

**Mactaquac Aquatic Ecosystem Study Report
Series 2015-013**



**METHODS PAPER: Atlantic Salmon
Smolt and Adult Movements**

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26 February 2015



Canadian
Rivers Institute



Correct citation for this publication:

Babin, A. 2015. METHODS PAPER: Atlantic Salmon Smolt and Adult Movements. Mactaquac Aquatic Ecosystem Study Report Series 2015-013. Canadian Rivers Institute, University of New Brunswick 13 p.

DISCLAIMER

Intended use and technical limitations of the report, “METHODS PAPER: Atlantic Salmon Smolt and Adult Movements”. This report describes the general sampling approaches for Atlantic Salmon in the biotelemetry studies of the MAES project. The CRI assumes no liability for any use of the included data outside the stated scope.

Introduction

The Report: The following METHODS PAPER describes the general process of tracking Atlantic Salmon in the MAES project.

Background: Atlantic Salmon (*Salmo salar*) naturally migrate down rivers from their place of birth to the ocean where food is plentiful. As adults, they return to their natal rivers and head upstream to spawn, eventually returning to the ocean. These migrations are partially driven by river current, either carrying juveniles (smolts) downstream, or being fought against by returning adults.

The Mactaquac Generating Station (MGS) and its associated 96 km reservoir pose a large challenge to migrating Atlantic Salmon. The large reservoir has minimal water current, which could potentially affect salmon migration. This project is investigating the movement rates and success of smolts, adults, and post-spawned adults as they navigate the reservoir. The objectives are to: (1) Determine the up- and downstream migration success of three life stages of Atlantic Salmon (smolt, adult, post-spawned adult) within the MGS reservoir, (2) identify habitat use of Atlantic Salmon, especially for post-spawners whose overwintering habitat is currently unknown, (3) identify where and why Atlantic Salmon migration may be delayed.

Acoustic telemetry was used to address these objectives. Salmon were either captured in the wild, or obtained from the Mactaquac Biodiversity Facility (MBF), as representative of all migratory salmon found within the Saint John River (SJR). The sample sizes used were a trade-off between ensuring accuracy and minimizing impacts on the population. These fish were outfitted with acoustic tags, allowing individual identification. The acoustic signals were detected by receivers placed along the Saint John River, focusing on the MGS reservoir. The signals were also tracked via portable receiver and boat.

Section 1: Atlantic Salmon smolt movements May-July 2014

Hatchery and wild Atlantic Salmon smolts were acoustically tagged and tracked to determine downstream movement rates and success.

Hatchery smolts were of Tobique River stock but raised at the MBF (45.95885 -66.84392). Ten fish (Group 1) were tagged on site on 21 May 2014 (details in Table 1). Group 1 was transported in a 45 L aerated cooler for 2 h to a release site (46.52326 -67.62338) 4 km downstream of the Beechwood Generating Station (BGS; 46.54325 -67.66864). Ten more fish (Group 2) were tagged at MBF on 26 May 2014, transported for 3 h in the same tank, then released at a site (46.39621 -67.60308) 20 km downstream of BGS for ease of access.

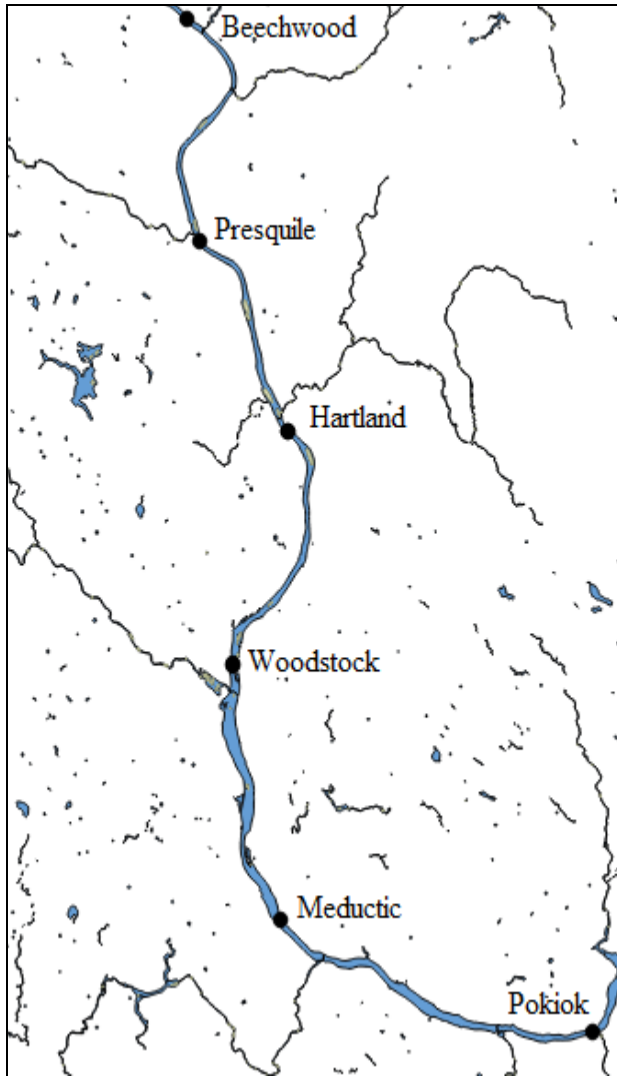
Wild smolts were captured from the gatewells of the BGS. Fourteen fish (Group 3) were tagged on site on 29 May 2014, and six fish (Group 4) on 1 June 2014. Both groups were transported for 2 h 40 min in the same tank and at the same release site at Group 2.

