one whitefish and one walleye that were obtained from the forebay of the GS) no association of capture location and post-release movement and habitat use was obvious. Many of these fish moved extensively in the Nelson River, including the mouth of the Grass River (stationary receiver R3), or likely left the tracking area to the northeast (Appendix 1). The 13 fish that were captured either in the Grass River (locations E1 and GN2 in Figure 1) or from East Bay (locations E4 and A3 in Figure 1) show some suggestion of "homing". Both locations are characterized by relatively calm waters that are less turbid than the Nelson River mainstem, and that must be of different chemical composition because of the massive (Grass River) or at least noticeable (East Bay) input of DOC and particulate carbon rich run-off from adjacent peatlands (see Figure 15). Of the only two fish that were ever acoustic-tracked east of the spillway, one pike (#75690) was initially caught in East Bay, the other (walleye #86683) had been electrofished in the Grass River. Furthermore, of the two other fish that were acoustic-tracked east of the powerhouse (but not past the spillway), one walleye (#75699) was also one of the eight fish captured in East Bay. Other than walleye #86683, of the remaining four fish captured from the Grass River, walleye #86682 and pike #86595 returned after turbine passage and had their last acoustic signal recorded in the Grass River. Considering that the tracking effort was very low at locations east of the powerhouse (i.e., no stationary receiver), it is possible that other fish returning to their capture locations were missed (see Section 4.3.3). Although not conclusive, these observations suggest that some pike and walleye showed an affinity to their capture habitat or to some of its characteristics (e.g., water chemistry, low velocities).

### 4.3.3 Quantitative and qualitative fish movement

#### *4.3.3.1 Length and frequency of acoustic signal reception*

There were no substantial differences in the pattern of acoustic signal reception between control fish and treatment fish in this study. Although several treatment pike and walleye were no longer tracked after the first 11 days post-passage, whereas all control fish were tracked for at least 14 days (Table 6; also see Section 4.1), this initial discrepancy between the two groups did not result in a significant difference in the mean number of days to last signal reception in either pike (61.1 control, 56.6 treatment) or walleye (78.4 control, 67.4

treatment). Similarly, the mean number of days an acoustic signal was received did not significantly differ between control (14.3) and treatment (10.6) pike or control (22.4) and treatment (32.5) walleye. However, in contrast to the number of days to last signal, the number of days with a signal significantly differed between species, for both control and treatment fish. This was mainly due to the fact that more than one third of all walleye had their signal received on 22-71 days, whereas this proportion was less than 15% for pike, and no pike signal was received for more than 71 days (Table 7). The one acoustic-tagged whitefish was tracked on 12 days, including 6 October, the last day of the study (Appendix 1).

Figure 15. Mixing zone of the Grass River (dark colored water) and the Nelson River (blue-grey coloured water) near the shore north of manual tracking location VR 19 (see Figure 14), showing differences in water characteristics.

#### *4.3.3.2 Distance of movement*

Mean MDM of pike was higher for control (18.8 km) than for treatment (11.0 km) fish, whereas the reverse pattern existed for walleye (treatment 24.8 km, control 15.9 km; Table 8). Similarly, mean MaxD was larger for control pike (6.0 km) than for treatment pike (4.9 km), and was smaller for control walleye (4.5 km) than for walleye that had passed through the turbine (5.5 km). However, all these differences in the quantitative measures of fish movement were not statistically significant. The interaction effect of species and experiment type (i.e., control or treatment) in the 2-way ANOVA on MDM resulted in a P-value of 0.09. Thus, there was no clear evidence that treatment and control fish differed in their distance of movements or that pike and walleye differed in the way control and treatment fish moved quantitatively. Similarly to the results for 2006, treatment walleye had a significantly higher MDM than treatment pike. MaxD also was higher in turbine-passed walleye than in pike in 2008, however, unlike in 2006, this difference was not significant. The one treatment whitefish had moved a minimum distance of 10.5 km over the 12 days it was tracked and during which it was located maximally 4.8 km away from Kelsey GS (Appendix 1).

The MDM and MaxD of treatment walleye in 2008 were almost identical to that of turbine-passed walleye in 2006 (23.8 km and 5.5 km, respectively). However, for treatment pike, the MDM of fish tracked in 2008 was significantly (P=0.011) higher than in 2006 (6.8 km). Similarly, MaxD of treatment pike in 2008 was significantly (P=0.031) higher than in 2006 (3.2 km). Higher distances of movement, at least in MDM, of the 2008 fish could be expected because of the approximately one month longer study period in that year, providing additional opportunities for fish movement. However, the time period from 4 September (the first day after the end of the 2006 study) to 6 October, 2008 fell into the period of steep decline in Nelson River water temperatures which had started approximately two weeks earlier (Figure 16). Although there were a few exceptions (see Figures 19 and 20, below), walleye tended to move less than pike during the latter part of this cooling period, which may help to explain the observed species difference in MDM between 2006 and 2008.

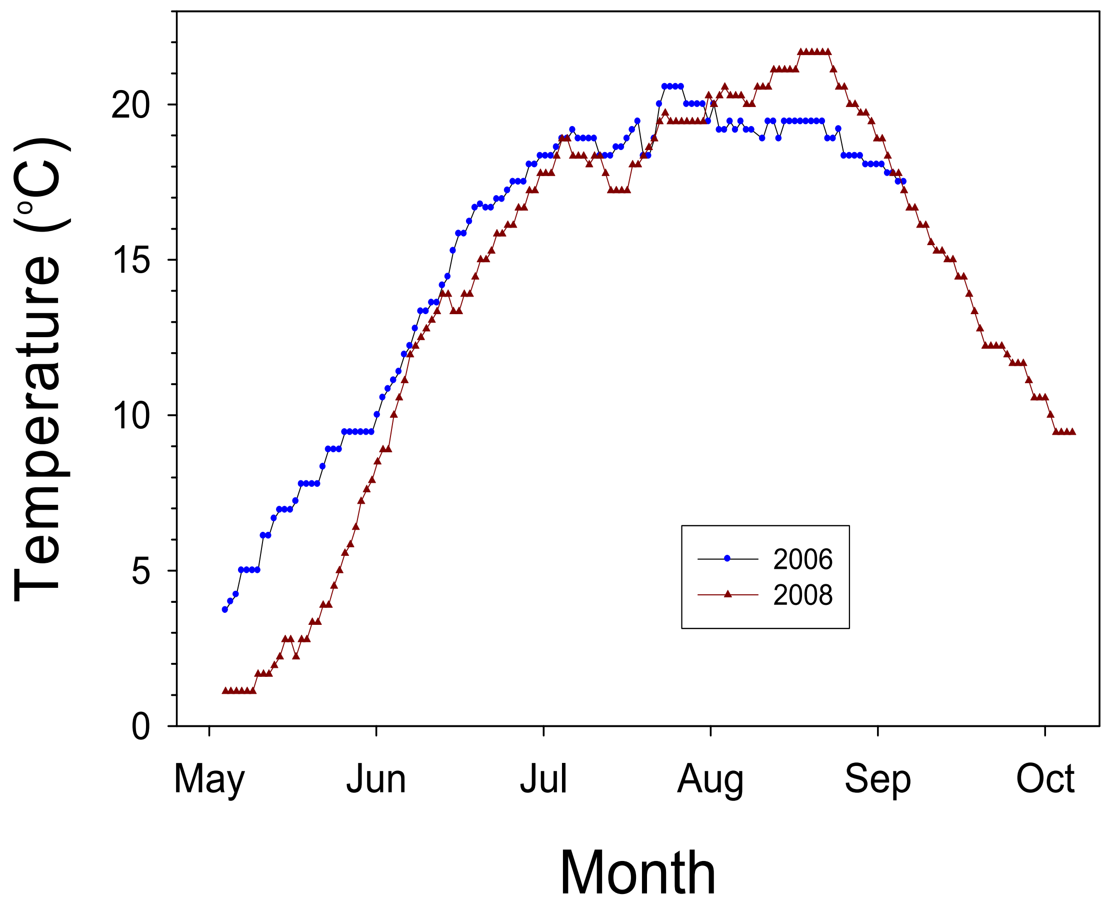


Figure 16. Daily Nelson River water temperatures at the Kelsey GS forebay in 2006 and 2008. Measurements were taken at the Unit 1 cooling water inlet.

### *4.3.3.3 Pattern of movements*

Control and treatment fish also were quite similar in their qualitative patterns of movement. Relatively few fish remained in the immediate area of the GS, but moved north on the Nelson River, west into the Grass River, or were located in both of these rivers (Table 9). The few differences between treatment and control fish were that none of the control walleye moved north on the Nelson River, that only one (i.e., 14%) of the control pike moved into the Grass River, but not into Area 3 (compared to 48% of the treatment pike), and that almost half of the control pike moved into both the Grass and northern Nelson rivers (Table 9). However, it must be noted that with eight walleye and seven pike the number of control fish is low compared to the number of treatment fish, leading to relatively large changes in percentage values with small changes in absolute numbers. Thus some of the above differences between treatment and control fish appear inflated. The one acoustic-tracked whitefish moved north into the Nelson River, but had not left the Study Area by the end of tracking on 6 October.

Compared to the pattern observed in 2006, the only difference of note was that more treatment pike (48%) moved into the Grass River (but not into the northern Nelson River) in 2008 (Table 9) than in 2006 (21%; control fish were removed from the calculations in Table 8 of Jansen and Murray 2007). Correspondingly, fewer treatment pike remained in the Kelsey GS area in 2008 (9%) as compared to 2006 (36%).

In terms of the five movement patterns distinguished in this study, the seven control pike showed almost all of the patterns that were observed for the 23 treatment pike (Table 10); Control pike #74752, for example, showed fast movement north into the Nelson River past locations R4 or R5 (Figure 17). This fish was tracked for exactly one month near Kelsey GS near stationary receiver R1. Over an approximately two-hour period on 13 July, this fish made a brief foray to location R3, returned to R1 and was located at R2 from 20:28 to 20:32 h. The next signal came from location R5 at 6:56 h the morning of 14 July. After spending less than three hours at or near R5, pike #74752 was never tracked again, suggesting that this fish moved further east on the southern arm of the Nelson River and out of the Study Area

Of the treatment pike, fish #86817, for example, showed fast movement to location R4 and potentially further north on the Nelson River. This pike was tracked for approximately 1.5 hours on 13 June when moving twice between R1 and R2 (or at least between the edges of the receivers detection ranges; Figure 18). Pike #86577 was next detected at location VR38 during manual tracking on 17 June before being tracked for the last time by receiver R4 for 30 minutes on 26 June.

