Mactaquac Aquatic Ecosystem Study
Report Series 2016-052

PRESENCE AND ABUNDANCE OF FRESHWATER MUSSELS IN THE VICINITY OF MACTAQUAC GENERATING STATION

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09 December 2016

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Correct citation for this publication:

MacLean, H., Linnansaari, T., and Wegscheider, B. 2016. Presence and Abundance of Freshwater Mussels in the Vicinity of Mactaquac Generation Station. Mactaquac Aquatic Ecosystem Study Report Series 2016-052. Canadian Rivers Institute, University of New Brunswick. iii + 18 pp.

EXECUTIVE SUMMARY

This report provides a baseline characterization of the presence and abundance of freshwater mussels in the Saint John River in the vicinity of the Mactaquac Generating Station and downstream in areas representing the modeled sediment depositional zone following the removal of the Mactaquac Dam contemplated as Option 3 of the Mactaquac Project. Of the 55 species of freshwater mussels recorded in Canada, 11 have been documented in the Saint John River. Using snorkeling surveys, this study identified the presence, abundance, and spatial distribution of different freshwater mussel species at 28 sites along the Saint John River in the Fredericton area (22 sites representing the Mactaquac Generating Station downstream near-field) and the Oromocto-Gagetown area (6 sites representing the modeled sediment depositional zone). The study also attempts to characterize, in a general sense, the different habitats supporting these mussel assemblages. The surveys found a total of 6,713 mussels including 5 of the 11 species that have been recorded previously in the Saint John River. Neither of the two mussel species listed as special concern under the federal Species at Risk Act – the yellow lampmussel (*Lampsilis cariosa*) and brook floater (*Alasmidonta varicosa*) – were observed. Both mussel abundance and diversity increased in study sites further downstream from the dam reaching a maximum near Fredericton, while the abundance was comparatively lower in the Oromocto/Gagetown area. Substrate composition also changed moving downstream from a coarse/fine flow-sorted mixture in the upstream reaches to a nearly homogenous sandy substrate further downstream. The areas with higher mussel abundance had predominantly sandy substrate and consequently high embeddedness, thus substrate composition appeared to be the most important microhabitat parameter for mussels though the variation between sites of similar substrate suggests other contributing factors such as depth and flow.

1 INTRODUCTION

1.1 PURPOSE OF THIS REPORT

The purpose of this report is to establish the presence and abundance of different freshwater mussel species in two discrete areas of the downstream environment of the Mactaquac Generating Station (MGS). Of specific interest was to document the presence or absence of two mussel species that are listed in the federal Species at Risk Act (SARA) that have historically been known to exist in the SJR and to document any unique mussel assemblage characteristics in the Oromocto/Gagetown area which is defined as an area of interest due to potential sediment transport dynamics under Option 3 of the Mactaquac Project (Ndong and Haralampides; unpbl). The report is intended as background material primarily in support of subsequent regulatory requirements of the selection of a Mactaquac Project option, should they be required.

It should be noted that as of the writing of this report, no specific attempt has been made to establish a relationship between the presence, or operational regimes (e.g. hydropeaking), of dams on the Saint John River (including the Mactaquac Generating Station) and freshwater mussel populations. The remaining information provided in Sections 1.2 – 1.5 of this report provides additional historical and scientific information that are similarly intended in support of subsequent regulatory requirements of the selection of a Mactaquac Project option, should they be required.

1.2 ECOLOGICAL IMPORTANCE OF MUSSELS

Freshwater mussels are a significant component of freshwater ecosystems and often make up the largest biomass within these systems (Strayer *et al*., 1999). Freshwater mussels can influence water quality, nutrient cycling, and the structure of the benthic environment, and they have an important role within aquatic food webs (Strayer *et al*., 1994; Strayer *et al*., 1999). As adults, mussels feed on fine particulate organic matter from the water column, while juveniles buried within the sediment are deposit feeders (Nedeau *et al.,* 2000). The combined filtering capacity of an entire mussel community can remove a great amount of suspended material from the water column (Strayer *et al*., 1999). Excess nutrients are quickly released back to the aquatic environment by excretion and biodeposition, and become available in soluble form for use by primary producers (Strayer *et al*., 1999). In this manner, freshwater mussels can greatly influence nutrient cycling by converting suspended material into forms that can be assimilated by other organisms (Strayer *et al.,* 1999). Due to their high biomass and longevity, freshwater mussels are especially essential for the long-term storage and release of certain elements such as calcium, nitrogen, and carbon (Nedeau *et al*., 2000). As a result, they are able to retain nutrients and energy for several years, unlike aquatic plants and insects which have a much faster turnover rate (Nedeau *et al*., 2000).

The movements of freshwater mussels can also affect the benthic environment. They create mixing and increase the exchange of oxygen and nutrients between the water column and the sediment by moving both horizontally and vertically through the substrate, (McCall *et al*., 1979; Nalepa *et al*., 1991). Freshwater mussels also alter the retention of organic material within the substrate, the porosity of the sediment, and the heterogeneity of the substrate (McCall *et al*., 1979). By improving local conditions, they may in fact boost the diversity and abundance of other aquatic organisms (Sephton *et al*., 1980). Mussels also act as stabilizing substrates and their shells provide a good colonization surface for other flora and fauna (Vaughn and Hakenkamp, 2001). Because they often settle in densely populated clusters, or "beds" the area downstream of the bed can oftentimes provide refugia from the flow for other aquatic organisms (Strayer, 1999). Additionally, in sandy or silty environments, their shells can be one of the only stable surfaces that organisms can attach to (Strayer *et al*., 1994, Beckett *et al*., 1996). In fact, many invertebrates parasitize freshwater mussels, such as protozoans, flatworms, leeches, aquatic earthworms, midges, and water mites (Beckett *et al*., 1996).

