PHASE 2 Technical Memorandum for Red and Assiniboine Ammonia Criteria Study

From: M. J. Lawrence
Task Leader, Fish Behaviour Workstream

To: City of Winnipeg Project Management Committee
Study Team Members

Subject: **Fish Behaviour Technical Memorandum # FB 03**

Title: **Movements of Fish Tagged with Acoustic Transmitters in the Vicinity of the City of Winnipeg's Water Pollution Control Centres, 1999 - 2000.**

Prepared by: C.C. Barth and M. J. Lawrence

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EXECUTIVE SUMMARY

This memorandum is the third in a series of memoranda that describe fish behaviour in the Red and Assiniboine rivers, within the City of Winnipeg's Ammonia Criteria Study Area. This document describes the movements of 49 fish, representing five species, tagged with acoustic transmitters downstream of the City of Winnipeg's Water Pollution Control Centres from August 1999 to February 2000.

Fish were tracked using three stationary receivers and a portable receiver. One stationary receiver was placed at each of the three boundaries of the study area to identify the date and time that fish left or re-entered the study area, and the portable receiver was used to track fish movements within the study area.

Discharges in the Red and Assiniboine rivers during the time of this study were well above average levels. Therefore, the fish movement data were collected during a period when sewage effluent from the City of Winnipeg's Water Pollution Control Centres was likely diluted by high river flows, which may have resulted in relatively low in-situ ammonia concentrations. It is unknown if these data are representative of fish behaviour under different conditions (i.e., higher ammonia concentrations).

A large percentage of fish (57%) tagged within the City of Winnipeg moved out of the study area prior to the onset of winter; 39% and 14% moved north and south on the Red River, respectively, and 4% moved west on the Assiniboine River. Fish moved through or around each of the City of Winnipeg's effluent plumes suggesting that the plumes were not acting as barriers to fish during the open water period.

During late summer, carp (*Cyprinus carpio*) and freshwater drum (*Aplodinotus grunniens*) were located in the vicinity of the WEWPCC and NEWPCC effluent outfalls, respectively, and appeared to have been attracted to the outfalls. Channel catfish and walleye were not located within 2 km of a City of Winnipeg Water Pollution Control Centre outfall, suggesting that these species were not attracted to effluent plumes.

A minimum of 18% of the fish tagged remained in the study area during winter, a time of year when the effects of ammonia on fish are typically exacerbated due to low river discharge, low algal uptake, reduced rates of bacterial degradation and the potential increased sensitivity of fish to unionized ammonia toxicity at lower temperatures (Williamson 1988). With the exception of one freshwater drum, all tagged fish that remained in the study area during winter were

located between 3.5 - 8.0 km downstream of a City of Winnipeg Water Pollution Control Centre outfall.

The results of this study indicate that fish are highly mobile and may undergo seasonal migrations into and out of the study area. Thus, exposure of resident fish to municipal sewage effluents is generally intermittent and may be dependent upon season.

The fish movements and behaviour recorded during this study will assist in understanding the potential for exposure of fish to ammonia from the City of Winnipeg Water Pollution Control Centres.

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1.0 INTRODUCTION

The City of Winnipeg initiated the Ammonia Criteria Study in response to the Clean Environment Commission's recommendations to the Minister of Environment regarding water quality objectives for the Red and Assiniboine rivers within and downstream of the City of Winnipeg (Tetr*ES* Consultants Inc. 1999). The City of Winnipeg operates three water pollution control centres: the North End Water Pollution Control Centre (NEWPCC); the South End Water Pollution Control Centre (SEWPCC); and the West End Water Pollution Control Centre (WEWPCC). Each water pollution control centre discharges treated sewage effluent into the Red or Assiniboine rivers.

Knowledge of fish movements is important when estimating exposure of fish to point sources of contaminants, such as municipal effluent plumes. The duration, timing (i.e., season), and intermittency of time spent within and downstream of effluent plumes is critical in terms of both exposure and toxicity of contaminants to fish. Exposure regime is particularly relevant to potential chronic toxicity of contaminants to fish (i.e., effects on growth, reproduction and susceptibility to disease).

Treated sewage effluent has been found to affect fish movements and fish behaviour (Fava and Tsai 1976, Alexander et al. 1977). Fish have been shown to exhibit both preference and avoidance responses to treated effluent plumes (Osborne et al. 1981). Thus, preference/avoidance behaviour is an integral factor determining the acute and chronic toxicity of effluents to fish residing in receiving waters. As part of the fish behaviour workstream of the City of Winnipeg ammonia criteria study, an acoustic tagging investigation was conducted from August 1999 to February 2000. The purposes of the investigation were to map the range and extent of fish movements in the Red and Assiniboine rivers during summer, fall and winter, and to describe the distribution and behaviour of fish in relation to the three effluent mixing zones located in the study area.

The objectives of this investigation included:

- to examine the extent to which fish movement (behaviour) causes or minimizes exposure to un-ionized ammonia in the City of Winnipeg's effluent mixing zones during the summer, fall and winter seasons; and,
- to collect baseline data on fish movements and distribution in the Red and Assiniboine rivers.

2.0 METHODS

2.1 Study Area

Davies and MacDonell (2000) divided the City of Winnipeg Ammonia Criteria Study Area into 86 segments in the Red River and 30 segments in the Assiniboine River, to assist in describing the habitat conditions found within each river (Figure 1 and 2). These segments were used in the present study to describe the location of tagged fish.

The study area was also divided into five different zones of potential ammonia influence as described in Davies and MacDonell (2000) (Figure 3):

Zone 1 – extended from the St. Adolphe to the SEWPCC on the Red River, and was not influenced by effluent from the City of Winnipeg's Water Pollution Control Centres.
Zone 2 – extended from the SEWPCC to the NEWPCC on the Red River. The area from the SEWPCC to the Forks was subject to effluent from the SEWPCC effluent plume; and the area from the confluence of the Red and Assiniboine rivers to the NEWPCC was subject to effluent from both the SEWPCC and the WEWPCC.
Zone 3 – extended from the NEWPCC to the Sugar Island (Segment 86), and was subject to effluent from the SEWPCC, the WEWPCC and the NEWPCC.
Zone 4 – extended from the WEWPCC on the Assiniboine River to the confluence of the Assiniboine and Red rivers, and was subject to effluent from the WEWPCC.
Zone 5 – extended from Headingly to the WEWPCC on the Assiniboine River and was not influenced by effluent from the City of Winnipeg's Water Pollution Control Centres.

The study area for the present study included the Red River between the South Perimeter Bridge (Segment 24) and Sugar Island (Segment 86) and the Assiniboine River between Segment 106 and its mouth at The Forks (Segment 130) (Figures 1 and 2). Three water pollution control centres operated by the City of Winnipeg are located in the study area. Effluents from the SEWPCC and NEWPCC are discharged into the Red River in Segments 27 and 57, respectively. Effluents from the WEWPCC enter the Assiniboine River in Segment 108 (Figure 3).

2.2 Fish Collection

Hoopnets were used to capture fish for acoustic tagging. This method of capture ensured that fish obtained for tagging were in good condition prior to the tagging process. Hoopnets were set downstream of each of the three Water Pollution Control Centres: in segments 28, 29 and 32 in Zone 2; segments 58, 59, 60 and 62 in Zone 3; and, segments 111, 113, 116 and 117 in Zone 4. Each hoopnet was oriented to catch fish moving upstream and was checked daily.

Data for fish captured in the hoopnets are presented by Remnant et al. (2000) and Cooley and Davies (2000).

Acoustic transmitters were attached to channel catfish, freshwater drum, walleye, northern pike and carp. A summary of common names, scientific names and abbreviations for fish tagged with acoustic transmitters is provided in Table 1.

2.3 Transmitter Attachment

2.3.1 Acoustic Transmitters

Fifty V16-4H-R256 coded pinger acoustic transmitters manufactured by VEMCO Ltd. (Shad Bay, Nova Scotia) were used in the study (49 attached to fish, 1 utilized as a test tag). Each acoustic transmitter was 68 mm long, weighed 12 grams in water, and had a 240 day battery life. Acoustic transmitters allow several different transmitters to operate on the same frequency since each transmits a different pulse train recognizable by either a VR-60 ultrasonic portable receiver, or a submersible VR1 stationary receiver. Pulse trains are transmitted at variable 15 – 45 second intervals.

2.3.1.1 Harness Attachment

Prior to attachment, each transmitter was fitted with a wire harness. Two wire fishing leaders were attached to each transmitter: one tied to a plastic wire loop at the anterior end of the transmitter; and the other looped around the centre of the transmitter and secured with two minute Cold Cure epoxy. In addition, a label indicating the address and phone number of North/South Consultants was glued to each tag to facilitate tag returns.

2.3.1.2 Transmitter Activation

To activate each tag, two protruding wires located on the anterior end of each transmitter were cut to approximate 1 cm lengths, stripped of insulation, twisted together and soldered. The soldered wires were glued to the transmitter with epoxy resin for protection. Prior to attachment, each transmitter was air tested with the VR-60 ultrasonic receiver to ensure that a recognizable pulse was being transmitted.

2.3.1.3 Attachment Process

Fish to be fitted with acoustic transmitters were measured for fork length (± 1 mm) and weight (± 25 g). Two 8.0 cm long, hollow, stainless steel veterinary needles, spaced 4 cm apart, were

inserted into the right side of the fish below the dorsal fin (Figure 4). The needles were pushed through the dorsal musculature, between the dorsal pterygiophores, immediately posterior to the anterior dorsal spine. A soft neoprene pad was fitted over the needles to act as a cushion between the exterior of the fish and the transmitter. The mounting wires were then passed through the needles from the left side (Figure 5) and the needles were removed from the right side of the fish, leaving the mounting wires exposed. A second neoprene mounting pad (Figure 6) and hard plastic disc were fitted over the exposed wires. The mounting wires were then pulled snug, knotted at each end to secure the tag, and free ends of the mounting wires passed through a wire crimp (Figure 7). The crimp was then compressed, and the excess wire clipped (Figure 8). Tagged fish were placed in a tub of river water for a minimum of two minutes (for recovery) before being released (Figures 9 and 10).

2.4 Tracking Fish Movements

The were tracked using two types of equipment, VR1 stationary receivers and a VR-60 portable ultrasonic receiver.

2.4.1 VR1 Stationary Receivers

Three VR1 submersible, acoustic receivers, manufactured by VEMCO Ltd., were used in the investigation. The VR1 receivers operate with an omni-directional hydrophone and internal data logger. The omni-directional hydrophone detects the pulse train transmitted from activated transmitters within its range. The transmitter code number, as well as date and time of location for each valid detection, are stored in the data logger. Data are stored within the data logger until downloaded by an IBM/PC/AT computer, operating with a VR1PC computer interface.

VR1 stationary receivers were located approximately 2 km upstream of both the SEWPCC and WEWPCC, and approximately 1 km upstream from the St. Andrews Locks (Figure 3). The VR1 receivers were used to detect fish leaving and returning to the study area along the Red and Assiniboine rivers. VR1 stationary receivers do not discern direction of movement, therefore, fish that were detected by the VR1 stationary receivers, and not located during tracking runs throughout the city, were presumed to have left the study area.

Stationary receivers were deployed at all sites on 09 August 1999 prior to the release of any fish tagged with acoustic transmitters. The receivers remained at these sites until 24 November 1999 when all three were removed from the rivers in order to avoid damage due to ice formation. When ice conditions throughout the study area were deemed safe enough for travel (20 January 2000), stationary receivers were returned to the same locations as in the open water period. Due to an

early spring breakup along the Red and Assiniboine rivers, all three receivers were removed on 24 February 2000.

During the open water period, VR1 receivers were completely submersed in water, anchored to the bottom with a cinderblock, and held vertical in the water column with a float attached to the hydrophone end. The float also functioned to maintain the hydrophone elevated above the river bottom. To facilitate retrieval, the cinderblocks were tied to the river bank. Retrieval involved following the rope out from the river bank and pulling up the cinderblock and VR1 receiver. During operation under ice cover, VR1 receivers were anchored to the bottom with a 5 lb anchor, and held vertically in the water column by a chain frozen into the ice. Retrieval involved drilling a hole beside the chain, and reaching down beneath the ice to lift the chain and receiver from the water.

The range of each VR1 receiver was tested prior to deployment at each location. It was estimated that VR1 stationary receivers could detect activated transmitters up to a distance of approximately 800 m. However, this distance was influenced by background noise from environmental factors such as wind and water turbulence.

Data recorded by the VR1 receivers were downloaded using a portable laptop computer and VR1PC computer interface during each tracking run with the VR-60 portable receiver (approximate 2 week intervals).

2.4.2 Portable (VR-60) Ultrasonic Receiver

The battery powered portable (VR-60) ultrasonic receiver is designed to receive underwater signals from acoustic pinger transmitters. The code number for each transmitter detected is displayed on a LCD screen on the face of the VR-60 receiver. It operates with both an omni-directional hydrophone and a directional hydrophone. During this study only the omni-directional hydrophone was used. In order to receive underwater signals from activated transmitters, the omni-directional hydrophone must be completely submersed in the water column. During testing, the range of the portable receiver was estimated to be 500 m, but could vary according to conditions. The optimal conditions for tracking with the portable receiver were days with little or no wind. High winds could reduce the range of the portable receiver by increasing the amount of water turbulence and, therefore, interference detected by the hydrophone. Consequently, tracking throughout the study area was conducted at two to three week intervals on days with little or no wind.

In order to ensure consistency between each tracking run, fixed points, approximately 500 m apart, were marked on a map and programmed into a GPS unit (navigational quality). Readings were taken at these fixed points on each tracking run.

A summary of tracking dates and locations is provided in Appendix 1. During the open water period, tracking was accomplished by boat. The boat was stopped at each fixed point location, and allowed to drift with the current. The omni-directional hydrophone was lowered approximately 1 m and held there for 1 - 1.5 minutes. If a transmitter was detected, attempts were then made to find the area where the strongest signal could be received. The date, time, and location for each detection was then recorded.

During winter, a snowmobile was used to travel over the ice. Holes were drilled at each fixed point location, and the hydrophone was lowered approximately 1 m below the ice. Tracking through the ice commenced on 23 January 2000, and was terminated due to unsafe ice conditions on 23 February 2000.

Two tracking runs downstream of St. Andrews Locks were conducted on 26 October 1999 and 17 February 2000. These extended from St. Andrews Locks to Sugar Island in Segment 86. Tracking was conducted as above.

3.0 RESULTS

A summary of fork length, weight, tagging date and tagging location for all fish tagged with acoustic transmitters is provided in Appendix 2. In total, 49 fish, including 20 channel catfish, 16 freshwater drum, six walleye, five carp and two northern pike, were tagged with acoustic transmitters. Fifteen fish were tagged in each of Zone 2 (downstream of the SEWPCC) and Zone 4 (downstream of the WEWPCC), and 19 fish were tagged in Zone 3 (downstream of the NEWPCC). A summary of the total number of fish tagged, by species and location, is provided in Table 2.

Fifty seven percent (n=28) of all fish tagged with acoustic transmitters were last located by one of the stationary receivers (Table 3). Since these fish were not located during subsequent tracking runs with the portable receiver, they were assumed to have moved out of the study area. Based on this assumption, it can be concluded that, of these 28 fish, 19 moved north (downstream) on the Red River, seven moved south (upstream) on the Red River, and two moved west (upstream) on the Assiniboine River. Summaries of fish species that moved north, south, and west out of the study area, are provided in Tables 4, 5, and 6, respectively.

Thirty three percent (n=16) of all fish tagged with acoustic transmitters were last located by the portable receiver within the bounds of the study area. Location dates, times and sites for all fish that remained within the study area are provided in Table 7.

In addition to the fish that left the study area (n=28), and those that remained within the study area (n=16), four tagged fish remained stationary for the duration of the study. These fish are suspected to have died or their tags were displaced following tagging. No data were retrieved from one additional transmitter, which was suspected to be faulty. A complete description of the movements exhibited by each fish tagged with an acoustic transmitter is presented in Figures 11 – 25, and documented in Appendix 3.

Four fish (tag codes 3, 33, 35 and 43) were located during manual tracking north of St. Andrews Locks on the Red River. The dates and sites where these fish were located are presented in Figure 25. All fish located downstream of Lockport were previously located by the north end stationary receiver.

3.1 Channel Catfish

In general, channel catfish exhibited considerable movement throughout the study area. Sixty-five percent (n=13) of the catfish tagged moved out of the study area; 45% (n=9) moved north (downstream) on the Red River and 20% (n=4) moved south (upstream) on the Red River. The

remaining thirty-five percent (n=7) stayed within the study area. Channel catfish movements are presented in Figures 11 - 16.

3.1.1 Summer and Fall Movement

3.1.1.1 Channel Catfish Tagged in Zone 2 (Downstream of the SEWPCC)

All five channel catfish tagged in Zone 2 moved out of the study area (Figure 11). Tag codes 3, 4 and 11 moved north (downstream) on the Red River, leaving the study area within nine days of being tagged. Tag codes 2 and 6 moved south (upstream) on the Red River, out of the study area 6 and 14 days after being tagged, respectively.

3.1.1.2 Channel Catfish Tagged in Zone 3 (Downstream of the NEWPCC)

Movements of 10 channel catfish tagged in Zone 3 are presented in Figures 12 – 14. Of the 10 catfish tagged, seven moved out of the study area; six moved north on the Red River (downstream) and one moved south on the Red River (upstream). Tag codes 35, 38, 42 and 43 moved north (downstream) out of the study area within eight days of being tagged. Tag code 41 remained in the study area for 25 days before it moved north (downstream) on the Red River, out of the study area. Tag code 37 was located by the north end stationary receiver one day after being tagged. This fish was subsequently located on 20 October just upstream of the St. Andrews Locks. Because this fish was not located in the study area during previous tracking runs with the portable receiver, it is possible that this fish moved upstream over the St. Andrews Locks using the fish ladder. Tag code 29 was the only catfish tagged in Zone 3 that moved south (upstream) on the Red River out of the study area. This fish moved out of the study area 11 days after being tagged.

Three catfish tagged in Zone 3 (tag codes 27, 36, and 40) remained in the study area during the open water period. Each of these fish moved both upstream and downstream on the Red River. Tag code 36 was the only tagged fish that moved upstream on both the Red and Assiniboine rivers, moving as far upstream on the Assiniboine River as Segment 115 (St. Charles golf course).

3.1.1.3 Channel Catfish Tagged in Zone 4 (Downstream of the WEWPCC)

Movements of the five channel catfish tagged in Zone 4 (downstream of the WEWPCC) are presented in Figures 15 and 16. Three catfish (tag codes 17, 20 and 21) remained on the Assiniboine River for the duration of the open water period. These three catfish moved only short distances upstream or downstream from their tagging locations (Figure 18). The other two catfish (tag codes 18 and 19) moved downstream out of the Assiniboine River into the Red River. Once in the Red River, both catfish moved south (upstream) and were located by the south end

stationary receiver. Tag code 18 moved out of the study area 10 days after being tagged. Tag code 19 was located by the south end stationary receiver 31 days after being tagged, but subsequently moved downstream where it was relocated within the bounds of the study area at the mouth of the Assiniboine River.

3.1.2 Winter Movement

Of the 20 tags applied to channel catfish, 25% (n=5) were located within the study area during the winter season. Two catfish (tag codes 19 and 27) were neither observed moving out of the study area during the summer or fall, nor were they located during the winter season. It is possible that these fish moved out of the study area after the stationary receivers were removed from the rivers on 24 November.

Tag codes 36 and 40, tagged in Zone 3 (downstream of the NEWPCC), were located in segments 34 and 31, respectively (Figures 15 and 16). Segment 34 and 31 are located approximately 5 and 3.5 km downstream of the SEWPCC outfall, respectively.

Three catfish (tag codes 17, 20 and 21), tagged in Zone 4 (downstream of the WEWPCC), were located on the Assiniboine River in Segments 115 and 116 (near the St. Charles golf course) (Figure 18). These segments of the Assiniboine River are located approximately 5 to 5.5 km downstream from the WEWPCC effluent outfall.

The five catfish that remained within the study area during winter exhibited no movement over the five-week winter tracking period.

3.2 Freshwater Drum

In total, sixteen freshwater drum were tagged with acoustic transmitters, including five in Zone 2 (downstream of the SEWPCC), five in Zone 4 (downstream of the WEWPCC) and six in Zone 3 (downstream of the NEWPCC). Movements of freshwater drum are presented in Figures 17 - 20. In total, 69% (n=11) of the freshwater drum tagged moved out of the study area; 63% (n=10) moved north (downstream) on the Red River within one month of being tagged, and six percent (n=1) moved south (upstream) on the Red River. Nineteen percent (n=3) of the freshwater drum tagged did not leave the study area during the summer and fall season. Of the remaining two tagged freshwater drum, one did not move during the study (and is presumed to have either lost its tag or died following tagging), and no data were retrieved from the other (presumed to be a faulty tag).

