Assessment of a Constructed Non-Sportfish Migration Barrier on the Salmo River Using Radio Telemetry and Floy Tagging

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EXECUTIVE SUMMARY

In 1989, BC Hydro constructed a fish migration barrier on the Salmo River to limit the upstream movement of non-sportfish (predominantly sucker (*Catostomus* spp.) and northern pikeminnow (*Ptychocheilus oregonensis*)) from Seven Mile Reservoir into the upper Salmo River. During this study, I assessed whether the barrier was functioning in its intended design (10 years post-construction) by Floy tagging and radio tagging sucker and pikeminnow below the barrier in the early summer, and monitoring the movements of the tagged fish. Telemetry identified that one radio tagged sucker ascended the barrier, summered in the upper Salmo River, and then descended the barrier. Snorkel surveys identified that at least five Floy tagged sucker also successfully migrated upstream over the barrier. Other radio tagged sucker and northern pikeminnow made movements within Seven Mile Reservoir. The results of the study are discussed with relation to the potential impacts of non-sportfish on the trout and char populations of the Salmo River, and the possibility of barrier enhancement.

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INTRODUCTION

The Seven Mile Dam and generating station were constructed on the Pend d'Oreille River by BC Hydro between 1975 and 1980. With the construction of the facility, the resultant reservoir was raised in 1980 to a level of 522.7 m to avoid flooding the Pend d'Oreille River upstream into the United States (EAO 1996). However, in May of 1988, BC Hydro raised the operating level of the reservoir to an elevation of 527.3 m, the planned normal operating level of the reservoir. This subsequent raising extended Seven Mile Reservoir to the tailwater of Boundary Dam in the United States (1.5 km upstream of the international border). In addition, the second raising impounded the lower sections of the Salmo River where the system flowed into Seven Mile Reservoir. This flooding eliminated a series of rapids and high gradient cascades in the lower Salmo River that had possibly limited upstream migration of non-sportfish into the upper reaches of the Salmo River (BC Hydro 1989). The Ministry of Environment, Lands and Parks (MELP) was concerned about the possible biological effects of non-sportfish colonization on the trout population that existed upstream of the reservoir, and requested that BC Hydro mitigate the potential issue (BC Hydro 1989).

In the summer and fall of 1989, BC Hydro initiated the design and construction of a low head waterfall (fish barrier) to restrict the access of non-sportfish from Seven Mile Reservoir into the upper Salmo River. It was thought that this barrier would limit the potential impact (i.e., displacement and competition) on native salmonid populations upstream of the reservoir. The design of the barrier (see Appendix I) was completed by late summer of 1989, and site construction of the barrier was undertaken on October 5th 1989 (BC Hydro 1989). Construction of the barrier utilized natural boulders greater than 2 m in diameter, which were set in an excavated trench across the river. The weir that was constructed created a 1.4 to 1.5 m vertical drop, and it was felt by BC Hydro personnel that the construction of the weir would function in its designed purpose (BC Hydro 1989).

With the proposed addition of a fourth generating unit at the Seven Mile Dam, the Salmo River has again become the focus of increased attention with regard to its fisheries resources. A Habitat Compensation Agreement (HCA) negotiated between BC Hydro, Fisheries and Oceans Canada (DFO) and MELP directed BC Hydro to undertake fish and fish habitat enhancement projects in selected areas of the Pend d'Oreille River (Seven Mile Reservoir) and Salmo River watersheds. This agreement included compensation directed to rainbow trout (*Oncorhynchus mykiss*) and bull trout (*Salvelinus confluentus*) populations. With the initiation of studies on the two species of concern, there was further discussion as to the status and design function of the previously installed non-sportfish barrier, as an aerial overflight of the barrier suggested that during high flow events the barrier might not limit the upstream migration of non-sportfish. As such, in further discussions with DFO and MELP, it was requested that BC Hydro initiate studies to address whether the constructed barrier was functioning as it was originally designed.

To address these concerns, BC Hydro initiated a preliminary assessment in the summer of 1999 (see Appendix II). This assessment was conducted by Rheal Finnigan and involved determining whether or not the barrier was functioning properly, and recommending possible solutions to improving the function of the barrier. In general, it was felt that the barrier likely was not functioning during high flow conditions, but that a low cost solution to the problem was not a feasible option. An engineered structure could be designed to address the issue, but the costs of the project would likely be prohibitive, and the aesthetic nature of the canyon and the river would be compromised.

After further review and discussion with DFO and MELP, a project to assess whether non-sportfish were ascending the barrier was proposed in the fall of 1999. The proposed project was designed to monitor the migration of suckers (*Catostomus* spp.) and northern pikeminnow (*Ptychocheilus oregonensis*) in Seven Mile Reservoir, and to determine whether upstream movements were occurring into the upper Salmo River. The project was initiated in the late spring of 2000, and was implemented with the objective of using radio telemetry and Floy tagging as the primary methods to assess whether upstream migrations were occurring.

Baxter Environmental was retained by BC Hydro to undertake this study, with the specific objectives of the project being to:

- assess the upstream movement of sucker and northern pikeminnow into the Salmo River through Floy tagging and radio telemetry of ten individual fish in Seven Mile Reservoir;
- establish a fixed radio tracking station at the non-sportfish barrier on the Salmo River;
- track the ten radio tagged non-sportfish by mobile and fixed tracking;
- monitor movements of Floy tagged non-sportfish fish by snorkel surveys above the barrier; and
- make recommendations on the status of the non-sportfish barrier and possible opportunities for enhancement.

STUDY AREA AND BACKGROUND

The study area for this project included the Pend d'Oreille River watershed (Seven Mile Reservoir) and the Salmo River watershed from Seven Mile Reservoir to the town of Salmo (Figure 1).

The Salmo River rises from the Selkirk Mountains 12 km southeast of Nelson, B.C. and flows in a southerly direction for approximately 60 km to the confluence with the Pend d'Oreille River (Seven Mile Reservoir). The system is a 5th order stream, and has a total drainage basin area of roughly 123,000 ha (Table 1).

Elevation in the basin ranges from 564 m at its confluence to 2,343 m at the height of land. Within this elevation range, the system comprises two biogeoclimatic zones (Braumandl and Curran 1992). At lower elevations, the valley lies within the Interior Cedar-Hemlock (ICH) zone, while areas in the higher elevations are found within the Englemann Spruce-Subalpine Fir (ESSF) zone. The Salmo River has a total of eight 2nd and 3rd order tributaries (including Apex Creek, Clearwater Creek, Hall Creek, Barrett Creek, Ymir Creek, Porcupine Creek, Erie Creek, and Hidden Creek) and two 4th order tributaries (Sheep Creek and the South Salmo River) (Figure 1). The Water Survey of

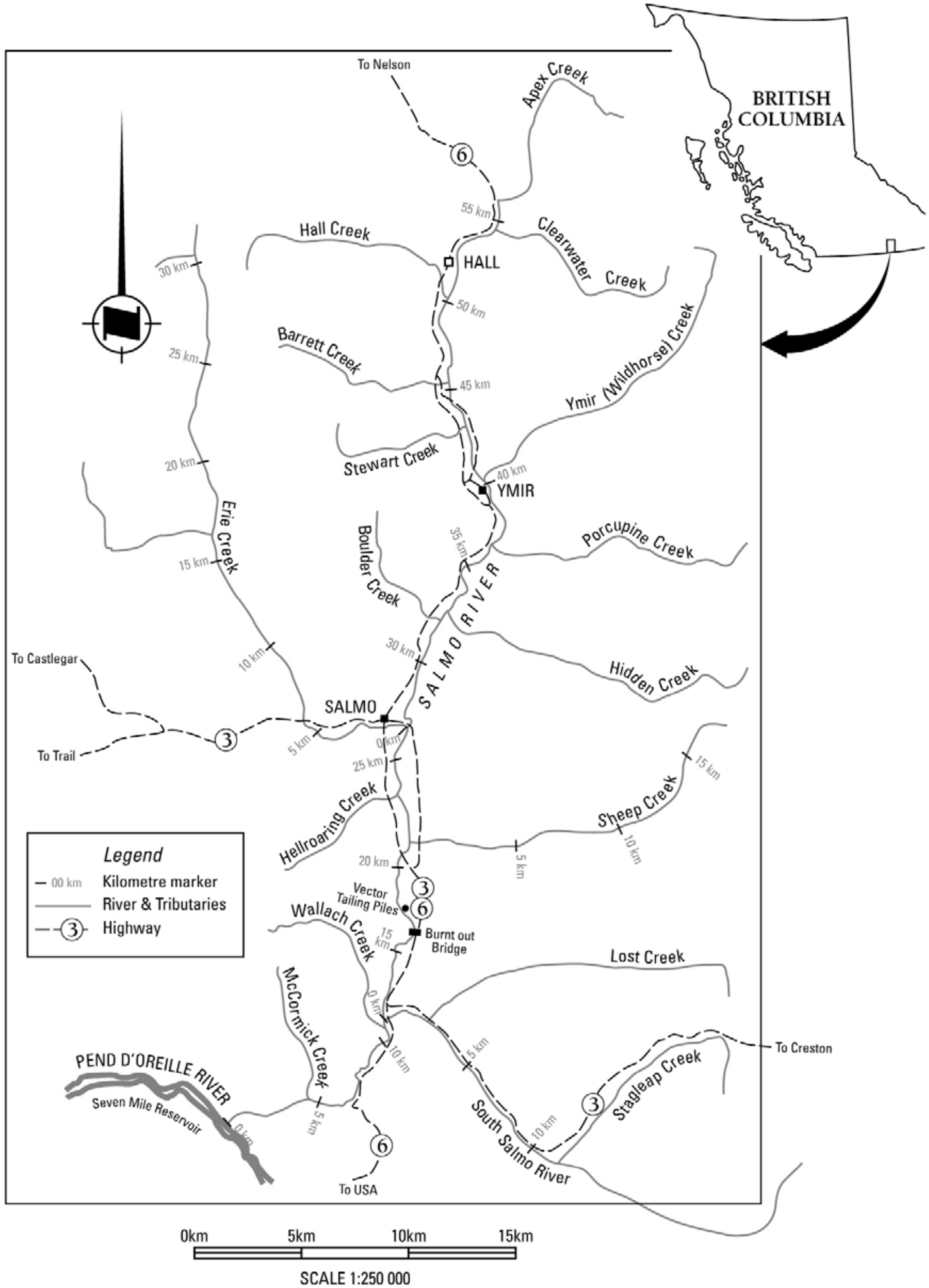

Figure 1. Study area for the Seven Mile Reservoir and Salmo River non-sportfish migration study.

Canada (WSC) maintains a gauging station on the Salmo River near the town of Salmo (Anonymous 1977). Mean annual discharge in the Salmo River (1949-1976) was 32.5 $m^3 \cdot sec^{-1}$, with mean monthly minimum and maximum values of 7.5 and 128.5 $m^3 \cdot sec^{-1}$, respectively. Runoff peaks in May, with the highest annual flows between April and July. In addition to bull trout and rainbow trout, many other fish species are distributed in the watershed. These include Eastern brook trout (*S. fontinalis*), mountain whitefish (*Prosopium williamsoni*), largescale sucker (*Catostomus macrocheilus*), longnose sucker (*C. catastomus*), northern pikeminnow, longnose dace (*Rhinicthys cataractae*), redside shiner (*Richardsonius balteatus*), and slimy sculpin (*Cottus cognatus*) (Sigma Engineering Ltd. 1996). Natural populations of steelhead trout (*O. mykiss*) and chinook salmon (*O. tshawytscha*) have been extirpated from this system due to hydroelectric development on the Columbia and Pend d'Oreille rivers.

Table 1. Summary of geographic information for the Salmo River.

Gazetted Name	Stream Length (km)	Area (ha)
Salmo River	60	123,000
Geographic Information		
Approximate distance and direction to the nearest town, city or landmark	12 km southeast of Nelson, B.C.	
MELP Region	4	
MELP Management Unit	4-8	
DFO District	Interior South East (#30)	
Ministry of Forests Region	Nelson	
Ministry of Forests District	Kootenay Lake	
NTS Base Map Reference	82 F/3 and 82 F/6	

The fish community of Seven Mile Reservoir is also well studied and includes many species (Table 2). Some of these species are likely downstream migrants from the United States, and have colonized Seven Mile Reservoir due to favourable environmental conditions. Prior to the construction of Seven Mile Dam and the formation of Seven Mile Reservoir, sucker and northern pikeminnow were previously documented in the Pend d'Oreille River and Salmo River above the cascade falls (Envirocon 1975). This would suggest that there was likely some limited upstream migration of the two species into the Salmo River prior to flooding of the rapid and cascade areas of the lower Salmo River in 1988.

Study Timing

The timing of the work conducted during this project is summarized in Table 3. Components of the project included tagging of fish, fixed tracking of fish, aerial tracking of fish, and snorkel surveys in the upper Salmo River.

Table 2. Fish species composition in Seven Mile Reservoir (from R.L.&L. 1995)

Family	Common Name	Scientific Name
Sportfish		
Salmonidae	rainbow trout	*Oncorhynchus mykiss*
	brown trout	*Salmo trutta*
	brook Trout	*Salvelinus fontinalis*
	bull trout	*Salvelinus confluentus*
	cutthroat trout	*Oncorhynchus clarki lewisi*
	mountain whitefish	*Prosopium williamsoni*
	yellow Perch	*Perca flavescens*
	black crappie	*Pomoxis nigromaculatus*
	pumpkinseed	*Lepomis gibbosus*
	smallmouth bass	*Micropterus dolomieu*
Non-sportfish		
Catostomidae	longnose sucker	*Catostomus catostomus*
	largescale sucker	*Catostomus macrocheilus*
	bridgelip sucker	*Catostomus columbianus*
Cyprinidae	redside shiner	*Richardsonius balteatus*
	northern pikeminnow	*Ptychocheilus oregonensis*
	tench	*Tinca tinca*
	peamouth chub	*Mylocheilus caurinus*
	longnose dace	*Rhinicthys cataractae*
Cottidae	prickly sculpin	*Cottus asper*
	mottled sculpin	*Cottus bairdi*
	torrent sculpin	*Cottus rhotheus*
	slimy sculpin	*Cottus cognatus*

Table 3. Timing of the various components of the non-sportfish migration study in Seven Mile Reservoir and the Salmo River watershed.

Study Component	Survey Method	Study Period
Tagging of fish	Boat electroshocking and angling	June 17th – July 13th
Fixed tracking of fish	Fixed station	June 22nd – November 15th
Aerial tracking of fish	Aerial surveys	July 29th – November 16th
Above barrier surveys	Snorkel surveys	June 22nd – August 25th

METHODS

Fish Capture and Tagging

Boat electrofishing and a limited amount of angling were used as the capture techniques to sample adult sucker and northern pikeminnow at the mouth of the Salmo River or in Seven Mile Reservoir up to 1 km downstream of the Salmo River confluence. All boat electrofishing was conducted at night, with the sampling boat run parallel to the shore. Sample crews netted all electroshocked fish, and held them in aerated tanks prior to processing. Once the index section had been sampled, the crew returned to shore to process all fish captured. Boat electrofishing was conducted on a total of three sampling dates.

Floy Tagging

All sampled fish were identified to species and measured for length (cm) and weight (g). In addition all sampled sucker and northern pikeminnow >30 cm were Floy tagged at the base of the dorsal fin. Floy tags used for this study were Floy FD-94 T-Bar anchor tags, with 2.5 cm bare monofilament below the tubing, inserted with a Mark II super heavy duty tagging gun having a 2.5 cm insertion using Mark II long, regular needles (outside diameter = 0.22 cm). Two colors of Floy tag were utilized, for visual distinction during snorkel surveys, depending on the location where a fish was sampled. Green tags were used on fish that were sampled at the mouth of the Salmo River, while blue tags were used on fish sampled in Seven Mile Reservoir (one km downstream of the Salmo River confluence).