1.3 THREATS TO FRESHWATER MUSSELS

Freshwater mussels are among the most endangered North American animals (Martel *et al.*, 2010). Over 70% of the species are believed to be endangered, threatened, or of special concern (Williams *et al*., 1993). Some of the threats to existing mussel populations include pollution, as well as habitat destruction and alteration due to barriers such as dams and impoundments, hydrologic change, and watershed and riparian alterations (Martel *et al*., 2010). Biological threats include: the introduction of exotic species, exploitation of mussels, recruitment failure, loss of fish hosts and predation (Geist, 2010; Martel *et al.,* 2010; Strayer *et al.,* 2004).

The larvae of freshwater mussels, referred to as glochidia, are obligate parasites on fish (Nedeau *et al*., 2000). The glochidia attaches to the gills of a host fish and releases when it has grown to the appropriate size (Nedeau *et al*., 2000). As a result of this, freshwater mussels are also threatened by the loss of fish hosts (Bogan, 2008). Different mussel species rely on different fish species to complete this portion of their life cycle (Strayer, 2008). Certain mussel species are specialists; only a small number of closely related fish species are suitable hosts for the development of the larvae (Nedeau *et al*., 2000). Non-native fish can be a threat to native fish as they can compete with them for food and habitat, or become predators of native fish species (Strayer, 2008). Consequently, the decline of appropriate host fish may decrease or completely eradicate the development of mussel larvae and their subsequent recruitment (Strayer, 2008).

Globally, habitat degradation due to the construction of dams has had a tremendous impact on freshwater mussels (Bogan, 1993). They have major ecological effects on mussels both upstream and downstream. They produce significant changes in hydrology, water temperature, water chemistry, sediment transport, and nutrient cycling (Baxter, 1977). Generally, areas of fine sediment are preferred substrate for many freshwater mussels (Strayer and Ralley, 1993). Since the sediment load is held upstream of a dam, the substrate of downstream reaches eventually become dominated by large size particles (Layzer *et al*., 1993). In some studies, no live mussels were found below a large hydropower dam for roughly eight miles, mainly due to the disappearance of fine particle sediment (Layzer *et al*., 1993). Dams also block the movement of fish, which influences the mussels that use these fish as hosts (Watters, 1996).

Dams which change the thermal regime of a river may also affect species that use temperature as biological cues for growth or reproduction (Nedeau *et al.*, 2000). Water levels in tailrace below dams vary at unnatural intervals for hydroelectric reasons. If water levels are low, then the temperature may increase, which can be fatal to mussels if the temperature remains high for extended periods (Martel *et al.*, 2010). Conversely, deep-release dams release water from the bottom of the reservoir that is relatively colder (Ward, 1976) and persistently cold temperatures may slow down metabolic processes or delay reproductive cycles (Matteson, 1948; Lellis and Johnson, 1996). Furthermore, when exposed out of the water for prolonged periods of time, freshwater mussels will desiccate and die, such as during periods of rapid water level decline below hydropeaking dams (Martel *et al*., 2010).

1.4 FRESHWATER MUSSELS AS BIOINDICATORS

Humans benefit from freshwater mussels because they are useful indicators of ecosystem health (Nedeau *et al*., 2000). Many mussel species are susceptible to stressors such as pollution and habitat alteration (Nedeau *et al*., 2000). Unlike some aquatic organisms, which can move to avoid possible threats, mussels are relatively sedentary, with a long life span (typically 6-15+ years), meaning that any contaminants that they accumulate are from a limited geographic area (Geist, 2010; Metcalfe-Smith and Green, 1992). This allows for studies monitoring ecosystem health that encompass repeated, non-lethal analyses of individuals (Metcalfe-Smith and Green, 1992). If local conditions are too polluted or disturbed to tolerate, they will perish (Nedeau *et al*., 2000). Because of their large size, mussels are easier to collect than other benthic invertebrates and provide sufficient amounts of tissue for analysis (Nedeau *et al*., 2000) and costs of analyses can be less than similar water chemistry programs (Nedeau *et al*., 2000). In addition, because they are so long-lived, individual mussels can be singled out and they can be monitored over time for growth rates and survival (Nedeau *et al*., 2000). If environmental conditions remain stable, the distance between annual growth lines on the shell is even and growth can be determined (Martel *et al*., 2010).

Freshwater mussels have been used as indicators of heavy metals such as mercury, lead, arsenic (Salanki *et al.,* 2003; Salanki and Balogh, 1989; Metcalfe-Smith and Green, 1992). These contaminants frequently have long-term ramifications for aquatic environments that are challenging to identify over short periods of time (Nedeau *et al*., 2000). The chemistry of the freshwater shell can serve as a record of environmental conditions of the mussel's habitat (Mutvei and Westermark, 2000). For instance, techniques involving freshwater mussel shells have been used to detect acidification and oxygen depletion of the water (Mutvei and Westermark, 2000), as well as historical fluctuations in dissolved oxygen and eutrophication (Dunca *et al.*, 2005). As of yet, freshwater mussels have not been commonly used as biomonitors in Atlantic Canada (Martel *et al*., 2010).

1.5 NEW BRUNSWICK FRESHWATER MUSSELS

As well as their key role in aquatic ecosystems, freshwater mussels have also long been of importance to humans. Indigenous tribes in North America used their shells and pearls for decorations and ornamentation, as well as implements such as spoons, hide scrapers, hoes, and dippers (Nedeau *et al*., 2000). Freshwater mussels also served as an important food source for some indigenous tribes (Parmalee and Klippel, 1974), however, because of their unpleasant taste, they were infrequently collected for food (Nedeau *et al*., 2000). Freshwater mussels have also had substantial economic importance to modern societies and have been harvested for button manufacturing and for freshwater pearls (Nedeau *et al*., 2000). Button manufacturing was never an important industry in Eastern North America, where most mussels tend to be small and thin-shelled (Coker 1919), although there are historical records of some harvesting of eastern pearlshell (*Margaritifera margaritifera*) in New Brunswick for pearl collection (Ganong, 1889).

