



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. All rights reserved.*

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Executive Summary

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

103
104 In summer 2009, an array was designed and deployed in the Bulkley River system by
105 Kintama Research, with the assistance of a local river guide. Twelve acoustic receivers were
106 deployed in the Bulkley River on 10-12 July 2009 and 67 returning wild steelhead were
107 subsequently tagged with individually identifiable Vemco V9-2H acoustic tags. One fish was
108 harvested and therefore omitted from the data analysis (n=66). Fish were released from 5 August
109 to 24 September at two collection sites: (a) the beach seine site immediately below the
110 Moricetown Canyon and (b) the dip-net site located at the Moricetown Canyon falls. We
111 recovered all receivers between the 9-11 November 2009, approximately four months later. Over
112 the deployment period, a total of 38,808 detections were recorded from 63 of the 66 tagged adult
113 steelhead.

114 .

115 Key findings of the 2009 Bulkley River study:

- 116 • Only between 56 and 59% of fish passed the recapture site during active recapture
117 efforts (excludes: Fish that remained below (33%), undetected tagged fish (5%),
118 and fish passing recapture site after the recapture efforts were terminated (3-6%)).
- 119 • 2009 drop-back rate (<0.7 km): 83% of all tagged fish (n=66)
- 120 • 2009 drop-back rate (<11 km): 35% of all tagged fish (18% in 2008).
- 121 • Average time from release to passing the Moricetown Canyon recapture site (300
122 m upstream of release): 13.5 days (range: 0.9-52.5 days).

- 123
- Twenty-two (33%) of all tagged steelhead remained below the Moricetown Canyon release site and were never exposed to recapture at the recapture site.
- 124
- 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.
- 125
- 126
- 127

128

129 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.

130

131

132 **1.0 Introduction**

133
134 The Bulkley River in British Columbia is renowned world-wide for its summer run of
135 wild steelhead and yearly mark-recapture studies to evaluate this resource have been conducted
136 by the Wet'suwet'en Fisheries since 1999. These mark-recapture studies focus on coho, sockeye,
137 and steelhead moving through Moricetown Canyon. The Bulkley is 257 km long, drains an area
138 of 12400 km² and is a major tributary to Skeena River (NRCAN 2010). The Skeena is one of the
139 largest watersheds flowing entirely in British Columbia. All five Pacific salmon species and 30
140 other fish species, including multiple populations of steelhead trout, use the Skeena and Bulkley
141 river spawning and rearing habitats. Many of the salmon and trout populations face intense
142 harvest during the summer and fall while returning to these spawning grounds. Chudyk and
143 Narver (1976) reported that fishing pressure from commercial, recreational, and aboriginal
144 fisheries have all contributed to the decline of Skeena River steelhead. Skeena steelhead are
145 currently subject to significant fishing pressure as a result of incidental capture in commercial
146 sockeye and pink salmon gillnet fisheries (Oguss and Evans 1978). A genetic study of the
147 steelhead caught in the Tye Test Fishery (Skeena River mouth) identified the dominant steelhead
148 stock as originating from the Bulkley River drainage, which includes the Morice and Bulkley
149 rivers, and Toboggan Creek (2007: 29% ; 2008: 40%) (Beacham and Beere 2009).

150
151 Despite the many different management strategies, stock assessment techniques, and
152 research programs implemented since the 1970's on Skeena River populations, the Skeena
153 steelhead are thought to still be declining (Walters *et al* 2008). In 2006, the Tye Test Fishery,
154 located at the mouth of the Skeena River, identified an unexpectedly large sockeye run while
155 steelhead numbers appeared relatively low. A commercial sockeye opening in Area 4 (the river
156 mouth) subsequently exposed co-migrating Skeena steelhead to fishing pressure for 11
157 consecutive days. This decision caused intense public debate and controversy and led to a
158 demand for review of Skeena River salmon and steelhead management strategies. In 2007, an
159 independent science review panel (ISRP) reviewed these strategies and other issues facing the
160 Skeena River watershed (Walters *et al* 2008). Walters *et al* identified a number of critical issues
161 and made several recommendations; one of them was the need for a telemetry study of steelhead
162 removed from the water in the Area 4 fisheries. In addition to the final recommendations in the

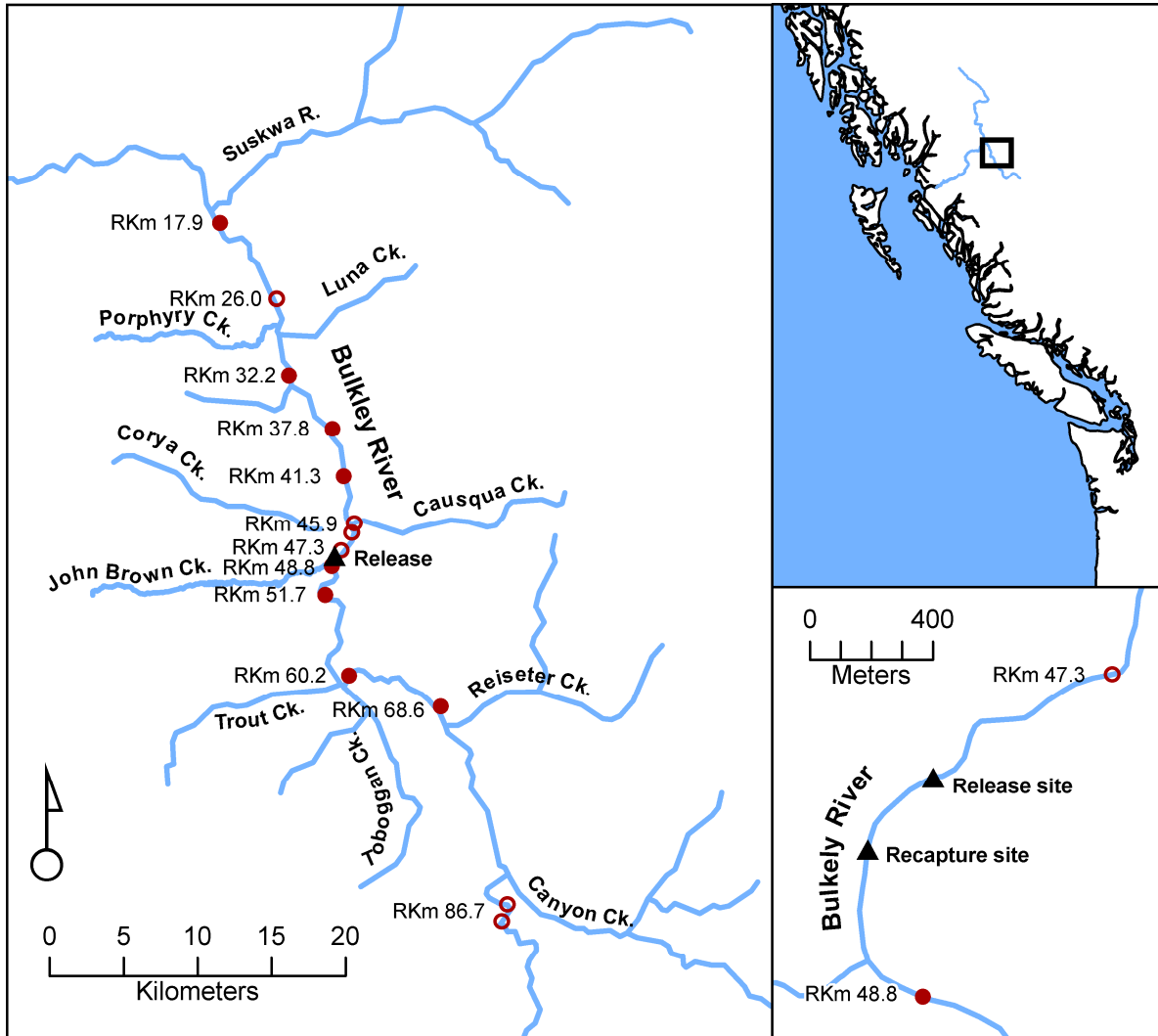
163 ISRP report, a recommendation by DFO biologists is put forth, suggesting a multispecies
164 telemetry study of sockeye, coho and steelhead captured in the Moricetown Canyon mark-
165 recapture studies to provide information on survival, drop-back behaviour and migration rates.