Radio Tagging

Individual sucker and northern pikeminnow were selected from all fish that were sampled by electrofishing for surgical implantation of radio tags. Fish that were suitable for radio tagging were held overnight in flow through containers prior to processing and implantation of the radio tag. Fish targeted for tagging were a minimum 35 cm in fork length and 400 g in weight, so that the weight of the radio transmitter did not exceed 2% of the fish weight. Sterile conditions were maintained at the surgery site with the biologist scrubbing up with Betadine liquid soap, and donning sterile gloves. All operating instruments and radio tags were sterilized in a container of ethanol.

Once fish were ready for processing they were immersed in a 20 L anaesthetic bath (Plate 1) with a concentration of clove oil at 100 PPM (2 mL of clove oil emulsified in ethanol per 20 L water). The fish were taken to stage IV of anaesthesia (equilibrium lost, operculum movement slow and irregular, no response to external stimuli), which was achieved after a period of approximately three minutes in the bath (Plates 2 and 3). The fish was then removed from the bath, laid on its back in a V-shaped operating trough lined with foam, and the gills irrigated with water using a sitz bath bag and tubing that was placed into the fish's mouth (Plates 4 and 5). The incision into the abdominal cavity (left hand body side wall about 3 to 5 cm anterior of the pelvic fins; see Plate 6) was then made with a scalpel fitted with a curved (No. 12) blade.

After the incision was complete, a 16 gauge stainless steel needle was inserted through the abdominal wall posterior to the incision and back out the incision (Plate 7). The antennae of the radio tag was then threaded through the needle, and the needle pulled out leaving the antennae coming out the side wall of the fish (Plate 8). The radio tag was then inserted into the abdominal cavity, and the incision was closed with three interrupted sutures of 2/0 monofilament on a cutting needle (Plate 9) or by closure with stainless steel staples. Betadine was then applied to the closed incision and exit point of the antennae. After the surgical procedure, a numbered Floy tag was inserted between the dorsal fin pterigiphores, and fork length (cm) and weight (g) measurements were taken. The fish was also sexed where possible. The entire procedure took approximately 4-5 minutes, after which the fish was allowed a 15-20 minute recovery period in a flow through container. The location (UTM co-ordinate) of capture was recorded and the fish was released.

Radio tags used for this study were manufactured by Lotek Engineering in Newmarket Ontario. We used one model MCFT-3A tag (16 mm diameter, 50 mm length, 6.2 g weight in water, operation life >680 days) on a large northern pikeminnow (50 cm, 1205 g), and nine model MCFT-3EM tags (11 mm diameter, 49 mm length, 4.3 g weight in water, operation life >399 days) on smaller sucker and northern pikeminnow. The tags were digitally coded and transmitted at a 5 second burst rate on a frequency of 149.620 Mhz (MCFT-3EM tags) or 149.700 Mhz (MCFT-3A tag).

Tracking of Radio Tagged Fish

Fixed Tracking

A fixed data-logging tracking station was established at the non-sportfish barrier on the Salmo River (Plate 10). This station was established to determine if radio tagged fish ascended the barrier into the upper Salmo River. The fixed station consisted of a battery powered receiver (Lotek SRX-400 with data logging software) within a weatherproof housing and connected to an upstream and downstream antennae (four element Yagi antennae) to resolve movement direction. The battery was replaced every two to three weeks, at which time recorded data were downloaded to a portable computer.

Aerial Tracking

Although both ground and aerial tracking of radio tagged sucker and northern pikeminnow provided data on locations of fish in the Salmo River and Seven Mile Reservoir, aerial tracking provided the most consistent opportunity to locate the majority of radio tagged fish. As part of an ongoing bull trout radio telemetry study conducted in the Salmo River watershed by Baxter Environmental for BC Hydro (Kootenay Generation, Castlegar) and the Salmo Watershed Streamkeepers Society (SWSS), aerial surveys were conducted on a regular basis through the summer, fall and winter of 2000 (Baxter and Nellestijn 2000a). During these surveys, radio tagged sucker and northern pikeminnow were tracked to holding locations on the day of survey. Aerial monitoring was carried out in a helicopter (A-Star), and we used a Lotek SRX-400 receiver in conjunction with a single two or three element Yagi antennae. During tracking, the location of each fish was noted as a description (river or reservoir location) and UTM co-ordinate.

Snorkel Surveys in the Upper Salmo River

For this component of the study, observations were made during repetitive snorkel surveys over the summer in the Salmo River from the town of Salmo to the South Salmo River confluence. These surveys were conducted after the initial tagging of non-sportfish, and were utilized to enumerate Floy tagged and untagged non-sportfish, and to estimate the distribution, relative abundance, and migration timing of non-sportfish in the mainstem Salmo River. The river was surveyed by a crew of 2-5 swimmers (depending on water levels), and an appropriate number of swimmers aligned themselves perpendicular to stream flow to ensure adequate coverage of the stream. Each swimmer reported the total number of each non-sportfish and sportfish species observed in the section of river that was surveyed. Generally, counts were recorded every 200 to 250 m at known locations. This work was carried out in conjunction with a study undertaken by SWSS to document non-sportfish abundance in the watershed (Baxter and Nellestijn 2000b).

RESULTS

Fish Capture and Tagging

Boat electrofishing was carried out on three occasions in the early summer of 2000. On June 17th and 25th, two sites at the mouth of the Salmo River and a site on Seven Mile Reservoir (1 km downstream of the Salmo River confluence) were sampled as a component of an ongoing project conducted by R.L.&L. Environmental Services Ltd. in Seven Mile Reservoir for Seattle City Power and Light. One other sampling event occurred on July 13th, and northern pikeminnow were specifically targeted during this sampling event. Summary data from electrofishing catches of sucker and northern pikeminnow are presented in Appendix III.

Floy Tagging

In total, 240 largescale sucker, two longnose sucker, one mountain sucker (*Catostomus platyrhynchus*), and 24 northern pikeminnow were captured during electrofishing (Table 4). Summary data for the electrofishing catches and Floy tagging of suckers and northern pikeminnow sampled on June 17th and 25th are presented in Appendix III. Of the largescale sucker, longnose sucker, mountain sucker and northern pikeminnow sampled, 123, 1, 0, and 11 were Floy tagged, respectively (Table 4). The average length and weight of the four target species sampled are presented in Table 5.

Table 4. Summary of the number of largescale sucker, longnose sucker, mountain sucker, and northern pikeminnow sampled by boat electrofishing at two sites in the lower Salmo River and Seven Mile Reservoir (summer 2000).

	Largescale Sucker		**Longnose Sucker**		**Mountain Sucker**		**Northern PM**	
Date-Location	**N**	**Tagged**	**N**	**Tagged**	**N**	**Tagged**	**N**	**Tagged**
June 17-Salmo	21	14	2	1	1	0	6	5
June 25-Salmo	60	60	0	0	0	0	1	1
June 25-Reservoir	159	49	0	0	0	0	17	5
	240	**123**	**2**	**1**	**1**	**0**	**24**	**11**

Radio Tagging

All fish that were selected for radio tagging were held overnight at the mouth of the Salmo River. A total of five sucker (all largescale sucker) and five northern pikeminnow were tagged. Radio tagged sucker averaged 41 cm and 742 g in fork length and weight, respectively (Table 6). Radio tagged northern pikeminnow averaged 44 cm and 960 g in fork length and weight, respectively (Table 6). It is noteworthy that both species were very prone to haemorrhaging at the incision, needle insertion point, and suture location during surgical implantation of radio tags (see Plate 9). The use of clove oil as an anaesthetic also put the fish into Stage IV of anaesthesia very quickly. It was also noted that the relatively small 3EM tag was as big a radio tag that could be used on sucker, even though it was well within the acceptable weight range of the fish, due to the large size of the intestine and other organs in the abdominal cavity. The use of a suture over a surgical staple was preferred for these species due to thin body walls. All tagged fish recovered well from the surgery, and swam away strongly after a 20 minute recovery period.

Table 5. Summary of the average length and weight of largescale sucker, longnose sucker, mountain sucker, and northern pikeminnow sampled by boat electrofishing at two sites in the lower Salmo River and Seven Mile Reservoir (summer 2000).

	Largescale Sucker	Longnose Sucker	Mountain Sucker	Northern Pikeminnow
Length (cm)				
Mean	27.9	39.6	37.4	23.1
S.E.	0.6	1.8	n/a	2.1
Range	11.1-41.5	37.8-41.4	n/a	13.2-54.2
N	240	2	1	24
Weight (g)				
Mean	309	627	675	236
S.E.	15	45	n/a	83
Range	15-795	582-671	n/a	25-1980
N	240	2	1	24

Table 6. Summary of the biological characteristics of largescale sucker (LSS) and northern pikeminnow (NPM) radio tagged in lower Salmo River (summer 2000).

Date	Species	Length (cm)	Weight (g)	Floy Tag	Radio Tag Freq.	Radio Tag Code	Suture Type
18-Jun	LSS	42	692	G-0953	149.620	1	staples
18-Jun	LSS	42.5	769	G-0952	149.620	2	staples
18-Jun	NPM	40	696	G-0963	149.620	3	staples
26-Jun	NPM	54	1980	B-0428	149.620	4	sutures
26-Jun	LSS	41	795	G-0919	149.620	5	sutures
26-Jun	LSS	41	740	G-0911	149.620	6	sutures
26-Jun	LSS	39	715	G-0927	149.620	7	sutures
13-Jul	NPM	36	485	G-0905	149.620	10	sutures
13-Jul	NPM	50	1205	G-0901	149.700	81	sutures
13-Jul	NPM	40.5	432	G-0902	149.620	8	sutures

Tracking of Radio Tagged Fish

Fixed Tracking

In 2000, the fixed station was set up on June 22nd and removed on November 15th. At the time of initial installation of the fixed tracking station, the barrier was likely not functioning in preventing upstream migration of non-sportfish species. The drop over the barrier was less than 60 cm (Plates 11 and 12) and there was a slow water drop on the right upstream bank (RUB) that could be easily ascended by most fish species (Plates 11, 12, and 13). The old placer mining diversion channel did not have water flowing through it (Plate 13).

In total, the fixed station was downloaded seven times during the above period. Almost immediately after installation, a radio tagged largescale sucker (Code 2) migrated up to the barrier on the evening of June 26th. It remained in the area below the barrier for a period of one day, after which it moved above the barrier on the evening of June 27th. The tagged fish then moved slowly upstream of the barrier and was last picked up by the station's upstream antennae on noon of June 30th. The general upstream migration pattern of the tagged fish could be characterized as a migration up to the barrier, a resting or holding period while it found a slow water or velocity break area to ascend, and a slow continual movement upstream after successful navigation of the barrier. No other radio tagged non-sportfish were tracked by the fixed station.

The sucker that did migrate upstream of the barrier remained in the upper Salmo River for the majority of the summer, and was tracked moving downstream of the fixed station on August 12th. The tagged fish descended the barrier in the early morning and was last picked up by the station's downstream antennae on noon of the same date. The general downstream migration pattern of the tagged sucker could be characterized as a rapid downstream movement over the barrier, and a continued downstream migration toward Seven Mile Reservoir.

Aerial Tracking

In total, eight aerial tracking flights were conducted during this study, although non-sportfish were not located on every survey. The majority of fish moved into Seven Mile Reservoir after initial tagging, with some fish making extensive migrations within the reservoir. As confirmed through the use of the fixed station, only one largescale sucker (Code 2) successfully ascended the non-sportfish barrier into the upper Salmo River.

Code 1

This largescale sucker made a short migration upstream of the mouth of the Salmo River, and returned to Seven Mile Reservoir to make an extensive upstream migration to the base of Boundary Dam. The fish them moved downstream in Seven Mile Reservoir to the mouth of the Salmo River where it remained stationary through other tracking events (Figure 2, Appendix IV).

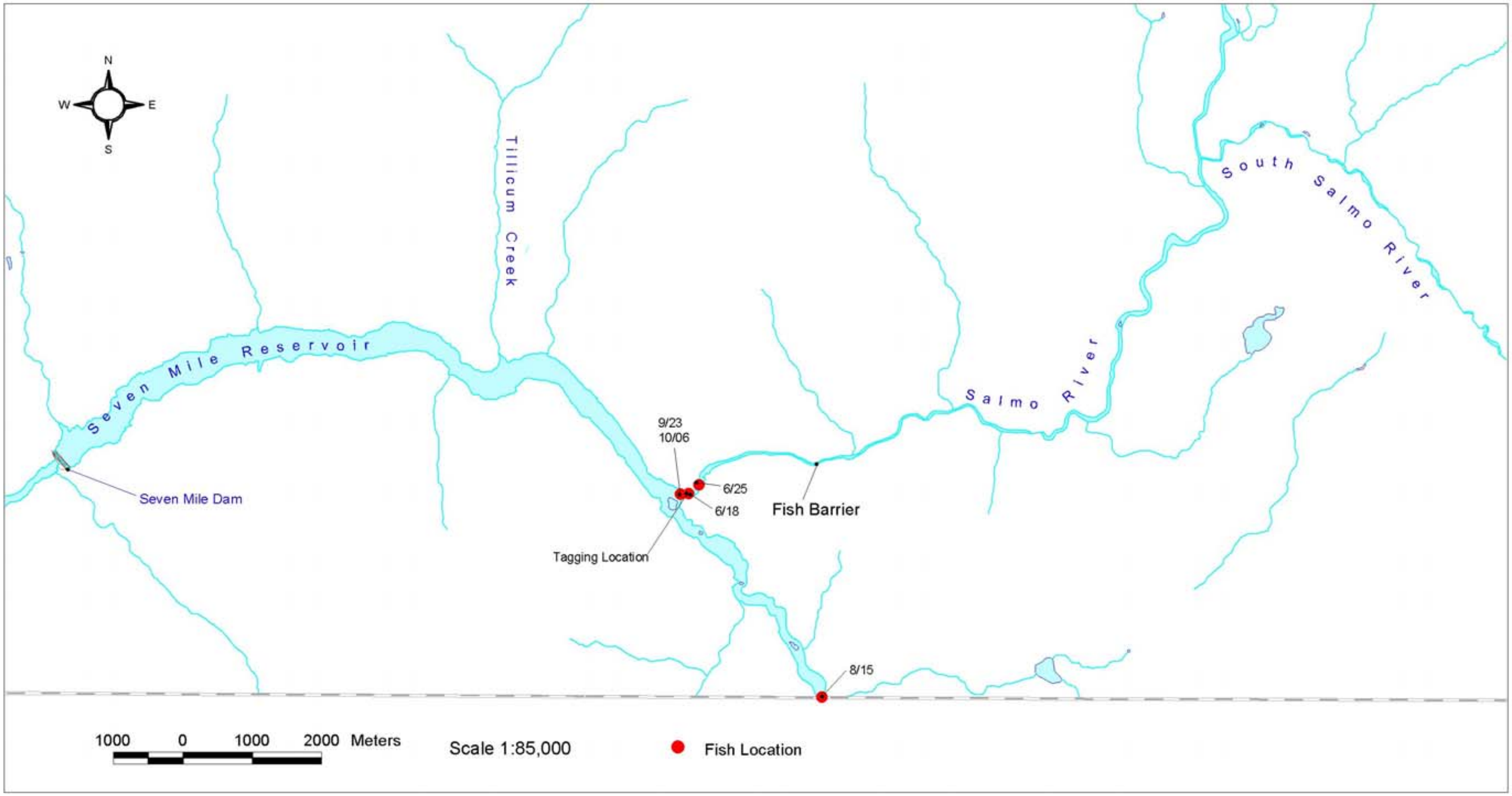

Figure 2. Tracking locations of a radio tagged largescale sucker (Code 1) in the Salmo River and Seven Mile Reservoir in 2000.

