

The Recent Spread and Potential Distribution of *Phragmites australis* subsp. *australis* in Canada

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To provide information on geographic occurrence, rate of spread, and potential distribution of European Common Reed, *Phragmites australis* subsp. *australis*, in Canada, we measured 1740 herbarium specimens from 21 collections across Canada, entered the information into a database, and mapped and analyzed these records. The European subspecies *australis* was first documented in Canada 100 years before it was recognized as an alien invader. It was not until the invading plants had entered a phase of rapid local increase after 1990 that they attracted sufficient attention that a comparison of the invasive and non-invasive plants was made. By 2001, two different races had been distinguished, and soon after they were separated as different subspecies. The first Canadian collection of the alien subsp. *australis* was made in southwestern Nova Scotia in 1910. By the 1920s, it occurred in southern Nova Scotia, along the St. Lawrence River near Quebec City and at Montreal. The first southwestern Ontario specimen was collected in 1948. Thus by 1950 subsp. *australis* was known from only four relatively small areas of Canada based on 22 collections. At this same time, the native race, subsp. *americanus*, had a widespread distribution in Canada represented by 325 collections. This strongly supported the comparable and limited distribution of subsp. *australis* at the time. By 1970, subsp. *australis* had spread locally but was still found only in southwestern Nova Scotia, in the St. Lawrence River valley, and in southwestern Ontario. By 1990, subsp. *australis* had become much more frequent in the St. Lawrence River valley and in southwestern Ontario, and it had extended westward into eastern Ontario. By 2010, it had spread throughout much of southern Ontario and southern Quebec, and it had a more extensive distribution in Atlantic Canada, but the biggest change was its spread into western Canada. It appeared in northern Ontario, northwestern Ontario, southern Manitoba, and interior southern British Columbia. The rate of spread is increasing and within a decade or two, based on the extent of appropriate plant hardiness zones currently occupied, it is expected to become abundant in the prairie provinces and across most of southern Canada.

Key Words: European Common Reed, *Phragmites australis* subsp. *australis*, *Phragmites australis* subsp. *americanus*, invasive alien, weed, spread, potential distribution, biodiversity, Canada, prairies, prairie provinces, plant hardiness zones.

Information on the geographic occurrence of invasive species is essential for the protection of native biodiversity. The Convention on Biological Diversity (United Nations 1992*) calls for “the eradication of those alien species which threaten ecosystems, habitats or species.” The Canadian Biodiversity Strategy (Biodiversity Convention Office 1995, article 1.81) recommends that ways to identify and monitor alien organisms be developed and implemented, that priorities be determined, and that databases that will help predict the spread of these organisms be developed and analyzed. A related goal of Agriculture and Agri-Food Canada is to minimize risks to native biodiversity from exotic organisms (Agriculture and Agri-Food Canada Environment Bureau 1997). The global strategy for plant conservation adopted by the conference

of the parties to the Convention on Biological Diversity in 2002 included among its outcome targets for 2010 “management plans in place for at least 100 major alien species that threaten plants, plant communities and associated habitats and ecosystems.” This target has yet to be properly evaluated (Secretariat of the Convention on Biological Diversity 2009), but clearly the European subspecies of Common Reed (*Phragmites australis* (Cav.) Trin. ex Steud. var. *australis*) is a major alien species. It is currently ranked as the foremost invasive plant threat to native biodiversity in Canada that is lacking a comprehensive management plan (Catling 2005*). It is rapidly spreading in Canada, and geographic information is urgently needed.

As a result of confusion with the native *P. australis* subsp. *americanus* Saltonstall, P. M. Peterson & Soreng