166
167 In 2009, a Moricetown Canyon project was initiated by the Ministry of Environment
168 (MoE), the Pacific Salmon Foundation, and Kintama to specifically assess the behaviour of the
169 Bulkley River steelhead following tagging. Collecting data in these areas would complement
170 multiple steelhead studies previously conducted in this area (Beere 1991a-d; 1995, 1996, 1997).

171
172 Acoustic telemetry has a significant advantage over radio telemetry in that the signals
173 transmit effectively in both salt and fresh water, potentially allowing much broader geographic
174 study of the species. Off-setting this potential advantage, the deployment of large-scale acoustic
175 arrays is more complex than when radio frequencies are used due to the nature of acoustic
176 propagation in water. In recent years, large-scale acoustic telemetry systems have been used to
177 study the survival and migratory behaviours of several fish species (e.g., Crossin *et al* 2008,
178 Chittenden *et al* 2008, Welch *et al* 2008, Melnychuk *et al* 2007) and the large-scale Pacific Ocean
179 Shelf Tracking acoustic array, “POST”, www.postcoml.org) has been deployed semi-permanently
180 along the Pacific Shelf (including two major rivers) between northern Oregon and southeast
181 Alaska.

182
183 To investigate the behaviours of returning Bulkley River steelhead released from the
184 annual Wet’suwet’en mark-recapture study, a sub-array of 12 acoustic receivers were deployed in
185 the Bulkley River in the summer of 2009 (Figure 1). Adult steelhead were primarily seined and
186 tagged below the Moricetown Canyon release site (n=57) but a small subset (n=10) were tagged
187 at the recapture site. One fish was subsequently removed from the data analysis as it was
188 harvested during the study period (n=66). All steelhead were tagged externally with uniquely
189 coded acoustic transmitters. In the fall of 2009, flows in the Bulkley became very low and a few
190 of the acoustic receivers became exposed. One of the receivers (#12) was disturbed on a few
191 occasions. MoE staff effectively redeployed and in some cases re-located the receivers in
192 question. All units were recovered and successfully uploaded in November 2009. The purpose of
193 this report is to present background data and survey results valuable to the interpretation of the

194 yearly Moricetown mark-recapture studies by identifying drop-back rates, residence numbers,
 195 time to pass through the canyon from release, and extent and percentages of up or downstream
 196 travel.
 197



198
 199 **Figure 1. Location of acoustic receivers deployed in the Bulkley River. The red dots indicate the twelve**
 200 **receiver locations used to monitor acoustically tagged steelhead during the fall of 2009. Four receivers were**
 201 **repositioned or moved during the study due to low water conditions or disturbance and are indicated using**
 202 **hollow red dots (if moved, both the initial and final location are indicated as open circles). Distances are**
 203 **measured as river kilometer (RKm) from the Bulkley River confluence to the Skeena River. Bathymetric and**
 204 **topographic data ©Department of Natural Resources Canada.**
 205

206 **2.0 Methods**

207 **2.1 Acoustic Sub-array**

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

217
218 The sub-array in the Bulkley River was compatible with the Pacific Ocean Shelf Tracking
219 (POST) array; POST is a large scale marine acoustic tracking network which extends from
220 northern Oregon, throughout coastal British Columbia, and up to southeast Alaska (Cover;
221 www.postcoml.org). Acoustic receivers are deployed in specific locations in the coastal ocean
222 with set spacing with the goal of providing near-complete coverage of coastal marine shelf areas
223 from the beach to the shelf break (200m). Elements of the array are also deployed in multiple
224 locations within several river systems other than the Skeena.

225
226 During 10-12 July 2009, Kintama Research deployed twelve acoustic receivers within the
227 Bulkley River with the assistance of Fred Seiler, Silvertip EcoTours, Terrace. Seven receivers
228 were deployed downriver of the Moricetown Canyon at locations ranging from 17.9 to 47.3 Rkm
229 from the Bulkley-Skeena confluence and five were positioned above the canyon (Rkm 48) at
230 river positions 48.8 - 86.7 Rkm (Table 1 and Figure 1). Locations were selected which appeared
231 to have a high probability of detecting the acoustically tagged steelhead and positions recorded
232 using a WAAS enabled handheld GPS receiver. At the time of instalment, river transects were
233 surveyed using an onboard depth sounder to ensure sufficient water depth and avoid areas with
234 larger trenches. However, due to a combination of a period of increased discharge that occurred

235 immediately following instalment of receivers and subsequent low river flow in the fall of 2009,
 236 four receivers were redeployed by MoE staff because they were found to be either very close to
 237 the surface or no longer in the river. This resulted in gaps in the detection record for the telemetry
 238 array (as tagged fish will not be detected if the receiver's hydrophone is not submerged). All
 239 units were successfully recovered four months later on 9-11 November 2009.

240

241 **Table 1. Detail of 2009 receiver and tagging locations within the Bulkley River. Sites denoted with**
 242 **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 |

243

244

245

246 **2.2 Tagging**

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

253
254 The acoustic tags were attached externally using braided Spiderwire line. Prior to the
255 actual tagging event, individual Spiderwire harnesses were created for each tag and fastened
256 using epoxy. The harness location was distal to the transmission end of the tag such that the
257 signal was not compromised by the attachment (Figure 2).

258



259

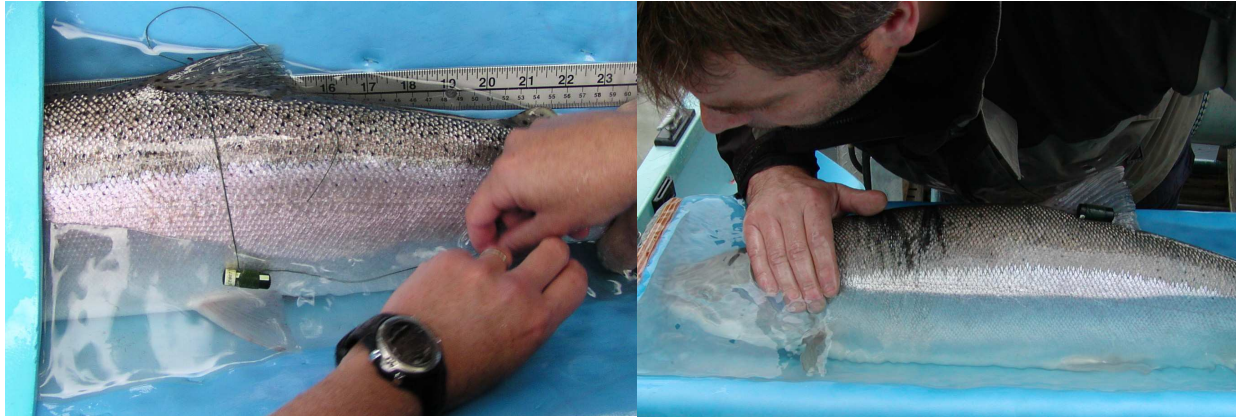
260 **Figure 2. A Vemco V9-2H tag after attaching the spiderwire line as a harness. Photo courtesy of MoE.**

261

262 A tagging trough was lined with 5 mm Thinsulate foam and a hole was drilled at one end
263 to accommodate a hose that supplied a constant flow of water through the trough. Acoustic tags
264 were applied on the left side of the steelhead with the transmission end directed posterior.
265 Needles were threaded between the pterygiophores and a surgeon's knot was used to securely
266 join the ends (Figure 3). Finally, a Scotty brass connector sleeve, intended for downrigger wire,

267 was crimped on above the knot. Tag number, sex, nose-fork length, and time of release were
268 recorded.

