Kintama Research Corp.
10-1850 Northfield Road
Nanaimo, British Columbia
Canada V9S 3B3
T: (250) 729-2600
F: (250) 729-2622

"Creating a Revolution in Marine Science"

Acoustic Telemetry Measurements of Migration and Movements of Adult Steelhead (Oncorhynchus mykiss) within the Bulkley River, 2009

Project Name: Sonic Telemetry Project

May 12, 2010

Location of the acoustic sub-arrays arrays in 2009. Base map credit: *GLOBE Task Team et al eds., 1999. The Global Land One-kilometer Base Elevation (GLOBE) Digital Elevation Model, Version 1.0. National Oceanic and Atmospheric Administration, National Geophysical Data Center, 325 Broadway, Boulder, Colorado 80305-3328, U.S.A. (URL:http://www.ngdc.noaa.gov/mgg/topo/globe.html).* Bathymetric and topographic data courtesy of the Department of Natural Resources, Canada.

Suggested Citation:

Welch, D.W., Lydersen, H., Porter, A.D., Neaga, L., and Muirhead, Y. (2009) “Acoustic Telemetry Measurements of Survival and Movements of Adult Steelhead (*Oncorhynchus mykiss*) within the Bulkley River, 2009”. Kintama Research Corporation, Final Report to the B.C. Ministry of the Environment, 47 pages.

Table of Contents

List of Figures

List of Tables

Executive Summary

The Moricetown Canyon on the Bulkley River is the site of yearly steelhead (*Oncorhynchus mykiss*) mark-recapture studies done by Wet'suwet'en Fisheries. In 2008, a pilot-scale acoustic telemetry study was conducted where adult steelhead were tagged with acoustic tags and released back into the river along side fish used the annual *mark-recapture* study. A drop back rate of 18% was measured for acoustically tagged adult steelhead (we define "drop-back" as fish going downstream after release, rather than continuing to migrate upstream past the recapture site, as conventionally assumed). In 2009, the acoustic study was expanded in Moricetown Canyon, and drop back rates were assessed more closely.

In summer 2009, an array was designed and deployed in the Bulkley River system by Kintama Research, with the assistance of a local river guide. Twelve acoustic receivers were deployed in the Bulkley River on 10-12 July 2009 and 67 returning wild steelhead were subsequently tagged with individually identifiable Vemco V9-2H acoustic tags. One fish was harvested and therefore omitted from the data analysis (n=66). Fish were released from 5 August to 24 September at two collection sites: (a) the beach seine site immediately below the Moricetown Canyon and (b) the dip-net site located at the Moricetown Canyon falls. We recovered all receivers between the 9-11 November 2009, approximately four months later. Over the deployment period, a total of 38,808 detections were recorded from 63 of the 66 tagged adult steelhead.

.

Key findings of the 2009 Bulkley River study:

- Only between 56 and 59% of fish passed the recapture site during active recapture efforts (excludes: Fish that remained below (33%), undetected tagged fish (5%), and fish passing recapture site after the recapture efforts were terminated (3-6%)).
- 2009 drop-back rate (<0.7 km): 83% of all tagged fish (n=66)
- 2009 drop-back rate (<11 km): 35% of all tagged fish (18% in 2008).
- Average time from release to passing the Moricetown Canyon recapture site (300 m upstream of release): 13.5 days (range: 0.9-52.5 days).

- Twenty-two (33%) of all tagged steelhead remained below the Moricetown Canyon release site and were never exposed to recapture at the recapture site.
- Between two to four (3-6%) of the tagged steelhead passed the recapture site after termination of the recapture effort and were never exposed to recapture at the dip-net site.

This evidence coupled with the extensive movements that a substantial proportion of the tagged steelhead made downstream and then upstream past the release site is potentially of major importance for the interpretation of data from the Moricetown mark-recapture analysis.

1.0 Introduction

The Bulkley River in British Columbia is renowned world-wide for its summer run of wild steelhead and yearly mark-recapture studies to evaluate this resource have been conducted by the Wet'suwet'en Fisheries since 1999. These mark-recapture studies focus on coho, sockeye, and steelhead moving through Moricetown Canyon. The Bulkley is 257 km long, drains an area of 12400 km^2 and is a major tributary to Skeena River (NRCAN 2010). The Skeena is one of the largest watersheds flowing entirely in British Columbia. All five Pacific salmon species and 30 other fish species, including multiple populations of steelhead trout, use the Skeena and Bulkley river spawning and rearing habitats. Many of the salmon and trout populations face intense harvest during the summer and fall while returning to these spawning grounds. Chudyk and Narver (1976) reported that fishing pressure from commercial, recreational, and aboriginal fisheries have all contributed to the decline of Skeena River steelhead. Skeena steelhead are currently subject to significant fishing pressure as a result of incidental capture in commercial sockeye and pink salmon gillnet fisheries (Oguss and Evans 1978). A genetic study of the steelhead caught in the Tyee Test Fishery (Skeena River mouth) identified the dominant steelhead stock as originating from the Bulkley River drainage, which includes the Morice and Bulkley rivers, and Toboggan Creek (2007: 29% ; 2008: 40%) (Beacham and Beere 2009).

Despite the many different management strategies, stock assessment techniques, and research programs implemented since the 1970's on Skeena River populations, the Skeena steelhead are thought to still be declining (Walters *et al* 2008). In 2006, the Tyee Test Fishery, located at the mouth of the Skeena River, identified an unexpectedly large sockeye run while steelhead numbers appeared relatively low. A commercial sockeye opening in Area 4 (the river mouth) subsequently exposed co-migrating Skeena steelhead to fishing pressure for 11 consecutive days. This decision caused intense public debate and controversy and led to a demand for review of Skeena River salmon and steelhead management strategies. In 2007, an independent science review panel (ISRP) reviewed these strategies and other issues facing the Skeena River watershed (Walters *et al* 2008). Walters *et al* identified a number of critical issues and made several recommendations; one of them was the need for a telemetry study of steelhead removed from the water in the Area 4 fisheries. In addition to the final recommendations in the

ISRP report, a recommendation by DFO biologists is put forth, suggesting a multispecies telemetry study of sockeye, coho and steelhead captured in the Moricetown Canyon mark-recapture studies to provide information on survival, drop-back behaviour and migration rates.

In 2009, a Moricetown Canyon project was initiated by the Ministry of Environment (MoE), the Pacific Salmon Foundation, and Kintama to specifically assess the behaviour of the Bulkley River steelhead following tagging. Collecting data in these areas would complement multiple steelhead studies previously conducted in this area (Beere 1991a-d; 1995, 1996, 1997).

Acoustic telemetry has a significant advantage over radio telemetry in that the signals transmit effectively in both salt and fresh water, potentially allowing much broader geographic study of the species. Off-setting this potential advantage, the deployment of large-scale acoustic arrays is more complex than when radio frequencies are used due to the nature of acoustic propagation in water. In recent years, large-scale acoustic telemetry systems have been used to study the survival and migratory behaviours of several fish species (e.g., Crossin *et al* 2008, Chittenden *et al* 2008, Welch *et al* 2008, Melnychuk *et al* 2007) and the large-scale Pacific Ocean Shelf Tracking acoustic array, "POST", www.postcoml.org) has been deployed semi-permanently along the Pacific Shelf (including two major rivers) between northern Oregon and southeast Alaska.

To investigate the behaviours of returning Bulkley River steelhead released from the annual Wet'suwet'en mark-recapture study, a sub-array of 12 acoustic receivers were deployed in the Bulkley River in the summer of 2009 (Figure 1). Adult steelhead were primarily seined and tagged below the Moricetown Canyon release site (n=57) but a small subset (n=10) were tagged at the recapture site. One fish was subsequently removed from the data analysis as it was harvested during the study period (n=66). All steelhead were tagged externally with uniquely coded acoustic transmitters. In the fall of 2009, flows in the Bulkley became very low and a few of the acoustic receivers became exposed. One of the receivers (#12) was disturbed on a few occasions. MoE staff effectively redeployed and in some cases re-located the receivers in question. All units were recovered and successfully uploaded in November 2009. The purpose of this report is to present background data and survey results valuable to the interpretation of the yearly Moricetown mark-recapture studies by identifying drop-back rates, residence numbers, time to pass through the canyon from release, and extent and percentages of up or downstream travel.

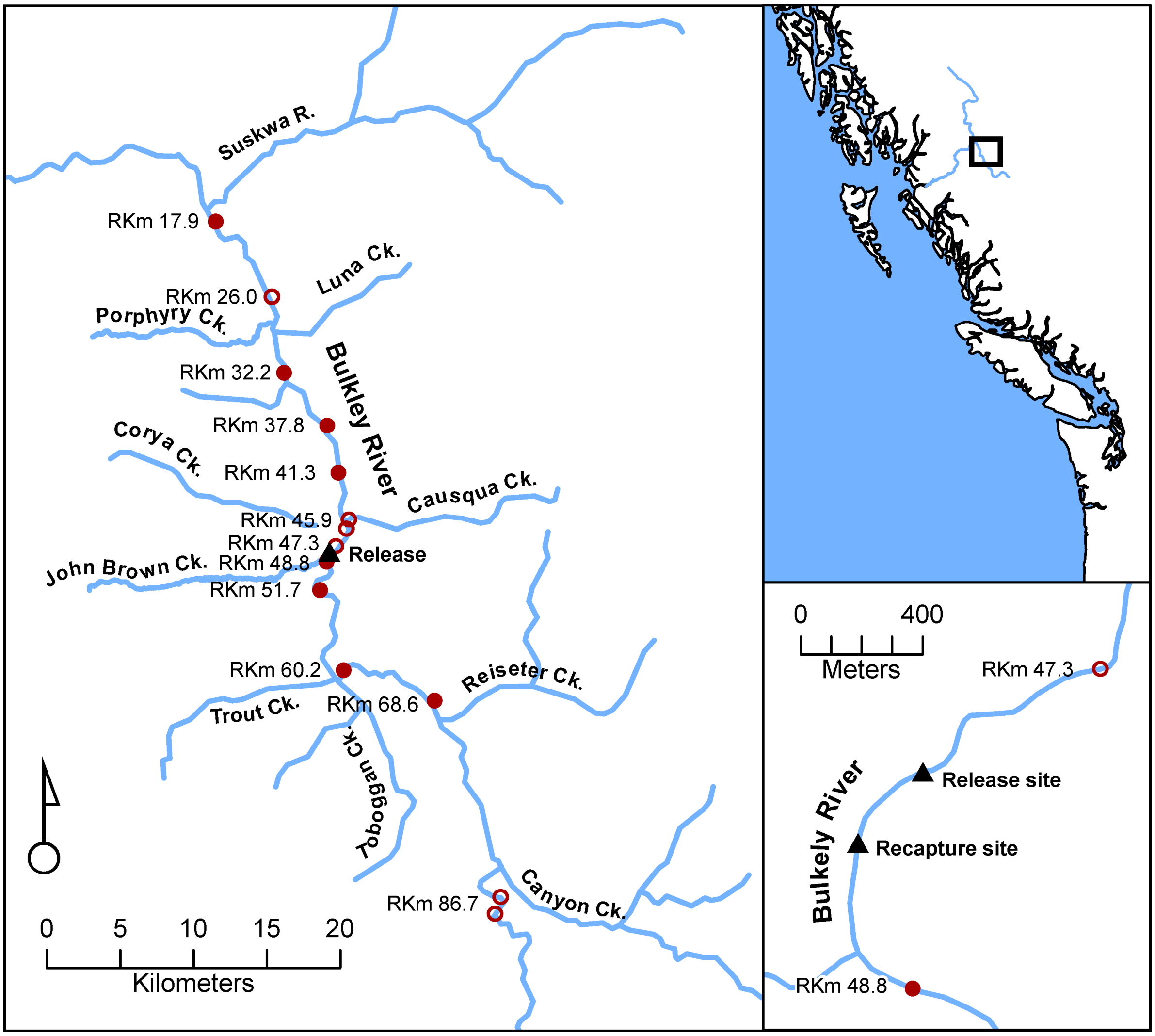

Figure 1. Location of acoustic receivers deployed in the Bulkley River. The red dots indicate the twelve receiver locations used to monitor acoustically tagged steelhead during the fall of 2009. Four receivers were repositioned or moved during the study due to low water conditions or disturbance and are indicated using hollow red dots (if moved, both the initial and final location are indicated as open circles). Distances are measured as river kilometer (RKm) from the Bulkley River confluence to the Skeena River. Bathymetric and topographic data ©Department of Natural Resources Canada.

2.0 Methods

2.1 Acoustic Sub-array

An acoustic sub-array consisting of twelve Vemco (Halifax, Nova Scotia) VR2 acoustic receivers was deployed in the Bulkley River to monitor movements and migratory patterns of adult steelhead tagged at Moricetown Canyon in 2009. Vemco VR2 receivers consist of a transducer; internal electronics with a clock capable of measuring and logging validated detections to flash memory, and a battery, all housed in a submersible case. These receivers are capable of detecting and recording the passage of fish implanted with tags which transmit unique ID codes, potentially allowing for the reconstruction of the complete movement and extent of migration record of individual tagged animals, depending upon the geographic extent and performance of the array.

The sub-array in the Bulkley River was compatible with the Pacific Ocean Shelf Tracking (POST) array; POST is a large scale marine acoustic tracking network which extends from northern Oregon, throughout coastal British Columbia, and up to southeast Alaska (Cover; www.postcoml.org). Acoustic receivers are deployed in specific locations in the coastal ocean with set spacing with the goal of providing near-complete coverage of coastal marine shelf areas from the beach to the shelf break (200m). Elements of the array are also deployed in multiple locations within several river systems other than the Skeena.