Code 2

After tagging, this largescale sucker made a rapid upstream migration from the mouth of the Salmo River to the fish barrier. The fish then successfully ascended the barrier and continued upstream through the canyon section of the river to an area of low gradient. The fish summered in the mainstem Salmo River near the WSC station, after which it migrated rapidly downstream to the mouth of the Salmo River in mid-August (Figures 3 and 4, Appendix IV).

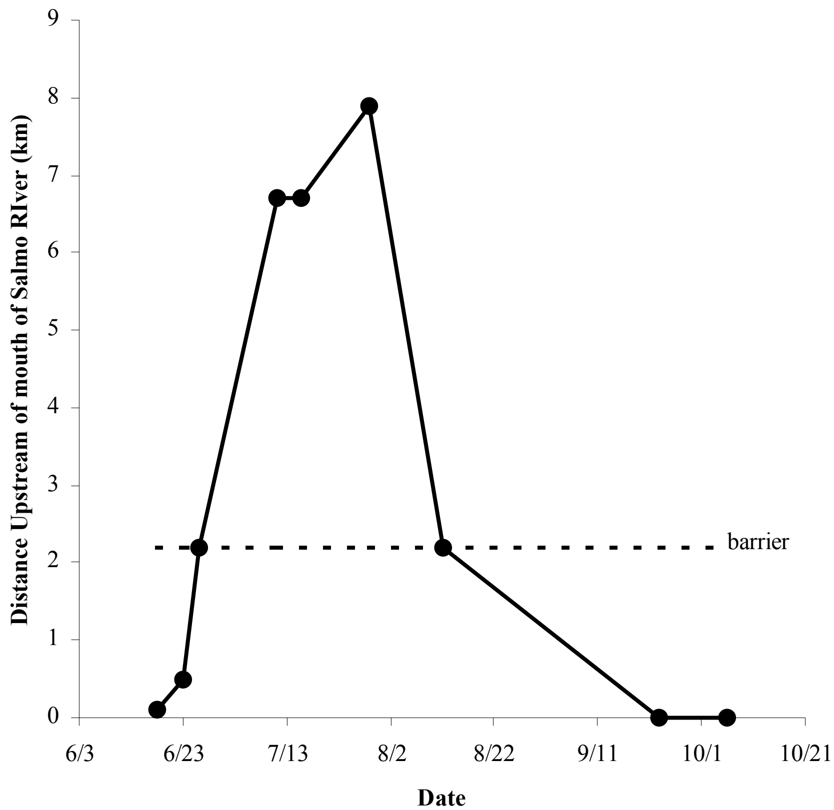

Figure 3. Migratory pattern of a largescale sucker (Code 2) that was radio tagged at the mouth of the Salmo River.

Code 3

After tagging, this northern pikeminnow was not tracked on subsequent aerial surveys. It was located once on June 25th, one week after initial tagging (Figure 5, Appendix IV).

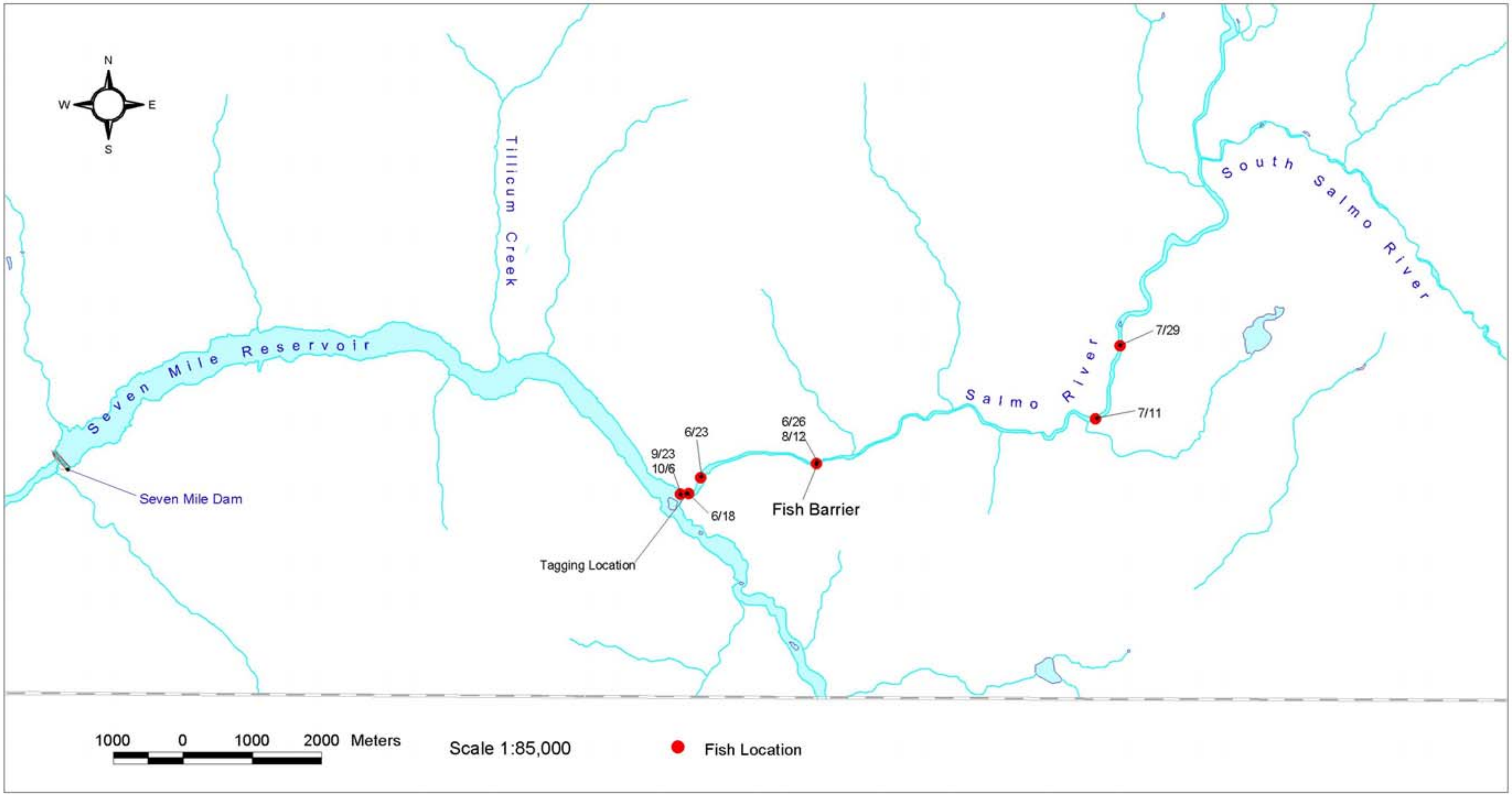

Figure 4. Tracking locations of a radio tagged largescale sucker (Code 2) in the Salmo River and Seven Mile Reservoir in 2000.

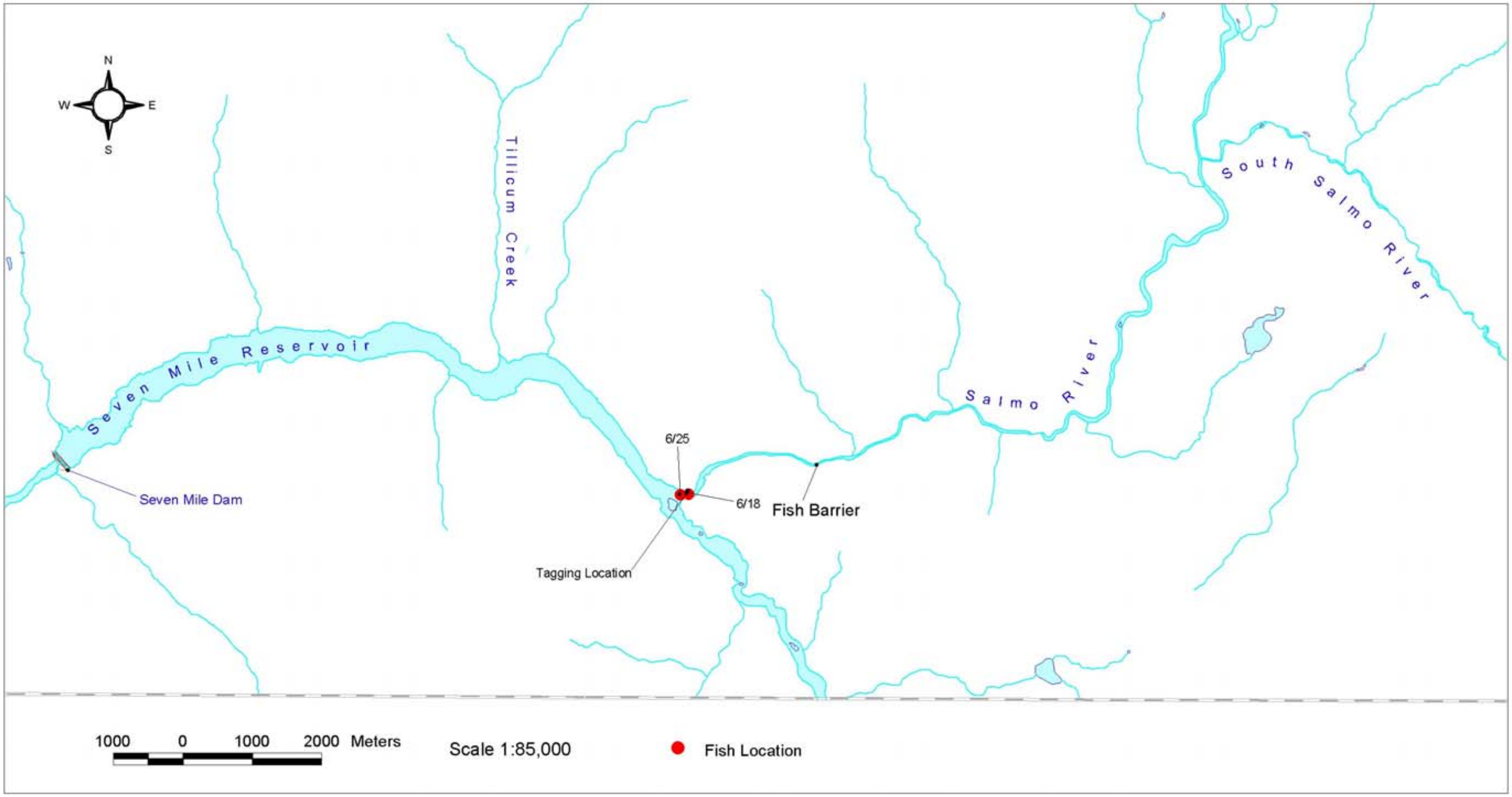

Figure 5. Tracking locations of a radio tagged northern pikeminnow (Code 3) in the Salmo River and Seven Mile Reservoir in 2000.

Code 4

After tagging, this northern pikeminnow remained in the general area of initial tagging (the mouth of the Salmo River) until the end of July. The fish then migrated ~1 km downstream in Seven Mile Reservoir (Pend d'Oreille River) where it was located on subsequent tracking flights (Figure 6, Appendix IV).

Code 5

This largescale sucker was not successfully tracked on most aerial surveys, but was located at the mouth of the Salmo River on September 23rd (Figure 7, Appendix IV).

Code 6

After initial tagging, this largescale sucker made a rapid upstream migration in Seven Mile Reservoir (Pend d'Oreille River) to the base of Boundary Dam. It was located at this point on most subsequent tracking flights (Figure 8, Appendix IV).

Code 7

After initial tagging, this largescale sucker remained in the general area where it was radio tagged. The sucker then made a migration downstream in Seven Mile Reservoir (Pend d'Oreille River) to a location 300 m downstream of the mouth of Tillicum Creek where it remained during subsequent tracking flights (Figure 9, Appendix IV).

Code 8

Following initial tagging, this northern pikeminnow moved rapidly downstream in Seven Mile Reservoir (Pend d'Oreille River) to the mouth of Tillicum Creek. The fish then remained in Seven Mile Reservoir, making limited migrations with the system for the duration of the study period (Figure 10, Appendix IV).

Code 81

After initial tagging, this northern pikeminnow was not located on subsequent tracking surveys (Figure 11, Appendix IV).

Code 10

Following initial tagging, this northern pikeminnow slowly ascended the Salmo River to the start of the high gradient canyon section, where it remained in this location for the duration of the tracking surveys (Figure 12, Appendix IV).

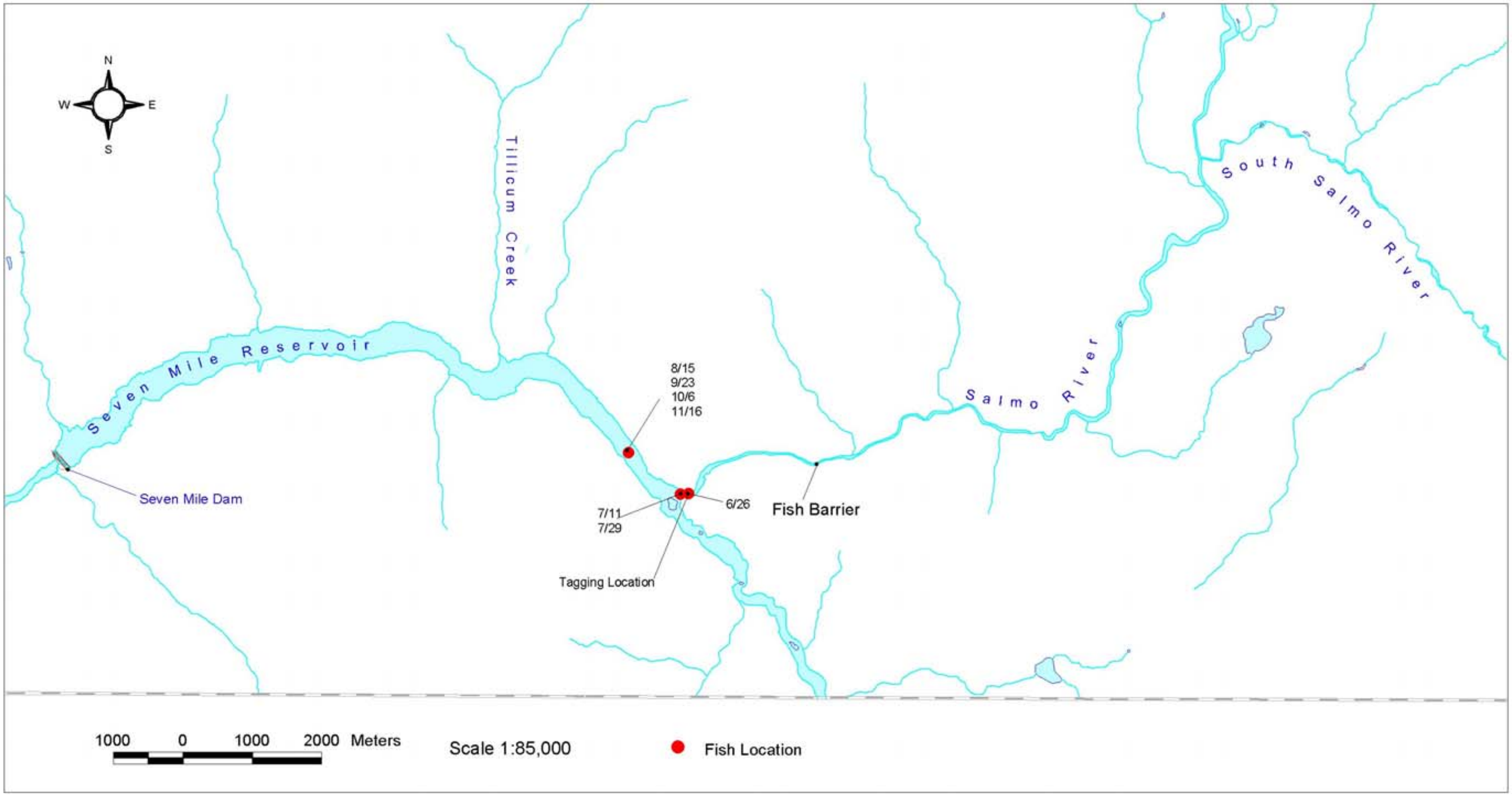

Figure 6. Tracking locations of a radio tagged northern pikeminnow (Code 4) in the Salmo River and Seven Mile Reservoir in 2000.