In partial contrast to the observations on pike, the eight control walleye displayed only stationary or extensive movement, whereas the 25 treatment walleye showed all types of movement patterns (Table 10). Most (36%) of these latter fish showed extensive movements, whereas most (48%) treatment pike remained stationary. This species difference in the proportion of stationary and extensively moving treatment fish was similar to that observed in 2006 (Jansen and Murray 2007). Of those walleye moving extensively in 2008, fish #85490 had one of the largest MDMs of any control fish, mainly because it moved repeatedly between locations near Kelsey GS and receiver R5 (Figure 19). Treatment walleye #75698 also moved extensively within the study area between R1/R2 and R5 and was the only fish that was observed east of location R5, when it was manually tracked at VR51 on the last day of the study (Figure 20).

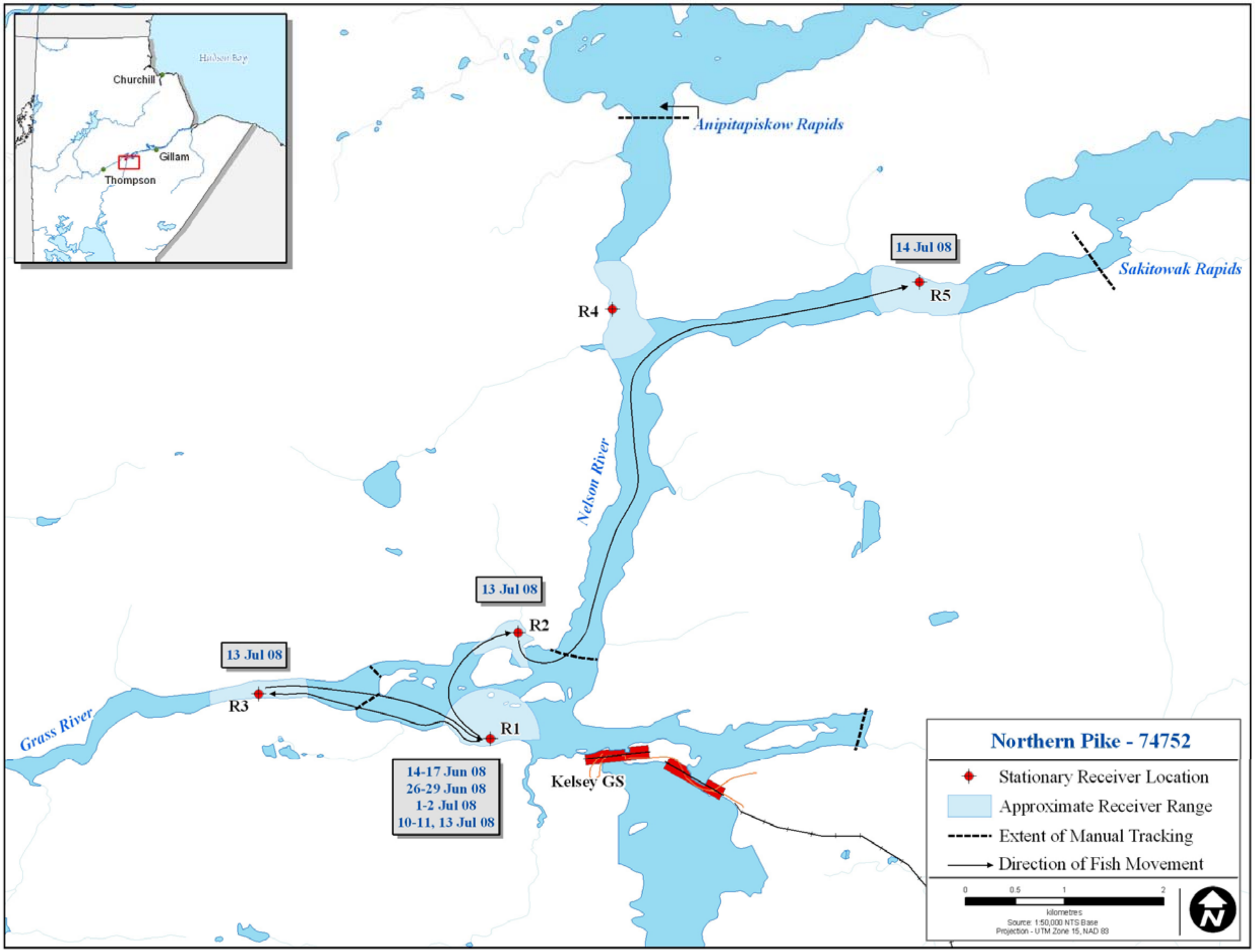


Figure 17. Movement of control pike #74752 between 14 June (release date) and 14 July, 2008.

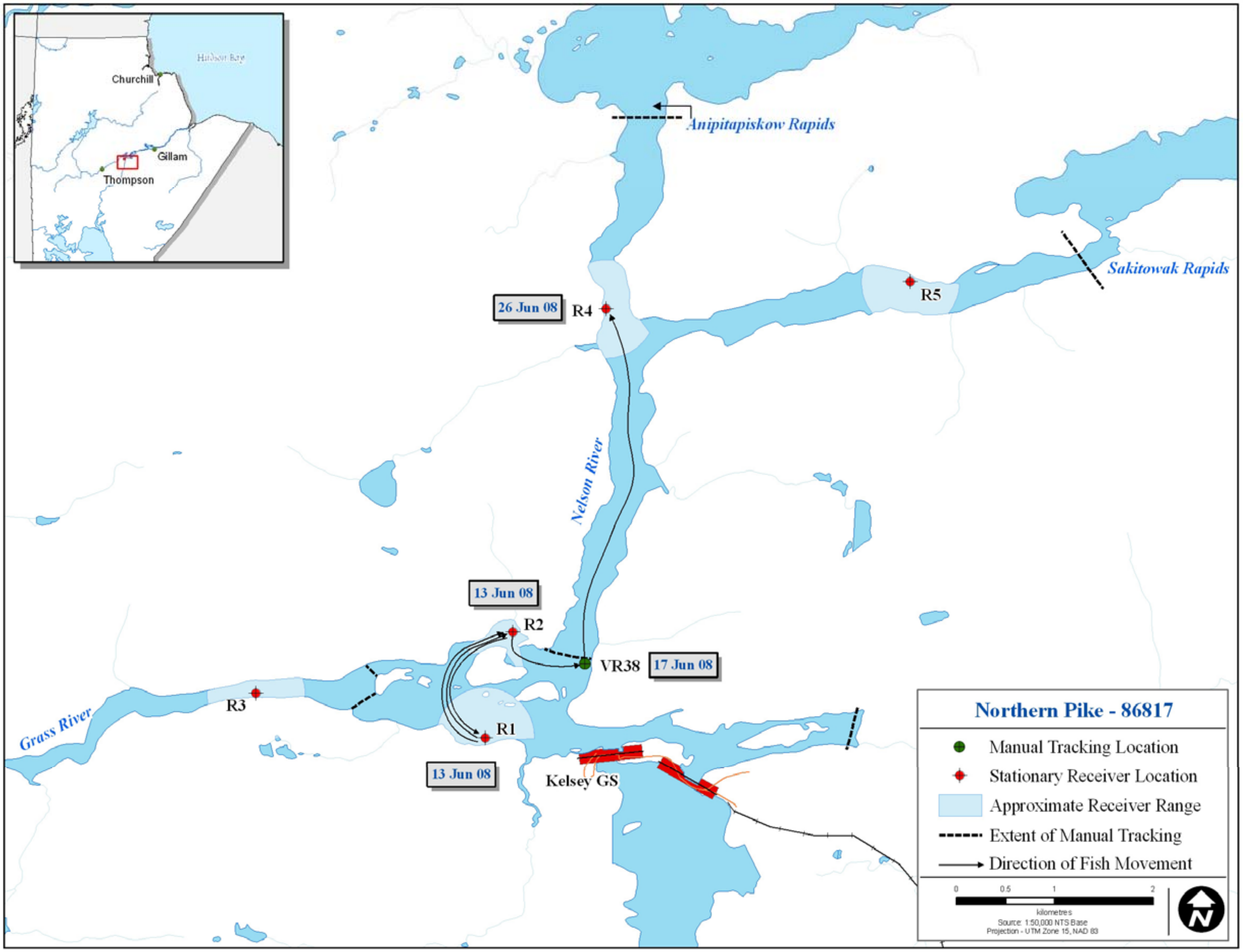


Figure 18. Movement of treatment pike #86817 between 13 and 26 June, 2008 after turbine passage on 12 June, 2008.