Acoustic (69 kHz) V7 tags (Vemco, Halifax NS) were 7 mm in diameter, 20 mm in length, weighing 1.6 g in air and 0.75 g in water. The tag/body weight ratio was kept under 5% (average = 3.9 %). Tagging was performed using 5 ppm clove oil anesthetic (9.3-16.9 °C, 238 ± 6 s), with surgery lasting 265 ± 10 s. The fish recovered in a 45 L aerated cooler, with no more than 11 fish in a cooler.

Smolts were passively tracked downstream through the SJR and MGS reservoir using 32 VR2W receivers (see Figures 1 and 2). These receivers were deployed from May-Nov 2014 (see Table 2).

Table 1. Average weight and lengths of acoustically tagged Atlantic Salmon smolts.

	Number of fish	Tagging Date	Fish Weight (g)	Fork length (cm)	Total length (cm)
(1)Hatchery	10	21 May 2014	41.71 ± 1.68	16.8 ± 0.2	18.2 ± 0.3
(2)Hatchery	10	26 May 2014			
(3)Wild	14	29 May 2014	41.43 ± 2.28	17.2 ± 0.3	18.4 ± 0.3
(4)Wild	6	1 June 2014			



VR2W Station	Latitude	Longitude
Beechwood	46.51950	-67.61685
Presquile	46.39592	-67.60342
Hartland	46.29138	-67.52450
Woodstock	46.16162	-67.56887
Meductic	46.01945	-67.52610
Pokiok	45.95951	-67.25353

Figure 1. Saint John River locations of VR2W receivers from May-Nov 2014.

Figure 2. MGS reservoir locations of VR2W receivers from May-Nov 2014.

VR2W Station	Position	Latitude	Longitude
Pokiok		45.95951	-67.25353
Nackawic Line	Left	45.99352	-67.21790
	Middle (upper/lower)	45.99110	-67.21822
	Right	45.98912	-67.21977
Coac Stream Line	Left	45.97543	-67.16093
	Middle	45.97346	-67.16156
	Right	45.97093	-67.16227
Coac Reach Line	Left	45.93832	-67.08083
	Middle	45.93531	-67.08388
	Right	45.93214	-67.08675
Lower Prince William Line	Left	45.89540	-66.99541
	Right	45.89243	-66.99837
Scoodawabscook Line	Left	45.87926	-66.94028
	Middle	45.87706	-66.94169
	Right	45.87436	-66.94195
Longs Creek		45.86619	-66.91395
Kellys Creek		45.87790	-66.90714
Kingsclear Line	Left	45.89450	-66.91902
	Right	45.89254	-66.91614
Mactaquac Line	Left	45.94542	-66.87857
	Middle (upper/lower)	45.94503	-66.87519
	Right	45.94436	-66.87222
MGS		45.95444	-66.87236
Mactaquac Causeway		45.97476	-66.88736
Mactaquac Arm		46.01433	-66.93268