269



270

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

274

275 Wet'suwet'en Fisheries conduct an annual mark-recapture program to estimate adult
276 salmon abundance. The program utilizes a jet-boat to deploy a beach seine and then mark
277 captured salmonids (Figure 4). Recapture is accomplished via a dip-net fishery approximately
278 300 meters upstream of the tagging site. In 2009, acoustic tags were applied in the manner
279 described above in conjunction with the annual mark-recapture study. The fish were caught, and
280 immediately tagged and released. Prior to release, an individually numbered, coloured anchor-T
281 tag was placed at the base of the dorsal fin as a secondary mark. The ten steelhead caught and
282 tagged at the dip-net fishery (the recapture site) were passed to a second net which was then
283 carried to a holding tank and subsequently tagged as described above.



284

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

286

287 **2.3 Data Analysis**

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

293 Due to the proximity of the two 2009 release sites (300 m apart) the tagged steelhead were
294 mostly treated as one release site throughout the report, the exception being when comparing the
295 2008 and 2009 data; this distinction is made when comparing the two years in order to maintain a
296 uniform treatment of fish between years.

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

299

300

301 2.3.1 *False detection screening*

302 We identified and excluded any detection likely to be false (as a result of aliasing or tag
303 collisions) using the two criteria recommended by VEMCO (Pincock 2008). Detections met the
304 first criteria if there was at least one short interval (<0.5 hour) between successive detections of
305 an ID code on a receiver and if there were more short intervals between detections than long ones
306 (>0.5 hour). Detections not meeting the first criteria were then examined individually to
307 determine if there was possible collision activity on the receiver (i.e. when two or more tags were
308 simultaneously transmitting in the vicinity of the receiver; overlapping transmissions – collisions
309 – may potentially result in the generation of a spurious tag code). We considered the detection of
310 another tag code within five minutes on either side of the time of detection of the questionable tag
311 code as representing possible collision activity, and did not include such detections unless they
312 met the first criteria.

313
314 2.3.2 *Minimum migration*
315 Minimum migration estimates at each location were calculated by dividing the number of
316 fish detected on each acoustic receiver by the number released. These values underestimate
317 migration because they do not account for fish that may have passed the array but which were not
318 detected.

319
320 2.3.3 *Direction and Extent of Apparent Migration Movement.*

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

332
333

334 Method 1

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

343 the sub-arrays 2-11, Rkm 26 through 68.6. The calculated detection efficiencies are presented in
344 this report (section 3.4).

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

353

354 Method 2

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

365

366 **3.0 Results**

367 **3.1 False Detection Screening**

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

372

373 **3.2 Unique ID Codes Detected at Each Location**

374 *3.2.1 Moricetown steelhead detections*

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

385

386 Of the 66 released steelhead, two were re-captured at the dipnet site and lost their tags. As
 387 these tags could not subsequently be detected above the canyon, the total number of available
 388 tagged fish above the recapture site have been adjusted to 64. Fourteen (22%) tagged steelhead
 389 were heard on the first upstream location while 19 (30%) and 21 (33%) unique tag codes were
 390 heard on the second and third receivers upstream of the canyon. At the fourth upstream receiver,
 391 located 20.6 Rkm above the tagging site (Receiver 11: Rkm68.6), 33 of 64 (52%) steelhead were
 392 recorded. Receiver 11 was a deep site and it is possible that this was a holding location for
 393 steelhead during their upstream travel. The receiver furthest upstream (Rkm 86.7) only recorded
 394 16 fish as this receiver was disturbed and removed from the river on a few occasions.

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

399

400

401 **Table 2. Number of acoustically-tagged, wild adult steelhead recorded on the Kintama array in the**
 402 **Bulkley River in 2009. Distances specified as river kilometres (Rkm) from the Bulkley-Skeena**
 403 **confluence. Locations with additional bracketed distances were receivers moved during the study**
 404 **period. Tagging site is indicated by double line division between Rkm47.3 and Rkm48.8. Below the**
 405 **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 |

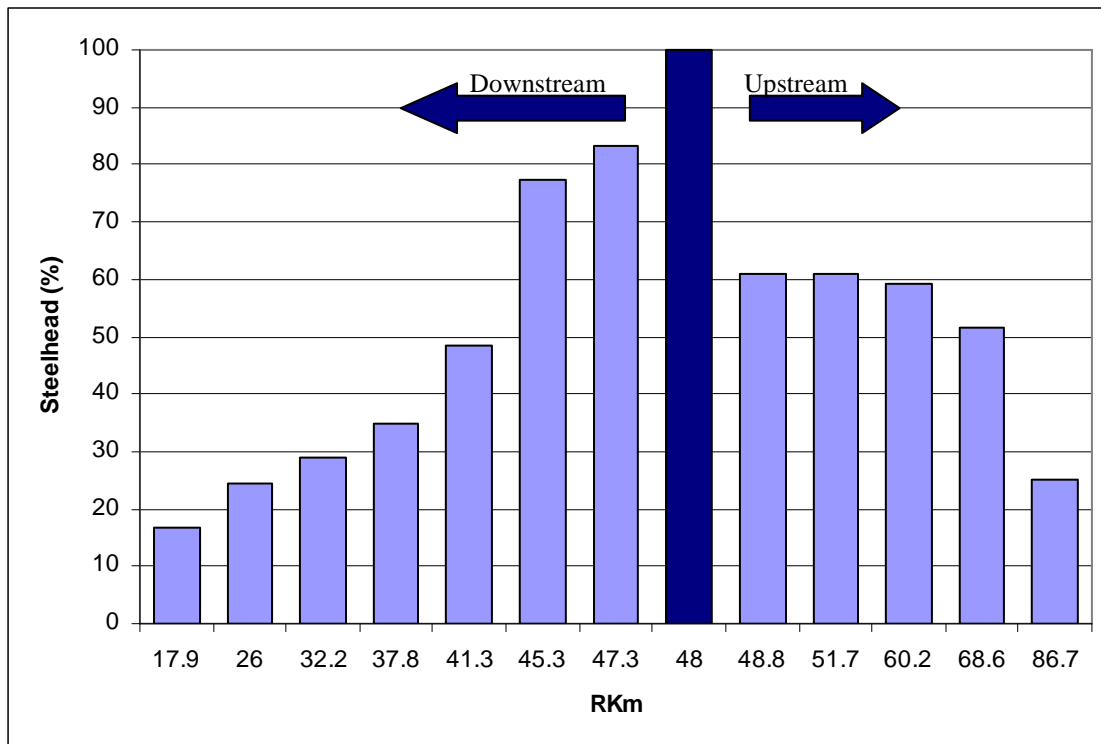
406 Release sites are treated as one due to their close proximity.

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

408 **3.3 Direction and Extent of Migration**

409 The majority (55 fish; 83%) of the adult steelhead released at Moricetown Canyon in
410 2009 dropped back and were detected on receivers below the canyon: 11 (17%) migrated
411 downstream at least as far as Receiver #1, Rkm17.9, located 30.1 Rkm below the tagging site
412 (Table 3; Figure 5). Of the fish that dropped back, 31 fish of 55 (56%) were detected on receivers
413 above the canyon. In addition to those 31 fish, two fish lost their tags during recapture when the
414 steelhead were migrating back up through the canyon (total 60%).