During 10-12 July 2009, Kintama Research deployed twelve acoustic receivers within the Bulkley River with the assistance of Fred Seiler, Silvertip EcoTours, Terrace. Seven receivers were deployed downriver of the Moricetown Canyon at locations ranging from 17.9 to 47.3 RKm from the Bulkley-Skeena confluence and five were positioned above the canyon (Rkm 48) at river positions 48.8 - 86.7 RKm (Table 1 and Figure 1). Locations were selected which appeared to have a high probability of detecting the acoustically tagged steelhead and positions recorded using a WAAS enabled handheld GPS receiver. At the time of instalment, river transects were surveyed using an onboard depth sounder to ensure sufficient water depth and avoid areas with larger trenches. However, due to a combination of a period of increased discharge that occurred immediately following instalment of receivers and subsequent low river flow in the fall of 2009, four receivers were redeployed by MoE staff because they were found to be either very close to the surface or no longer in the river. This resulted in gaps in the detection record for the telemetry array (as tagged fish will not be detected if the receiver's hydrophone is not submerged). All units were successfully recovered four months later on 9-11 November 2009.

Table 1. Detail of 2009 receiver and tagging locations within the Bulkley River. Sites denoted with an A were redeployed during the study period.

Site description	Deployment date (UTC)	Distance (RKm) from tagging site	Bulkley RKm	Latitude (°)	Longitude (°)
Bulkley receiver # 1	10-Jul-09	-30.1	17.9	55.21915	-127.43847
Bulkley receiver # 2	10-Jul-09	-22.0	26.0	55.17220	-127.38058
Bulkley receiver # 2A	26-Aug-09	-22.0	26.0	55.17228	-127.38053
Bulkley receiver # 3	10-Jul-09	-15.8	32.2	55.12563	-127.36901
Bulkley receiver # 4	10-Jul-09	-10.2	37.8	55.09270	-127.32439
Bulkley receiver # 5	10-Jul-09	-6.7	41.3	55.06348	-127.31347
Bulkley receiver # 6	10-Jul-09	-2.7	45.3	55.03471	-127.30402
Bulkley receiver # 6A	26-Aug-09	-2.1	45.9	55.02909	-127.30676
Bulkley receiver # 7	10-Jul-09	-0.7	47.3	55.01836	-127.31673
Bulkley receiver # 7A	19-Aug-09	-0.7	47.3	55.01836	-127.31673
Tagging site		0	48	55.01540	-127.32510
Bulkley receiver # 8	11-Jul-09	+0.8	48.8	55.00951	-127.32812
Bulkley receiver # 9	11-Jul-09	+3.7	51.7	54.99218	-127.33611
Bulkley receiver # 10	11-Jul-09	+12.2	60.2	54.94255	-127.31300
Bulkley receiver # 11	11-Jul-09	+20.6	68.6	54.92229	-127.21705
Bulkley receiver # 12	12-Jul-09	+38.7	86.7	54.79522	-127.16322
Bulkley receiver # 12A	23-Sep-09	+39.7	87.7	54.80118	-127.15254

2.2 Tagging

Adult steelhead were caught and tagged between August 11th and September 24th at two locations. Ten steelhead were dip-netted and tagged at Moricetown Canyon falls while 57 additional steelhead were caught using a beach seine and tagged 300 meters below the Moricetown Canyon falls. Each fish was externally tagged just below the dorsal fin with an individually identifiable Vemco V9-2H. Vemco V9-2H transmitters are 9 mm in diameter and weigh 3.5 grams. Tags used in the Bulkley study operated at 69 KHz frequency.

The acoustic tags were attached externally using braided Spiderwire line. Prior to the actual tagging event, individual Spiderwire harnesses were created for each tag and fastened using epoxy. The harness location was distal to the transmission end of the tag such that the signal was not compromised by the attachment (Figure 2).

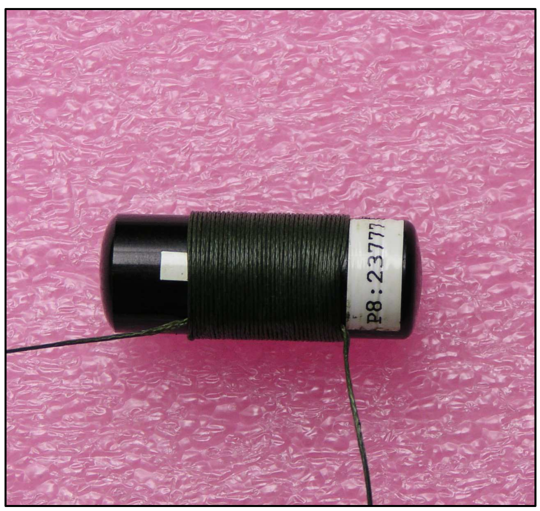

Figure 2. A Vemco V9-2H tag after attaching the spiderwire line as a harness. Photo courtesy of MoE.

A tagging trough was lined with 5 mm Thinsulate foam and a hole was drilled at one end to accommodate a hose that supplied a constant flow of water through the trough. Acoustic tags were applied on the left side of the steelhead with the transmission end directed posterior. Needles were threaded between the pterygiophores and a surgeon's knot was used to securely join the ends (Figure 3). Finally, a Scotty brass connector sleeve, intended for downrigger wire, was crimped on above the knot. Tag number, sex, nose-fork length, and time of release were recorded.

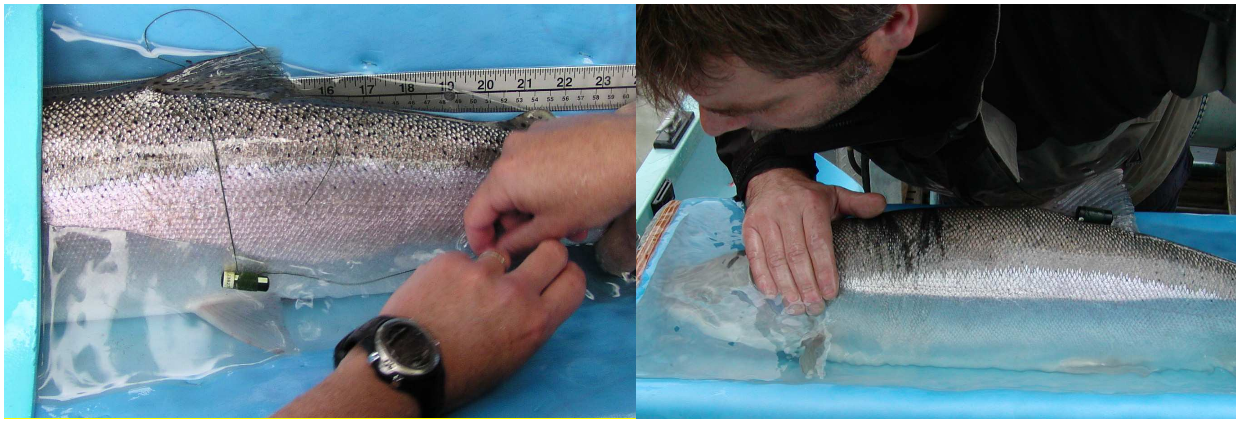

Figure 3. Left: attaching an acoustic tag on the left side of the steelhead. Right: inspecting a recently captured Skeena steelhead in the tagging trough with the acoustic tag secured in place. Photo courtesy of MoE.

Wet'suwet'en Fisheries conduct an annual mark-recapture program to estimate adult salmon abundance. The program utilizes a jet-boat to deploy a beach seine and then mark captured salmonids (Figure 4). Recapture is accomplished via a dip-net fishery approximately 300 meters upstream of the tagging site. In 2009, acoustic tags were applied in the manner described above in conjunction with the annual mark-recapture study. The fish were caught, and immediately tagged and released. Prior to release, an individually numbered, coloured anchor-T tag was placed at the base of the dorsal fin as a secondary mark. The ten steelhead caught and tagged at the dip-net fishery (the recapture site) were passed to a second net which was then carried to a holding tank and subsequently tagged as described above.

Figure 4. Deploying a beach seine in the Moricetown Canyon in the Bulkley River. Photo courtesy of MoE.

2.3 Data Analysis

All data files collected from the array underwent standard quality assurance and quality control procedures. System data recorded in the telemetry receivers were reviewed, and the data files checked for gaps or inconsistencies. Detection data were then compiled into an Access database for false detection screening and analysis of array performance, fish survival, and migratory behaviour.

Due to the proximity of the two 2009 release sites (300 m apart) the tagged steelhead were mostly treated as one release site throughout the report, the exception being when comparing the 2008 and 2009 data; this distinction is made when comparing the two years in order to maintain a uniform treatment of fish between years.

One tagged steelhead was harvested post tagging without being detected on any of the 12 receivers. This fish has been omitted from the data analysis (n=66).

2.3.1 False detection screening

We identified and excluded any detection likely to be false (as a result of aliasing or tag collisions) using the two criteria recommended by VEMCO (Pincock 2008). Detections met the first criteria if there was at least one short interval (<0.5 hour) between successive detections of an ID code on a receiver and if there were more short intervals between detections than long ones (>0.5 hour). Detections not meeting the first criteria were then examined individually to determine if there was possible collision activity on the receiver (i.e. when two or more tags were simultaneously transmitting in the vicinity of the receiver; overlapping transmissions – collisions – may potentially result in the generation of a spurious tag code). We considered the detection of another tag code within five minutes on either side of the time of detection of the questionable tag code as representing possible collision activity, and did not include such detections unless they met the first criteria.

2.3.2 Minimum migration

Minimum migration estimates at each location were calculated by dividing the number of fish detected on each acoustic receiver by the number released. These values underestimate migration because they do not account for fish that may have passed the array but which were not detected.

2.3.3 Direction and Extent of Apparent Migration Movement.

Minimum migration is an underestimate of true migration because it does not take into account the fish that were not detected at a given line. Generally, it is possible to compensate for this shortfall by estimating the detection efficiency of the sub-arrays and using these to correct for missed fish. However, this is only appropriate when fish have a unidirectional migration. The Bulkley study presents a unique situation (at least for the downstream migrators) because the fish swim in two directions and may turn around at any location. When fish pass multiple times over the sub-arrays, the detection efficiency estimates are biased high and do not correct properly for fish that passed over the line only one time and were not detected. Below we present two methods of correcting the minimum migration estimates for the detection efficiency of the array: Method 1 is the method we employ for unidirectional migration; Method 2 is a more manual approach that we hope is more appropriate for the Bulkley River.

Method 1

To correct for limitations in equipment performance at each detection site, the detection efficiency (*p*) for sub-array (*i*) was calculated using a modification of the ratio of fish detected at each sub-array (m_i) divided by the total number that swam past (equals m_i plus the number missed at sub-array but detected later, z_i) (Jolly 1982)). The minimal movement estimates were then adjusted by dividing by the detection efficiency to obtain the estimated number of tagged fish reaching the i^{th} sub-array. This adjustment can be made for sub-arrays with other sub-arrays further along the migration path (upstream or downstream depending upon direction of movement) and with sufficient sample size to estimate z_i. Detection efficiency was estimated for the sub-arrays 2-11, RKm 26 through 68.6. The calculated detection efficiencies are presented in this report (section 3.4).

Due to the milling behaviour of the Bulkley steelhead these detection efficiencies are skewed high because fish may pass over a sub-array multiple times. The level of overestimation varies depending on the location of the specific sub-array as the sites closer to the beach seine have repeat fish crossing the sub-array more frequently than the ones further away. This repeat crossing behaviour increases the detection efficiency calculated and subsequently lowers the estimate of apparent migration. Calculating apparent movement estimates based on these values would be not be a true representation of the data; therefore detection efficiency is not used for further analysis.

Method 2

Detection logs from receivers were analyzed and tag ID codes cross referenced allowing for a manually adjusted migration estimate per sub-array based on tags detected either on the receiver in question or further along the migratory path. That is, a count of all the unique ID codes heard on that sub-array or further along the route. This method causes an underestimate of the extent of migration because it does not include fish that were missed on sub-arrays further along in the migratory path. The underestimation using this method is also variable depending on the location of the specific receiver within the array as travel extent will be increasingly underestimated towards the upper and lower receivers. We have decided to present the data using method 2 for cumulative apparent migration because we believe it provides a less biased estimate and includes only true detections, rather than adjusted numbers.

3.0 Results

3.1 False Detection Screening

The total number of detections on all receivers was 38,810. False detection screening excluded only two invalid detections (0.005% of total); leaving 38,808 detections that we believe are real. The vast majority of the retained data consisted of multiple detections closely spaced in time on a given sub-array.

3.2 Unique ID Codes Detected at Each Location

3.2.1 Moricetown steelhead detections

In the Bulkley River, 66 adult steelhead were tagged with V9-2H tags and released at the Moricetown Canyon (RKm 48). For this section the two release sites are treated as one due to their close proximity. Table 2 presents the unique number codes recorded on individual receivers (minimum travel) whereas Table 3 (section 3.3) presents the apparent cumulative number of fish which passed the receivers (i.e. number detected at each sub-array plus the number that must have passed each sub-array because they were recorded further along the migration path). Receiver 12 was intermittently in and out of the water during the study and as such the detections on this receiver are expected to be significantly underestimated; as this is the final upstream receiver any meaningful quantitative estimates cannot be made to accommodate the lesser number of detections likely recorded.

Of the 66 released steelhead, two were re-captured at the dipnet site and lost their tags. As these tags could not subsequently be detected above the canyon, the total number of available tagged fish above the recapture site have been adjusted to 64. Fourteen (22%) tagged steelhead were heard on the first upstream location while 19 (30%) and 21 (33%) unique tag codes were heard on the second and third receivers upstream of the canyon. At the fourth upstream receiver, located 20.6 Rkm above the tagging site (Receiver 11: RKm68.6), 33 of 64 (52%) steelhead were recorded. Receiver 11 was a deep site and it is possible that this was a holding location for steelhead during their upstream travel. The receiver furthest upstream (RKm 86.7) only recorded 16 fish as this receiver was disturbed and removed from the river on a few occasions.