3.2.1 Summer Movements

3.2.1.1 Freshwater Drum Tagged in Zone 2 (Downstream of the SEWPCC)

Movements of the five freshwater drum tagged in Zone 2 (downstream of the SEWPCC) are shown in Figure 17. Of the five fish tagged, four moved north (downstream) on the Red River out of the study area. One (tag code 7) moved downstream out of the study area immediately (two days) after being tagged. The other three (tag codes 8, 9 and 10) moved gradually downstream on the Red River, leaving the study area 12, 18 and 26 days after being tagged, respectively. The other freshwater drum tagged in Zone 2 (tag code 15) did not move for the duration of the study.

3.2.1.2 Freshwater Drum Tagged in Zone 3 (Downstream of the NEWPCC)

Movements of the six freshwater drum tagged in Zone 3 (downstream of the NEWPCC) are shown in Figures 19 and 20. Of the six tagged, two (tag codes 33 and 39) moved north (downstream) on the Red River and out of the study area within six days of being tagged. The remaining four (tag codes 32, 34, 44 and 45) moved short distances upstream on the Red River following tagging. After moving upstream, tag code 32 moved gradually north (downstream) on the Red River, leaving the study area 29 days after being tagged. Tag codes 34, 44 and 45 moved only short distances from their tagging location.

3.2.1.3 Freshwater Drum Tagged in Zone 4 (Downstream of the WEWPCC)

Movements of the five freshwater drum tagged in Zone 4 (downstream of the WEWPCC) are presented in Figure 18. Four of the five freshwater drum tagged in Zone 4 moved downstream out of the Assiniboine River into the Red River and subsequently out of the study area. Three fish (tag codes 24, 25 and 26) moved north (downstream) on the Red River out of the study area within three weeks of being tagged. One fish (tag code 22) moved south (upstream) on the Red River, exiting the study area 41 days after being tagged. No data were retrieved from the one remaining transmitter.

3.2.2 Freshwater Drum - Winter Movements

Tag code 34 was the only freshwater drum located during the winter. Between 25 November (last tracking run of the open water period) and 28 January (first tracking run of the winter season), this fish moved downstream on the Red River from Segment 60 (near the North Perimeter Bridge) to Segment 70 (near the St. Andrews Cathedral). This fish was located in Segment 70 for the duration of the winter tracking period (Figure 19).

3.3 Carp

3.3.1 Summer and Fall Movements

A total of five carp were tagged on the Assiniboine River in Segment 109, immediately downstream of the WEWPCC. Carp movements are presented in Figures 21 and 22. One carp (tag code 50) moved upstream on the Assiniboine River five days after being tagged. The remaining four carp were located within 200 m of the WEWPCC effluent outfall (Segment 109) on 31 August and 16 September. Between 16 September and 01 October, all four carp moved away from the WEWPCC effluent outfall. Two carp (tag codes 47 and 48) moved gradually west (upstream) on the Assiniboine River, and were located by the west end stationary receiver 47 and 57 days, respectively, after being tagged. The other two carp (tag codes 46 and 49) moved downstream on the Assiniboine River. Tag code 49 moved to the mouth of Sturgeon Creek (Segment 118). Tag code 46 moved downstream out of the Assiniboine River to the Red River, and subsequently moved south (upstream) on the Red River and out of the study area 29 days after being tagged.

3.3.2 Winter Movements

One carp (tag code 49) was located within the study area during the winter season. On 09 November this fish was located at the mouth of Sturgeon Creek. On 25 January (the first tracking run on the Assiniboine River in winter), this fish was located approximately 80 m upstream from the mouth of Sturgeon Creek (Segment 118), which is located approximately 7 km downstream from the WEWPCC effluent outfall.

3.4 Walleye

Walleye were difficult to locate with the VR-60 receiver and were occasionally not located during tracking runs. The reasons for the poor success in locating walleye are unknown. This problem was not evident for other fish species.

3.4.1 Summer and Fall Movements

A total of six walleye were tagged with acoustic transmitters, five in Zone 2 (downstream of the SEWPCC) and one in Zone 3 (downstream of the NEWPCC). Their movements are presented in Figures 23 and 24, respectively.

3.4.1.1 Walleye Tagged in Zone 2 (Downstream of the SEWPCC)

Of the five walleye tagged in Zone 2, tag code 1 was the only walleye that moved out of the study area. This fish moved south (upstream) on the Red River two days after being tagged. Tag codes 14 and 16 moved downstream into Zone 3 after being tagged. The remaining two walleye were located in the same area for the duration of the study and are assumed to have died or lost their tags.

3.4.1.2 Walleye Tagged in Zone 3 (Downstream of the NEWPCC)

Tag code 31 was the only walleye tagged in Zone 3. This fish moved only short a distance downstream from its tagging location during the open water period.

3.4.2 Winter Movements

Two walleye (tag codes 14 and 31) were located during the winter season. Tag code 14 was located in Segment 63, where it was previously located in the fall. Tag code 31 moved downstream from its fall location in Segment 61 to Segment 64. No movement was recorded from either walleye during the winter season. Segments 63 and 64 are located approximately 7 and 8 km downstream from the NEWPCC effluent outfall, respectively.

3.5 Northern Pike

Two northern pike were tagged in Zone 3 (downstream of the NEWPCC). One did not move for the duration of the study and may have died following tagging. The other northern pike was located at its tagging location one day after being tagged and was not re-located for the duration of the study.

4.0 DISCUSSION

4.1 River Conditions

To assess how ammonia concentrations may have influenced fish movements, it is necessary to consider the ammonia concentrations that fish would have encountered throughout the study area during the study period. In September 1999, ammonia concentrations measured in the Red and Assiniboine rivers ranged from 0.00 - 0.47 mg/L-N and were well within values considered acceptable by the Manitoba Surface Water Quality Objectives (Williamson 1988, Davies and Toews 2000). The ammonia concentrations during the remainder of the study period are presently unavailable. However, Tetr*ES* Constultants Inc. is currently characterizing ammonia concentrations in the Red and Assiniboine rivers for the study period. Once these data are available, the fish movements observed during the present study can be related to the actual ammonia concentrations to which the fish would have been exposed.

Ammonia concentrations in the Red and Assiniboine rivers depend upon a number of environmental factors, including river flows. In general, periods of low flow are associated with higher ammonia concentrations than periods of high flow due to the ratio of sewage effluent to river discharge. Discharges on the Red and Assiniboine rivers were exceptionally high during the summer of 1999 and winter of 1999/2000, and were the highest on record for autumn 1999 (Davies and Toews 2000). Due to the high river discharges that occurred during this study, it is likely that ammonia concentrations in the Red and Assiniboine rivers were relatively low and that the effects of sewage effluent (from the City of Winnipeg's Water Pollution Control Centres) on fish behaviour were less significant than in years of comparatively low river discharge.

4.2 Fish Movements

4.2.1 Channel Catfish

At least two previous studies have described channel catfish movements along the Red River. Clarke et al. (1980) Floy-tagged 1,310 channel catfish within the City of Winnipeg during the spring, summer, and fall of 1974. Catfish were recaptured as far south as Halstad, Minnesota (approximate distance of 412 km), as far north as Dogwood Point on Lake Winnipeg (approximate distance of 246 km), and as far west as Portage La Prairie on the Assiniboine River. Twice as many catfish tagged within the City of Winnipeg by Clarke et al. (1980) were recaptured downstream, as opposed to upstream. Clarke et al. (1980) hypothesized that catfish moved up the Red River during spring, and down to the lower reaches of the Red River and Lake Winnipeg during summer and fall to overwinter.

Tyson (1996) tracked the movements of 29 radio-tagged catfish on the lower Red River, downstream of Lockport, from October 1991 to September 1993, and recorded catfish movements of up to 37 km in one day. In general, Tyson (1996) found that channel catfish moved downstream to Lake Winnipeg during fall, and moved up the Red River during spring.

Catfish movements observed during this study were similar to those observed by Tyson (1996) and Clarke et al. (1980). All movements of catfish downstream out of the study area occurred during late summer and early fall. In addition, more than twice the number of tagged catfish (45%) moved downstream on the Red River out of the study area to overwinter, than upstream (20%). Catfish were also found to be highly mobile. For example, one fish moved approximately 25 km in 18 hours.

Prior to the current study, information regarding overwintering of catfish within the City of Winnipeg was scarce. Twenty-five percent of the catfish tagged overwintered within the city limits. Two moved up the Red River during fall and overwintered in Zone 2 near the University of Manitoba in segments 31 and 34. These segments are located approximately 3.5 and 5 km downstream of the SEWPCC, with depths reaching 8.0 m and 5.5 m, respectively. Three catfish overwintered in the Assiniboine River (Zone 4) near the St. Charles golf course in segments 115 and 116. These segments are located approximately 5 to 5.5 km downstream of the WEWPCC, with depths reaching 5.0 m (Davies and MacDonell 2000). Because depths of 5.0 m and over are uncommon in the Assiniboine River within the City of Winnipeg, Segments 115 and 116 may offer some of the most favourable overwintering habitat in this reach of the Assiniboine River. After 23 January, no movement was observed from the catfish remaining in the study area. Channel catfish dormancy during winter periods has been well documented in the literature (Crawshaw 1984, Lubinsky 1984, Newcomb 1989).

4.2.2 Freshwater Drum

Movements of freshwater drum in the Red River have previously been studied by Clarke et al. (1980). In 1974, Clarke et al. (1980) Floy-tagged 1,108 freshwater drum in the City of Winnipeg. Tags were returned from as far south as Drayton, North Dakota, and as far north as Rabbit Point in Lake Winnipeg. One freshwater drum was found to have moved 29.5 km downstream in one day. Clarke et al. (1980) hypothesized that freshwater drum moved upstream in the Red River from Lake Winnipeg during spring and early summer to spawn, and that they began to move back downstream in late June to overwinter in Lake Winnipeg.

Freshwater drum tagged in this study moved downstream in late summer. By 20 September, 10 of 16 tagged freshwater drum had moved north (downstream) on the Red River out of the study area, compared with one that moved south (upstream). Downstream movement of fish immediately

after tagging is often attributed to stress from the tagging procedure. However, four of 10 drum that moved downstream out of the study area were initially located upstream of the tagging location, indicating that these movements were not likely caused by handling stress. Like channel catfish, freshwater drum were considerably mobile. For example, one freshwater drum moved approximately 55 km in two days.

One of the 16 tagged freshwater drum overwintered in the study area. In November, it was located near the north perimeter bridge, but moved downstream and was located near the St. Andrews Church (Segment 70) on 28 January and 23 February.

4.2.3 Carp

There is little information available regarding the movement of carp within the Red and Assiniboine rivers. Clarke et al. (1980) Floy-tagged 54 carp on the Red River but did not obtain any recapture information. Data gathered during the present study provided some indication that carp may be highly mobile with movements up to 48.5 km in five days recorded. In addition, there is some evidence that carp exhibited a preference for the WEWPCC effluent plume. Large numbers of carp were observed in the WEWPCC effluent plume from mid-August to mid-September. Of the five carp tagged in the vicinity of the WEWPCC effluent outfall on 23 August, four were located in the plume on 31 August and again on 16 September. It is unknown whether carp exhibit a preference for the SEWPCC or NEWPCC on the Red River during this time period. Due to the relatively high discharge in the Red River, and the characteristics of these plumes (e.g., SEWPCC outfall located at the bottom of the river), it is more difficult to assess numbers and identifications of fish in these plumes.

Although based on little data, there is also evidence that carp may overwinter in the study area. One carp overwintered in the Assiniboine River (Segment 118) approximately 80 m upstream of Sturgeon Creek and approximately 7 km downstream of the WEWPCC. This segment of the Assiniboine River is characterized by depths of 1.75 – 2.75 m during summer (Davies and MacDonell 2000).

4.2.4 Walleye

Although only six walleye were tagged in the study area (all in the Red River), the available data indicated only limited movements of this species. Only one walleye moved south (upstream) out of the study area and no walleye moved downstream past St. Andrews Locks. Three walleye were located downstream of the NEWPCC in Zone 3 during the open water season, where they moved only short distances up and downstream. Two of these three walleye overwintered in the study area

approximately 7 to 8 km downstream of the NEWPCC effluent outfall. This area is characterized by depths up to 4.75 m (Davies and MacDonell 2000).

The results of other studies on walleye in the area concur with the results of the present study. Tag recapture data collected by Kristofferson (1994) and Clarke et al. (1980) suggest limited movement between walleye utilizing the Red River in the City of Winnipeg and walleye utilizing Lake Winnipeg and the Red River downstream of Lockport. Kristofferson (1994) Floy-tagged 1,786 walleye in the lower Red River (between Lake Winnipeg and Lockport) and the south basin of Lake Winnipeg from 1988 to 1992. Only one of these fish were recaptured south of Lockport. Clarke et al. (1980) tagged sixty-five walleye within the City of Winnipeg of which eight were subsequently recaptured, four south of Winnipeg, one between the north perimeter bridge and the St. Andrews Locks, one in the Assiniboine River, and two within the City of Winnipeg, a short distance from their original tagging location. No walleye tagged during Clarke's study were recaptured north of the St. Andrews Locks.

4.2.5 Northern Pike

No information was recovered from the two tags applied to pike during the current study. The fourth technical memorandum in this series deals exclusively with the behaviour of 10 northern pike tagged in the vicinity of the NEWPCC effluent plume (Barth et al. 2000). Four of 65 pike tagged by Clarke et al. (1980) in 1974 were recaptured. Two of these four northern pike were recaptured in the Seine River; the other two were recaptured near their respective tagging locations.

4.3 Fish Behaviour in Relation to Ammonia Exposure

4.3.1 Open-Water Period

It is apparent that populations of channel catfish, freshwater drum, and carp, and likely most other species in the Red and Assiniboine rivers were highly mobile during the 1999 open water period. Results of this study indicate that, of the species tagged in this study, a large proportion of fish present in the City of Winnipeg during summer may leave prior to winter. There is evidence to suggest that many of these movements are part of normal seasonal migratory patterns (Clarke et al. 1980).

All species of fish tagged with acoustic transmitters (with the exception of northern pike) moved through or around the City of Winnipeg's effluent plumes during the open water period. Thus, under the river discharge and ammonia concentrations encountered during the study, the sewage effluent plumes from the City of Winnipeg's Water Pollution Control Centres did not act as thermal or chemical barriers to fish movement during the open water period.

During the open water period, only freshwater drum and carp were found in the immediate vicinity of an effluent outfall. None of the tagged catfish or walleye were located within 2 km of an effluent outfall. Furthermore, data from hoopnetting in the vicinity of the NEWPCC in October 1999 indicates that catfish and walleye comprised a small percentage of the catch immediately downstream of the effluent outfall (Lawrence and Barth 2000). However, catfish comprised 74% of the catch at a reference site upstream of the outfall. These data suggest that, during the open-water period, catfish and walleye are not attracted to the outfall area, where higher concentrations of ammonia would be found.

4.3.2 Winter Season

During winter, the effects that ammonia may have on fish and fish behaviour may be increased relative to the spring through fall seasons, due to lower river flows relative to effluent discharge, low or non-existent algal uptake of ammonia, reduced rates of nitrification (i.e., bacterial degradation of ammonia) in the rivers, and potential increased sensitivity of fish to unionized ammonia toxicity at lower temperatures (Williamson 1988). It can be assumed that fish overwintering downstream from the City of Winnipeg's Water Pollution Control Centres would be exposed to some level of ammonia. The determination of these ammonia concentrations is required to assess exposure of fish to ammonia, and hence the potential for chronic or acute toxicity of ammonia to resident fish.

Results of a gillnetting survey conducted in the vicinity of the NEWPCC in March 1991, found that mooneye (*Hiodon tergisus*) were more abundant immediately downstream of the NEWPCC outfall than either upstream or more distant downstream locations. A number of hypothesis that included consideration of habitat differences and water chemistry were suggested to explain their distribution. It was suggested that non-chemical characteristics of the effluent discharge (turbulence, open water) may be more important in explaining their distribution than the small variations in water chemistry between netting locations (Tetr*ES* Consultants Inc.1992). In addition to mooneye (n=60), other fish species captured immediately downstream of the NEWPCC outfall during this study included goldeye (n=8) and single specimens of walleye, catfish and white sucker (Tetr*ES* Consultants Inc. 1992). Results of a similar gillnet survey conducted in the vicinity of the NEWPCC in March 1999, found that pike (n=11), white sucker (n=2), goldeye (n=2) and mooneye (n=1) were the only fish species captured in areas exposed to the effluent plume from the NEWPCC (Lawrence 1999). The differences in fish abundance and species composition observed when comparing the results of these two studies cannot be explained, however, both studies suggest that catfish, walleye, freshwater drum, and carp may not be attracted to the immediate vicinity of the NEWPCC effluent outfall during winter.

A minimum of 18% of all fish tagged during this study overwintered in the study area. With the exception of one freshwater drum (that overwintered near the St. Andrews church), all tagged fish that remained in the study area overwintered 3.5 - 8.0 km downstream from one of the City of Winnipeg's Water Pollution Control Centres. It is unknown to what extent the location that fish chose to overwinter was influenced by the City of Winnipeg's Water Pollution Control Centres.,

The fish movements and behaviour recorded during this study will assist in understanding the potential for exposure of fish to ammonia from the City of Winnipeg Water Pollution Control Centres.

5.0 CONCLUSIONS

1. Of the species studied, it was shown that fish populations in the Red and Assiniboine rivers were highly mobile during the 1999 open water period, and that fish may undergo seasonal migrations into and out of the study area. Thus, the exposure of resident fish to the City of Winnipeg's municipal effluents is generally intermittent and may be dependant upon season.

2. A large percentage of fish (57%) tagged within the City of Winnipeg moved out of the study area prior to the onset of winter. However, a minimum of 18% of the fish tagged remained within the study area during winter. With the exception of one freshwater drum which overwintered near the St. Andrews church, all tagged fish that remained in the study area during winter were located 3.5 - 8.0 km downstream from one of the City of Winnipeg's Water Pollution Control Centre outfalls.

3. River discharge in the Red and Assiniboine rivers during the time of this study were above average levels. Therefore, the fish behaviour data were collected during a period when effluents from the City of Winnipeg's Water Pollution Control Centres were likely diluted, and the potential for effects of ammonia in the effluents on fish behaviour may have been low relative to years of comparatively low river discharge.

4. Effluent plumes from the City of Winnipeg's Water Pollution Control Centres did not act as barriers to fish movement during the 1999 open water period. It is unknown if the effluent plumes acted as barriers to movement during winter.

5. Carp and freshwater drum were attracted to effluent from the WEWPCC and NEWPCC during late summer and early autumn, respectively. Evidence suggests that channel catfish and walleye were not attracted to the effluent from the Water Pollution Control Centres during the open water period and that channel catfish, walleye, carp and freshwater drum were not attracted to these areas during winter.

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Tables, Figures and Appendices

Table 1. A list of fish species tagged with acoustic transmitters during the 1999-2000 fish behaviour investigation.

Common name	Scientific name	Abbreviation
Channel catfish	*Ictalurus punctatus*	CHCT
Freshwater drum	*Aplodinotus grunniens*	FRDR
Walleye	*Stizostedion vitreum*	WALL
Carp	*Cyprinus carpio*	CARP
Northern pike	*Esox lucius*	NRPK

Table 2. Number of fish tagged, by species, with acoustic transmitters downstream of each of the City of Winnipeg's Pollution Control Centres, 1999.

	Pollution Control Centre			
Species	NEWPCC	SEWPCC	WEWPCC	TOTAL
CHCT	10	5	5	20
FRDR	6	5	5	16
CARP			5	5
WALL	1	5		6
NRPK	2			2
TOTAL	19	15	15	49

Table 3. Total number of fish, by species, last detected by a stationary receiver from 10 August, 1999 to 24 February, 2000.

	Stationary receiver			
Species	North end	South end	West end	Total
CHCT	9	4		13
FRDR	10	1		11
WALL		1		1
CARP		1	2	3
TOTAL	19	7	2	28

Table 4. Date, location tagged and subsequent re-location dates and sites for fish that moved north on the Red River out of the study area, August 1999 - February 2000 (in chronological order).