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



421
422 **Figure 5. Apparent direction and extent of migration estimated (section 2.3.2) for returning wild Bulkley**
423 **River steelhead released at the Moricetown Canyon site in 2009 (Rkm 48 – dark blue). Estimates are**
424 **corrected between Rkm 26-68.6 using method 2 (section 2.3.3); data for the most distant upstream and**
425 **downstream sites cannot be corrected owing to the lack of information from more distant locations. Two tags**
426 **were lost during recapture and therefore n is adjusted to 64 above the release site.**

427

428 **Table 3. Cummulative tagged adult steelhead travelling upriver and downriver from tagging site on**
 429 **the Bulkley River 2009. Number of fish represents all unique ID codes detected at a specific receiver**
 430 **and beyond. Distances specified as river kilometres (Rkm) from the Bulkley-Skeena confluence.**
 431 **Receivers with additional bracketed distances were moved during the study period. Two tags were**
 432 **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.

433

434

435 **3.4 Detection Efficiency**

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

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

448 **Table 4. Estimated detection efficiency (p_i) of the 2009 Bulkey River array for returning adult wild**
 449 **steelhead released at Moricetown. Number of fish detected at site i : m_i ; Number of fish missed at site**
 450 **i : z_i ; Number of fish detected both at and beyond site i : r_i ; Detection Efficiency: p_i ; NA: not**
 451 **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 |

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

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

454

455 **3.5 In-River Movements**

456 Most (83%) of the returning adult steelhead tagged at Moricetown Canyon in 2009
457 dropped downstream after release. It is not unexpected that newly released fish would either
458 swim downstream to regain stamina before attempting again to pass up through the fast moving
459 canyon or were carried downstream by the current while re-orienting itself post-tagging. In 2008,
460 the first receiver downstream of the canyon was located 11 km below the tagging site. The 2009
461 study saw receivers deployed in a much tighter fashion to finely evaluate the nature of any
462 milling that occurred and accordingly the first receiver was located only 0.7 km downstream of
463 the tagging site. The 2009 drop back rate accounted for 83%, but more significantly: 36% of all
464 tagged fish were only detected on downstream receivers – none of which were ever detected
465 above the canyon past the dip-net site (Table 5). As two of these fish (3%) lost their tags during
466 recapture at the dip-net site, 33% are believed to have remained resident below the recapture site.
467 2008 and 2009 data is compared in section 3.5.5.

468
469 Once above the canyon, most fish travelled swiftly upstream. Only three fish were
470 observed above the canyon and subsequently turned downstream (Tag ID codes: 24510, 23906
471 and 23809); these fish are described in detail in section 3.5.2. A total of 62 percent of the tagged
472 steelhead travelled through the canyon (including the 3% accounted for by tag loss at the
473 recapture site) and 52% reached Receiver 11.

474

475 **Table 5. Overview of tags applied and their migratory fate in relation to the tagging site at the**
476 **Moricetown Canyon. Beach seine and dip-net tagging are treated together owing their close**
477 **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 |

478 *Excludes two tags lost a recapture site

479

480

481
482 *3.5.1 Moricetown steelhead migrating after end of recapture effort.*
483 Tagging continued at the beach seine site until September 24 and operations at the dip-net
484 site, ~300m upstream, continued until 1 October 2009. Four fish (6%) travelled up through the
485 canyon past the capture locations used for the mark-recapture study around or after the
486 termination date of the mark-recapture study (Figure 6). Of these four fish, two passed through
487 the canyon after the termination of recapture efforts, while two passed through the canyon during
488 a time period that included both active recapture efforts and a period after the mark-recapture
489 study ended. These 2 to 4 fish would not have been exposed to recapture efforts.

490
491 1) Fish ID 23847:
492 The fish was tagged on September 8. After release, the fish dropped back to Receiver 3
493 (15.8 Rkm below the release site) by September 18 and then turned upstream, remaining
494 in the area between Receivers 5 and 6 (2.7-6.7 Rkm below the release site) from
495 September 24 – October 21. On October 22, the fish was detected immediately below the
496 tagging site (Receiver 7). It then travelled up through the canyon, past the dip-net site,
497 between October 22 and 25, 44-46 days after tagging. This steelhead was last detected on
498 Receiver 9 on the October 25.

499
500 2) Fish ID 23852:
501 Tagged on September 8, the steelhead dropped back to receiver 3 (15.8 Rkm below the
502 release site) and then resumed upstream migration. Below the canyon, this fish ID was
503 last detected on receiver #5 (6.7 Rkm below the release site) on September 24. The tag ID
504 was detected again on October 31 above the canyon, but only on receiver #11 (20.6 Rkm
505 above the release site: 18 detections). It is possible that the fish was simply not detected
506 swimming past any of the 5 receivers in between, but unlikely; other modes of transport
507 of the tag/fish might be considered (such as fishing or predation and passing of tag by
508 non-aquatic animals). This fish would have passed through the canyon, past the dip-net
509 site, around October 2 ca. 23 days after tagging if we assume a constant travel speed.

510
511

512 3) Fish ID 24512:

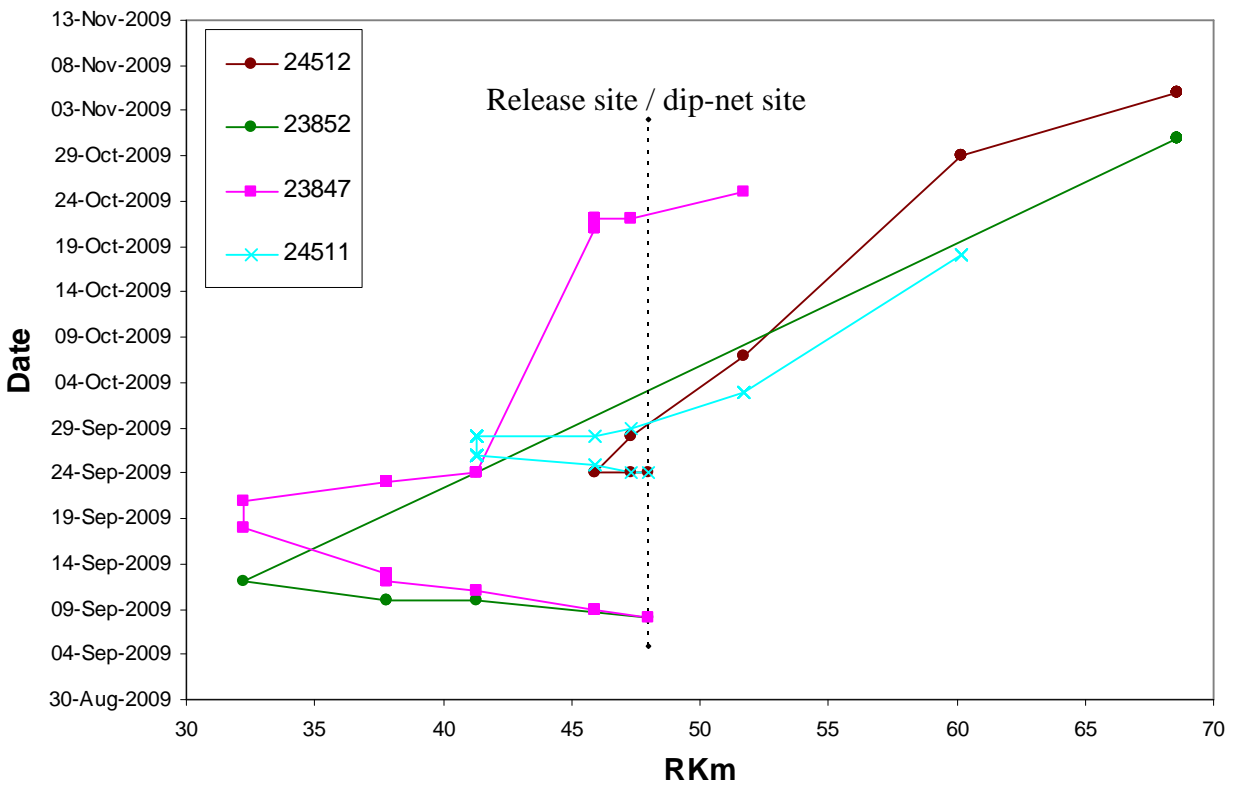
513 Tagged on September 24, the steelhead remained below the canyon in the area of
514 Receivers 6 and 7 (0.7-2.7 Rkm below release site) for at least 3¼ days after tagging (until
515 September 28) and was then detected on Receiver 9 (3.7 Rkm above the release site) on
516 October 7: 12 days, 7 hours after tagging. Above the canyon, this fish travelled upstream
517 slowly and was last detected on Receiver 11 on November 5; at the observed mean rate of
518 movement this fish would have passed through the canyon sometime between September
519 28 and October 7.