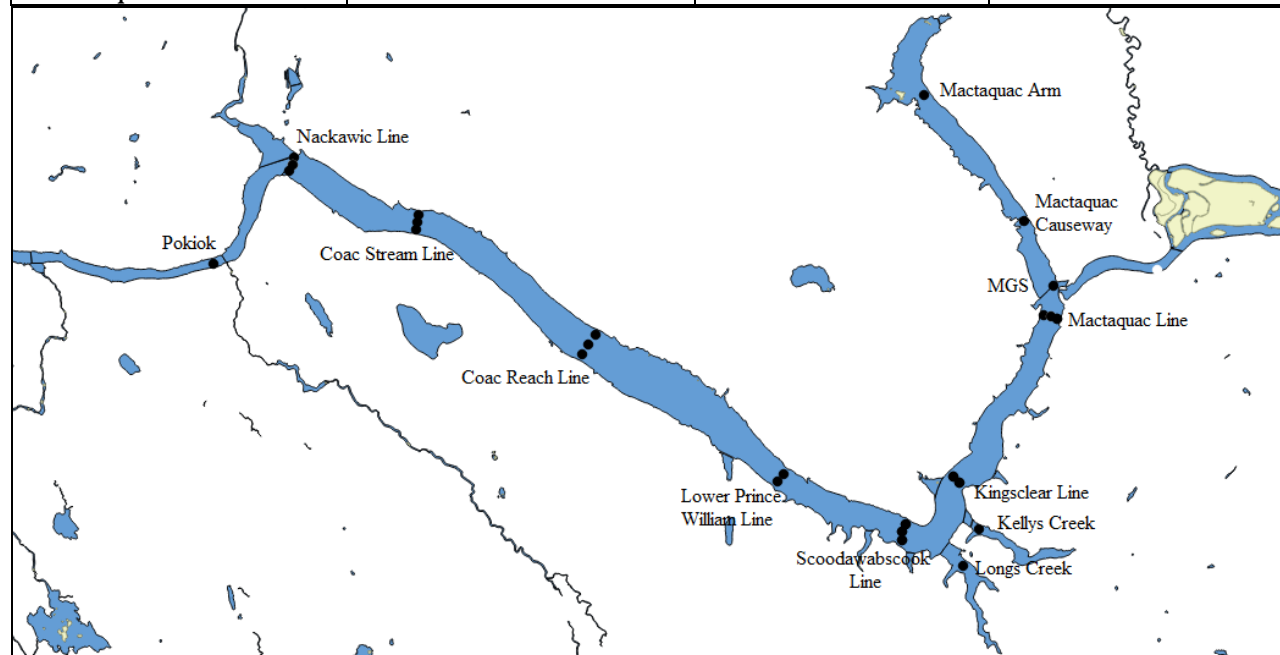


Table 2. VR2W receiver deployment and retrieval schedule May-Nov 2014.

VR2W Station	Position	Deployment Date	Download/Redeploy	Retrieval Date
Beechwood headpond		14 Aug 2014		15 Oct 2014
Beechwood		5 May 2014		30 Oct 2014
Presquile		5 May 2014		19 Sep 2014
Hartland		5 May 2014		19 Sep 2014
Woodstock		5 May 2014		19 Sep 2014
Meductic		21 May 2014		Not recovered
Pokiok		7 May 2014		2 Oct 2014
Nackawic Line	Left	7 May 2014		15 Oct 2014
	Middle-Upper	7 May 2014	8 Jul-9 Aug 2014	15 Oct 2014
	Middle-Lower	7 May 2014		15 Oct 2014
	Right	7 May 2014		15 Oct 2014
Coac Stream Line	Left	7 May 2014		28 Oct 2014
	Middle	7 May 2014		28 Oct 2014
	Right	7 May 2014		28 Oct 2014
Coac Reach Line	Left	7 May 2014		Not recovered
	Right	7 May 2014		Not recovered
	Middle	7 May 2014		28 Oct 2014
Lower Prince William Line	Left	6 May 2014		29 Oct 2014
	Right	6 May 2014		29 Oct 2014
Scodawabscook Line	Left	6 May 2014		28 Oct 2014
	Middle	6 May 2014		28 Oct 2014
	Right	6 May 2014		28 Oct 2014
Longs Creek		6 May 2014		29 Oct 2014
Kellys Creek		6 May 2014		29 Oct 2014
Kingsclear Line	Left	6 May 2014		29 Oct 2014
	Right	6 May 2014		29 Oct 2014
Mactaquac Line	Left	8 May 2014		14 Oct 2014
	Middle-Lower	8 May 2014	8-22 Jul 2014	21 Nov 2014
	Middle-Upper	8 May 2014	22 Jul 2014	21 Nov 2014
	Right	8 May 2014		14 Oct 2014
MGS		8 May 2014		14 Oct 2014
Mactaquac Causeway		5 May 2014		21 Nov 2014
Mactaquac Arm		21 May 2014		14 Oct 2014

The fish were also actively tracked at set listening stations (see Table 3) using a VR100 receiver, with a total effort of 47.3 h between 22 May 2014 and 14 July 2014. Active tracking was restricted to daylight hours and wind speeds below 25 km/h. A tracking protocol was followed. An omnidirectional hydrophone was used to listen for 300 s. If there was a successful detection, a directional hydrophone was used to listen for 150 s in each of the four directions (upstream, downstream, river left, river right), noting signal strength. This was repeated at up to three nearby listening stations.