Tag Code #	Species	Tagging Date	Segment Tagged	Date Located	Time Located	Site Located	Date Last Location	Time Last Location	Equipment Type
7	FRDR	11-Aug	33						
				13-Aug	16:59	73	13-Aug	22:49	Stationary Receiver
3	CHCT	10-Aug	28						
				19-Aug	05:42	73	19-Aug	06:37	Stationary Receiver
11	CHCT	12-Aug	28						
				19-Aug	15:11	73	19-Aug	15:14	Stationary Receiver
33	FRDR	18-Aug	59						
				19-Aug	08:28	73	19-Aug	10:51	Stationary Receiver
				19-Aug	11:03	73	19-Aug	11:13	Stationary Receiver
				20-Aug	13:09	73	20-Aug	13:15	Stationary Receiver
8	FRDR	11-Aug	28						
				23-Aug	02:36	73	23-Aug	03:50	Stationary Receiver
				23-Aug	11:23	73	23-Aug	12:17	Stationary Receiver
				23-Aug	16:02	73	23-Aug	16:11	Stationary Receiver
43	CHCT	21-Aug	62						
				23-Aug	09:01	73	23-Aug	09:48	Stationary Receiver
				23-Aug	10:36	73	23-Aug	11:37	Stationary Receiver
				23-Aug	12:24	73	23-Aug	12:44	Stationary Receiver
				24-Aug	01:49	73	24-Aug	02:29	Stationary Receiver
				24-Aug	04:20	73	24-Aug	16:18	Stationary Receiver
24	FRDR	16-Aug	116						
				24-Aug	14:33	73	24-Aug	16:19	Stationary Receiver
35	CHCT	19-Aug	62						
				23-Aug	05:30	73	23-Aug	05:47	Stationary Receiver
				23-Aug	09:40	73	23-Aug	10:29	Stationary Receiver
				23-Aug	15:53	73	23-Aug	16:24	Stationary Receiver
				24-Aug	10:09	73	24-Aug	12:41	Stationary Receiver
				24-Aug	23:56	73	25-Aug	00:09	Stationary Receiver
36	FRDR	20-Aug	59						
				26-Aug	18:57	73	26-Aug	20:06	Stationary Receiver
44	CHCT	20-Aug	59						
				26-Aug	19:46	73	27-Aug	01:24	Stationary Receiver
				27-Aug	10:46	73	27-Aug	13:02	Stationary Receiver
				27-Aug	15:08	73	27-Aug	16:08	Stationary Receiver
				27-Aug	20:38	73	28-Aug	05:36	Stationary Receiver
				28-Aug	14:26	73	28-Aug	16:56	Stationary Receiver
42	CHCT	21-Aug	62						
				25-Aug	05:34	73	25-Aug	08:09	Stationary Receiver
				27-Aug	00:52	73	27-Aug	04:52	Stationary Receiver
				27-Aug	05:39	73	27-Aug	06:58	Stationary Receiver
				28-Aug	22:43	73	29-Aug	07:50	Stationary Receiver
9	FRDR	12-Aug	29						
				26-Aug	06:20	73	26-Aug	11:04	Stationary Receiver
				26-Aug	12:20	73	26-Aug	12:46	Stationary Receiver
				26-Aug	14:26	73	26-Aug	15:02	Stationary Receiver
				26-Aug	15:22	73	26-Aug	21:26	Stationary Receiver
				27-Aug	00:35	73	27-Aug	00:41	Stationary Receiver
				27-Aug	01:14	73	27-Aug	03:01	Stationary Receiver
				27-Aug	04:56	73	27-Aug	05:36	Stationary Receiver
				27-Aug	07:22	73	27-Aug	13:16	Stationary Receiver

Table 4. Cont'd

Tag Code #	Species	Tagging Date	Segment Tagged	Date Located	Time Located	Site Located	Date Last Location	Time Last Location	Equipment Type
				27-Aug	18:31	73	28-Aug	03:09	Stationary Receiver
				29-Aug	13:17	73	29-Aug	13:20	Stationary Receiver
				30-Aug	01:43	73	30-Aug	01:54	Stationary Receiver
4	CHCT	10-Aug	28						
				16-Aug	11:37	73	16-Aug	13:32	Stationary Receiver
				17-Aug	08:05	73	17-Aug	8:14	Stationary Receiver
				1-Sep	12:15	74			Portable Receiver
26	FRDR	16-Aug	113						
				1-Sep	09:00	53			Portable Receiver
				5-Sep	07:33	73	5-Sep	09:32	Stationary Receiver
10	FRDR	12-Aug	29						
				30-Aug	10:45	46			Portable Receiver
				1-Sep	10:00	58			Portable Receiver
				7-Sep	18:51	73	7-Sep	23:23	Stationary Receiver
25	FRDR	16-Aug	117						
				17-Aug	21:56	73	23-Aug	04:25	Stationary Receiver
				24-Aug	00:10	73	24-Aug	02:59	Stationary Receiver
				26-Aug	3:41	73	26-Aug	05:45	Stationary Receiver
				27-Aug	13:02	73	28-Aug	19:45	Stationary Receiver
				29-Aug	08:25	73	29-Aug	13:05	Stationary Receiver
				29-Aug	15:42	73	29-Aug	16:34	Stationary Receiver
				31-Aug	01:30	73	1-Sep	12:16	Stationary Receiver
				1-Sep	12:15	74			Portable Receiver
				1-Sep	12:40	73	2-Sep	07:06	Stationary Receiver
				13-Sep	11:10	73	13-Sep	14:19	Stationary Receiver
41	CHCT	21-Aug	62						
				1-Sep	11:25	63			Portable Receiver
				8-Sep	15:46	73	8-Sep	22:17	Stationary Receiver
				9-Sep	12:34	73	9-Sep	12:58	Stationary Receiver
				9-Sep	17:23	73	9-Sep	21:14	Stationary Receiver
				10-Sep	00:01	73	10-Sep	05:23	Stationary Receiver
				10-Sep	13:10	73	10-Sep	14:15	Stationary Receiver
				12-Sep	16:23	73	10-Sep	16:32	Stationary Receiver
				15-Sep	00:18	73	15-Sep	09:38	Stationary Receiver
32	FRDR	19-Aug	62						
				1-Sep	08:40	49			Portable Receiver
				15-Sep	11:55	49			Portable Receiver
				17-Sep	00:26	73	17-Sep	01:46	Stationary Receiver
37	CHCT	20-Aug	62						
				20-Aug	21:20	73	20-Aug	22:06	Stationary Receiver
				20-Aug	23:40	73	21-Aug	00:14	Stationary Receiver
				21-Aug	0031	73	21-Aug	00:32	Stationary Receiver
				21-Aug	01:46	73	21-Aug	02:42	Stationary Receiver
				21-Aug	04:25	73	21-Aug	04:29	Stationary Receiver
				21-Aug	04:53	73	21-Aug	05:06	Stationary Receiver
				21-Aug	05:17	73	21-Aug	05:37	Stationary Receiver
				21-Aug	06:01	73	21-Aug	06:10	Stationary Receiver
				21-Aug	06:45	73	21-Aug	07:22	Stationary Receiver
				21-Aug	07:28	73	21-Aug	08:16	Stationary Receiver

Table 4. Cont'd

Tag Code #	Species	Tagging Date	Segment Tagged	Date Located	Time Located	Site Located	Date Last Location	Time Last Location	Equipment Type
				21-Aug	08:32	73	21-Aug	08:41	Stationary Receiver
				21-Aug	12:01	73	21-Aug	12:16	Stationary Receiver
				21-Aug	12:52	73	21-Aug	13:03	Stationary Receiver
				21-Aug	13:10	73	21-Aug	17:15	Stationary Receiver
				20-Oct	15:50	74			Portable Receiver

* - Portable receiver locates fish at only a single point in time

Table 5. Date, location tagged, and subsequent location dates and sites for fish that moved south on the Red River out of the study area, 1999 - 2000 (in chronological order).

Tag Code #	Species	Tagging Date	Segment Tagged	Date Located	Time Located	Site Located	Date Last Location	Time Last Location	Equipment Type
1	WALL	10-Aug	28						
				11-Aug	7:17	24	13-Aug	20:19	Stationary Receiver
2	CHCT	10-Aug	28						
				16-Aug	14:05	24	16-Aug	15:12	Stationary Receiver
6	CHCT	10-Aug	28						
				18-Aug	16:10	60			Portable Receiver
				24-Aug	20:12	24	24-Aug	21:08	Stationary Receiver
18	CHCT	15-Aug	117						
				25-Aug	00:55	24	25-Aug	03:05	Stationary Receiver
29	CHCT	18-Aug	62						
				19-Aug	11:00	63			Portable Receiver
				28-Aug	11:57	24	28-Aug	12:04	Stationary Receiver
				28-Aug	14:37	24	28-Aug	14:48	Stationary Receiver
				28-Aug	15:24	24	28-Aug	15:32	Stationary Receiver
				28-Aug	17:42	24	29-Aug	21:17	Stationary Receiver
22	FRDR	16-Aug	111						
				23-Aug	15:30	118			Portable Receiver
				31-Aug	14:30	118			Portable Receiver
				14-Sep	20:48	24	15-Sep	01:10	Stationary Receiver
				22-Sep	20:21	24	22-Sep	21:59	Stationary Receiver
				26-Sep	01:05	24	26-Sep	02:19	Stationary Receiver
46	CARP	22-Aug	109						
				31-Aug	12:45	109			Portable Receiver
				16-Sep	09:05	109			Portable Receiver
				21-Sep	15:40	24	21-Sep	16:53	Stationary Receiver
				27-Sep	12:15	24	27-Sep	23:53	Stationary Receiver
				28-Sep	18:01	24	28-Sep	22:20	Stationary Receiver
				29-Sep	09:37	24	30-Sep	18:11	Stationary Receiver
				30-Sep	22:48	24	2-Oct	07:53	Stationary Receiver
				2-Oct	09:21	24	2-Oct	10:59	Stationary Receiver
				3-Oct	12:44	24	3-Oct	14:06	Stationary Receiver
				4-Oct	06:07	24	4-Oct	07:02	Stationary Receiver
				4-Oct	08:02	24	4-Oct	08:47	Stationary Receiver

* - Portable receiver locates fish at only a single point in time.

Table 6. Date, location tagged and subsequent location dates and sites for fish that moved west on the Assiniboine River out of the study area, 1999 - 2000 (in chronological order).

Tag Code #	Species	Tagging Date	Segment Tagged	Date Located	Time Located	Site Located	Date Last Location	Time Last Location	Equipment Type
50	CARP	23-Aug	109						
				24-Aug	15:33	106	28-Aug	07:06	Stationary Receiver
				28-Aug	19:58	106	28-Aug	20:46	Stationary Receiver
47	CARP	23-Aug	109						
				31-Aug	12:45	109			Portable Receiver
				9-Sep	16:13	106	11-Sep	01:28	Stationary Receiver
				16-Sep	09:05	109			Portable Receiver
				1-Oct	14:55	107			Portable Receiver
				3-Oct	11:37	106	3-Oct	14:53	Stationary Receiver
				3-Oct	15:26	106	3-Oct	17:43	Stationary Receiver
				3-Oct	18:08	106	3-Oct	21:23	Stationary Receiver
				4-Oct	19:57	106	4-Oct	23:53	Stationary Receiver
				5-Oct	04:50	106	5-Oct	04:51	Stationary Receiver
				5-Oct	09:22	106	5-Oct	10:43	Stationary Receiver
				6-Oct	03:58	106	6-Oct	04:08	Stationary Receiver
				7-Oct	06:11	106	7-Oct	06:38	Stationary Receiver
				8-Oct	15:02	106	9-Oct	00:36	Stationary Receiver

* Portable receiver locates fish at only a single point in time.

Table 7. Date, location tagged and subsequent re-location dates and sites for fish that remained inside the study area on the Red and Assiniboine rivers, August 1999 - February 2000.

Tag Code #	Species	Tagging Date	Segment Tagged	Date Located	Time Located	Site Located	Date Last Location	Time Last Location	Equipment Type
14	WALL	13-Aug	33						
				20-Oct	14:50	63			Portable Receiver
				8-Nov	14:36	64			Portable Receiver
				25-Nov	12:40	64			Portable Receiver
				28-Jan	14:25	64			Portable Receiver
16	WALL	14-Aug	33						
				18-Aug	16:10	60			Portable Receiver
				3-Oct	14:50	69			Portable Receiver
17	CHCT	15-Aug	117						
				23-Aug	14:30	118			Portable Receiver
				31-Aug	14:20	117			Portable Receiver
				16-Sep	10:05	117			Portable Receiver
				1-Oct	15:40	115			Portable Receiver
				18-Oct	12:15	117			Portable Receiver
				9-Nov	11:00	115			Portable Receiver
				25-Jan	13:20	115			Portable Receiver
				24-Feb	12:05	115			Portable Receiver
19	CHCT	15-Aug	116						
				1-Sep	11:40	65			Portable Receiver
				10-Sep	15:19	24	10-Sep	16:22	Stationary Receiver
				14-Sep	23:38	24	15-Sep	01:38	Stationary Receiver
				15-Sep	04:19	24	15-Sep	05:25	Stationary Receiver
				15-Sep	09:30	28			Portable Receiver
				16-Sep	11:30	48			Portable Receiver
20	CHCT	15-Aug	116						
				23-Aug	14:30	111			Portable Receiver
				31-Aug	13:15	111			Portable Receiver
				16-Sep	09:22	111			Portable Receiver
				1-Oct	15:20	111			Portable Receiver
				18-Oct	11:45	110			Portable Receiver
				9-Nov	10:35	110			Portable Receiver
				25-Jan	13:20	115			Portable Receiver
				24-Feb	10:50	115			Portable Receiver
21	CHCT	15-Aug	116						
				23-Aug	14:30	111			Portable Receiver
				31-Aug	13:15	111			Portable Receiver
				16-Sep	09:22	111			Portable Receiver
				1-Oct	15:20	111			Portable Receiver
				18-Oct	11:50	112			Portable Receiver
				9-Nov	10:40	111			Portable Receiver
				25-Jan	13:45	116			Portable Receiver
27	CHCT	18-Aug	62						
				19-Aug	11:00	62			Portable Receiver
				24-Aug	02:21	73	24-Aug	02:54	Stationary Receiver
				24-Aug	04:17	73	24-Aug	04:27	Stationary Receiver
				24-Aug	04:58	73	24-Aug	16:03	Stationary Receiver
				24-Aug	22:01	73	24-Aug	22:36	Stationary Receiver

Table 7. (cont'd)

Tag Code #	Species	Tagging Date	Segment Tagged	Date Located	Time Located	Site Located	Date Last Location	Time Last Location	Equipment Type
				25-Aug	00:20	73	25-Aug	01:39	Stationary Receiver
				25-Aug	10:58	73	25-Aug	22:47	Stationary Receiver
				15-Sep	14:25	65			Portable Receiver
				3-Oct	14:45	67			Portable Receiver
				20-Oct	15:10	67			Portable Receiver
30	NRPK	18-Aug	62						
				18-Aug	11:00	62			Portable Receiver
31	WALL	18-Aug	59						
				15-Sep	13:55	62			Portable Receiver
				25-Nov	12:05	61			Portable Receiver
				28-Jan	15:50	63			Portable Receiver
				17-Feb	13:55	63			
34	FRDR	19-Aug	58						
				1-Sep	10:20	59			Portable Receiver
				15-Sep	13:35	60			Portable Receiver
				3-Oct	14:10	62			Portable Receiver
				20-Oct	13:48	58			Portable Receiver
				8-Nov	13:50	60			Portable Receiver
				25-Nov	12:00	60			Portable Receiver
				28-Jan	11:47	70			Portable Receiver
				23-Feb	13:15	70			Portable Receiver
36	CHCT	20-Aug	62						
				1-Sep	11:20	63			Portable Receiver
				15-Sep	12:25	53			Portable Receiver
				16-Sep	11:30	48			Portable Receiver
				1-Oct	15:40	116			Portable Receiver
				20-Oct	11:15	35			Portable Receiver
				8-Nov	10:45	34			Portable Receiver
				25-Nov	09:30	34			Portable Receiver
				31-Jan	15:50	34			Portable Receiver
				23-Feb	10:45	34			Portable Receiver
40	CHCT	21-Aug	62						
				30-Aug	11:00	45			Portable Receiver
				15-Sep	13:35	60			Portable Receiver
				3-Oct	14:10	62			Portable Receiver
				20-Oct	11:23	36			Portable Receiver
				8-Nov	10:30	31			Portable Receiver
				24-Nov	10:12	24			Stationary Receiver
				25-Nov	09:15	31			Portable Receiver
				31-Jan	16:40	31			Portable Receiver
				23-Feb	10:30	31			Portable Receiver
44	FRDR	21-Aug	59						
				1-Sep	10:25	60			Portable Receiver
				15-Sep	13:00	57			Portable Receiver
45	FRDR	21-Aug	59						
				1-Sep	10:00	58			Portable Receiver
				15-Sep	13:00	57			Portable Receiver
				3-Oct	13:35	57			Portable Receiver
				20-Oct	13:45	57			Portable Receiver
				8-Nov	13:30	59			Portable Receiver
				25-Nov	11:30	57			Portable Receiver

Table 7. (cont'd)

Tag Code #	Species	Tagging Date	Segment Tagged	Date Located	Time Located	Site Located	Date Last Location	Time Last Location	Equipment Type
48	CARP	23-Aug	109						
				31-Aug	12:50	109			Portable Receiver
				16-Sep	09:05	109			Portable Receiver
				18-Oct	11:15	107			Portable Receiver
				19-Oct	12:19	106	21-Oct	10:25	Stationary Receiver
				9-Nov	10:10	108			Portable Receiver
49	CARP	23-Aug	109						
				31-Aug	12:55	109			Portable Receiver
				16-Sep	9:15	109			Portable Receiver
				1-Oct	15:55	118			Portable Receiver
				18-Oct	12:15	117			Portable Receiver
				9-Nov	11:30	118			Portable Receiver
				25-Jan	14:23	118			Portable Receiver
				24-Feb	11:37	118			Portable Receiver

* - Portable receiver locates fish at only a single point in time.

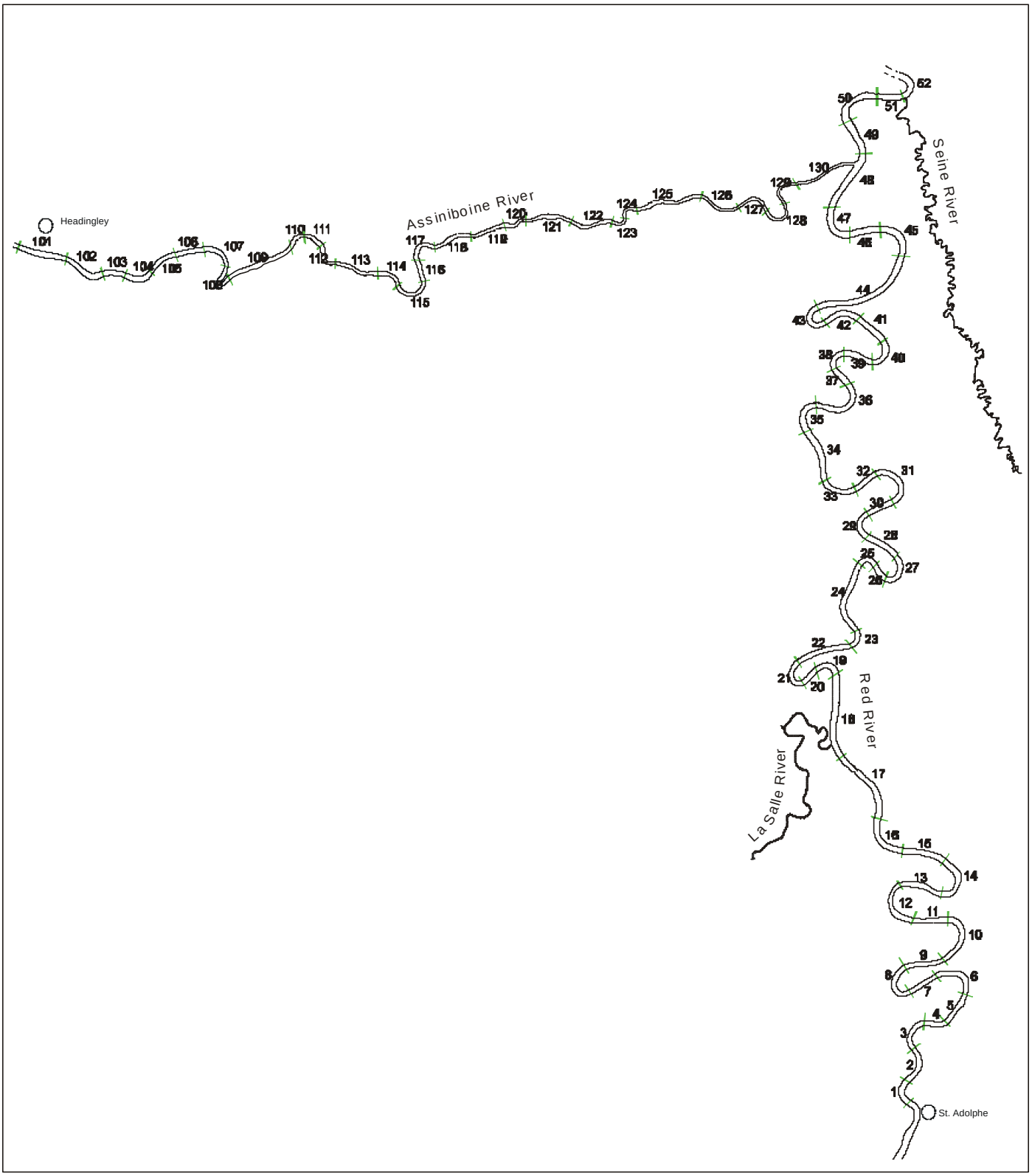

Figure 1. Fish habitat survey segments on the Red River, south of the Forks, and on the Assiniboine River.

