Morphological traits to differentiate between native and invasive *Phragmites* & an update on biocontrol

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Alberta Invasive Species Council

March 20, 2024

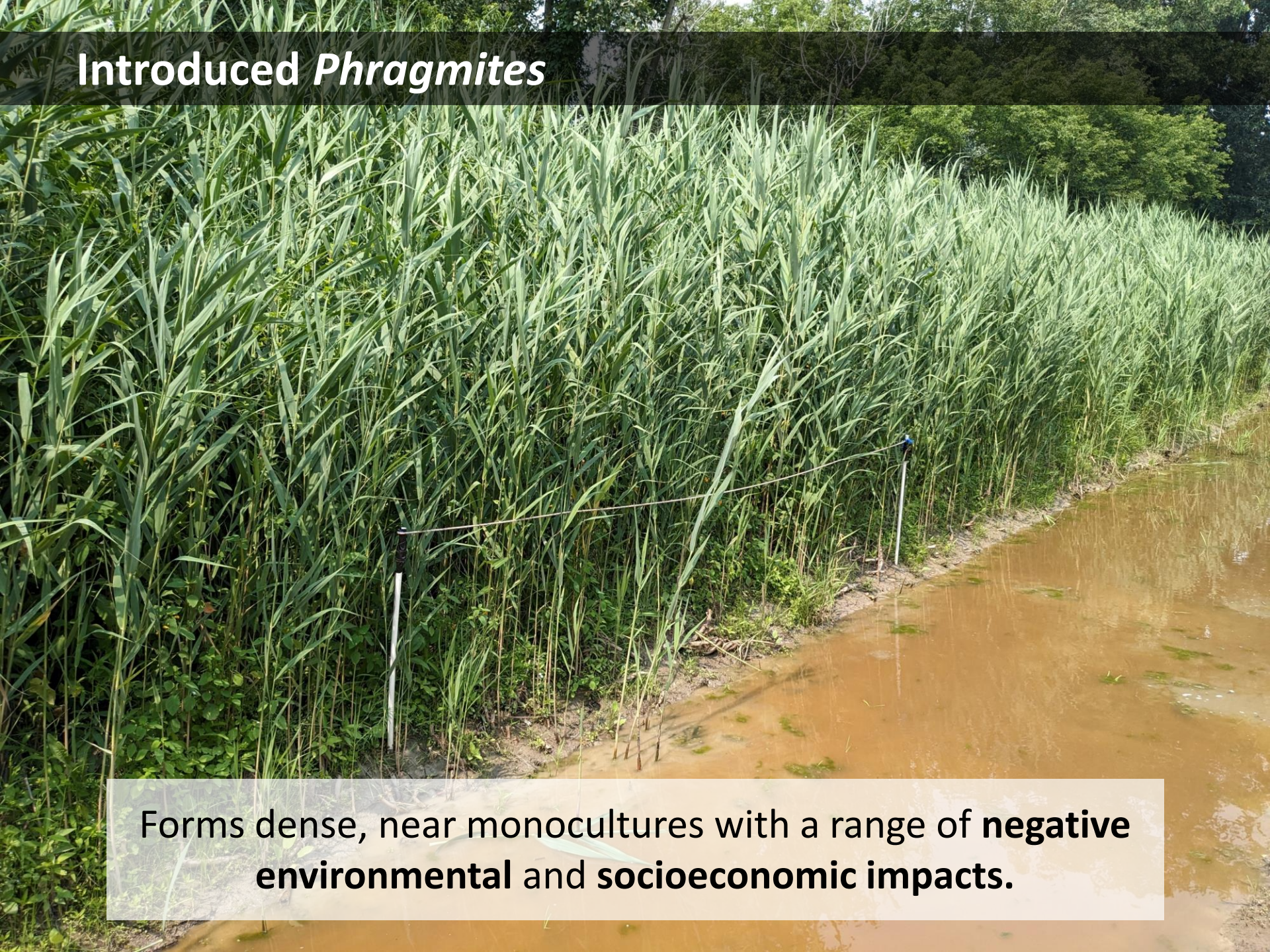
UNIVERSITY OF TORONTO

Agriculture and Agri-Food Canada

Introduced *Phragmites*

- **Introduced *Phragmites*** (*Phragmites australis australis*) named one of the worst weeds in North America (AAFC 2005).
- Tall **non-native, invasive grass** that spreads primarily through clonal belowground growth.
- Introduced to North America from Europe in the late 1800s.

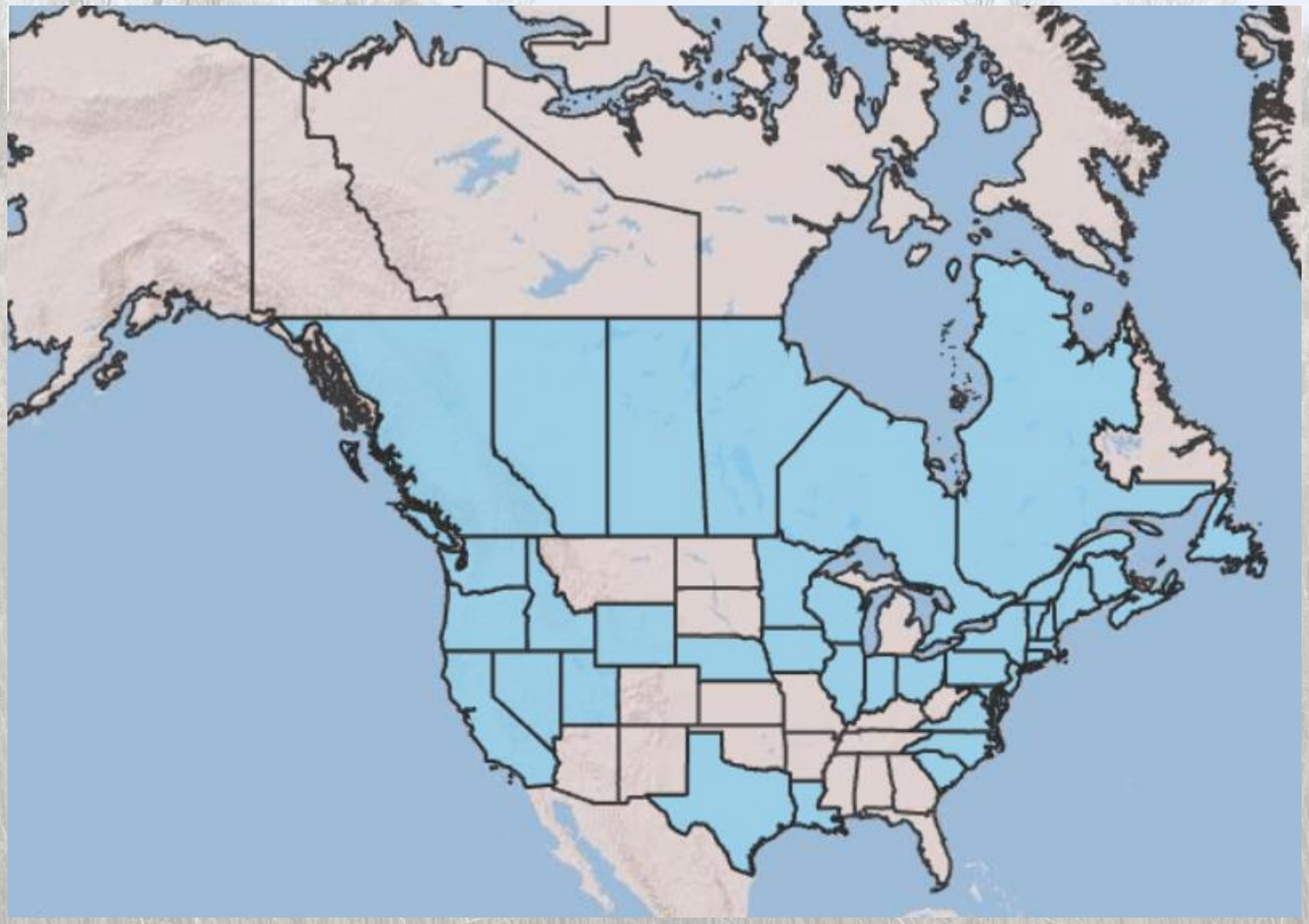
Introduced *Phragmites*



Forms dense, near monocultures with a range of **negative environmental** and **socioeconomic impacts.**

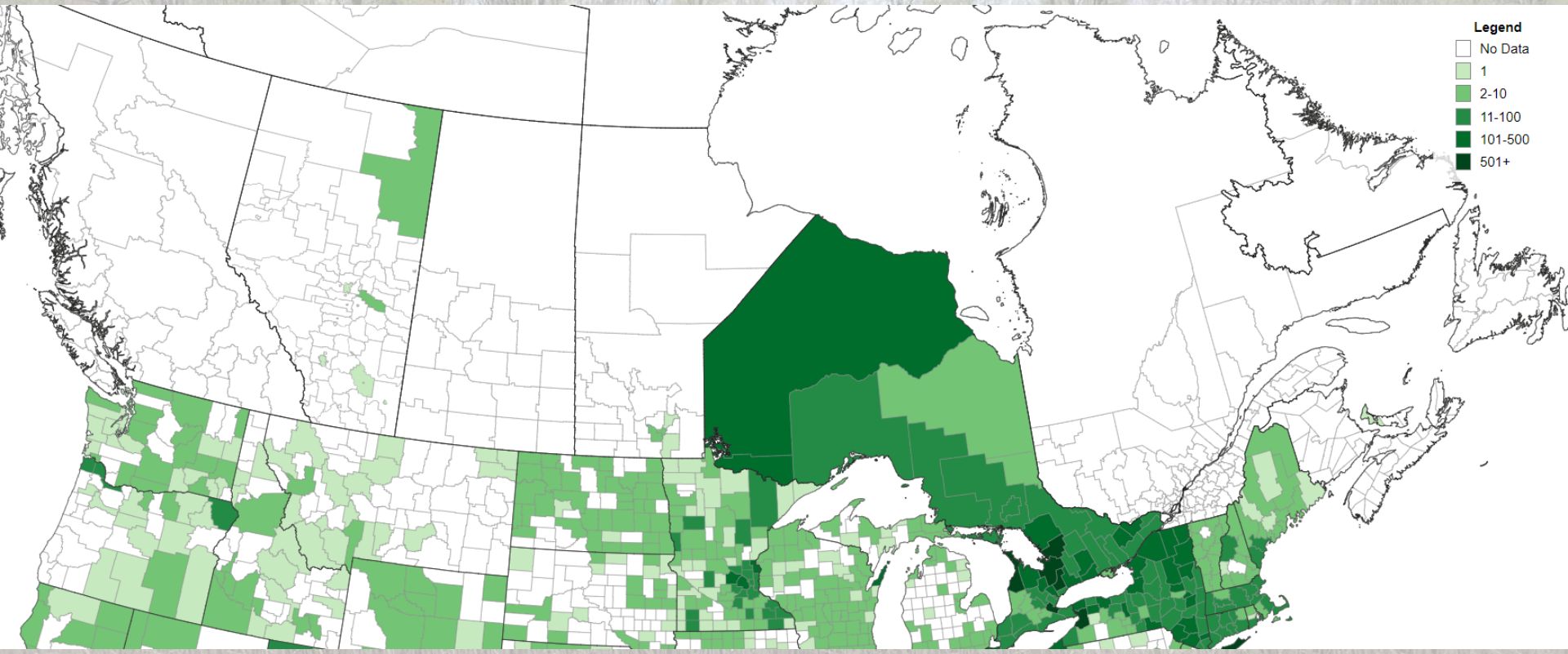
Introduced *Phragmites*

Common throughout Canada & US (USDA PLANTS database).



Introduced *Phragmites*

Different stage of invasion in AB vs. ON (EDDMapS).



Introduced *Phragmites*

- Two populations found near Brooks AB in 2016 and managed (alberta.ca).
- New populations documented around AB as of 2020.
- Likely gaps in reporting.
- Disturbance, spread, climate change → further invasion likely.