As the water level dropped in the fall, the receiver immediately downstream of the canyon release site was exposed and the number of detections reflects this: only 33 fish (50%) were heard on this receiver below the canyon whereas 41 fish (62%) were detected at the next downstream river site (Rkm45.3) 2.7 RKm below the tagging site.

Table 2. Number of acoustically-tagged, wild adult steelhead recorded on the Kintama array in the Bulkley River in 2009. Distances specified as river kilometres (RKm) from the Bulkley-Skeena confluence. Locations with additional bracketed distances were receivers moved during the study period. Tagging site is indicated by double line division between RKm47.3 and RKm48.8. Below the tagging site n=66 but due to tagloss at recapture n=64 above the tagging site.

Release Location	Origin	Tag Type	Unique ids heard	BULKLEY											
				RKm17.9	RKm26.0	RKm32.2	RKm37.8	RKm41.3	RKm45.3 (45.9)	RKm47.3	RKm48.8	RKm51.7	RKm60.2	RKm68.6	RKm86.7 (87.7)
BULKLEY	W	V9-2H	Count	11	15	19	20	32	41	33	14	19	21	33	16
BULKLEY	W	V9-2H	Percent	17	23	29	30	48	62	50	22	30	33	52	25

Release sites are treated as one due to their close proximity.

*Receiver 12 was intermittently in and out of water during the study period.

3.3 Direction and Extent of Migration

The majority (55 fish; 83%) of the adult steelhead released at Moricetown Canyon in 2009 dropped back and were detected on receivers below the canyon: 11 (17%) migrated downstream at least as far as Receiver #1, Rkm17.9, located 30.1 RKm below the tagging site (Table 3; Figure 5). Of the fish that dropped back, 31 fish of 55 (56%) were detected on receivers above the canyon. In addition to those 31 fish, two fish lost their tags during recapture when the steelhead were migrating back up through the canyon (total 60%).

Only 59% of all tagged steelhead were subsequently detected above the canyon after release, including the 31 tagged steelhead which initially dropped back before subsequently migrated upriver (Table 3, Table 5). Between 2 and 4 tagged steelhead passed the recapture site after the termination of the mark-recapture study (section 3.5.1). Three fish were not detected on the array in 2009, one for which the ID code was detected at the tagging site during the mobile acoustic survey (section 3.6).

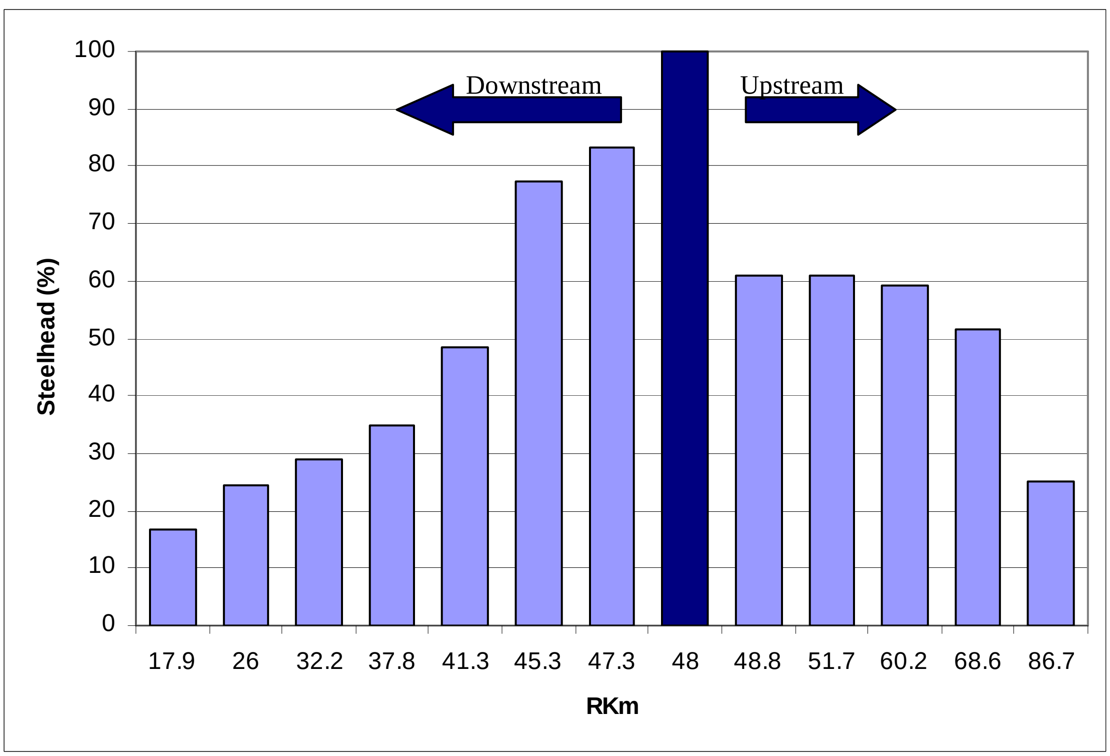

Figure 5. Apparent direction and extent of migration estimated (section 2.3.2) for returning wild Bulkley River steelhead released at the Moricetown Canyon site in 2009 (Rkm 48 – dark blue). Estimates are corrected between RKm 26-68.6 using method 2 (section 2.3.3); data for the most distant upstream and downstream sites cannot be corrected owing to the lack of information from more distant locations. Two tags were lost during recapture and therefore n is adjusted to 64 above the release site.

Table 3. Cummulative tagged adult steelhead travelling upriver and downriver from tagging site on the Bulkley River 2009. Number of fish represents all unique ID codes detected at a specific receiver and beyond. Distances specified as river kilometres (RKm) from the Bulkley-Skeena confluence. Receivers with additional bracketed distances were moved during the study period. Two tags were lost during recapture and therefore n is adjusted to 64 above the release site.

A) Downriver movement (drop back)

Location	River Km	Number of fish	Percent
Release site	***RKm48***	*66*	100
Receiver 7	RKm47.3	55	83
Receiver 6	RKm45.3 (45.9)	51	77
Receiver 5	RKm41.3	32	48
Receiver 4	RKm37.8	23	35
Receiver 3	RKm32.2	19	29
Receiver 2	RKm26.0	16	24
Receiver 1	RKm17.9	11	17

B) Upriver movement

Location	River Km	Number of fish	Percent
Release site	***RKm48***	*64*	100
Receiver 8	RKm48.8	39	61
Receiver 9	RKm51.7	39	61
Receiver 10	RKm60.2	38	59
Receiver 11	RKm68.6	33	52
Receiver 12	RKm86.7 (87.7)	16*	25

*Receiver 12 was intermittently in and out of water during the study.

3.4 Detection Efficiency

The detection efficiency of each site was calculated using the ratio of fish detected at each line (m_i) divided by the total number known to have passed the site (m_i plus the number missed at the line but detected later z_i (Jolly 1982)).

The detection efficiency estimates for the steelhead captured and released at Moricetown were high (100%) for RKm 32.2 and 68.6 (Table 4). The high detection efficiency at RKm 68.6 might be biased as the calculation is based on only one receiver further upstream (RKm 86.7) and this receiver was intermittently out of the water during the study period. Receivers 1, 2, 12 and possibly 6 were out of water at some point during the 2009 study either because of physical removal or dropping river levels. Detection efficiency cannot be estimated for the most distant receivers (1 and 12) but the detection efficiency for Receiver 2 and 6 are lower than expected under normal conditions. The receiver at RKm 48.8, immediately above the canyon, was probably located in an acoustically poor environment (detection efficiency 36%).

Table 4. Estimated detection efficiency (*pi*) of the 2009 Bulkey River array for returning adult wild steelhead released at Moricetown. Number of fish detected at site i: m_i; Number of fish missed at site i: z_i; Number of fish detected both at and beyond site i: r_i; Detection Efficiency: p_i; NA: not applicable.

Sub-array number	Location	m_i	z_i	r_i	p_i
1+	**RKm17.9**	11	NA	NA	NA
2+	**RKm26.0**	15	8	3	32%
3	**RKm32.2**	19	0	13	100%
4	**RKm37.8**	20	3	16	84%
5	**RKm41.3**	32	1	23	96%
6+	**RKm45.3 (45.9)**	41	9	19	68%
7	**RKm47.3**	33	22	29	57%
8	**RKm48.8**	14	25	14	36%
9	**RKm51.7**	19	20	18	47%
10	**RKm60.2**	21	17	16	49%
11	**RKm68.6**	33	0	16	100%
12*	**RKm86.7 (87.7)**	16	NA	NA	NA

*Receiver 12 was intermittently in and out of water during the study period.

+Receivers 1, 2 and possibly 6 were out of the water during the study period.

3.5 In-River Movements

Most (83%) of the returning adult steelhead tagged at Moricetown Canyon in 2009 dropped downstream after release. It is not unexpected that newly released fish would either swim downstream to regain stamina before attempting again to pass up through the fast moving canyon or were carried downstream by the current while re-orienting itself post-tagging. In 2008, the first receiver downstream of the canyon was located 11 km below the tagging site. The 2009 study saw receivers deployed in a much tighter fashion to finely evaluate the nature of any milling that occurred and accordingly the first receiver was located only 0.7 km downstream of the tagging site. The 2009 drop back rate accounted for 83%, but more significantly: 36% of all tagged fish were only detected on downstream receivers – none of which were ever detected above the canyon past the dip-net site (Table 5). As two of these fish (3%) lost their tags during recapture at the dip-net site, 33% are believed to have remained resident below the recapture site. 2008 and 2009 data is compared in section 3.5.5.

Once above the canyon, most fish travelled swiftly upstream. Only three fish were observed above the canyon and subsequently turned downstream (Tag ID codes: 24510, 23906 and 23809); these fish are described in detail in section 3.5.2. A total of 62 percent of the tagged steelhead travelled through the canyon (including the 3% accounted for by tag loss at the recapture site) and 52% reached Receiver 11.

Table 5. Overview of tags applied and their migratory fate in relation to the tagging site at the Moricetown Canyon. Beach seine and dip-net tagging are treated together owing their close proximity.

	Count	Percent
Total number of tags applied (beach seine: 56; dip net: 10)	66	100
Number of tags not detected	3	5
Number of tags only detected upstream	8	12
Number of tags only detected downstream*	22	33
Number of tags only detected on downstream receivers but which were lost at the recapture site during upstream migration.	2	3
Number of tags detected both up and down stream*	31	47

*Excludes two tags lost a recapture site

3.5.1 Moricetown steelhead migrating after end of recapture effort.

Tagging continued at the beach seine site until September 24 and operations at the dip-net site, ~300m upstream, continued until 1 October 2009. Four fish (6%) travelled up through the canyon past the capture locations used for the mark-recapture study around or after the termination date of the mark-recapture study (Figure 6). Of these four fish, two passed through the canyon after the termination of recapture efforts, while two passed through the canyon during a time period that included both active recapture efforts and a period after the mark-recapture study ended. These 2 to 4 fish would not have been exposed to recapture efforts.

1) Fish ID 23847:

The fish was tagged on September 8. After release, the fish dropped back to Receiver 3 (15.8 RKm below the release site) by September 18 and then turned upstream, remaining in the area between Receivers 5 and 6 (2.7-6.7 Rkm below the release site) from September 24 – October 21. On October 22, the fish was detected immediately below the tagging site (Receiver 7). It then travelled up through the canyon, past the dip-net site, between October 22 and 25, 44-46 days after tagging. This steelhead was last detected on Receiver 9 on the October 25.

2) Fish ID 23852:

Tagged on September 8, the steelhead dropped back to receiver 3 (15.8 Rkm below the release site) and then resumed upstream migration. Below the canyon, this fish ID was last detected on receiver #5 (6.7 Rkm below the release site) on September 24. The tag ID was detected again on October 31 above the canyon, but only on receiver #11 (20.6 RKm above the release site: 18 detections). It is possible that the fish was simply not detected swimming past any of the 5 receivers in between, but unlikely; other modes of transport of the tag/fish might be considered (such as fishing or predation and passing of tag by non-aquatic animals). This fish would have passed through the canyon, past the dip-net site, around October 2 ca. 23 days after tagging if we assume a constant travel speed.

3) Fish ID 24512:

Tagged on September 24, the steelhead remained below the canyon in the area of Receivers 6 and 7 (0.7-2.7 Rkm below release site) for at least 3¼ days after tagging (until September 28) and was then detected on Receiver 9 (3.7 Rkm above the release site) on October 7: 12 days, 7 hours after tagging. Above the canyon, this fish travelled upstream slowly and was last detected on Receiver 11 on November 5; at the observed mean rate of movement this fish would have passed through the canyon sometime between September 28 and October 7.

4) Fish ID 24511:

Tagged on September 24, this steelhead remained in the area below the canyon (Receiver 5, 6 and 7, 0.7-2.7 RKm below the release site) for at least 4½ days. It was not detected on Receiver 8 (0.8 RKm above the release site), and first picked up on Receiver 9 (3.7 RKm above the release site) on October 3 (8½ days after tagging). This fish likely would have passed through the canyon between September 29 and October 3.

