

Source Locality Effects on Restoration Potential in *Sphagnum palustre* L. from 3 Ohio Sites

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ABSTRACT. Understanding whether propagules from different donor sources differ in their performance at a site may be important for restoration of many habitats. This study aimed at evaluating source effects in *Sphagnum palustre* L, a peatland moss species, for potential use in a restoration setting. Tamarack Bog, a remnant peatland in Bath Township, Ohio, is being restored. One goal is to increase *Sphagnum* coverage. This study focused on the dominant species of peat moss at the bog, *S. palustre*. To test for source effects, *S. palustre* and water samples were collected from 3 different locations (Mentor Marsh, Tamarack Bog, and Singer Lake) and used in 2 experiments. Plant performance was assessed by measuring growth in length and increase in mass. In the first experiment, a full factorial test was conducted: moss sampled from each location was grown directly in water collected from each location. In the second experiment—also a full factorial test—moss sampled from each location was separately grown on a uniform, commercially harvested, peat substrate and supplied with water collected from each location. In the design of both experiments, local adaptation would be indicated by better performance (both experiments measured length change and mass change, plus capitulum counts in the second experiment) for plants grown in their home water source than for plants grown in water from other sites. Ultimately, the study team did not observe evidence for local adaptation in these experiments. However, there were strong plant source effects in both experiments and some indication of differences in response to the water from different sources. Interpreting these results from a restoration standpoint, using donor plants from several source sites may improve the success of restoration.

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INTRODUCTION

Native plant restorations often involve the introduction of propagules from other sites to initiate or augment local populations (Hufford and Mazer 2003). In any one particular site, propagules from one source may be best; at a different site, another source may be superior. This pattern may reflect local adaptation of plant populations, an important concept in conservation (Leimu and Fischer 2008). Local adaptation occurs when an organism has higher fitness in its home habitat than in others (Williams 1966; Kawecki and Ebert 2004). Local adaptation can be tested by growing individuals from different populations of the same species together at a site or in a common garden; finding that individuals perform better under the conditions of their home site provides evidence for local adaptation (Williams 1966; Kawecki and Ebert 2004; Leimu and Fischer 2008). However, the differences in fitness are not always associated with genetic differences, such as the case with tolerance of sulfur compounds in the *Sphagnum* of the Southern Pennines (Lee and Studholme 1992), so local adaptation can be difficult to detect in *Sphagnum*.

Local adaptation may be especially important in understanding the biology and restoration of peatlands. Peatland restoration relies on reestablishment of appropriate vegetation, including particularly *Sphagnum* moss. Sources of propagules for *Sphagnum* reestablishment are typically chosen because of similar plant species composition and environmental conditions to those of the proposed restoration site (Quinty and Rochefort 2003), and because the sites are geographically nearby (Gorham and Rochefort 2003). These decisions capitalize on the fact that *Sphagnum* can sometimes perform better when grown in pH conditions most similar to those of the collection site (Såstad et al. 1999). In many plant species, local populations may have as much as 50% higher fitness than foreign populations (Hereford 2009). Therefore, studying source effects may also be useful in the restoration of peatlands.

Sphagnum often occurs along chemical and physical gradients (Andrus 1986), and local adaptation is one proposed mechanism explaining differential success along the gradients. pH is one important gradient

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determining the species distribution of bryophytes in peatland habitats (Vitt and Chee 1990; Rydin and Jeglum 2013). Different haplotypes of *S. fuscum* (Schimp.) Klingrr. were found to occur in different microtopographic and pH conditions (Gunnarsson et al. 2007). Mikulášková et al. (2014) performed a principal coordinates analysis of *S. warnstorffii* genotypes and, of the 20 ecological variables measured, the only variable correlated with the genetic structure of the populations was pH (ranging from 4.3 to 7.2). However, numerous other ecological factors may affect responses. A study of *S. magellanicum* found that niche differentiation was driven by differences in light intensity, abundance of vascular plants, air humidity, and water table depth (Yousefi et al. 2017).

More research on local adaptation is needed to examine the causes and consequences of home and away differences (Kawecki and Ebert 2004). Here, we examine this topic for *Sphagnum palustre* L. This species occurs in a variety of pH conditions, ranging from acidic (≈ 3.9) to circumneutral (7.0; Andrus 1986; Hájková and Hájek 2007). Since pH gradients are important components of variation within peatlands (Rydin and Jeglum 2013), it would be beneficial to determine whether the different populations of *S. palustre* have differing localized water preferences.