Introduced *Phragmites*

To effectively manage introduced *Phragmites*…

How can we reliably identify introduced Phragmites?

How do we practically manage a large-scale invasion?


How can we reliably identify introduced Phragmites?
BYCL 430
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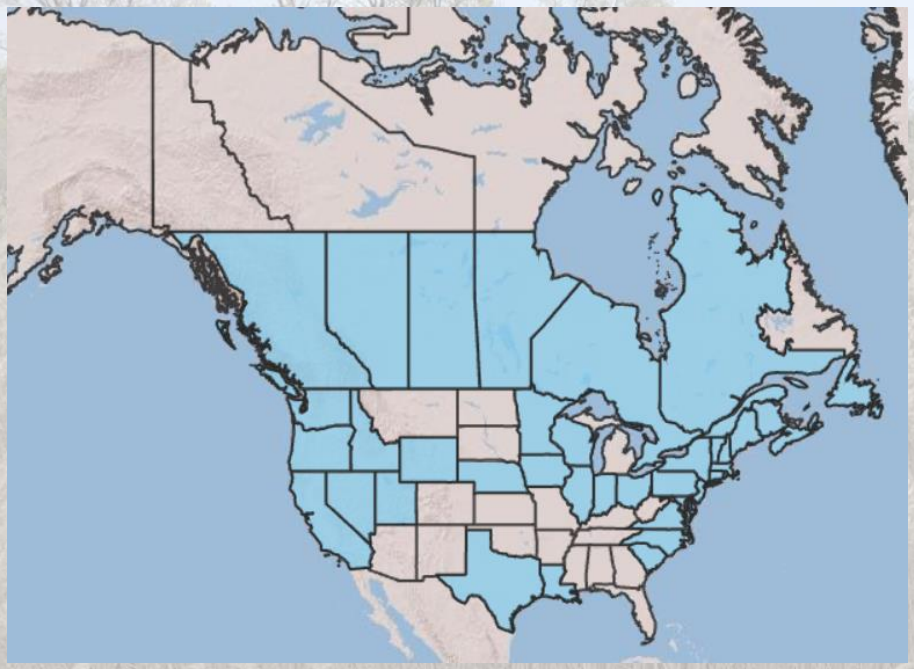
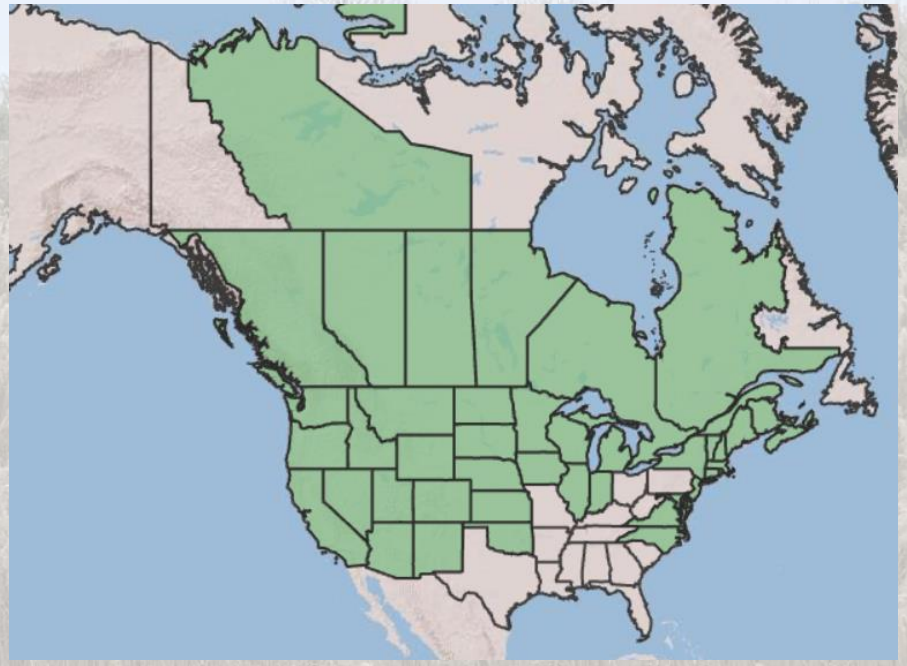
Morphological identification

Challenge: There are two main *Phragmites* lineages in Canada.



"Introduced *Phragmites*"
(*Phragmites australis australis*)

- "Canada's worst weed"
- Spreading.



"Native *Phragmites*"
(*Phragmites australis americanus*)

- Desirable native species.
- Rarer and disappearing.

Morphological identification

Despite guides, land managers are frequently worried about populations with "**atypical**" traits.

<u>Sources of confusion</u>

1. High concern about hybrids (very rare, not yet found in Canada).
2. High phenotypic plasticity.
3. Subjective traits.
4. "Common wisdom" and "rules of thumb".

Morphological identification

"Common wisdom" and "rules of thumb".

Native *Phragmites*

Introduced *Phragmites* always has large stems and leaves, high stem density, rough brown stems, and large panicles.

Morphological identification

E.g., moderate density patch with medium-sized, reddish-brown stems, and a mix of panicle sizes.

- **Genetic ID** is the most reliable option (including hybrid screening).
- Inaccessible to many land managers (e.g., lack of contacts, finances, collection knowledge).

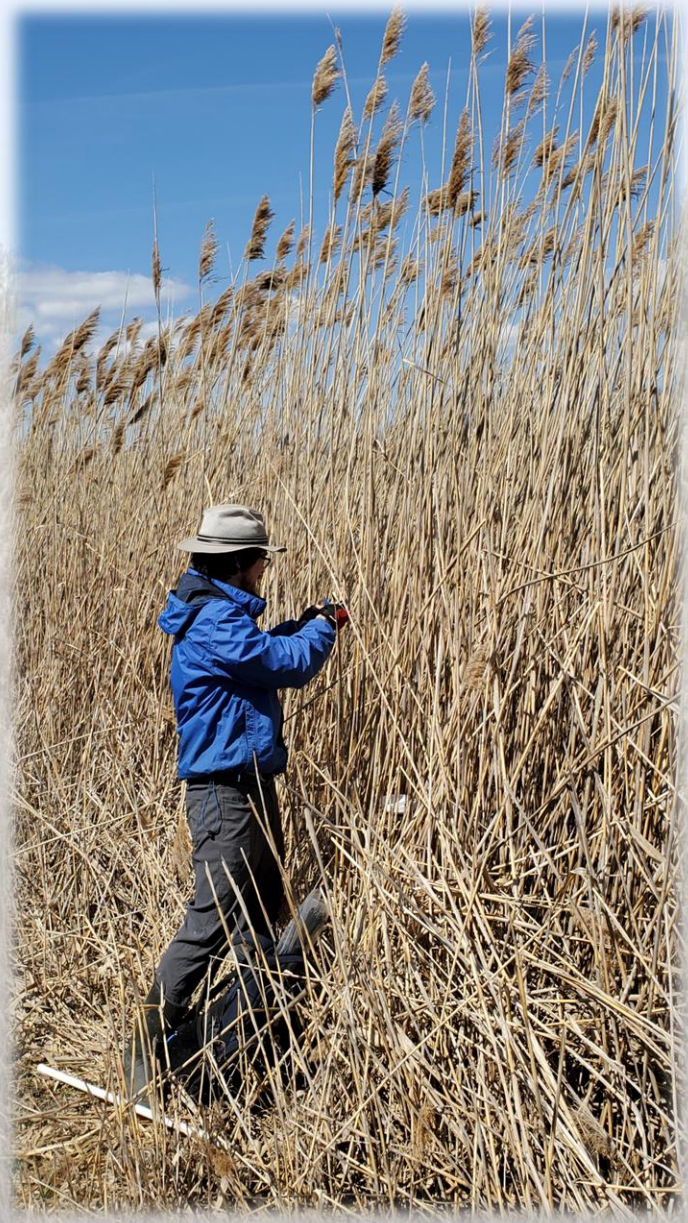
Morphological identification

Research objective:

To identify the best morphological traits to quickly and easily distinguish between introduced and native *Phragmites*.

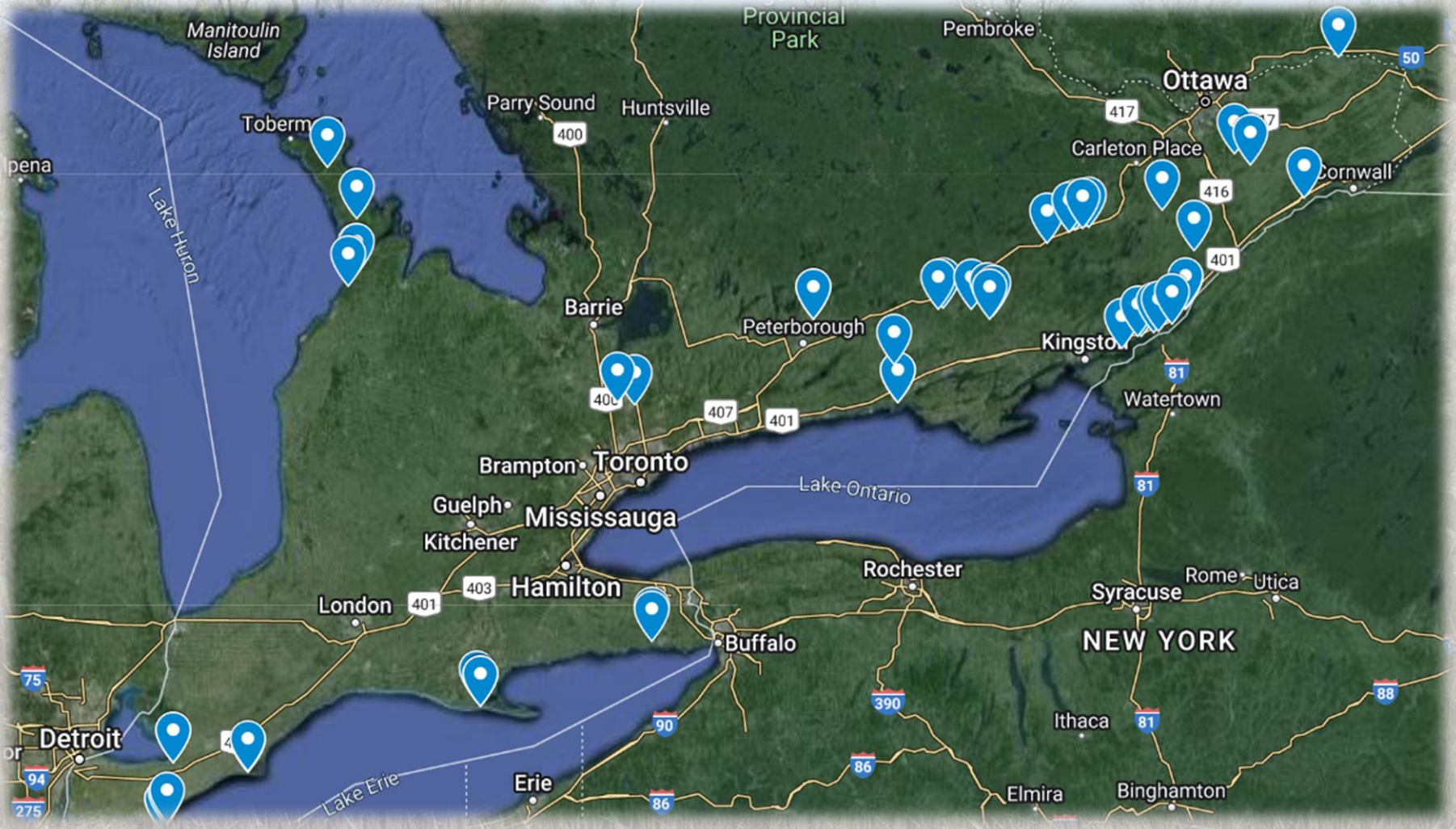
Management outcome:

Provide a free, easy-to-use *Phragmites* ID guide for land managers and researchers.



Morphological identification

Fall 2019: **Field surveys and collections** of 21 introduced and 27 native *Phragmites* populations in southern/eastern ON.