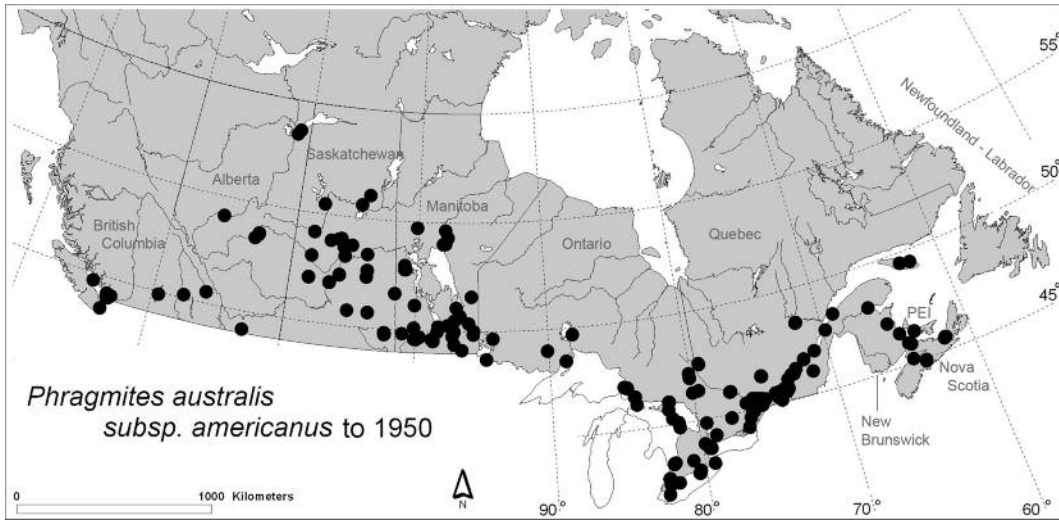


FIGURE 1. Distribution of the native *Phragmites australis* subsp. *americanus* in Canada up to 1950, showing the widespread distribution anticipated for a native taxon. Specimens examined from the following herbaria: ACAD, ALTA, CAN, DAO, MMMN, MT, MTMG, NSPM, QFA, QUE, SASK, TRT, TRTE, UBC, UNB, UPEI, UWO, V, WAT, and WIN.

(a native plant of fens, bogs and rivershores), subsp. *australis* was not included among the invasive species covered by White *et al.* (1993). Possible “invasive biotypes” were alluded to in 2001 (Small and Catling 2001), and the status and identification of native and introduced races were clarified for Canada in 2003 (Catling *et al.* 2003). Also, by 2003, the presence of non-native genotypes had been well established (Saltonstall 2002, 2003). The two subspecies, then treated as races, were only briefly alluded to by Mal and Narine (2004) based on Catling *et al.* (2003). In 2004, the widespread native North American race was described as the distinct subspecies *americanus* (Salt-onstall *et al.* 2004). The identification of the introduced *Phragmites australis* subsp. *australis* was clarified by Catling (2007*) and Catling *et al.* (2007).

In eastern Canada, the invasive alien subsp. *australis* is having major impacts (Mitrow and Catling 2009*); it is displacing native vegetation in rich salt marshes in the estuary of the St. Lawrence River (personal observation); it has become the most significant threat to native vegetation in the St. Lawrence River area (Lavoie *et al.* 2003); it is replacing native wetland vegetation in Long Point Biosphere Reserve on the Lake Erie shore of Ontario (Wilcox *et al.* 2003); it is eliminating the habitat of the endangered Eastern Prairie Fringed Orchid (*Platanthera leucophaea*) (COSEWIC 2003) and other native prairie plant species at risk in the Lake St. Clair marshes (personal observation); it is displacing the rich biodiversity of shoreline fens on Lake Huron (Bickerton 2007*); and it is invading cereal crops in parts of eastern Ontario and southern Que-

bec (personal observation). Recent studies have described the characteristics that enable it to achieve these kinds of environmental damage especially with regard to outcompeting *Typha* in wetlands (Bellavance and Brisson 2010). It was first reported (i.e., not recorded indirectly as a misidentified specimen) in western Canada in 2003 (Martin 2003*; Schueler *et al.* 2003*) and first in Atlantic Canada in 2004 (Catling *et al.* 2004*). Using a well-supported assessment protocol (Morse *et al.* 2004), it was ranked as the top priority invasive alien plant in Canada in 2005 (Catling and Mitrow 2005; Catling 2005*).

A useful map of mostly invasive *Phragmites* in Canada, based on a recent extensive survey (Schueler 2002*), provided a valuable benchmark but did not distinguish subspecies, since it was generated prior to the work that enabled convenient identification. The synthesis of biological information on *Phragmites australis sensu lato* in North America for the “Biology of Canadian Weeds” series also preceded the taxonomic understanding of two separate entities. Consequently, Mal and Narine (2004) produced a map of the Canadian distribution that did not distinguish between subspecies. Maps of the two subspecies are available online via a searchable database with geographic querying capability (Catling 2007*; Catling and Mitrow 2009a*). Although this was a useful step, the data on which the maps are based has not been subject to analysis aimed at documenting rate of spread. Potential distribution in Canada was discussed by Catling and Mitrow (2009b*), but no detailed mapping was provided. The present work responds to the needs outlined above by pro-