Of the 55 species of freshwater mussels recorded in Canada, 11 occur in the Saint John River system. These include: eastern pearlshell, dwarf wedgemussel (*Alasmidonta heterodon*)*,* triangle floater (*Alasmidonta undulata*)*,* brook floater (*Alasmidonta varicosa*)*,* alewife floater (*Anodonta implicata*)*,* eastern elliptio (*Elliptio complanata*)*,* yellow lampmussel (*Lampsilis cariosa*)*,* eastern lampmussel (*Lampsilis radiata*)*,* tidewater mucket (*Leptodea ochracea*)*,* eastern floater (*Pyganodon cataracta*)*,* creeper (*Strophitus undulata*) (Martel *et al*., 2010). The dwarf wedgemussel is considered extirpated (Hanson and Locke, 2001). Based on assessments by the Committee on the Status of Wildlife in Canada (COSEWIC), two freshwater mussels species that are found in the Saint John River system are now listed under the federal Species at Risk Act (SARA); yellow lampmussel and brook floater have both been listed as species of special concern (COSEWIC, 2004; COSEWIC, 2009).

2 METHODS

2.1 STUDY AREA

The Study Area included two general locations within the Saint John River in New Brunswick, Canada (Figure 1). Field work was initiated in July 2016 once the river water levels had dropped to a level allowing for safe and efficient sampling conditions, and concluded in October 2016 when water temperatures had cooled and mussels were less likely to be visible at the surface of the river substratum. An initial reconnaissance survey was conducted to preliminarily identify locations of mussel beds and choose potential study sites. The surveyed sites were chosen based on:

1. their location at each of the Mactaquac Aquatic Ecosystem Study supersites (four generic areas of different overall habitat characteristics situated between the MGS and City of Fredericton; see e.g. Linnansaari et al. 2016) which were the main focus of our study;
2. accessibility; and
3. different levels of mussel abundance in reconnaissance surveys.

Supplementary investigations were conducted at two sites in Gagetown and four in Oromocto (Figure 1) because the current MAES hydrodynamic and sediment transport model predicts these areas to be areas of higher sediment deposition under the dam removal scenario (*i.e.,* Option 3; Ndong and Haralampides; Unpubl.). Site locations and coordinates are presented in Table 1.

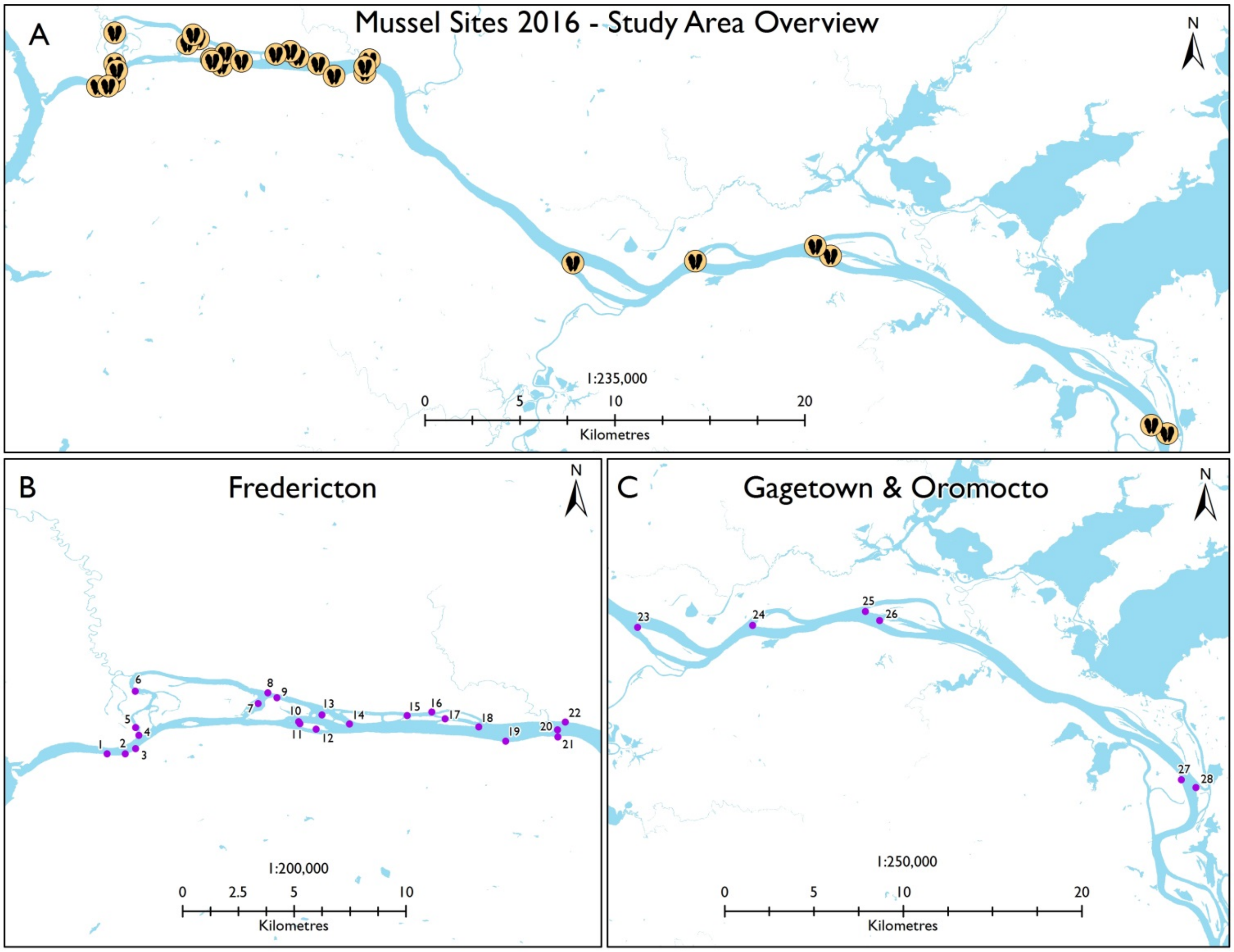

Figure 1. Map of A) The section of the Saint John River, New Brunswick, Canada containing the mussel survey study sites in 2016, B) the Fredericton area study sites (N=22), and C) the Gagetown and Oromocto study sites (N=6) with the corresponding study site ID numbers.