This question was posed: Does water from different collecting sites affect *S. palustre*? To determine if source effects are important for *S. palustre*, plants from 3 source populations were grown in water collected from each location. If there are source effects, some *S. palustre* populations will perform well regardless of growth conditions. Evidence for source effects would encourage project managers to focus donor collections on sites with especially vigorous plants. Evidence against source effects would support collection of donor material for restorations from a broader range of environmental conditions.

METHODS AND MATERIALS

Site Characteristics

Located in the Bath Nature Preserve in Bath Township, Ohio, a tamarack peatland (Tamarack Bog; lat 41°10'37"N, long 81°38'35"W) is shrinking because drainage ditches, established in the 1960s (Miletti et al. 2005), have greatly changed the hydrology and allowed invasive species to establish. Such peatland destruction is common and is a leading cause of wetland loss in Ohio (Andreas and Knoop 1992). Restoration efforts are now underway at the Tamarack

Bog to stabilize the remaining habitat, and help the degraded margins recover to their original state. One goal of the project is to improve *Sphagnum* coverage. Transplanting *Sphagnum* from donor sites may be necessary to achieve this goal. The study sought to better understand the potential of *Sphagnum* source to affect transplant success. This work involves *S. palustre*, the *Sphagnum* species that is most common in the Tamarack Bog (personal observation).

Three source populations were chosen for this study; all contained *S. palustre*, but were intended to provide differing environments for *Sphagnum* growth in terms of pH and light. The first location was the Tamarack Bog in Bath Township, Ohio. This site is categorized as a "poor fen," with substantial groundwater inflow and outflow and a circumneutral pH (6.5 to 7; Mezentseva 2015). The site is dominated by wetland shrubs such as *Alnus incana*, *Vaccinium corymbosum*, and *Toxicodendron vernix* that provide shaded conditions in the understory across the fen. Water levels are within ≈ 10 cm of the peat surface throughout the year (Miletti et al. 2005).

The second location was a red maple (*Acer rubrum*) swamp located in Mentor, Ohio (part of the Mentor Marsh complex; Bernstein 1981). At this location, *S. palustre* was growing on hummocks built up around the roots of dead and living *A. rubrum*. Also, at this site was an encroaching population of *Phragmites australis*, which, along with the red maples, provided mainly shaded conditions. The pH of the water at this site has not been previously reported in the literature. At Mentor Marsh, the swamp habitat had flooded conditions throughout the year.

The third location was an acidic kettle bog, Singer Lake Bog (hereafter referred to as Singer Lake), located near Green, Ohio. This location is an open, floating mat dominated by *Sphagnum* and leatherleaf (*Chamaedaphne calyculata*) with some poison sumac (*Toxicodendron vernix*) providing sparse shade. The *S. palustre* for the current study was collected from a hummock that receives sunlight throughout the day. The water level at Singer Lake appears to be steady throughout the year, so the collected *Sphagnum* was on a hummock between 10 to 20 cm above the water table.

For collections at each site, field identifications were confirmed using a microscope and identification key (Crum 1984) in the lab. All mosses from each site were collected from a single hummock, and the water was collected from the nearest pool (within 1 meter of the hummock). Rainfall in the month leading up to water

collection was average or below average at each of the sites, so water conditions should be representative of typical conditions.

Two controlled experiments investigated whether the *S. palustre* from different sites responded differently to water sources. In experiment 1, the moss from each source was grown directly in water from different sources. In experiment 2, the moss was grown on a peat substrate and watered with water from those same sources.

Experiment 1

To test for local adaptation, *S. palustre* and source water were collected from each of the study's locations between June 24 and July 15, 2015. The water sources from Singer Lake and Tamarack Bog were collected on June 24 and 25, respectively. Samples from Mentor Marsh were collected on July 15. An amount of 3.79 liters (1 US gallon) of water was collected from each location and then stored in the refrigerator (dark, 4 °C). Twenty-four hours after collection, pH was measured with a temperature-compensated pH meter (VWR® SympHony® B10P). Nitrate, sulfate, and chloride concentration were also evaluated using ion chromatography (Dionex™ DX-100; Dionex Corp (now Thermo Scientific™); Sunnyvale, California). The *Sphagnum*—collected at the same time as the water—was stored in sealed clear-plastic bags in the refrigerator until the beginning of the experiment; storage times were between 1 to 3 weeks. The trials ran for 30 days beginning in late July 2015.