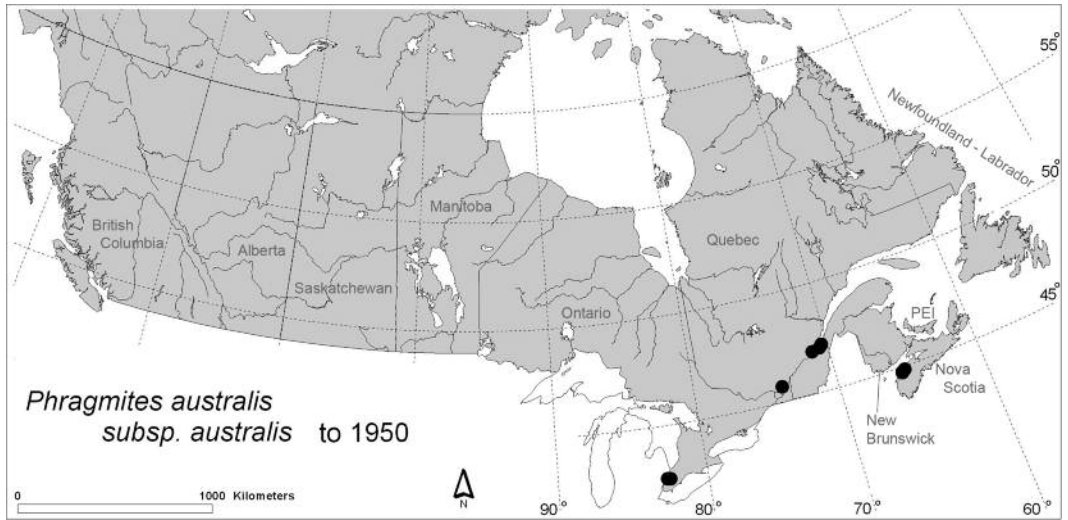


FIGURE 2. Distribution of the alien *Phragmites australis* subsp. *australis* in Canada up to 1950, showing the limited distribution anticipated for an introduced taxon, here largely limited to urban areas of introduction. Specimens examined from the following herbaria: ACAD, ALTA, CAN, DAO, MMMN, MT, MTMG, NSPM, QFA, QUE, SASK, TRT, TRTE, UBC, UNB, UPEI, UWO, V, WAT, and WIN.

viding an analysis of geographic information relating to the status, spread, and current and potential distribution of *Phragmites australis* subsp. *australis*.

Methods

Herbarium specimens were measured and identified, and the label data were recorded and mapped in order to provide information on geographic occurrence. Herbaria at the following institutions supplied specimens: Acadia University (ACAD), the University of Alberta (ALTA), the Canadian Museum of Nature (CAN), Agriculture and Agri-Food Canada (DAO), the Eastern Ontario Biodiversity Museum (EOBM, now in DAO), Carleton University (CCO, now in DAO), the Manitoba Museum (MMMN), the Université de Montréal (MT), Macdonald Campus of McGill University (MTMG), the Nova Scotia Museum of Natural History (NSPM), Université Laval (QFA), the Herbarium du Québec Ministère des Ressources naturelles et de la Faune du Québec (provincial herbarium, Québec ministry of natural resources and wildlife) (QUE), the University of Saskatchewan (SASK), the Royal Ontario Museum (TRT), Erindale College of the University of Toronto (TRTE), the University of Calgary (UAC), the University of British Columbia (UBC), the University of New Brunswick (UNB), the University of Prince Edward Island (UPEI), the University of Western Ontario (UWO), the Royal British Columbia Museum (V), the University of Waterloo (WAT), and the University of Winnipeg (WIN) (acronyms from

Thiers 2011*). These 21 collections differ in their regional representation but collectively represent all of Canada. The collection information was organized into a database of 1740 records. Most of the specimen data used are readily available at <http://www.cbif.gc.ca/> (see Catling 2007*; Catling and Mitrow 2009a*).

Of the specimens in the database, only 728 could be used because only these specimens could be identified to subspecies with a high level of confidence. For Figure 1, 156 plants with prominent reddish-purple basal stem internodes and 169 plants lacking lower stems but with lower glumes over 4.4 mm were plotted. For Figures 2 to 5, 413 plants were considered: 248 with yellow lower stem internodes and 165 without lower stems but with lower glumes less than 3.8 mm long.

These decisions exclude plants with intermediate stem colours and intermediate lower glume lengths and correspond to recent identification keys separating the two subspecies (Catling *et al.* 2007). The colour of the lower stem internodes is considered the most reliable character in both fresh and dried material. Most of the 1012 excluded specimens had immature inflorescences or were lacking basal parts. Only 3% of the exclusions were the result of intermediacy of internode colour. On the basis of intermediate lower glume lengths alone, 30.5% of specimens fulfilled the exclusion criteria for intermediacy. The intermediates were not obviously hybrids and were considered to represent extremes.