2.2 FIELD METHODS

A field team of two people searched a 10 by 10 metre area for a cumulative total of one (1) person-hours. Each surveyor snorkelled and searched different sections of the survey site, collecting any observed mussels in a bucket along the route. At the end of the timed survey, the mussels were identified *in situ* and then returned to the river. Mussel beds were characterized on the basis of water temperature, dissolved oxygen and other physical habitat characteristics such as depth, velocity, substrate, and embeddedness. Photographs of each survey site were also taken as a reference. Temperature and dissolved oxygen were measured using a YSI Pro20 handheld multi-parameter meter. In each site, water depths and velocities were taken at locations situated 2.5 m, 5 m and 7.5 m along three transects that were set-up perpendicular to the flow. Water velocity was taken at either 60% or both 80 % and 20% of the water depth using an Ott meter (Type C20 "10.005") with a calibration counter (model CMCsp from Hydrological Services Inc.). The dominant and subdominant substrate type and embeddedness at each point along the three transects were visually characterized using methods described in Gautreau et al. (2015). Overall macrophyte percent coverage and macrophyte type were recorded for each site.

Areas deeper than roughly 1.5 metres were not surveyed during the main survey, preventing coverage of the entire river width. However, a deep-water survey was done at two sites using SCUBA diving, and by having one surveyor swim along a transect for 30 minutes, collecting mussels along the survey route. The total distance travelled was 230 m for site 8 and 330 m for site 20 (Figure 1). Substrate type, embeddedness, average depth, and macrophyte type and percent coverage were also noted for the deep dive sites.

2.3 LABORATORY METHODS

One mussel was kept from each site as a sample collection for later stable isotope analysis. If a mussel could not be identified in the field, a specimen was brought back to the lab for further examination. Dead mussels present on shore were inspected and 50 shells of different species were collected for a reference collection to be verified by independent research personnel at the New Brunswick Museum in Saint John.

3 RESULTS

Overall, five mussel species were identified in the 2016 surveys: eastern elliptio, eastern floater, alewife floater, eastern lampmussel, and tidewater mucket. Five of the 11 potential species, including both SARA-listed species, were not found at any of the sites, these are: triangle floater, creeper, brook floater, yellow lampmussel and eastern pearlshell. Two specimens of eastern elliptio were identified in the lab. The 50 reference specimens identified by the MAES team and subsequently subjected to an independent identification at the New Brunswick Museum were confirmed 100% as accurate identifications. The surveys found a total of 6,713 mussels. Freshwater mussel total abundance was highest at site 14 (1,741) and lowest at sites 4, 5, 7, 11 (0) (Figure 2). The highest diversity (N=5 species) was at sites 14, 15, 19, 21, 22, 23 and 24, lowest at sites 4, 5, 7, 11 (N = 0 species; Table 1, Figure 3). Eastern elliptio was found more frequently than any other species (Figure 4). Eastern elliptio was found at 23 out of the 28 sites for a total of 5,050 specimens identified (Table 1, Figure 4). Tidewater mucket was found the least frequently; it was only identified at nine of the sites and was found more frequently at the downstream sites (Table 1, Figure 4).

Based on the 2016 surveys, both mussel abundance and diversity appear to increase when moving further downstream from the MGS (Figure 2, Figure 3). Eastern elliptio dominated species composition downstream, whereas eastern floater was more abundant at sites upstream (Figure 3). Substrate composition also changed moving downstream; cobble, small pebble, pebble and silt dominated closer to the MGS whereas sand dominated further downstream (Table 2). The areas with high mussel abundance had sandy substrate and high embeddedness (Table 2). The areas with low mussel abundance had cobble/pebble substrate, and embeddedness ranging from low to high (Table 2). At the deep SCUBA sites 8 and 20, only 29 and 18 mussels respectively were found in the 30-minute survey. In contrast, the sites adjacent but shallower had much higher abundances, even when correcting for different catch-per-unit-effort, i.e. 30 vs 60 min effort (Table 2, Figure 2). At site 8, the substrate was cobble rather than sand-dominated substrate found in the adjacent shallower site 9 (Table 2). At site 20, the substrate was similar to the adjacent shallower sites 21, but no macrophytes were present and the subtrate was covered in a mat of algae.

Mean water depth over the mussel beds ranged from 24.8 to 610 cm during the sampling period and mean water velocity from 0.01 to 0.64 m/s (Table 2). No apparent trends in terms of dissolved oxygen, temperature, depth, macrophyte type and percent coverage relating to species composition or abundance (Table 2).

The results presented herein are only a preliminary description of the data, and a more thorough analysis of this data will be presented in an Honours thesis in spring 2017.