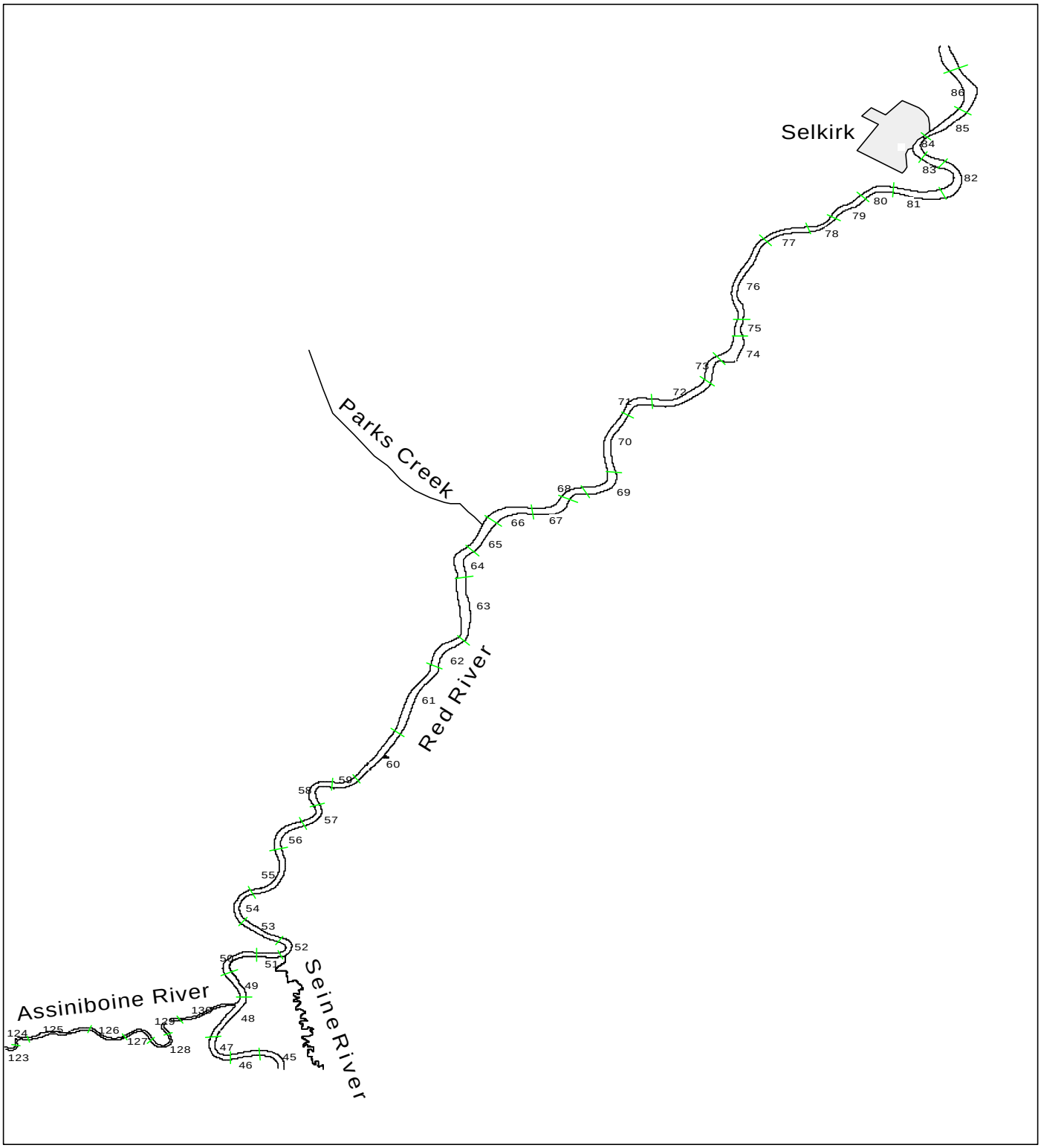

Figure 2. Fish habitat survey segments on the Red River north of the Forks.

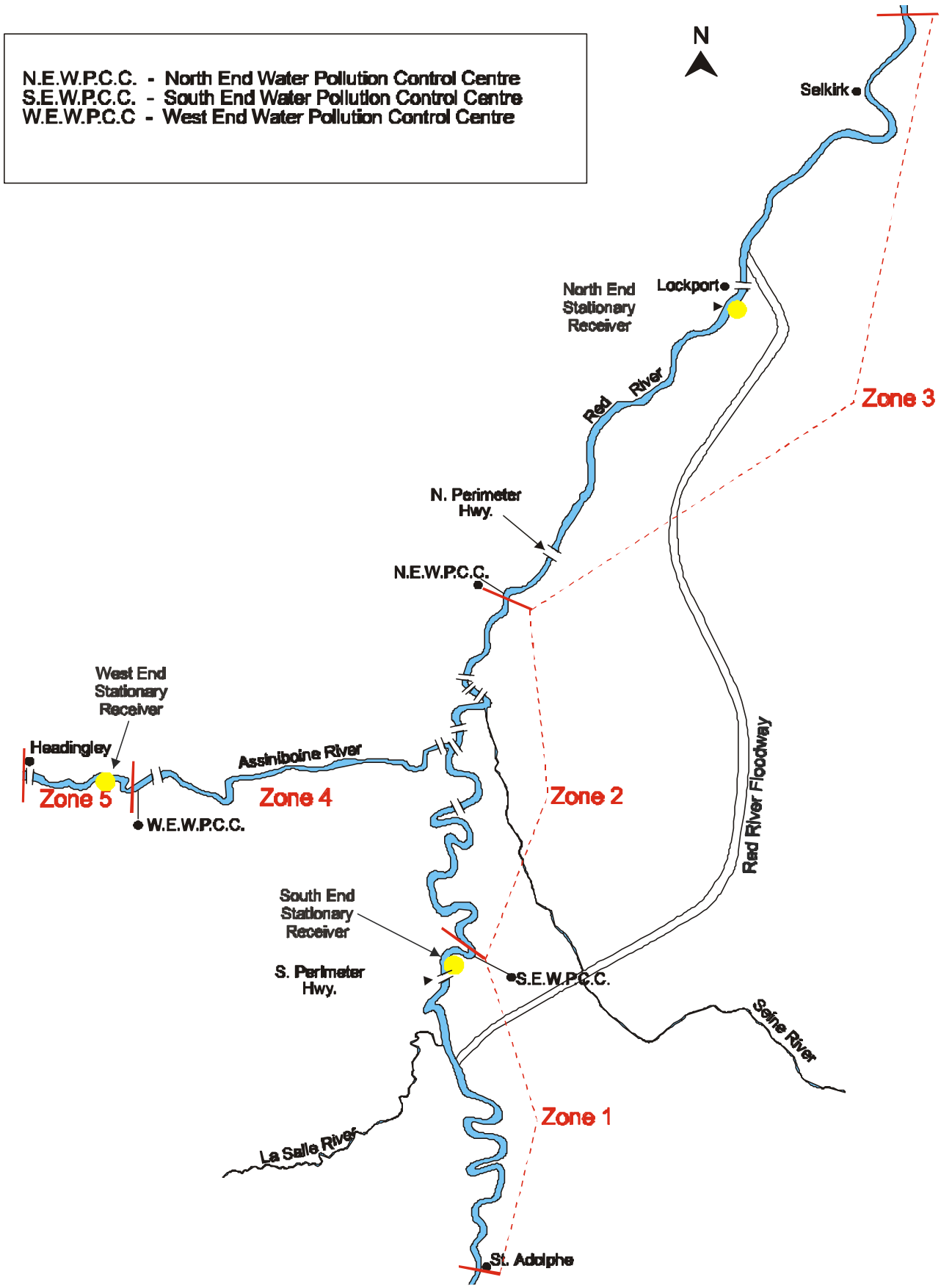

Figure 3. Locations of the three stationary receivers used in the August, 1999 - February, 2000 acoustic tagging investigation.

Figure 4. Insertion of hypodermic needles.

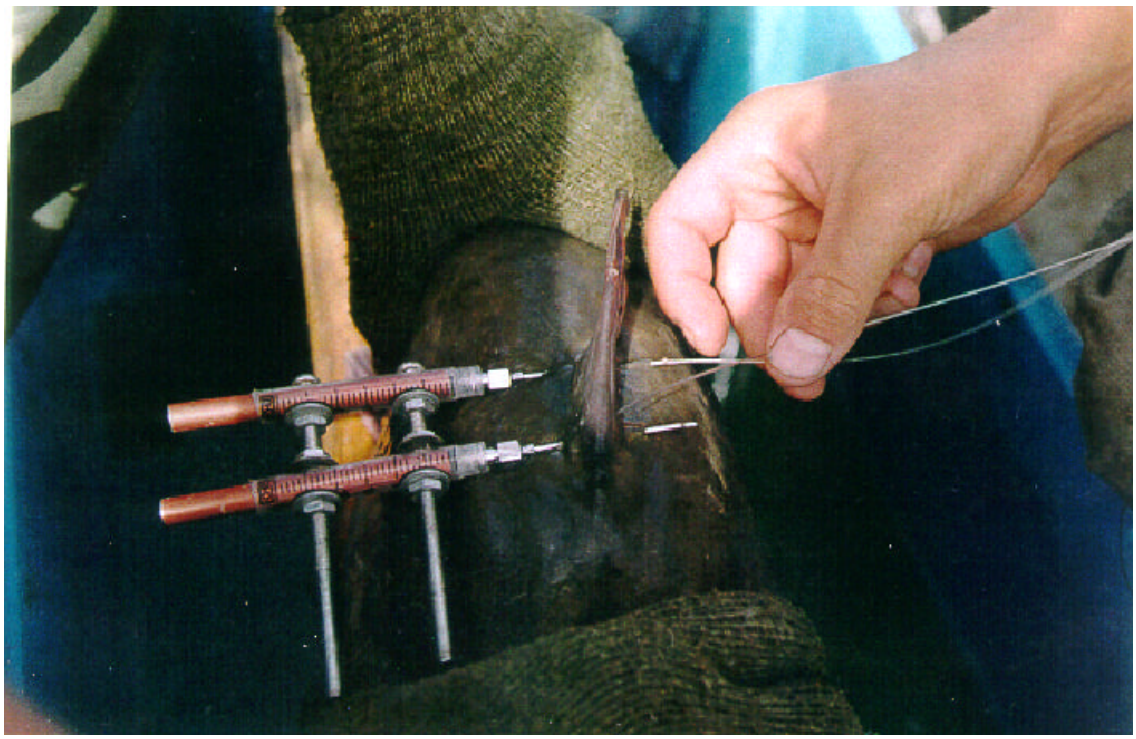

Figure 5. Insertion of attachment wires into hypodermic needles.

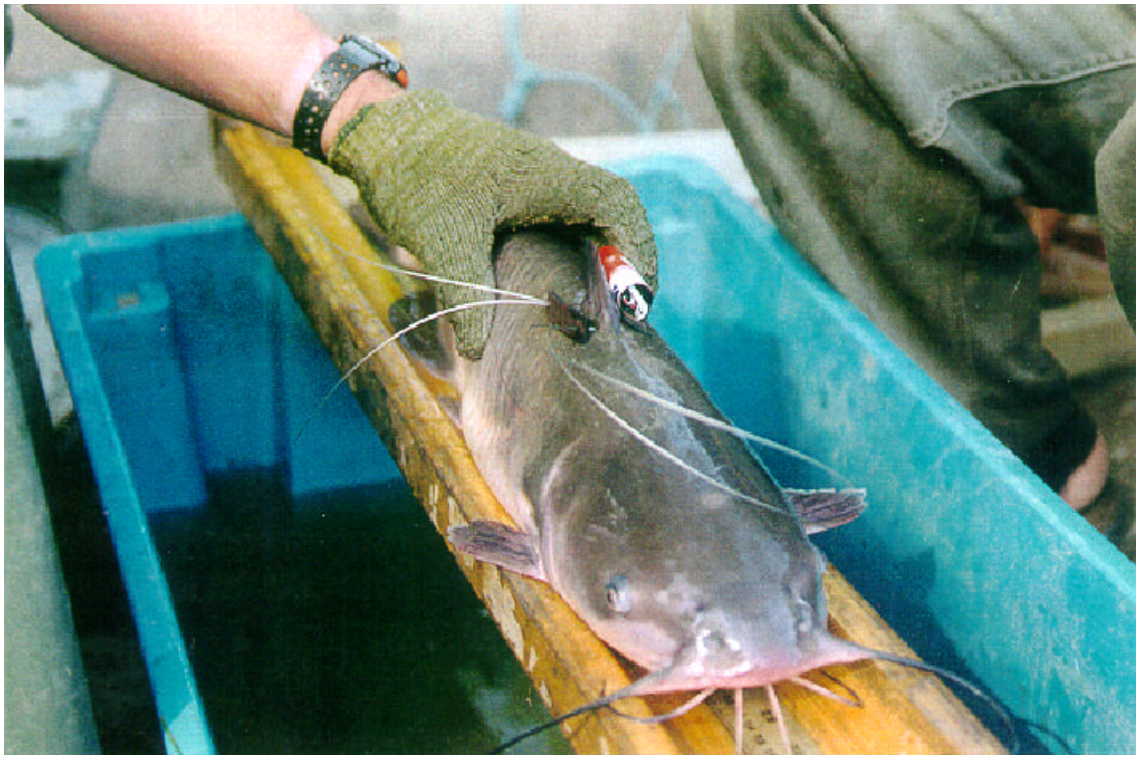

Figure 6. Soft neoprene pad passed through the attachment wires.

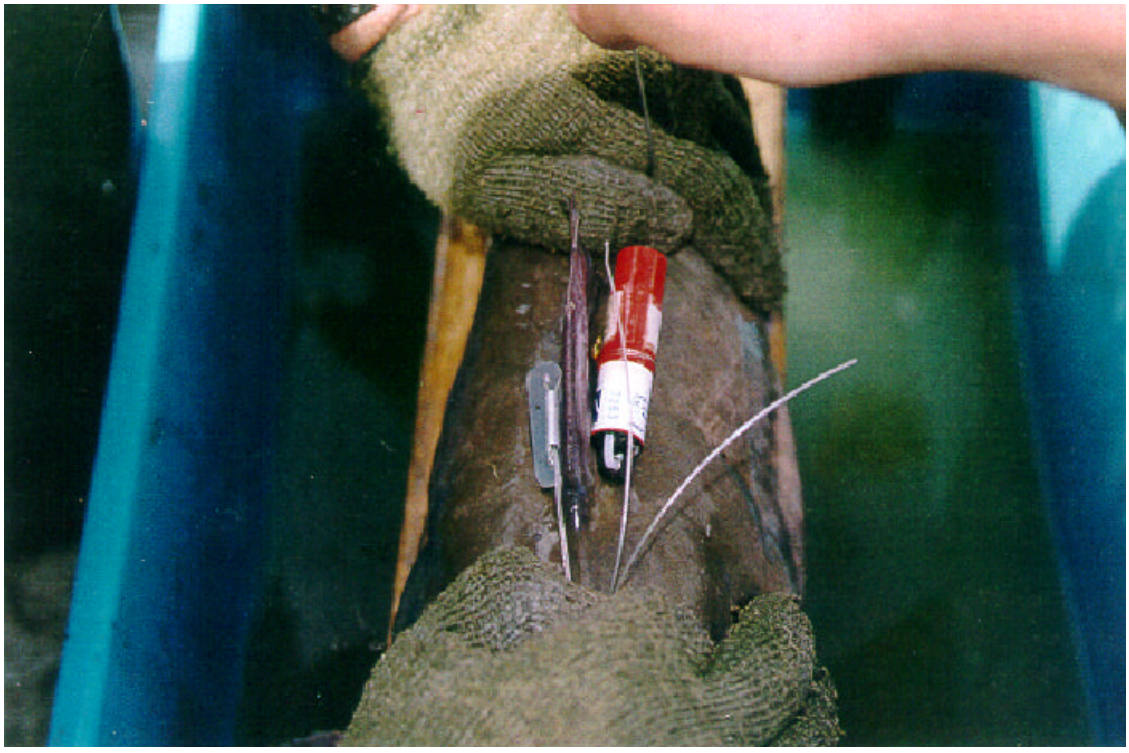

Figure 7. Attachment of transmitter with plastic plate and wire crimp.

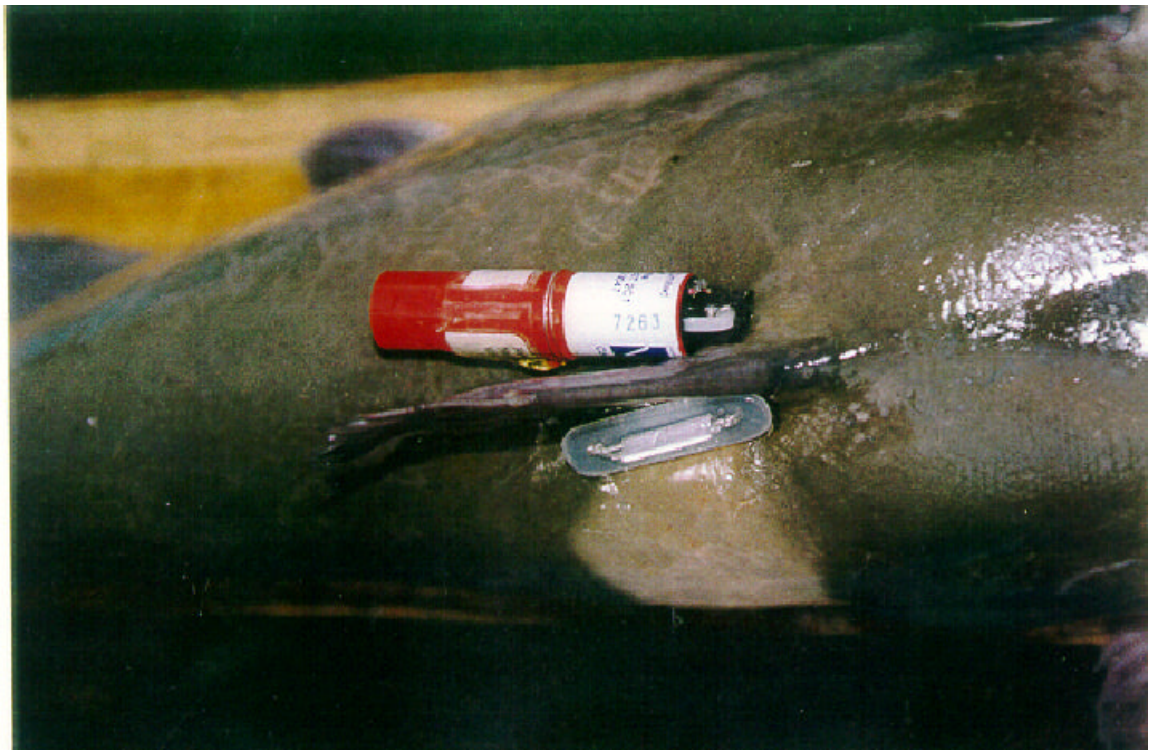

Figure 8. Completion of the attachment process.

Figure 9. Release of tagged channel catfish.

Figure 10. Release of tagged walleye.