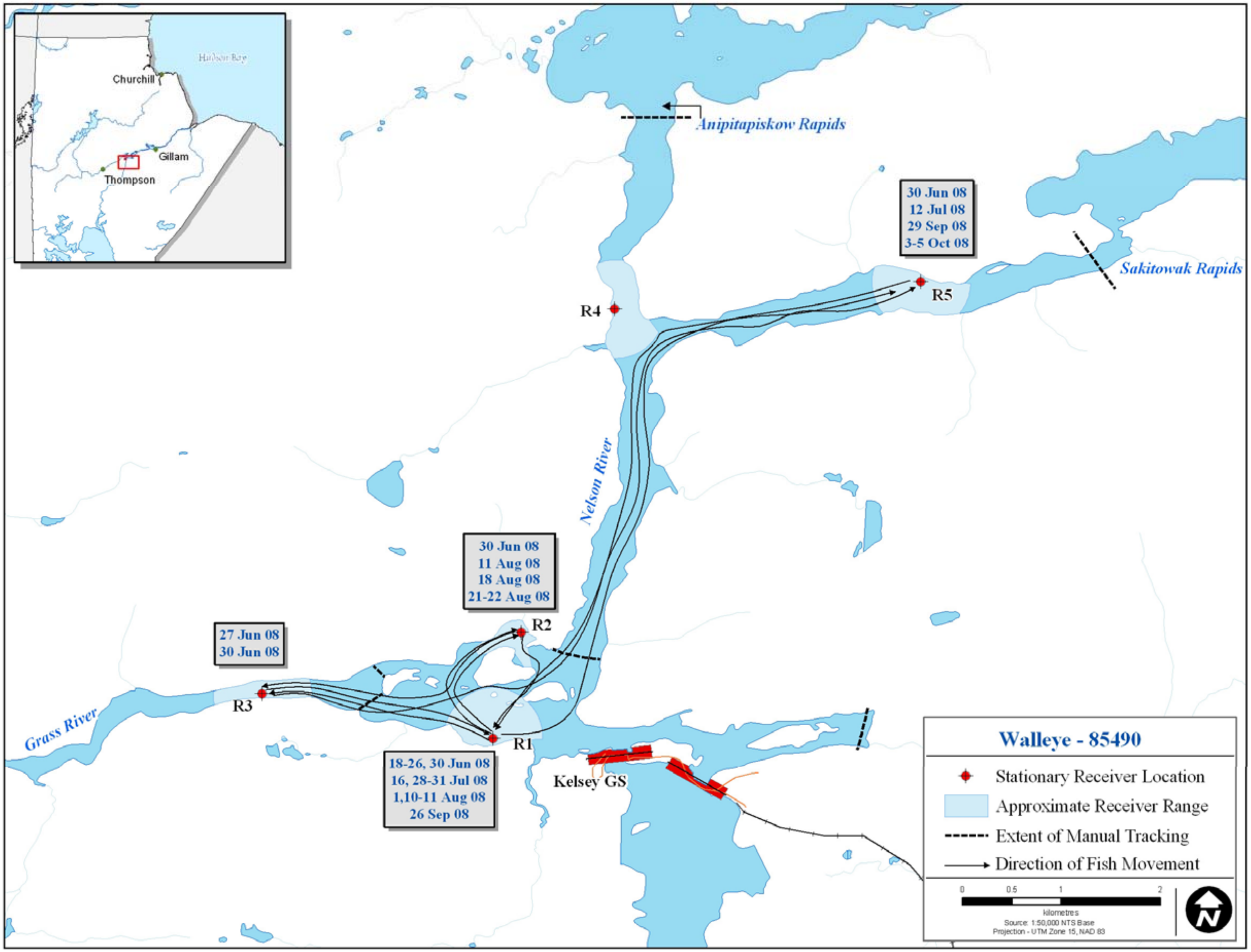


Figure 19. Movement of control walleye #85490 between 18 June and 5 October, 2008 after being released on 16 June, 2008.

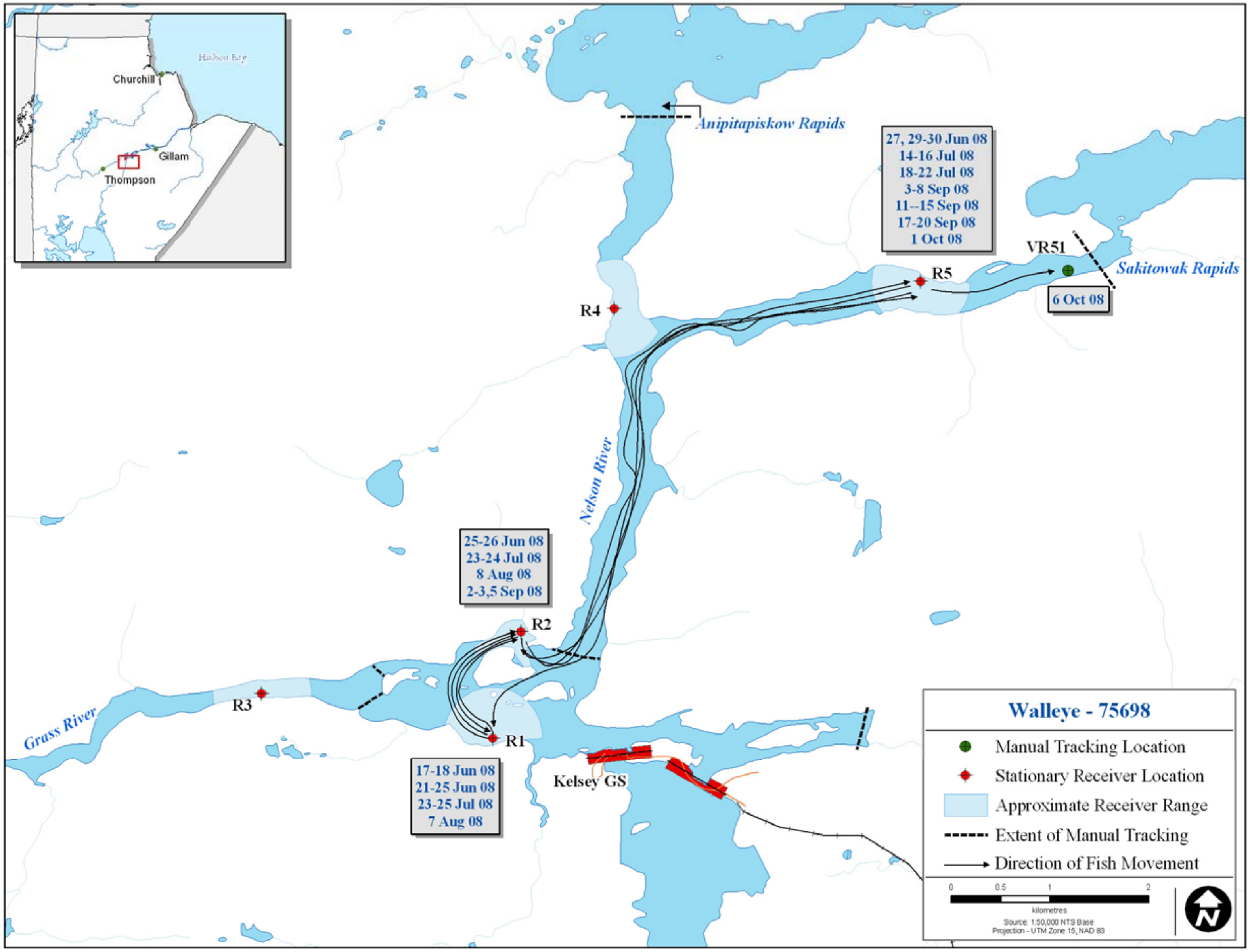


Figure 20. Movement of treatment walleye #75698 between 17 June and 6 October, 2008 after turbine passage on 16 June, 2008.

#### *4.3.3.4 Tracking of fish that had been acoustic-tagged in 2006*

Ten pike and walleye each were tracked between 9 August and the end of the 2006 study on 3 September, and were considered alive at that time. Of these 20 fish, which all had passed through the turbine, the signal of six pike and five walleye was acoustic-tracked in 2008, close to the end of the life expectancy of the V13 transmitters. The timing and geographic distribution of signal reception of the pike indicated that fish #84698 was very likely alive, that the status of three other fish is questionable, and that fish #84201 and #84692 are likely dead, the transmitter lying on the river bottom (Appendix 3). In contrast to the pike, the status of only one of the walleye is unknown, whereas the remaining four fish can be assumed to be alive. Three of these fish (84661, 84676, and 84652) that had moved extensively during the three months of the 2006 study (see Figures 22 and 23 in Jansen and Murray 2007 for examples) continued to do so over the almost four months they were tracked in 2008, showing sometimes repeated movements between the Grass River and the northern Nelson River (Appendix 3). Thus, these fish not only document the long-term (>2 years) survival of turbine-passed fish, but also provide further evidence that the movements observed in June-September of 2006 were not a transient artifact and affected by the trauma of turbine passage, but potentially reflect long-term behavioral patterns of individual fish.

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# 6.0 GLOSSARY

**Anadromous** – a species of fish that lives primarily in saltwater and migrates into freshwater to reproduce.

**Catadromous** – a species of fish that lives primarily in freshwater and migrates into saltwater to reproduce.

**DOC –** Dissolved Organic Carbon.

**Potamodromous –** a species of fish that lives and reproduces exclusively within freshwater, sometimes undertaking migrations to reach specific habitats.

**Smolts -** Young salmon when it becomes covered with silvery scales and first migrates from fresh water to the sea.

# TABLES

Table 1. Locations (UTM 14 V coordinates) of stationary receivers R1-R7[1], dates of deployment, and the shortest in-water distance to other receivers and the powerhouse of the Kelsey GS.

| | **Location** | | **Deployment** | **Removal** | **Distance to (km)** | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Receiver** | **Easting** | **Northing** | **Date** | **Date** | R1 | R2 | R3 | R4 | R5 | Kelsey[2] |
| R1 | 652090 | 6213338 | 8-Jun-08 | 6-Oct-08 | - | 1.3 | 2.4 | 5.0 | 7.5 | 1.3 |
| R2 | 652281 | 6214435 | 8-Jun-08 | 6-Oct-08 | 1.3 | - | 2.8 | 4.3 | 6.8 | 1.6 |
| R3 | 649720 | 6213588 | 8-Jun-08 | 6-Oct-08 | 2.4 | 2.8 | - | 7.0 | 9.5 | 3.6 |
| R4 | 652939 | 6217795 | 8-Jun-08 | 6-Oct-08 | 5.0 | 4.3 | 7.0 | - | 3.2 | 4.8 |
| R5 | 656006 | 6218338 | 8-Jun-08 | 6-Oct-08 | 7.5 | 6.8 | 9.5 | 3.2 | - | 7.4 |
| R6 | 652957 | 6219075 | 8-Jun-08 | lost before 6 Aug | - | - | - | - | - | - |
| R7 | 654688 | 6213565 | 8-Jun-08 | lost before 6 Aug | - | - | - | - | - | - |

[1] – R6 and R7 were lost before the first download of fish tracking data.

[2] – Tailrace of the powerhouse.