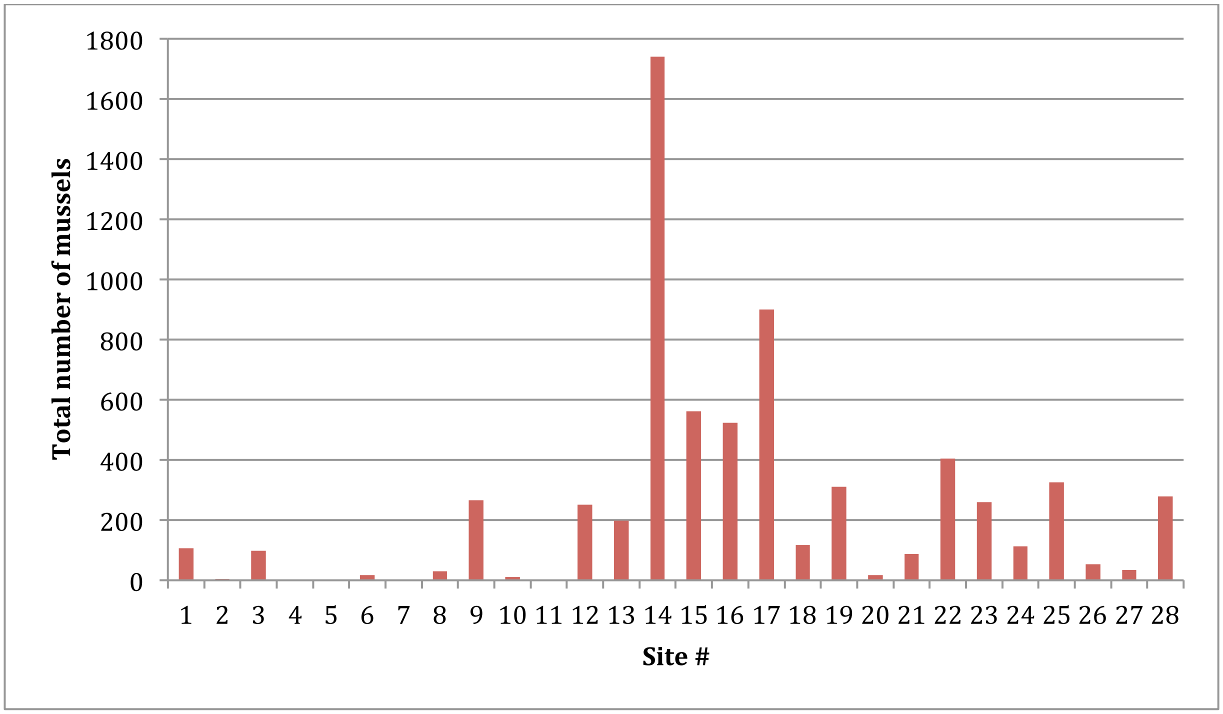

Figure 2. Total abundance of freshwater mussels at each of the 28 sites sampled from July 27th 2016 to October 6th, 2016. Note that the abundance on sites 8 and 20 represent a sample of 30 minute SCUBA survey; all other sites represent abundance from a 60 minute search effort.

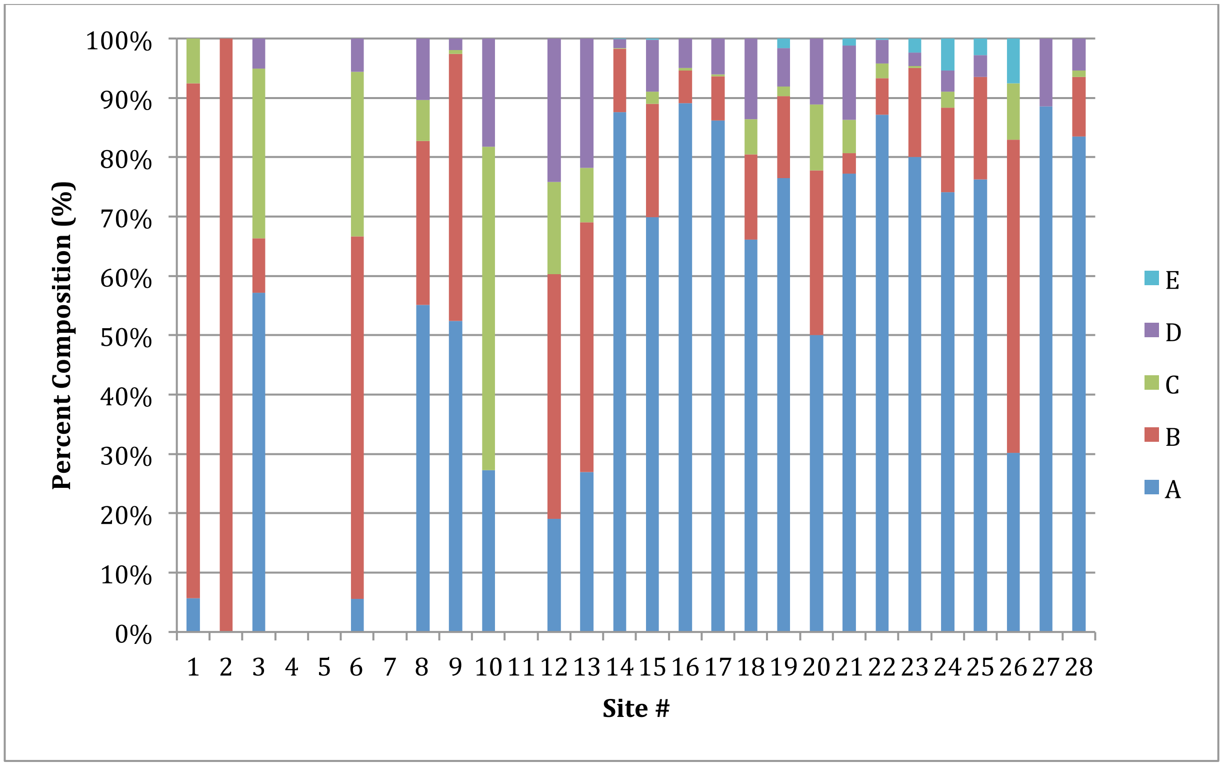

Figure 3. Percent compositions of freshwater mussel species at each of the 28 sites sampled from July 27th 2016 to October 6th 2016. Species names are represented by letters. A= eastern elliptio, B= eastern floater, C= alewife floater, D= eastern lampmussel, E= tidewater mucket.