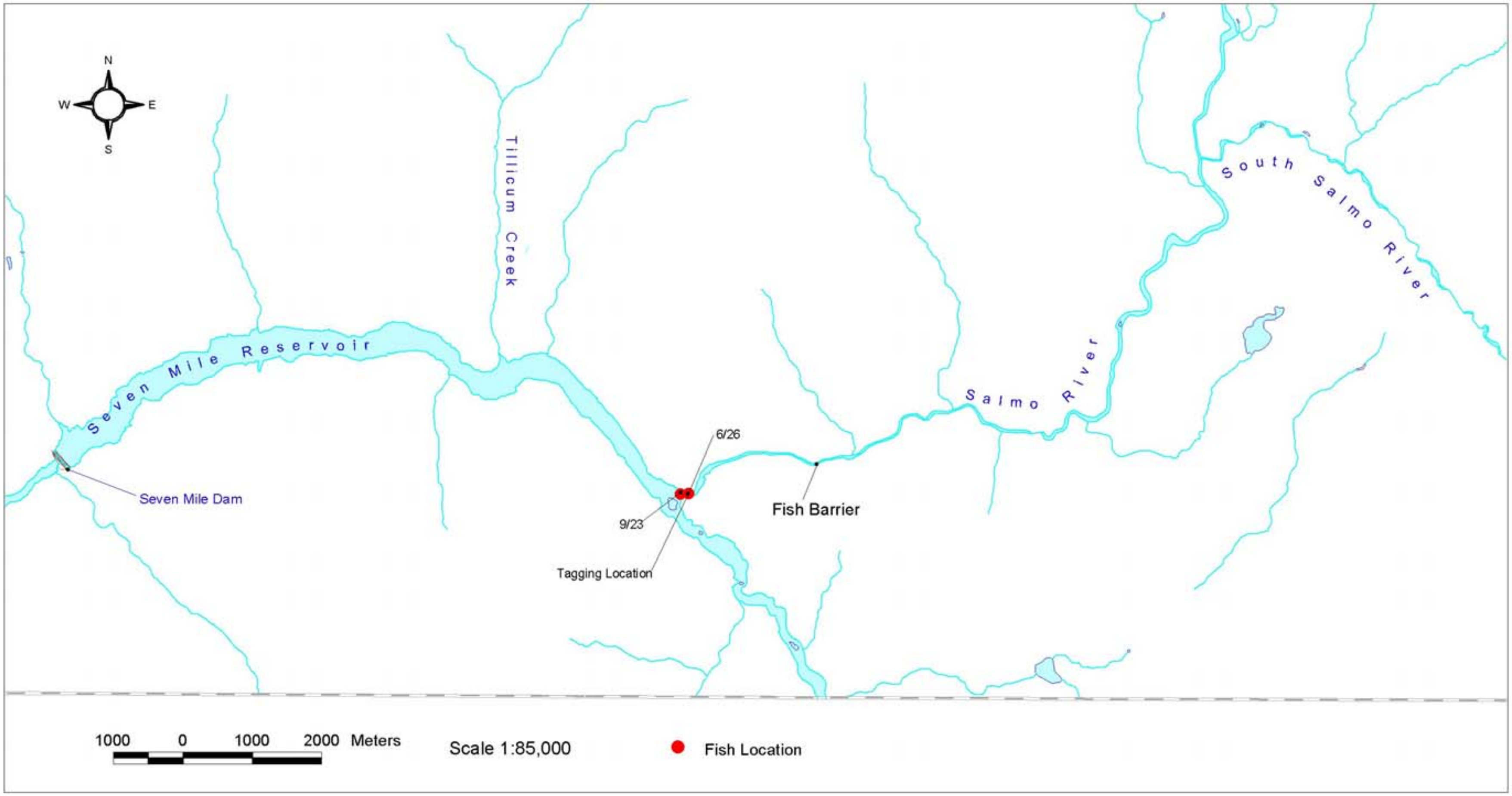

Figure 7. Tracking locations of a radio tagged largescale sucker (Code 5) in the Salmo River and Seven Mile Reservoir in 2000.

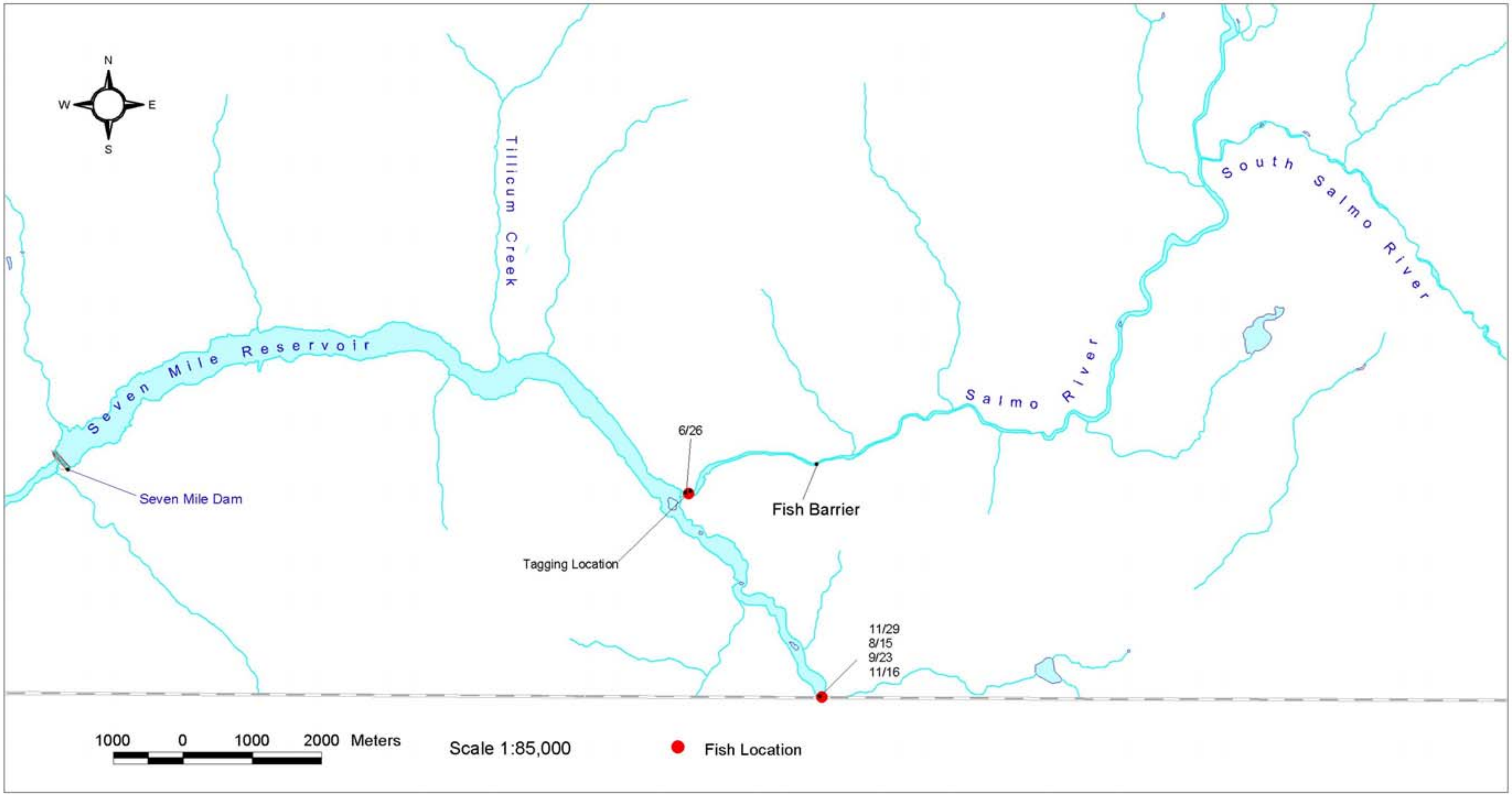

Figure 8. Tracking locations of a radio tagged largescale sucker (Code 6) in the Salmo River and Seven Mile Reservoir in 2000.

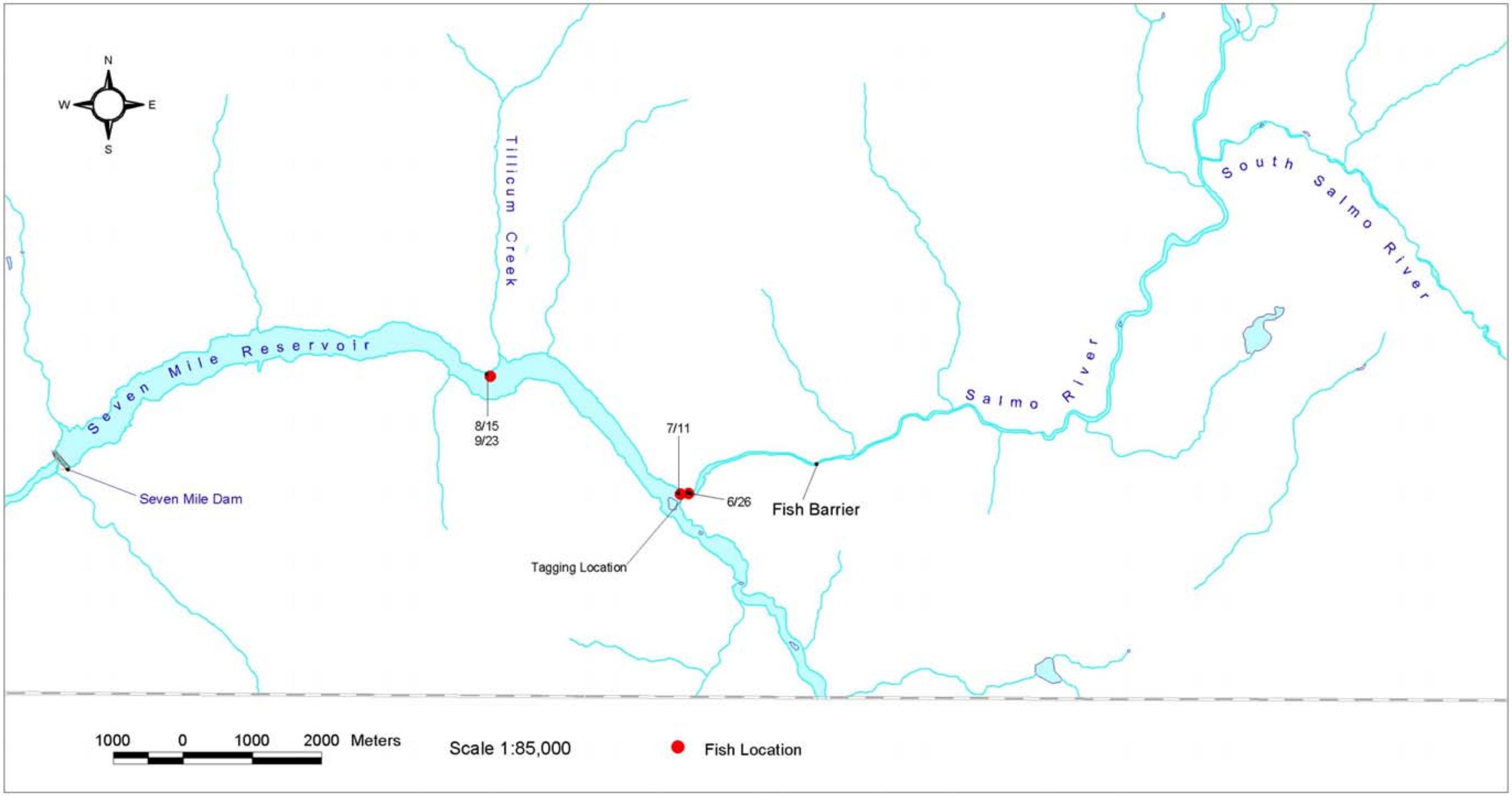

Figure 9. Tracking locations of a radio tagged largescale sucker (Code 7) in the Salmo River and Seven Mile Reservoir in 2000.

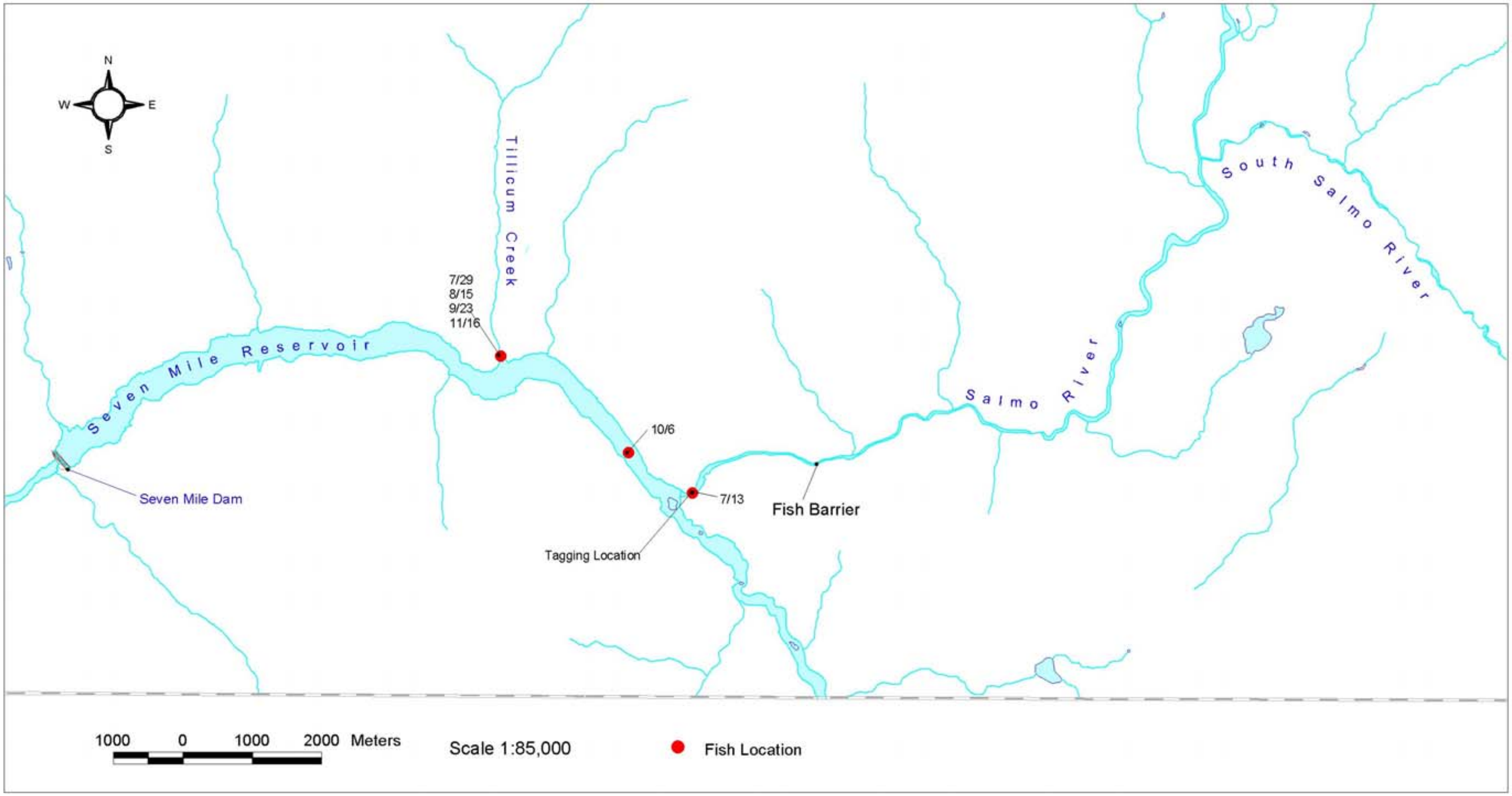

Figure 10. Tracking locations of a radio tagged northern pikeminnow (Code 8) in the Salmo River and Seven Mile Reservoir in 2000.