Table 3. Locations of River Listening Stations (RLS) and reservoir Listening Stations (LS).

Listening Station	Latitude	Longitude	Listening Station	Latitude	Longitude	Listening Station	Latitude	Longitude	Listening Station	Latitude	Longitude
RLS114	46.39410	-67.60070	RLS086	46.24088	-67.50580	RLS058	46.10815	-67.56308	RLS030	45.99645	-67.45268
RLS113	46.39028	-67.59265	RLS085	46.23400	-67.50545	RLS057	46.10332	-67.55960	RLS029	45.99505	-67.44485
RLS112	46.38715	-67.58368	RLS084	46.22725	-67.50770	RLS056	46.09837	-67.55543	RLS028	45.99163	-67.43846
RLS111	46.38403	-67.57488	RLS083	46.22130	-67.50955	RLS055	46.09223	-67.55436	RLS027	45.98707	-67.43260
RLS110	46.37932	-67.56846	RLS082	46.21533	-67.51435	RLS054	46.08667	-67.55370	RLS026	45.98380	-67.42486
RLS109	46.37287	-67.56480	RLS081	46.20968	-67.51993	RLS053	46.08063	-67.55051	RLS025	45.98135	-67.41750
RLS108	46.35635	-67.56216	RLS080	46.20410	-67.52515	RLS052	46.08122	-67.55783	RLS024	45.97783	-67.41086
RLS107	46.36162	-67.56458	RLS079	46.19910	-67.53138	RLS051	46.07612	-67.55576	RLS023	45.97530	-67.40480
RLS106	46.36647	-67.56153	RLS078	46.19548	-67.53778	RLS050	46.07068	-67.55683	RLS022	45.97287	-67.39885
RLS105	46.35978	-67.55856	RLS077	46.19050	-67.54395	RLS049	46.06410	-67.55923	RLS021	45.97050	-67.39316
RLS104	46.35275	-67.55715	RLS076	46.18697	-67.55201	RLS048	46.05758	-67.55888	RLS020	45.96845	-67.38630
RLS103	46.34615	-67.55588	RLS075	46.18403	-67.56003	RLS047	46.05143	-67.55648	RLS019	45.96650	-67.37893
RLS102	46.33933	-67.55303	RLS074	46.17863	-67.56506	RLS046	46.04618	-67.55091	RLS018	45.96527	-67.37140
RLS101	46.33250	-67.55040	RLS073	46.17307	-67.56708	RLS045	46.04228	-67.54503	RLS017	45.96330	-67.36501
RLS100	46.32582	-67.54768	RLS072	46.16710	-67.56843	RLS044	46.03742	-67.54033	RLS016	45.96255	-67.35678
RLS099	46.31947	-67.54593	RLS071	46.16082	-67.56976	RLS043	46.03308	-67.53710	RLS015	45.96188	-67.34826
RLS098	46.31368	-67.54071	RLS070	46.15425	-67.56928	RLS042	46.02905	-67.53311	RLS014	45.96148	-67.33940
RLS097	46.30172	-67.53045	RLS069	46.14802	-67.56775	RLS041	46.02443	-67.53125	RLS013	45.96137	-67.33081
RLS096	46.30807	-67.53555	RLS068	46.14252	-67.56951	RLS040	46.02073	-67.52805	RLS012	45.96067	-67.32216
RLS095	46.29513	-67.52936	RLS067	46.13925	-67.57701	RLS039	46.01560	-67.52158	RLS011	45.95865	-67.31351
RLS094	46.29082	-67.52286	RLS066	46.13682	-67.57140	RLS038	46.01110	-67.51476	RLS010	45.95683	-67.30496
RLS093	46.28658	-67.51603	RLS065	46.13157	-67.56911	RLS037	46.00728	-67.50825	RLS009	45.95588	-67.29660
RLS092	46.28093	-67.51011	RLS064	46.13040	-67.57401	RLS036	46.00278	-67.50115	RLS008	45.95580	-67.28863
RLS091	46.27463	-67.50600	RLS063	46.12413	-67.57630	RLS035	45.99928	-67.49336	RLS007	45.95633	-67.27938
RLS090	46.26820	-67.50508	RLS062	46.12480	-67.56886	RLS034	45.99860	-67.48561	RLS006	45.95652	-67.26996
RLS089	46.26135	-67.50686	RLS061	46.11923	-67.56490	RLS033	45.99710	-67.47610	RLS005	45.95850	-67.26135
RLS088	46.25440	-67.50756	RLS060	46.11798	-67.57190	RLS032	45.99608	-67.46836	RLS004	45.96023	-67.25240
RLS087	46.24757	-67.50635	RLS059	46.11285	-67.56648	RLS031	45.99580	-67.46020	RLS003	45.96263	-67.24370