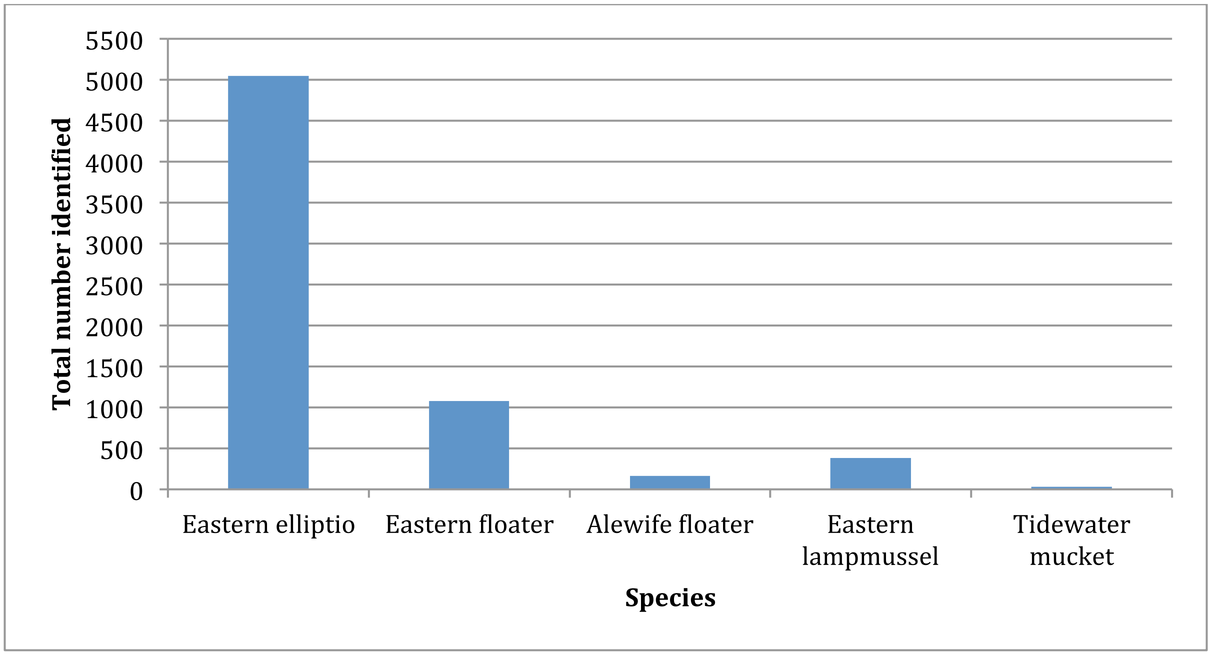

Figure 4. Total abundances of each freshwater mussel species identified at all 28 sites sampled from July 27th 2016 to October 6th 2016.

Table 1. Locations of the study sites, survey dates and the species presence and abundance for each site. Species names are represented by letters. A= eastern elliptio, B= eastern floater, C= alewife floater, D= eastern lampmussel, E= tidewater mucket.

Site Location	Site #	Latitude	Longitude	Survey Date	Species Presence and Abundance
BELOW DAM	1	45.95921	-66.83321	9 Aug	A(6), B(92), C(8), D(0), E(0)
BELOW DAM	2	45.9593	-66.82592	4 Oct	A(0), B(4), C(0), D(0), E(0)
BELOW DAM	3	45.96138	-66.82172	4 Aug	A(56), B(9), C(28), D(5), E(0)
BELOW DAM	4	45.96675	-66.8204	4 Oct	A(0), B(0), C(0), D(0), E(0)
SIDE CHANNEL	5	45.96981	-66.82172	4 Oct	A(0), B(0), C(0), D(0), E(0)
SIDE CHANNEL	6	45.98447	-66.82185	3 Aug	A(1), B(11), C(5), D(1), E(0)
ISLANDS	7	45.97943	-66.77235	6 Oct	A(0), B(0), C(0), D(0), E(0)
SIDE CHANNEL	8*	45.98377	-66.76843	22 Sep	A(16), B(8), C(2), D(3), E(0)
SIDE CHANNEL	9	45.98179	-66.76473	8 Aug	A(140), B(17), C(7), D(16), E(0)
ISLANDS	10	45.97223	-66.75608	5 Aug	A(3), B(0), C(6), D(2), E(0)
ISLANDS	11	45.97137	-66.75548	6 Oct	A(0), B(0), C(0), D(0), E(0)
ISLANDS	12	45.96923	-66.74898	29 Jul	A(48), B(104), C(39), D(61), E(0)
ISLANDS	13	45.97491	-66.74669	5 Aug	A(53), B(83), C(18), D(43), E(0)
ISLANDS	14	45.97127	-66.73561	8 Aug	A(1526), B(186), C(1), D(27), E(1)
SIDE CHANNEL	15	45.97463	-66.712281	3 Aug	A(393), B(107), C(12), D(49), E(1)
SIDE CHANNEL	16	45.97612	-66.70235	29 Jul	A(467), B(29), C(2), D(26), E(0)
SIDE CHANNEL	17	45.97332	-66.69705	28 Jul	A(777), B(67), C(3), D(54), E(0)
MAIN CHANNEL	18	45.97012	-66.68349	27 Jul	A(78), B(17), C(7), D(16), E(0)
MAIN CHANNEL	19	45.96439	-66.67264	27 Jul	A(238), B(43), C(5), D(20), E(5)
MAIN CHANNEL	20*	45.96898	-66.65179	22 Sep	A(9), B(5), C(2), D(2), E(0)
MAIN CHANNEL	21	45.96606	-66.65166	2 Aug	A(68), B(3), C(5), D(11), E(1)
MAIN CHANNEL	22	45.97211	-66.64867	2 Aug	A(353), B(25), C(10), D(16), E(1)
OROMOCTO	23	45.876047	-66.51046	27 Sep	A(208), B(39), C(1), D(6), E(6)
OROMOCTO	24	45.87701	-66.42735	27 Sep	A(83), B(16), C(3), D(4), E(6)
OROMOCTO	25	45.88391	-66.34607	29 Sep	A(248), B(56), C(0), D(12), E(9)
OROMOCTO	26	45.87934	-66.33592	29 Sep	A(16), B(28), C(5), D(0), E(4)
GAGETOWN	27	45.79868	-66.11889	20 Sep	A(31), B(0), C(0), D(4), E(0)
GAGETOWN	28	45.79467	-66.10824	20 Sep	A(232), B(28), C(3), D(15), E(0)

* Note, that the two deep sites, i.e. Site 8 and 20, represent 1 person, 30 minute catch-per-unit-effort (CPUE), whereas the CPUE at other sites was 2 person 30 minute effort, i.e. total CPUE of 60 min.