The first method of testing source effects was modeled after Ingerpuu and Vellak (2013). Beginning in July 2015, *S. palustre* from each location was grown in clear-plastic cups (radius = 5.5 cm, height = 6.5 cm) for 30 days in a greenhouse (ranging between 22 to 24 °C). The experiment was designed as a full factorial of the 3 water source treatments and the 3 *S. palustre* source locations—with 9 replicates—for a total $n = 81$ cups. For each cup, 5 shoots of *S. palustre* from a particular location (with capitulum intact) were each cut to 1.5 cm length, and their combined fresh mass was measured following Ingerpuu and Vellak (2013; i.e., pressing shoots between paper towels for 3 seconds before weighing). The cups were initially watered with 15 mL of water from the appropriate source, and the fill line was marked on each cup. The cup was filled to the mark every Monday, Wednesday, and Friday. The cups were placed on trays in deep shade in The University of

Akron greenhouse, as earlier trials had shown that direct sunlight in these conditions led to desiccation. The design yielded 3 trays of cups that were rotated biweekly. Greenhouse temperatures were set at 22 °C with a natural photoperiod.

At the end of the experiment, the length of each shoot and the mass of the combined shoots were measured. When the experiment ended, some cups only contained 4 shoots. For this reason, and for each response variable, the mean value per shoot per cup was used in the analysis. Two of the collected water sources occasionally harbored duckweed (*Lemna minor*), which was removed. Also at the end of the experiment, some shoots had fragmented into unmeasurable pieces, resulting in final measurements using the mean of 4 shoots.

Experiment 2

A second experiment was conducted to assess the effect of each water source on each *Sphagnum* source. The design of the experiment entailed testing a full factorial of moss and water collected from the same 3 locations as in experiment 1, plus another water source (reverse osmosis water) as a control. As the mosses collected from the field were found growing at or above the water surface, a standardized substrate of commercially-harvested peat (Mosser Lee Co., Millston, Wisconsin) was used to provide a substrate for the mosses to grow on (different than experiment 1, where the mosses were grown directly in water). Water and moss were collected in October 2015 using the same sources and methods as for experiment 1. A total of 37.9 liters (10 US gallons) of water was collected from each of the 3 locations and subsequently stored in refrigerated, opaque, tubs at the experiment location at The University of Akron greenhouse. Water pH and nutrient (nitrate, sulfate, and chloride) levels were measured after an initial 24-hour refrigeration period.

In preparation, the commercial peat was first soaked in reverse osmosis water for 3 days and then placed into 120 individual porous-plastic pots (8 cm high × 6 cm long × 6 cm wide). *S. palustre* from each site was cut into uniform 0.5-cm-long fragments (without capitula) and held in separate piles. Fragments were cut from the top 10 cm of the *Sphagnum* shoots, necessary because fragments from farther down on the shoot produce lower regeneration potentials in some species (Campeau and Rochefort 1996).

Eight fragments of *S. palustre*, all from the same source, were weighed (providing an initial fresh mass

measurement) and placed into one of the previously prepared peat-filled pots. This was repeated for $n = 120$ pots: 40 containing exclusively Singer Lake moss, 40 containing exclusively Mentor Marsh moss, and 40 containing exclusively Tamarack Bog moss. Groups of 6 pots—2 each with moss from each of the 3 sources—were then placed together into 1 open-topped, clear plastic shoebox ($34.6 \times 21.0 \times 12.4$ cm); resulting in a total of 20 identically configured shoeboxes. Next, 4 shoeboxes—each one labeled to receive water from 1 of the 4 different sources—were then placed together into a 110-liter clear plastic container; resulting in a total of 5 identically configured clear plastic containers. Ultimately, the final configuration of experiment 2 (all 120 total pots) was enclosed within these 5 identically configured, 110-liter clear plastic containers: each container housing 2 replicates of the full factorial of water/moss combinations. Later, during analysis, data on the 2 replicates in each of the 110-liter containers were averaged, yielding $n = 5$ for each water/moss combination.