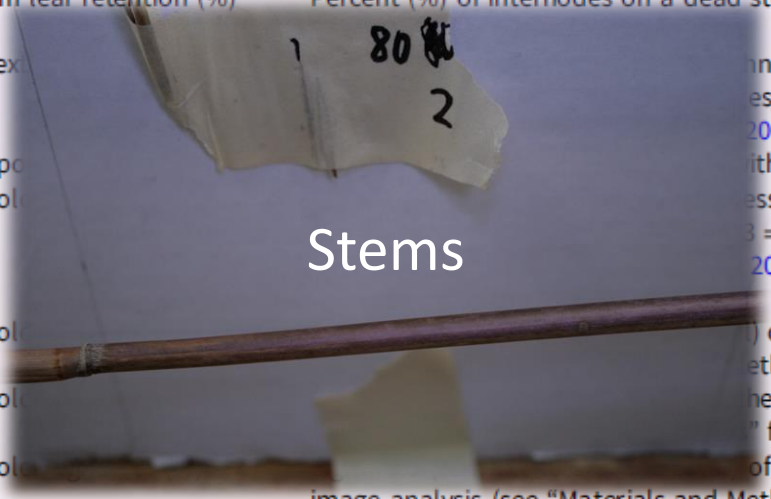


Morphological identification

Five subsamples per location: **field measurements** (e.g., stem density) + **stems** for lab + **dried leaf samples** for genetic ID (AAFC).

Measurement[a]	Description and reference(s)
1. Old stem density (m^{-2})	Density of old, standing, dead stems (m^{-2}) (Nichols 2020; Swearingen et al. 2022)
2. Living stem density (m^{-2})	Density of living, green stems (m^{-2}) (Nichols 2020; Swearingen et al. 2022)
3. Old stem leaf retention (%)	Percent (%) of internodes on a dead stem with leaf sheaths attached (Blossey 2003; Nichols 2020; Saltonstall et al. 2004; Swearingen et al. 2022)
4. Stem texture (1–4)	Categorical classification of the roughness of the second fully complete internode from the base of the stem (1 = very smooth; 2 = smooth with gentle ridges; 3 = lightly coarse/ridged; 4 = very coarse/ridged) (Allen et al. 2017; Blossey 2003; Nichols 2020; Saltonstall et al. 2004; Swearingen et al. 2022)
5. Stem spot fungus (%)	Percent (%) of five collected stems with any fungal spots on the internodes (Blossey 2003; Swearingen et al. 2022)
6. Stem color (1–4)	Categorical classification of the redness of the second fully complete internode from the base of the stem (1 = no redness; 2 = tinges of light redness; 3 = patches of darker red over <1/2 of internode; 4 = dark red over ≥1/2 of internode) (Allen et al. 2017; Blossey 2003; Catling and Mitrow 2011; Catling and Robichaud 2003; Catling et al. 2007; Nichols 2020; Swearingen et al. 2022)
7. Stem color hue	Hue (0–360 position on a color wheel) of the second fully complete internode from the base of the stem assessed by image analysis (see "Materials and Methods" for additional details)
8. Stem color saturation (%)	Saturation (% pigment intensity) of the second fully complete internode from the base of the stem assessed by image analysis (see "Materials and Methods" for additional details)
9. Stem color lightness (%)	Lightness (% whiteness of the color) of the second fully complete internode from the base of the stem assessed by image analysis (see "Materials and Methods" for additional details)
10. Stem height (m)	Height (m) from the base of the stem to the base of the inflorescence, measured using a meter stick (Nichols 2020)
11. Basal stem diameter (mm)	Diameter (mm) at the bottom of the stem, measured with calipers (Nichols 2020)
12. Mid-stem diameter (mm)	Diameter (mm) halfway up the stem, measured with calipers (Nichols 2020)
13. Top stem diameter (mm)	Diameter (mm) at the top of the stem at the base of the inflorescence, measured with calipers (Nichols 2020)
14. Inflorescence fullness (1–4)	Categorical classification of the fullness of the inflorescence, omitted if no inflorescence present (1 = small and spindly; 2 = small but filled out; 3 = large but sparse; 4 = bushy and full) (Nichols 2020; Swearingen et al. 2022)
15. Inflorescence height (cm)	Height (cm) from the base of the inflorescence to its highest point, measured using a meter stick (Allen et al. 2017; Nichols 2020)
16. Leaf length (cm)	Length (cm) of a leaf blade collected from the middle of the stem, measured from the center top of the ligule to the leaf tip (i.e., excluding the sheath), measured using a ruler (Allen et al. 2017)
17. Leaf width (cm)	Width (cm) of the same leaf measured for length at the widest point, measured using a ruler (Allen et al. 2017)
18. Ligule base height (mm)	Height (mm) of the dark tissue of the ligule, excluding the hairy fringe, measured with calipers under a microscope (Allen et al. 2017; Catling and Mitrow 2011; Catling et al. 2007; Nichols 2020)
19. Ligule full height (mm)	Height (mm) of the center of the ligule, including the dark tissue and hairy fringe, measured with calipers under a microscope (Catling et al. 2007; Saltonstall et al. 2004; Swearingen et al. 2022)
20. Lower glume length (mm)	Mean length of the lower glume (mm) from two random florets per sample, measured using calipers under a microscope (Allen et al. 2017; Catling and Mitrow 2011; Catling and Robichaud 2003; Catling et al. 2007; Nichols 2020; Saltonstall et al. 2004; Swearingen et al. 2022)
21. Upper glume length (mm)	Mean length of the upper glume (mm) from two random florets per sample, measured using calipers under a microscope (Allen et al. 2017; Nichols 2020; Saltonstall et al. 2004; Swearingen et al. 2022)
22. Lemma length (mm)	Mean length of the lemma (mm) from two random florets per sample, measured using a scale bar under a microscope (Allen et al. 2017; Nichols 2020; Saltonstall et al. 2004)

Measurement[a]	Description and reference(s)
1. Old stem density (m^{-2})	Density of old, standing, dead stems (m^{-2}) (Nichols 2020; Swearingen et al. 2022)
2. Living stem density (m^{-2})	Density of living, green stems (m^{-2}) (Nichols 2020; Swearingen et al. 2022)
3. Old stem leaf retention (%)	Percent (%) of internodes on a dead stem with le… et al.
4. Stem tex…	…ness of the … (1 = very …es; 3 = light… …lossey …2004; Swear…
5. Stem spo…	…ith any fung… …2022)
6. Stem col…	…ss of the se… = no …3 = patches … 2 of …2003; Catlin… …l. 2007;
7. Stem col…	…) of the sec… …ssed by …ethods" for …
8. Stem col…	…he second fu… …by image …" for additio…
9. Stem col…	…of the secon… …sed by image analysis (see "Materials and Methods" for additional details)
10. Stem height (m)	Height (m) from the base of the stem to the base of the inflorescence, measured using a meter stick (Nichols 2020)
11. Basal stem diameter (mm)	Diameter (mm) at the bottom of the stem, measured with calipers (Nichols 2020)
12. Mid-stem diamet…	…d with calip… (Nichols 2020)
13. Top stem diamet…	…ase of the i… …s 2020)
14. Inflorescence full…	…inflorescen… …mall and spindly; …4 = bushy a… …2)
15. Inflorescence hei…	…to its highe… …n et al. 2017;
16. Leaf length (cm)	…middle of t… …e ligule to the …using a ruler…
17. Leaf width (cm)	…th at the wi… …al. 2017)
18. Ligule base heigh…	…cluding the … …microscope …tling et al. 2…
19. Ligule full height	…ing the dark… …ers under a …al. 2004; Swe…
20. Lower glume leng…	…o random fl… …nder a …ow 2011; Ca… …; Nichols 2020;
21. Upper glume leng…	…o random florets per sample, measured using calipers under a …ltonstall et al. 2004; Swearingen et al. 2022)
22. Lemma length (m…	…dom florets per sample, measured using a scale bar under a microscope (Allen et al. 2017; Nichols 2020; Saltonstall et al. 2004)