Listening Station	Latitude	Longitude	Listening Station	Latitude	Longitude	Listening Station	Latitude	Longitude	Listening Station	Latitude	Longitude
RLS002	45.96850	-67.24080	LS028	45.95193	-67.10800	LS057	45.89073	-66.98986	LS086	45.92118	-66.89416
RLS001	45.97398	-67.23756	LS029	45.94690	-67.10998	LS058	45.88828	-66.98335	LS087	45.92363	-66.88760
LS001	45.98057	-67.23598	LS030	45.94678	-67.09876	LS059	45.88535	-66.97588	LS088	45.92837	-66.88385
LS002	45.98623	-67.23288	LS031	45.94133	-67.10271	LS060	45.88040	-66.97028	LS089	45.93335	-66.88136
LS003	45.99122	-67.22675	LS032	45.94140	-67.09125	LS061	45.88538	-66.96770	LS090	45.93957	-66.87916
LS004	45.99027	-67.21711	LS033	45.93560	-67.09535	LS062	45.88205	-66.95973	LS091	45.94467	-66.87516
LS005	45.99665	-67.22335	LS034	45.93715	-67.08323	LS063	45.88100	-66.95146	LS092	45.94917	-66.87520
LS006	45.99882	-67.23258	LS035	45.93142	-67.08571	LS064	45.87593	-66.94643	LS093	45.95543	-66.87325
LS007	45.00315	-67.24271	LS036	45.93490	-67.07478	LS065	45.87983	-66.94106	LS094	45.95465	-66.87961
LS008	45.98918	-67.20575	LS037	45.92770	-67.07536	LS066	45.87202	-66.93675	LS095	45.96128	-66.88036
LS009	45.98557	-67.20960	LS038	45.93142	-67.06466	LS067	45.87627	-66.93030	LS096	45.96717	-66.88486
LS010	45.98133	-67.20165	LS039	45.92392	-67.06673	LS068	45.87123	-66.92380	LS097	45.97345	-66.88625
LS011	45.98508	-67.19525	LS040	45.92820	-67.05588	LS069	45.87892	-66.92275			
LS012	45.97710	-67.19391	LS041	45.92117	-67.06161	LS070	45.86762	-66.91556			
LS013	45.98093	-67.18465	LS042	45.91983	-67.05341	LS071	45.86190	-66.90926			
LS014	45.97330	-67.18496	LS043	45.92643	-67.04685	LS072	45.85478	-66.90956			
LS015	45.97607	-67.17526	LS044	45.91950	-67.04188	LS073	45.84710	-66.90503			
LS016	45.97158	-67.17478	LS045	45.91518	-67.04576	LS074	45.88630	-66.92311			
LS017	45.97462	-67.15373	LS046	45.92397	-67.03651	LS075	45.88262	-66.91438			
LS018	45.97012	-67.15401	LS047	45.91215	-67.03640	LS076	45.89233	-66.92853			
LS019	45.97103	-67.14356	LS048	45.91828	-67.03081	LS077	45.89017	-66.91696			
LS020	45.96653	-67.14371	LS049	45.91022	-67.02710	LS078	45.89588	-66.91751			
LS021	45.97313	-67.16416	LS050	45.91527	-67.02126	LS079	45.89485	-66.90686			
LS022	45.96797	-67.13356	LS051	45.90470	-67.02221	LS080	45.90127	-66.90855			
LS023	45.96173	-67.13538	LS052	45.90885	-67.01473	LS081	45.90078	-66.89996			
LS024	45.96263	-67.12491	LS053	45.90097	-67.01236	LS082	45.90805	-66.90461			
LS025	45.95760	-67.12625	LS054	45.90307	-67.00560	LS083	45.90887	-66.89715			
LS026	45.95715	-67.11600	LS055	45.89725	-67.00368	LS084	45.91485	-66.90160			
LS027	45.95222	-67.11840	LS056	45.89430	-66.99701	LS085	45.91648	-66.89086			

Section 2: Atlantic Salmon adult movements July-August 2014

Wild Atlantic Salmon adults were acoustically tagged and tracked to determine upstream movement rates and success.