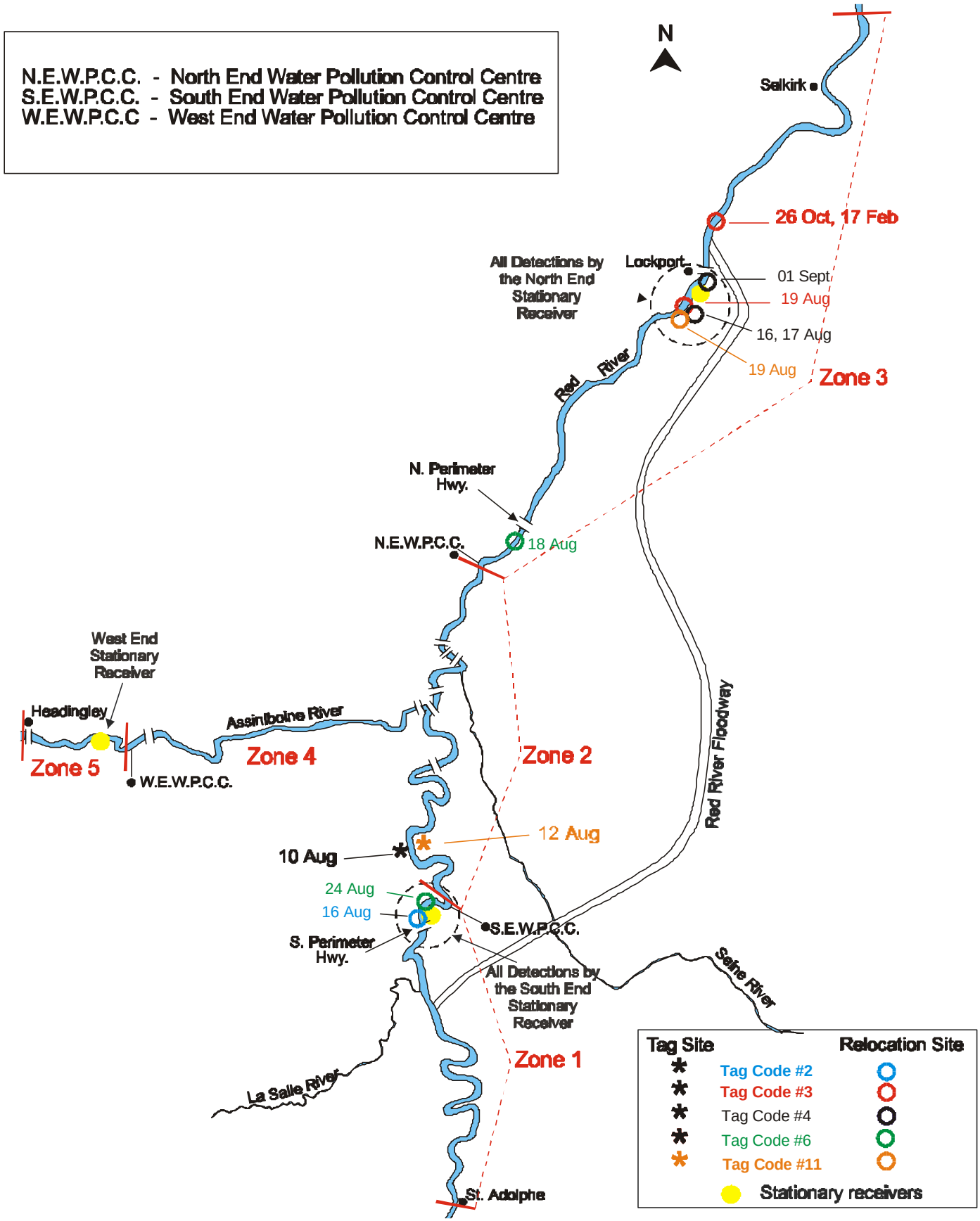

Figure 11. Movements of five channel catfish tagged downstream of the SEWPCC, 10 August, 1999 to 24 February, 2000.

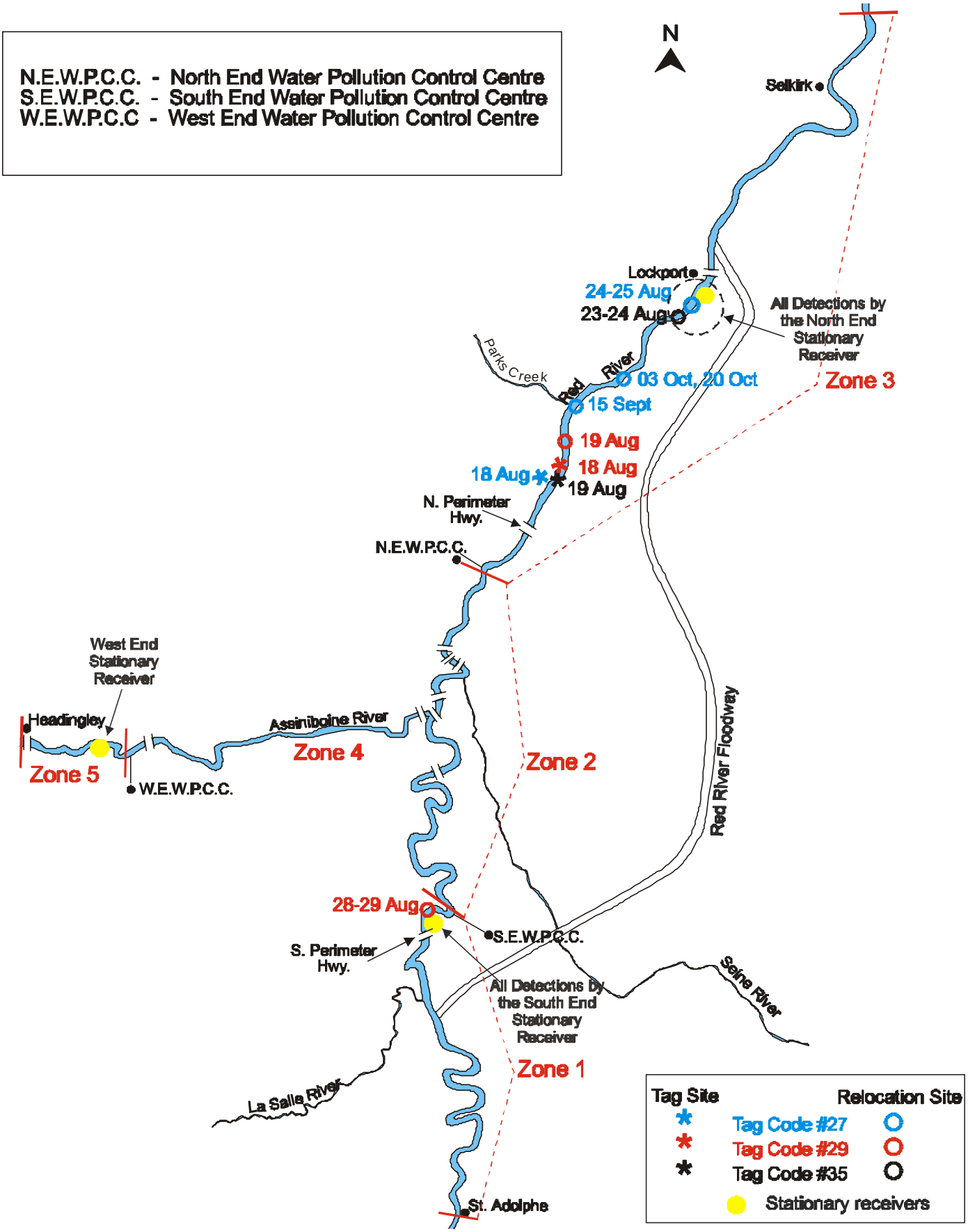

Figure 12. Movements of three channel catfish tagged downstream of the NEWPCC, 18 August, 1999 - 24 February, 2000.

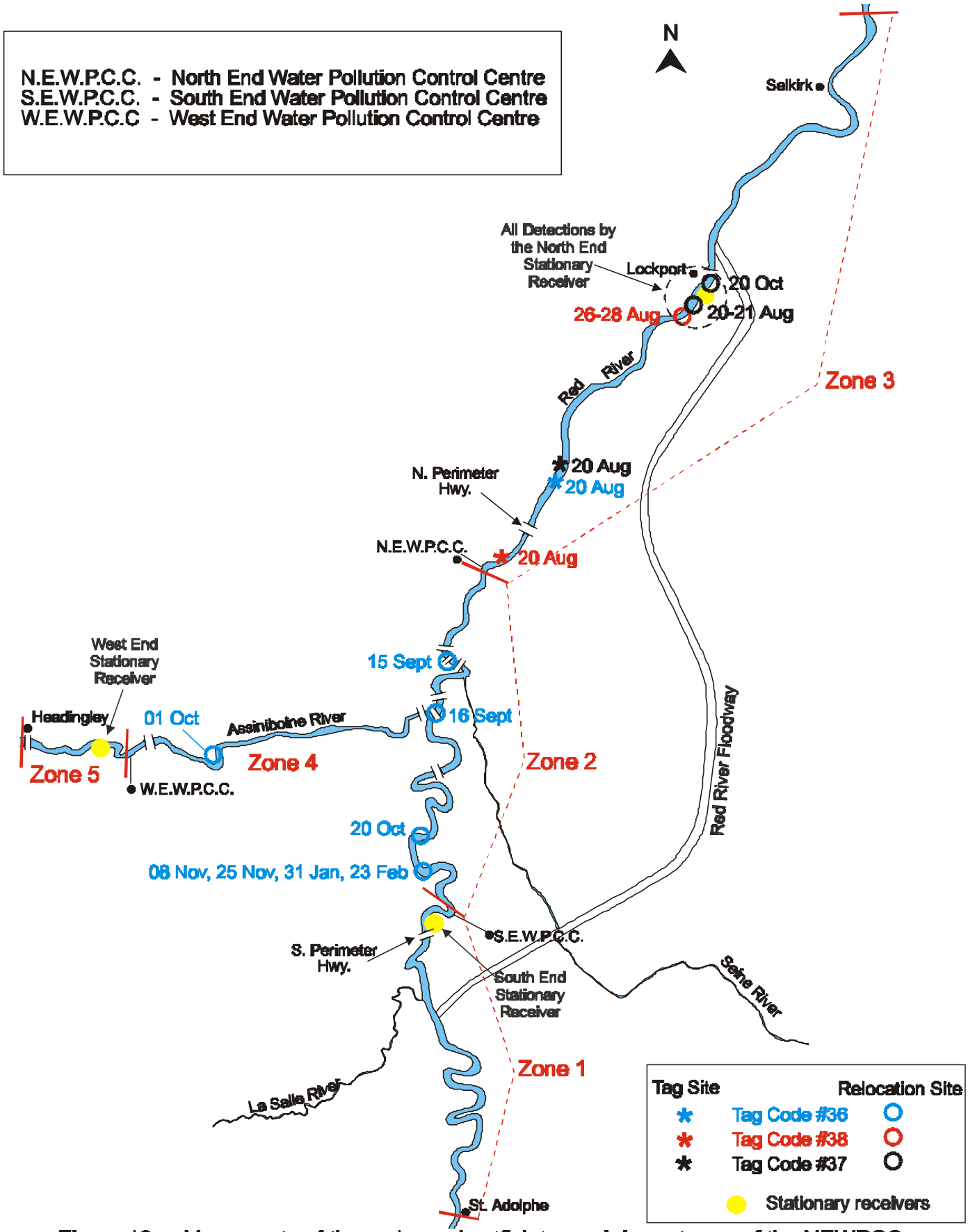

Figure 13. Movements of three channel catfish tagged downstream of the NEWPCC, 20 August, 1999 - 24 February, 2000

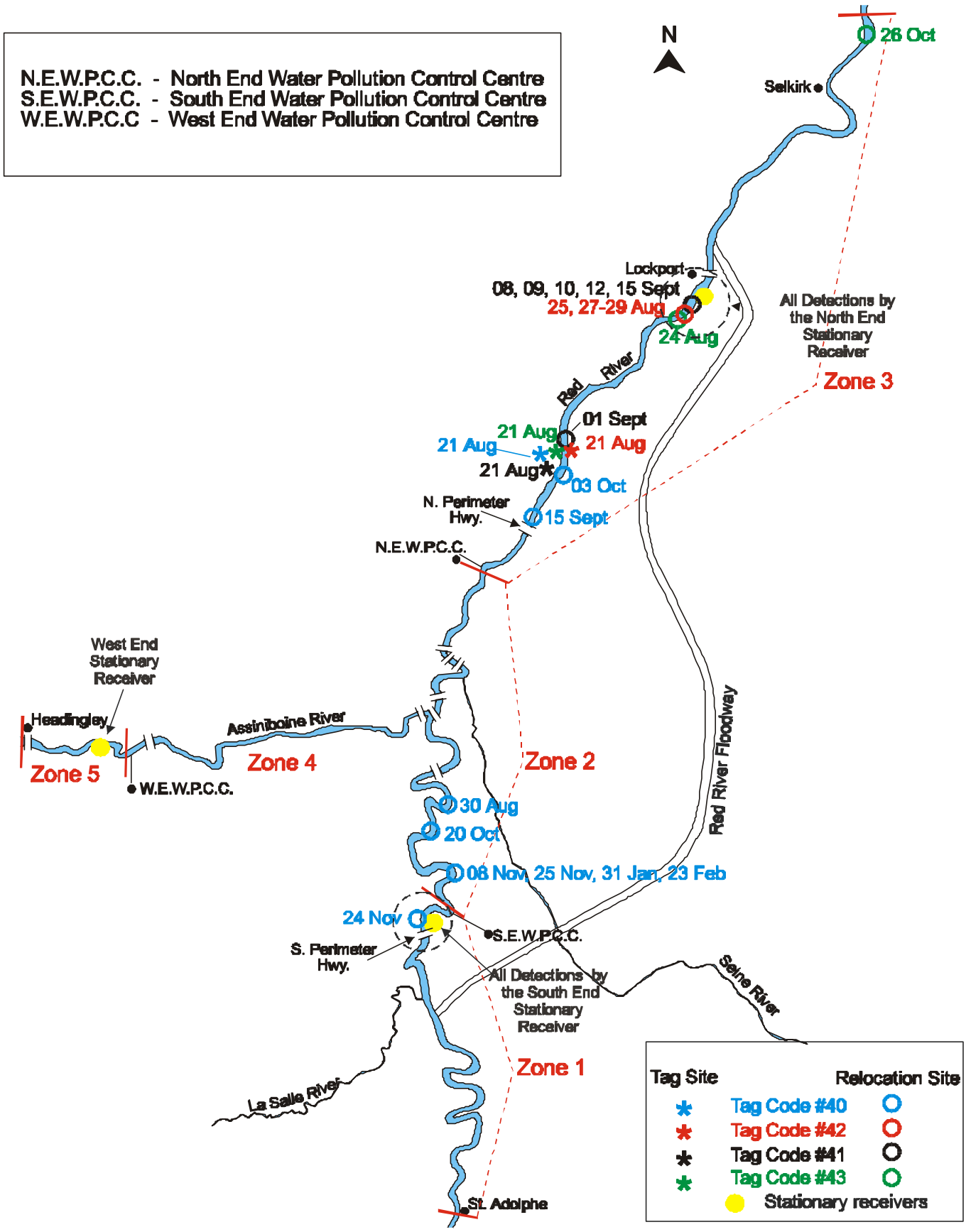

Figure 14. Movements of four channel catfish tagged downstream of the NEWPCC, 21 August, 1999 - 24 February, 2000.

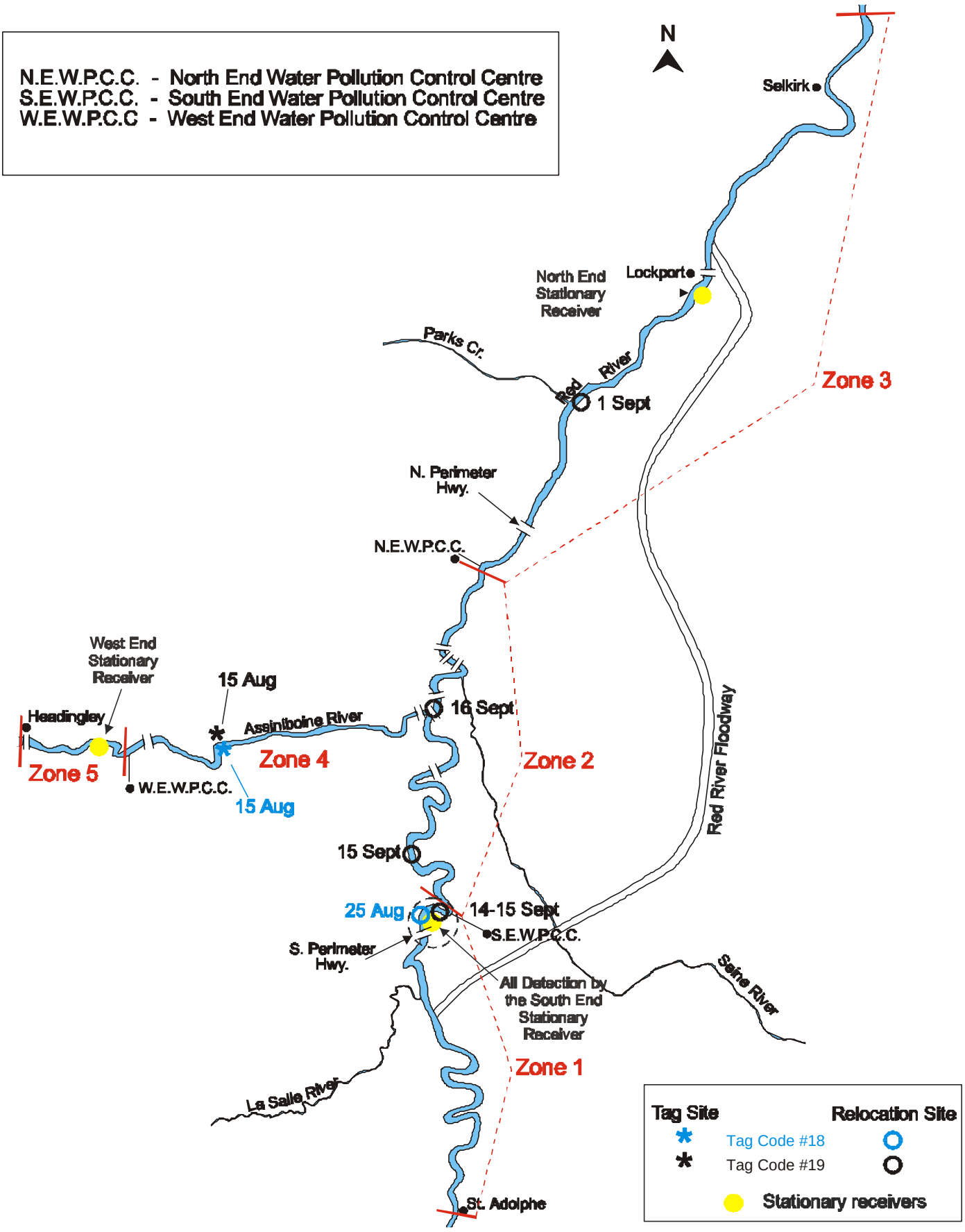

Figure 15. Movements of two channel catfish tagged downstream of the WEWPCC, 15 August, 1999 - 24 February, 2000.