Table 2. Description of the habitat characteristics of each of the surveyed sites.

SITE #	Dissolved Oxygen (mg/L)	Temperature (◦C)	Dominant Substrate	Subdominant Substrate	Embeddedness	Mean Depth ±SD (cm)	Mean Velocity±SD (cm/s)	Macrophyte coverage (%)	Macrophyte type
1	10.2	23.3	Cobble	Silt	4	56±1	3±1	60	Mixed
2	8.7	19.5	Silt	Sm Pebble	5	56±7	1±0	50	Grassy
3	7.7	22.5	Cobble	N/A	2	87±23	4±2	5	Mixed
4	9	18.5	Pebble	Sm Pebble	1	44±3	4±1	0	N/A (40% algae)
5	8.6	17.1	Cobble	Pebble	0	37±5	5±2	0	N/A (90% algae)
6	8.8	22.8	Silt	Cobble	4	103±20	5±2	60	Mixed
7	N/A	N/A	Sm Pebble	Pebble	2	44±15	24±9	1	Bushy
8	N/A	N/A	Cobble	N/A	2	610	N/A	0	N/A
9	8.4	22.9	Sand	N/A	5	85±21	12±3	10	Mixed
10	8.6	22.1	Cobble	N/A	2	82±8	16±4	20	Leafy and Grassy
11	N/A	N/A	Pebble	Sm Pebble	1	88±8	64±5	1	Mixed
12	8.8	22.5	Silt	Cobble	5	114±14	5±2	60	Grassy
13	8.7	23.1	Silt	Cobble	3	86±17	4±1	50	Leafy and Grassy
14	9.3	23.2	Sand	N/A	5	74±4	7±2	20	Mixed
15	8.5	23.5	Sand	Silt	5	74±30	1±1	30	Grassy
16	7.1	22.5	Sand	N/A	5	87±7	3±1	80	Grassy
17	8.3	24.4	Sand	Silt	5	65±14	1±0	70	Mixed
18	8.3	23.6	Sand	N/A	5	75±15	4±3	30	Grassy
19	8.7	26.6	Sand	Silt	5	67±4	1±0	25	Mixed
20	N/A	N/A	Sand	N/A	5	400	N/A	0	N/A Algae only
21	8.2	24	Sand	Cobble	3	101±27	1±0	5	Mixed
22	8.5	28.9	Silt	Clay	5	52±7	1±0	95	Mixed
23	N/A	N/A	Sand	N/A	5	56±14	5±5	0	N/A
24	N/A	N/A	Sand	N/A	5	59±11	2±2	0	N/A
25	N/A	N/A	Sand	N/A	5	25±9	6±2	0	N/A
26	N/A	N/A	Sand	Silt	5	39±10	2±2	0	N/A
27	N/A	N/A	Sand	N/A	5	52±10	8±2	10	Grassy
28	N/A	N/A	Sand	N/A	5	62±4	1±0	10	Grassy

4 DISCUSSION

The surveys carried out in this study documented the presence/absence and an index of abundance of various mussel species in the areas in the 20 km section downstream of MGS, and in addition in selected sites in the Oromocto/Gagetown area. Five of the potential 11 mussel species were not found at any of the surveyed sites, including the two species (yellow lampmussel, brook floater) listed by the federal Species At Risk Act. Both SARA-listed species had the potential to be found in the area of review, or have existed there recently, however, no live specimens or shells of either species was encountered.

The yellow lampmussel has previously been found in the lower Saint John River system downstream of Mactaquac and in tributaries (Sabine *et al*., 2004), but was not found during this survey. The local population is believed to be relatively stable (COSEWIC, 2004). This mussel species prefers large, wide, downstream reaches with slow-moving water and sand or small gravel substrates (COSEWIC, 2004; Martel *et al*., 2010). Existing population threats include habitat degradation related to siltation and other pollutants (COSEWIC, 2004). COSEWIC (2004) also lists the reduction of host species such as white perch (*Morone americana)* or yellow perch (*Perca flavescens*) as another potential threat for yellow lampmussel, but the MAES fish abundance surveys carried out in the same areas where mussel surveys indicate that yellow perch is one of the most abundant fish species in the area, with white perch being common (Linnansaari *et al*., 2016).

The brook floater was also not present at any of the sites sampled. The only historical record of the brook floater within the Saint John River system is from the Aroostook River in 1960, but it is possible that the species could be present in small tributaries (COSEWIC, 2009). Brook floaters are habitat specialists that prefer riffles or rapids of shallow rivers or streams with moderate to high water flows, with a substrate composed of rocks or cobble with sand-pocket areas (Athearn and Clarke, 1962; COSEWIC, 2009). In Canada, the brook floater is only found in New Brunswick and Nova Scotia (COSEWIC, 2009). Its preferred habitat can be threatened due to eutrophication, contaminants from industry runoff, riparian modifications, siltation, and barriers impeding the migration of host species such as ninespine stickleback (*Pungitius pungitius*), blacknose dace (*Rhinichthys atratulus*), yellow perch, and golden shiner (*Notemigonus crysoleucas*) (COSEWIC, 2009). The absence of brook floater in the studied sites is likely that the suitable habitat for this species is not present in high abundance.