Twelve hatchery adults were used as a control group to observe the effects of gastric tagging. This method was chosen to avoid surgical methods impacting spawning success. The fish were starved for 3 days before being tagged on 21 July 2014 (details in Table 4). Fish were observed 1 day, 2 days, 7 days (resume feeding), 17 days, and 23 days after tagging. One tag was found regurgitated after 17 days, and another two tags were found 23 days after tagging. There were no mortalities.

Wild adults were captured from the fishway of the MGS (45.95547 -66.86549), then transported to the MBF for assessment and tagging. Twenty fish were tagged on 28 July 2014. The fish were held at MBF for 2-4 d and treated in a 1:300 formaldehyde concentration bath for 45 min. Ten fish were released (45.93048 -66.87725) 2 km upstream of the MGS on 30 July 2014, nine on 31 July 2014, and one on 1 August 2014.

Acoustic (69 kHz) V13 tags (Vemco, Halifax NS) were 13 mm in diameter, 36 mm in length, weighing 11 g in air and 6 g in water. The tag/body weight ratio averaged 0.5 %. Gastric tagging was performed using 5 ppm clove oil anesthetic (210 ± 10 s), with surgery lasting 172 ± 14 s. The tags had o-rings fixed in the middle with fusion tape, to decrease the chance of regurgitation. Tags were placed by using a long vinyl tube lubricated with glycerin to gently move the tag into the stomach (18.8 ± 1.3 cm, 32 % body length). The fish recovered in a 72 m³ hatchery pool at 60 cm depth.

Table 4. Average weight and lengths of acoustically tagged Atlantic Salmon adults.

	Number of fish	Tagging Date	Fish Weight (kg)	Fork length (cm)
Hatchery	12	21 July 2014	2.8 ± 0.2	58.4 ± 1.7
Wild	20	28 July 2014	2.7 ± 0.3	62.3 ± 2.1

Adults were passively tracked upstream through the MGS reservoir and SJR using 32 VR2W receivers (see Figures 1 and 2). These receivers were deployed from May-Nov 2014.

The fish were also actively tracked at set listening stations (see Table 3) using the same protocol (see Section 1) with a total effort of 48.5 h between 16 July 2014 and 27 August 2014.

Section 3: Atlantic Salmon post-spawned adult movements Nov 2014-Mar 2015

Hatchery and wild post-spawned Atlantic Salmon adults were acoustically tagged and tracked to determine downstream movement rates and success, as well as overwintering habitat.

Two post-spawned adults were captured in a rotary screw trap located at Three Brooks, New Brunswick (46.86914 -67.42933). One was captured and tagged on site on 10 November 2014, and the other on 12 November 2014, both with temperature and depth (TD) sensor tags (details in Table 5). Both fish had adipose fin clippings, and therefore were of hatchery origin originally. The fish were transported for 1 h 15 min to the release site (46.51054 -67.59780) 6.5 km below the BGS.

Twelve post-spawners were angled with double hooked barbless spoons at the Forks of Tobique River (47.24502 -67.15644); four females of hatchery origin, five wild females, one wild

male, one female of unknown origin, and one male of unknown origin. Seven of these fish were captured on 14 November 2014, transported for 1 h 25 min to a heated shed at Three Brooks (46.86883 -67.43107) for tagging (four TD tags), and then transported for 1 h 25 min to the same release site as the previous two fish. The remaining five fish were captured on 17 November 2014, tagged on site (two TD tags), and transported to the release site.

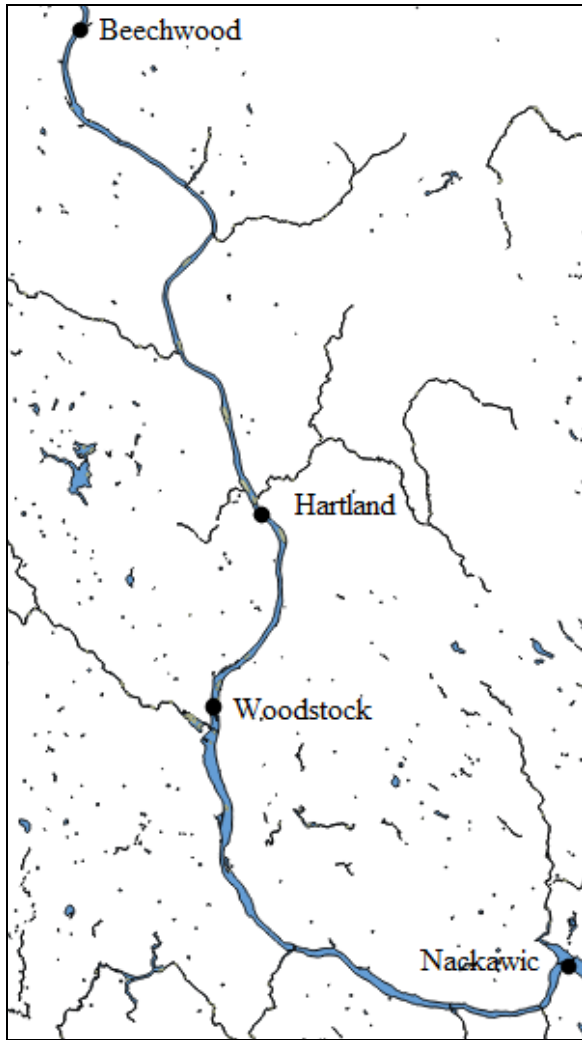
Eleven hatchery post-spawners were also tagged. These fish were of Tobique River origin, but were captured as 2011 pre-smolts and raised to maturity at MBF. The fish were spawned on site as part of a broodstock program. They were tagged (two TD tags on 24 November 2014. The fish were held at MBF for 2 d and treated in a 1:300 formaldehyde concentration bath for 45 min, and then released at the same site on 26 November 2014.