The experiment commenced in October 2015 and was planned for 90 days. During the experiment, the 6 pots in each shoebox were watered twice a week using 1 of the 4 different water treatments: the same source water being consistently applied to each shoebox at each watering. During watering each shoebox was filled to the level of the peat surface, allowing the common water source to flow into and saturate the peat in each pot.

Environmental conditions were monitored and controlled. Existing research (Bugnon et al. 1997; Price 1997; Price et al. 1998; Rochefort et al. 2003) and trials in the greenhouse indicate that maintenance of a moist microenvironment and high humidity is important in the establishment of *Sphagnum*. Therefore, the lids of the 110-liter containers were placed to maintain the humidity. To guard against any microhabitat variations in the greenhouse, the 110-liter containers were systematically rotated on

a weekly basis. Additionally, any herbaceous plants emerging in the pots were carefully removed.

Experiment 2 was completed after 90 days. The growth of *S. palustre* in each of the 120 pots was determined by measuring final shoot length, mass change, and number of capitula. To obtain length measurements, a plastic ruler was placed into the peat and the longest shoot was measured from the peat surface to the head of the capitulum. The final fresh mass for each pot was measured, and the percent change in mass was then obtained by dividing the change in mass by the initial fresh mass.

Analysis

JMP® Pro 12 was used to run statistical tests on the above experiments. For water chemistry, an analysis of variance (ANOVA) was used to evaluate differences among sites and water collection dates. In each of the plant growth experiments, full factorial ANOVAs were used to observe effects caused by water location, *Sphagnum* location, and the interaction of these 2 categories. For post-hoc contrasts, we used the Tukey's test.

RESULTS

Water Results

Water chemistry varied greatly among sites and collection dates (Table 1). The pH differed among collecting sites ($p < 0.01$), being highest in the Tamarack Bog and lowest in Singer Lake on both dates. Nitrate differed by collecting site and collecting date ($p < 0.0001$ for each). The nitrate was lowest in Singer Lake on both dates and, in July, highest in Mentor Marsh. However, in October, all 3 sites had similar and very low nitrate levels. Sulfate differed only by collection site ($p < 0.001$) with Mentor Marsh having the highest sulfate levels. The chloride differed by collecting site and date ($p < 0.01$ for each) with Mentor Marsh having higher chloride levels. Chloride levels were higher at each site in the October collection compared to the July collection.

Table 1
Water chemistry for the 3 source locations

Site	pH		Nitrate (mg/L)		Sulfate (mg/L)		Chloride (mg/L)	
	Jul 2015 ^a	Oct 2015 ^b	Jul 2015 ^a	Oct 2015 ^b	Jul 2015 ^a	Oct 2015 ^b	Jul 2015 ^a	Oct 2015 ^b
Tamarack Bog	7.24	6.95	7.44	4.15	15.37	17.29	2.13	4.61
Mentor Marsh	6.27	6.80	19.84	3.72	97.02	81.65	78.00	120.53
Singer Lake	5.70	5.85	0	0.62	6.72	2.88	3.55	14.19

^a $n = 1$; experiment 1. ^b mean of $n = 2$; experiment 2.

Table 2
ANOVA values for experiment 1 (error DF^a = 72)

Source	Number of DF ^a	F ratio (length)	p-value (length) ^b	F ratio (mass change)	p-value (mass change) ^b
<i>Sphagnum</i> source	2	10.6853	<0.0001	10.5358	<0.0001
Water source	2	43.2483	<0.0001	15.8299	<0.0001
<i>Sphagnum</i> × water source	4	4.4797	0.003	1.2475	0.3

^aDegrees of freedom. ^b Bold type in column indicates values of $p < 0.05$.

Experiment 1

Length change in experiment 1 differed nearly 10-fold across all moss/water combinations (Fig. 1A), over 2-fold among *Sphagnum* sources, and nearly 3-fold among water sources ($p < 0.0001$; Table 2). The interaction of water and *Sphagnum* source was also significant ($p = 0.003$). Every combination of *Sphagnum* source and water source gained some amount of length, but shoots from all sources performed best in Singer Lake water (Fig. 1A). Moss from the Tamarack Bog performed notably worse than the others in both Singer Lake and Tamarack Bog waters—but all 3 mosses performed similarly in Mentor Marsh water. Responses to water source were similar for moss from Singer Lake and Mentor Marsh, tending to be highest in Singer Lake water, and similarly low in the other sources. While the increase in length of the Tamarack Bog moss was not significantly different in the Singer Lake and Mentor Marsh water sources, the Tamarack Bog moss actually performed the worst (of any moss/water combination) in water from its home source (Tamarack Bog).