520

521 4) Fish ID 24511:

522 Tagged on September 24, this steelhead remained in the area below the canyon (Receiver
523 5, 6 and 7, 0.7-2.7 Rkm below the release site) for at least 4½ days. It was not detected on
524 Receiver 8 (0.8 Rkm above the release site), and first picked up on Receiver 9 (3.7 Rkm
525 above the release site) on October 3 (8½ days after tagging). This fish likely would have
526 passed through the canyon between September 29 and October 3.

527



528

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

531
 532

533 *3.5.2 Steelhead migrating back downstream through the Moricetown Canyon.*

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

537

538 1) Fish ID 24510:

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

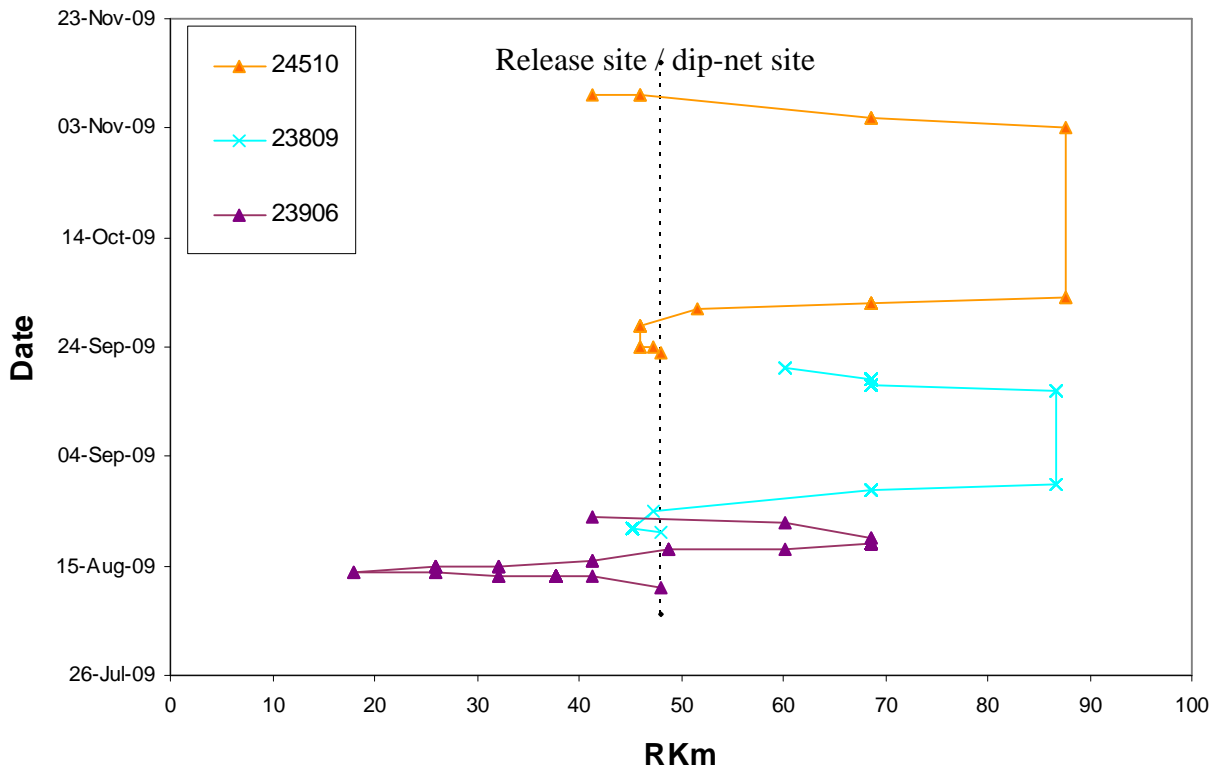
543

544

545 2) Fish ID 23809:
 546 Tagged and released on August 21 - this fish dropped back to Receiver 6 (2.7 Rkm below
 547 the release site) and then travelled upstream to Receiver 12 (39.7 Rkm above the release
 548 site) before turning around and was last detected on Receiver 10 (12.2 Rkm above the
 549 release site) and as such did not pass through the canyon again.

550
 551 3) Fish ID 23906:
 552 Tagged and released on August 11 - this fish migrated all the way downstream to
 553 Receiver 1 (30.1 Rkm below release site) before reinitiating upstream migration.
 554 Upstream migration to Receiver 11 (20.6 Rkm above release site) was relatively quick
 555 with no milling detected (~50 Rkm from August 14 to 19). After turning around and
 556 returning downstream, the fish came through the Moricetown Canyon between August 23
 557 and 24 while beach seining was still occurring.