Table 2. Number of acoustic-tagged northern pike, walleye, and lake whitefish that were released as control and treatment fish, experienced different outcomes as treatment fish, and that were acoustic-tracked at Kelsey GS from June to October 2008.

| | Pike | Walleye | Whitefish | Total |
|---|---|---|---|---|
| Acoustically tagged | 41 | 35 | 1 | 77 |
| Control | 8 | 8 | 0 | 16 |
| Treatment | 33 | 27 | 1 | 61 |
| Treatment: not recovered | 1 | 0 | 0 | 1 |
| Treatment: dead within 48 hours | 9 | 2 | 0 | 11 |
| Treatment: recovered and released alive | 23 | 25 | 1 | 49 |
| Control: recovered and released alive | 8 | 8 | 0 | 16 |
| Total released into river | 31 | 33 | 1 | 65 |
| Acoustic-tracked | 30 | 33 | 1 | 64 |
| Not acoustic-tracked | 1 | 0 | 0 | 1 |

Table 3. Number of northern pike and walleye, by release depth and date, implanted with acoustic transmitters at the Kelsey GS in June 2008.

| | Northern Pike | | Walleye | |
|---|---|---|---|---|
| | **Number** | **Date** | **Number** | **Date** |
| Control | 8 | 14-June | 8 | 16-June |
| Treatment: shallow | 12 | 14-June | 11 | 16-June |
| Treatment: mid | 9 | 12-June | 9 | 12-June |
| Treatment: deep | 12 | 10, 11-June | 7 | 11-June |

Table 4. Comparison of the mean total length (standard error; SE) and round weight between all northern pike and walleye released as treatment or control fish and the subsample of fish that were acoustically tagged and re-released into the river.

| **Species** | **Treatment** | | | **Control** | | |
|---|---|---|---|---|---|---|
| | **Length (mm)** | | **Weight (g)** | **Length (mm)** | | **Weight (g)** |
| | **Mean (SE)** | **Range** | **Mean (SE)** | **Mean (SE)** | **Range** | **Mean (SE)** |
| | | | Acoustic-tagged fish | | | |
| Northern Pike | 583 (16) | 431-691 | 1246 (79) | 617 (13) | 571-690 | 1406 (73) |
| Walleye | 435 (11) | 332-550 | 915 (60) | 438 (20) | 371-530 | 931 (130) |
| | | | All experimental fish [1] | | | |
| Northern Pike | 586 ( 8) | 431-769 | - | 593 (10) | 433-690 | - |
| Walleye | 430 ( 7) | 332-653 | - | 428 (11) | 326-562 | - |

[1] For pike, only fish ≥431 mm were considered in the calculation for all experimental fish.

Table 5. Number of acoustic-tagged fish that were tracked by stationary or mobile receivers during three time periods between 10 June and 6 October, 2008.

| Species | 10 - 17 June [1] | | | 18 June - 7 August [2] | | | 8 August - 6 October [3] | | | All Periods | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Tracked manually | Stationary receiver | Total | Tracked manually | Stationary receiver | Total | Tracked manually | Stationary receiver [4] | Total | Tracked manually | Stationary receiver | Total |
| Northern pike | 20 | 28 | 30 | 4 | 25 | 25 | 3 | 10 | 13 | 21 | 30 | 30 |
| Walleye | 19 | 31 | 32 | 6 | 33 | 33 | 8 | 16 | 18 | 23 | 33 | 33 |
| Sum | 39 | 59 | 62 | 10 | 58 | 58 | 11 | 26 | 31 | 44 | 63 | 63 |
| Total [5] | 40 | 60 | 63 | 11 | 59 | 59 | 12 | 27 | 32 | 45 | 64 | 64 |

1 - Manual tracking was conducted on 13 and 17 June.
2 - Manual tracking was conducted on 6 and 7 of August.
3 - Manual tracking was conducted on 6 October.
4 - Receivers were removed from the water on 6 October.
5 - Includes one lake whitefish.

Table 6. Frequency of occurrence (%), by number of days, between release and last acoustic signal reception for treatment and control northern pike and walleye.

| Days | Northern Pike | | | Walleye | | | Total* |
|---|---|---|---|---|---|---|---|
| | Control | Treatment | All | Control | Treatment | All | |
| 2 - 11 | 0 ( 0) | 3 (13.0) | 3 (10.0) | 0 ( 0) | 2 ( 8.0) | 2 ( 6.1) | 5 ( 7.8) |
| 14 - 26 | 2 (28.6) | 4 (17.4) | 6 (20.0) | 2 (25.0) | 7 (28.0) | 9 (27.3) | 15 (23.4) |
| 29 - 52 | 2 (28.6) | 5 (21.7) | 7 (23.3) | 1 (12.5) | 3 (12.0) | 4 (12.1) | 11 (17.2) |
| 57 - 76 | 0 ( 0) | 4 (17.4) | 4 (13.3) | 0 ( 0) | 1 ( 4.0) | 1 ( 3.0) | 5 ( 7.8) |
| 85 - 91 | 1 (14.3) | 1 ( 4.3) | 2 ( 6.7) | 0 ( 0) | 0 ( 0) | 0 ( 0) | 2 ( 3.1) |
| 93 - 119 | 2 (28.6) | 6 (26.1) | 8 (26.7) | 5 (62.5) | 12 (48.0) | 17 (51.5) | 26 (40.6) |

* Includes one lake whitefish.

Table 7. Frequency of occurrence (%), by number of days, an acoustic signal was received for treatment and control fish.

| Days | Northern Pike | | | Walleye | | | Total* |
|---|---|---|---|---|---|---|---|
| | Control | Treatment | All | Control | Treatment | All | |
| 1 - 8 | 3 (42.9) | 12 (50.0) | 15 (48.4) | 0 | 4 (16.0) | 4 (12.1) | 19 (29.7) |
| 9 - 21 | 3 (42.9) | 9 (37.5) | 12 (38.7) | 5 (62.5) | 9 (36.0) | 14 (42.4) | 26 (40.6) |
| 22 - 71 | 1 (14.3) | 3 (12.5) | 4 (12.9) | 3 (37.5) | 9 (36.0) | 12 (36.4) | 16 (25.0) |
| 72 - 119 | 0 | 0 | 0 | 0 | 3 (12.0) | 3 ( 9.1) | 3 ( 5.0) |

* Includes one lake whitefish.

Table 8. Mean (SE) and number of fish in different distance classes for Minimum Distance of Movement (MDM) and Maximum Distance from Kelsey GS (MaxD) for 30 and 32 acoustically tracked northern pike and walleye, respectively, after their release near the tailrace of the powerhouse.

| Species | MDM (km) | | | | | MaxD (km) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Mean | < 6.0 | 6 - 20 | >20 - 50 | >50 | Mean | <4 | 4 - 7 | >7 |
| Northern pike | 12.8 ± 1.9 | 3 | 23 | 4 | 0 | 5.1 ± 0.4 | 12 | 6 | 12 |
| Treatment | 11.0 ± 1.6 | 2 | 19 | 2 | 0 | 4.9 ± 0.4 | 10 | 6 | 7 |
| Control | 18.8 ± 6.1 | 1 | 4 | 2 | 0 | 6.0 ± 1.0 | 2 | 0 | 5 |
| Walleye | 22.6 ± 3.6 | 7 | 11 | 12 | 3 | 5.2 ± 0.4 | 16 | 1 | 16 |
| Treatment | 24.8 ± 4.4 | 4 | 9 | 9 | 3 | 5.5 ± 0.5 | 11 | 1 | 13 |
| Control | 15.9 ± 8.2 | 3 | 2 | 3 | 0 | 4.5 ± 0.9 | 5 | 0 | 3 |

Table 9. Number (%) of acoustic-tagged fish that were relocated at least once in three different sections of the Study Area.

| Study Area Section | Northern Pike | | | Walleye | | | Total* |
|---|---|---|---|---|---|---|---|
| | Control | Treatment | All | Control | Treatment | All | |
| Kelsey GS | 1 (14.3) | 2 ( 8.7) | 3 (10.0) | 2 (25.0) | 4 (16.0) | 6 (18.2) | 9 (14.1) |
| Grass River | 1 (14.3) | 11 (47.8) | 12 (40.0) | 3 (37.5) | 7 (28.0) | 10 (30.3) | 22 (34.3) |
| Nelson River, north | 2 (28.6) | 8 (34.8) | 10 (33.3) | 0 | 6 (24.0) | 6 (18.2) | 17 (26.6) |
| Grass and Nelson rivers | 3 (42.9) | 2 ( 8.7) | 5 (16.7) | 3 (37.5) | 8 (32.0) | 11 (33.3) | 16 (25.0) |

* Includes one lake whitefish.

Table 10. Number (%) of acoustic-tagged fish that showed different type of movements: stationary, extensive, foray to R4 or R5, fast movement to or past locations R4 or R5 and no signals thereafter, fast movement into the Grass River and no signals thereafter. For two fish the type of movement could not be assessed because of a short period of signal reception.

| Study Area Section | Northern Pike | | | Walleye | | | Total* |
|---|---|---|---|---|---|---|---|
| | Control | Treatment | All | Control | Treatment | All | |
| Stationary | 2 (28.6) | 11 (47.8) | 13 (43.3) | 4 (50.0) | 7 (28.0) | 11 (33.3) | 24 (37.5) |
| Extensive | 1 (14.3) | 2 ( 8.7) | 3 (10.0) | 3 (37.5) | 9 (36.0) | 12 (36.4) | 15 (23.4) |
| Foray | 2 (28.6) | 3 (13.0) | 5 (16.7) | 0 | 3 (12.0) | 3 ( 9.1) | 9 (14.1) |
| Fast & distant | 2 (28.6) | 5 (21.7) | 7 (23.3) | 0 | 3 (12.0) | 3 ( 9.1) | 10 (15.6) |
| Grass River | 0 | 2 ( 8.7) | 2 ( 6.7) | 0 | 2 ( 8.0) | 2 (6.1) | 4 ( 6.3) |
| No assessment | 0 | 0 | 0 | 1 (12.5) | 1 ( 4.0) | 2 (6.1) | 2 ( 3.1) |

* Includes one lake whitefish.

# APPENDICES

Appendix 1. Biological, capture, tagging, and relocation information for acoustic-tagged lake whitefish, northern pike, and walleye that were passed through a turbine (treatment) or released as control fish at the Kelsey GS from 10-16 June, 2008.