Percent change in mass varied significantly with *Sphagnum* source and water source. Moss only gained mass in water from Singer Lake, and shoots from the Tamarack Bog lost mass in all water sources (Fig. 1B). For the water source effect, Tukey's test confirms that

the advantage to growing in water from Singer Lake is significant, and that growth in water from Mentor Marsh and Tamarack Bog was not distinguishable. For the moss source effect, shoots originating from the Tamarack Bog lost significantly more mass than those collected from Mentor Marsh and Singer Lake (Tukey's comparison). Mentor Marsh and Singer Lake mosses were indistinguishable in terms of percentage gain (or loss) in mass.

Experiment 2

In experiment 2, the only significant cause of variation for any response variable was *Sphagnum* source, with water source and interaction not significant in all cases (Table 3). Percent gain in mass—averaged across all water sources—was nearly 20% higher for Tamarack Bog moss than Singer Lake moss (Figure 2B; Table 3). The number of capitula produced was higher in *Sphagnum* originating from Mentor Marsh and Tamarack Bog than in the *Sphagnum* originating from Singer Lake (Fig. 2C); Mentor Marsh moss and Tamarack Bog moss having, on average, ≈ 1.5 more capitula than Singer Lake moss (Table 3; *Sphagnum* source; $p = 0.0002$). Final length was not significantly affected by either *Sphagnum* source or water source (Figure 2A; Table 3), although in 3 of 4 growth conditions, the Tamarack Bog moss grew longest.

Table 3
ANOVA values for experiment 2 (error DF^a = 48)

Source	Number of DF ^a	F ratio (length)	p-value (length)	F ratio (mass change)	p-value (mass change) ^b	F ratio (capitula number)	p-value (capitula number) ^b
<i>Sphagnum</i>	2	1.2323	0.30	3.4603	0.04	10.4616	0.0002
Water	3	0.2308	0.87	0.8766	0.46	1.5773	0.21
<i>Sphagnum</i> × water	6	0.3778	0.89	0.1028	0.99	0.7287	0.63

^aDegrees of freedom. ^b Bold type in column indicates values of $p < 0.05$.