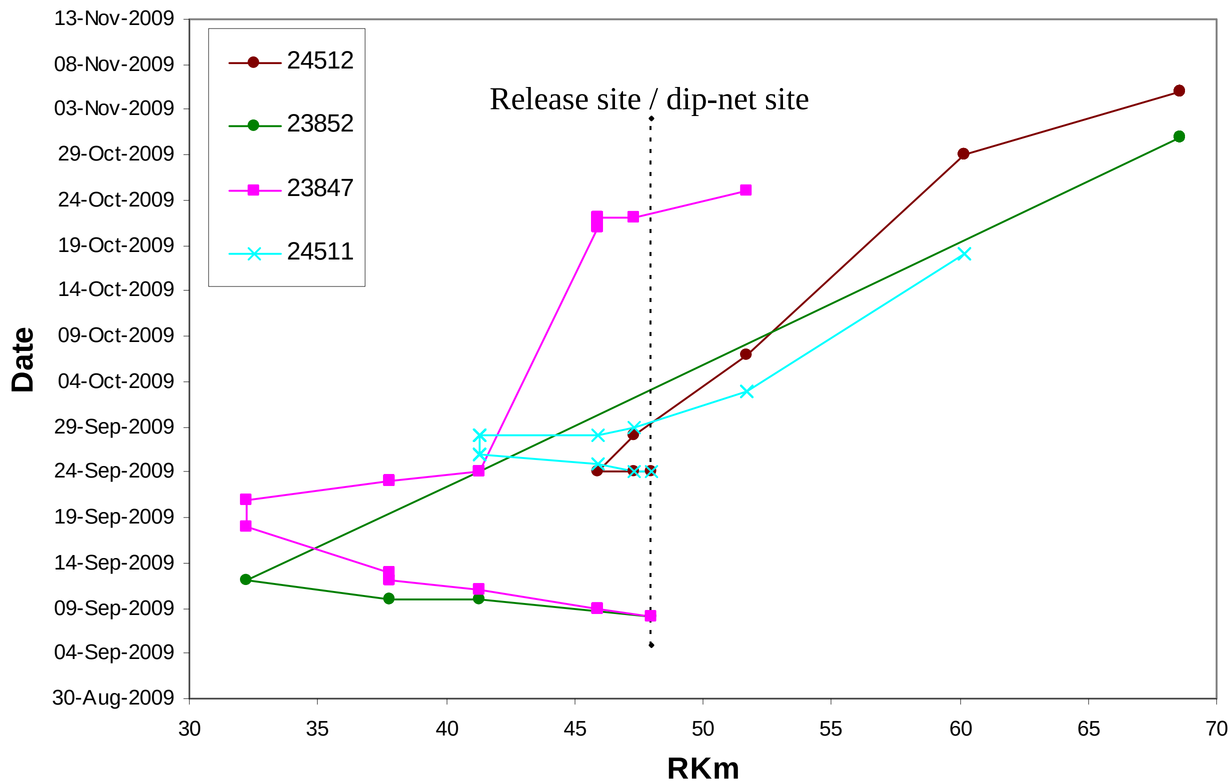

Figure 6. Detailed view of adult steelhead movement through the Moricetown Canyon, past the recapture site, around the termination time of recapture efforts.

3.5.2 Steelhead migrating back downstream through the Moricetown Canyon.

Of the 55 steelhead migrating up through the Moricetown Canyon in 2009, three were observed turning around and coming back down through or towards the canyon (Figure 7). However, only one (1.5%) came past the tagging site while capture operations were still active.

1) Fish ID 24510:

Tagged and released on September 23. This steelhead dropped back to Receiver 6 (2.7 Rkm below the release site), then rapidly migrated upstream reaching receiver #12 (39.7 Rkm above the release site) before starting an equally rapid downstream transit. This fish went through the canyon after termination of the mark-recapture study.

2) Fish ID 23809:

Tagged and released on August 21 - this fish dropped back to Receiver 6 (2.7 Rkm below the release site) and then travelled upstream to Receiver 12 (39.7 Rkm above the release site) before turning around and was last detected on Receiver 10 (12.2 Rkm above the release site) and as such did not pass through the canyon again.

3) Fish ID 23906:

Tagged and released on August 11 - this fish migrated all the way downstream to Receiver 1 (30.1 Rkm below release site) before reinitiating upstream migration. Upstream migration to Receiver 11 (20.6 Rkm above release site) was relatively quick with no milling detected (~50 Rkm from August 14 to 19). After turning around and returning downstream, the fish came through the Moricetown Canyon between August 23 and 24 while beach seining was still occurring.

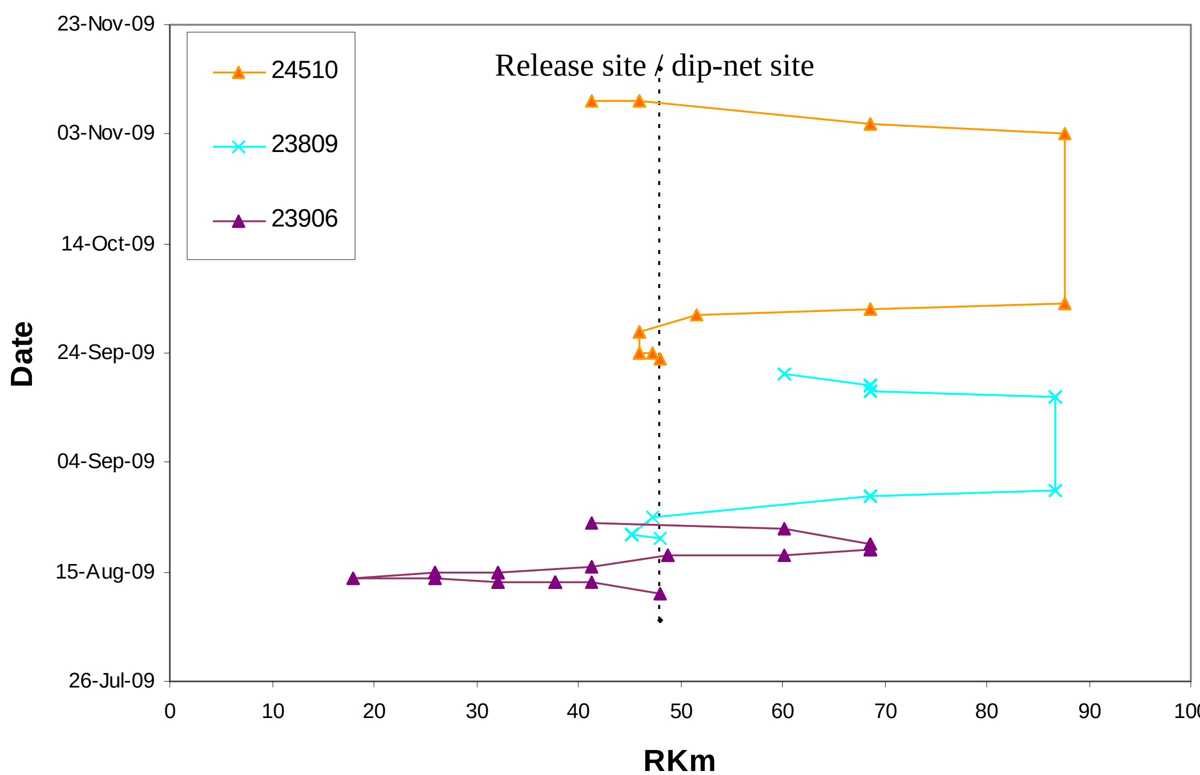

Figure 7. Detailed movement of 2009 adult steelhead which migrated up through the Moricetown Canyon and then subsequently went back down through the canyon.

3.5.3 Immediate upstream movement.

Only 8 of 66 fish (12%) were observed migrating upstream without any detected drop back (Figure 8). This is significantly different from the number reported in 2008 where 82% were reported as traveling upstream in a uni-directional fashion post-tagging – this difference is mostly due to the greater distance between the first downstream receiver in 2008 (Rkm 37; 11 km below release site) and the location of the first downstream receiver in 2009 (Rkm 47.3; 0.7 km below release site). A direct comparison between 2008 and 2009 can be found in section 3.5.5. In 2009, fish were tagged in two different locations (beach seine: 56 fish; dip-net: 10 fish) whereas all 2008 fish were tagged at the beach seine site location below the falls. The 2008 to 2009 difference in the number of tagged steelhead that immediately travelled upstream after release becomes even more marked if the 2009 data are restricted to only include steelhead released at the beach seine location; this lowers the 2009 number further from 8 to 5 fish (7.5%). It is possible that these 5 steelhead, tagged and released at the beach seine, either held at or near the tagging site prior to resuming their upstream migration.

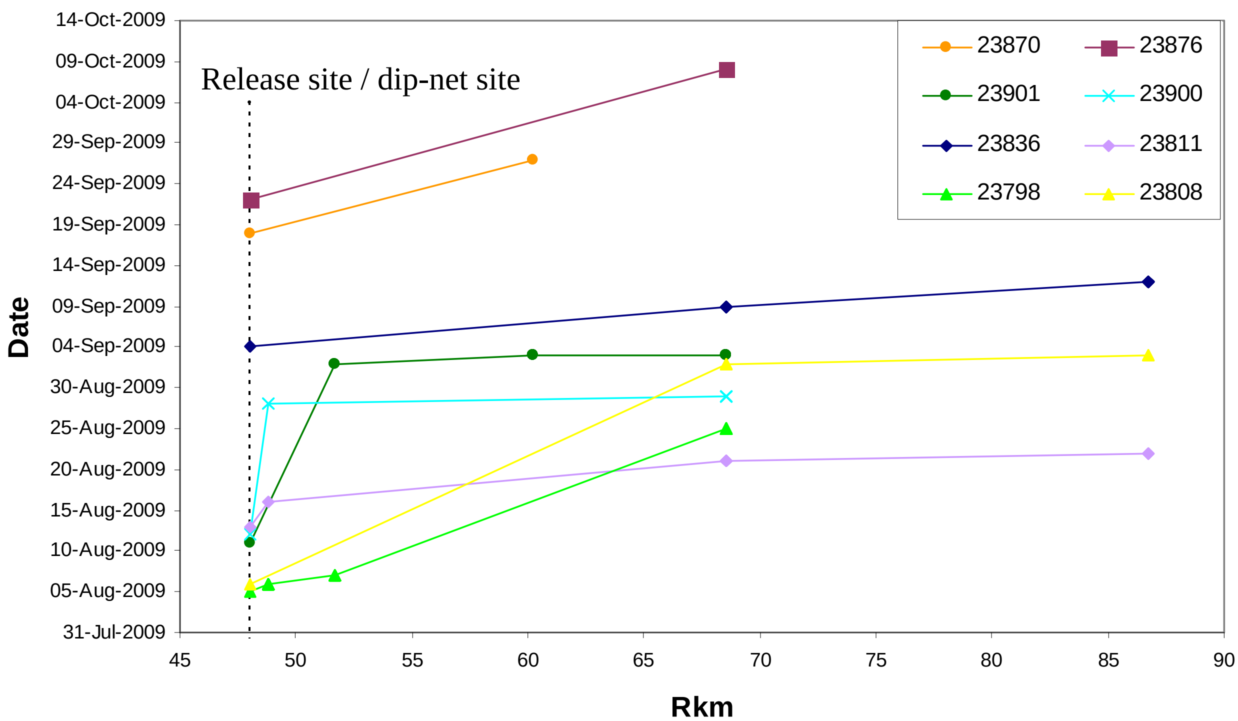

Figure 8. Bulkley River fish observed swimming upstream in a single direction after release.

3.5.4 Resident steelhead.

One of the large unknowns in mark-recapture studies is the behavioural changes that may result from handling and tagging. During the 2009 Bulkley River study, a large proportion (83%) of steelhead were identified as dropping back downstream following treatment, and it is unknown if untreated fish would exhibit the same behaviour. A perhaps more significant observation in 2009 is the number of steelhead which remained resident below the recapture site following tagging, thereby effectively excluding themselves from the possibility of recapture. In 2009, 24 tagged fish were not detected on any acoustic receivers above the Moricetown Canyon, but two of these were recaptured at the dip-net site and lost their tags. 22 (33%) of the tagged fish did not travel upstream through the canyon and several of these disappeared downstream fairly quickly after release (Figure 9). Time from release to last detection for these 22 steelhead is shown in Figure 10 and the final receiver they were detected on can be seen in Table 6. It is not possible to know if these fish died or if they simply decided to hold downstream – but it is certain that whatever their specific fate, they were removed from the potential recapture pool following tagging.