| | | | | | | | | | | | | | **Period 1: 10 - 17 June** | | | **Period 2: 18 June - 7 August** | | | **Period 3: 8 August - 6 October** | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Species** | **Capture date** | **Capture location** | **Capture method** | **Total Length (mm)** | **Round Weight (g)** | **AC Code** | **Floy-tag number** | **Group** | **Date released** | **Release depth** | **Status Hi-Z Tag** | **Status acoustic** | **Manual track[1]** | **Station receiver** | **Receiver number(s)** | **Manual track[2]** | **Station receiver** | **Receiver number(s)** | **Manual track[3]** | **Station receiver** | **Receiver number(s)** | **# days with signal** | **# days to last signal** | **Period(s) of relocation** | **Area** | **MDM (km)** | **MaxD (km)** | **Movement pattern** |
| LKWH | 16-Jun-08 | GN 3 | Gillnet | 620 | 3600 | 162 | 88642 | Treatment | 17-Jun-08 | shallow | released | yes | 1 | 1 | R1 | 1 | 1 | R1,R4 | 1 | 0 | - | 12 | 112 | 17-26 June; 6 August; 6 October | N | 10.5 | 4.8 | (Foray) |
| NRPK | 13-Jun-08 | A1 | Angling | 603 | 1250 | 5790 | 75161 | Control | 14-Jun-08 | n.a. | released | no | 0 | 0 | - | 0 | 0 | - | 0 | 0 | - | 0 | 0 | - | n.a | n.a | n.a | n.a |
| NRPK | 13-Jun-08 | A 1 | Angling | 606 | 1600 | 148 | 74752 | Control | 14-Jun-08 | n.a. | released | yes | 0 | 1 | R1 | 0 | 1 | R1,R2,R3,R5 | 0 | 0 | - | 14 | 31 | 14-17,26-29 June; 1-2,10-11,13-14 July | G, N | 11.8 | 7.4 | FD |
| NRPK | 11-Jun-08 | E 3 | E-Fish | 690 | 1700 | 149 | 75677 | Control | 14-Jun-08 | n.a. | released | yes | 0 | 1 | R1,R2,R3 | 0 | 1 | R1,R2,R3,R5 | 0 | 0 | - | 17 | 42 | 14-29 June; 17,25 July | G, N | 35.5 | 7.4 | Extensive |
| NRPK | 13-Jun-08 | A 1 | Angling | 630 | 1600 | 150 | 75200 | Control | 14-Jun-08 | n.a. | released | yes | 0 | 1 | R1,R2,R3 | 0 | 0 | - | 0 | 1 | R1,R2,R3 | 6 | 115 | 14-16 June; 1-2, 6 October | G | 7.4 | 3.6 | Stationary |
| NRPK | 11-Jun-08 | A 1 | Angling | 571 | 1150 | 5793 | 86833 | Control | 14-Jun-08 | n.a. | released | yes | 1 | 1 | R1 | 0 | 1 | R1 | 0 | 1 | R1 | 15 | 90 | 15-28 June; 9-11 September | K | 3.5 | 1.3 | Stationary |
| NRPK | 11-Jun-08 | A 1 | Angling | 637 | 1400 | 5794 | 75686 | Control | 14-Jun-08 | n.a. | released | yes | 1 | 1 | R1,R3 | 0 | 1 | R1,R3,R5 | 0 | 1 | R3 | 41 | 112 | 16-21,30 Jun; 14,16,18 Jul; 6-8,10,13-14,23,25 Aug; 7,9-30 Sep; 1-3 Oct | G, N | 46.5 | 7.4 | Extensive |
| NRPK | 11-Jun-08 | E 3 | E-Fish | 580 | 1200 | 5798 | 86850 | Control | 14-Jun-08 | n.a. | released | yes | 1 | 1 | R1 | 0 | 1 | R4,R5 | 0 | 0 | - | 4 | 11 | 14,16,17,24 June | N | 9.7 | 7.4 | FD |
| NRPK | 11-Jun-08 | A 1 | Angling | 620 | 1350 | 5796 | 75683 | Control | 14-Jun-08 | n.a. | released | yes | 0 | 1 | R1,R4,R5 | 0 | 1 | R1 | 0 | 0 | - | 3 | 26 | 14,16 June; 6 July | N | 17.0 | 7.4 | Foray |
| NRPK | 8-Jun-08 | A 1 | Angling | 573 | 1500 | 153 | 86652 | Treatment | 10-Jun-08 | deep | released | yes | 1 | 1 | R1,R2,R3 | 1 | 1 | R3 | 1 | 0 | - | 12 | 119 | 10-17,26 June; 1,5-6,8-9 July; 6 Oct | G | 6.5 | 4.9 | Stationary |
| NRPK | 8-Jun-08 | A 1 | Angling | 660 | 1850 | 155 | 86914 | Treatment | 10-Jun-08 | deep | released , minor I | yes | 1 | 1 | R1,R3 | 1 | 1 | R1 | 0 | 1 | R2,R5 | 10 | 70 | 10,13-14,16,19-20 June; 16 July; 6, 17-18 Aug | G, N | 36.7 | 7.4 | Extensive |
| NRPK | 8-Jun-08 | A 1 | Angling | 601 | 1400 | 160 | 86925 | Treatment | 10-Jun-08 | deep | released , minor I | yes | 1 | 1 | R1,R3 | 0 | 1 | R1 | 0 | 0 | - | 9 | 41 | 10,13-16 June; 13-14,19-20 July | G | 7.7 | 3.6 | Stationary |
| NRPK | 8-Jun-08 | A 1 | Angling | 637 | 1400 | 6499 | 86924 | Treatment | 10-Jun-08 | deep | released , minor I | yes | 1 | 1 | R1,R2 | 0 | 1 | R1,R2,R3 | 0 | 0 | - | 11 | 32 | 11-12,13,15-20,24 June; 11 July | G | 13.9 | 3.6 | Stationary |
| NRPK | 9-Jun-08 | A 2 | Angling | 506 | 875 | 6488 | 86591 | Treatment | 11-Jun-08 | deep | released , minor I | yes | 1 | 1 | R1 | 0 | 1 | R1,R5 | 0 | 0 | - | 5 | 45 | 13,29 June; 17-18,25 July | N | 8.9 | 7.4 | (Foray) |
| NRPK | 9-Jun-08 | A 1 | Angling | 641 | 1350 | 6493 | 86576 | Treatment | 11-Jun-08 | deep | kept 48h, major I | yes | 1 | 1 | R1,R2,R3 | 1 | 1 | R1 | 0 | 1 | R2,R5 | 33 | 93 | 13 Jun-2 Jul; 6,8-10,15-21,25 Aug; 3-4,9-11 Sep | G, N | 26.6 | 7.4 | Extensive |
| NRPK | 9-Jun-08 | A 1 | Angling | 515 | 650 | 6495 | 86556 | Treatment | 11-Jun-08 | deep | released | yes | 0 | 1 | R1,R4 | 0 | 0 | - | 0 | 0 | - | 3 | 3 | 11-13 June | N | 6.3 | 4.8 | FD |
| NRPK | 10-Jun-08 | GN 2 | Gillnet | 691 | 1600 | 161 | 86595 | Treatment | 12-Jun-08 | mid | released | yes | 1 | 1 | R1,R2,R3 | 0 | 1 | R3 | 1 | 0 | - | 6 | 117 | 13,15-18 June; 6 October | G | 6.1 | 4.4 | Stationary |
| NRPK | 10-Jun-08 | E 2 | E-Fish | 431 | 700 | 5805 | 85482 | Treatment | 12-Jun-08 | mid | released | yes | 1 | 0 | - | 0 | 1 | R5 | 0 | 0 | - | 3 | 19 | 13,17,30 June | N | 9.0 | 7.4 | FD |
| NRPK | 10-Jun-08 | E 2 | E-Fish | 645 | 1550 | 5806 | 86807 | Treatment | 12-Jun-08 | mid | released | yes | 1 | 1 | R1,R2,R3 | 0 | 1 | R1,R2 | 0 | 1 | R2 | 9 | 75 | 13-15 June; 11-16 July; 25 August | G | 9.5 | 3.6 | Stationary |
| NRPK | 10-Jun-08 | E 2 | E-Fish | 452 | 750 | 5811 | 86808 | Treatment | 12-Jun-08 | mid | released | yes | 1 | 1 | R1 | 0 | 1 | R1,R3 | 0 | 1 | R1 | 39 | 116 | 13-14,17 Jun; 9 Jul-13 Aug; 27,30 Sep; 2,5 Oct | G | 8.3 | 3.6 | Stationary |
| NRPK | 9-Jun-08 | A 1 | Angling | 675 | 1700 | 6487 | 86582 | Treatment | 12-Jun-08 | mid | released | yes | 1 | 1 | R1,R2,R3 | 1 | 1 | R1,R3 | 0 | 0 | - | 23 | 57 | 13-30 June; 1-2,6-13 July; 7 August | G | 11.2 | 3.6 | Stationary |

Appendix 1. Continued.