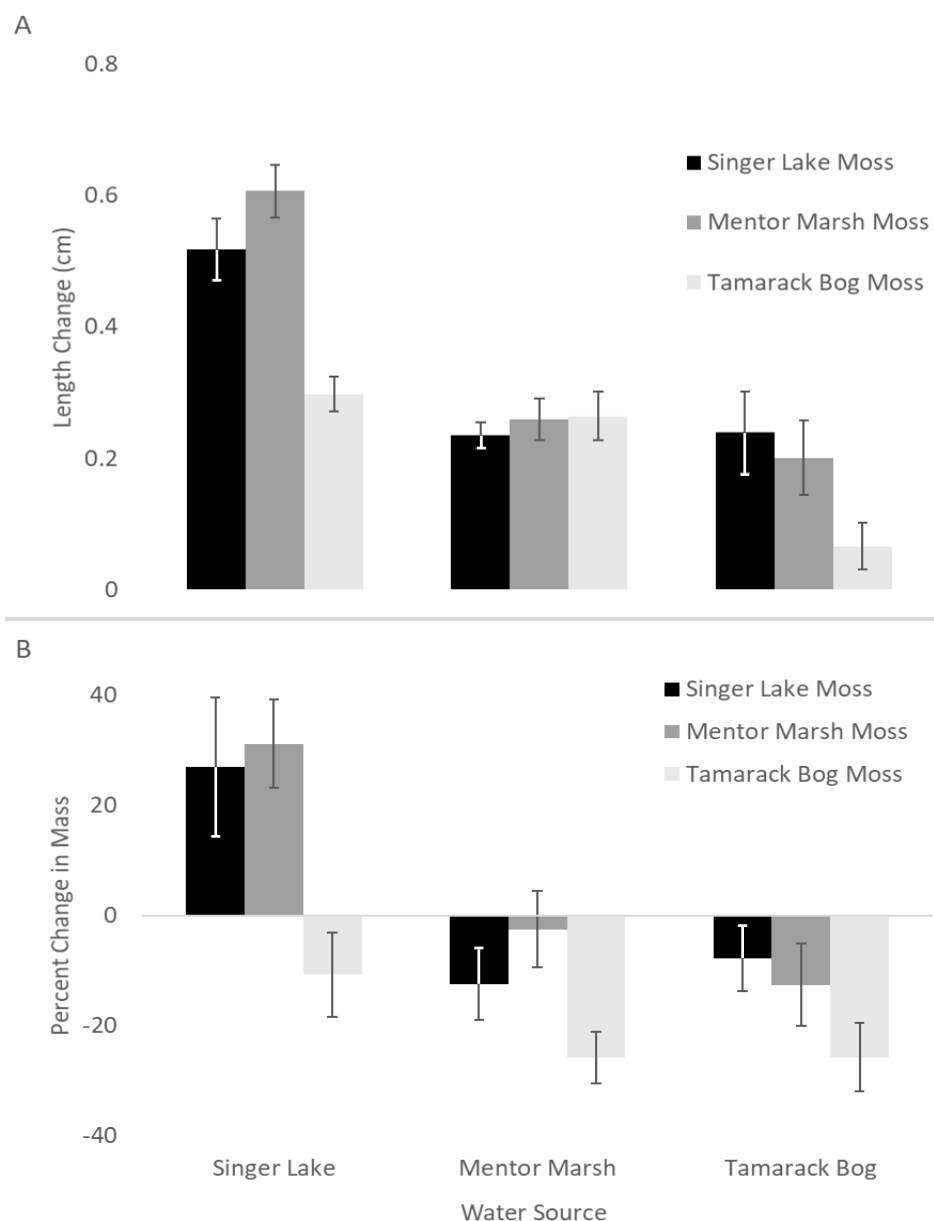


FIGURE 1. *S. palustre* (A) length change and (B) percent change in mass in experiment 1 (error bars represent SE; $n/\bar{=}$ 9 cups)

DISCUSSION

Water Chemistry and Experiment 1

Singer Lake water was more conducive to *S. palustre* growth than the Tamarack Bog or Mentor Marsh water sources. The Singer Lake water source was the only source that produced an increase in length and an increase in mass of *Sphagnum* in experiment 1. The other 2 water sources resulted in decreased mass. Referring to Table 1, there are a few possibilities that could explain this difference. One possible explanation for the better performance in the Singer Lake water source involves pH. Clymo (1973) found that some *Sphagnum* species (*S. palustre* was not tested) cannot withstand experimental increases in pH. The Singer Lake water source was the lowest pH of the 3 wetlands

(5.70). However, *S. palustre* is commonly found in areas ranging in pH from 4.0 to 7.0 (Rydin and Jeglum 2013; although see also Andrus (1986) which suggests pH > 6.5 is marginal for *S. palustre*). With the pH of the Tamarack Bog water (pH = 7.24) being only slightly above this range—and with a similar change in mass in the Mentor Marsh (pH = 6.27) and Tamarack Bog waters—pH is less likely to be a potential driver of the observed differences.

Another possible explanation is the concentrations of the different nutrients. Increases in nitrate, sulfur compounds, and chlorides have all been shown to reduce *Sphagnum* growth (Ferguson et al. 1978; Press et al. 1986; Wilcox 1986). Singer Lake water had less nitrate and sulfate than the other 2 sites. As for