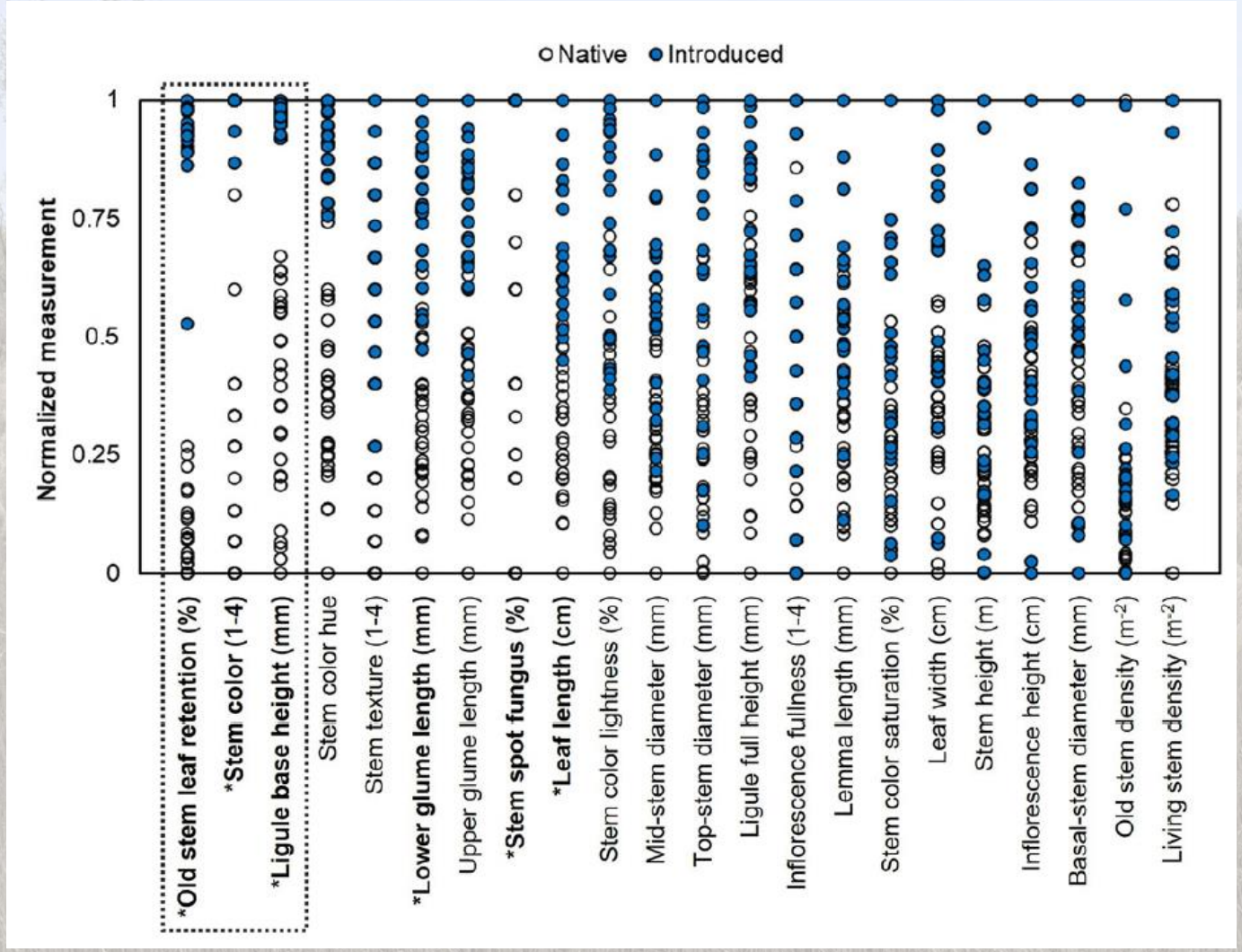
Morphological identification

Most traits differed between introduced and native *Phragmites* as expected…

Measurement	*F*-statistic and P-value	ω^2 effect size	% Overlap	Introduced	Native
				mean ± SD (range)	
Old stem leaf retention (%)	$F(1, 45) = 1026.3$, **$P < 0.001$**	0.96	0	92 ± 10 (53–100)	8 ± 8 (0–27)
Stem color (1–4)	$F(1, 28) = 419.7^{\star}$, **$P < 0.001$**	0.87	0	1.0 ± 0.1 (1.0–1.4)	3.4 ± 0.6 (1.6–4.0)
Ligule base height (mm)	$F(1, 27) = 207.6^{\star}$, **$P < 0.001$**	0.76	0	0.11 ± 0.02 (0.08–0.15)	0.63 ± 0.19 (0.37–0.96)
Stem color hue	$F(1, 36) = 183.6^{\star}$, **$P < 0.001$**	0.76	4	41.6 ± 7.7 (26.4–51.6)	−12.4 ± 18.8 (−50.8–27.2)
Stem texture (1–4)	$F(1, 31) = 126.8^{\star}$, **$P < 0.001$**	0.74	15	3.0 ± 0.6 (1.8–4.0)	1.4 ± 0.3 (1.0–2.2)
Lower glume length (mm)	$F(1, 46) = 111.9$, **$P < 0.001$**	0.70	19	3.55 ± 0.45 (2.82–4.47)	4.99 ± 0.49 (3.96–5.95)
Upper glume length (mm)	$F(1, 46) = 83.1$, **$P < 0.001$**	0.63	31	5.58 ± 0.60 (4.59–6.90)	7.19 ± 0.61 (5.91–8.56)
Stem spot fungus (%)	$F(1, 25) = 105.4$, **$P < 0.001$**	0.63	49	0 ± 0 (0)	64 ± 32 (0–100)
Leaf length (cm)	$F(1, 41) = 7.05$, **$P < 0.001$**	0.62	28	46 ± 4 (40–55)	36 ± 4 (28–44)
Stem color lightness (%)	$F(1, 46) = 48.8$, **$P < 0.001$**	0.50	42	52 ± 8 (40–61)	38 ± 7 (27–51)
Mid-stem diameter (mm)	$F(1, 46) = 31.4$, **$P < 0.001$**	0.39	60	5.7 ± 0.9 (4.1–7.6)	4.5 ± 0.6 (3.2–5.9)
Top stem diameter (mm)	$F(1, 33) = 27.3^{\star}$, **$P < 0.001$**	0.37	69	2.9 ± 0.7 (1.5–3.8)	2.0 ± 0.5 (1.3–3.0)
Ligule full height (mm)	$F(1, 46) = 22.7$, **$P < 0.001$**	0.31	54	0.82 ± 0.15 (0.59–1.06)	1.05 ± 0.18 (0.73–1.40)
Inflorescence fullness (1–4)	$F(1, 46) = 21.6$, **$P < 0.001$**	0.30	92	2.6 ± 0.8 (1.0–3.8)	1.6 ± 0.6 (1.0–3.4)
Lemma length (mm)	$F(1, 46) = 21.4$, **$P < 0.001$**	0.30	79	9.5 ± 1.0 (7.3–11.6)	10.7 ± 0.8 (9.1–12.1)
Stem color saturation (%)	$F(1, 28) = 13.1^{\star}$, **$P = 0.003$**	0.22	83	14 ± 4 (8–23)	11 ± 2 (7–16)
Leaf width (cm)	$F(1, 25) = 10.9^{\star}$, **$P = 0.003$**	0.20	77	2.4 ± 0.5 (1.4–3.2)	1.9 ± 0.3 (1.3–2.6)
Stem height (m)	$F(1, 28) = 5.7^{\star}$, **$P = 0.024$**	0.09	88	2.30 ± 0.45 (1.63–3.35)	2.05 ± 0.23 (1.62–2.60)
Inflorescence height (cm)	$F(1, 46) = 5.6$, **$P = 0.022$**	0.09	90	26 ± 7 (11–40)	21 ± 5 (15–35)
Basal stem diameter (mm)	$F(1, 46) = 4.9$, **$P = 0.032$**	0.08	88	7.0 ± 1.2 (4.6–9.1)	6.3 ± 0.9 (5.0–8.0)
Old stem density (m^{-2})	$F(1, 44) = 4.6$, **$P = 0.037$**	0.07	98	36 ± 33 (0–132)	17 ± 27 (0–134)
Living stem density (m^{-2})	$F(1, 44) = 3.2$, $P = 0.083$	0.04	91	65 ± 28 (24–129)	52 ± 23 (4–101)

…but there was high **variability** and **overlap**.

Morphological identification



Only three traits provided complete separation

(**% leaf retention on dead stems**, **stem colour**, **ligule base height**).

Morphological identification

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				mean ± SD (range)	
Old stem leaf retention (%)	$F(1, 45) = 1026.3$, **P < 0.001**	0.96	0	92 ± 10 (53–100)	8 ± 8 (0–27)
Stem color (1–4)	$F(1, 28) = 419.7^{\star}$, **P < 0.001**	0.87	0	1.0 ± 0.1 (1.0–1.4)	3.4 ± 0.6 (1.6–4.0)
Ligule base height (mm)	$F(1, 27) = 207.6^{\star}$, **P < 0.001**	0.76	0	0.11 ± 0.02 (0.08–0.15)	0.63 ± 0.19 (0.37–0.96)
Stem color hue	$F(1, 36) = 183.6^{\star}$, **P < 0.001**	0.76	4	41.6 ± 7.7 (26.4–51.6)	−12.4 ± 18.8 (−50.8–27.2)
Stem texture (1–4)	$F(1, 31) = 126.8^{\star}$, **P < 0.001**	0.74	15	3.0 ± 0.6 (1.8–4.0)	1.4 ± 0.3 (1.0–2.2)
Lower glume length (mm)	$F(1, 46) = 111.9$, **P < 0.001**	0.70	19	3.55 ± 0.45 (2.82–4.47)	4.99 ± 0.49 (3.96–5.95)
Upper glume length (mm)	$F(1, 46) = 83.1$, **P < 0.001**	0.63	31	5.58 ± 0.60 (4.59–6.90)	7.19 ± 0.61 (5.91–8.56)
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Top stem diameter (mm)	$F(1, 33) = 27.3^{\star}$, **P < 0.001**	0.37	69	2.9 ± 0.7 (1.5–3.8)	2.0 ± 0.5 (1.3–3.0)
Ligule full height (mm)	$F(1, 46) = 22.7$, **P < 0.001**	0.31	54	0.82 ± 0.15 (0.59–1.06)	1.05 ± 0.18 (0.73–1.40)
Inflorescence fullness (1–4)	$F(1, 46) = 21.6$, **P < 0.001**	0.30	92	2.6 ± 0.8 (1.0–3.8)	1.6 ± 0.6 (1.0–3.4)
Lemma length (mm)	$F(1, 46) = 21.4$, **P < 0.001**	0.30	79	9.5 ± 1.0 (7.3–11.6)	10.7 ± 0.8 (9.1–12.1)
Stem color saturation (%)	$F(1, 28) = 13.1^{\star}$, **P = 0.003**	0.22	83	14 ± 4 (8–23)	11 ± 2 (7–16)
Leaf width (cm)	$F(1, 25) = 10.9^{\star}$, **P = 0.003**	0.20	77	2.4 ± 0.5 (1.4–3.2)	1.9 ± 0.3 (1.3–2.6)
Stem height (m)	$F(1, 28) = 5.7^{\star}$, **P = 0.024**	0.09	88	2.30 ± 0.45 (1.63–3.35)	2.05 ± 0.23 (1.62–2.60)
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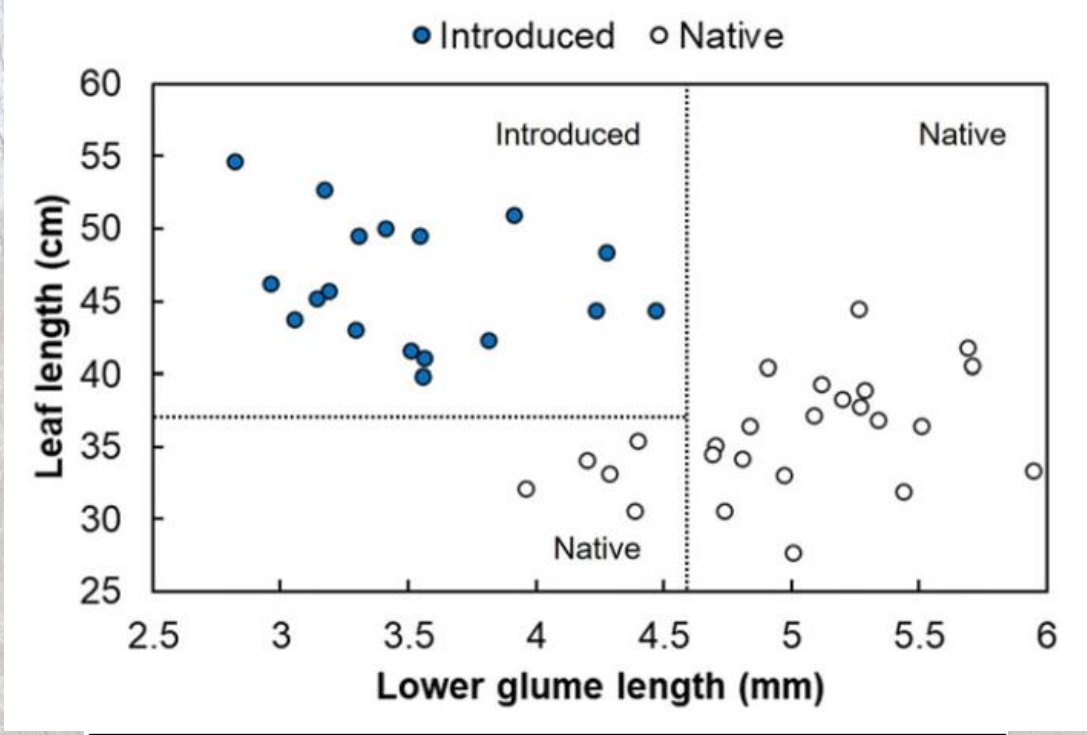
Basal stem diameter (mm)	$F(1, 46) = 4.9$, **P = 0.032**	0.08	88	7.0 ± 1.2 (4.6–9.1)	6.3 ± 0.9 (5.0–8.0)
Old stem density (m^{-2})	$F(1, 44) = 4.6$, **P = 0.037**	0.07	98	36 ± 33 (0–132)	17 ± 27 (0–134)
Living stem density (m^{-2})	$F(1, 44) = 3.2$, P = 0.083	0.04	91	65 ± 28 (24–129)	52 ± 23 (4–101)

Also, **stem spot fungus** ONLY occurs on native
(i.e., absence is uninformative, presence is diagnostic).

Morphological identification



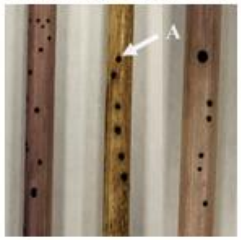
1A. Lower glume length > 4.6 mm: native *Phragmites australis* ssp. *americanus*
1B. Lower glume length < 4.6 mm:
2A. Leaf length > 37 cm: introduced *Phragmites australis* ssp. *australis*
2B. Leaf length < 37 cm: native *Phragmites australis* ssp. *americanus*

Finally, a simple binomial key of **lower glume length** and **leaf length** also provides separation.

Morphological identification

Native vs. introduced *Phragmites* ID checklist (Adapted from McTavish MJ, Smith T, Mechanda S, Smith SM, Bourchier RS. 2023. Morphological traits for rapid and simple separation of native and introduced *Phragmites australis*. *Invasive Plant Science and Management*)

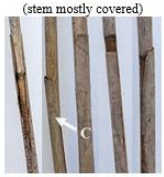
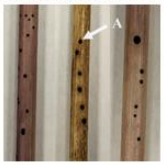
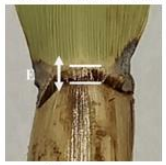
Use this checklist to help identify unknown populations of *Phragmites* as native (*Phragmites australis americanus*) or introduced (*Phragmites australis australis*). For each trait, follow "How to measure" and check the corresponding box. If all check boxes match either native or introduced *Phragmites*, the sample can be identified with high confidence. If there is incomplete consensus, identification should be considered inconclusive and followed by genetic testing where possible. For best results: (a) measure as many traits as possible; (b) test multiple stems per patch; and (c) collect measurements in late summer or fall when the differences are most pronounced. Contact: michael.mctavish@alum.utoronto.ca.