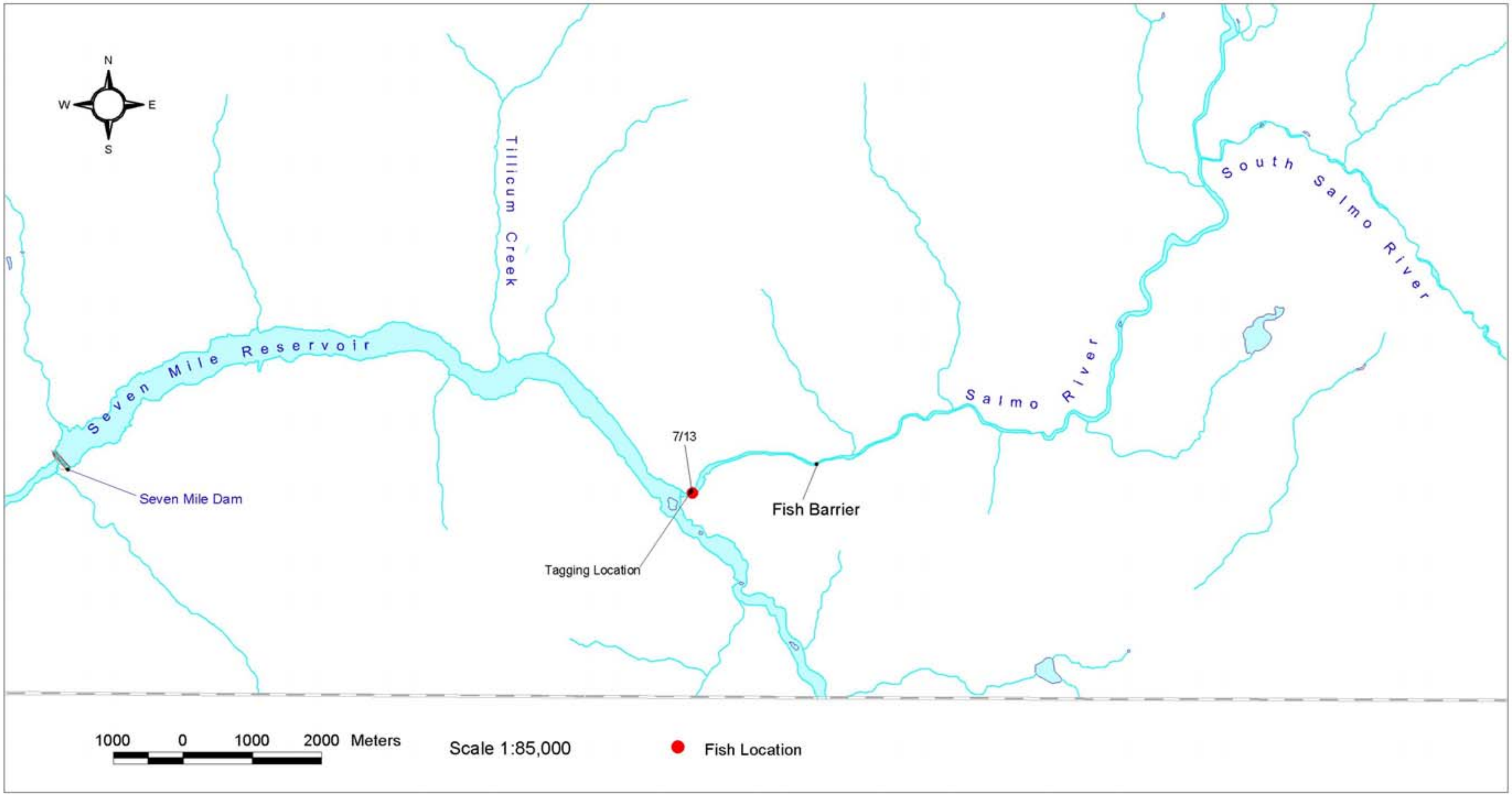

Figure 11. Tracking locations of a radio tagged northern pikeminnow (Code 81) in the Salmo River and Seven Mile Reservoir in 2000.

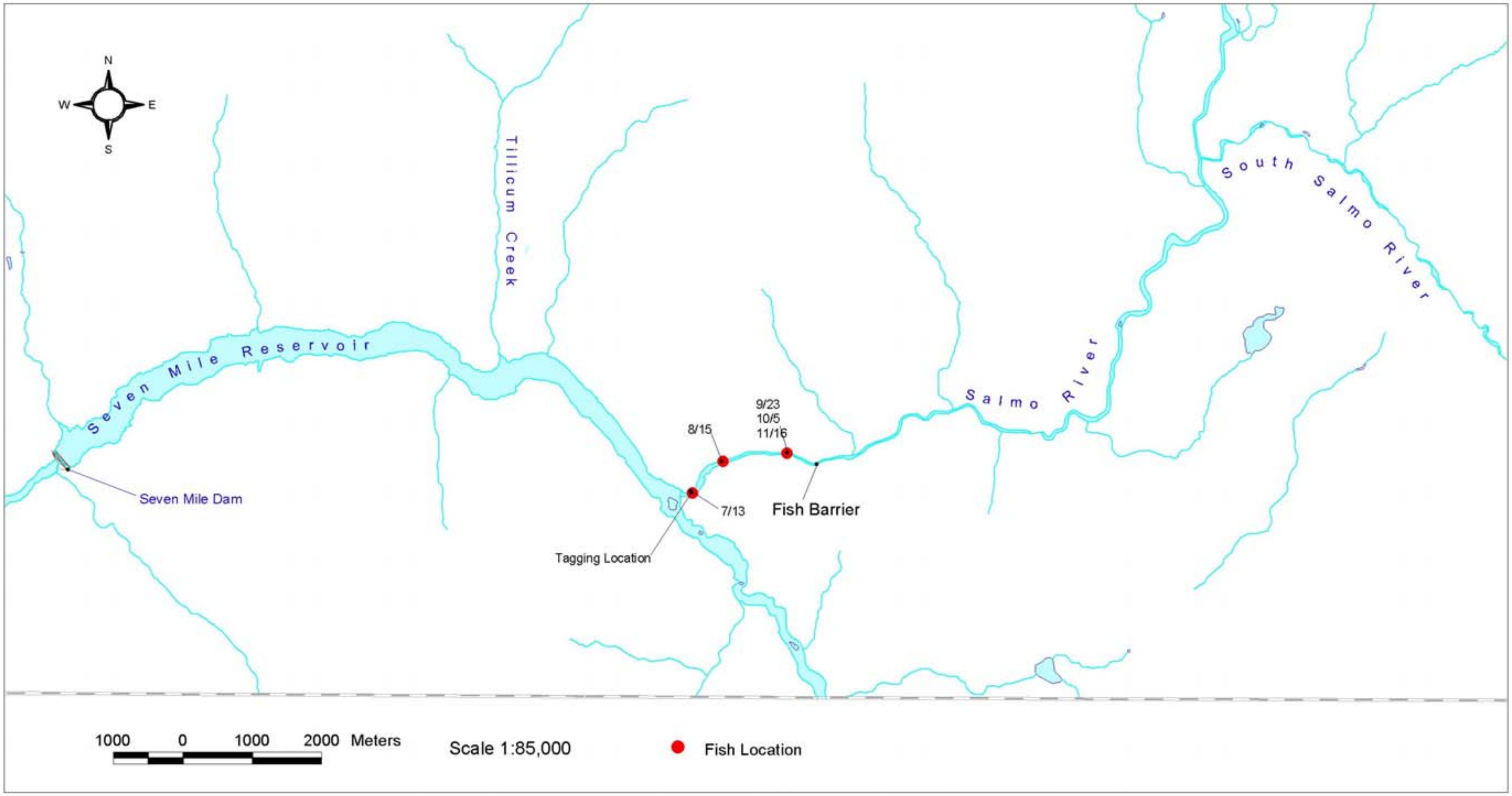

Figure 12. Tracking locations of a radio tagged northern pikeminnow (Code 10) in the Salmo River and Seven Mile Reservoir in 2000.

Snorkel Surveys in the Upper Salmo River

The data for this component of the study were collected in conjunction with another study being undertaken by SWSS (Baxter and Nellestijn 2000b). In total, five surveys were conducted on the mainstem Salmo River after Floy tagging of sucker and northern pikeminnow had occurred below the barrier (Table 7). The surveys began downstream of the town of Salmo at Lagoon road (27.35 km), and were carried out for a minimum distance of 10.1 km (Table 7). Few non-sportfish species were observed in the upper sections of the survey area, suggesting that sucker and northern pikeminnow distribution is limited to mainstem areas downstream of Erie Creek.

Table 7. Summary of dates, locations, visibility, and number of swimmers on non-sportfish snorkel surveys in the Salmo River in 2000.

Survey Date	Start Location	End Location	Total Distance	Visibility	Number of Swimmers
June 22	27.35 km	11.55 km	15.70 km	1 m	3
June 30	27.35 km	16.85 km	10.50 km	2 m	5
July 7	27.35 km	16.85 km	10.50 km	3 m	5
July 17	27.35 km	16.85 km	10.50 km	4-5 m	3
August 24/25	33.00 km	16.85 km	16.15 km	4-5 m	2

A summary of the total number of each fish species observed during the surveys is presented in Table 8. The observations during the surveys suggested that there is an early summer upstream migration of sucker species (SU) and, to a lesser extent, northern pikeminnow (NPM) into the upper Salmo River (Table 8, Figure 13). During the surveys, rainbow trout (RB), bull trout (BT), eastern brook trout (EB), and mountain whitefish (MWF) were also observed (Table 8). A number of Floy tagged sucker were observed during snorkel surveys (in total five Floy tagged sucker), and a summary of these observations is presented in Table 9.

Table 8. Summary of the number of fish species observed during non-sportfish snorkel surveys in the Salmo River in 2000.

	Total Number Observed				
Species	June 22	June 30	July 07	July 17	August 24/25
SU	13	80	179	205	221
NPM	0	0	0	3	27
MWF	3	3	2	2	0
EBT					
<30 cm	0	0	2	6	23
>30 cm	0	2	4	6	7
BT					
<30 cm	0	4	0	5	2
>30 cm	6	17	26	19	8
RB					
<30 cm	5	33	58	268	245
>30 cm	23	31	107	147	208

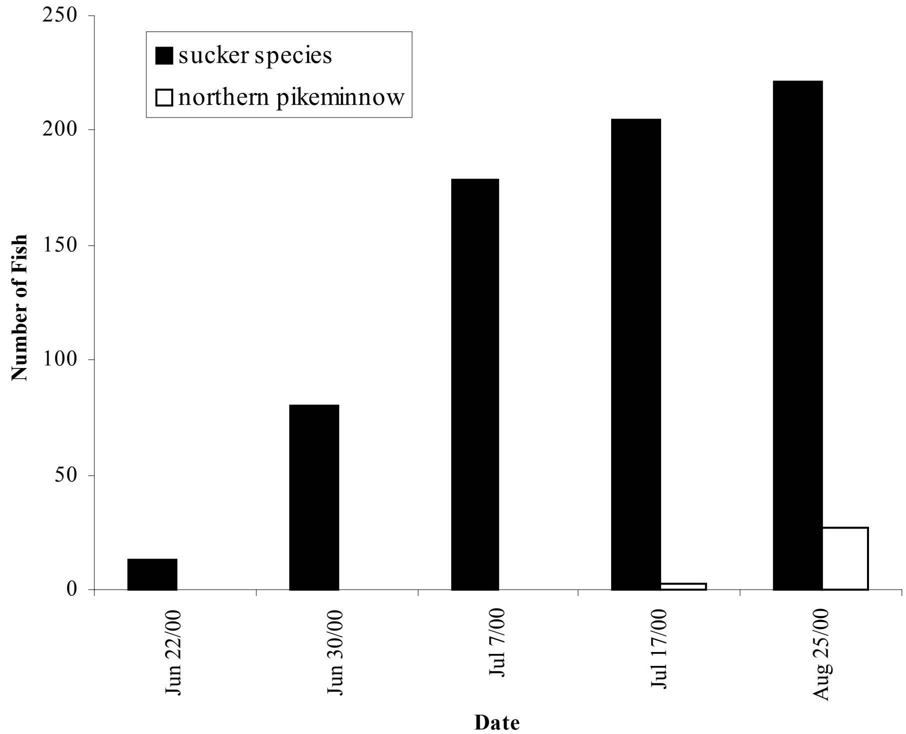

Figure 13. Summary of increases in the number of sucker and northern pikeminnow observed in the Salmo River above the fish barrier during non-sportfish snorkel surveys in 2000.

Table 9. Summary of observed Floy tagged sucker during non-sportfish snorkel surveys in the Salmo River in 2000.

Date	Location	River km	Number Observed	Floy Tag Color
July 17th	Carbody Run	18.3	2	Green
August (early)	South Salmo mouth	12.2	1	Green
August 25th	Carbody Run	18.3	2	Green

DISCUSSION

The use of fish migration barriers is a common technique utilized by fisheries biologists to limit the impacts of introduced or non-native species, or to restrict the colonization of upstream areas by unwanted species in many river systems. This type of work has been used successfully in limiting colonization of streams from reservoirs created by hydroelectric developments in the past (Bulow et al. 1988), where it is known that reservoir construction can impact species composition (e.g., Martinez et al. 1994). These techniques have also been employed in keeping species out of watersheds where it was felt that there may be competition with native fish populations (Crumby et al. 1990; Thompson and Rahel 1998). At the request of MELP, BC Hydro constructed the barrier on the lower Salmo River in 1989 in an attempt to limit the possible impact of non-sportfish colonization on the native trout and char populations of the upper Salmo River. After construction, it was felt that the barrier would function in its designed purpose, but there was limited assessment of the utility of the barrier post-construction.

Ten years after construction, this project has demonstrated that there is an early summer upstream migration of non-sportfish (predominantly sucker species) past the barrier into the upper Salmo River. The one radio tagged sucker that migrated upstream of the barrier did so just after the peak of discharge (June 15) in the year 2000 (Gordon Corcoran, Environment Canada, Nelson, B.C.; personal communication). At this time water levels were high enough that the barrier would not prevent upstream migrations of large fish of any species (see Plates 11, 12 and 13). In comparison, later in the year (September) the drop at the barrier was greater than one meter (see Plates 14, 15, and 16), and at this period the structure was likely functioning in its intended design.

Although it might be assumed that the upstream migration of sucker and northern pikeminnow could impact the bull trout and rainbow trout populations of the Salmo River through habitat displacement, predation, and/or competition, it is currently unknown what the ecological relationship is among these species. As such, a number of points need to considered for fisheries management and habitat enhancement options in the Salmo River watershed. These include:

1. the potential impacts of sucker and northern pikeminnow on rainbow trout and bull trout;
2. the possible distribution of non-sportfish species in the Salmo River watershed pre-construction of the Seven Mile Dam; and
3. the potential advantages and disadvantages of upgrading the barrier.

Potential Impacts of Non-Sportfish Species on Salmonid Populations

There is a preconception by the public and some fisheries biologists that sucker often impact salmonid populations by feeding on eggs and limiting fry production. Although there is the documented movement of this species into areas where bull trout and rainbow trout are distributed in the Salmo River, sucker are probably ecologically, temporally and spatially separated from the species in some ways.