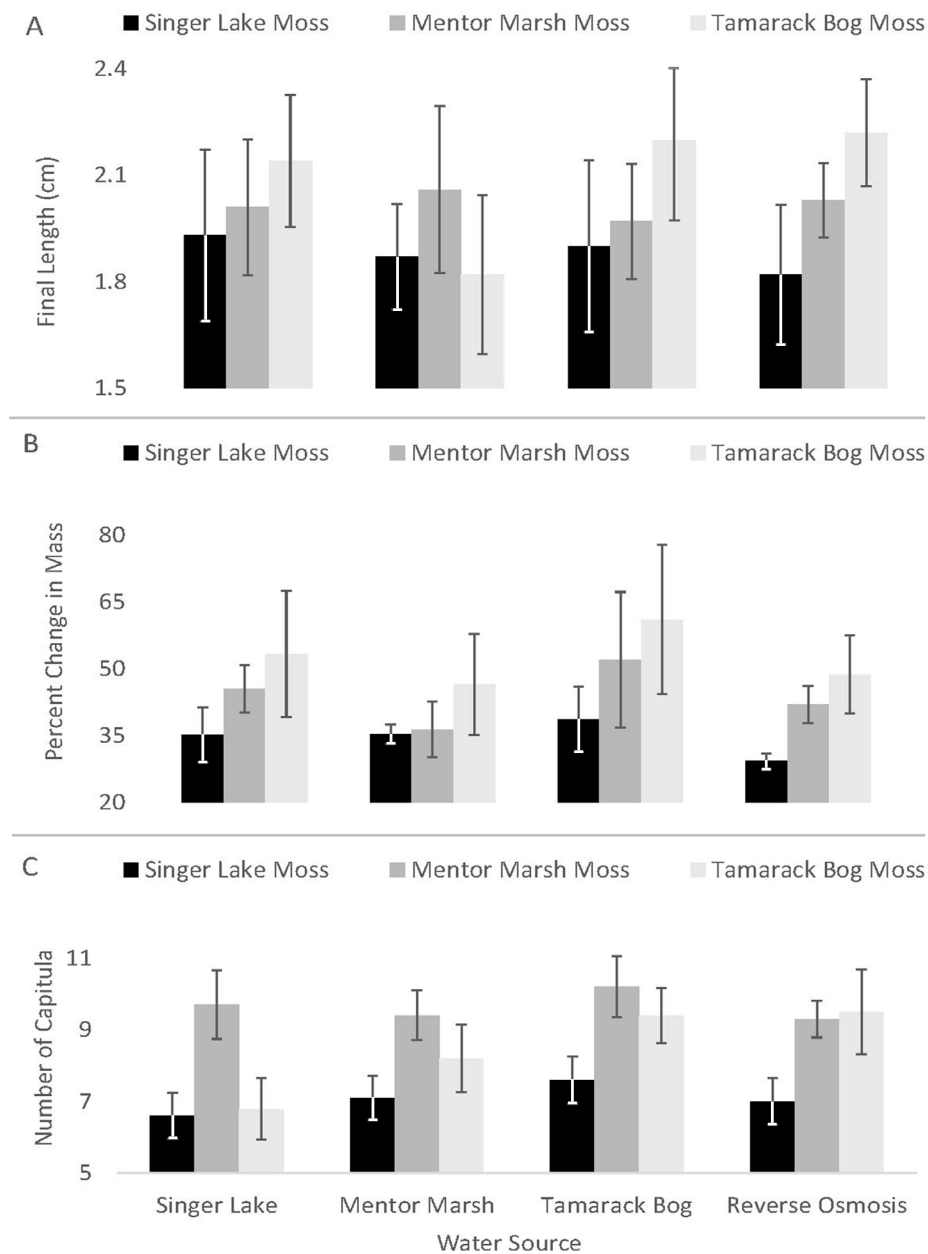


FIGURE 2. *S. palustre* (A) final length, (B) percent change in mass, and (C) number of capitula produced in experiment 2 (error bars represent SE; n/bar=5 replicates)

chloride, it was highest in the Mentor Marsh water (July = 78.00 mg/L). This coincides with the history of Mentor Marsh. This site is fed by one stream that has experienced increases in chloride content because of nearby mining (Bernstein 1981). Yet another possible explanation is calcium. Increases in calcium can negatively impact *Sphagnum* growth (Clymo 1973). In November 2015, water samples were taken for measurements of calcium. The calcium level was lowest at Singer Lake (4.01 mg/L) and highest at Mentor Marsh (64.13 mg/L); Tamarack Bog water (32.06 mg/L) was intermediate between Singer Lake and Mentor Marsh. Calcium was in a different range than found in a study from the Netherlands, which

found *S. palustre* in sites ranging from 20.04 to 90.18 mg/L (Wassen et al. 1988). The data presented here cannot distinguish among these potential causes, but it is a useful focus for future research.