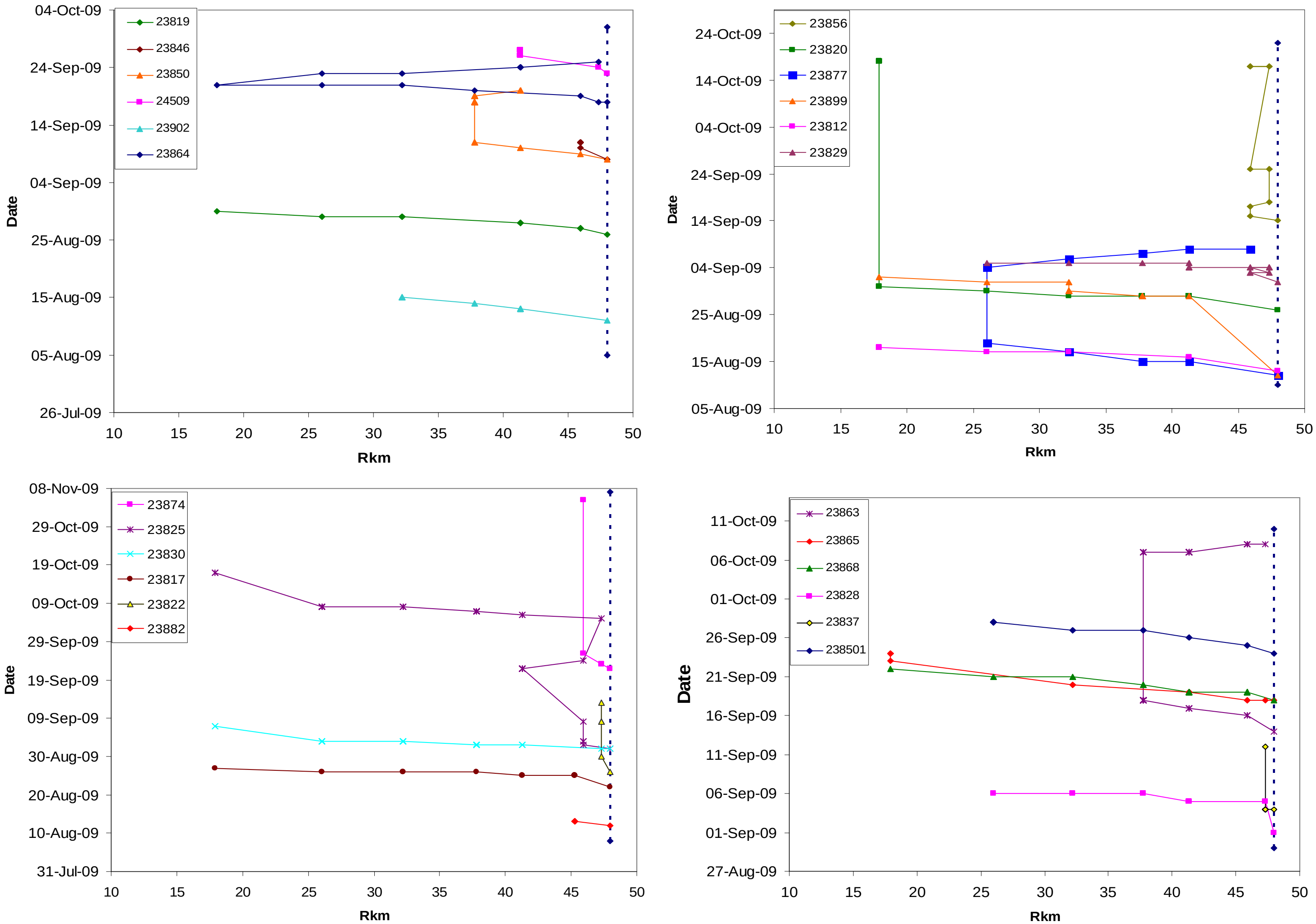

Figure 9. Detailed movement of the 22 steelhead which only travelled downstream from the Moricetown Canyon after tagging event in 2009 and the two fish that lost their tags at the recapture site prior to upstream migration past the canyon (23850 and 23864). Blue dotted line indicates release site.

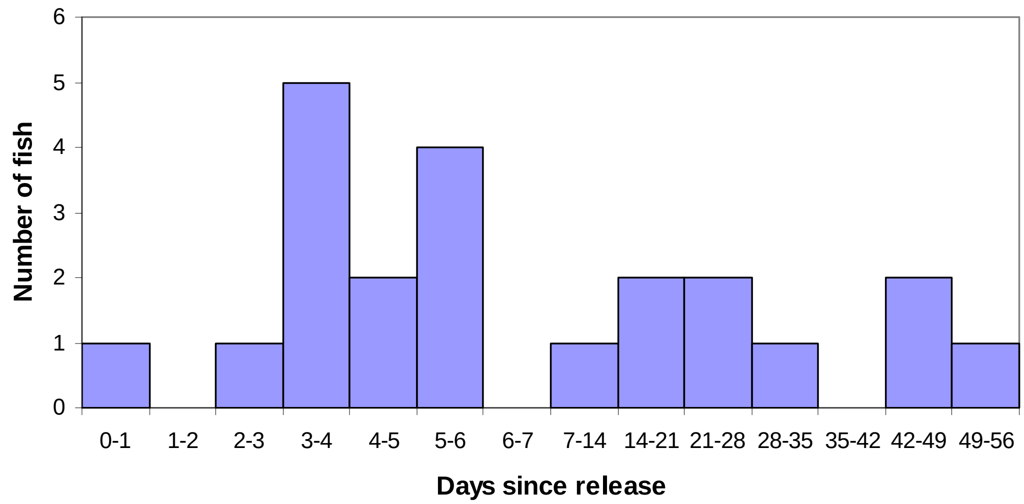

Figure 10. Time to last detection for the 22 steelhead only observed travelling downstream from the Moricetown Canyon following tagging in 2009.

Table 6. Location of final detection for the n=22 2009 steelhead which remained downstream of the Moricetown Canyon following release (excludes two fish that were not detected on upstream receivers but lost their tags during recapture).

Station #	Bulkley Rkm	Number of fish with final detection at receiver
Receiver 1	17.92	9
Receiver 2	26.03	4
Receiver 3	32.24	0
Receiver 4	37.77	0
Receiver 5	41.3	1
Receiver 6	45.28	4
Receiver 7	47.33	4

3.5.5 Comparison of the 2008 and 2009 Bulkley River drop back rates.

The 2009 Moricetown study was designed with a dense telemetry array situated around the Moricetown Canyon. Twelve acoustic receivers were positioned (7 below the release site and 5 above), with the goal of refining information on the drop back rates observed in 2008. In 2008, only three acoustic receivers were in place below the canyon (Table 7; Figure 11).

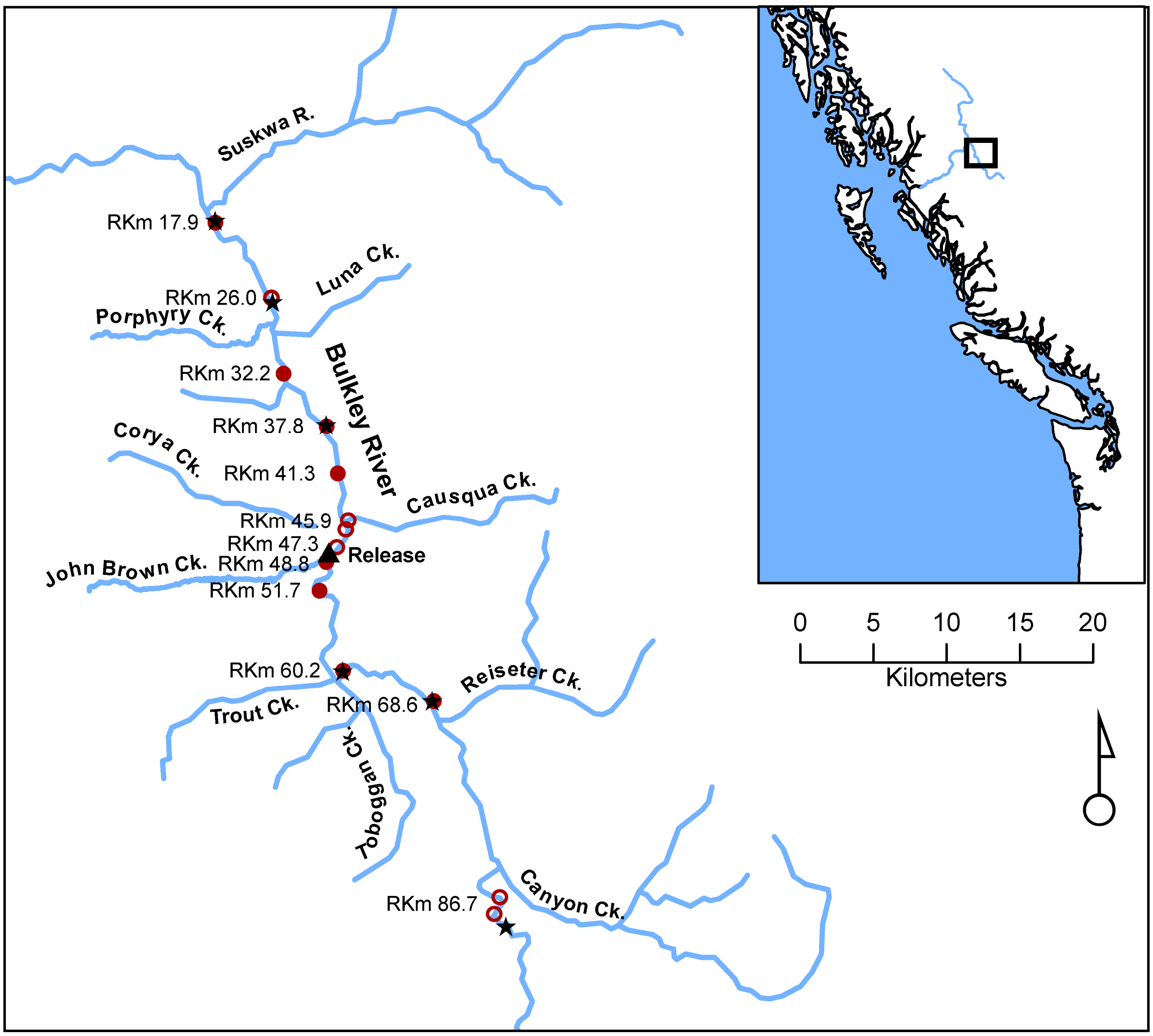

Figure 11. Map of Bulkley River acoustic receivers in 2009 (red dots with Rkm) and 2008 (black stars). Unfilled red dots indicate a receiver which was either moved or re-deployed during the study period.

The drop back rate reported from the beach seine site in 2008 was 18% (9 of 50 fish) and only 5 of these fish (56%) were subsequently detected above Moricetown Canyon. To have been counted as a fish that dropped back in 2008 required downstream travel of at least 11 km (to Rkm37). It is quite possible that the number of actual drop backs in 2008 was significantly higher but went unnoticed if the fish resumed their upstream migration prior to reaching the first downstream receiver at Rkm37.

The drop back rate for the 2009 study was 83% (Table 5) but a fish was only required to travel 0.7km downstream in order to be detected and listed as a drop back. To compare the studies it is necessary to evaluate the location of the receivers between the two years and use the location match of a 2009 receiver to the first downstream receiver in 2008. As can be seen in Table 7, the best fit is Receiver 4 located at Rkm37.8, approximately 800 meters below the 2008 site. The drop back rate to this location in 2009 was 35% (Table 3) which is still substantially higher than the 18% seen in 2008. However, to allow direct comparison all fish should have the same treatment among years. In 2008 all adult steelhead were tagged at the beach seine site. In 2009, ten fish were tagged at the dip-net site above the canyon. Of these ten, three were part of the fish going downstream and passing Rkm37.8. Excluding the ten fish tagged at the dip-net site such that the 2009 data includes only the beach seined fish yields a drop back rate of 36% (20 fish of 56 tagged), almost identical to the rate calculated including the dip-net caught steelhead.

The interpretation of the results of the acoustic study for the mark-recapture study at Moricetown Canyon depends upon the assumptions that are made concerning fish movements after tagging (see SKR 2008).

Table 7. The location of 2009 and 2008 detection sites.

2009		2008	
Location	RKm	Location	RKm
Receiver 1	RKm17.9	Receiver 1	RKm19
Receiver 2	RKm26.0	Receiver 2	RKm27
Receiver 3	RKm32.2		
Receiver 4	RKm37.8	Receiver 3	RKm37
Receiver 5	RKm41.3		
Receiver 6	RKm45.3 (45.9)		
Receiver 7	RKm47.3		
Tagging site	RKm48	Tagging site	RKm48
Receiver 8	RKm48.8		
Receiver 9	RKm51.7		
Receiver 10	RKm60.2	Receiver 4	RKm59
Receiver 11	RKm68.6	Receiver 5	RKm66
Receiver 12	RKm86.7 (87.7)	Receiver 6	RKm86

3.5.2 Travel rate to specific point of interest – release to above Moricetown Canyon.

Each year, the possibility exists for tagged steelhead to move upstream of the Moricetown Canyon mark-recapture study site after the recapture effort (dip-netting) is terminated, and consideration to the timeline of termination of both tagging and recapture efforts is given yearly. In 2009, the last tag was applied September 24 and dip-netting continued for a week until October 1. Between 2 and 4 steelhead (3-6% of the total released) were detected above the canyon after the termination of the recapture effort. If the proportion of tagged animals not available for subsequent recapture is significant, and not adjusted for, then population estimates will potentially be too high.

Rather than establishing a general travel rate for the tagged 2009 Bulkley River fish (as in 2008), we decided, in agreement with MoE, that identifying travel rate to a specific point of interest may have more practical value. Therefore the data was analyzed to establish the time from release to time first detected above the Moricetown Canyon to get an estimate of the number of days Bulkley River steelhead take from release to passage through the canyon, past the dip-net site (Figure 12). The average travel time from release to above canyon is 13.5 days (range: 0.9-52.5 days). For the presentation of the travel time distribution data (Figure 12), we do not distinguished which receiver the fish were first detected on; that is, if a fish was missed on Receiver 8 and 9 and first detected on Receiver 10 no attempts were made to extrapolate time of travel to the first receiver above the canyon (Receiver 8) in order to standardize. As such, the time from release to first detection above the canyon will be exaggerated for fish missed on the lower receivers – however, as can be seen in Figure 8, once above the canyon fish tended to migrate upstream quickly.