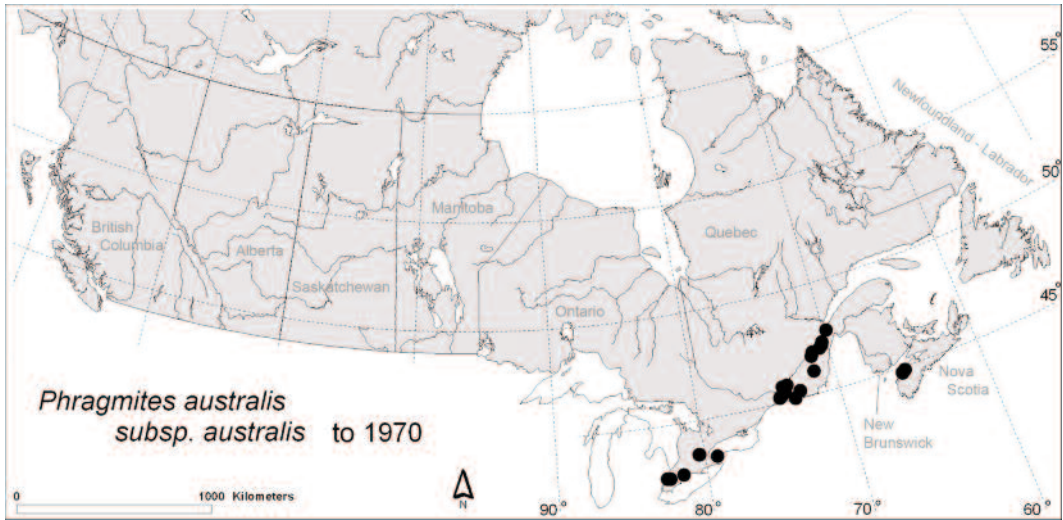


FIGURE 3. Distribution of the alien *Phragmites australis* subsp. *australis* in Canada up to 1970. Specimens examined from the following herbaria: ACAD, ALTA, CAN, DAO, MMMN, MT, MTMG, NSPM, QFA, QUE, SASK, TRT, TRTE, UBC, UNB, UPEI, UWO, V, WAT, and WIN.

The identification key used was as follows:

- 1a. Lower stem internodes yellowish or yellowish-brown; lower glumes 2.6–4.2 (4.8) mm long; ligule of middle leaf excluding fringe usually 0.1–0.4 mm high subsp. *australis* (introduced)
- 1b. Lower stem internodes reddish-purple; lower glumes 3.8–7.0 mm long; ligule of middle leaf excluding fringe usually 0.4–0.9 mm high . . . subsp. *americanus* (native)

Variation in sampling effort over time can lead to biases in interpreting periods of invasiveness. These biases can be overcome to some extent by a comparison with the rate at which similar native and exotic taxa have been collected (Deslile *et al.* 2003). Here we compare the distribution of the native subsp. *americanus* up to 1950 to that of the introduced subsp. *australis* by the same date to help establish the invasive period of the latter. Arrival in a particular region may have been in advance of the date of the first collection, and at any particular time an invasive species may be more widespread at the time than collections indicate. Using collections to represent distributions, especially of invading species, is only an approximation, but it is also an indication of what is definitely known with a background of proof. It has worked relatively well because field botanists are distributed

across Canada and have increased in number over the last century.

With regard to predicting the potential area of distribution in Canada of the introduced subsp. *australis*, we used the simple yet useful approach of anticipating full occupation across Canada of hardiness zones (Agriculture and Agri-Food Canada 2010*, United States Department of Agriculture 2011*) currently occupied by subspecies *australis* in the east. Hardiness zones, which are based on both assessments of plant response to climate and climate data, have been updated to reflect recent changes in Canadian climate and to develop a more objective approach to climate mapping (McKenney *et al.* 2001). Mean maximum temperature of the coldest month and the number of frost-free days are the most important correlates of hardiness. Using the hardiness zones projection, potential range is based on occurrences and climatic tolerances of genotypes already present. The potential range assumes the ability to spread (see below) and it assumes that substrate requirements will be met. Although substrate may determine the level of impact in local areas, it is not likely to restrict broad scale distribution because calcium-rich alkaline soils are widespread or continuous across much of Canada and regions without such soils are connected due to the use of de-icing salt on roads which serve as the major invasion pathway (Catling and Carbyn 2006; Lelong *et al.* 2007; Jodoin *et al.* 2008; Brisson *et al.* 2010).