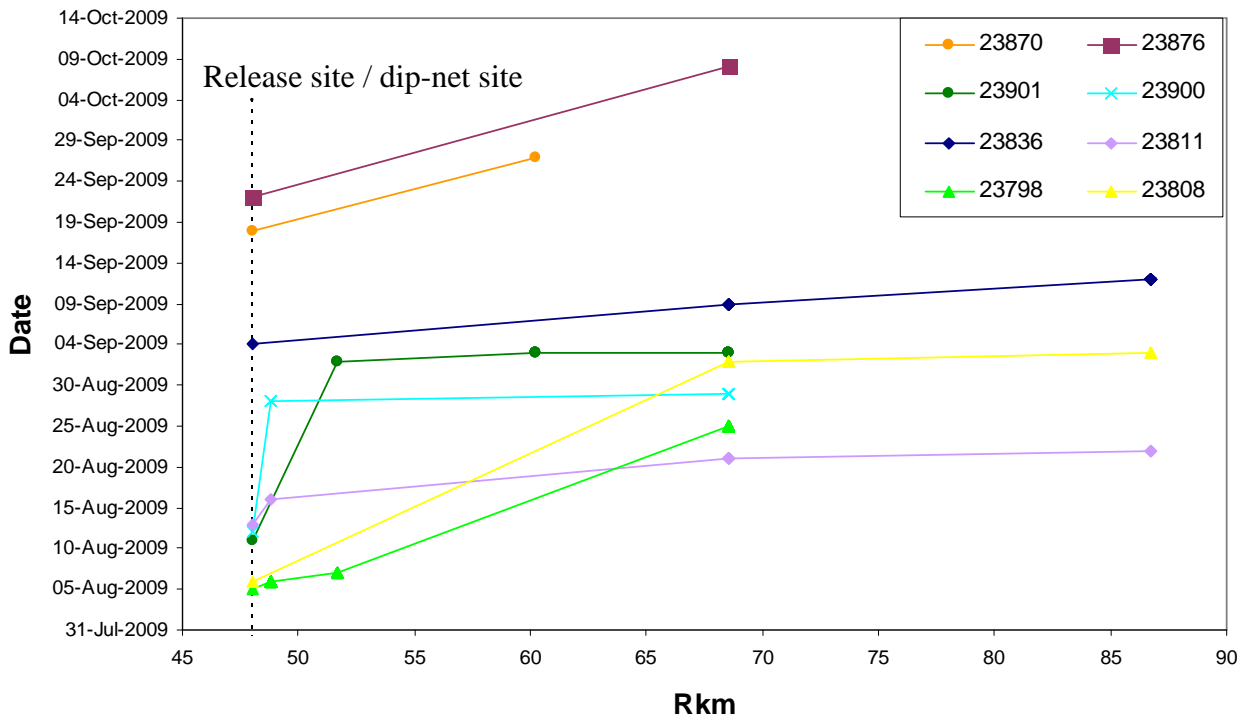
558



559
 560 **Figure 7. Detailed movement of 2009 adult steelhead which migrated up through the Moricetown Canyon and**
 561 **then subsequently went back down through the canyon.**

562 3.5.3 Immediate upstream movement.

563 Only 8 of 66 fish (12%) were observed migrating upstream without any detected drop
 564 back (Figure 8). This is significantly different from the number reported in 2008 where 82%
 565 were reported as traveling upstream in a uni-directional fashion post-tagging – this difference is
 566 mostly due to the greater distance between the first downstream receiver in 2008 (Rkm 37; 11 km
 567 below release site) and the location of the first downstream receiver in 2009 (Rkm 47.3; 0.7 km
 568 below release site). A direct comparison between 2008 and 2009 can be found in section 3.5.5. In
 569 2009, fish were tagged in two different locations (beach seine: 56 fish; dip-net: 10 fish) whereas
 570 all 2008 fish were tagged at the beach seine site location below the falls. The 2008 to 2009
 571 difference in the number of tagged steelhead that immediately travelled upstream after release
 572 becomes even more marked if the 2009 data are restricted to only include steelhead released at
 573 the beach seine location; this lowers the 2009 number further from 8 to 5 fish (7.5%). It is
 574 possible that these 5 steelhead, tagged and released at the beach seine, either held at or near the
 575 tagging site prior to resuming their upstream migration.
 576



577
 578 **Figure 8. Bulkley River fish observed swimming upstream in a single direction after release.**

579 3.5.4 *Resident steelhead.*

580 One of the large unknowns in mark-recapture studies is the behavioural changes that may
581 result from handling and tagging. During the 2009 Bulkley River study, a large proportion (83%)
582 of steelhead were identified as dropping back downstream following treatment, and it is unknown
583 if untreated fish would exhibit the same behaviour. A perhaps more significant observation in
584 2009 is the number of steelhead which remained resident below the recapture site following
585 tagging, thereby effectively excluding themselves from the possibility of recapture. In 2009, 24
586 tagged fish were not detected on any acoustic receivers above the Moricetown Canyon, but two
587 of these were recaptured at the dip-net site and lost their tags. 22 (33%) of the tagged fish did not
588 travel upstream through the canyon and several of these disappeared downstream fairly quickly
589 after release (Figure 9). Time from release to last detection for these 22 steelhead is shown in
590 Figure 10 and the final receiver they were detected on can be seen in Table 6. It is not possible to
591 know if these fish died or if they simply decided to hold downstream – but it is certain that
592 whatever their specific fate, they were removed from the potential recapture pool following
593 tagging.

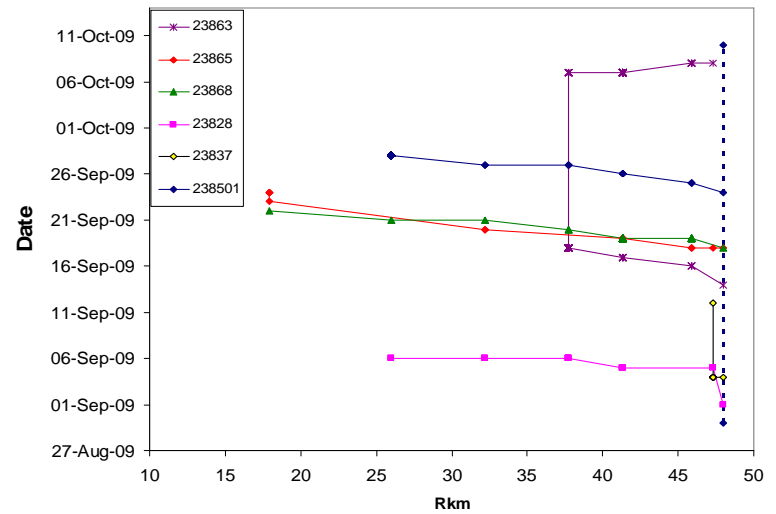
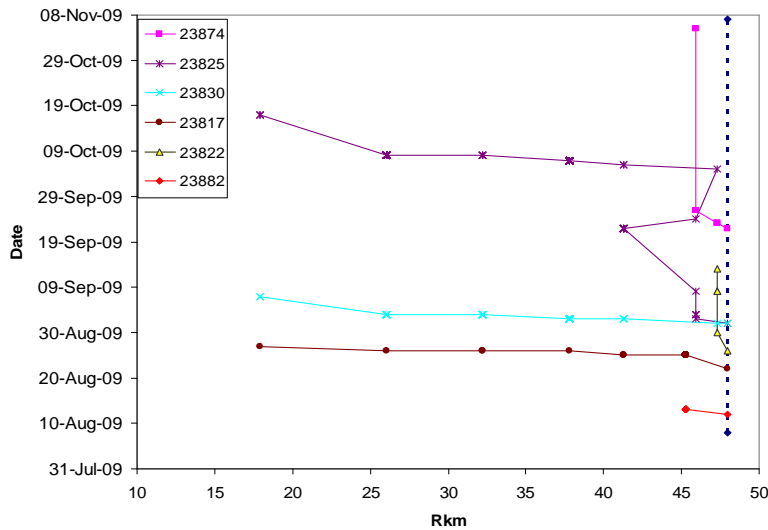
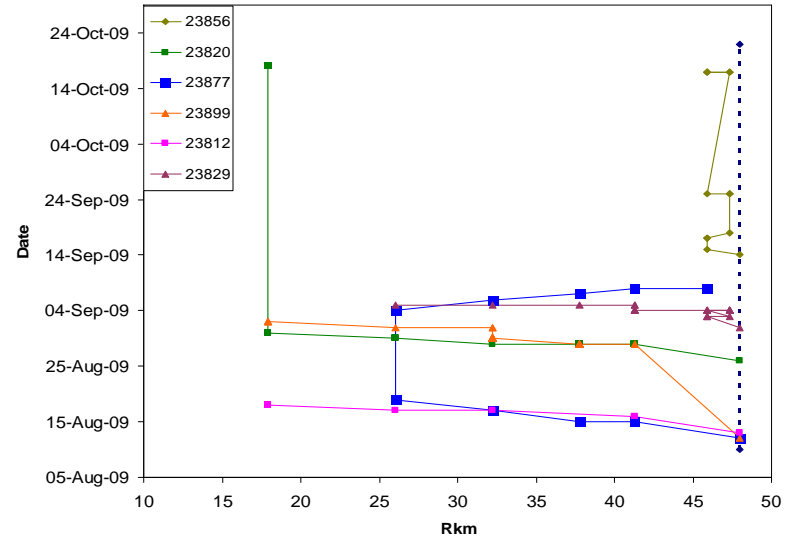
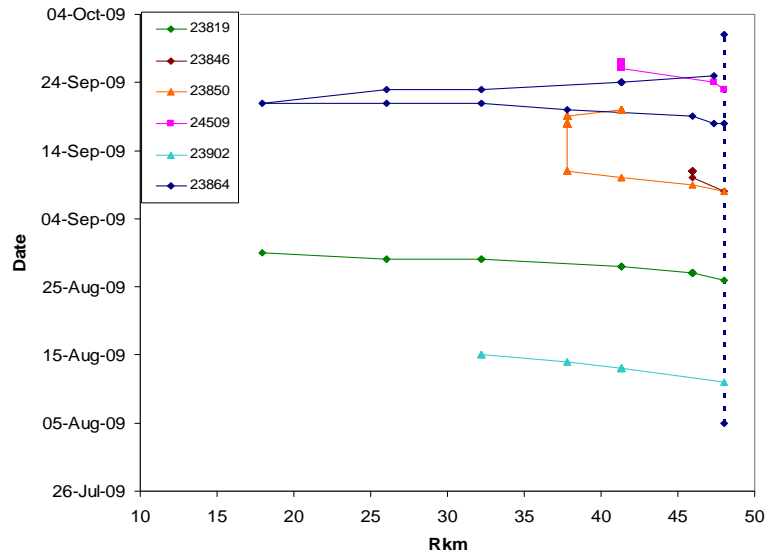