Trait	Stem spot fungus	Stem colour	Leaf retention	Ligule base height	Lower glume length + leaf length
How to measure	Check living stems for dark round fungal spots (arrow A).	Check the base of the stem for dark red colouration.	Inspect greying dead stems (i.e., not living stems) to determine how much is still covered by attached leaf sheaths (arrow C). When leaf sheaths have fallen off, the stem below will be bare (arrow D).	Remove a leaf from the middle of the plant. Use calipers or a ruler to measure the height of the dark membranous band where the leaf meets the stem (i.e., the ligule), excluding any light-coloured, hairy fringe at the top of the band (arrow E).	Press a floret under glass and measure lower glume length (arrow F) using calipers or a ruler under a microscope. Find a leaf near the middle of the stem. Measure its length from ligule to tip (arrow G) using a ruler.
Introduced *Phragmites australis*	Stems without round fungal spots (arrow A) or dark red may be either introduced or native *P. australis*. Dark smudges (arrow B) are not diagnostic. 		☐ > 50% attached (stem mostly covered) 	☐ ≤ 0.15 mm 	☐ Lower glume < 4.6 mm and leaf length > 37 cm 
Native *Phragmites australis*	 ☐ Round spots present	 ☐ Dark red, up to 100% coverage	 ☐ < 30% attached (stem mostly bare)	 ☐ > 0.35 mm	 ☐ Lower glume > 4.6 mm, OR lower glume < 4.6 mm and leaf length < 37 cm

Morphological identification

Native vs. introduced *Phragmites* ID checklist (Adapted from McTavish MJ, Smith T, Mechanda S, Smith SM, Bourchier RS. 2023. Morphological traits for rapid and simple separation of native and introduced *Phragmites australis*. *Invasive Plant Science and Management*)

Use this checklist to help identify unknown populations of *Phragmites* as native (*Phragmites australis americanus*) or introduced (*Phragmites australis australis*). For each trait, follow "How to measure" and check the corresponding box. If all check boxes match either native or introduced *Phragmites*, the sample can be identified with high confidence. If there is incomplete consensus, identification should be considered inconclusive and followed by genetic testing where possible. For best results: (a) measure as many traits as possible; (b) test multiple stems per patch; and (c) collect measurements in late summer or fall when the differences are most pronounced. Contact: michael.mctavish@alum.utoronto.ca.

Trait	Stem spot fungus	Stem colour	Leaf retention	Ligule base height	Lower glume length + leaf length
How to measure	Check living stems for dark round fungal spots (arrow A).	Check the base of the stem for dark red colouration.	Inspect greying dead stems (i.e., not living stems) to determine how much is still covered by attached leaf sheaths (arrow C). When leaf sheaths have fallen off, the stem below will be bare (arrow D).	Remove a leaf from the middle of the plant. Use calipers or a ruler to measure the height of the dark membranous band where the leaf meets the stem (i.e., the ligule), excluding any light-coloured, hairy fringe at the top of the band (arrow E).	Press a floret under glass and measure lower glume length (arrow F) using calipers or a ruler under a microscope. Find a leaf near the middle of the stem. Measure its length from ligule to tip (arrow G) using a ruler.
Introduced *Phragmites australis*	Stems without round fungal spots (arrow A) or dark red may be either introduced or native *P. australis*. Dark smudges (arrow B) are not diagnostic. 		☐ > 50% attached (stem mostly covered) 	☐ ≤ 0.15 mm 	☐ Lower glume < 4.6 mm and leaf length > 37 cm 
Native *Phragmites australis*	 ☐ Round spots present	 ☐ Dark red, up to 100% coverage	 ☐ < 30% attached (stem mostly bare)	 ☐ > 0.35 mm	 ☐ Lower glume > 4.6 mm, OR lower glume < 4.6 mm and leaf length < 37 cm

How to use:

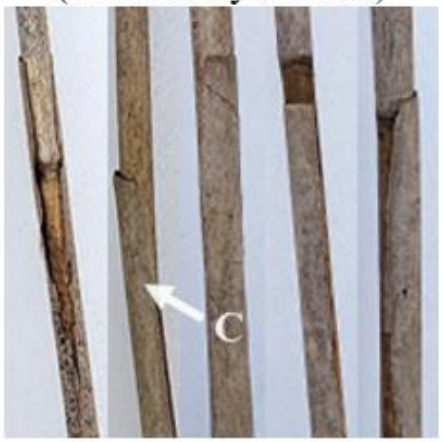
1. Read "How to measure".
2. Measure stem.
3. Check corresponding box (native or introduced).
4. Check for agreement across as many traits as possible.

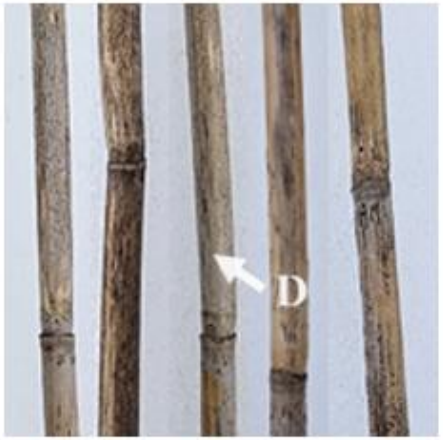
Morphological identification

Introduced *Phragmites*:

Native *Phragmites*:

☐ > 50% attached
(stem mostly covered)





☐ < 30% attached
(stem mostly bare)

Leaf retention

Inspect greying dead stems (i.e., not living stems) to determine how much is still covered by attached leaf sheaths (arrow C). When leaf sheaths have fallen off, the stem below will be bare (arrow D).

Morphological identification

Introduced *Phragmites*:

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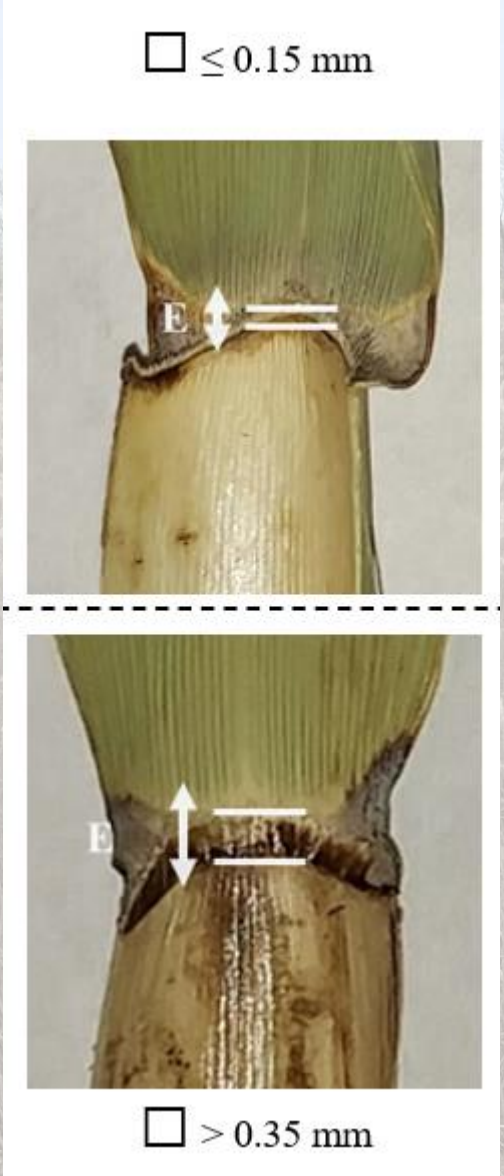

Ligule base height

Remove a leaf from the middle of the plant. Use calipers or a ruler to measure the height of the dark membranous band where the leaf meets the stem (i.e., the ligule), excluding any light-coloured, hairy fringe at the top of the band (arrow E).

Morphological identification

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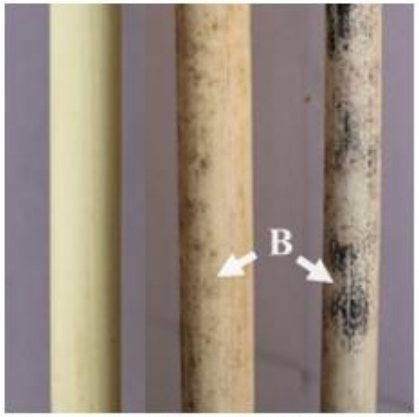

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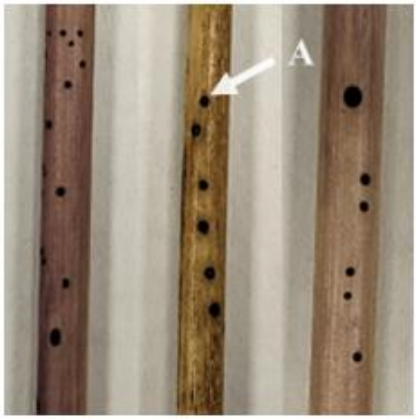

☐ Round spots present

Stem spot fungus

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Morphological identification

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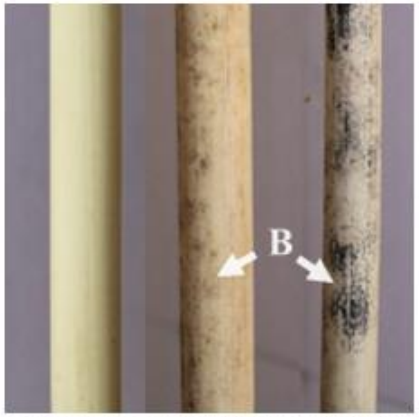


Native *Phragmites*:

☐ Dark red, up to 100% coverage

Stem colour

Check the base of the stem for dark red colouration.

Morphological identification

Introduced *Phragmites*:

☐ Lower glume < 4.6 mm and leaf length > 37 cm

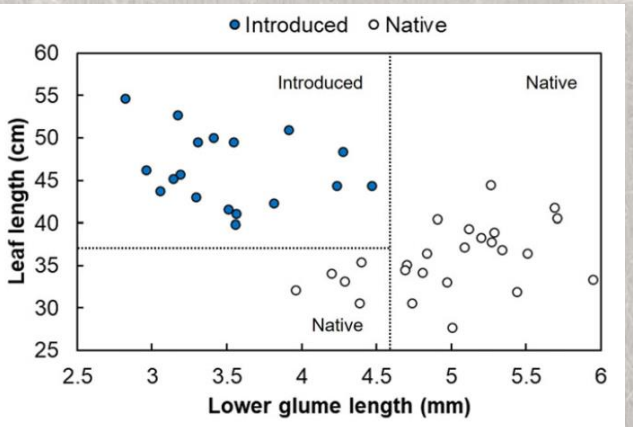
☐ Lower glume > 4.6 mm, OR lower glume < 4.6 mm and leaf length < 37 cm

Native *Phragmites*:

Lower glume length + leaf length

Press a floret under glass and measure lower glume length (arrow F) using calipers or a ruler under a microscope.

Find a leaf near the middle of the stem. Measure its length from ligule to tip (arrow G) using a ruler.