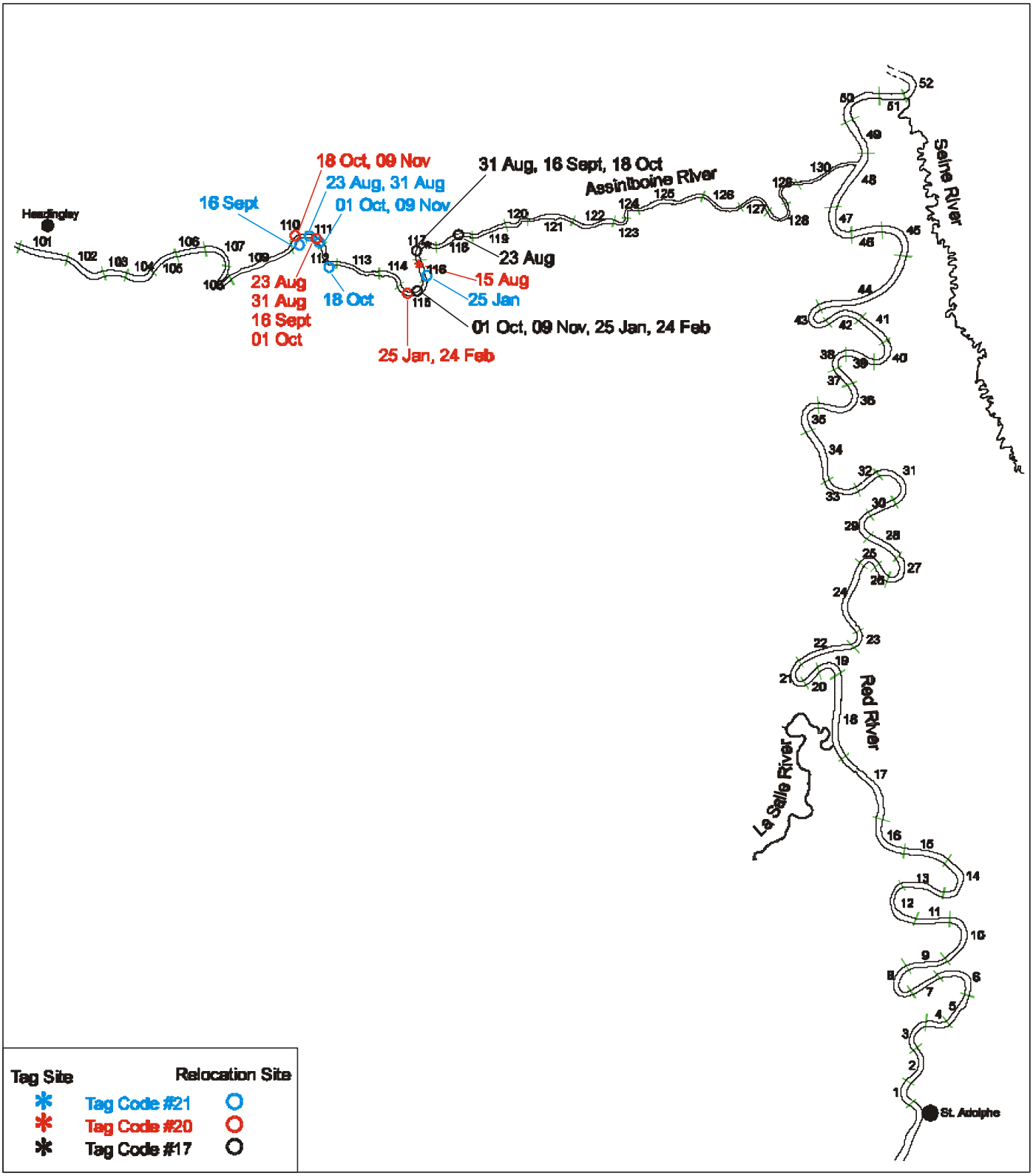

Figure 16. Movements of three channel catfish tagged downstream of the WEWPCC, 15 August, 1999 - 24 February, 2000.

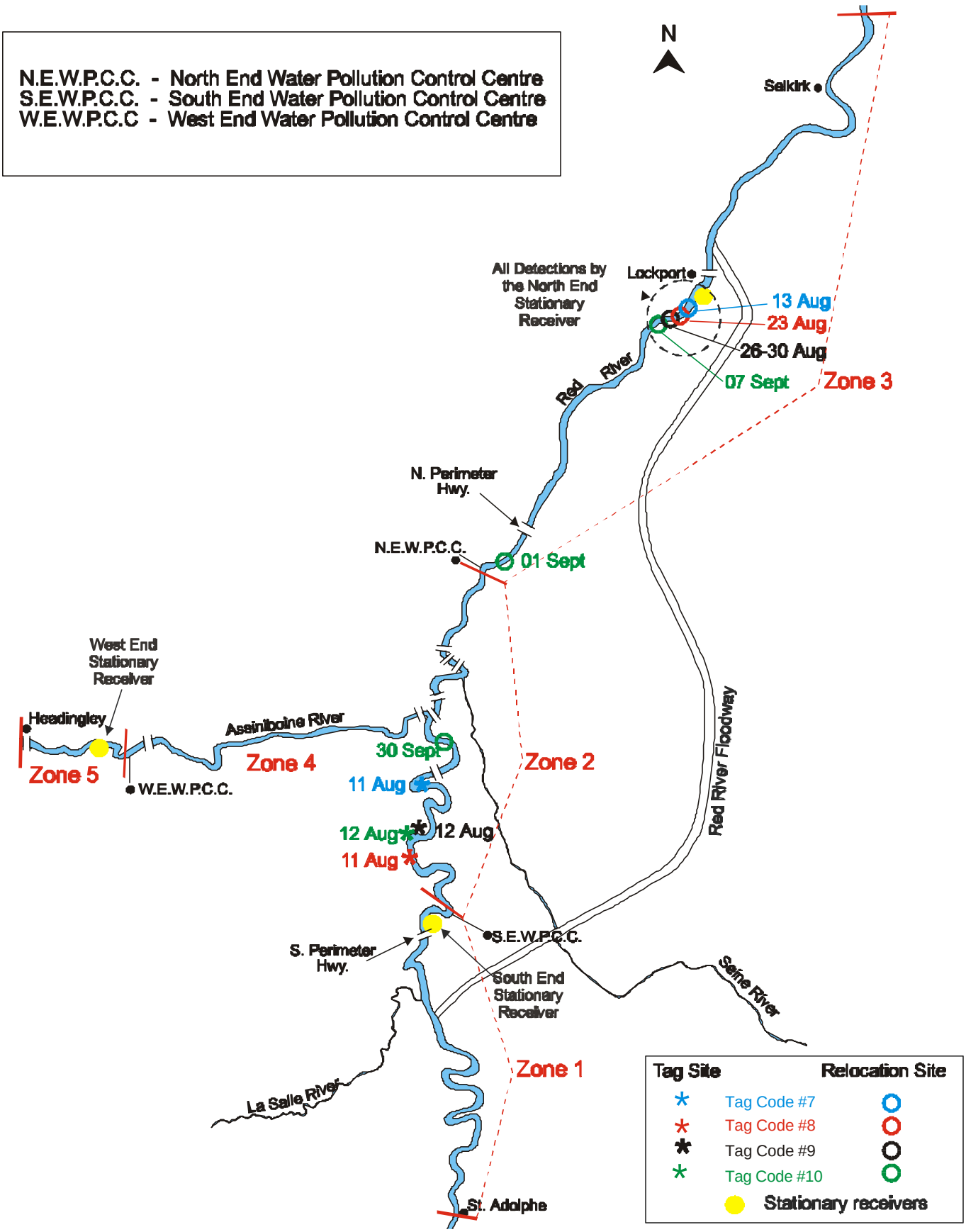

Figure 17. Movements of four freshwater drum tagged downstream of the SEWPCC, 10 August, 1999 - 24 February, 2000.

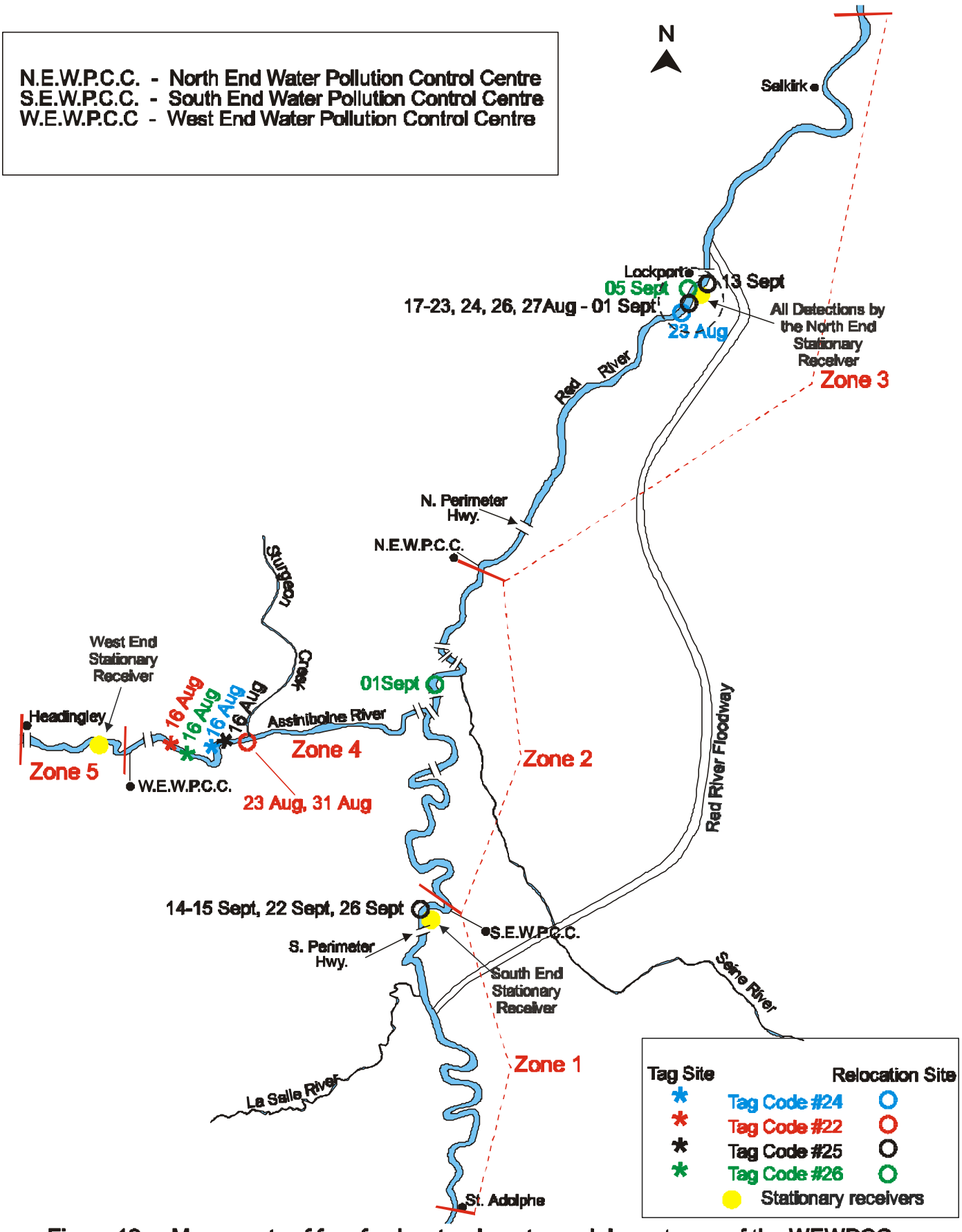

Figure 18. Movements of four freshwater drum tagged downstream of the WEWPCC, 15 August, 1999 - 24 February, 2000.

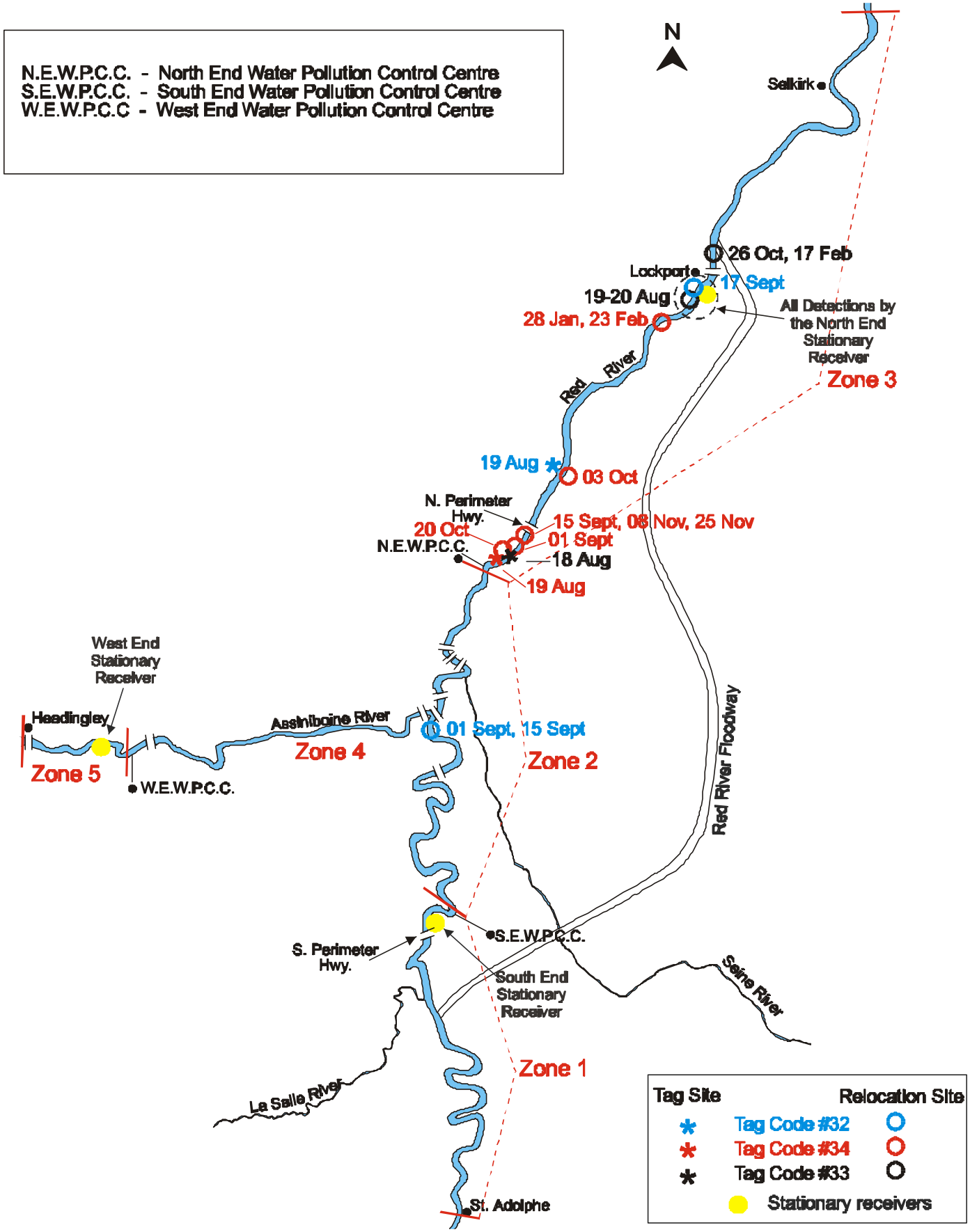

Figure 19. Movements of three freshwater drum tagged downstream of the NEWPCC, 18 August, 1999 - 24 February, 2000.

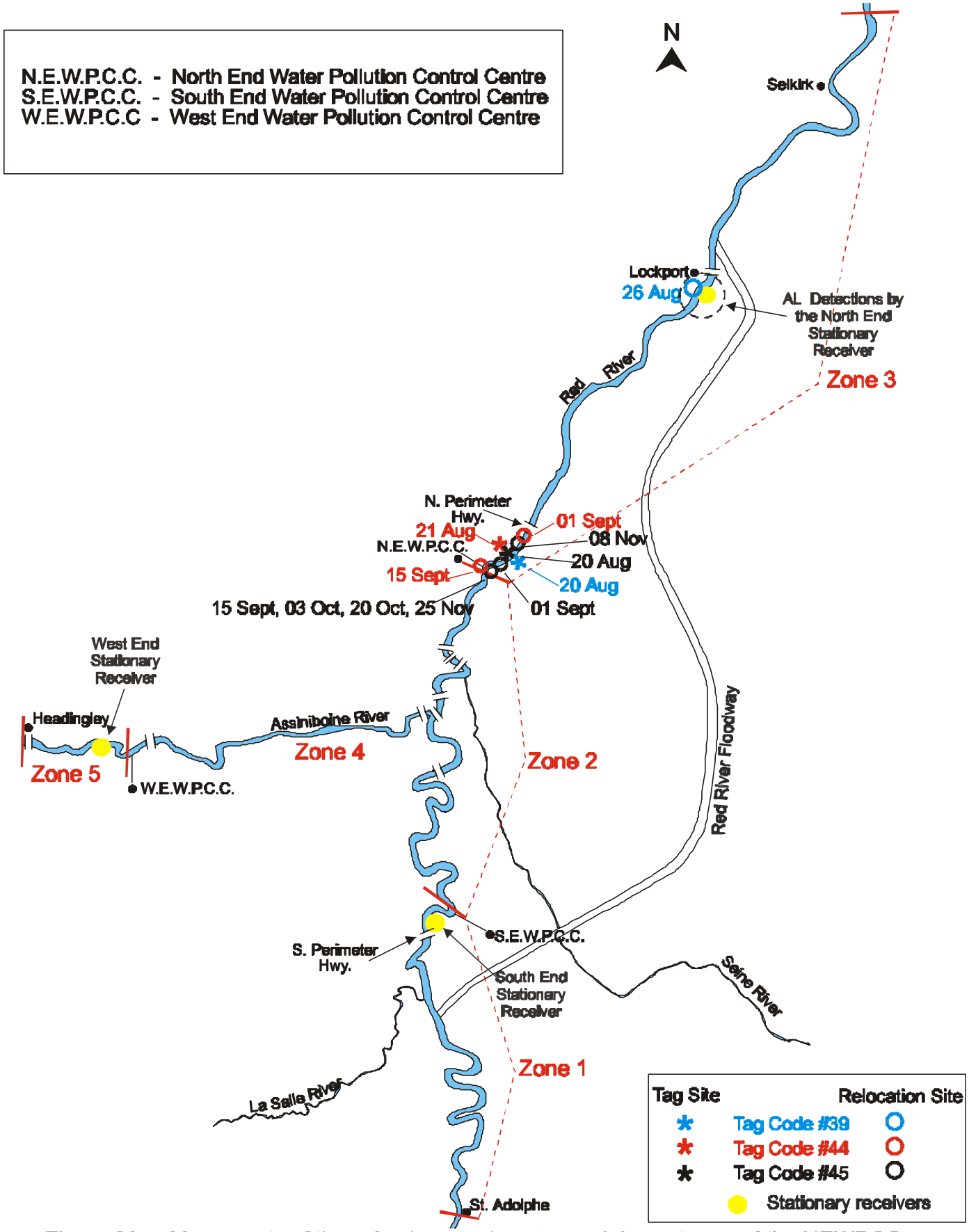

Figure 20. Movements of three freshwater drum tagged downstream of the NEWPCC, 20 August, 1999 - 24 February, 2000.

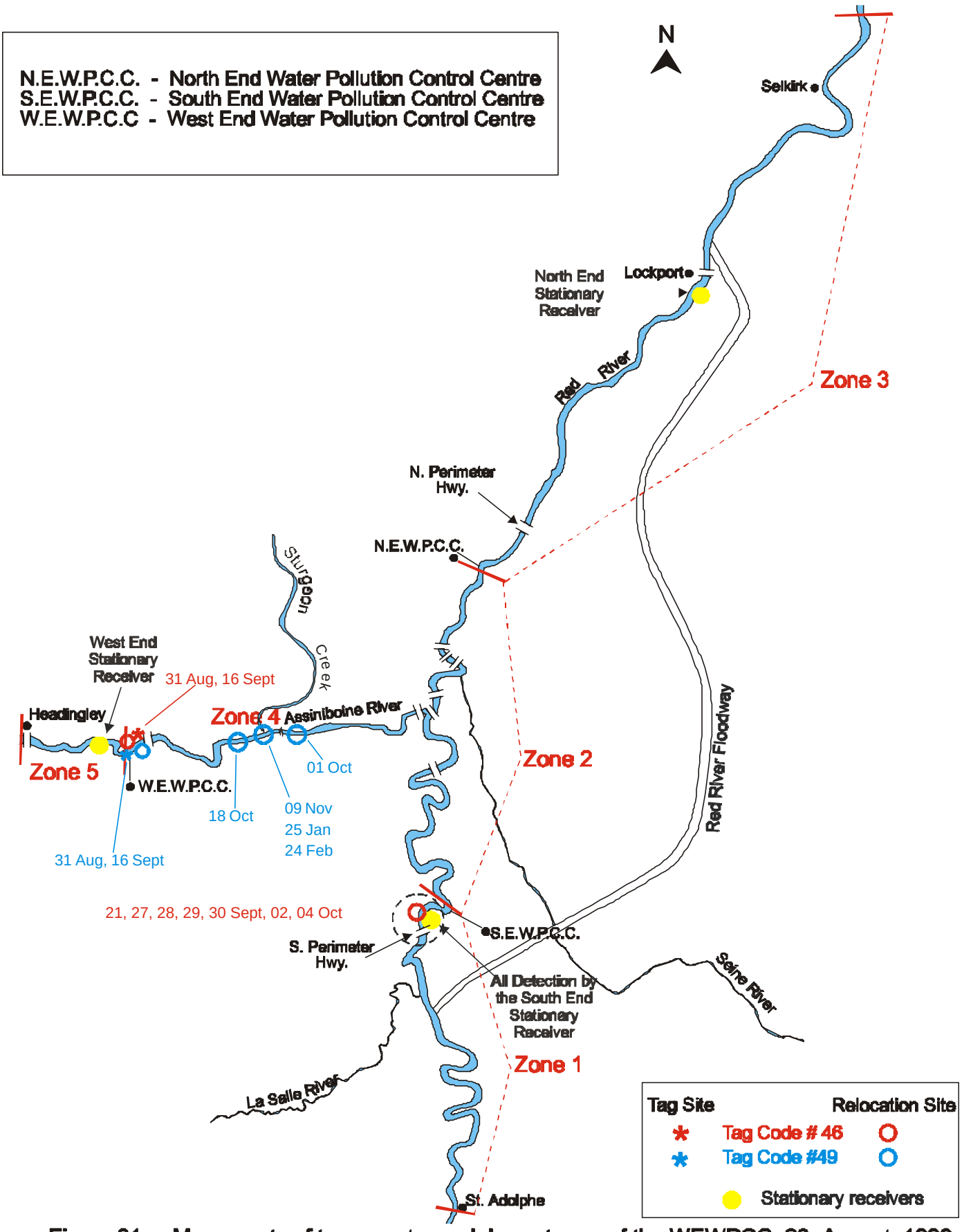

Figure 21. Movements of two carp tagged downstream of the WEWPCC, 23 August, 1999 - 24 February, 2000.