It is known that sucker are spatially and temporally absent from the high gradient and cold water areas where bull trout spawn (Baxter et al. 1998; Baxter 1999; Baxter and

Nellestijn 2000a), and thus could have no possible impact on bull trout production. Although not confirmed, sucker are also likely spatially and temporally absent from areas where rainbow trout spawn. This is suggested by the high rainbow trout fry densities in tributaries of the Salmo River and the upper mainstem, and the fact that in the early summer (to the end of June) very low numbers of rainbow trout yearlings are observed in the mainstem Salmo River (James Baxter; personal observations). Temporally, the data from this study suggest that an upstream migration of sucker species occurs after mid June, and thus sucker species would not be present in high numbers in the mainstem Salmo River during the spawning period of both rainbow trout. This again would limit the possible impact that non-sportfish species would have on rainbow trout during spawning or egg development.

It is possible that if non-sportfish spawn in the mainstem Salmo River that there may be competition with juvenile salmonids. However, data from other studies suggests that these fish do not spawn in the mainstem Salmo River. There were no juvenile sucker or northern pikeminnow sampled in 28 closed electrofishing sites in the Salmo watershed in a previous study, and catches of bull trout juveniles were low in areas where adult suckers and northern pikeminnow have been observed (Baxter et. al 1998). The biology of adult rainbow trout, bull trout, and sucker species would also suggest that the impact of the non-sportfish would be limited, since they are largely ecologically separated in areas where they occur in sympatry (e.g., Marrin and Erman 1982; Tremblay and Magnan 1991; Bourke et al. 1999). Sucker are benthic feeders while rainbow trout are drift feeders and bull trout are piscivores. These suggestions are supported by a study conducted in a California reservoir where brown trout and sucker had a minimal dietary overlap, and where, in fact, the sucker became prey of the brown trout once they became piscivorous (Marrin and Erman 1982).

It has been suggested that sucker impact salmonid populations during spawning. However, I could find no reference to sucker species (or northern pikeminnow) predating eggs after I conducted a literature review from 1980 to 2000 from a database that included: *The North American Journal of Fisheries Management*; *Transactions of the American Fisheries Society*; *The Canadian Journal of Fisheries and Aquatic Sciences*; and *The Canadian Journal of Zoology*.

It is known that northern pikeminnow are predators on juvenile salmonids (predominantly on salmon species in lakes), and in the United States of America, programs of northern pikeminnow eradication continue to this day (Friesen and Ward 1999). However, a review of the impact of northern pikeminnow on salmonid populations suggested that these fish are not significant predators or competitors with trout in streams, especially where they occur in low densities (Brown and Moyle 1980). While there are limited data on northern pikeminnow abundance and distribution in the mainstem Salmo River, results from this and other studies (Baxter et al. 1998; Baxter 1999), suggest that this species occurs in low abundance. In all cases where northern pikeminnow have been observed in the mainstem river, they have been heavily associated with woody cover and not in typical habitat where bull trout or rainbow trout are distributed.

Distribution of Sucker and Northern Pikeminnow in the Salmo River Watershed

It is currently unclear whether or not sucker species and northern pikeminnow invaded the Salmo River after the raising of Seven Mile Reservoir. It is known that, in the Columbia drainage basin, the lower Columbia is unique in that sucker can be commonly distributed above waterfalls or velocity barriers (McPhail and Carveth 1993). A review of data collected from studies that were undertaken prior to raising of the reservoir suggests that sucker and pikeminnow were present in the Salmo River above the "waterfall" on the lower river (Envirocon 1975). In addition, fish collection records at the University of British Columbia also report sucker as present in Erie Creek prior to the construction of Seven Mile Dam (J.D. McPhail, University of British Columbia, Vancouver, B.C.; personal communication). If this is the case, then these species likely had access to the upper river as well, and could have colonized the areas where they are currently found. However, the construction of Seven Mile Reservoir could have provided a more suitable environment to allow populations of non-sportfish species to increase in size, and thus led to the movement of more non-sportfish into the Salmo River than previously occurred. This is in fact supported by observations of local community members who report that the number of sucker present in the river has increased since the creation of Seven Mile Reservoir.

Summary

In summary, when deciding whether or not to remediate the existing barrier, there are advantages and disadvantages that must be considered in a basic trade-off analysis.

Potential advantages might include:

- a reduction, or complete eradication of non-sportfish species in the Salmo River;
- a reduction in the migration of non-sportfish species from Seven Mile Reservoir; and
- a recovery of the trout and char populations of the Salmo due to the reduction of the abundance of non-sportfish (assuming some sort of negative impacts).

Potential disadvantages of barrier improvement might be:

- the construction of a barrier that functions in its design (i.e., extremely high), would likely be a significant safety risk to individuals that use the river for recreation (whitewater sports);
- the construction of a barrier that functions in its design may also limit the upstream migration of sportfish if these movements occur between Seven Mile Reservoir and the upper Salmo River; and
- a possible disruption of the ecological dynamics of the Salmo River if non-sportfish and sportfish occurred in sympatry pre-construction.

I believe that a cautionary approach must be taken when weighing the potential advantages and disadvantages of barrier improvement, and in my opinion, the barrier should not be improved. There is not enough known about the ecological relationship of non-sportfish and sportfish dynamics in the upper river to justify barrier improvement, and added to the potential social costs, it suggests remaining status quo is likely the best current option. Regardless, the project has demonstrated that the techniques employed in the study were successful tools in meeting the objectives of assessing the effectiveness of the barrier. Although we have identified that the barrier is not functioning in its intended design, the completion of the project should allow more informed management and habitat enhancement decisions to be made.

CONCLUSIONS AND RECOMMENDATIONS

1. Through a review of previous studies, and the results of the radio telemetry, Floy tagging and snorkel surveys of this study, it has been documented that sucker, and possibly northern pikeminnow, migrate into the upper reaches of the Salmo River over the constructed non-sportfish barrier. Based on these biological data, the review of the structure in 1999, and the potential recreational impacts with improvement or alteration of the barrier, I would suggest that the barrier not be improved or altered in any way. The results of this study should be reported to the regulatory agencies for review and input into these conclusions. It is recommended that an annual visual assessment of the barrier be conducted to ensure that any high water event will not destroy the barrier that is currently in place. Although the barrier is not functioning completely in its designed purpose, this is recommended as the structure likely limits movement of some non-sportfish upstream. Further sampling activity in Seven Mile Reservoir where large numbers of northern pikeminnow are collected should include the continued Floy tagging of this species to allow for identification in future snorkel surveys in the Salmo River above the barrier.

2. While the biological relationships are among the fish species complex in the Salmo River are largely unknown, it is likely that sucker and pikeminnow do not predate or compete with bull trout and rainbow trout. It is, however, unknown if these non-sportfish species provide a prey base for the bull trout population. It is recommended that a small study be undertaken on the bull trout population to determine what they are utilizing for food. This should be a non-destructive project (i.e., stomach pumps for food content) that would have minimal effects on the bull trout population, but provide data for a better understanding of sportfish/non-sportfish interactions. Further understanding of rainbow trout life-history and spawning areas in the watershed is also needed to determine the relationship of sucker and pikeminnow with rainbow trout.

3. This study has shown that in conjunction with Floy tagging, snorkel surveys can provide information on fish migration and abundance in a cost-effective manner. It is recommended that further snorkel survey swims (two per year) be considered for the next two years to allow annual monitoring of non-sportfish, rainbow trout, and bull trout populations.

4. As the radio tags used in this study will be functioning through the summer of 2001, it is recommended that these fish be tracked during ongoing radio telemetry flights for bull trout and/or rainbow trout.

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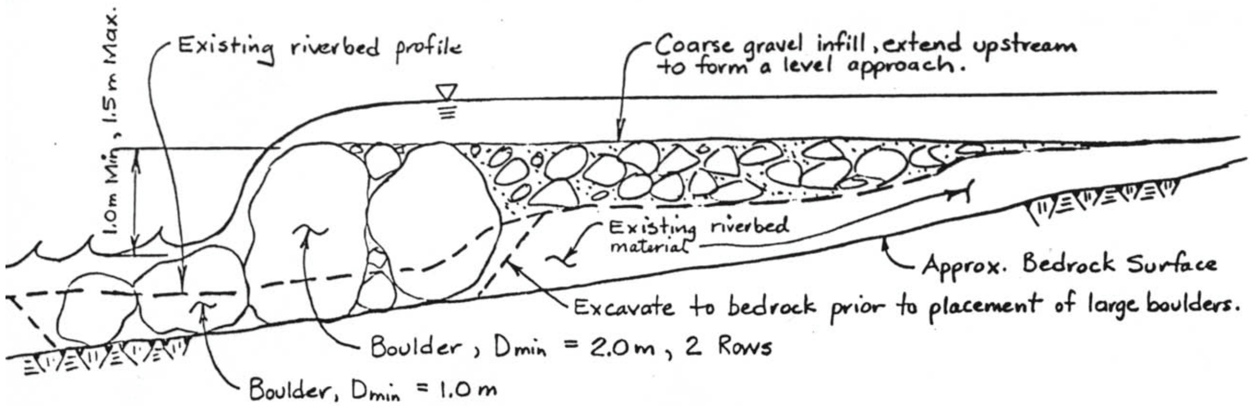
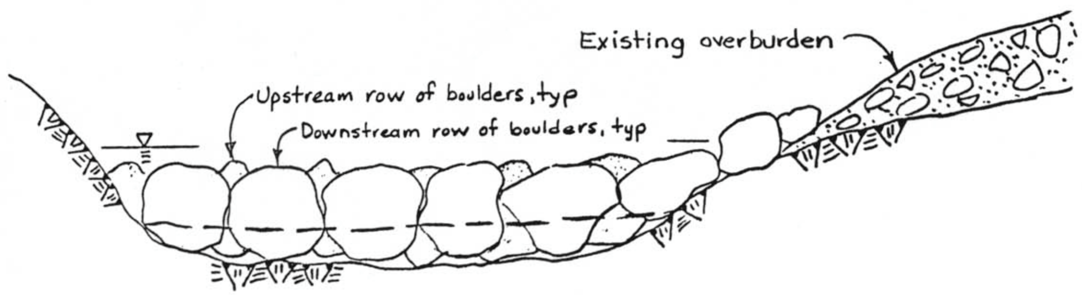
Appendix I. Original design of the Salmo River non-sportfish barrier, 1989.



RIVERBED PROFILE



X-SECTION, LOOKING UPSTREAM

NOTES

OCT/89

1. Excavate keyway to bedrock for full width of river prior to placement of boulders.
2. Rows of boulders shall be staggered to produce interlocking.
3. Place medium size boulders, D_{min} = 1.0m downstream of fall to prevent scour.
4. Infill materials shall be obtained from gravel stockpiles on the left bank remaining from placer mining activities.

Appendix II. Summary of conclusions by Rheal Finnigan as to options available for improvement of the Salmo River non-sportfish barrier, 1999.

MEMORANDUM
DATE: August 16, 1999
TO: Dean den Biesen
FROM: Rheal Finnigan
RE: Coarse Fish Barrier on the Salmo River

Further to our recent telephone conversation regarding the subject matter, I submit the following comments for your consideration;

- I reviewed various items that I have in my library and was not able to find any specific information on the swimming capabilities of coarse fish species such as squawfish. I have some information on other types of fish and I've attached a table listing the sustained, prolonged and burst speeds of various species for your information.
- The last column of the foregoing table also lists maximum jump heights observed for coho, sockeye and steelhead. By comparing these maximum jump heights and the corresponding bursting speeds, it is interesting to note that there is a ratio of approximately 1 to 3; i.e. a sockeye salmon has a burst speed of 6.3 meters per second and a maximum jump height of 2.1 meters. If we employ this extrapolation for whitefish with a listed burst speed of 2.7 meters per second, we conclude that a whitefish is able to jump a maximum height of 0.9 meters. Although whitefish may not be good jumpers and may not necessarily be able to leap over a 0.9 meter obstruction, they may be able to swim up the water column of a waterfall and negotiate a vertical drop in the neighborhood 0.9 meters.
- I speculate that squawfish or other larger coarse fish species present in the Salmo River may have swimming speeds similar to those listed for whitefish in the attached table. If this were the case, and if we can extrapolate using the rational mentioned above concerning burst speeds, a vertical drop in excess of 0.9 meters would likely be an impassable obstruction to coarse fish.
- However, when large boulders are used to construct a weir, very often there often exists small pockets between the boulders that fish are able to take advantage of in effort to circumvent the weir. This is particularly noticeable near the outer edges of boulder weirs where the water tends to cascade in smaller pockets along the banks.
- Furthermore, whenever a river experiences high flow conditions, there is a tendency for the water surface profile to flatten out in the steeper sections and to become steeper in the flatter sections. Hence, riffles and low weirs become less noticeable during high river discharges. Quite often, fish will take advantage of rising or receding water levels to navigate over partial obstructions.
- I reviewed the photographs that you forwarded to me and noted evidence of extreme high water marks in the vicinity or the boulder weir in question. I suspect that under such high flow events, the boulder weir would be virtually submerged and not create a significant obstruction to the upstream migration of larger species of coarse fish present in the Salmo River.
- In your notes dated July 24, 1998 concerning a site inspection, you make reference to a side channel on the left bank of the river circumventing the boulder weir during high flow events. Undoubtedly, this side channel would become a fish passage route around the boulder weir during high flow events.
- In my opinion, the challenges of constructing an obstruction across a stream to allow passage of certain species of fish and exclude others at all flow levels becomes extremely difficult when dealing with fluctuating water levels; particularly if the undesirable target species are inclined to migrate upstream during high flow events. It

may be possible to design and construct an weir which could be adjusted seasonally to coincide with the upstream migration of the target species. However, such an engineered structure would be an rather expensive and may not satisfy aesthetic objectives for the area. Also, the aforementioned side channel would need to be incorporated into the design of such a structure.

At this juncture, I cannot think of an appropriate low-cost solution to the problem. I hope that the above comments are of use to you.

I am returning hereto the Task Completion Report for the Salmo River Fish Barrier and the photographs which you forwarded to me earlier.

I have also attached an invoice for my services to date for your consideration. Do not hesitate to call me if you have any questions or would like further assistance in the matter.

Regards,

Rheal Finnigan

Species	Life Stage	Maximum Swimming Speed (m/sec)			Maximum Jump Height (m)
		Sustained*	Prolonged**	Burst***	
Coho and Chinook	Adults	2.7	3.2	6.6	2.2, 2.4
	Juv. (120 mm)		0.6		
	Juv. (50 mm)		0.4		
Sockeye	Adults	1.0	3.1	6.3	2.1
	Juv. (130 mm)	0.5	0.7		
	Juv. (50 mm)	0.2	0.4	0.6	
Cutthroat and Rainbow	Adults	0.9	1.8	4.3	
	Juv. (125 mm)	0.4	0.7	1.1	
	Juv. (50 mm)	0.1	0.3	0.4	
Steelhead	Adults	1.4	4.2	8.1	3.4
Chum/Pink	Adults	1.0	2.3	4.6	
Whitefish	Adults	0.4	1.3	2.7	
Grayling	Adults	0.8	2.1	4.3	

* Sustained swimming speeds are the swimming velocities that can be maintained for extended periods of time.

** Prolonged speeds are swimming velocities that can be maintained for passage through difficult areas.

*** Burst speeds are the swimming velocities for escape and feeding.

Appendix III. Summary of boat electrofishing captures of sucker and northern pikeminnow in the lower Salmo River and Seven Mile Reservoir, 2000 (CSU=largescale sucker, LSU=longnose sucker, MSU=mountain sucker, NPM=northern pikeminnow).