| | | | | | | | | | | | | | Period 1: 10 - 17 June | | | Period 2: 18 June - 7 August | | | Period 3: 8 August - 6 October | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Species** | **Capture date** | **Capture location** | **Capture method** | **Total Length (mm)** | **Round Weight (g)** | **AC Code** | **Floy-tag number** | **Group** | **Date released** | **Release depth** | **Status Hi-Z Tag** | **Status acoustic** | **Manual track[1]** | **Station receiver** | **Receiver number(s)** | **Manual track[2]** | **Station receiver** | **Receiver number(s)** | **Manual track[3]** | **Station receiver** | **Receiver number(s)** | **# days with signal** | **# days to last signal** | **Period(s) of relocation** | **Area** | **MDM (km)** | **MaxD (km)** | **Movement pattern** |
| NRPK | 9-Jun-08 | A 1 | Angling | 544 | 1000 | 6489 | 86577 | Treatment | 12-Jun-08 | mid | released , minor I | yes | 1 | 0 | - | 0 | 0 | - | 0 | 1 | R1,R5 | 11 | 86 | 13 June; 10,16-29 August; 5 September | N | 8.8 | 7.4 | (FD or Foray) |
| NRPK | 10-Jun-08 | E 2 | E-Fish | 645 | 1650 | 6491 | 86817 | Treatment | 12-Jun-08 | mid | released | yes | 1 | 1 | R1,R2 | 0 | 1 | R4 | 0 | 0 | - | 3 | 15 | 13,17,26 June | N | 6.7 | 4.8 | FD |
| NRPK | 10-Jun-08 | E 2 | E-Fish | 650 | 1575 | 154 | 86811 | Treatment | 14-Jun-08 | shallow | released , major I | yes | 1 | 1 | R1 | 0 | 1 | R5 | 0 | 0 | - | 4 | 26 | 15,17 June; 7,9 July | N | 8.9 | 7.4 | FD |
| NRPK | 13-Jun-08 | GN 3 | Gillnet | 682 | 1800 | 156 | 74757 | Treatment | 14-Jun-08 | shallow | not recovered | yes | 0 | 1 | R4 | 1 | 1 | R4 | 1 | 1 | R2 | 15 | 115 | 13,20-27 Jun; 6 Aug; 18-20 Sep; 3 Oct | N | 13.6 | 4.8 | Extensive |
| NRPK | 10-Jun-08 | GN 2 | Gillnet | 689 | 1675 | 157 | 85481 | Treatment | 14-Jun-08 | shallow | released | yes | 0 | 1 | R1,R2,R4 | 0 | 0 | - | 0 | 0 | - | 2 | 4 | 15,17 June | N | 6.9 | 4.8 | FD |
| NRPK | 12-Jun-08 | A 1 or A 2 | Angling | 547 | 900 | 5787 | 75663 | Treatment | 14-Jun-08 | shallow | released | yes | 0 | 1 | R1,R3 | 0 | 1 | R1,R2,R3 | 0 | 0 | - | 18 | 29 | 15-20,23,30 June; 2-12 July | G | 11.7 | 3.6 | Stationary |
| NRPK | 12-Jun-08 | A 1 or A 2 | Angling | 532 | 900 | 5788 | 75665 | Treatment | 14-Jun-08 | shallow | released | yes | 1 | 1 | R1 | 0 | 1 | R1,R2 | 0 | 0 | - | 11 | 32 | 15,17,20,27,29 June; 6,10-15 July | K | 4.4 | 1.6 | Stationary |
| NRPK | 13-Jun-08 | A 3 | Angling | 496 | 850 | 5789 | 75165 | Treatment | 14-Jun-08 | shallow | released | yes | 1 | 1 | R1 | 0 | 1 | R1,R5 | 0 | 1 | R2 | 8 | 76 | 15-17,27 June; 21 July; 6,17,28 August | N | 17.2 | 7.4 | Foray |
| NRPK | 13-Jun-08 | A 3 | Angling | 555 | 1025 | 5791 | 75178 | Treatment | 14-Jun-08 | shallow | released | yes | 1 | 1 | R1,R3 | 0 | 1 | R3 | 0 | 0 | - | 6 | 23 | 15-18 June; 3,6 July | G | 6.1 | 4.9 | Grass R |
| NRPK | 13-Jun-08 | A 1 | Angling | 580 | 1300 | 5792 | 75199 | Treatment | 14-Jun-08 | shallow | released | yes | 0 | 1 | R1,R2,R3 | 0 | 1 | R3 | 0 | 0 | - | 6 | 8 | 16-21 June | G | 5.4 | 3.6 | Grass R |
| NRPK | 11-Jun-08 | E 4 | E-Fish | 510 | 900 | 5797 | 75690 | Treatment | 14-Jun-08 | shallow | released , minor I | yes | 0 | 1 | R1,R2 | 0 | 1 | R1,R2 | 1 | 0 | - | 6 | 115 | 15-18,21 June; 6 October | K | 19.7 | 1.6 | Stationary |
| NRPK | 12-Jun-08 | A 1 or A 2 | Angling | 541 | 1000 | 6494 | 75664 | Treatment | 14-Jun-08 | shallow | released , minor I | yes | 0 | 1 | R1,R3 | 0 | 0 | - | 0 | 1 | R1,R2 | 5 | 100 | 15-17 June; 22-23 September | G | 7.4 | 3.6 | Stationary |
| WALL | 11-Jun-08 | E 4 | E-Fish | 530 | 1550 | 5778 | 75658 | Control | 16-Jun-08 | n.a. | released | yes | 0 | 1 | R1,R3 | 0 | 1 | R1,R2,R3,R5 | 0 | 0 | - | 18 | 51 | 17-21 June; 7-10,13-17,20,29-31 July | G, N | 36.6 | 7.4 | Extensive |
| WALL | 11-Jun-08 | E 3 | E-Fish | 522 | 1450 | 5781 | 86840 | Control | 16-Jun-08 | n.a. | released | yes | 0 | 1 | R1 | 0 | 1 | R1,R3 | 0 | 0 | - | 22 | 23 | 17 June - 8 July | G | 5.0 | 3.6 | Stationary |
| WALL | 11-Jun-08 | E 4 | E-Fish | 405 | 600 | 5782 | 75699 | Control | 16-Jun-08 | n.a. | released | yes | 0 | 1 | R1 | 0 | 1 | R1,R2 | 1 | 0 | - | 11 | 113 | 17-21, 25-27 June; 5,7 July; 6 October | K | 5.7 | 1.6 | Stationary |
| WALL | 11-Jun-08 | E 3 | E-Fish | 420 | 700 | 5784 | 86843 | Control | 16-Jun-08 | n.a. | released | yes | 1 | 1 | R1 | 0 | 1 | R1,R2,R3 | 0 | 0 | - | 10 | 11 | 17-26 June | G | 8.8 | 3.6 | Short |
| WALL | 11-Jun-08 | E 3 | E-Fish | 406 | 700 | 5786 | 86848 | Control | 16-Jun-08 | n.a. | released | yes | 0 | 1 | R1 | 0 | 1 | R1,R2,R3 | 1 | 1 | R1,R3 | 57 | 113 | 17 June -19 August; 3,6 October | G | 14.4 | 3.6 | Stationary |
| WALL | 11-Jun-08 | E 3 | E-Fish | 422 | 875 | 5795 | 86842 | Control | 16-Jun-08 | n.a. | released | yes | 0 | 1 | R1 | 0 | 1 | R1 | 0 | 1 | R1 | 18 | 106 | 17-30 Jun; 2 Jul; 19,23,26,27,29 Sep | K | 1.3 | 1.3 | Stationary |
| WALL | 10-Jun-08 | E 2 | E-Fish | 371 | 650 | 5810 | 85490 | Control | 16-Jun-08 | n.a. | released | yes | 0 | 0 | - | 0 | 1 | R1,R2,R3,R5 | 0 | 1 | R1,R2,R5 | 28 | 113 | 18-30 Jun; 12,16,28-31 Jul; 10-11,18,21-22 Aug; 26,29 Sep; 3-5 Oct | G, N | 31.8 | 7.4 | Extensive |
| WALL | 11-Jun-08 | E 4 | E-Fish | 431 | 925 | 5770 | 75655 | Control | 16-Jun-08 | n.a. | released | yes | 0 | 1 | R1 | 0 | 1 | R1,R2,R3,R5 | 0 | 1 | R1,R2,R5 | 15 | 97 | 17-25 June; 6-9 July; 14,19-20 Sep | G, N | 23.6 | 7.4 | Extensive |
| WALL | 8-Jun-08 | E 1 | E-Fish | 497 | 1400 | 6497 | 86683 | Treatment | 11-Jun-08 | deep | released | yes | 1 | 1 | R1 | 0 | 1 | R1 | 1 | 0 | - | 9 | 115 | 11-17 June; 3 August; 6 October | K | 9.4 | 1.4 | Stationary |
| WALL | 8-Jun-08 | E 1 | E-Fish | 550 | 1550 | 6492 | 86657 | Treatment | 11-Jun-08 | deep | released | yes | 1 | 1 | R1,R2 | 0 | 1 | R4,R5 | 0 | 1 | R2,R5 | 42 | 74 | 12-17,19-29 June; 11-21 July; 28 July - 24 August | N | 63.8 | 7.4 | Extensive |

Appendix 1. Continued.