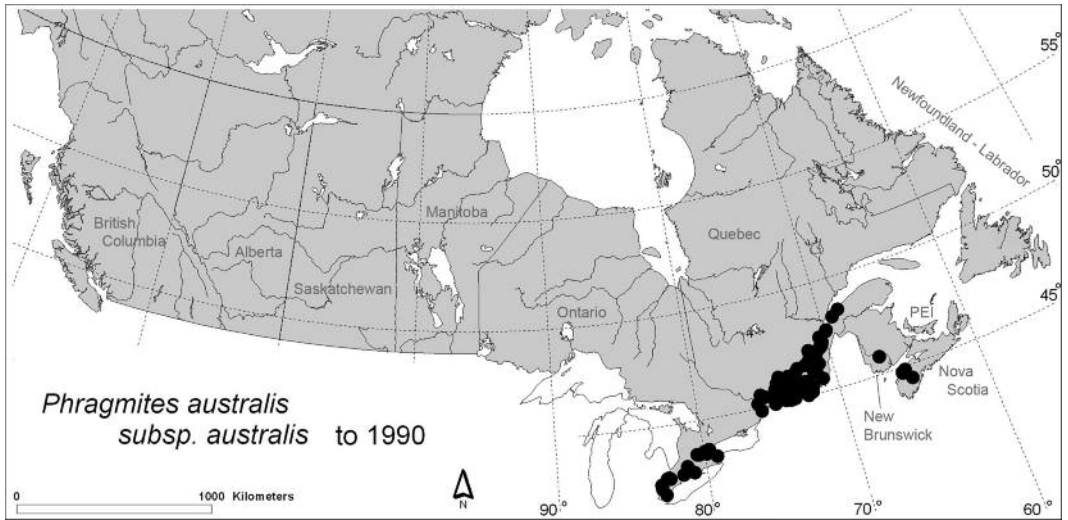


FIGURE 4. Distribution of the alien *Phragmites australis* subsp. *australis* in Canada up to 1990. Specimens examined from the following herbaria: ACAD, ALTA, CAN, DAO, MMMN, MT, MTMG, NSPM, QFA, QUE, SASK, TRT, TRTE, UBC, UNB, UPEI, UWO, V, WAT, and WIN.

Results

Arrival and initial spread to 1950

The native and very similar *P. australis* subsp. *americanus* was first collected in Canada in Montreal in 1820 (approximately 45.56326°N, 73.66830°W, 1820, *Holmes s.n.*, MT). By 1910, there were 39 collections. Based on 317 collections, its distribution in North America had been established as being widespread by 1950 (Figure 1). The Canada-wide distribution has been filled and slightly extended since that time, but the changes are not substantial (personal observation).

The first Canadian record of *P. australis* subsp. *australis* is from Annapolis Royal in southwestern Nova Scotia (44.73937°N, 65.51820°W, 1 September 1910, *J. Macoun 82089*, CAN 34069). By 1950, it had a distinctly introduced distribution pattern, being known from only four locations, three of which were seaports (Figure 2). The number of collections before 1950 was only 22. This number of collections and distribution pattern (Figure 2), compared to that of the native subsp. (Figure 1), strongly support the concept of subsp. *australis* being an alien taxon with a very limited distribution in Canada for a long period. Unlike the situation with the native subsp. *americanus*, the range of the introduced subsp. *australis* has been substantially extended since then.

Following the early collections, subsp. *australis* was subsequently found many times at Annapolis Royal by a series of collectors (Catling *et al.* 2004*) (e.g., 30 August 1921, *M.L. Fernald and B. Long 23296*,

ACAD, CAN 34067, MT). In that town it is currently known as “elephant grass,” and it is believed to have been introduced with straw on trains carrying elephants and other circus animals in the early 1900s (Catling *et al.* 2004*). Of course, it may also have originated in packing material or hay on ships arriving from Europe. It was also collected early at Bridgetown, Nova Scotia (44.83670°N, 65.28681°W, 14 September 1928, *H.G. Perry and M.V. Roscoe 13820, 13954, 13957*, ACAD, MTMG 25805, NSPM).

The first specimen of subsp. *australis* from the St. Lawrence River downstream from Quebec City was collected at L'Islet (46.87733°N, 71.11144°W, August 1916, *Frère Marie-Victorin s.n.*, CAN 332090). The first record from the Montreal region was from Thérèse-de-Blainville (approximately 45.68330°N, 73.78330°W, September 1929, *S. Lauzon 39*, MT).