				Length	Mass	Tag	
Date	River	Site	Species	(mm)	(g)	C	Number
17-Jun-00	Salmo	SRES1	CSU	375	630	G	966
17-Jun-00	Salmo	SRES1	CSU	303	301	G	954
17-Jun-00	Salmo	SRES1	CSU	328	381	G	955
17-Jun-00	Salmo	SRES1	CSU	385	575	G	956
17-Jun-00	Salmo	SRES1	CSU	395	655	G	957
17-Jun-00	Salmo	SRES1	CSU	391	652	G	958
17-Jun-00	Salmo	SRES1	CSU	355	466	G	959
17-Jun-00	Salmo	SRES1	CSU	358	537	G	960
17-Jun-00	Salmo	SRES1	CSU	331	438	G	962
17-Jun-00	Salmo	SRES1	CSU	415	750	G	965
17-Jun-00	Salmo	SRES1	CSU	394	594	G	971
17-Jun-00	Salmo	SRES1	CSU	330	394	G	972
17-Jun-00	Salmo	SRES1	CSU	365	530	G	974
17-Jun-00	Salmo	SRES1	CSU	365	583	G	975
17-Jun-00	Salmo	SRES1	CSU	380	619	G	999
17-Jun-00	Salmo	SRES1	CSU	395	769	G	952
17-Jun-00	Salmo	SRES1	CSU	358	546	G	998
17-Jun-00	Salmo	SRES1	CSU	370	553	G	1000
17-Jun-00	Salmo	SRES1	CSU	408	753	G	996
17-Jun-00	Salmo	SRES1	CSU	368	672		
17-Jun-00	Salmo	SRES1	CSU	388	692	G	953
17-Jun-00	Salmo	SRES1	LSU	378	582	G	973
17-Jun-00	Salmo	SRES1	LSU	414	671	G	951
17-Jun-00	Salmo	SRES1	MSU	374	675	G	997
17-Jun-00	Salmo	SRES1	NPM	297	309	G	961
17-Jun-00	Salmo	SRES1	NPM	375	696	G	963
17-Jun-00	Salmo	SRES1	NPM	273	211	G	964
17-Jun-00	Salmo	SRES1	NPM	288	250	G	967
17-Jun-00	Salmo	SRES1	NPM	293	270	G	970
17-Jun-00	Salmo	SRES1	NPM	222	107		

				Length	Mass	Tag	
Date	River	Site	Species	(mm)	(g)	C	Number
25-Jun-00	Salmo	SRES2	CSU	345	515	G	908
25-Jun-00	Salmo	SRES2	CSU	364	525	G	909
25-Jun-00	Salmo	SRES2	CSU	320	410	G	910
25-Jun-00	Salmo	SRES2	CSU	406	740	G	911
25-Jun-00	Salmo	SRES2	CSU	293	295	G	912
25-Jun-00	Salmo	SRES2	CSU	342	460	G	913
25-Jun-00	Salmo	SRES2	CSU	380	570	G	915
25-Jun-00	Salmo	SRES2	CSU	384	685	G	916
25-Jun-00	Salmo	SRES2	CSU	391	640	G	917
25-Jun-00	Salmo	SRES2	CSU	373	660	G	918
25-Jun-00	Salmo	SRES2	CSU	411	795	G	919
25-Jun-00	Salmo	SRES2	CSU	386	630	G	920
25-Jun-00	Salmo	SRES2	CSU	407	730	G	921
25-Jun-00	Salmo	SRES2	CSU	362	515	G	923
25-Jun-00	Salmo	SRES2	CSU	372	545	G	924
25-Jun-00	Salmo	SRES2	CSU	317	365	G	925
25-Jun-00	Salmo	SRES2	CSU	366	520	G	926
25-Jun-00	Salmo	SRES2	CSU	393	715	G	927
25-Jun-00	Salmo	SRES2	CSU	363	535	G	928
25-Jun-00	Salmo	SRES2	CSU	341	500	G	929
25-Jun-00	Salmo	SRES2	CSU	385	635	G	930
25-Jun-00	Salmo	SRES2	CSU	312	385	G	931
25-Jun-00	Salmo	SRES2	CSU	357	550	G	932
25-Jun-00	Salmo	SRES2	CSU	383	575	G	933
25-Jun-00	Salmo	SRES2	CSU	380	565	G	934
25-Jun-00	Salmo	SRES2	CSU	353	460	G	935
25-Jun-00	Salmo	SRES2	CSU	378	560	G	936
25-Jun-00	Salmo	SRES2	CSU	345	490	G	937
25-Jun-00	Salmo	SRES2	CSU	384	620	G	938
25-Jun-00	Salmo	SRES2	CSU	338	465	G	939
25-Jun-00	Salmo	SRES2	CSU	375	600	G	940
25-Jun-00	Salmo	SRES2	CSU	375	555	G	941
25-Jun-00	Salmo	SRES2	CSU	405	735	G	942
25-Jun-00	Salmo	SRES2	CSU	413	775	G	943
25-Jun-00	Salmo	SRES2	CSU	355	505	G	944
25-Jun-00	Salmo	SRES2	CSU	317	405	G	945
25-Jun-00	Salmo	SRES2	CSU	402	770	G	946
25-Jun-00	Salmo	SRES2	CSU	332	440	G	947
25-Jun-00	Salmo	SRES2	CSU	385	610	G	948
25-Jun-00	Salmo	SRES2	CSU	374	565	G	949
25-Jun-00	Salmo	SRES2	CSU	380	605	G	950
25-Jun-00	Salmo	SRES2	CSU	377	595	G	976
25-Jun-00	Salmo	SRES2	CSU	345	445	G	977
25-Jun-00	Salmo	SRES2	CSU	403	635	G	978
25-Jun-00	Salmo	SRES2	CSU	415	725	G	979
25-Jun-00	Salmo	SRES2	CSU	355	520	G	980

25-Jun-00	Salmo	SRES2	CSU	342	395	G	981
25-Jun-00	Salmo	SRES2	CSU	400	745	G	982
25-Jun-00	Salmo	SRES2	CSU	323	370	G	983
25-Jun-00	Salmo	SRES2	CSU	363	435	G	984
25-Jun-00	Salmo	SRES2	CSU	314	325	G	985
25-Jun-00	Salmo	SRES2	CSU	331	380	G	986
25-Jun-00	Salmo	SRES2	CSU	305	295	G	987
25-Jun-00	Salmo	SRES2	CSU	404	660	G	988
25-Jun-00	Salmo	SRES2	CSU	308	290	G	989
25-Jun-00	Salmo	SRES2	CSU	315	325	G	990
25-Jun-00	Salmo	SRES2	CSU	330	380	G	991
25-Jun-00	Salmo	SRES2	CSU	272	210	G	993
25-Jun-00	Salmo	SRES2	CSU	395	745	G	994
25-Jun-00	Salmo	SRES2	CSU	339	380	G	995
25-Jun-00	Salmo	SRES2	NPM	274	245	G	992

				Length	Mass	Tag	
Date	**River**	**Site**	**Species**	**(mm)**	**(g)**	**C**	**Number**
26-Jun-00	7 Mile Res.	ES3	CSU	298	275	B	0
26-Jun-00	7 Mile Res.	ES3	CSU	310	355	B	426
26-Jun-00	7 Mile Res.	ES3	CSU	323	335	B	427
26-Jun-00	7 Mile Res.	ES3	CSU	298	270	B	451
26-Jun-00	7 Mile Res.	ES3	CSU	289	265	B	452
26-Jun-00	7 Mile Res.	ES3	CSU	343	445	B	453
26-Jun-00	7 Mile Res.	ES3	CSU	301	285	B	454
26-Jun-00	7 Mile Res.	ES3	CSU	320	390	B	455
26-Jun-00	7 Mile Res.	ES3	CSU	314	350	B	456
26-Jun-00	7 Mile Res.	ES3	CSU	348	470	B	457
26-Jun-00	7 Mile Res.	ES3	CSU	297	275	B	458
26-Jun-00	7 Mile Res.	ES3	CSU	314	355	B	460
26-Jun-00	7 Mile Res.	ES3	CSU	302	275	B	461
26-Jun-00	7 Mile Res.	ES3	CSU	310	315	B	462
26-Jun-00	7 Mile Res.	ES3	CSU	365	510	B	463
26-Jun-00	7 Mile Res.	ES3	CSU	363	490	B	464
26-Jun-00	7 Mile Res.	ES3	CSU	365	560	B	466
26-Jun-00	7 Mile Res.	ES3	CSU	347	450	B	467
26-Jun-00	7 Mile Res.	ES3	CSU	359	500	B	468
26-Jun-00	7 Mile Res.	ES3	CSU	365	560	B	469
26-Jun-00	7 Mile Res.	ES3	CSU	365	495	B	470
26-Jun-00	7 Mile Res.	ES3	CSU	312	295	B	471
26-Jun-00	7 Mile Res.	ES3	CSU	328	410	B	472
26-Jun-00	7 Mile Res.	ES3	CSU	387	645	B	473
26-Jun-00	7 Mile Res.	ES3	CSU	339	400	B	474
26-Jun-00	7 Mile Res.	ES3	CSU	328	370	B	476
26-Jun-00	7 Mile Res.	ES3	CSU	378	620	B	477
26-Jun-00	7 Mile Res.	ES3	CSU	385	650	B	478
26-Jun-00	7 Mile Res.	ES3	CSU	333	375	B	479
26-Jun-00	7 Mile Res.	ES3	CSU	294	280	B	480
26-Jun-00	7 Mile Res.	ES3	CSU	403	700	B	481
26-Jun-00	7 Mile Res.	ES3	CSU	318	335	B	482
26-Jun-00	7 Mile Res.	ES3	CSU	348	430	B	483
26-Jun-00	7 Mile Res.	ES3	CSU	327	355	B	484
26-Jun-00	7 Mile Res.	ES3	CSU	365	530	B	485
26-Jun-00	7 Mile Res.	ES3	CSU	320	365	B	486
26-Jun-00	7 Mile Res.	ES3	CSU	318	370	B	487
26-Jun-00	7 Mile Res.	ES3	CSU	310	310	B	488
26-Jun-00	7 Mile Res.	ES3	CSU	320	390	B	489
26-Jun-00	7 Mile Res.	ES3	CSU	316	350	B	490
26-Jun-00	7 Mile Res.	ES3	CSU	319	350	B	491
26-Jun-00	7 Mile Res.	ES3	CSU	316	305	B	492
26-Jun-00	7 Mile Res.	ES3	CSU	300	300	B	493
26-Jun-00	7 Mile Res.	ES3	CSU	292	270	B	494
26-Jun-00	7 Mile Res.	ES3	CSU	295	260	B	496
26-Jun-00	7 Mile Res.	ES3	CSU	331	380	B	497

26-Jun-00	7 Mile Res.	ES3	CSU	392	645	B	498
26-Jun-00	7 Mile Res.	ES3	CSU	300	300	B	499
26-Jun-00	7 Mile Res.	ES3	CSU	295	275	B	500
26-Jun-00	7 Mile Res.	ES3	CSU	355	455		
26-Jun-00	7 Mile Res.	ES3	CSU	249	210		
26-Jun-00	7 Mile Res.	ES3	CSU	176	80		
26-Jun-00	7 Mile Res.	ES3	CSU	142	35		
26-Jun-00	7 Mile Res.	ES3	CSU	148	40		
26-Jun-00	7 Mile Res.	ES3	CSU	111	15		
26-Jun-00	7 Mile Res.	ES3	CSU	240	150		
26-Jun-00	7 Mile Res.	ES3	CSU	212	110		
26-Jun-00	7 Mile Res.	ES3	CSU	283	240		
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26-Jun-00	7 Mile Res.	ES3	CSU	221	145		
26-Jun-00	7 Mile Res.	ES3	CSU	274	285		
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26-Jun-00	7 Mile Res.	ES3	CSU	168	55		
26-Jun-00	7 Mile Res.	ES3	CSU	178	65		
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26-Jun-00	7 Mile Res.	ES3	CSU	198	75		
26-Jun-00	7 Mile Res.	ES3	CSU	200	90		
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26-Jun-00	7 Mile Res.	ES3	CSU	202	90		
26-Jun-00	7 Mile Res.	ES3	CSU	192	85		
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26-Jun-00	7 Mile Res.	ES3	CSU	201	100		
26-Jun-00	7 Mile Res.	ES3	CSU	200	100		
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26-Jun-00	7 Mile Res.	ES3	CSU	174	55		
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26-Jun-00	7 Mile Res.	ES3	CSU	142	35		
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26-Jun-00	7 Mile Res.	ES3	CSU	157	40		
26-Jun-00	7 Mile Res.	ES3	CSU	203	105		
26-Jun-00	7 Mile Res.	ES3	CSU	161	45		
26-Jun-00	7 Mile Res.	ES3	CSU	198	95		

26-Jun-00	7 Mile Res.	ES3	CSU	160	50		
26-Jun-00	7 Mile Res.	ES3	CSU	184	70		
26-Jun-00	7 Mile Res.	ES3	CSU	200	90		
26-Jun-00	7 Mile Res.	ES3	CSU	179	70		
26-Jun-00	7 Mile Res.	ES3	CSU	163	50		
26-Jun-00	7 Mile Res.	ES3	CSU	156	40		
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26-Jun-00	7 Mile Res.	ES3	CSU	198	90		
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26-Jun-00	7 Mile Res.	ES3	CSU	200	90		
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26-Jun-00	7 Mile Res.	ES3	CSU	214	115		
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26-Jun-00	7 Mile Res.	ES3	CSU	180	70		
26-Jun-00	7 Mile Res.	ES3	CSU	268	225		
26-Jun-00	7 Mile Res.	ES3	CSU	215	105		
26-Jun-00	7 Mile Res.	ES3	CSU	174	70		
26-Jun-00	7 Mile Res.	ES3	CSU	155	45		
26-Jun-00	7 Mile Res.	ES3	CSU	148	40		
26-Jun-00	7 Mile Res.	ES3	CSU	217	105		
26-Jun-00	7 Mile Res.	ES3	CSU	177	70		
26-Jun-00	7 Mile Res.	ES3	CSU	186	75		
26-Jun-00	7 Mile Res.	ES3	CSU	194	85		
26-Jun-00	7 Mile Res.	ES3	CSU	210	115		
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26-Jun-00	7 Mile Res.	ES3	CSU	300	275		
26-Jun-00	7 Mile Res.	ES3	CSU	190	80		
26-Jun-00	7 Mile Res.	ES3	CSU	240	155		
26-Jun-00	7 Mile Res.	ES3	CSU	262	220		
26-Jun-00	7 Mile Res.	ES3	CSU	171	60		
26-Jun-00	7 Mile Res.	ES3	CSU	190	75		
26-Jun-00	7 Mile Res.	ES3	CSU	213	115		
26-Jun-00	7 Mile Res.	ES3	CSU	183	85		
26-Jun-00	7 Mile Res.	ES3	CSU	180	70		
26-Jun-00	7 Mile Res.	ES3	CSU	130	35		
26-Jun-00	7 Mile Res.	ES3	CSU	212	115		
26-Jun-00	7 Mile Res.	ES3	CSU	270	235		
26-Jun-00	7 Mile Res.	ES3	CSU	201	115		
26-Jun-00	7 Mile Res.	ES3	CSU	182	70		
26-Jun-00	7 Mile Res.	ES3	CSU	261	195		
26-Jun-00	7 Mile Res.	ES3	CSU	210	115		
26-Jun-00	7 Mile Res.	ES3	CSU	207	95		
26-Jun-00	7 Mile Res.	ES3	CSU	190	85		
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26-Jun-00	7 Mile Res.	ES3	CSU	165	55		
26-Jun-00	7 Mile Res.	ES3	CSU	320	345		

26-Jun-00	7 Mile Res.	ES3	CSU	183	70		
26-Jun-00	7 Mile Res.	ES3	CSU	183	90		
26-Jun-00	7 Mile Res.	ES3	CSU	197	85		
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26-Jun-00	7 Mile Res.	ES3	CSU	260	185		
26-Jun-00	7 Mile Res.	ES3	CSU	181	75		
26-Jun-00	7 Mile Res.	ES3	CSU	197	105		
26-Jun-00	7 Mile Res.	ES3	CSU	165	50		
26-Jun-00	7 Mile Res.	ES3	CSU	180	75		
26-Jun-00	7 Mile Res.	ES3	CSU	182	70		
26-Jun-00	7 Mile Res.	ES3	CSU	162	50		
26-Jun-00	7 Mile Res.	ES3	CSU	166	55		
26-Jun-00	7 Mile Res.	ES3	CSU	203	60		
26-Jun-00	7 Mile Res.	ES3	CSU	162	50		
26-Jun-00	7 Mile Res.	ES3	CSU	153	45		
26-Jun-00	7 Mile Res.	ES3	NPM	542	1980	B	428
26-Jun-00	7 Mile Res.	ES3	NPM	291	245	B	459
26-Jun-00	7 Mile Res.	ES3	NPM	366	490	B	465
26-Jun-00	7 Mile Res.	ES3	NPM	247	175	B	475
26-Jun-00	7 Mile Res.	ES3	NPM	290	250	B	495
26-Jun-00	7 Mile Res.	ES3	NPM	143	30		
26-Jun-00	7 Mile Res.	ES3	NPM	160	40		
26-Jun-00	7 Mile Res.	ES3	NPM	132	25		
26-Jun-00	7 Mile Res.	ES3	NPM	140	30		
26-Jun-00	7 Mile Res.	ES3	NPM	175	55		
26-Jun-00	7 Mile Res.	ES3	NPM	172	60		
26-Jun-00	7 Mile Res.	ES3	NPM	160	40		
26-Jun-00	7 Mile Res.	ES3	NPM	136	30		
26-Jun-00	7 Mile Res.	ES3	NPM	142	35		
26-Jun-00	7 Mile Res.	ES3	NPM	135	30		
26-Jun-00	7 Mile Res.	ES3	NPM	140	30		
26-Jun-00	7 Mile Res.	ES3	NPM	151	35		

Appendix IV. Summary of locations of radio tagged sucker and northern pikeminnow in the lower Salmo River and Seven Mile Reservoir, 2000.