| | | | | | | | | | | | | | Period 1: 10 - 17 June | | | Period 2: 18 June - 7 August | | | Period 3: 8 August - 6 October | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Species | Capture date | Capture location | Capture method | Total Length (mm) | Round Weight (g) | AC Code | Floy-tag number | Group | Date released | Release depth | Status Hi-Z Tag | Status acoustic | Manual track[1] | Station receiver | Receiver number(s) | Manual track[2] | Station receiver | Receiver number(s) | Manual track[3] | Station receiver | Receiver number(s) | # days with signal | # days to last signal | Period(s) of relocation | Area | MDM (km) | MaxD (km) | Movement pattern |
| WALL | 8-Jun-08 | A 2 | Angling | 456 | 1000 | 6498 | 86567 | Treatment | 11-Jun-08 | deep | released | yes | 1 | 1 | R1 | 0 | 1 | R1,R5 | 0 | 0 | - | 14 | 19 | 13-26 June; 1 July | N | 10.5 | 7.4 | FD |
| WALL | 8-Jun-08 | A 2 | Angling | 492 | 1250 | 6501 | 86566 | Treatment | 11-Jun-08 | deep | released | yes | 1 | 1 | R1 | 1 | 1 | R1,R2,R3 | 1 | 1 | R1,R2,R3 | 26 | 118 | 11,13,15-17 Jun; 3,7,10,13,23-25, 31 Jul; 6,18,28-29 Aug; 17-20 Sep; 2-6 Oct | K | 24.6 | 3.6 | Stationary |
| WALL | 8-Jun-08 | A 2 | Angling | 466 | 800 | 6502 | 86568 | Treatment | 11-Jun-08 | deep | released , minor I | yes | 0 | 1 | R1 | 0 | 1 | R1,R2,R5 | 0 | 1 | R1,R2,R3 | 30 | 104 | 11-13,17,19-25 Jun; 2,5,6,8,24,28, 29 Aug; 10-22 Sep | G, N | 28.6 | 7.4 | Foray |
| WALL | 8-Jun-08 | E 1 | E-Fish | 456 | 900 | 6503 | 86682 | Treatment | 11-Jun-08 | deep | released | yes | 1 | 1 | R1 | 0 | 1 | R1,R2,R3 | 0 | 0 | - | 17 | 24 | 11,13 June; 18 June - 4 July | G | 26.8 | 3.6 | Stationary |
| WALL | 8-Jun-08 | A 2 | Angling | 474 | 1300 | 6504 | 86569 | Treatment | 11-Jun-08 | deep | released | yes | 1 | 1 | R1,R3 | 1 | 1 | R1,R2,R4,R5 | 1 | 1 | R1,R2,R3,R5 | 55 | 118 | 11-22,24 Jun; 9-15,26,30 Jul; 5-6,10-15,22-31 Aug; 8-15,21-30 Sep; 1-6 Oct | G, N | 81.4 | 7.4 | Extensive |
| WALL | 10-Jun-08 | E 2 | E-Fish | 451 | 900 | 5799 | 86809 | Treatment | 12-Jun-08 | mid | released | yes | 1 | 1 | R1 | 0 | 1 | R1,R3 | 0 | 0 | - | 13 | 13 | 12-23,25 June | G | 4.3 | 3.6 | Grass R |
| WALL | 10-Jun-08 | E 2 | E-Fish | 377 | 625 | 5800 | 85486 | Treatment | 12-Jun-08 | mid | released | yes | 1 | 1 | R1 | 0 | 1 | R1,R2,R3,R5 | 0 | 0 | - | 11 | 44 | 12-14,21-27 June; 25 July | G, N | 20.8 | 7.4 | Foray |
| WALL | 10-Jun-08 | E 2 | E-Fish | 365 | 600 | 5801 | 86804 | Treatment | 12-Jun-08 | mid | released | yes | 1 | 1 | R1 | 0 | 1 | R1,R2,R3,R4,R5 | 0 | 0 | - | 16 | 18 | 12-27,29 June | G, N | 22.0 | 7.4 | Foray |
| WALL | 10-Jun-08 | E 2 | E-Fish | 382 | 600 | 5802 | 86805 | Treatment | 12-Jun-08 | mid | kept 48h, major I | yes | 1 | 1 | R1 | 0 | 1 | R1,R2,R4,R5 | 0 | 0 | - | 8 | 11 | 15-22 June | N | 13.4 | 7.4 | Extensive |
| WALL | 10-Jun-08 | E 2 | E-Fish | 332 | 500 | 5803 | 85485 | Treatment | 12-Jun-08 | mid | released | yes | 1 | 1 | R1 | 1 | 1 | R1,R3 | 1 | 1 | R1,R2,R3 | 84 | 117 | 12-28 Jun; 4 Jul-2 Sep; 6,10-26 Sep; 6 Oct | G | 33.5 | 5.8 | Extensive |
| WALL | 10-Jun-08 | E 2 | E-Fish | 387 | 650 | 5807 | 86810 | Treatment | 12-Jun-08 | mid | released | yes | 1 | 1 | R1 | 1 | 1 | R1,R4 | 0 | 1 | R1,R2,R5 | 17 | 117 | 12-17,25 June; 6,9-12 August; 8,13,21,23 September; 6 October | N | 43.5 | 7.4 | Extensive |
| WALL | 10-Jun-08 | E 2 | E-Fish | 361 | 650 | 5808 | 85487 | Treatment | 12-Jun-08 | mid | released , minor I | yes | 1 | 1 | R1 | 0 | 1 | R1,R3 | 0 | 1 | R1 | 108 | 117 | 15-17, 19,21,24-30 June; 1 July - 6 October | G | 7.1 | 3.6 | Stationary |
| WALL | 10-Jun-08 | E 2 | E-Fish | 388 | 700 | 5809 | 86815 | Treatment | 12-Jun-08 | mid | released | yes | 1 | 1 | R1 | 0 | 1 | R1,R2,R3,R5 | 0 | 1 | R5 | 101 | 117 | 12 Jun - 26 Aug; 6 Sep - 6 Oct | G, N | 17.9 | 7.4 | (Extensive) |
| WALL | 11-Jun-08 | A 1 | Angling | 451 | 1050 | 5771 | 75680 | Treatment | 16-Jun-08 | shallow | released | yes | 0 | 1 | R1 | 0 | 1 | R1 | 0 | 0 | - | 6 | 14 | 17-20,28-29 June | K | 1.3 | 1.3 | Stationary |
| WALL | 11-Jun-08 | A 1 | Angling | 391 | 700 | 5772 | 86834 | Treatment | 16-Jun-08 | shallow | released | yes | 0 | 1 | R1 | 0 | 1 | R1,R3,R5 | 0 | 0 | - | 12 | 34 | 16-23 June; 11-16,19 July | G, N | 18.4 | 7.4 | FD |
| WALL | 11-Jun-08 | A 1 | Angling | 463 | 1150 | 5773 | 86837 | Treatment | 16-Jun-08 | shallow | released | yes | 0 | 1 | R1 | 0 | 1 | R1,R3 | 0 | 1 | R1,R3 | 56 | 110 | 16,17,19-24 Jun; 2-7,10-31 Jul; 2,4,6,9-10,22,30 Aug; 3-4,7-9,16-29 Sep; 2-3 Oct | G | 36.8 | 3.6 | Stationary |
| WALL | 11-Jun-08 | A 1 | Angling | 463 | 950 | 5774 | 75679 | Treatment | 16-Jun-08 | shallow | released | yes | 1 | 1 | R1 | 1 | 1 | R1,R2,R5 | 0 | 1 | R1,R2,R3,R5 | 62 | 99 | 16 June - 5 July; 11-12 July; 17 July - 22 August; 27-29 August; 3-4, 21-22 September | G, N | 78.0 | 7.4 | Extensive |
| WALL | 11-Jun-08 | A 1 | Angling | 497 | 1200 | 5775 | 86838 | Treatment | 16-Jun-08 | shallow | released | yes | 1 | 1 | R1 | 0 | 1 | R1,R3 | 0 | 0 | - | 10 | 23 | 16,17,20,22,25,28 June; 2-3,6,8 July | G | 8.7 | 3.6 | Stationary |
| WALL | 11-Jun-08 | E 3 | E-Fish | 512 | 1350 | 5776 | 86841 | Treatment | 16-Jun-08 | shallow | released | yes | 1 | 0 | - | 0 | 1 | R4,R5 | 0 | 0 | - | 7 | 16 | 17,23-26 June; 30 June - 1 July | N | 8.1 | 7.4 | FD |

Appendix 1. Continued.

| Species | Capture date | Capture location | Capture method | Total Length (mm) | Round Weight (g) | AC Code | Floy-tag number | Group | Date released | Release depth | Status Hi-Z Tag | Status acoustic | Period 1: 10 - 17 June Manual track[1] | Period 1: Station receiver | Period 1: Receiver number(s) | Period 2: 18 June - 7 August Manual track[2] | Period 2: Station receiver | Period 2: Receiver number(s) | Period 3: 8 August - 6 October Manual track[3] | Period 3: Station receiver | Period 3: Receiver number(s) | # days with signal | # days to last signal | Period(s) of relocation | Area | MDM (km) | MaxD (km) | Movement pattern |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WALL | 14-Jun-08 | GN 3 | Gillnet | 456 | 1000 | 5777 | 86663 | Treatment | 16-Jun-08 | shallow | released | yes | 0 | 1 | R1 | 0 | 1 | R1 | 0 | 0 | - | 5 | 5 | 16-20 June | K | 1.3 | 1.3 | Short |
| WALL | 11-Jun-08 | E 4 | E-Fish | 391 | 600 | 5779 | 75698 | Treatment | 16-Jun-08 | shallow | released | yes | 0 | 1 | R1 | 0 | 1 | R1,R2,R5 | 1 | 1 | R1,R2,R5 | 42 | 113 | 17-30 Jun; 14-25 Jul; 7-8 Aug; 2-20 Sep; 1,6 Oct | N | 35.5 | 8.9 | Extensive |
| WALL | 11-Jun-08 | A 1 | Angling | 421 | 800 | 5780 | 86836 | Treatment | 16-Jun-08 | shallow | released | yes | 1 | 1 | R1 | 0 | 1 | R1,R3 | 0 | 0 | - | 31 | 32 | 17 June - 17 July | G | 5.7 | 3.6 | Grass R |
| WALL | 11-Jun-08 | E 4 | E-Fish | 392 | 650 | 5785 | 75653 | Treatment | 16-Jun-08 | shallow | released | yes | 0 | 1 | R1 | 1 | 1 | R1,R2 | 1 | 1 | R1,R2,R3 | 31 | 113 | 16 Jun-3 Jul; 25-26 Jul; 6,8,11-18,24 Aug; 5-6 Sep; 6 Oct | G, N | 17.6 | 3.6 | (Foray) |

[1] Manual tracking was done on 13 and 17 June.
[2] Manual tracking was done from 6-7 August.
[3] No manual tracking was done on 6 October.

Group = treatment fish (Turbine) or control fish (Control).
MDM = Minimum Distance of Movement
MaxD = Largest recorded distance from GS
Receiver (R) 1-5 locations are provided in Table 1 and Figure 1.

**Status Hi-Z 'Tag = fate of a fish after treatment or control release:**
not recovered = not caught by recapture crew after treatment or control release; balloons and radio tag remained attached.
released = released back into the Nelson R after balloons & radio tag were taken off and health status was assessed.
released, minor I = fish was released into the Nelson R with minor injuries.
released, major I = fish was released into the Nelson R with what was later assessed as a major injury.
kept 48 h, major I = fish was kept for 48 h in holding tank after recapture and was then released because injury was deemed survivable.

**Area (see Figure 1):**
K= Near Kelsey GS (Area 1)
G= Grass River (Area 2)
N= Nelson River north of Area 1 (Area 3)

**Movement pattern:**
Short= signal was received only for a few days, no pattern was assessed
FD= fast movement to a distant location and out of the study area
Extensive= wider ranging movements between several locations over at least a one month period
Stat= little movement near Kelsey GS (including location R3).
Foray= mainly stationary near Kelsey GS (including location R3) with one foray to location R4 or R5.
Grass R= movement into the Grass River (location R3 or further west); signal lost soon after.

**Species codes:**
LKWH = lake whitefish
NRPK = northern pike
WALL = walleye

Appendix 2. Locations (UTM 14 V coordinates) of fish relocations from manual tracking. For each location, the tracked fish (identified by its acoustic code) and the date(s) of tracking are provided.