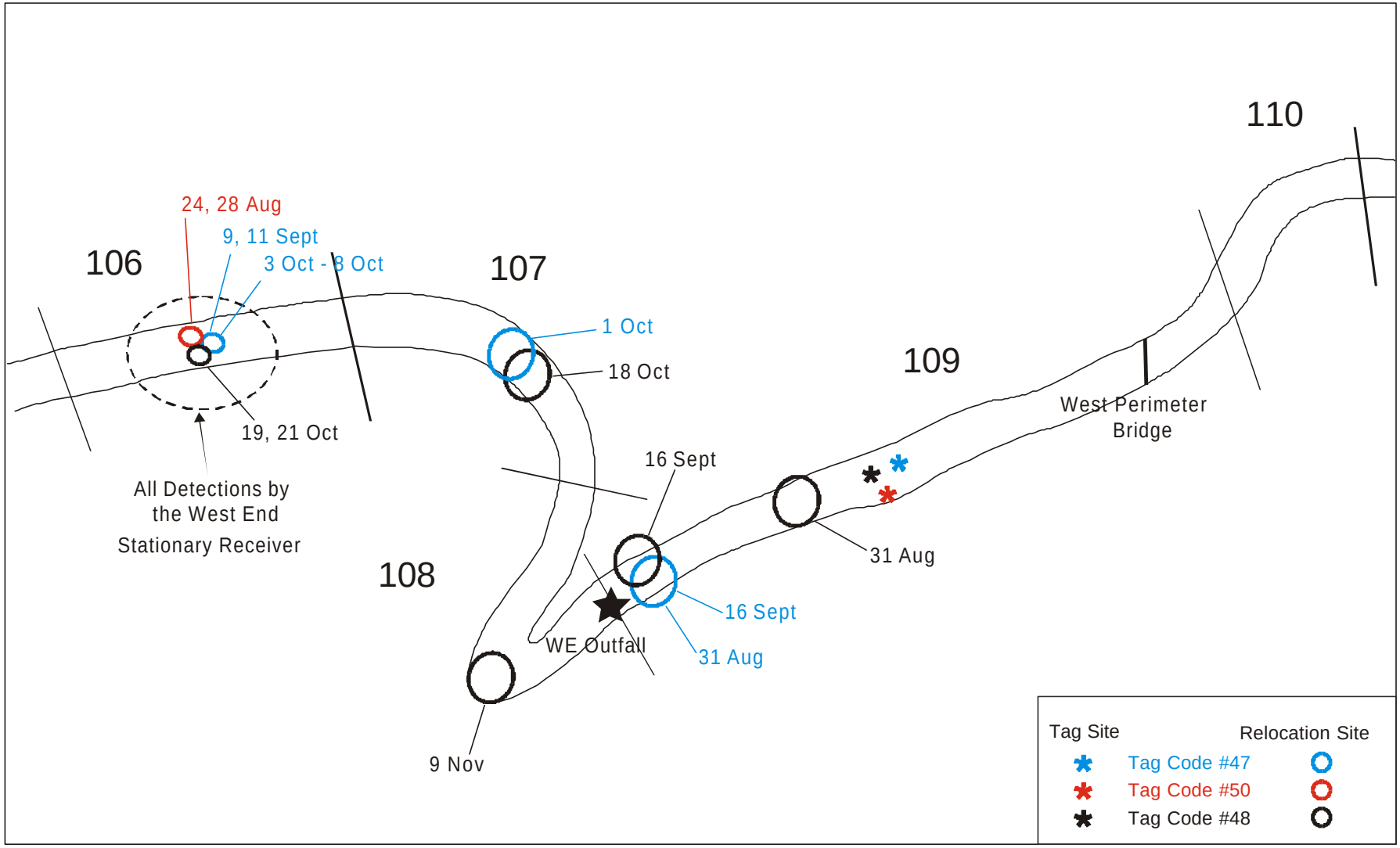

Figure 22. Movements of three carp tagged downstream of the WEWPCC, 24 August, 1999 - 24 February, 2000.

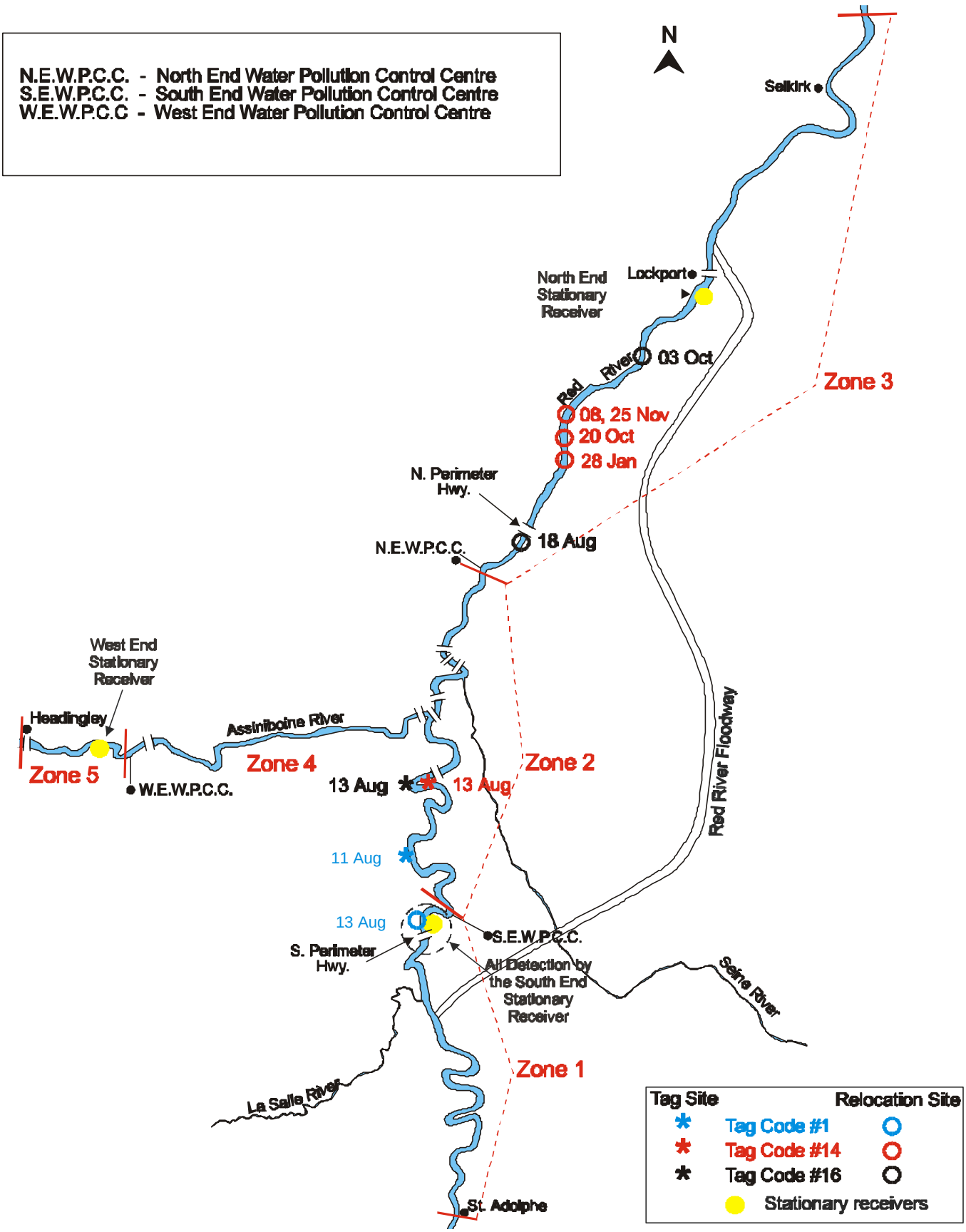

Figure 23. Movements of three walleye tagged downstream of the SEWPCC, 11 August, 1999 - 24 February, 2000.

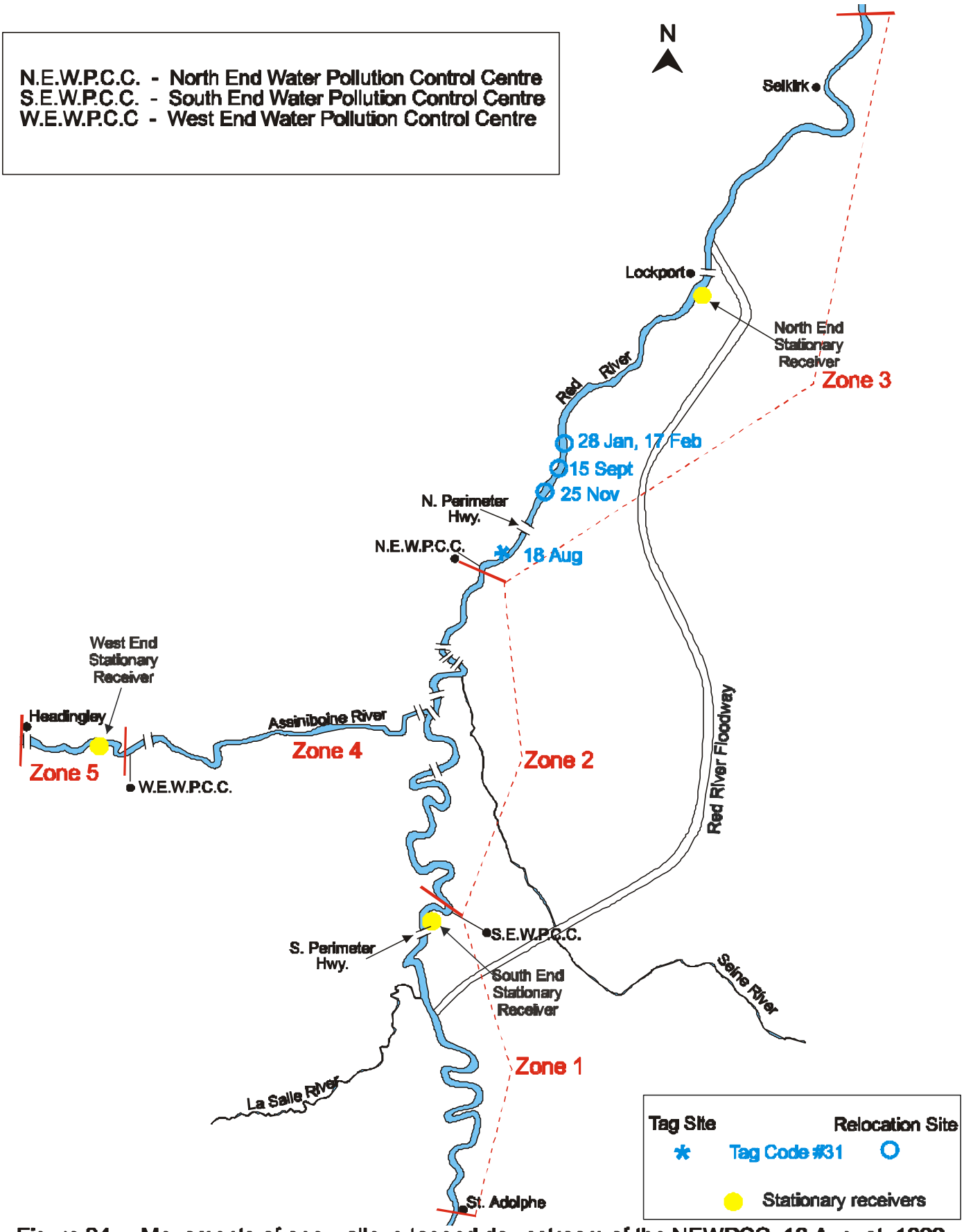

Figure 24. Movements of one walleye tagged downstream of the NEWPCC, 18 August, 1999 - 24 February, 2000.

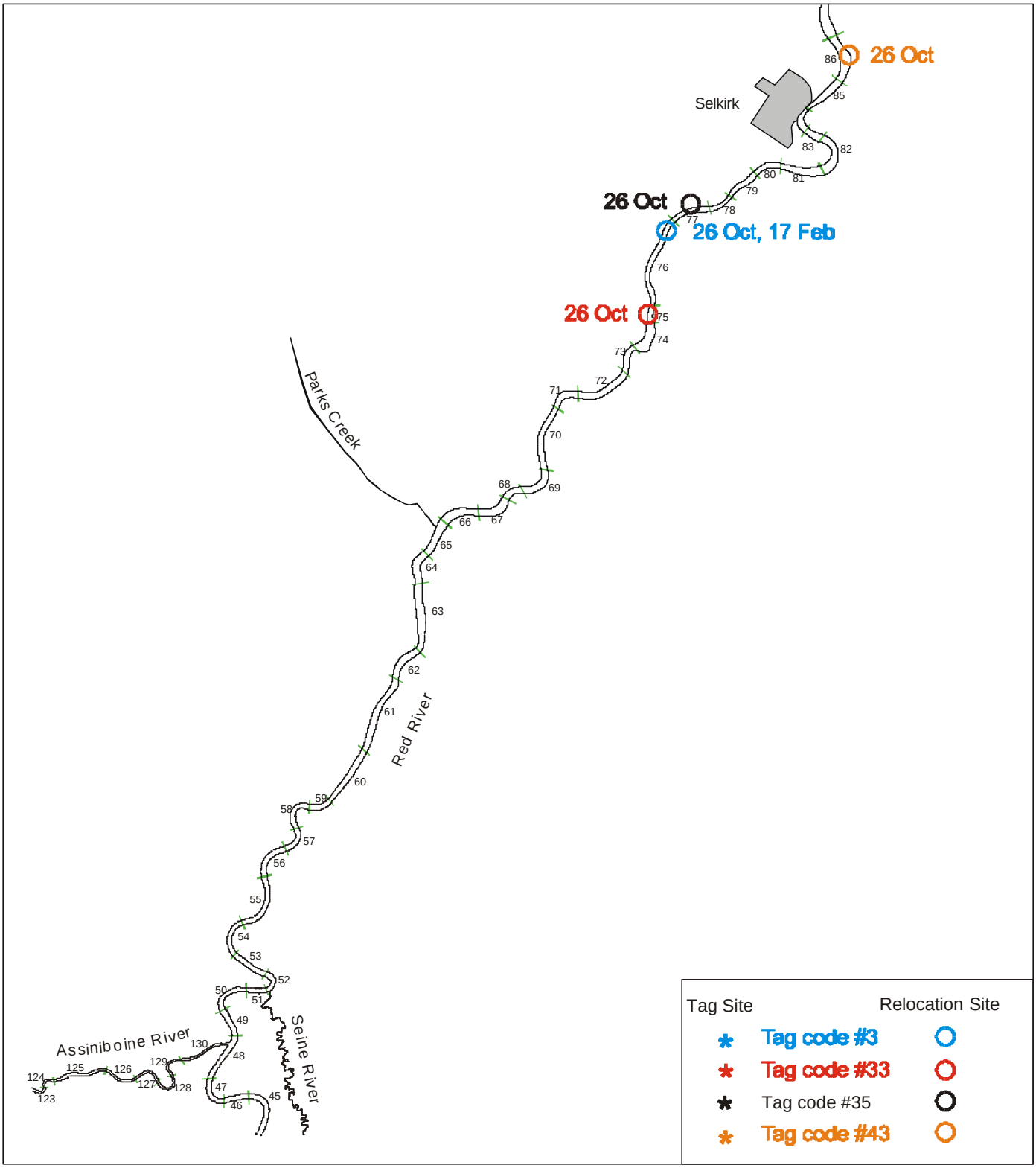

Figure 25. Fish located north of St. Andrews Locks, during tracking runs on 26 October 1999, and 17 February, 2000.

Appendix 1. Summary of tracking dates and tracking locations on the Red and Assiniboine rivers 1999 - 2000.

Tracking date	Tracking location
30-Aug-99	Zone #2
31-Aug-99	Zone #4
1-Sep-99	Zone #3
15-Sep-99	Zone #2 - Zone #3
16-Sep-99	Zone #4
1-Oct-99	Zone #4
3-Oct-99	Zone #2 - Zone #3
18-Oct-99	Zone #4
20-Oct-99	Zone #2 - Zone #3
26-Oct-99	D/S Lockport
8-Nov-99	Zone #2 - Zone #3
9-Nov-99	Zone #4
25-Nov-99	Zone #2 - #3
25-Jan-00	Zone #4
26-Jan-00	Zone #3
28-Jan-00	Zone #3
31-Jan-00	Zone #2
17-Feb-00	D/S Lockport
22-Feb-00	Zone #2
23-Feb-00	Zone #3
24-Feb-00	Zone #4

Appendix 2. A summary of tag number, fish number, fork length, weight, tag date, and tagging location for fish tagged with acoustic transmitters on the Red and Assiniboine rivers, August, 1999.

Tag Code #	Fish #	Species	Fork Length (mm)	Weight (g)	Tag date	Segment Tagged	Zone
1	1	WALL	515	1400	10-Aug	28	2
2	6	CHCT	560	2600	10-Aug	28	2
3	7	CHCT	575	2600	10-Aug	28	2
4	8	CHCT	605	3600	10-Aug	28	2
5	72	WALL	540	1700	11-Aug	33	2
6	9	CHCT	705	5600	10-Aug	28	2
7	87	FRDR	382	1000	11-Aug	33	2
8	50	FRDR	452	1200	11-Aug	28	2
9	97	FRDR	524	2200	12-Aug	29	2
10	98	FRDR	447	1200	12-Aug	29	2
11	104	CHCT	688	4350	12-Aug	28	2
12	TEST	TAG					
13	111	WALL	603	2500	13-Aug	33	2
14	112	WALL	472	1200	13-Aug	33	2
15	113	FRDR	395	1200	13-Aug	33	2
16	159	WALL	429	950	14-Aug	33	2
17	163	CHCT	717	4700	15-Aug	117	4
18	164	CHCT	586	2900	15-Aug	117	4
19	173	CHCT	502	1500	15-Aug	116	4
20	174	CHCT	728	4700	15-Aug	116	4
21	175	CHCT	680	3900	15-Aug	116	4
22	208	FRDR	603	3500	16-Aug	111	4
23	226	FRDR	507	1900	16-Aug	116	4
24	227	FRDR	462	1300	16-Aug	116	4
25	231	FRDR	485	1550	16-Aug	117	4
26	264	FRDR	437	1100	16-Aug	113	4
27	271	CHCT	618	3800	18-Aug	62	3
28	290	NRPK	515	1000	18-Aug	62	3
29	327	CHCT	810	7200	18-Aug	62	3
30	328	NRPK	636	1950	18-Aug	62	3
31	433	WALL	678	4350	18-Aug	59	3
32	589	FRDR	425	1350	19-Aug	62	3
33	491	FRDR	393	900	18-Aug	59	3
34	534	FRDR	585	2500	19-Aug	58	3
35	590	CHCT	548	2200	19-Aug	62	3
36	638	CHCT	795	8100	20-Aug	62	3
37	639	CHCT	782	7700	20-Aug	62	3
38	656	CHCT	664	3900	20-Aug	59	3
39	657	FRDR	366	900	20-Aug	59	3
40	672	CHCT	820	8800	21-Aug	62	3
41	673	CHCT	595	3900	21-Aug	62	3
42	674	CHCT	658	6100	21-Aug	62	3
43	749	CHCT	512	1700	21-Aug	62	3
44	776	FRDR	480	1600	21-Aug	59	3

Appendix 2. (Contd..)

Tag Code #	Fish #	Species	Fork Length (mm)	Weight (g)	Tag date	Tagging Location	Zone
45	774	FRDR	395	900	21-Aug	59	3
46	786	CARP	627	4750	22-Aug	W.E PLUME	4
47	787	CARP	507	2600	23-Aug	W.E PLUME	4
48	788	CARP	560	3200	23-Aug	W.E PLUME	4
49	789	CARP	590	3900	23-Aug	W.E PLUME	4
50	790	CARP	600	4400	23-Aug	W.E PLUME	4

Appendix 3. A summary of all fish tagged with acoustic transmitters, including date tagged, relocation sites, relocation dates, and type of equipment used during the 1999 - 2000 acoustic tagging investigation.