The first known occurrence of subsp. *australis* from southwestern Ontario was on Walpole Island, Lake St. Clair (approximately 42.52917°N, 82.47851°W, 8 August 1948, *R.W. Neal 786*, DAO 25225).

1970

By 1970, subsp. *australis* had spread locally but was still known from only the three regions: southwestern Nova Scotia, the St. Lawrence River valley, and southwestern Ontario. However, it had become more continuously distributed in the St. Lawrence River valley, with collections between Quebec City and Montreal on the south shore of the St. Lawrence River, suggesting spread along roads (e.g., Black Lake, 46.04111°N,

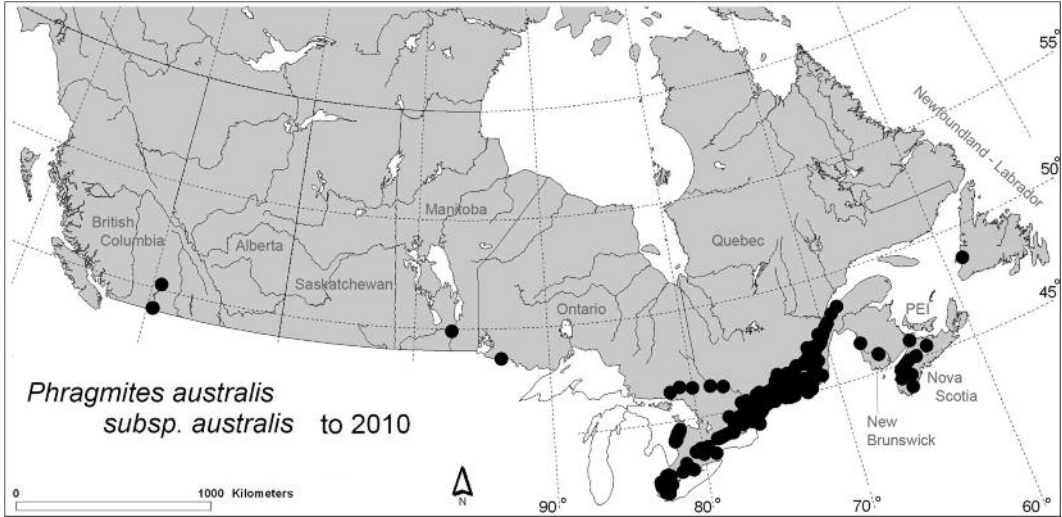


FIGURE 5. Distribution of the alien *Phragmites australis* subsp. *australis* in Canada up to 2010. Specimens examined from the following herbaria: ACAD, ALTA, CAN, DAO, MMMN, MT, MTMG, NSPM, QFA, QUE, SASK, TRT, TRTE, UBC, UNB, UPEI, UWU, V, WAT, and WIN.

71.361944°W, 12 July 1965, *G. Deshaies*, *P. Forest*, *V. Blais 10397*, MT). Over this 20-year period, it had also become distributed throughout much of the Carolinian zone of southwestern Ontario (Figure 3).

1990

By 1990, subsp. *australis* had become frequent and abundant in the St. Lawrence River valley and had recently appeared in the lower Ottawa River valley (Catling and Carbyn 2006), where it was first collected near Manotick (west side of Highway 16, 45.18614°N, 75.72348°W, 8 September 1976, *A. Hanes s.n.*, DAO 153254). Its known range had extended northeast in the St. Lawrence River valley to Rimouski (48.45000°N, 68.50000°W, 25 August 1987, *E. Côté 47*, MT). In Nova Scotia, it was still confined to the southwestern part of the province, but it was found for the first time in New Brunswick (2 miles south of Beaver Dam, 45.77212°N, 66.68840°W, 21 May 1981, *H. Hinds 4181*, MTMG 117304, UNB 36992). It had also developed a more continuous distribution in the Carolinian zone of southwestern Ontario by this time (Figure 4). 2010

Between 1991 and 2010 (Figure 5), there were two major changes. Firstly, there were substantial increases in the distribution at the local level. The St. Lawrence and southwestern Ontario regions of occurrence of subsp. *australis* were joined as a result of expansion along highways. Likewise, distributions became more continuous in the Maritimes (Catling *et al.* 2004*).