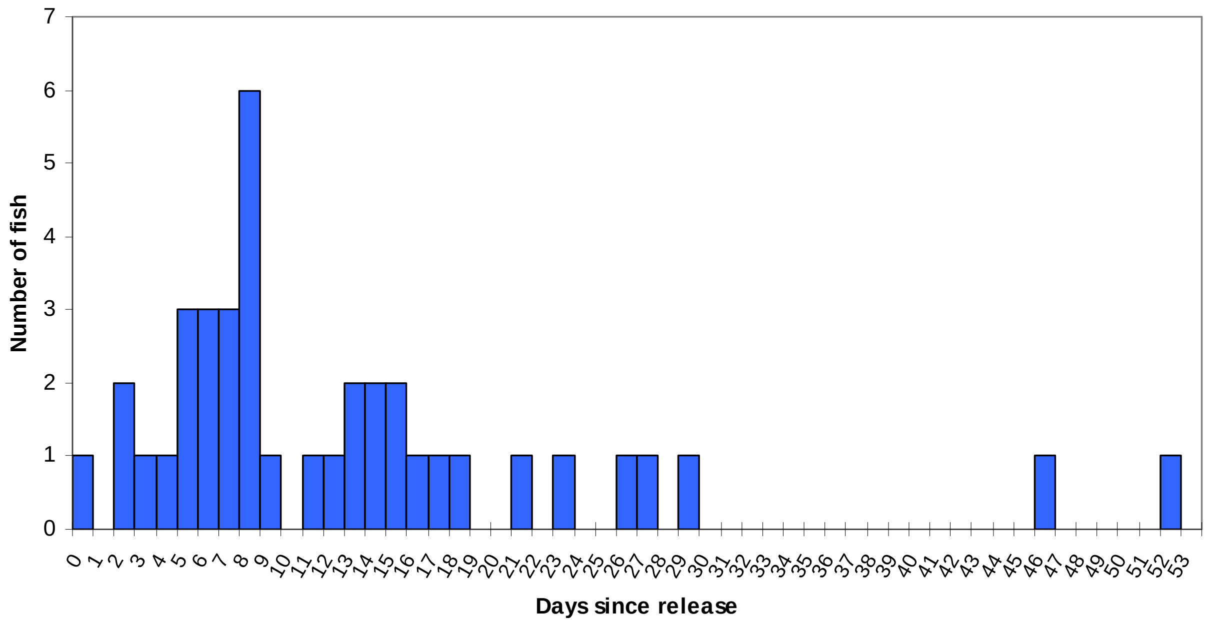

Figure 12. Elapsed time from release to first detection above the Moricetown Canyon. No new fish were observed above the canyon between day 30 and 46 post-release (n=39).

3.6 Mobile Acoustic Survey.

A river survey was done in the Bulkley River at the time of receiver recovery in early November 2009 in order to find acoustic tags located within or immediately above the study area. The survey was done using an omni-directional Vemco VR100 hydrophone which decodes the tag IDs and allows the user to hear the pinging of the transmitting tags.

Most sites were surveyed using a river boat and other areas were accessed by foot. Where possible, the boat was anchored while listening for tags, but in areas where flows were too fast for the anchor to hold the boat, drift surveys were done (Figure 13). During the acoustic survey of the river, seven individual tags were detected, four of which were recorded at the beach seine/tagging location. These seven tags are summarized below.

1) Fish ID 23882: Tag was detected multiple times at the tagging site (beach seine) during survey. It was heard on the Bulkley array (Receiver 6 only, 2.7 Rkm below release site) following tagging and it was last detected one day after tagging.

2) Fish ID 23818: Tag was detected multiple times at the tagging site (beach seine) within a very narrow spatial range during the survey. This tag code was never detected on any receivers within the Bulkley array.

3) Fish ID 23856: Tag was detected multiple times at the tagging site (beach seine) during the survey. This fish had dropped back to Receiver 6 and was observed moving back and forth between Receivers 6 and 7 over a 33 period post tagging. It was last detected on Receiver 7 on Oct 17.

4) Fish ID 24570: Tag was detected once only at the tagging site (beach seine) during the river survey. This is not a valid Bulkley River tag code and probably is a false positive detection resulting from tag collisions.

5) Fish ID 23875: Tag detected multiple times at a location upstream of Receiver 10 during the river survey. This tag had initially dropped back to Receiver 6A before turning upstream. It was detected on Receivers 8, 9 and 10. It was first heard above canyon 15 days post tagging on Receiver 8.

6) Fish ID 23847: At the time of survey this tag was detected multiple times approximately one Rkm below the location of Receiver 11. This fish initially dropped all the way back to Receiver 3 before returning upstream (detected on Receivers: 6A, 5, 4, 3, 4, 5, 6A, 7 and 9). It was first detected above the canyon 17 days post release (Receiver 9).
Last detection on array was on Receiver 9 on October 25.

7) Fish ID 23844: Tag was detected multiple times above the study area. This area was investigated while drifting in the boat and the tag ID was decoded during most of the drift. After tagging, this fish initially dropped back to Receiver 3 before turning upstream (detected on Receivers: 6A, 5, 4, 3, 5, 6A, 7, 9, 10, 11, 12A). It was first detected above the canyon 15 days post tagging (Receiver 9).

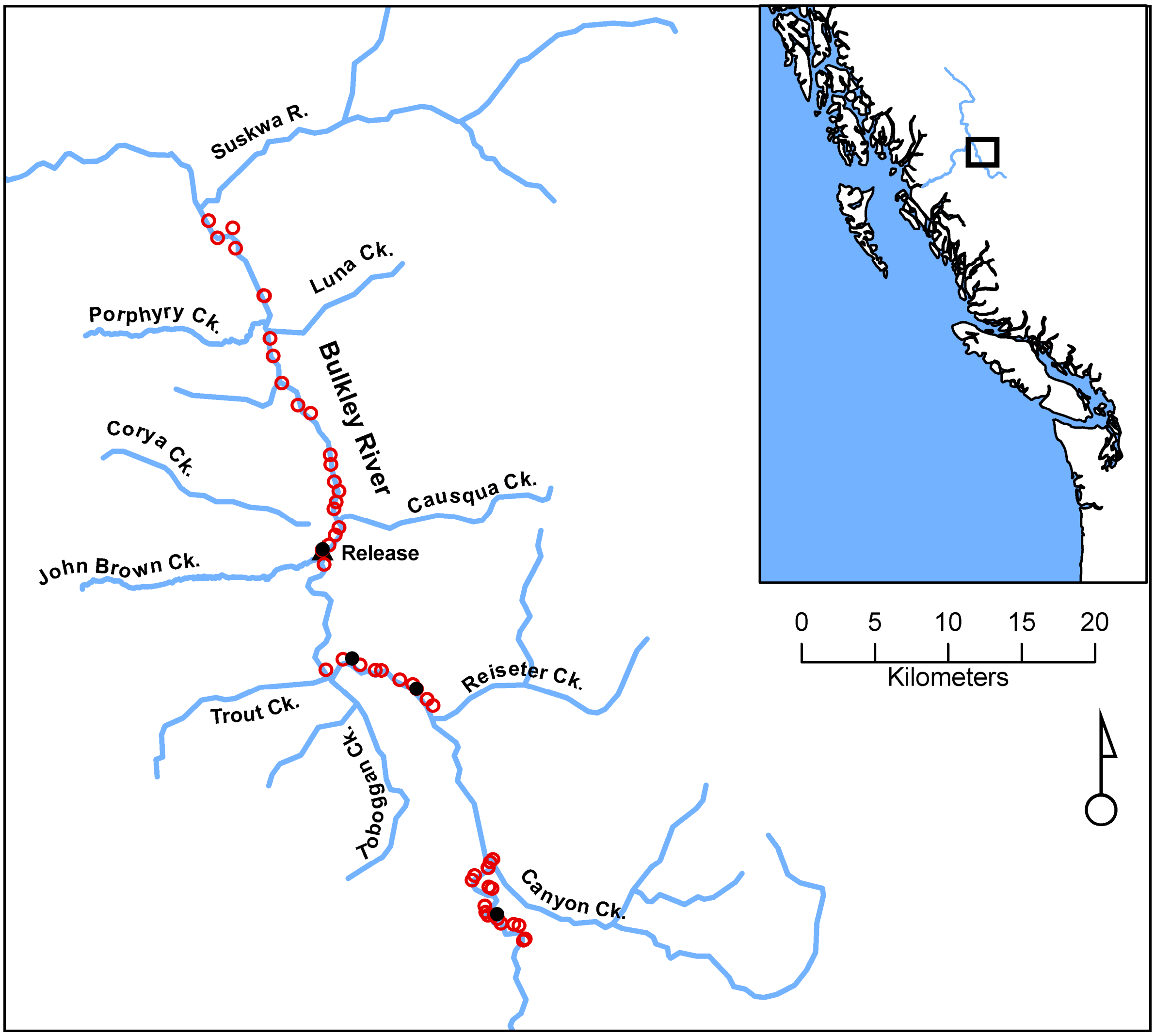

Figure 13. Locations of acoustic surveys at the termination of the Bulkley River project in 2009. Red circles indicate areas of survey and black dots indicate the sites where tags were detected.

3.7 Animation of Steelhead Movements.

To show in-river movements of the 2009 tagged steelhead, a computer animation was generated using MatLab. Tag detection data were retrieved from the database, screened for false detections, and then used to establish in-river rates of movement for each animal based on the recorded time of detection on each receiver and the in-river distance between receivers.

The animation allows a clear visual assessment of the pattern and speed of movement of the Moricetown Canyon adult steelhead releases over time. A copy of the animation has been provided to MoE and can also be obtained by contacting Kintama Research Corporation.

3.8 Potential Impact on Mark-Recapture estimates.

In 2009, 41 of 66 tagged steelhead went upstream past the recapture site (includes the two fish which lost their tags at the recapture site). Of these 41 tagged fish, 2 to 4 passed after the termination of the recapture effort. Tagged fish that were harvested (1) are ignored in the mark-recapture study. This means that between 37-39 (56-59%) of tagged steelhead were potentially available to recapture during the 2009 mark-recapture study.

Calculating the adjusted Petersen estimate using the tentative 2009 mark-recapture data and the travel data from the acoustic study in 2009, yields the following abundance estimates:

Adjusted Petersen estimate:

$N = (M+1)(C+1) / (R + 1)$

Where,

N = Size of population at time of marking

M = Number of fish marked

C = catch or sample taken for census

R = number of recapture marks in the sample

In 2009, 1366 fish were marked at the beach seine site; we corrected the number of fish tagged and available for recapture (M) according to the proportion of fish which travelled upstream in 2009. The estimated number migrating upstream during the mark-recapture study yields (C=2169, R=123):

a) M = 765 (56%); implying an abundance estimate of only 13,405.

b) M = 806 (59%); yields an abundance estimate of 14,123.

Of the 66 fish that were tagged in 2009, three were not detected on any receivers. If these fish were omitted from the study, thereby lowering the number of fish tagged to 63 and increasing the number of fish available to recapture (M) to between 806 – 847.

Of the 66 fish tagged in 2009, three were not subsequently detected by any of the fixed receivers. If these fish are excluded from the analysis, thereby lowering the number of fish tagged to 63, the result is to increase the proportion of tagged steelhead moving upstream by 3% (to 59-62% from 56-59%). This changes the number of fish available to recapture (M), and therefore the upstream population abundance estimates, to:

c) M = 806 (59%); implying an abundance estimate of 14,123.

d) M = 847 (62%); implying an abundance estimate of 14,840.

Calculating the abundance estimate without correction for the acoustic data yields an abundance estimate of 23,922 steelhead. Taking into account the proportion of acoustically tagged steelhead migrating upstream changes this estimate to 13,405-14,123, while excluding the 3 tagged steelhead unaccounted for by the array increases this estimate to 14,123-14,840 (a 3% increase).

4.0 Discussion

In July 2009, an acoustic study was initiated in conjunction with the annual adult steelhead mark-recapture study at Moricetown Canyon on the Bulkley River, BC. The acoustic technology was used to access the behaviour of the returning adult steelhead after tagging to provide data to help refine the yearly abundance estimates produced by the mark-recapture program. Acoustic receivers were deployed at seven locations downstream of the Moricetown Canyon release site and five receivers were deployed above. The primary focus was to address the drop-back rate of tagged fish. From August 5 until September 24, 2009, a total of 67 adult steelhead were caught at two locations by Wet'suwet'en Fisheries and tagged by SKR consulting. Fifty-seven were tagged at the beach seine site immediately below the canyon and 10 were tagged at the recapture site/dip-net site located at the top of the canyon, approximately 300m upstream. Subsequently one of the fish tagged at the beach seine was excluded from the study as it was harvested (as per mark-recapture protocol). All fish were tagged externally, below the dorsal fin with a Vemco V9 acoustic tag.

All twelve receivers were recovered and successfully uploaded in early November 2009. The units contained a total of 38,808 detections from 63 of 66 tagged steelhead. The majority of tagged fish eventually moved upstream (62%) but significant delays were observed in passage times through the canyon following tagging and release. The average delay in passing Moricetown Canyon was 13.5 days (range: 0.9-52.5 days). Although some steelhead migrated upstream immediately following tagging (12%), the majority initially moved back downstream of the release site (83% of total tagged). A total of 33% of the released steelhead failed to migrate upstream following release during the study period; it is not clear to what degree this represents tagging-induced mortality or failure to migrate (either by choosing downriver migration or holding in-river). The evidence that a significant fraction of captured steelhead may not move upstream following release may have significant implications for the interpretation of the mark-recapture data collected from the Moricetown site, as a significant non-migratory component to the tagged population could bias population abundance estimates high.

In 2008, only steelhead that moved at least 11 km downstream of tagging site could be identified as "drop backs" and the 2008 study reported drop-back rate was 18%. The 2009 receiver equivalent to the location of the first downstream receiver in 2008 is at Rkm37.8 – this receiver recorded a total drop-back rate of 35% (36% if excluding steelhead tagged at the dip-net site). The total drop back for the 2009 study is 83% with the first receiver was located approximately 0.7km below the beach seine site. If this drop-back behaviour was caused by the capture or tagging process, as opposed to it being a natural occurrence ("milling") then there is significant potential to overestimate the abundance of Bulkley River steelhead, as well as expose the steelhead to repeated capture and handling at the beach seine site. If the fish initially caught at the Moricetown seine site hold at some position downstream of the canyon after release rather than continuing to migrate upstream (as assumed) then the recapture site at the head of the canyon cannot capture them and abundance estimates for the steelhead population above Moricetown Canyon will be skewed high.