Acoustic (69 kHz) V13 tags (Vemco, Halifax NS) were 13 mm in diameter, 36 mm in length, weighing 11 g in air and 6 g in water. Ten tags had temperature and depth sensors, increasing their length to 45 mm, and their weight to 12 g in air and 6 g in water. The tag/body weight ratio averaged 0.5 %. Tagging was performed using 5 ppm clove oil anesthetic (374 ± 23 s), with surgery lasting 290 ± 23 s. The fish either recovered in a 72 m³ hatchery pool at 60 cm depth, or a 1000 L tank (wild).

Table 5. Average weight and lengths of acoustically tagged post-spawned Atlantic Salmon adults.

	Number of fish	Tagging Date	Fish Weight (kg)	Fork length (cm)
Hatchery	11(2TD)	24 Nov 2014	2.7 ± 0.2	60.5 ± 4.5
	1 (TD)	10 Nov 2014		
Wild	1 (TD)	12 Nov 2014	2.0 ± 0.4	49.2 ± 4.5
	7 (4TD)	14 Nov 2014		
	5 (2TD)	17 Nov 2014		

Post-spawned adults were passively tracked downstream through the SJR and MGS reservoir using 7 VR2W receivers (see Figures 3 and 4). These receivers were deployed in Nov 2014, and will be removed in Apr 2015 (see Table 6). The fish will also be actively tracked through the reservoir ice in Feb 2015 (see Figure 5).



VR2W Station	Latitude	Longitude
Beechwood	46.61623	-67.70883
Hartland	46.29138	-67.52450
Woodstock	46.16162	-67.56887
Nackawic	45.98875	-67.22126

Figure 3. Saint John River locations of VR2W receivers from Nov 2014-Apr 2015.

VR2W Station	Latitude	Longitude
Nackawic	45.98875	-67.22126
Longs Creek	45.87894	-66.92711
Marina	45.95080	-66.87806
MGS	45.95618	-66.87466