Figure 9. Detailed movement of the 22 steelhead which only travelled downstream from the Moricetown Canyon after tagging event in 2009 and the two fish that lost their tags at the recapture site prior to upstream migration past the canyon (23850 and 23864). Blue dotted line indicates release site.

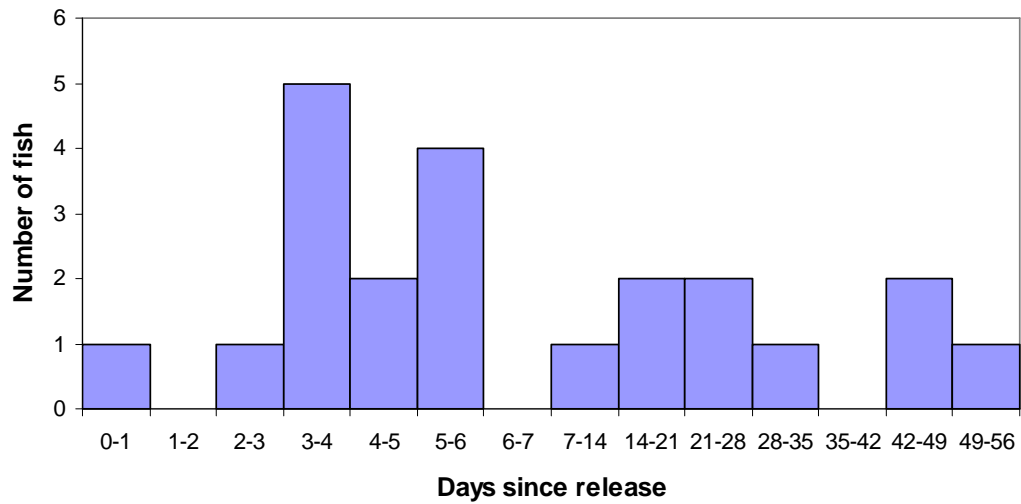


Figure 10. Time to last detection for the 22 steelhead only observed travelling downstream from the Moricetown Canyon following tagging in 2009.

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).

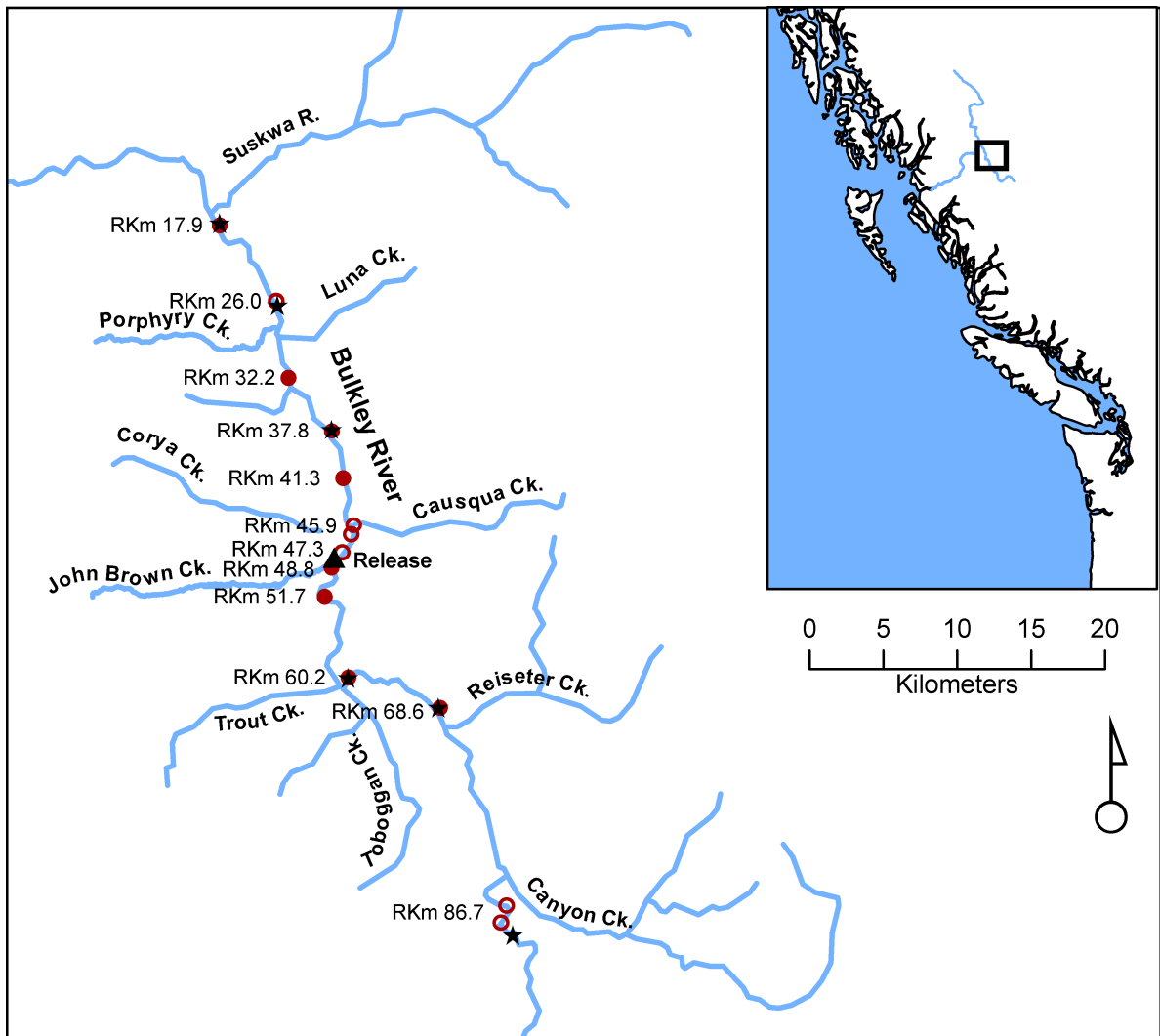


Figure 11. Map of Bulkley River acoustic receivers in 2009 (red dots with Rkm) and 2008 (black stars). Unfilled red dots indicate a receiver which was either moved or re-deployed during the study period.