| Location ID | Location Easting | Northing | Distance to GS (km) | Acoustic code | Detection Date(s) | Acoustic code | Detection Date(s) | Acoustic code | Detection Date(s) | Acoustic code | Detection Date(s) | Acoustic code | Detection Date(s) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| VR1 | 653229 | 6213370 | 0.1 | 5811 | 13-Jun-08 | 6488 | 13-Jun-08 | 6487 | 13-Jun-08 | 160 | 13-Jun-08 | 5799 | 13-Jun-08 |
| | | | | 6497 | 13-Jun-08 | 5802 | 17-Jun-08 | 5793 | 17-Jun-08 | | | | |
| VR2 | 652999 | 6213385 | 0.3 | 6487 | 13-Jun-08 | 5809 | 13-Jun-08 | 6488 | 13-Jun-08 | 6497 | 13-Jun-08 | 162 | 17-Jun-08 |
| | | | | 5788 | 17-Jun-08 | 5811 | 17-Jun-08 | 5780 | 17-Jun-08 | 5786 | 6-Oct-08 | | |
| VR3 | 652885 | 6213312 | 0.5 | 6498 | 13-Jun-08 | 6501 | 13-Jun-08 | 6503 | 13-Jun-08 | 5780 | 17-Jun-08 | 5811 | 17-Jun-08 |
| | | | | 5789 | 17-Jun-08 | | | | | | | | |
| VR4 | 652592 | 6213333 | 0.8 | 6504 | 13-Jun-08 | 160 | 13-Jun-08 | 5800 | 13-Jun-08 | 6497 | 13-Jun-08 | 161 | 13-Jun-08 |
| | | | | 6498 | 13-Jun-08 | 5807 | 13-Jun-08 | 6489 | 13-Jun-08 | 6498 | 13-Jun-08 | 161 | 13-Jun-08 |
| | | | | 5800 | 13-Jun-08 | 6504 | 13-Jun-08 | 6501 | 13-Jun-08 | 5807 | 13-Jun-08 | 6498 | 17-Jun-08 |
| | | | | 5808 | 17-Jun-08 | 5786 | 6-Oct-08 | | | | | | |
| VR5 | 652218 | 6213493 | 1.1 | 6492 | 13-Jun-08 | 6498 | 13-Jun-08 | 6501 | 13-Jun-08 | 5809 | 13-Jun-08 | 5801 | 13-Jun-08 |
| | | | | 6497 | 13-Jun-08 | 5801 | 17-Jun-08 | 5809 | 17-Jun-08 | | | | |
| VR6 | 651832 | 6213504 | 1.5 | 6492 | 13-Jun-08 | 5809 | 17-Jun-08 | | | | | | |
| VR7 | 651577 | 6213559 | 1.8 | 6492 | 13-Jun-08 | | | | | | | | |
| VR8 | 651159 | 6213547 | 2.2 | 149 | 17-Jun-08 | 6504 | 6-Oct-08 | 6501 | 6-Oct-08 | | | | |
| VR9 | 650793 | 6213589 | 2.5 | 6504 | 6-Oct-08 | | | | | | | | |
| VR10 | 650192 | 6213663 | 3.1 | 155 | 13-Jun-08 | 5806 | 13-Jun-08 | 6493 | 13-Jun-08 | 6487 | 7-Aug-08 | | |
| VR11 | 649755 | 6213611 | 3.6 | 5806 | 13-Jun-08 | 155 | 13-Jun-08 | | | | | | |
| VR12 | 649333 | 6213528 | 4.0 | 155 | 13-Jun-08 | 153 | 13-Jun-08 | | | | | | |
| VR13 | 649001 | 6213446 | 4.4 | 153 | 13-Jun-08 | 5794 | 17-Jun-08 | 153 | 7-Aug-08 | 153 | 6-Oct-08 | 5803 | 6-Oct-08 |
| | | | | 161 | 6-Oct-08 | | | | | | | | |
| VR14 | 648503 | 6213400 | 4.9 | 155 | 13-Jun-08 | 153 | 13-Jun-08 | | | | | | |
| VR15 | 648049 | 6212963 | 5.5 | 5803 | 7-Aug-08 | | | | | | | | |
| VR16 | 647756 | 6212766 | 5.9 | 5803 | 7-Aug-08 | 5803 | 6-Oct-08 | | | | | | |
| VR19 | 650583 | 6213725 | 2.8 | 5806 | 13-Jun-08 | 6487 | 7-Aug-08 | | | | | | |
| VR25 | 652241 | 6214312 | 1.2 | 5805 | 13-Jun-08 | | | | | | | | |
| VR26 | 652699 | 6214040 | 1.1 | 5805 | 13-Jun-08 | 5798 | 17-Jun-08 | 6501 | 17-Jun-08 | 6501 | 6-Aug-08 | | |
| VR27 | 654707 | 6213668 | 1.5 | 6497 | 17-Jun-08 | 6497 | 6-Oct-08 | 5797 | 6-Oct-08 | | | | |
| VR32 | 654697 | 6213418 | 1.5 | 6497 | 17-Jun-08 | | | | | | | | |

Appendix 2. Continued.

| Location ID | Location Easting | Location Northing | Distance to GS (km) | Acoustic code | Detection Date(s) | Acoustic code | Detection Date(s) | Acoustic code | Detection Date(s) | Acoustic code | Detection Date(s) | Acoustic code | Detection Date(s) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| VR34 | 653889 | 6213593 | 0.6 | 6499 | 13-Jun-08 | 5782 | 6-Oct-08 | | | | | | |
| VR36 | 652722 | 6213713 | 0.7 | 161 | 13-Jun-08 | 5803 | 13-Jun-08 | 6487 | 13-Jun-08 | 5800 | 13-Jun-08 | 6488 | 13-Jun-08 |
| | | | | 6498 | 13-Jun-08 | 6504 | 13-Jun-08 | 5799 | 13-Jun-08 | 6500 | 13-Jun-08 | 5809 | 13-Jun-08 |
| | | | | 5807 | 13-Jun-08 | 5803 | 17-Jun-08 | 5774 | 17-Jun-08 | 5784 | 17-Jun-08 | | |
| VR37 | 652327 | 6213587 | 1.0 | 6502 | 13-Jun-08 | 6501 | 13-Jun-08 | 5801 | 13-Jun-08 | | | | |
| VR38 | 653037 | 6214180 | 1.1 | 5773 | 17-Jun-08 | 6492 | 17-Jun-08 | 5776 | 17-Jun-08 | 6491 | 17-Jun-08 | 6504 | 6-Aug-08 |
| | | | | 6501 | 6-Aug-08 | | | | | | | | |
| VR39 | 652879 | 6214618 | 1.6 | 155 | 6-Aug-08 | 5785 | 6-Oct-08 | | | | | | |
| VR40 | 653161 | 6215110 | 2.1 | 155 | 6-Aug-08 | | | | | | | | |
| VR41 | 653005 | 6215427 | 2.4 | 5807 | 17-Jun-08 | 155 | 6-Aug-08 | | | | | | |
| VR42 | 653303 | 6215743 | 2.7 | 1157 | 6-Oct-08 | 162 | 6-Oct-08 | | | | | | |
| VR43 | 653339 | 6216225 | 3.2 | 5785 | 6-Aug-08 | | | | | | | | |
| VR44 | 653322 | 6216639 | 3.7 | 6493 | 6-Aug-08 | 162 | 6-Aug-08 | | | | | | |
| VR45 | 653478 | 6217555 | 4.7 | 156 | 6-Aug-08 | 156 | 6-Oct-08 | 162 | 6-Oct-08 | | | | |
| VR47 | 654819 | 6217930 | 6.1 | 5774 | 6-Aug-08 | | | | | | | | |
| VR51 | 657484 | 6218581 | 8.9 | 5779 | 6-Oct-08 | | | | | | | | |
| VR55 | 653239 | 6219647 | 6.8 | 5807 | 6-Aug-08 | | | | | | | | |
| VR56 | 653200 | 6216210 | 3.2 | 5807 | 17-Jun-08 | | | | | | | | |
| VR57 | 652484 | 6213596 | 0.9 | 6502 | 13-Jun-08 | 5803 | 13-Jun-08 | 5800 | 13-Jun-08 | 5799 | 13-Jun-08 | 6501 | 13-Jun-08 |
| | | | | 5809 | 13-Jun-08 | | | | | | | | |
| VR59 | 648530 | 6213302 | 4.9 | 5791 | 17-Jun-08 | | | | | | | | |
| VR62 | 652383 | 6214230 | 1.4 | 154 | 17-Jun-08 | | | | | | | | |
| VR63 | 652513 | 6214266 | 1.4 | 5805 | 17-Jun-08 | 154 | 17-Jun-08 | | | | | | |
| VR65 | 653149 | 6216231 | 2.4 | 6504 | 17-Jun-08 | 5809 | 17-Jun-08 | 5773 | 17-Jun-08 | | | | |

Appendix 3. Relocation information for northern pike and walleye that were acoustic-tagged in 2006 (see Appendix 2 in Jansen and Murray 2007) and tracked during the 2008 fish turbine passage study. For explanations of column headers see Appendix 1

| | | | | | | | | | Period 1: 10 - 17 June | | | Period 2: 18 June - 7 August | | | Period 3: 8 August - 6 October | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Species** | **Total length (mm)** | **Weight (g)** | **Acoustic Code** | **Floy-tag number** | **Group** | **Date released** | **Release depth** | **Status Hi-Z Tag (2006)** | **Manual track[1]** | **Stat receiver** | **Tracking location** | **Manual track[1]** | **Stat receiver** | **Tracking location** | **Manual track[1]** | **Stat receiver** | **Tracking location** | **# of days with signal** | **Assess alive / dead** |
| NRPK | 576 | 1150 | 186 | 84201 | Treatment | 8-Jun-2006 | mid | released | 1 | 0 | VR41 | 1 | 0 | VR41 | 0 | 0 | - | 2 | (dead) |
| NRPK | 563 | 1550 | 188 | 84690 | Treatment | 8-Jun-2006 | mid | released injured | 0 | 0 | - | 1 | 1 | R1,VR68 | 1 | 0 | VR4 | 7 | unknown |
| NRPK | 724 | 3650 | 193 | 84694 | Treatment | 8-Jun-2006 | mid | not recovered | 1 | 0 | VR4 | 0 | 0 | - | 0 | 0 | - | 1 | unknown |
| NRPK | 841 | 4250 | 1131 | 84687 | Treatment | 8-Jun-2006 | mid | released | 0 | 0 | - | 0 | 0 | - | 1 | 0 | VR39 | 1 | unknown |
| NRPK | 775 | 2950 | 1148 | 84692 | Treatment | 8-Jun-2006 | mid | released | 1 | 0 | VR36 | 0 | 0 | - | 1 | 0 | VR2,VR4 | 2 | (dead) |
| NRPK | 587 | 1350 | 1149 | 84698 | Treatment | 8-Jun-2006 | mid | released | 1 | 0 | VR19 | 1 | 1 | R3,VR19 | 0 | 1 | R3 | 13 | alive |
| WALL | 438 | 900 | 176 | 84676 | Treatment | 7-Jun-2006 | mid | released | 1 | 1 | R1,R4,R5, VR38 | 0 | 1 | R1,R2,R4,R5 | 1 | 1 | R1,R3,VR8 | 19 | alive |
| WALL | 445 | 1025 | 1134 | 84671 | Treatment | 7-Jun-2006 | mid | released | 0 | 0 | - | 0 | 0 | - | 1 | 0 | VR10 | 1 | unknown |
| WALL | 443 | 950 | 1138 | 84661 | Treatment | 5-Jun-2006 | shallow | released | 1 | 1 | R1,R3,VR14, VR15 | 1 | 1 | R1,R2,R3,R4,R5,VR48 | 1 | 1 | R1,R2,R5,VR4 | 113 | alive |
| WALL | 490 | 1450 | 1157 | 84652 | Treatment | 3-Jun-2006 | deep | released | 1 | 1 | R4,R5,VR38, VR56 | 1 | 1 | R4,R5,VR43 | 1 | 1 | R1,R2,R5,VR42 | 37 | alive |
| WALL | 490 | 1400 | 1251 | 84653 | Treatment | 3-Jun-2006 | deep | released | 0 | 0 | - | 1 | 1 | R1,VR8 | 0 | 1 | R1,R3 | 18 | alive |

[1] Manual tracking was done on 13 and 17 June.
[2] Manual tracking was done from 6-7 August.
[3] No manual tracking was done on 6 October.