Travel estimates are most appropriately called "apparent travel" because it is not possible to distinguish mortality from over-wintering in the mainstream or emigration into river tributaries. However, none of the tributaries within the current array configuration are believed to be suitable fore over-wintering steelhead as significant lake/canyons must be present within the tributaries for summer/fall immigration to occur. As the acoustic tags can be programmed to operate for multiple years, the possibility exists to monitor movements and survival of adult steelhead during the downriver migration the following spring, as well as the spawning migrations in the subsequent years.

Some of the key assumptions necessary for telemetry studies of this type to be valid are that tags are not lost and that neither the tags themselves nor the tagging process affect the fish. While we have no direct data, a previous study using externally attached tags suggests an approximate tag loss of 5% (SKR Consultants 2008). That study did not attempt to measure whether mortality occurred due to handling. Our results should be interpreted with the understanding that tag effects may result in underestimates of the extent of migration in the general population.

The implications of this study for the yearly mark-recapture studies done at the Moricetown Canyon can be quite significant as many tagged fish failed to migrate upstream past the recapture site. Three fish (5%) were not detected; this would agree with the assumed 5% tag loss used in the mark-recapture studies. A large proportion of fish, 22 of 66 (33%), remained below the recapture and some fish (3-6%) passed the recapture site after the termination of the recapture effort. This means that between 41 to 44% of the fish tagged were not available for recapture at the dip-net site. Using this data in the mark-recapture calculation yield abundance estimates that are quite different from the expected estimate without the input from the acoustic study. Incorporating the acoustic data implies an abundance estimate between 13,405 and 14,123 steelhead whereas the estimate without correction for the sonic data is 23,922 steelhead. The 2009 sonic data was quite different from the 2008 data which means that behaviour, and perhaps impacts of tagging, change from year to year depending on conditions and therefore care should be taken using the results from year on data from other years.

5.0 Recommendations

Several different avenues for future work can be identified based on the 2008 and 2009 studies:

1) There was a high variability in proportion of fish that travelled upstream following release and drop back rates in 2008 versus 2009. It is unclear to what degree the proportion of marked fish exposed to recapture efforts varies between years, and this should ideally be clarified in terms of its relevance to the mark-recapture study.
2) Acoustic tags can be programmed to operate for multiple years, so the possibility exists to monitor movements and survival of adult steelhead during the downriver migration the following spring, as well as subsequent spawning migrations in later years. To be effective, this would require both the re-deployment of a telemetry array during time periods when monitoring is desired and surgical implantation of the tags to ensure long-term tag retention. A spring deployment of an array could measure both out-migration survival of kelts and smolts and provide some important perspective on survival rates.
3) Although occasional removal of individual receivers from the river resulted in little disruption to the overall study objectives, planning for occasional site visits to verify receiver deployment would be a sensible step.

6.0 Acknowledgements

We would like to thank Mark Beere and Dean Peard for their support and advice throughout this project, and especially their assistance in redeployment of receivers. We also thank our boat operator Fred Seiler for his invaluable insight and suggestions during the deployment and recovery phases of the study.

We would also like to thank Wet'suwet'en Fisheries for their help conducting the captures and tagging of the steelhead, as well as facilitating access to some of the acoustic receivers for MoE personnel.

During both the 2009 Bulkley deployment and recovery operations, some of receivers were accessed through private properties, and in one instance through a private boat launch. The local support for this project was encouraging and we are grateful for all the assistance we encountered during this study.

7.0 References

Beacham, T.D. and M.C. Beere. 2009**.** Stock Identification of Skeena River Summer Steelhead using Microsatellite DNA Loci. Unpublished report to the Pacific Salmon Commission – Northern Panel : NF-2008-I-23. 25 pp.

Beere, M.C. 1991a. Steelhead migration behaviour and timing as evaluated from radio tagging at the Skeena River test fishery, 1989. Unpublished M.S. Skeena Fisheries Report NO. SK-69. Ministry of Environment, Lands and Parks, Smithers, B.C. 24 pp.

Beere, M.C. 1991b. Radio telemetry investigations of steelhead tagged in the lower Bulkley River,1989. Unpublished M.S. Skeena Fisheries Report #SK-70. Ministry of Environment, Lands and Parks, Smithers, B.C. 18pp.

Beere, M.C. 1991c. Radio telemetry investigations of Babine River steelhead, spring 1990. Unpublished M.S. Skeena Fisheries Report # SK 71. Ministry of Environment, Lands and Parks, Smithers, B.C. 17 pp.

Beere, M.C. 1991d. Memo to file. Re: Results of flight to Kitnayakwa River - Monitoring radio tagged steelhead, April 24, 1991. Ministry of Environment, Lands and Parks, Smithers, B.C. File No. 34560-27/ZYM/KITNAY.

Beere, M.C. 1995. Movements of summer run steelhead trout tagged with radio transmitters in the Zymoetz River during spring, 1994. Unpublished M.S. Skeena Fisheries Report #93. Ministry of Environment, Lands and Parks, Smithers, B.C. 22 pp.

Beere, M.C. 1996. Movements of summer run steelhead trout tagged with radio transmitters in the Babine River during spring, 1994. Unpublished M.S. Skeena Fisheries Report #94. Ministry of Environment, Lands and Parks, Smithers, B.C. 36 pp.

Beere, M.C. 1997. Movements of wild summer run steelhead tagged with radio transmitters in the Babine River during fall, 1994. Unpublished M.S. Skeena Fisheries Report #96. Ministry of Environment, Lands and Parks, Smithers, B.C. 42 pp.

Chittenden, C.M., S. Sura, K.G. Butterworth, K.F. Cubitt, N. Plantalech Manel-La, S. Balfry, F. Økland, and R.S. McKinley. 2008. Riverine, estuarine and marine migratory behaviour and physiology of wild and hatchery-reared coho salmon *Oncorhynchus kisutch* (Walbaum) smolts descending the Campbell River, BC, Canada. Journal of Fish Biology 72:614–628.

Chudyk, W.E. and D.W. Narver. 1976. Commercial interceptions of steelhead trout in the Skeena River: A preliminary review. B.C. Fish and Wildlife Branch. Unpublished Report. 25 pp.

Crossin, G. T., S. G. Hinch, S. J. Cooke, D. W. Welch, D. A. Patterson, S. R.M. Jones, A. G. Lotto, R. A. Leggatt, M. T. Mathes, J. M. Shrimpton, G. Van Der Kraak, and A. P. Farrell. 2008. Exposure To High Temperature Influences The Behaviour, Physiology, And Survival of Sockeye Salmon During Spawning Migration. Canadian J. Zoology 86(2):127-140

Jolly, G.M. 1982. Mark-recapture models with parameters constant in time. Biometrics 38: 301-321.

Melnychuk. M.C., D.W. Welch, C.J. Walters, and V. Christensen. 2007. Riverine and early ocean migration and mortality patterns of juvenile steelhead trout (*Oncorhynchus mykiss*) from the Cheakamus River, British Columbia. Hydrobiologia **582**: 55–65.

Natural resources Canada (NRCAN). Accessed 12 Jan 2010.

http://atlas.nrcan.gc.ca/site/english/learningresources/facts/rivers.html#pacific

Oguss, E. and L.K. Evans. 1978. Incidental catches of steelhead trout in the commercial salmon fisheries of Barkley Sound, Johnstone Strait, and the Skeena and Fraser Rivers. Fish. Mgmt. Report No. 14. British Columbia Marine Resources Branch, Victoria, B.C.

Pincock, D.G. 2008. False detections: What they are and how to remove them from detection data. Document #: DOC-004691 Version 01. Amerix Systems Inc. VEMCO Division. (http://www.vemco.com/pdf/false_detections.pdf).

SKR Consultants Ltd. and Wet'suwet'en Fisheries. 2008 Steelhead tagging project at Moricetown Canyon. Data Analysis and Recommendations.

Walters, C.J., J.A. Lichatowich, R.M. Peterman, and J.D. Reynolds. 2008. Report of the Skeena Independent Science Review panel. A report to the Canadian Department of Fisheries and Oceans and the British Columbia Ministry of the Environment. 144 pp.

Welch, D., Erin Rechisky, M. Melnychuk, A. Porter, C. Walters, S. Clements, B Clemens, R. McKinley and C. Schreck. 2008, Survival of Migrating salmon smolts in large rivers with and without dams. PLOS Biology, 6 (10).

8.0 List of Appendices

Appendix 1. Summary of the detections in the Bulkley River.

Appendix 1. Summary of detections of adult, wild steelhead heard on the acoustic array in the Bulkley River 2009.

Tag code	Bulkley 1			Bulkley 2			Bulkley 2A			Bulkley 3		
								Date detected			Date detected	
	Num	First	Last	Num	First	Last	Num	First	Last	Num	First	Last
23798												
23807												
23808												
23809												
23810												
23811												
23812	9	18-Aug 03:19	18:Aug 03:27	1	17:Aug 22:30	17:Aug 22:30				2	17:Aug 15:07	17:Aug 15:09
23813												
23815												
23816												
23817	1	27-Aug 15:39	27:Aug 15:39	1	26:Aug 10:34	26:Aug 10:34				2	26:Aug 04:58	26:Aug 04:59
23819	1	30-Aug 07:13	30:Aug 07:13				2	29:Aug 18:48	29-Aug 18:48	3	29:Aug 14:33	29:Aug 14:34
23820	779	31-Aug 04:37	18:Oct 15:09				7	30:Aug 01:51	30-Aug 02:19	1	29:Aug 14:27	29:Aug 14:27
23822												
23824												
23825	3	17-Oct 10:35	17:Oct 10:36				103	08:Oct 11:42	08-Oct 19:37	5	08:Oct 05:09	08:Oct 05:11
23826												
23828							3	06:Sep 20:09	06-Sep 20:11	4	06:Sep 13:53	06:Sep 13:57
23829							1	05:Sep 18:56	05-Sep 18:56	1	05:Sep 17:56	05:Sep 17:56
23830	2	07-Sep 02:52	07:Sep 02:53				10	03:Sep 13:57	03-Sep 14:07	11	03:Sep 05:26	03:Sep 07:41
23831												
23836												
23837												
23842												
23844										8	08:Sep 01:22	15:Sep 21:37
23845												
23846												
23847										3	18:Sep 14:46	21:Sep 01:30
23850												
23851												
23852										1	12:Sep 04:12	12:Sep 04:12
23856												

Appendix 1. Summary of detections of adult, wild steelhead heard on the acoustic array in the Bulkley River 2009.

Tag code	Bulkley 1			Bulkley 2			Bulkley 2A			Bulkley 3		
								Date detected			Date detected	
	Num	First	Last	Num	First	Last	Num	First	Last	Num	First	Last
23857												
23859												
23862												
23863												
23864	1	21-Sep 22:05	21:Sep 22:05				2	21:Sep 20:36	23-Sep 16:16	2	21:Sep 19:31	23:Sep 23:13
23865	4	23-Sep 00:29	24:Sep 13:09							2	20:Sep 13:34	20:Sep 13:35
23868	1	22-Sep 10:05	22:Sep 10:05				2	21:Sep 21:25	21-Sep 21:26	2	21:Sep 15:15	21:Sep 15:15
23869												
23870												
23871												
23874												
23875												
23876												
23877				101	19:Aug 20:20	19:Aug 22:13	6	04:Sep 14:58	04-Sep 15:05	97	17:Aug 01:30	06:Sep 19:08
23882												
23885												
23899	4	02-Sep 13:09	02:Sep 13:11				1	01:Sep 13:04	01-Sep 13:04	49	30:Aug 12:50	01:Sep 05:44
23900												
23901												
23902				1	15:Aug 21:05	15:Aug 21:05				4	15:Aug 14:47	15:Aug 14:49
23905												
23906	2	14-Aug 22:01	14:Aug 22:02	7	14:Aug 11:43	15:Aug 15:47				5	13:Aug 18:56	15:Aug 21:38
23907												
23908												
24508												
24509												
24510												
24511												
24512												
238501							666	28:Sep 01:26	28-Sep 13:08	2	27:Sep 21:46	27:Sep 21:47
238831												