Secondly, a number of populations were found far outside the traditional areas of occurrence. For example, subsp. *australis* invaded the Lake Huron coast-

line (Bickerton 2007*) and was found north in Ontario as far as Sudbury (e.g., on the side of Highway 17, 67 km west of Coniston, near Wabagishi Road, 46.33298°N, 81.56477°W, 4 August 2004, *P. M. Catling s.n.*, DAO 795731). Most important were long-distance disjunctions (within the Canadian range) to Newfoundland and Labrador, northwestern Ontario, Manitoba, and British Columbia. The Newfoundland and Labrador record is from insular Newfoundland in Stephenville (48.55000°N, 58.58330°W, 1 August 1991, *R. Day s.n.*, DAO 595274). The first record in northwestern Ontario is from Fort Frances (bank of Highway 11 on the west side of Fort Frances, 48.60461°N, 93.45773°W, 1 August 2004, *P. M. Catling and B. Kostiuk s.n.*, DAO 795730). It was predicted that subsp. *australis* would spread to the prairie provinces (Catling and Mitrov 2009b*). So quickly did the prediction come true that publication of the first Manitoba collection (Snyder 2009*) (Winnipeg, Fort Garry area, west side of Route 90, north of Route 155, 49.88444°N, 97.14639°W, 15 October 2009, *E. Snyder s.n.*, DAO 845029) accompanied the note predicting it in the same issue of Botanical Electronic News. Records from British Columbia were also reported during this period (Schueler *et al.* 2003*; Martin 2003*; Okanagan River, protected area east of the Okanagan Highway and west of the Osoyoos Indian Reserve, 25 September 2000, *F. W. Schueler*, DAO 793302; and edge of small *Typha latifolia* wetland in semi-urban setting near the head of the Vernon arm of Okanagan Lake, 50.25248°N, 119.34725°W, December 2003, *M. Martin s.n.*, DAO 793085).

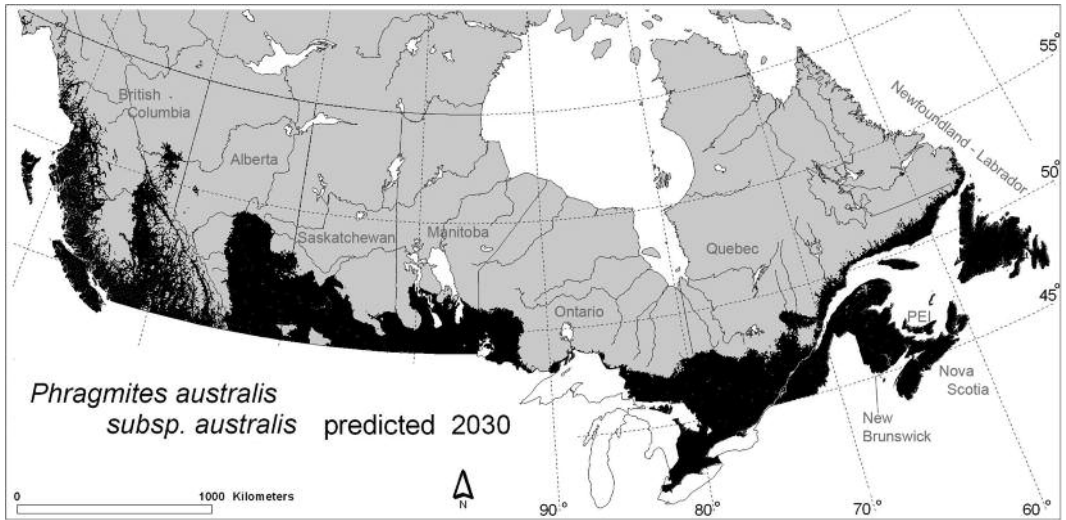


FIGURE 6. Predicted distribution of the alien *Phragmites australis* subsp. *australis* in Canada in 2030. The black areas on the map above represent the predicted range of European Common Reed in Canada within two decades based on the extent in Canada of plant hardiness zones currently occupied by subsp. *australis* in eastern Canada and taking into consideration both substrate and the past rate of spread. Note extensive anticipated occurrence in the prairie provinces. Since the rate of spread is increasing and the climate over much of Canada is getting warmer, the distribution of European Common Reed may extend north of the black areas over the shorter period of a single decade. The 2030 projection is a minimal area projection.

Rate and patterns of spread

The alien subsp. *australis* was introduced relatively early, but it wasn't until after 1970 and mostly over the past few decades that it invaded large parts of Canada (Figures 2 to 5). Initially most of the increase was within small local regions. Next there was expansion and consolidation of these regions, followed by major spread and long-distance dispersal.