Morphological identification

ID key considerations:

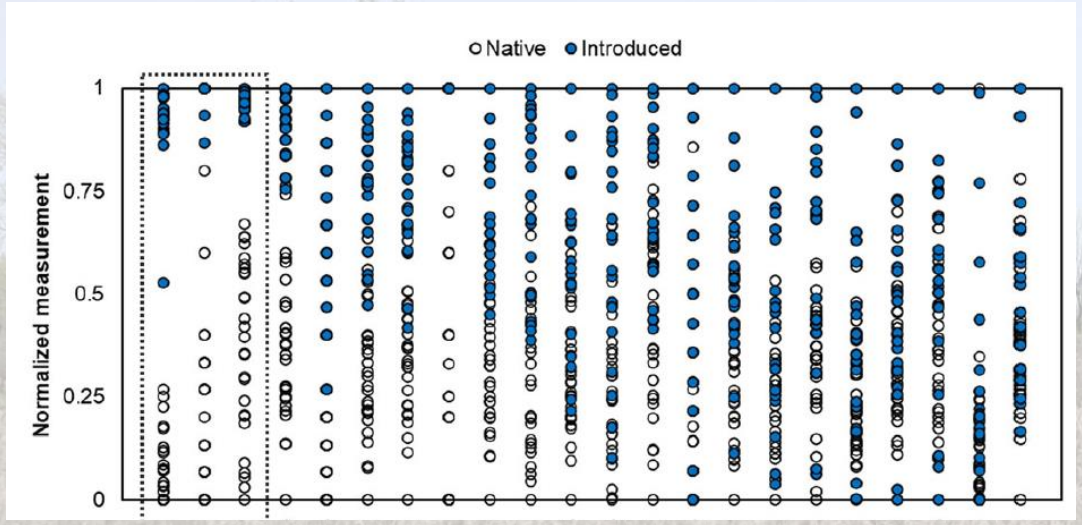
1. Differences most evident in late summer/fall (leaf sheath retention is year-round).

2. Measure as many stems as possible.

3. Lack of consensus → genetic testing.

4. Data based on 48 populations from Great Lakes region (likely still informative but may need local adjustments).

Morphological identification



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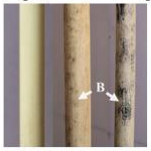
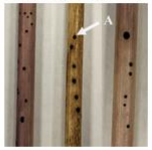
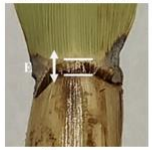
Introduced *Phragmites australis*	Stems without round fungal spots (arrow A) or dark red may be either introduced or native *P. australis*. Dark smudges (arrow B) are not diagnostic. 		☐ > 50% attached (stem mostly covered) 	☐ ≤ 0.15 mm 	☐ Lower glume < 4.6 mm and leaf length > 37 cm 
Native *Phragmites australis*	 ☐ Round spots present	 ☐ Dark red, up to 100% coverage	 ☐ < 30% attached (stem mostly bare)	 ☐ > 0.35 mm	 ☐ Lower glume > 4.6 mm, OR lower glume < 4.6 mm and leaf length < 37 cm

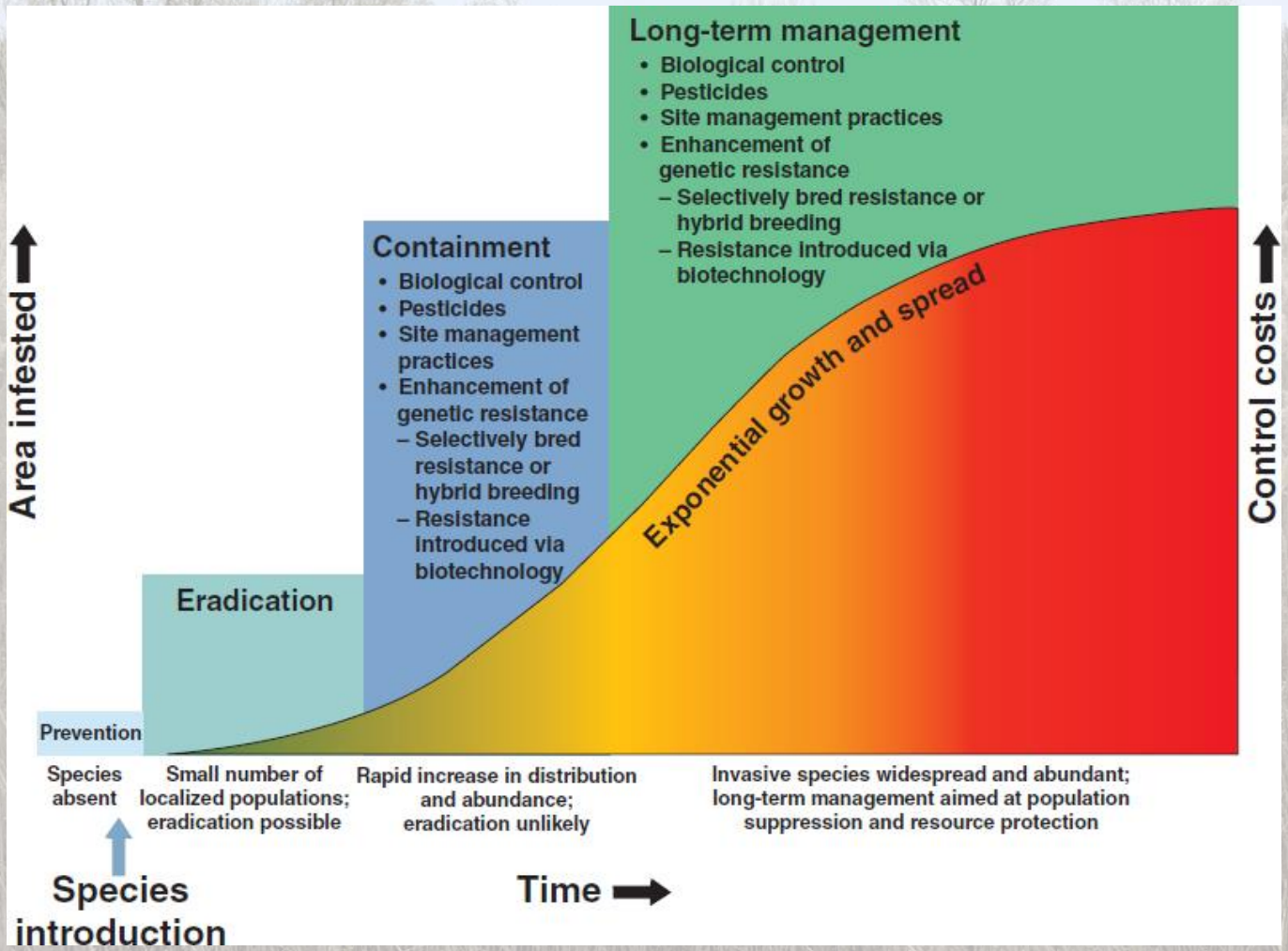
General conclusions

- Native and introduced have a lot of variation and overlap.
- "Atypical" intermediate traits → very common and normal!
- "Common wisdom" and "rules of thumb" may be misleading → diagnostic traits.

How do we practically manage a large-scale invasion?

Biological control of introduced *Phragmites*

Large-scale invasions quickly outpace practical and financial realities of eradication or containment.



Biological control of introduced *Phragmites*

Biological control provides “another tool in the toolbox” to manage the long-term, large-scale invasion of *Phragmites*.

Biological control of introduced *Phragmites*

Biological control or **"biocontrol"** uses living organisms to **gradually suppress** a pest at **large-scale** over the **long-term**.

<u>Why use biocontrol</u>?

1. Re-establish ecological balance.
2. Safe with low off-target environmental impact.
3. Cost-effective, large-scale, and long-term.

Biological control of introduced *Phragmites*

Biocontrol agents are two European moths with stem-boring larvae:

Archanara neurica

Lenisa geminipuncta

Larvae mine
3-4 stems

Kills young stems

Stem wilt

Borehole

Stunts older stems

Stem wilt

Borehole

Biological control of introduced *Phragmites*

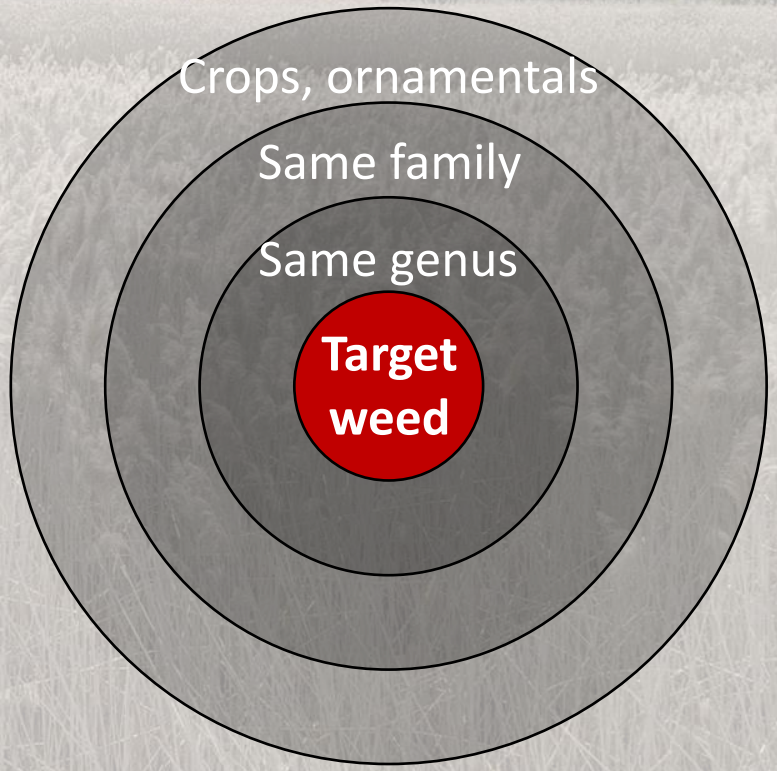
Larvae reduce *Phragmites* **stem density**, **stem height**, and **panicle formation** → less competitive → increased biodiversity & function.

Biological control of introduced *Phragmites*

1998-2019

Phase 1: Agent identification & permitting

- International team (Canada, US, Switzerland).
- Identify agents and extensive host range testing.
- Canadian release permit approved by CFIA in 2019.