Appendix 1

Tag code	Bulkley 4			Bulkley 5			Bulkley 6			Bulkley 6A		
		Date detected			Date detected			Date detected			Date detected	
	Num	First	Last	Num	First	Last	Num	First	Last	Num	First	Last
23798												
23807							88	12:Aug 20:17	12-Aug 22:35			
23808												
23809							103	22:Aug 14:07	22-Aug 21:14			
23810				4	16:Aug 12:24	16:Aug 13:42	1	21:Aug 20:09	21-Aug 20:09			
23811												
23812				2	16:Aug 06:28	16:Aug 06:30						
23813				15	26:Aug 01:18	29:Aug 17:04	6	23:Aug 04:59	29-Aug 05:11	1	29-Aug 22:32	29-Aug 22:32
23815							11	22:Aug 16:07	24-Aug 22:06			
23816				4787	25:Aug 00:15	28:Aug 19:47	36	23:Aug 10:05	23-Aug 12:53	3	29-Aug 15:49	29-Aug 15:49
23817	1	26:Aug 01:39	26:Aug 01:39	3	25:Aug 23:51	25:Aug 23:53	46	25:Aug 03:23	25-Aug 05:38			
23819				9	28:Aug 13:33	28:Aug 13:40				13	27-Aug 13:27	27-Aug 13:27
23820	75	29:Aug 06:18	29:Aug 07:36	103	29:Aug 01:51	29:Aug 04:05						
23822												
23824										9	14-Sep 15:07	14-Sep 15:07
23825	627	07:Oct 02:34	07:Oct 14:12	22	22:Sep 14:18	06:Oct 10:26				6	24-Sep 14:08	24-Sep 14:08
23826	10	04:Sep 23:01	04:Sep 23:10	36	03:Sep 03:09	20:Sep 16:51				2	21-Sep 19:15	21-Sep 19:15
23828	8	06:Sep 01:07	06:Sep 04:11	6	05:Sep 21:22	05:Sep 21:30						
23829	1	05:Sep 14:02	05:Sep 14:02	7	04:Sep 21:09	05:Sep 13:20				5	04-Sep 19:56	04-Sep 19:56
23830	154	02:Sep 15:54	02:Sep 19:22	4	02:Sep 13:46	02:Sep 13:50						
23831				24326	04:Sep 08:37	26:Sep 16:40				9	27-Sep 00:22	27-Sep 00:22
23836												
23837												
23842										5	06-Sep 13:35	06-Sep 13:35
23844	1	07:Sep 14:06	07:Sep 14:06	16	06:Sep 23:19	17:Sep 15:27				44	17-Sep 21:01	17-Sep 21:01
23845										72	08-Sep 15:05	08-Sep 15:05
23846										15	11-Sep 17:34	11-Sep 17:34
23847	48	12:Sep 11:44	23:Sep 15:03	9	11:Sep 19:08	24:Sep 03:19				31	22-Oct 20:05	22-Oct 20:05
23850	910	11:Sep 21:02	19:Sep 16:45	35	10:Sep 13:54	20:Sep 15:27				1	09-Sep 00:43	09-Sep 00:43
23851										15	13-Sep 20:21	13-Sep 20:21
23852	3	10:Sep 14:26	10:Sep 14:49	3	10:Sep 07:31	24:Sep 20:37						
23856										7	17-Oct 07:01	17-Oct 07:01

Appendix 1

Tag code	Bulkley 4			Bulkley 5			Bulkley 6			Bulkley 6A		
		Date detected			Date detected			Date detected			Date detected	
	Num	First	Last	Num	First	Last	Num	First	Last	Num	First	Last
23857										4	22-Sep 15:33	22-Sep 15:33
23859										2	16-Sep 14:46	16-Sep 14:46
23862	399	16:Sep 11:14	19:Sep 07:01	10	16:Sep 03:01	19:Sep 18:28				6	19-Sep 22:37	19-Sep 22:37
23863	846	18:Sep 00:31	07:Oct 02:59	87	17:Sep 04:33	07:Oct 14:46				9	08-Oct 12:41	08-Oct 12:41
23864	1	20:Sep 14:27	20:Sep 14:27	8	24:Sep 19:43	24:Sep 19:50				1	19-Sep 02:33	19-Sep 02:33
23865				4	19:Sep 00:43	19:Sep 00:46				2	18-Sep 22:57	18-Sep 22:57
23868	3	20:Sep 14:53	20:Sep 14:59	43	19:Sep 22:30	19:Sep 23:16				17	19-Sep 01:30	19-Sep 01:30
23869										4	22-Sep 15:12	22-Sep 15:12
23870												
23871										9	26-Sep 15:08	26-Sep 15:08
23874										2	05-Nov 23:36	05-Nov 23:36
23875										4	26-Sep 02:01	26-Sep 02:01
23876												
23877	3	15:Aug 13:11	07:Sep 18:29	6	15:Aug 04:47	08:Sep 08:01				2	08-Sep 15:52	08-Sep 15:52
23882							10	13:Aug 21:00	13-Aug 21:14			
23885							1	14:Aug 02:49	14-Aug 02:49			
23899	20	29:Aug 13:12	29:Aug 14:28	2	29:Aug 05:59	29:Aug 06:00						
23900												
23901												
23902	2	14:Aug 19:47	14:Aug 19:48	15	13:Aug 13:58	13:Aug 14:26						
23905				4	14:Aug 20:02	21:Aug 22:10						
23906	13	13:Aug 14:23	13:Aug 14:46	5	13:Aug 11:56	24:Aug 22:25						
23907												
23908				4	13:Aug 12:47	13:Aug 12:50	11	12:Aug 00:48	13-Aug 18:11			
24508												
24509				1071	26:Sep 01:30	27:Sep 05:37						
24510				1	09:Nov 19:36	09:Nov 19:36				8	09-Nov 05:44	09-Nov 05:44
24511				76	26:Sep 12:57	28:Sep 15:15				5	28-Sep 23:28	28-Sep 23:28
24512										2	24-Sep 23:07	24-Sep 23:07
238501	3	27:Sep 04:54	27:Sep 05:14	5	26:Sep 14:47	26:Sep 14:50				3	25-Sep 13:54	25-Sep 13:54
238831										6	29-Sep 22:38	29-Sep 22:38

Appendix 1

Tag code	Bulkley 7			Bulkley 8			Bulkley 9			Bulkley 10		
		Date detected			Date detected			Date detected			Date detected	
	Num	First	Last	Num	First	Last	Num	First	Last	Num	First	Last
23798				74	06-Aug 15:16	06-Aug 16:57	13	07-Aug 08:35	07-Aug 10:31			
23807				2	19-Aug 20:51	19-Aug 20:53	1	20-Aug 14:09	20-Aug 14:09			
23808												
23809	1	25-Aug 16:19	25-Aug 16:19							6	20-Sep 15:09	20-Sep 15:15
23810	1	24-Aug 15:00	24-Aug 15:00	2	26-Aug 22:57	26-Aug 22:58	1	27-Aug 01:27	27-Aug 01:27			
23811				1	16-Aug 15:46	16-Aug 15:46						
23812												
23813	1	29-Aug 23:47	29-Aug 23:47				3	31-Aug 20:18	31-Aug 20:20	2	02-Sep 15:16	02-Sep 15:17
23815	8	25-Aug 02:16	25-Aug 13:00				3	30-Aug 15:40	30-Aug 15:42	30	19-Sep 15:48	19-Sep 16:23
23816										5	09-Sep 16:39	09-Sep 16:42
23817												
23819												
23820												
23822	4	30-Aug 14:39	13-Sep 13:38									
23824	450	15-Sep 03:10	15-Sep 13:26	1	24-Sep 22:14	24-Sep 22:14	1	25-Sep 00:29	25-Sep 00:29	3	25-Sep 12:04	25-Sep 12:07
23825	1	05-Oct 00:55	05-Oct 00:55									
23826	1	21-Sep 21:19	21-Sep 21:19				4	25-Sep 01:57	25-Sep 02:01	53	25-Sep 17:43	25-Sep 18:36
23828	2	05-Sep 15:38	05-Sep 15:39									
23829	6	03-Sep 16:07	04-Sep 18:36									
23830	1	01-Sep 20:17	01-Sep 20:17									
23831							2	29-Sep 04:42	29-Sep 04:43			
23836												
23837	12	04-Sep 20:43	12-Sep 21:21									
23842	1	04-Sep 21:45	04-Sep 21:45									
23844	1	17-Sep 23:01	17-Sep 23:01				2	19-Sep 14:43	19-Sep 14:44	3	19-Sep 23:49	19-Sep 23:50
23845	1	09-Sep 00:42	09-Sep 00:42	2	09-Sep 15:35	09-Sep 15:36				4	10-Sep 08:21	10-Sep 08:24
23846												
23847	2	22-Oct 23:27	22-Oct 23:28				1	25-Oct 02:11	25-Oct 02:11			
23850												
23851	3	13-Sep 22:52	14-Sep 01:37	4	17-Sep 00:12	17-Sep 00:14				28	25-Sep 02:08	25-Sep 02:40
23852												
23856	5	18-Sep 14:38	17-Oct 09:49									

Appendix 1

Tag code	Bulkley 7			Bulkley 8			Bulkley 9			Bulkley 10		
		Date detected			Date detected			Date detected			Date detected	
	Num	First	Last	Num	First	Last	Num	First	Last	Num	First	Last
23857	1	22-Sep 18:29	22-Sep 18:29							12	28-Sep 00:12	28-Sep 00:23
23859	6	16-Sep 20:48	16-Sep 20:53									
23862	1	19-Sep 23:53	19-Sep 23:53							8	26-Sep 05:17	26-Sep 05:23
23863	1	08-Oct 17:09	08-Oct 17:09									
23864	2	18-Sep 18:57	25-Sep 00:50									
23865	1	18-Sep 22:23	18-Sep 22:23									
23868												
23869	1	19-Sep 02:23	19-Sep 02:23	2	25-Sep 02:49	25-Sep 02:50				238	29-Sep 16:40	29-Sep 21:11
23870										1	27-Sep 01:30	27-Sep 01:30
23871	3	23-Sep 02:33	23-Sep 14:59	2	28-Sep 02:03	28-Sep 02:04	5	30-Sep 23:05	30-Sep 23:08	49	07-Oct 00:49	07-Oct 01:41
23874	2	23-Sep 13:59	23-Sep 14:01									
23875				2	07-Oct 02:21	07-Oct 02:22	2	07-Oct 06:16	07-Oct 06:18	5	31-Oct 16:10	31-Oct 16:13
23876												
23877												
23882												
23885				1	18-Aug 15:10	18-Aug 15:10	2	18-Aug 17:07	18-Aug 17:08			
23899												
23900				2	28-Aug 00:56	28-Aug 00:57						
23901							2	02-Sep 20:16	02-Sep 20:16	6	03-Sep 12:22	03-Sep 12:27
23902												
23905												
23906				3	18-Aug 00:11	18-Aug 00:13				2	18-Aug 21:51	23-Aug 02:52
23907	1	23-Aug 05:02	23-Aug 05:02							1	28-Aug 08:57	28-Aug 08:57
23908							1	19-Aug 23:52	19-Aug 23:52			
24508	2	24-Sep 02:31	24-Sep 02:32							3	26-Sep 16:00	26-Sep 16:04
24509	1	24-Sep 01:16	24-Sep 01:16									
24510	1	24-Sep 01:46	24-Sep 01:46				1	01-Oct 21:34	01-Oct 21:34			
24511	2	24-Sep 19:15	29-Sep 02:06				5	03-Oct 02:00	03-Oct 02:03	4	18-Oct 05:30	18-Oct 05:33
24512	3	24-Sep 22:22	28-Sep 00:28				2	07-Oct 01:16	07-Oct 01:17	6	29-Oct 02:06	29-Oct 02:11
238501												
238831				3	30-Sep 22:07	30-Sep 22:10	2	01-Oct 01:21	01-Oct 01:23			

Appendix 1

Tag code	Bulkley 11			Bulkley 12			Bulkley 12A		
		Date detected			Date detected			Date detected	
	Num	First	Last	Num	First	Last	Num	First	Last
23798	16	25-Aug 16:29	25-Aug 16:44						
23807	4	30-Aug 15:10	30-Aug 15:12	8	04-Sep 15:26	04-Sep 15:36			
23808	5	02-Sep 17:04	02-Sep 17:12	2	03-Sep 08:40	03-Sep 08:41			
23809	671	29-Aug 17:03	18-Sep 13:25	13	30-Aug 17:00	16-Sep 20:57			
23810	9	28-Aug 03:28	28-Aug 03:37	8	29-Aug 02:47	29-Aug 02:53			
23811	7	21-Aug 03:48	21-Aug 03:57	2	22-Aug 16:00	22-Aug 16:01			
23812									
23813	10	02-Sep 23:33	02-Sep 23:44	7	04-Sep 12:13	05-Sep 09:05			
23815									
23816	5	11-Sep 22:56	11-Sep 23:00				11	07-Oct 14:56	07-Oct 15:07
23817									
23819									
23820									
23822									
23824	8	25-Sep 23:38	25-Sep 23:51						
23825									
23826	5	26-Sep 18:26	26-Sep 18:32				15	07-Oct 14:25	07-Oct 14:41
23828									
23829									
23830									
23831	9	01-Oct 19:25	01-Oct 19:32						
23836	6	09-Sep 20:33	09-Sep 20:41	21	12-Sep 07:14	12-Sep 11:03			
23837									
23842	17	11-Sep 23:27	22-Sep 05:56						
23844	12	20-Sep 22:45	20-Sep 22:58				8	06-Oct 17:22	06-Oct 17:31
23845	11	12-Sep 09:23	12-Sep 09:37	2	16-Sep 16:01	16-Sep 16:04			
23846									
23847									
23850									
23851	11	07-Oct 01:47	07-Oct 02:02						
23852	18	31-Oct 11:55	31-Oct 12:12						
23856									

Appendix 1

Tag code	Bulkley 11			Bulkley 12			Bulkley 12A		
		Date detected			Date detected			Date detected	
	Num	First	Last	Num	First	Last	Num	First	Last
23857	29	02-Oct 00:48	02-Oct 01:17						
23859	4	18-Sep 18:30	18-Sep 18:35						
23862	8	26-Sep 20:26	26-Sep 20:33				142	03-Oct 15:49	03-Oct 18:17
23863									
23864									
23865									
23868									
23869	7		07-Oct 01:40						
23870									
23871									
23874									
23875									
23876	8		08-Oct 22:35						
23877									
23882									
23885	11		19-Aug 13:20						
23899									
23900	9		29-Aug 01:51						
23901	6		03-Sep 21:55						
23902									
23905	3		29-Aug 17:10						
23906	15		20-Aug 15:48						
23907	6		28-Aug 15:20						
23908	8		20-Aug 21:00	2	21-Aug 19:00	21-Aug 19:01			
24508	9		27-Sep 00:17				1	28-Sep 00:13	28-Sep 00:13
24509									
24510	8		05-Nov 16:28				3	03-Oct 23:52	03-Nov 02:32
24511									
24512	16		05-Nov 22:51						
238501									
238831	17		01-Oct 22:03				9	03-Oct 10:22	03-Oct 10:30