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.

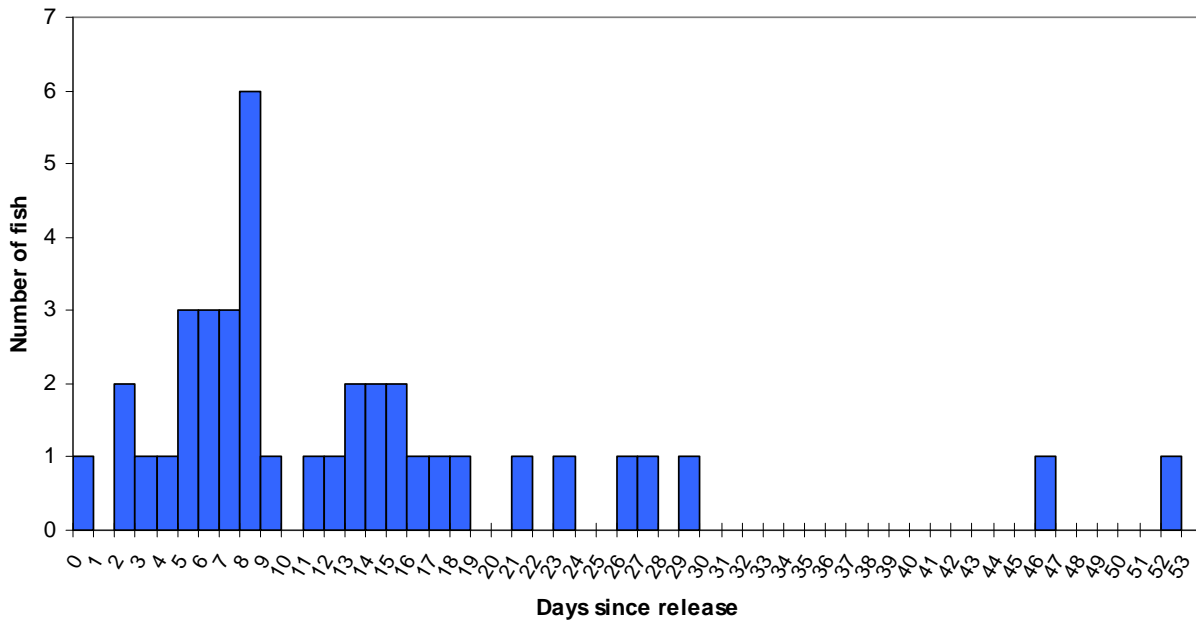


Figure 12. Elapsed time from release to first detection above the Moricetown Canyon. No new fish were observed above the canyon between day 30 and 46 post-release (n=39).

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).

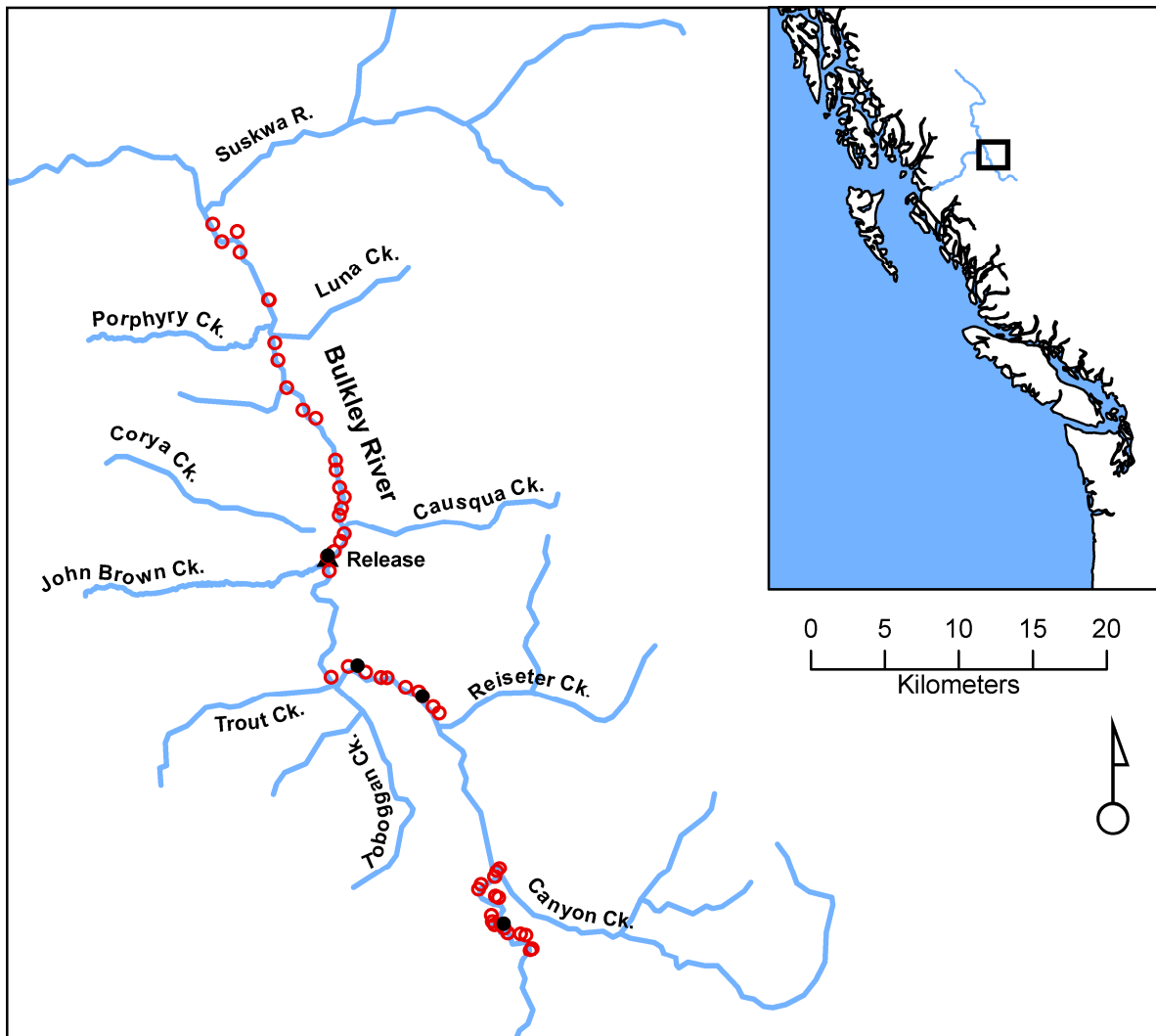


Figure 13. Locations of acoustic surveys at the termination of the Bulkley River project in 2009. Red circles indicate areas of survey and black dots indicate the sites where tags were detected.

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 assess 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 for 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

| 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 | | |
|----------|-----------|---------------|--------------|-----------|---------------|--------------|-----------|---------------|--------------|------------|---------------|--------------|
| | Num | Date detected | | Num | Date detected | | Num | Date detected | | Num | Date detected | |
| | | First | Last | | First | Last | | First | Last | | 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 | | |
|----------|-----------|---------------|--------------|-----------|---------------|--------------|-----------|---------------|--------------|------------|---------------|--------------|
| | Num | Date detected | | Num | Date detected | | Num | Date detected | | Num | Date detected | |
| | | First | Last | | First | Last | | First | Last | | 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 | | |
|----------|------------|---------------|--------------|------------|---------------|--------------|-------------|---------------|--------------|
| | Num | Date detected | | Num | Date detected | | Num | Date detected | |
| | | First | Last | | First | Last | | 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 |