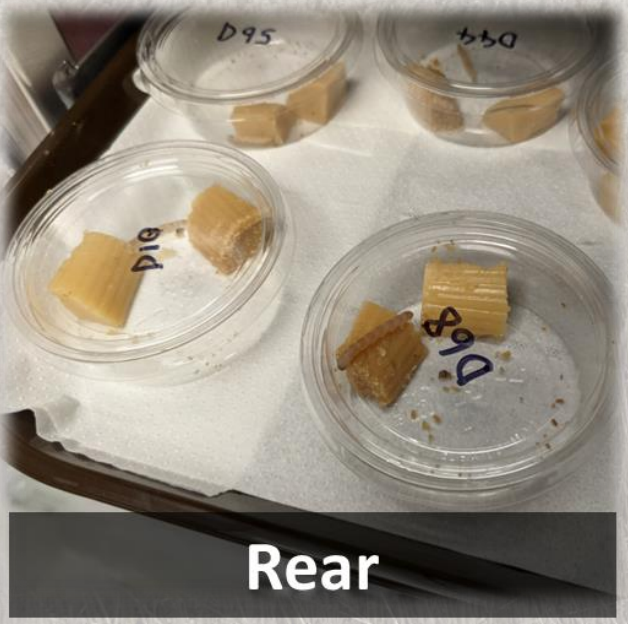


Biological control of introduced *Phragmites*

1998-2019 | **2019-2023**

Phase 2: Developing operational protocols

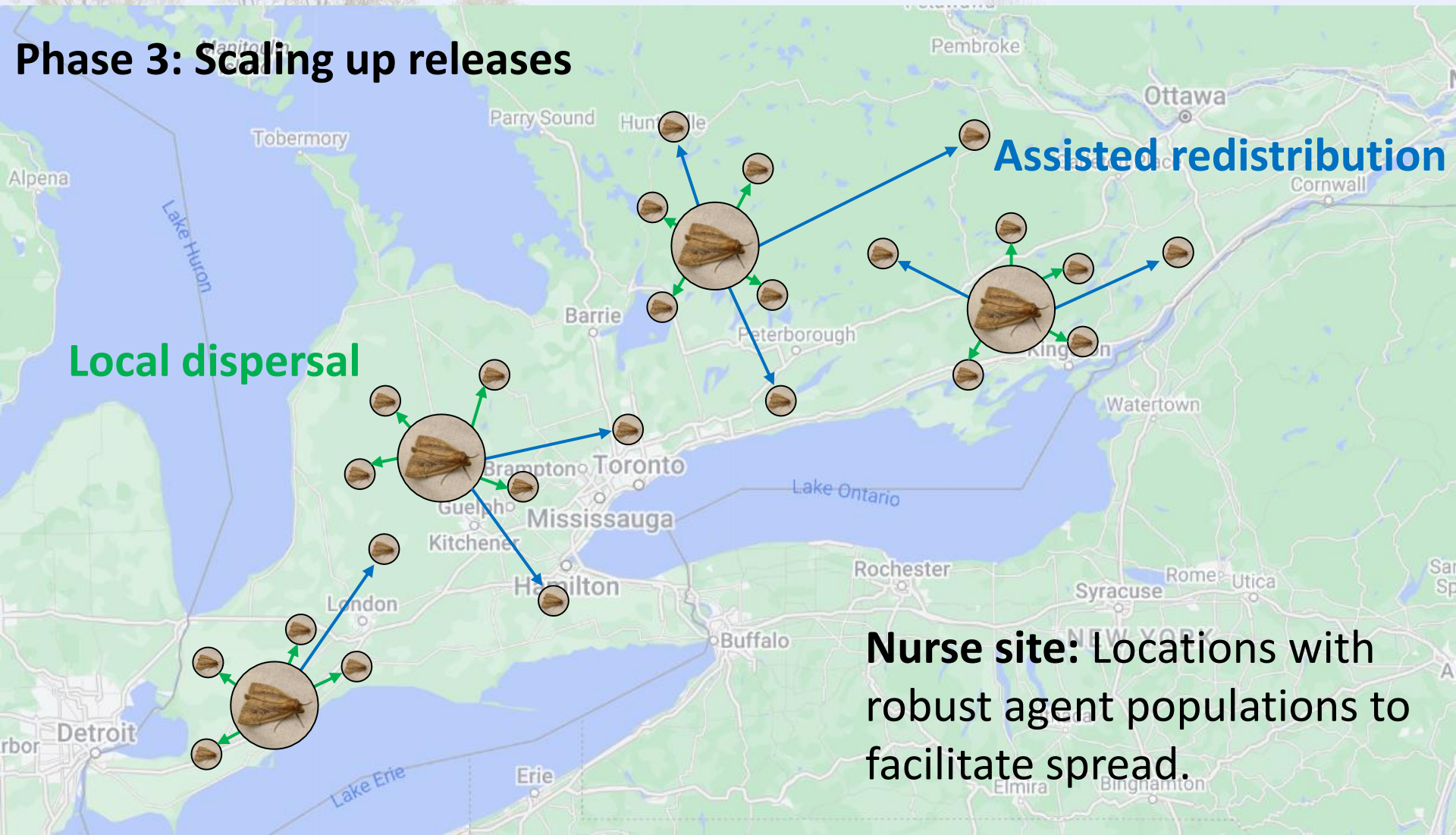
- First Canadian releases (Ontario).



Biological control of introduced *Phragmites*

1998-2019 | 2019-2023 | 2023+

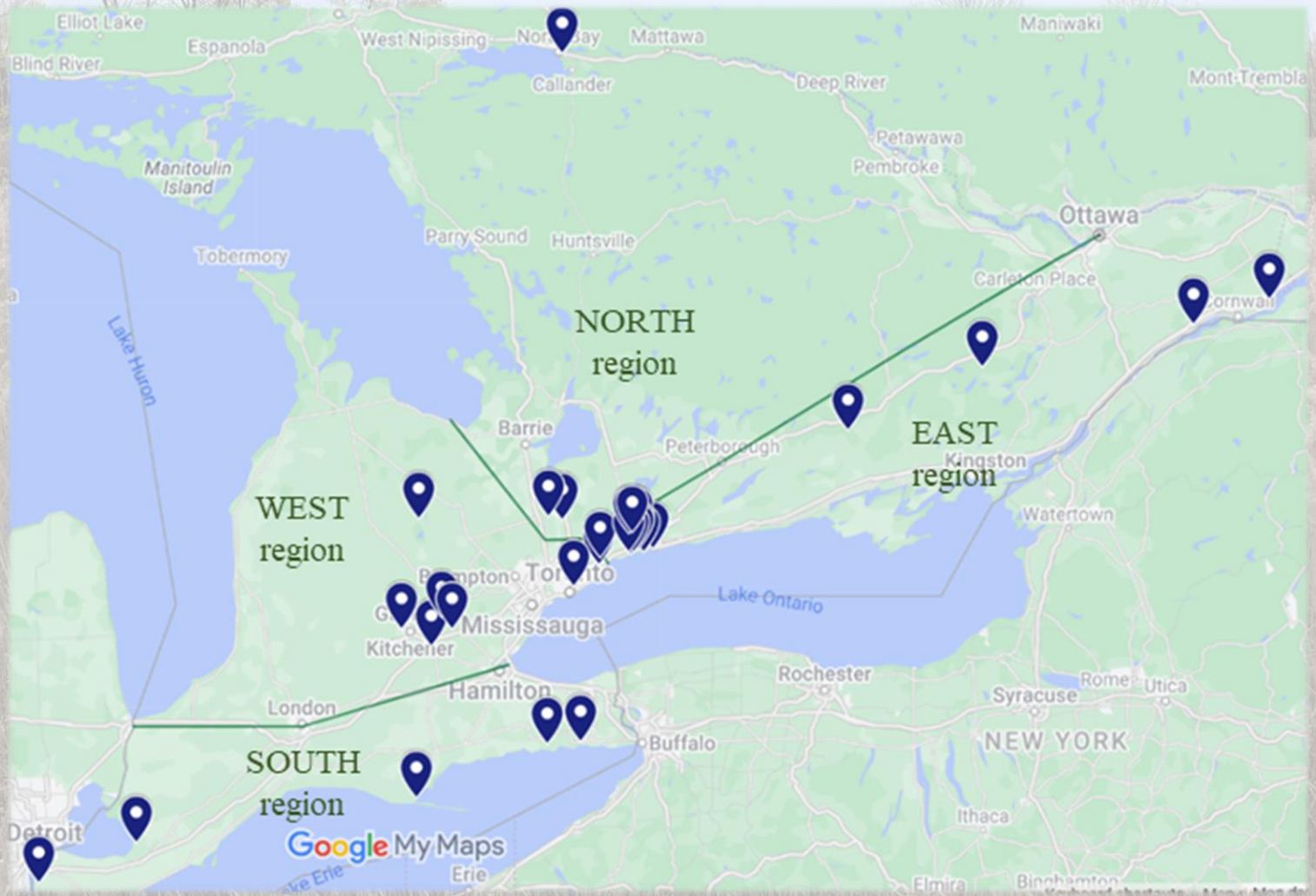
Phase 3: Scaling up releases



Nurse site: Locations with robust agent populations to facilitate spread.

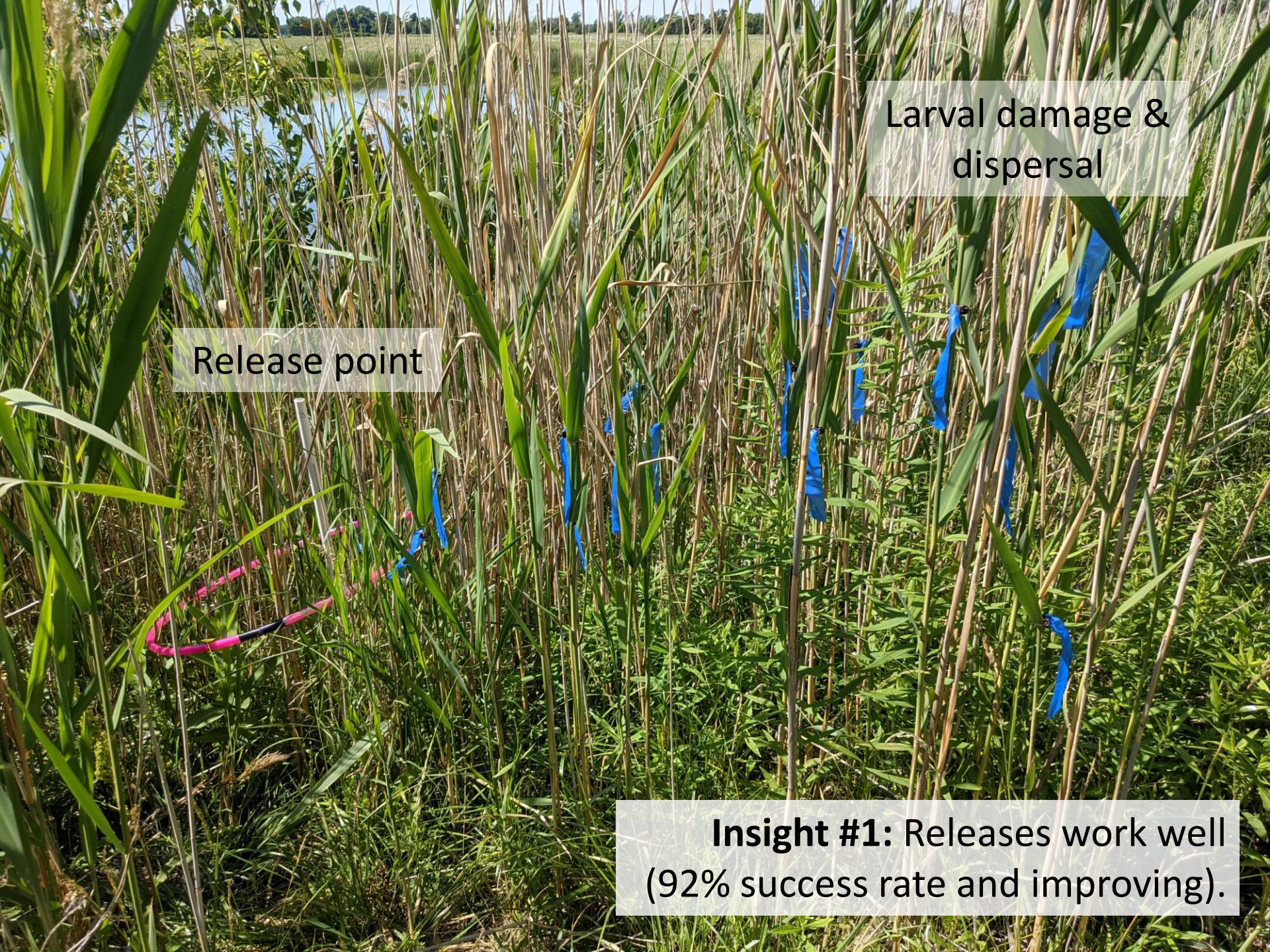
Biological control of introduced *Phragmites*

From 2019 to 2023, we have released ~**21,000 insects** across **30 sites** in Ontario.

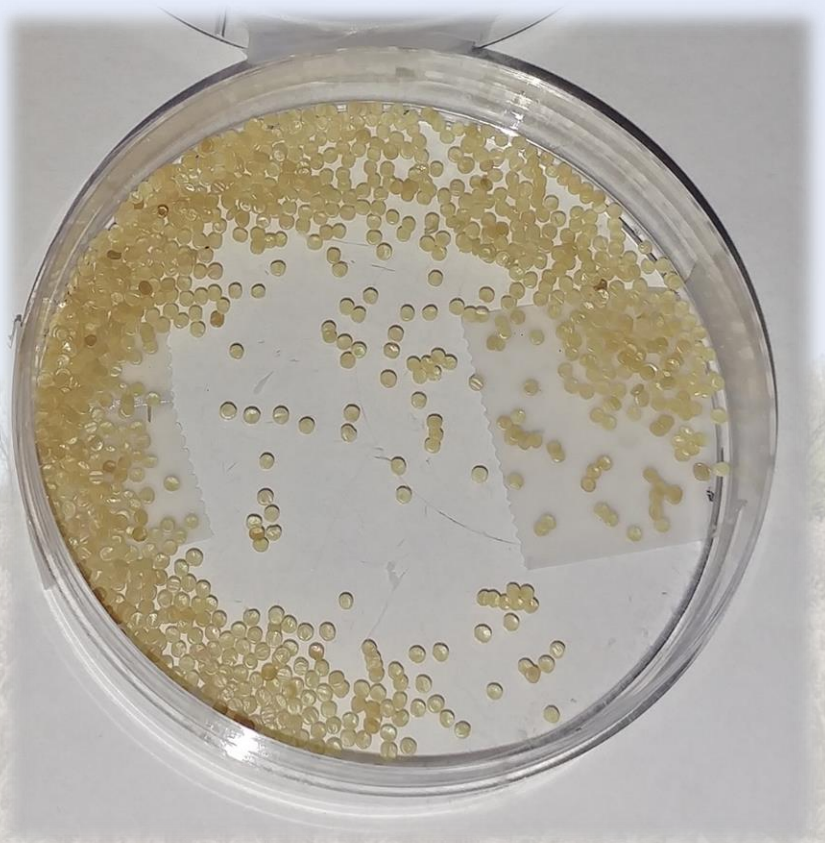


Growing **long-term annual dataset** tracking feeding damage (damaged stems per m^2).