Tag Code #	Fish #	Species	Fork Length (mm)	Weight (g)	Tagging date	Segment Tagged	Date First Located	Time First Located	Site Located	Date Last Detection	Time Last Detection	Equipment used
1	1	WALL	515	1400	10-Aug	28						
							11-Aug	7:17	24	13-Aug	20:19	Stationary Receiver
2	6	CHCT	560	2600	10-Aug	28						
							16-Aug	14:05	24	16-Aug	15:12	Stationary Receiver
3	7	CHCT	575	2600	10-Aug	28						
							19-Aug	05:42	73	19-Aug	06:37	Stationary Receiver
							26-Oct	14:15	76			Portable Receiver
							17-Feb	10:20	76			Portable Receiver
4	8	CHCT	605	3600	10-Aug	28						
							16-Aug	11:37	73	16-Aug	13:32	Stationary Receiver
							17-Aug	08:05	73	17-Aug	8:14	Stationary Receiver
							1-Sep	12:15	74			Portable Receiver
5	72	WALL	540	1700	11-Aug	33						
							30-Aug	13:00	34			Portable Receiver
							15-Sep	10:00	33			Portable Receiver
							3-Oct	11:20	34			Portable Receiver
							20-Oct	11:05	34			Portable Receiver
							8-Nov	13:30	34			Portable Receiver
							25-Nov	09:30	34			Portable Receiver
							31-Jan	16:00	34			Portable Receiver
6	9	CHCT	705	5600	10-Aug	28						
							18-Aug	16:10	60			Portable Receiver
							24-Aug	20:12	24	24-Aug	21:08	Stationary Receiver
7	87	FRDR	382	1000	11-Aug	33						
							13-Aug	16:59	73	13-Aug	22:49	Stationary Receiver
8	50	FRDR	452	1200	11-Aug	28						
							23-Aug	02:36	73	23-Aug	03:50	Stationary Receiver
							23-Aug	11:23	73	23-Aug	12:17	Stationary Receiver

Appendix 3. (cont'd)

Tag Code #	Fish #	Species	Fork Length (mm)	Weight (g)	Tagging date	Segment Tagged	Date First Located	Time First Located	Site Located	Date Last Detection	Time Last Detection	Equipment used
							23-Aug	16:02	73	23-Aug	16:11	Stationary Receiver
9	97	FRDR	524	2200	12-Aug	29						
							26-Aug	06:20	73	26-Aug	11:04	Stationary Receiver
							26-Aug	12:20	73	26-Aug	12:46	Stationary Receiver
							26-Aug	14:26	73	26-Aug	15:02	Stationary Receiver
							26-Aug	15:22	73	26-Aug	21:26	Stationary Receiver
							27-Aug	00:35	73	27-Aug	00:41	Stationary Receiver
							27-Aug	01:14	73	27-Aug	03:01	Stationary Receiver
							27-Aug	04:56	73	27-Aug	05:36	Stationary Receiver
							27-Aug	07:22	73	27-Aug	13:16	Stationary Receiver
							27-Aug	18:31	73	28-Aug	3:09	Stationary Receiver
							29-Aug	13:17	73	29-Aug	13:20	Stationary Receiver
							30-Aug	01:43	73	30-Aug	01:54	Stationary Receiver
10	98	FRDR	447	1200	12-Aug	29						
							30-Aug	10:45	46			Portable Receiver
							1-Sep	10:00	58			Portable Receiver
							7-Sep	18:51	73	7-Sep	23:23	Stationary Receiver
11	104	CHCT	688	4350	12-Aug	28						
							19-Aug	15:11	73	19-Aug	16:14	Stationary Receiver
12	TEST	TAG										
13	111	WALL	603	2500	13-Aug	33						
							30-Aug	11:00	45			Portable Receiver
							15-Sep	11:30	45			Portable Receiver
							3-Oct	12:25	45			Portable Receiver
							20-Oct	12:25	45			Portable Receiver
14	112	WALL	472	1200	13-Aug	33						
							20-Oct	14:50	63			Portable Receiver
							8-Nov	14:36	64			Portable Receiver
							25-Nov	12:40	64			Portable Receiver
							28-Jan	14:25	64			Portable Receiver
15	113	FRDR	395	1200	13-Aug	33						
							30-Aug	12:20	38			Portable Receiver
							15-Sep	10:40	38			Portable Receiver
							3-Oct	11:40	38			Portable Receiver
							20-Oct	11:30	38			Portable Receiver
16	159	WALL	429	950	14-Aug	33						
							18-Aug	16:10	60			Portable Receiver

Appendix 3. (cont'd)

Tag Code #	Fish #	Species	Fork Length (mm)	Weight (g)	Tagging date	Segment Tagged	Date First Located	Time First Located	Site Located	Date Last Detection	Time Last Detection	Equipment used
							3-Oct	14:50	69			Portable Receiver
17	163	CHCT	717	4700	15-Aug	117						
							23-Aug	14:30	118			Portable Receiver
							31-Aug	14:20	117			Portable Receiver
							16-Sep	10:05	117			Portable Receiver
							1-Oct	15:40	115			Portable Receiver
							18-Oct	12:15	117			Portable Receiver
							9-Nov	11:00	115			Portable Receiver
							25-Jan	13:20	115			Portable Receiver
							24-Feb	12:05	115			Portable Receiver
18	164	CHCT	586	2900	15-Aug	117						
							25-Aug	00:55	24	25-Aug	03:05	Stationary Receiver
19	173	CHCT	502	1500	15-Aug	116						
							1-Sep	11:40	65			Portable Receiver
							10-Sep	15:19	24	10-Sep	16:22	Stationary Receiver
							14-Sep	23:38	24	15-Sep	01:38	Stationary Receiver
							15-Sep	04:19	24	15-Sep	05:25	Stationary Receiver
							15-Sep	09:30	28			Portable Receiver
							16-Sep	11:30	48			Portable Receiver
20	174	CHCT	728	4700	15-Aug	116						
							23-Aug	14:30	111			Portable Receiver
							31-Aug	13:15	111			Portable Receiver
							16-Sep	09:22	111			Portable Receiver
							1-Oct	15:20	111			Portable Receiver
							18-Oct	11:45	110			Portable Receiver
							9-Nov	10:35	110			Portable Receiver
							25-Jan	13:20	115			Portable Receiver
							24-Feb	10:50	115			Portable Receiver
21	175	CHCT	680	3900	15-Aug	116						
							23-Aug	14:30	111			Portable Receiver
							31-Aug	13:15	111			Portable Receiver
							16-Sep	09:22	111			Portable Receiver
							1-Oct	15:20	111			Portable Receiver
							18-Oct	11:50	112			Portable Receiver
							9-Nov	10:40	111			Portable Receiver
							25-Jan	13:45	116			Portable Receiver

Appendix 3. (cont'd)

Tag Code #	Fish #	Species	Fork Length (mm)	Weight (g)	Tagging date	Segment Tagged	Date First Located	Time First Located	Site Located	Date Last Detection	Time Last Detection	Equipment used
22	208	FRDR	603	3500	16-Aug	111						
							23-Aug	15:30	118			Portable Receiver
							31-Aug	14:30	118			Portable Receiver
							14-Sep	20:48	24	15-Sep	01:10	Stationary Receiver
							22-Sep	20:21	24	22-Sep	21:59	Stationary Receiver
							26-Sep	01:05	24	26-Sep	02:19	Stationary Receiver
23	226	FRDR	507	1900	16-Aug	116						
24	227	FRDR	462	1300	16-Aug	116						
							23-Aug	14:33	73	23-Aug	16:10	Stationary Receiver
25	231	FRDR	485	1550	16-Aug	117						
							17-Aug	21:56	73	23-Aug	04:25	Stationary Receiver
							24-Aug	00:10	73	24-Aug	02:59	Stationary Receiver
							26-Aug	3:41	73	26-Aug	05:45	Stationary Receiver
							27-Aug	13:02	73	28-Aug	19:45	Stationary Receiver
							29-Aug	08:25	73	29-Aug	13:05	Stationary Receiver
							29-Aug	15:42	73	29-Aug	16:34	Stationary Receiver
							31-Aug	01:30	73	1-Sep	12:16	Stationary Receiver
							1-Sep	12:15	74			Portable Receiver
							13-Sep	11:10	73	13-Sep	14:19	Stationary Receiver
26	264	FRDR	437	1100	16-Aug	113						
							1-Sep	09:00	53			Portable Receiver
							5-Sep	07:33	73	5-Sep	09:32	Stationary Receiver
27	271	CHCT	618	3800	18-Aug	62						
							19-Aug	11:00	62			Portable Receiver
							24-Aug	02:21	73	24-Aug	02:54	Stationary Receiver
							24-Aug	04:17	73	24-Aug	04:27	Stationary Receiver
							24-Aug	04:58	73	24-Aug	16:03	Stationary Receiver
							24-Aug	22:01	73	24-Aug	22:36	Stationary Receiver
							25-Aug	00:20	73	25-Aug	01:39	Stationary Receiver
							25-Aug	10:58	73	25-Aug	22:47	Stationary Receiver
							15-Sep	14:25	65			Portable Receiver
							3-Oct	14:45	67			Portable Receiver
							20-Oct	15:10	67			Portable Receiver
28	290	NRPK	515	1000	18-Aug	62						
							19-Aug	11:00	62			Portable Receiver
							1-Sep	11:00	62			Portable Receiver
							3-Oct	14:15	62			Portable Receiver

Appendix 3. (cont'd)

Tag Code #	Fish #	Species	Fork Length (mm)	Weight (g)	Tagging date	Segment Tagged	Date First Located	Time First Located	Site Located	Date Last Detection	Time Last Detection	Equipment used
							20-Oct	14:35	62			Portable Receiver
							8-Nov	14:15	62			Portable Receiver
							25-Nov	12:15	62			Portable Receiver
29	327	CHCT	810	7200	18-Aug	62						
							19-Aug	11:00	63			Portable Receiver
							28-Aug	11:57	24	28-Aug	12:04	Stationary Receiver
							28-Aug	14:37	24	28-Aug	14:48	Stationary Receiver
							28-Aug	15:24	24	28-Aug	15:32	Stationary Receiver
							28-Aug	17:42	24	29-Aug	21:17	Stationary Receiver
30	328	NRPK	636	1950	18-Aug	62						
							18-Aug	11:00	62			Portable Receiver
31	433	WALL	678	4350	18-Aug	59						
							15-Sep	13:55	62			Portable Receiver
							25-Nov	12:05	61			Portable Receiver
							28-Jan	15:50	63			Portable Receiver
							17-Feb	13:55	63			
32	589	FRDR	425	1350	19-Aug	62						
							1-Sep	08:40	49			Portable Receiver
							15-Sep	11:55	49			Portable Receiver
							17-Sep	00:26	73	17-Sep	01:46	Stationary Receiver
33	491	FRDR	393	900	18-Aug	59						
							19-Aug	08:28	73	19-Aug	10:51	Stationary Receiver
							19-Aug	11:03	73	19-Aug	11:13	Stationary Receiver
							20-Aug	13:09	73	20-Aug	13:15	Stationary Receiver
							26-Oct	14:05	75			Portable Receiver
							17-Feb	10:20	75			Portable Receiver
34	534	FRDR	585	2500	19-Aug	58						
							1-Sep	10:20	59			Portable Receiver
							15-Sep	13:35	60			Portable Receiver
							3-Oct	14:10	62			Portable Receiver
							20-Oct	13:48	58			Portable Receiver
							8-Nov	13:50	60			Portable Receiver
							25-Nov	12:00	60			Portable Receiver
							28-Jan	11:47	70			Portable Receiver
							23-Feb	13:15	70			Portable Receiver
35	590	CHCT	548	2200	19-Aug	62						
							23-Aug	05:30	73	23-Aug	05:47	Stationary Receiver

Appendix 3. (cont'd)

Tag Code #	Fish #	Species	Fork Length (mm)	Weight (g)	Tagging date	Segment Tagged	Date First Located	Time First Located	Site Located	Date Last Detection	Time Last Detection	Equipment used
							23-Aug	09:40	73	23-Aug	10:29	Stationary Receiver
							23-Aug	15:53	73	23-Aug	16:24	Stationary Receiver
							24-Aug	10:09	73	24-Aug	12:41	Stationary Receiver
							24-Aug	23:56	73	25-Aug	00:09	Stationary Receiver
							26-Oct	14:25	77			Portable Receiver
36	638	CHCT	795	8100	20-Aug	62						
							1-Sep	11:20	63			Portable Receiver
							15-Sep	12:25	53			Portable Receiver
							16-Sep	11:30	48			Portable Receiver
							1-Oct	15:40	116			Portable Receiver
							20-Oct	11:15	35			Portable Receiver
							8-Nov	10:45	34			Portable Receiver
							25-Nov	09:30	34			Portable Receiver
							31-Jan	15:50	34			Portable Receiver
							23-Feb	10:45	34			Portable Receiver
37	639	CHCT	782	7700	20-Aug	62						
							20-Aug	21:20	73	20-Aug	22:06	Stationary Receiver
							20-Aug	23:40	73	21-Aug	00:14	Stationary Receiver
							21-Aug	0031	73	21-Aug	00:32	Stationary Receiver
							21-Aug	01:46	73	21-Aug	02:42	Stationary Receiver
							21-Aug	04:25	73	21-Aug	04:29	Stationary Receiver
							21-Aug	04:53	73	21-Aug	05:06	Stationary Receiver
							21-Aug	05:17	73	21-Aug	05:37	Stationary Receiver
							21-Aug	06:01	73	21-Aug	06:10	Stationary Receiver
							21-Aug	06:45	73	21-Aug	07:22	Stationary Receiver
							21-Aug	07:28	73	21-Aug	08:16	Stationary Receiver
							21-Aug	08:32	73	21-Aug	08:41	Stationary Receiver
							21-Aug	12:01	73	21-Aug	12:16	Stationary Receiver
							21-Aug	12:52	73	21-Aug	13:03	Stationary Receiver
							21-Aug	13:10	73	21-Aug	17:15	Stationary Receiver
							20-Oct	15:50	74	20-Oct	15:50	Portable Receiver
38	656	CHCT	664	3900	20-Aug	59						
							26-Aug	19:46	73	27-Aug	01:24	Stationary Receiver
							27-Aug	10:46	73	27-Aug	13:02	Stationary Receiver
							27-Aug	15:08	73	27-Aug	16:08	Stationary Receiver
							27-Aug	20:38	73	28-Aug	05:36	Stationary Receiver
							28-Aug	14:26	73	28-Aug	16:56	Stationary Receiver

Appendix 3. (cont'd)

Tag Code #	Fish #	Species	Fork Length (mm)	Weight (g)	Tagging date	Segment Tagged	Date First Located	Time First Located	Site Located	Date Last Detection	Time Last Detection	Equipment used
39	657	FRDR	366	900	20-Aug	59						
							26-Aug	18:57	73	26-Aug	20:06	Stationary Receiver
40	672	CHCT	820	8800	21-Aug	62						
							30-Aug	11:00	45			Portable Receiver
							15-Sep	13:35	60			Portable Receiver
							3-Oct	14:10	62			Portable Receiver
							20-Oct	11:23	36			Portable Receiver
							8-Nov	10:30	31			Portable Receiver
							24-Nov	10:12	24			Stationary Receiver
							25-Nov	09:15	31			Portable Receiver
							31-Jan	16:40	31			Portable Receiver
							23-Feb	10:30	31			Portable Receiver
41	673	CHCT	595	3900	21-Aug	62						
							1-Sep	11:25	63			Portable Receiver
							8-Sep	15:46	73	8-Sep	22:17	Stationary Receiver
							9-Sep	12:34	73	9-Sep	12:58	Stationary Receiver
							9-Sep	17:23	73	9-Sep	21:14	Stationary Receiver
							10-Sep	00:01	73	10-Sep	05:23	Stationary Receiver
							10-Sep	13:10	73	10-Sep	14:15	Stationary Receiver
							12-Sep	16:23	73	12-Sep	16:32	Stationary Receiver
							15-Sep	00:18	73	15-Sep	09:38	Stationary Receiver
42	674	CHCT	658	6100	21-Aug	62						
							25-Aug	05:34	73	25-Aug	08:09	Stationary Receiver
							27-Aug	00:52	73	27-Aug	04:52	Stationary Receiver
							27-Aug	05:39	73	27-Aug	06:58	Stationary Receiver
							28-Aug	22:43	73	29-Aug	07:50	Stationary Receiver
43	749	CHCT	512	1700	21-Aug	62						
							23-Aug	09:01	73	23-Aug	09:48	Stationary Receiver
							23-Aug	10:36	73	23-Aug	11:37	Stationary Receiver
							23-Aug	12:24	73	23-Aug	12:44	Stationary Receiver
							24-Aug	01:49	73	24-Aug	02:29	Stationary Receiver
							24-Aug	04:20	73	24-Aug	16:18	Stationary Receiver
							26-Oct	10:30	86			Portable Receiver
44	776	FRDR	480	1600	21-Aug	59						
							1-Sep	10:25	60			Portable Receiver
							15-Sep	13:00	57			Portable Receiver

Appendix 3. (cont'd)

Tag Code #	Fish #	Species	Fork Length (mm)	Weight (g)	Tagging date	Segment Tagged	Date First Located	Time First Located	Site Located	Date Last Detection	Time Last Detection	Equipment used
45	774	FRDR	395	900	21-Aug	59						
							1-Sep	10:00	58			Portable Receiver
							15-Sep	13:00	57			Portable Receiver
							3-Oct	13:35	57			Portable Receiver
							20-Oct	13:45	57			Portable Receiver
							8-Nov	13:30	59			Portable Receiver
							25-Nov	11:30	57			Portable Receiver
46	786	CARP	627	4750	22-Aug	109						
							31-Aug	12:45	109			Portable Receiver
							16-Sep	09:05	109			Portable Receiver
							21-Sep	15:40	24	21-Sep	16:53	Stationary Receiver
							27-Sep	12:15	24	27-Sep	23:53	Stationary Receiver
							28-Sep	18:01	24	28-Sep	22:20	Stationary Receiver
							29-Sep	09:37	24	30-Sep	18:11	Stationary Receiver
							30-Sep	22:48	24	2-Oct	07:53	Stationary Receiver
							2-Oct	09:21	24	2-Oct	10:59	Stationary Receiver
							3-Oct	12:44	24	3-Oct	14:06	Stationary Receiver
							4-Oct	06:07	24	4-Oct	07:02	Stationary Receiver
							4-Oct	08:02	24	4-Oct	08:47	Stationary Receiver
47	787	CARP	507	2600	23-Aug	109						
							31-Aug	12:45	109			Portable Receiver
							9-Sep	16:13	106	11-Sep	01:28	Stationary Receiver
							16-Sep	09:05	109			Portable Receiver
							1-Oct	14:55	107			Portable Receiver
							3-Oct	11:37	106	3-Oct	14:53	Stationary Receiver
							3-Oct	15:26	106	3-Oct	17:43	Stationary Receiver
							3-Oct	18:08	106	3-Oct	21:23	Stationary Receiver
							4-Oct	19:57	106	4-Oct	23:53	Stationary Receiver
							5-Oct	04:50	106	5-Oct	04:51	Stationary Receiver
							5-Oct	09:22	106	5-Oct	10:43	Stationary Receiver
							6-Oct	03:58	106	6-Oct	04:08	Stationary Receiver
							7-Oct	06:11	106	7-Oct	06:38	Stationary Receiver
							8-Oct	15:02	106	9-Oct	00:36	Stationary Receiver
48	788	CARP	560	3200	23-Aug	109						
							31-Aug	12:50	109			Portable Receiver
							16-Sep	09:05	109			Portable Receiver
							18-Oct	11:15	107			Portable Receiver

Appendix 3. (cont'd)

Tag Code #	Fish #	Species	Fork Length (mm)	Weight (g)	Tagging date	Segment Tagged	Date First Located	Time First Located	Site Located	Date Last Detection	Time Last Detection	Equipment used
							19-Oct	12:19	106	21-Oct	10:25	Stationary Receiver
							9-Nov	10:10	108			Portable Receiver
49	789	CARP	590	3900	23-Aug	109						
							31-Aug	12:55	109			Portable Receiver
							16-Sep	9:15	109			Portable Receiver
							1-Oct	15:55	118			Portable Receiver
							18-Oct	12:15	117			Portable Receiver
							9-Nov	11:30	118			Portable Receiver
							25-Jan	14:23	118			Portable Receiver
							24-Feb	11:37	118			Portable Receiver
50	790	CARP	600	4400	23-Aug	109						
							24-Aug	15:33	106	28-Aug	07:06	Stationary Receiver
							28-Aug	19:58	106	28-Aug	20:46	Stationary Receiver