The triangle floater has spotty distribution in a few watersheds in New Brunswick and is not abundant in its range (Martel *et al*., 2010). It is commonly found in medium and large-sized rivers and is found in areas where the current is steady rather than rough (Martel *et al*., 2010). It prefers gravel or sand substrates, but mostly mixtures of coarse or fine gravel with sand and mud (Clarke, 1981). Its host fish include (that are encountered in the SJR): common shiner (*Luxilus cornutus*), blacknose dace, white sucker (*Catostomus commersoni*), pumpkinseed sunfish

(*Lepomis gibbosus*), fallfish (*Semotilus corporalis*), slimy sculpin (*Cottus cognatus*), white perch (Kneeland and Rhymer, 2008; Nedeau *et al*., 2000). It was not found in this study.

The creeper is considered one of the most widely distributed freshwater mussels in North America; however, there are relatively few confirmed records of the species in the Maritimes (Martel *et al*., 2010). It occurs mainly in streams and small rivers, but can be found in large rivers (Clark, 1981; Nedeau *et al*., 2000). It prefers sand, silty sand or sand and gravel substrates (Martel *et al.*, 2010). It has a wide variety of hosts which include: Atlantic sturgeon (*Acipenser oxyrhynchus*), brook trout (*Salvelinus fontinalis*), fathead minnow (*Pimephales promelas*), fallfish, and yellow perch. It was not found in this study.

Eastern pearlshell is commonly found in clean, well-oxygenated, cool environments that support salmonid species which are their host fish (Athearn and Clarke, 1962). This mussel species is typically found in small or medium-sized streams and rivers (Athearn and Clarke, 2962). It is found in sand, gravel and cobble substrates, with a range of flow conditions, but often prefers fast-running streams (Martel *et al*., 2010). The decline in abundance of Atlantic salmon returning to MGS in last two decades (Jones *et al.*, 2014) and low general abundance of other salmonids in the studied (MAES, Unpubl. Data) area may be contributing to the absence of the eastern pearlshell in the studied reach.

Eastern elliptio was found more frequently than any other species, and was present in most studied sites. The eastern elliptio occupies a wide variety of habitats, from small streams to large rivers and lakes, and prefers substrates of clay, sand, mud and cobble (Nedeau *et al*., 2000). These mussels are not typically found in areas with silty or rocky substrates or in areas that are deep (Nedeau *et al*., 2000). They have a high tolerance for disturbed or polluted sites (Nedeau *et al.*, 2000). Tidewater mucket was found the least frequently although it was identified at nine of the studied sites. It was found more frequently at the downstream sites. This species is typically found in coastal freshwater habitats (Martel *et al*., 2010). It prefers mud or sand bottoms in calm waters, in the lower tidal sections of rivers (Clarke, 1981). Eastern floater, eastern elliptio, and eastern lampmussel were the three most common species as they have the ability to thrive in a variety of habitats (Nedeau *et al.*, 2000). In contrast, species such as eastern pearlshell and brook floater- two species not found during our surveys- have more specialized requirements.

In general, mussels prefer sand, gravel, and cobble substrates (Clarke, 1981), and indeed the areas with highest mussel abundance had sandy substrate and consequently, high embeddedness (Table 2). The areas with lowest mussel abundance had cobble/pebble substrate, and embeddedness ranging from low to high (Table 2). River bottoms with bedrock, boulders or large cobbles generally have few species since these substrates do not allow burrowing or horizontal movement (Martel *et al*., 2010). It is impossible to generalize the preferred microhabitat of freshwater mussels since some species are more specialized than others (Nedeau *et al*., 2000). Freshwater mussels can be found in a wide range of depths, from a few centimeters to 4 to 10 m (McMahon and Bogan, 2001). Most are found at depths from 0.3 to 4 m (Martel *et al.*, 2010). In the case of the MGS, it must be kept in mind that the station operates in a hydropeaking mode, and therefore, daily fluctuations in water level are experienced in the downstream environment. The "ramping zone", *i.e.* the area which is subject to temporary but frequent desiccation, may not be suitable mussel habitat as their lateral movement is slow, and mussels may become stranded. Therefore, the relatively shallow areas that are subject to frequent stranding may not be generally suitable for mussels. While not directly assessed in the current study, hydropeaking has been shown to have deleterious effects on many mussel species in other areas (Layzer and Scott, 2006; Bain, 2007).

There were relatively few mussels identified at the deep-dive sites. It is known that some freshwater mussel species are intolerant of standing water (Nedeau *et al*., 2000) and this may be the reason for the relatively lower numbers of mussels in deeper waters.

This study documented the generally lower abundance of mussels in the areas where the largest sediment deposition is predicted to occur based on current MAES hydrodynamic and sediment transport models (Ndong and Haralampides; Unpubl) in the dam removal scenario (Option 3) in comparison to areas in closer to City of Fredericton. No mussel species were found that would only exist in the Oromocto/Gagetown area; in general the mussel community was similarly diverse as the areas around Fredericton. The effects of the sediment deposition predicted in Option 3 on the mussel community in this area are currently unknown, however, it does not appear that SARA-listed species would be affected or that a unique mussel contingent would be present in this area. It should be noted that the authors were not able to verify a relationship between the historic and/or planned future operation of a dam at Mactaquac on these SARA listed species as historical information regarding their distribution in this area does not exist. In the event that an option is selected that continues the presence of a dam at Mactaquac, additional consideration of the long-term effects, based on habitat availability and linkages with fish species, may be required under subsequent regulatory processes.

5 ACKNOWLEDGEMENTS

The authors would like to recognize the funding for this project that is received from NB Power and NSERC's Collaborative Research and Development programme (CRDPJ: 462708-13). We also thank Vicki Nash, Craig Wall, Chris Palmer, Kaleb Zelman, Colin Decoste, and Sonja Stefani for their assistance in the field. Bronwyn Fleet-Pardy is acknowledged for her help in creating the study site map. A special thank you to Mary Sollows and Donald McAlpine at the New Brunswick Museum for their help and guidance throughout the project and for their assistance in providing the independent identification of the mussel reference collection.

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