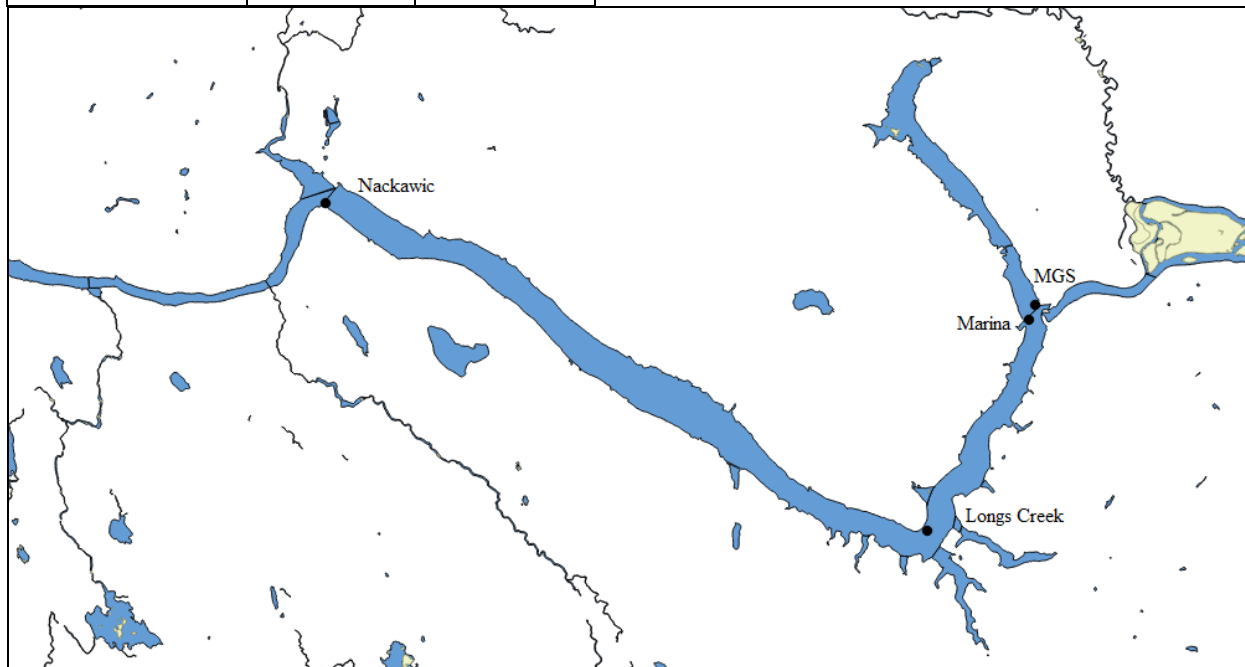


Figure 4. Mactaquac reservoir locations of VR2W receivers from Nov 2014-Apr 2015.

Table 6. VR2W receiver deployment schedule overwinter 2014-2015.

VR2W Station	Deployment Date
Beechwood	30 Oct 2014
Hartland	30 Oct 2014
Woodstock	30 Oct 2014
Nackawic	30 Oct 2014
Longs Creek	30 Oct 2014
Marina	21 Nov 2014
MGS	21 Nov 2014

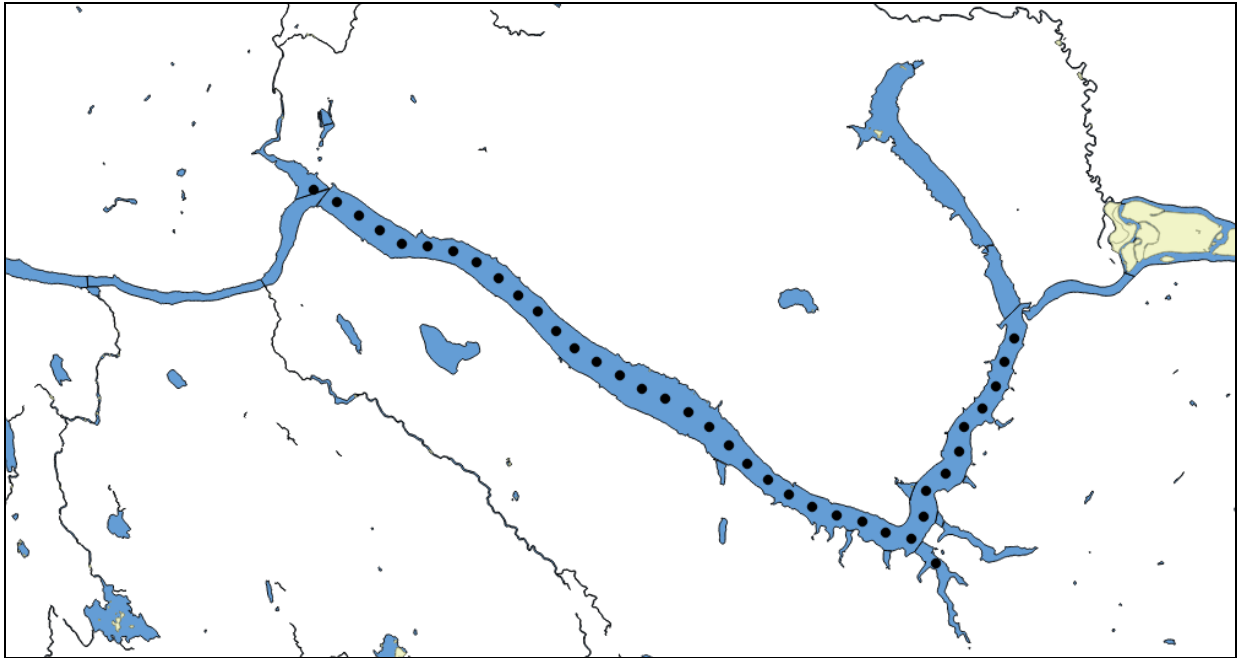


Figure 5. Mactaquac reservoir proposed locations of active tracking through ice for post-spawned adult Atlantic Salmon February 2015.