Estimating potential distribution

The collections occurred within a range of plant hardiness zones extending from 2b in the north to 6a in the south, and the area of occurrence extends to zone 8a in adjacent regions of the United States. Based on the occurrence of these zones across Canada, an extensive distribution for subsp. *australis* across Canada can be anticipated (Figure 6).

Discussion

The rate of recent spread suggested by collections corresponds to sudden appearance in a region noted by various authors (Bickerton 2007*; Catling and Carbyn 2007; Wilcox *et al.* 2003), followed by increasing local abundance over a period of several years. Its invasion of the Ottawa district began as recently as the 1970s (Catling and Carbyn 2007). Schueler (2002*) noted that he noticed *Phragmites*, through the 1980s and 1990s, in places and abundances it seemed not to have occupied in the 1970s. Lelong *et al.* (2007) reported that, starting in 1970, a complete shift occurred in Quebec

over the next two decades from dominance of subsp. *americanus* to dominance of subsp. *australis*.

Although Delisle *et al.* (2003) did not distinguish races or subspecies, using proportion curves they identified a period of expansion in Quebec beginning in the 1960s at the time of major highway construction in the province. Many authors noticed that expansion was associated with roads (Gervais *et al.* 1993; Schueler 2002*; Catling and Carbyn 2007; Lelong *et al.* 2007; Jodoin *et al.* 2008; Brisson *et al.* 2010). Catling and Carbyn (2007) suggested that dispersal of rhizomes along roads (Figure 7) is the major mechanism of dispersal, although plants may also reproduce by seed in some, but not all, circumstances (Gervais *et al.* 1993; Belzile *et al.* 2009). The rhizomes extend onto gravel shoulders and are broken and transported by construction equipment (Figure 7), including graders, ploughs, and mowers. They are also spread in the treads of many kinds of vehicles and have been transported on the undersides of vehicles in caked mud.

Although the hardiness zones are relatively current (McKenney *et al.* 2001), the extent of these zones in Canada gives a minimal potential range (Figure 6) because climate warming is not taken into account. Since the effect is expected to be greatest in western Canada (Johnston *et al.* 2009*, Natural Resources Canada 2011*), we may anticipate occurrences north of the limit shown in the prairie region where substrates are conducive to spread.



FIGURE 7. An excavator working along a highway in southwestern Quebec, where it is being used to deepen a roadside ditch. The excavated substrate containing rhizomes of *Phragmites australis* subsp. *australis* will be transported to a landfill, and rhizomes with shoots can be seen lodged in the tracks. The vehicle will likely introduce rhizomes to the next work site. Photo by P.M. Catling in southwestern Quebec in 2005.

It appears that subsp. *australis* arrived 100 years ago but did not spread much over the subsequent 60 years (Figures 2 and 3). It then became much more abundant and moved substantially into new territory after 1970. The initial lag period may be a consequence of initial rarity, but it also reflects much less opportunity for spread due to the more limited road network in the past. The pattern of initially slow and then exponentially increasing rate of spread has been documented in other high-priority invasive plants in Canada, such as Glossy Buckthorn (*Frangula alnus* P. Mill., previously *Rhamnus frangula*), which presents a very similar pattern (Catling and Porebski 1994). Much greater local abundance and longer distance expansion of subsp. *australis* occurred after 1990 (Figure 4). It took only two decades to move into and become abundant in eastern Ontario and other regions (see above). As it increases in abundance in source areas and as satellite populations are established, the rate of spread is likely to increase. Based on rate of spread in the east, it seems likely that it will extend abundantly into parts of the prairie provinces over the next decade. Increasing numbers of roads and traffic will contribute to the increasing rate of increase. Spread of plants along roads can be very rapid (Reznicek and Catling 1987), and roads are increasingly identified as a major factor in the spread of invasive species (Christen and Matlack 2009). Other factors such as increasing numbers of biotypes coming into contact may also play a role in providing the raw material for local adaptation (Culley and Hardiman 2007; Belzile *et al.* 2009).

The potential environmental damage associated with *Phragmites australis* subsp. *australis* is very substantial, since the prairie wetlands are host to a large native biodiversity that includes waterfowl of great economic importance. Substantial costs to agriculture may occur as a result of the invasion of irrigation systems in the western prairie region and of wild rice in the east. Sport fishing may be affected by a general decline in biodiversity in parts of southern and northwestern Ontario. Of course, the future is difficult to predict, but, based on what we have seen of its impacts in the east, it will be desirable to keep subsp. *australis* out of the Canadian prairies as long and as completely as possible.

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