When comparing change in mass—and across all water sources—the moss collected from Mentor Marsh and Singer Lake outperformed the moss collected from the Tamarack Bog in experiment 1. In fact, the Tamarack Bog moss of experiment 1 ended up losing, on average across all water sources, 20% of its mass. This is a troublesome finding that suggests a lack of vigor for the *S. palustre* population at the Tamarack Bog: Even when grown in the water from Singer Lake and Mentor Marsh, this moss still lost mass. Also,

the shoots (from all sites) grown in the Tamarack Bog and Mentor Marsh water sources appeared more frail than the shoots grown in the Singer Lake water source. In 7 of the 81 cups (and occurring in moss from all sites and in water from the Tamarack Bog and Mentor Marsh) the fragile shoots broke apart into unrecognizable pieces, and this led to the loss of a shoot. Additionally, shoots in at least 10 of the 81 cups (and occurring in moss from all sites) turned a grey-black color when grown in the Tamarack Bog or Mentor Marsh water sources. These 2 factors (shoot loss and color change) may indicate stressful conditions. Consistent with this, the Tamarack Bog and Mentor Marsh water sources had the highest measured pH and calcium levels, respectively.

Experiment 2

In experiment 2, the source of *S. palustre* was the only significant influence on plant growth; a result in contrast to experiment 1. The *S. palustre* from Mentor Marsh and Tamarack Bog grew more capitula, and produced a higher percent increase of mass, than *S. palustre* from Singer Lake. This is promising for successful restoration, as capitulum development has been useful for measuring the regeneration success of *Sphagnum*. (Campeau and Rochefort 1996).

Interestingly, water source had no significant effect on moss growth in the peat substrate (experiment 2). When moss was grown directly in the water of the Tamarack Bog in experiment 1, the moss from all sites lost mass on average and some shoots from each source were killed. However, when grown on a substrate and watered with the Tamarack Bog source (experiment 2), the mosses grew at similar rates as with the other water sources. One reason for this could be the seasonal differences in growth for this species. The growing season for *S. palustre* goes from spring to July, with the moss dying back from August on (Sobotka 1974). Moss for experiment 1 was collected in June and July, when mosses may have been at the end of their growing season, so they may not have grown well in the cups. Experiment 2 started in October, when mosses may have been emerging from late-summer dormancy and were therefore able to grow with more vigor.

Another interesting contrast between the 2 experiments was the behavior of the moss collected from the Tamarack Bog. In experiment 1, the *S. palustre* of the Tamarack Bog had—in 5 of 6 cases—the least growth (or greatest loss) in terms of mass gain and length gain. When grown on a peat substrate, in experiment 2, the *S. palustre* of the Tamarack Bog had the highest percent change in mass gain in every

case. Furthermore, in contrast to the observations in experiment 1, there was no observed shoot loss or color change across the water source treatments in experiment 2. One explanation for the differing results between the 2 experiments could be the filtering ability of peat. One area where peat has been shown to be an effective filter is in wastewater settings (Farnham and Brown 1972; Lens et al. 1994).

Implications for Restoration

The results of the greenhouse experiments provide information for bogs and fens undergoing restoration. First, the *S. palustre* in this experiment showed no evidence of local adaptation. This suggests that it is reasonable to make collections from a wide array of donor sites, as opposed to a narrow choice among source sites with similar vegetation and water conditions. This could be tested with a field transplant study. Secondly, the *S. palustre* collected from Mentor Marsh and Tamarack Bog formed significantly more capitula than the moss collected from Singer Lake. This provides evidence for the potential of vegetative reproduction (Cronberg 1992) because new shoots arise when a capitulum forms from a branch coming off the main stem.

As for the moss at the Tamarack Bog restoration site, it lost mass in each water treatment in experiment 1. This could simply reflect limits of growing directly in water with no substrate, or a problem with growth dormancy at that time of year. It could also indicate that the moss is not as healthy; however, given the results of experiment 2, this does not seem likely.

The findings of this study identify 2 key points for restoration. First, with respect to growth, moss collections from any site would work for restoring the Tamarack Bog; however, restoration could be better fostered by using mosses with higher capitulum production. Second, when spreading diaspores at the restoration site, they should be spread on a peat substrate that is less susceptible to flooding and standing water.

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