CODE	DATE	STREAM	LOCATION	DISTANCE	ZONE	EASTING	NORTHING
1	6/18	Salmo River	Bridge at mouth	0.1	11	472260	5430448
1	6/25	Salmo River	300 m u/s bridge at mouth	0.4	11	472406	5430580
1	8/15	Seven Mile	Boundary Pool		11	474175	5427523
1	9/23	Salmo River	Mouth	0.0	11	472140	5430446
1	10/6	Salmo River	Mouth	0.0	11	472140	5430446
2	6/18	Salmo River	Bridge at mouth	0.1	11	472260	5430448
2	6/23	Salmo River	400 m u/s bridge at mouth	0.5	11	472433	5430680
2	6/26	Salmo River	Fish Barrier	2.2	11	474096	5430885
2	7/11	Salmo River	Black Bluffs	6.7	11	478112	5431525
2	7/16	Salmo River	Black Bluffs	6.7	11	478112	5431525
2	7/29	Salmo River	Water Survey Station	7.9	11	478461	5432578
2	8/12	Salmo River	Fish Barrier	2.2	11	474096	5430885
2	9/23	Salmo River	Mouth	0.0	11	472140	5430446
2	10/6	Salmo River	Mouth	0.0	11	472140	5430446
3	6/18	Salmo River	Bridge at mouth	0.1	11	472260	5430448
3	6/25	Salmo River	Mouth	0.0	11	472140	5430446
4	6/26	Salmo River	Bridge at mouth	0.1	11	472260	5430448
4	7/11	Salmo River	Mouth	0.0	11	472140	5430446
4	7/29	Salmo River	Mouth	0.0	11	472140	5430446
4	8/15	Seven Mile	1 km d/s Salmo mouth		11	471397	5431042
4	9/23	Seven Mile	1 km d/s Salmo mouth		11	471397	5431042
4	10/6	Seven Mile	1 km d/s Salmo mouth		11	471397	5431042
4	11/16	Seven Mile	1 km d/s Salmo mouth		11	471397	5431042
5	6/26	Salmo River	Bridge at mouth	0.1	11	472260	5430448
5	9/23	Salmo River	Mouth	0.0	11	472140	5430446
6	6/26	Salmo River	Bridge at mouth	0.1	11	472260	5430448
6	7/29	Seven Mile	Boundary Pool		11	474175	5427523
6	8/15	Seven Mile	Boundary Pool		11	474175	5427523
6	9/23	Seven Mile	Boundary Pool		11	474175	5427523
6	11/16	Seven Mile	Boundary Pool		11	474175	5427523
7	6/26	Salmo River	Bridge at mouth	0.1	11	472260	5430448
7	7/11	Salmo River	Mouth	0.0	11	472140	5430446
7	8/15	Seven Mile	300 m d/s of Tillicum Creek		11	469406	5432142
7	9/23	Seven Mile	300 m d/s of Tillicum Creek		11	469406	5432142
8	7/13	Salmo River	100 m u/s bridge at mouth	0.2	11	472317	5430459
8	7/29	Seven Mile	Mouth of Tillicum Creek		11	469557	5432430
8	8/15	Seven Mile	Mouth of Tillicum Creek		11	469557	5432430
8	9/23	Seven Mile	Mouth of Tillicum Creek		11	469557	5432430
8	10/5	Seven Mile	1 km d/s Salmo mouth		11	471397	5431042
8	11/16	Seven Mile	Mouth of Tillicum Creek		11	469557	5432430
81	7/13	Salmo River	100 m u/s bridge at mouth	0.1	11	472317	5430459
10	7/13	Salmo River	100 m u/s bridge at mouth	0.1	11	472317	5430459
10	8/15	Salmo River	800 m u/s bridge at mouth	0.9	11	472755	5430914
10	9/23	Salmo River	Berts Drop	1.8	11	473676	5431030
10	10/5	Salmo River	Berts Drop	1.8	11	473676	5431030
10	11/16	Salmo River	Berts Drop	1.8	11	473676	5431030

Appendix V. Photographic plates.

Plate 1.	Anaesthetic bath used during the non-sportfish telemetry project.

Plate 2.	Northern pikeminnow at stage IV of anaesthesia.

Plate 3. Largescale sucker at stage IV of anaesthesia.

Plate 4. Northern pikeminnow in operating trough with sitz bath gill irrigation apparatus.

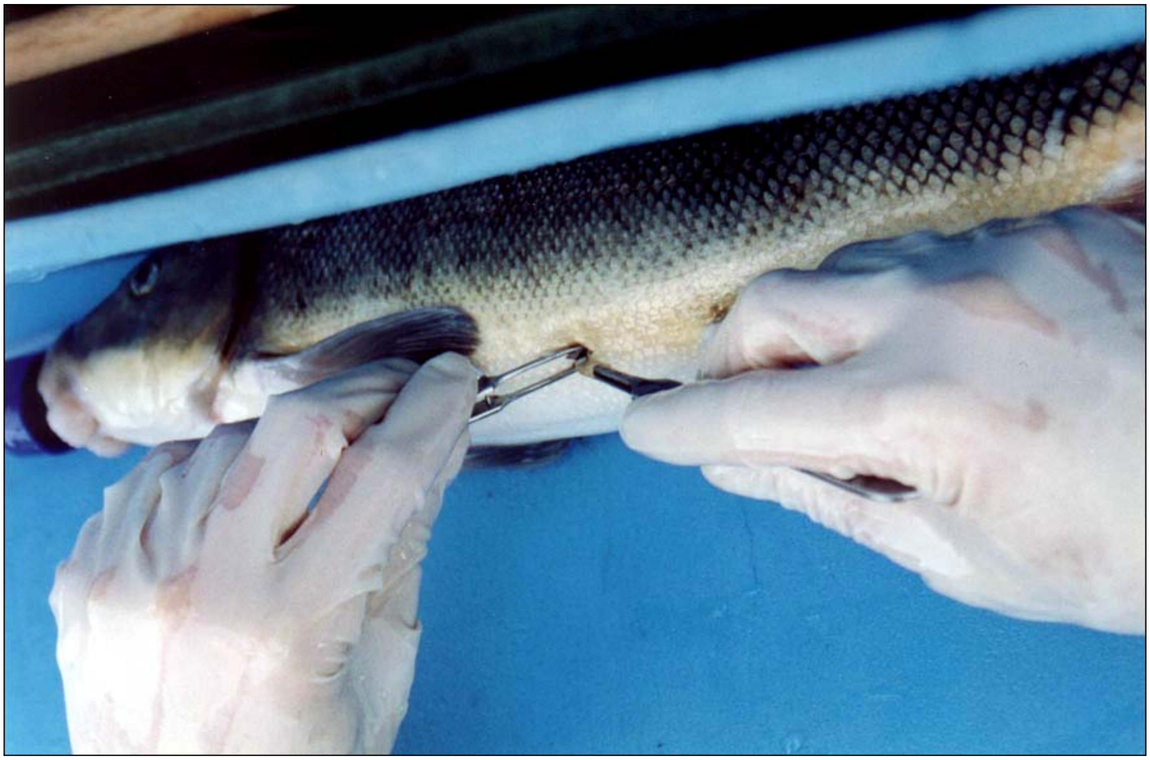

Plate 5. Largescale sucker in operating trough with sitz bath gill irrigation apparatus.

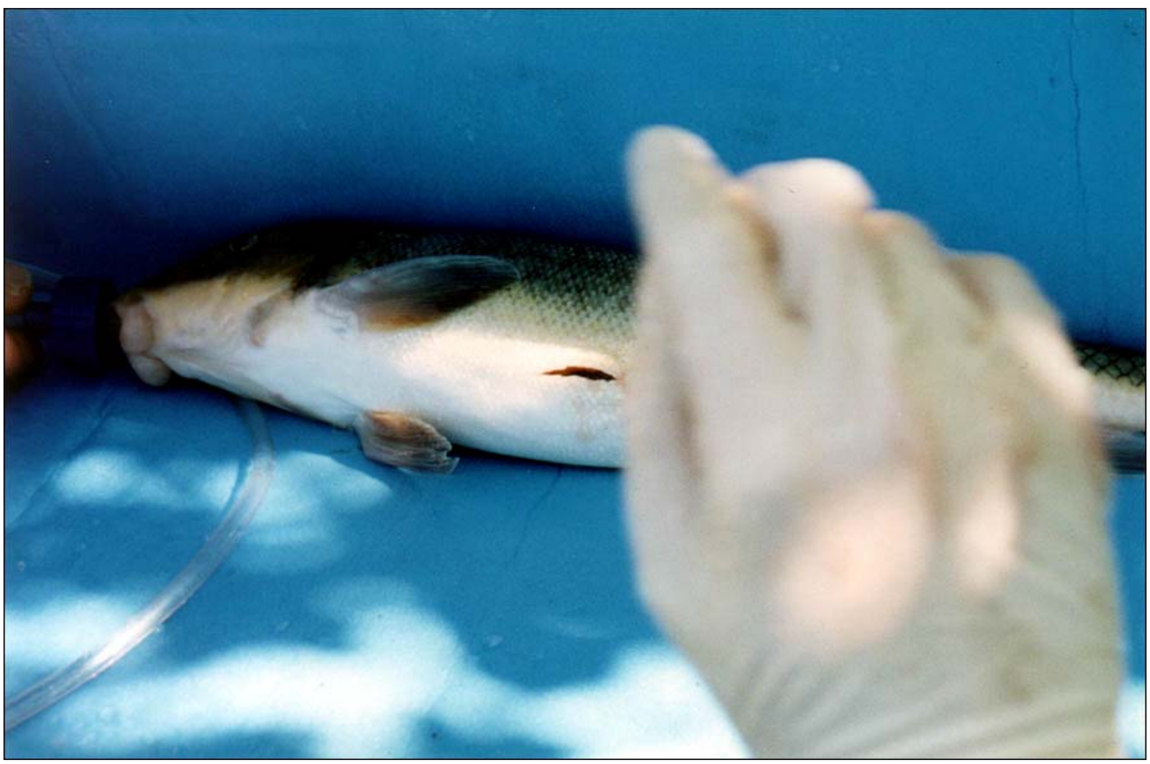

Plate 6. Incision made through body wall into abdominal cavity of a largescale sucker prior to insertion of radio tag.

Plate 7. Stainless steel needle inserted through body wall and out incision prior to inserting radio tag antennae through needle.

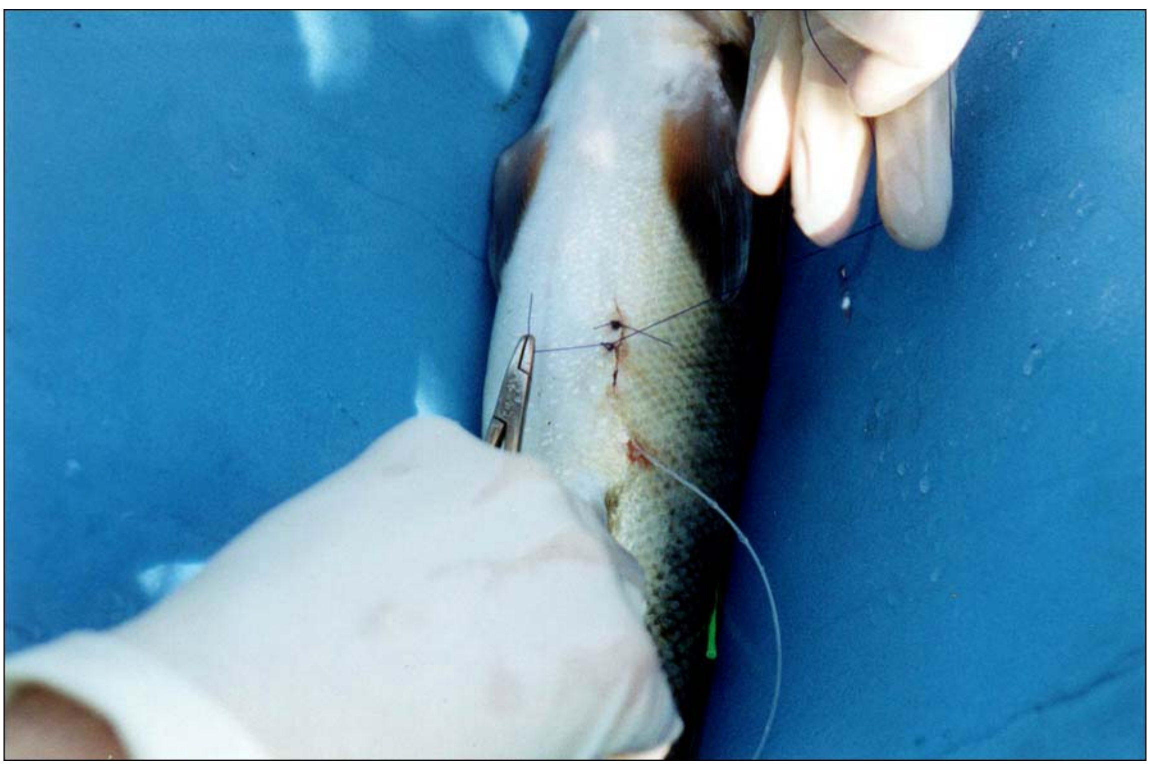

Plate 8. Radio tag antennae coming out the body wall and incision being sutured closed.

Plate 9. Closed incision with sutures and antennae coming out the body wall of the fish.

Plate 10. Fixed radio tracking station.

Plate 11. Looking upstream to non-sportfish barrier on the Salmo River on June 22 2000. Note the relatively short drop and slow water velocity on right upstream bank.

Plate 12. Looking across the stream channel at the non-sportfish barrier on the Salmo River on June 22 2000. Note the relatively short drop and slow water velocity on right upstream bank.

Plate 13. Slow water velocity drop at non-sportfish barrier on the Salmo River on June 22 2000. Note the absence of flow down old placer mining diversion channel.

Plate 14. Looking upstream to non-sportfish barrier on the Salmo River in mid September 2000. Note the increased drop at the barrier.

Plate 15. Looking upstream to non-sportfish barrier on the Salmo River in mid September 2000. Note the increased drop at the barrier site.

Plate 16. Looking upstream to non-sportfish barrier on the Salmo River in mid September 2000. Note the increased drop at the barrier site.