Site	Year 1 [release point]	Year 2 [patch level]	Year 3 [patch level]
P01: Davern	N/A	0.0 ± 0.0 (n = 14)	0.0 ± 0.0 (n = 14)
P02: Aurora	12.3 ± 16.0 (n = 11)	2.0 ± 2.4 (n = 38)	3.4 ± 2.0 (n = 39)
P03: Wainfleet	N/A	0.1 ± 0.2 (n = 18)	0.1 ± 0.2 (n = 18)
P04: Sinclair Campbell	18.5 ± 16.8 (n = 14)	5.2 ± 4.5 (n = 20)	4.7 ± 3.5 (n = 16)
P05: Oshawa	3.7 ± 8.2 (n = 9)	0.1 ± 0.3 (n = 53)	0.8 ± 1.0 (n = 42)
P07: Aultsville	N/A	0.1 ± 0.2 (n = 15)	0.5 ± 0.8 (n = 16)
P08: Madoc	N/A	0.0 ± 0.0 (n = 17)	0.1 ± 0.1 (n = 16)
P09: Scarborough	1.4 ± 3.9 (n = 11)	0.2 ± 0.3 (n = 20)	-
P10: Zoo	8.7 ± 15 (n = 3)	0.3 ± 0.4 (n = 14)	-
P11: Waterloo	14.1 ± 12.4 (n = 38)	3.3 ± 2.2 (n = 66)	-
P12: rare	12.9 ± 14.2 (n = 11)	1.8 ± 2.6 (n = 55)	-
P06: Koffler	28.1 ± 12.4 (n = 9)	-	-
P13: Dunnville	0.2 ± 0.2 (n = 6)	-	-
P14: Cranberry	11.0 ± 10.3 (n = 30)	-	-
P15: Mac Coutts	13.4 ± 8.2 (n = 9)	-	-
P16: Collavino	33.5 ± 20.3 (n = 18)	-	-
P17: Cooper	25.4 ± 13.1 (n = 9)	-	-
P18: Whitby	9.0 ± 8.0 (n = 3)	-	-
P19: Brickworks	15.6 ± 10.3 (n = 6)	-	-
P20: St. Lukes	26.1 ± 12.6 (n = 12)	-	-
P21: Brimblecombe	15.1 ± 12.9 (n = 6)	-	-
P22: North Bay	6.0 ± 10.4 (n = 3)	-	-
P23: Garrard	6.0 (n = 1)	-	-
P24: Nichol	6.0 (n = 1)	-	-
P25: Victoria	(Site destroyed)	-	-
P26: Gordon	9.0 (n = 1)	-	-
P27: Lakeridge	0.0 (n = 1)	-	-
P28: Cochrane	3.0 (n = 1)	-	-
P29: Brooklin	0.0 (n = 1)	-	-
P30: Donkey	1.5 ± 2.1 (n = 2)	-	-


Larval damage & dispersal
Release point
Insight #1: Releases work well (92% success rate and improving).

Insight #2: Annual damage persists post-release (indicating agent reproduction, overwintering, and local dispersal).



Insight #3: Eggs can be practically harvested from release sites by cutting stems (e.g., 3rd year nurse site: 116 stems → 367 eggs).

Biological control of introduced *Phragmites*

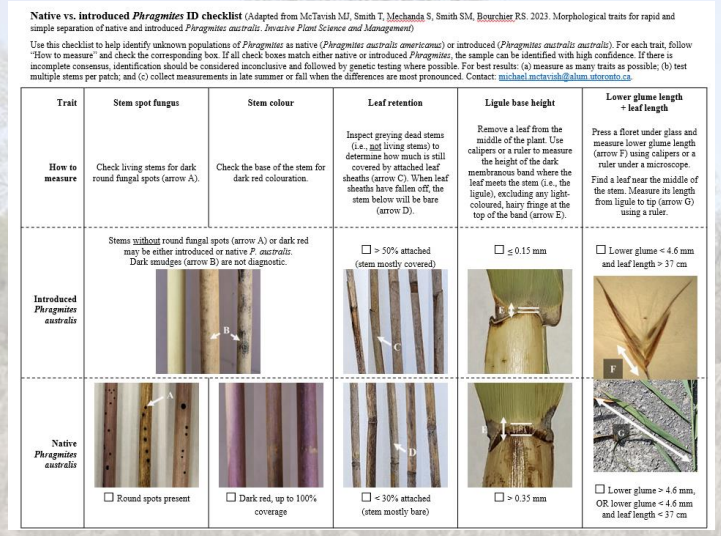
- Core protocols developed and initial releases **highly encouraging.**
- Focus on **scaling up** nurse sites and **integrating** with existing province-wide management plans (ON).
- Nurse sites on-track to begin producing additional eggs for **wider redistribution** (e.g., inter-provincial) to priority sites by spring 2025.

Summary

Summary

- **Introduced *Phragmites*** is a highly competitive invasive weed; widespread in ON, may become more common in AB.
- **Diagnostic traits** are essential to reliably and practically distinguish the weed from native *Phragmites*.
- **Biological control** is growing as a “new tool in the toolbox” to help manage introduced *Phragmites*.

Summary



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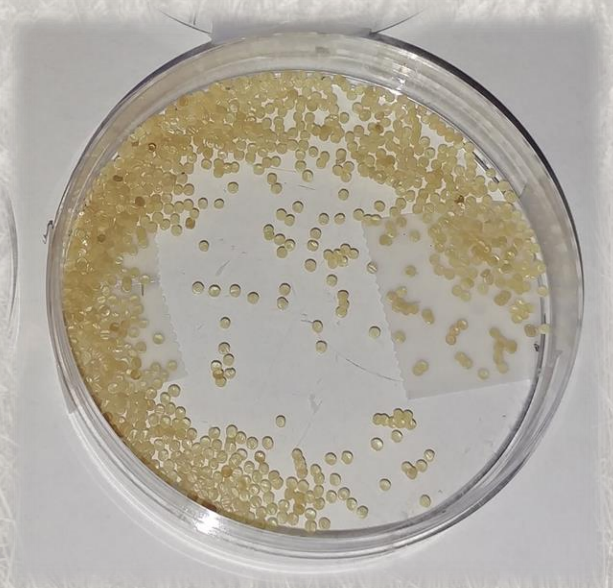


Recommendations for AB

1. Continue early detection and monitoring.
2. Confirm as introduced or native (ID key, genetic).
3. Prevent and eradicate small populations when practical.
4. For unmanageable populations, biocontrol agents may be available as early as spring 2025.

Additional resources

Invasive Plant Science and Management

www.cambridge.org/inp

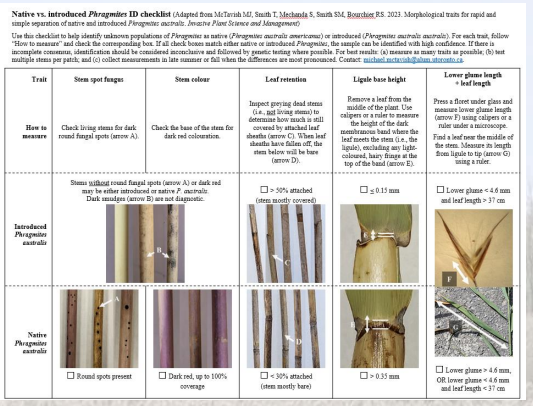
Morphological traits for rapid and simple separation of native and introduced common reed (*Phragmites australis*)

Michael J. McTavish[1], Tyler Smith[2], Subbaiah Mechanda[3], Sandy M. Smith[4] and Robert S. Bourchier[5]

[1]Postdoctoral Research Fellow, Institute of Forestry and Conservation, John H. Daniels Faculty of Architecture, Landscape and Design, University of Toronto, Toronto, Canada; [2]Research Scientist, Agriculture and Agri-Food Canada, Ottawa, Ontario, Canada; [3]Research Technician, Agriculture and Agri-Food Canada, Ottawa, Ontario, Canada; [4]Professor, Institute of Forestry and Conservation, John H. Daniels Faculty of Architecture, Landscape and Design, University of Toronto, Ontario, Canada and [5]Research Scientist, Agriculture and Agri-Food Canada, Alberta, Canada

Research Article

Cite this article: McTavish MJ, Smith T, Mechanda S, Smith SM, and Bourchier RS (2023). Morphological traits for rapid and simple separation of native and introduced common reed (*Phragmites australis*). Invasive Plant Sci. Manag. doi: 10.1017/inp.2023.15



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Use this checklist to help identify unknown populations of *Phragmites* as native (*Phragmites australis americanus*) or introduced (*Phragmites australis australis*). For each trait, follow "How to measure" and check the corresponding box. If all check boxes match either native or introduced *Phragmites*, the sample can be identified with high confidence. If there is incomplete consensus, identification should be considered inconclusive and followed by genetic testing where possible. For best results: (a) measure as many traits as possible; (b) test multiple stems per patch; and (c) collect measurements in late summer or fall when the differences are most pronounced. Contact: michael.mctavish@alum.utoronto.ca.

Trait	Stem spot fungus	Stem colour	Leaf retention	Ligule base height	Lower glume length ÷ leaf length
How to measure	Check living stems for dark round fungal spots (arrow A).	Check the base of the stem for dark red colouration.	Inspect greying dead stems (i.e., not living stems) to determine how much is still covered by attached leaf sheaths (arrow C). When leaf sheaths have fallen off, the stem below will be bare (arrow D).	Remove a leaf from the middle of the plant. Use calipers or a ruler to measure the height of the dark membranous band where the leaf meets the stem (i.e., the ligule), excluding any light-coloured, hairy fringe at the top of the band (arrow E).	Press a floret under glass and measure lower glume length (arrow F) using calipers or a ruler under a microscope. Find a leaf near the middle of the stem. Measure its length from ligule to tip (arrow G) using a ruler.
Introduced *Phragmites australis*	Stems without round fungal spots (arrow A) or dark red may be either introduced or native *P. australis*. Dark smudges (arrow B) are not diagnostic.		☐ > 50% attached (stem mostly covered)	☐ ≤ 0.35 mm	☐ Lower glume < 4.6 mm and leaf length > 37 cm
Native *Phragmites australis*	☐ Round spots present	☐ Dark red, up to 100% coverage	☐ < 50% attached (stem mostly bare)	☐ > 0.35 mm	☐ Lower glume > 4.6 mm, OR lower glume < 4.6 mm and leaf length < 37 cm

Contents lists available at ScienceDirect

Biological Control

journal homepage: www.elsevier.com/locate/ybcon

Field tests of egg and larval release methods of biological control agents (*Archanara neurica*, *Lenisa geminipuncta*) for introduced *Phragmites australis australis* (Cav.) trin. Ex Steud

Michael J. McTavish [a,*], Ian M. Jones [a], Patrick Häfliger [b], Sandy M. Smith [a], Robert S. Bourchier. [c]

Current status of biological control of introduced *Phragmites* in Canada: Insights from initial years of post-release monitoring and a larval density release experiment

Michael J. McTavish[a*], Ian M. Jones[a], Sandy M. Smith[a], Robert S. Bourchier[b]

Thank you to our many collaborators and supporters!

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