Distribution of Native and Exotic *Phragmites australis* in Rhode Island

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Abstract - Exotic populations of *Phragmites australis* (common reed) are now present in southern New England wetland habitats where native populations were once abundant. We surveyed Rhode Island to determine the distribution of native and exotic *P. australis*, and used this information to build a publicly accessible Geographic Information System (GIS) database. All *P. australis* populations sampled on the mainland were exotic. We only found native populations growing throughout a network of tidal marshes and ponds on Block Island, and several of these populations are being overrun by expanding exotic populations. The GIS database from this survey can be expanded to other regions, and can be used for the conservation of the native subspecies and for ensuring that control efforts target only exotic populations.

Introduction

Phragmites australis (Cav.) Trin. ex. Steudel (common reed) is a perennial grass native to North America. *Phragmites australis* has been present in the southwestern United States for 40,000 years (Hansen 1978) and in the northeast United States for at least 3500 years (Orson et al. 1987). In the past century, *P. australis* has increased in distribution and abundance across North America, especially along the Atlantic Coast (Chambers et al. 1999, Rice et al. 2000). This expansion is attributed to anthropogenic changes in wetland ecosystems that facilitate *P. australis* dispersal (Bertness et al. 2002, Marks et al. 1994), and to the introduction of European genotypes into the eastern United States (Besitka 1996, Saltonstall 2002). *Phragmites australis* expansion has deleterious effects on wetland ecosystems (Chambers et al. 1999, Marks et al. 1994, Rooth et al. 2003), leading to various control efforts against the invasive biotypes (Cross and Fleming 1989, Hellings and Gallagher 1992). However, these control efforts can impact non-target plants (Kay 1995), including native *P. australis* populations (A.M. Lambert, pers. observ.). In the northeastern US, native populations appear to be declining (Saltonstall 2002). In Saltonstall's analysis of modern populations, no native stands were found in Southeastern New England. Currently, there are insufficient data on the distribution of native haplotypes in the United States to effectively control exotic populations without harming native ones.

Saltonstall (2002) identified genetically distinct *P. australis* strains—or haplotypes—with native and exotic origins. In North America, 11 native

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haplotypes, one exotic haplotype, and one haplotype of unknown origin were identified. The native haplotypes vary in distribution and abundance throughout North America, but have unifying morphological characters that separate them from the other haplotypes now present in North America, leading to a new subspecies designation, *P. australis* subsp. *americanus* Saltonstall, P.M. Peterson, and Soreng (Saltonstall et al. 2004). Haplotype M, a close relative of European haplotypes, is the most abundant and rapidly expanding strain in North America.

Genetic analysis of pre-1900 herbarium specimens from southern New England showed that native haplotypes AA, E, and F were common in coastal plant communities (Saltonstall 2002). The only historic specimen tested from Rhode Island was an 1892 herbarium sample from Block Island, confirmed to be haplotype F (K. Saltonstall, University of Maryland, Cambridge, MD, pers. comm.). In the testing of modern populations in this region, only the exotic haplotype was found (Saltonstall 2002). Local extinctions of the native subspecies in these areas may have been caused by the invasion of haplotype M (Saltonstall 2003a).

Our objectives were to determine the present-day distribution of native and exotic *P. australis* in Rhode Island, and use this information to create a GIS database that can be used in efforts to protect the native subspecies. Specifically, we tested the hypothesis that *P. australis* populations in Rhode Island are comprised only of the exotic haplotype.

Methods

Sampling locations

We used field surveys, herbarium records, and information obtained from scientists in Rhode Island to determine sampling locations (Table 1). For field surveys, we used USGS 24,000 topographical quad maps for Rhode Island to find locations that had wetland habitat potentially suitable for *P. australis* growth. Ponds, lakes, swamps, rivers, and salt marshes were considered to be suitable wetlands. All relevant sites were visually surveyed for the presence of *P. australis*, and any *P. australis* stand found at a site was inspected using the methods described below. Overall, 50 populations were sampled throughout Rhode Island. Sampling intensity represented the population distribution of *P. australis* in Rhode Island, with most stands occurring in coastal marshes.

Herbaria databases in southeastern New England were searched for *P. australis* specimens that were collected in Rhode Island. Herbaria searched included Arnold Arboretum at Harvard University, the George Safford Torrey Herbarium at the University of Connecticut, the Steven T. Olney Herbarium at Brown University, the Providence College Herbarium, and the KIRI Herbarium at the University of Rhode Island. We were especially interested in samples dated before 1940 because these are most likely to be native (Saltonstall 2002). Herbaria were searched using the following species names: *Arundo phragmites* L., *P. communis* Trin., and *P. australis*

(Cav.) Trin. ex. Steudel (Tucker 1990). Two *P. australis* specimens were identified from the Arnold Arboretum at Harvard University: one from Tiverton and one from Block Island. Three locations were identified from specimens in the George Safford Torrey Herbarium: Bluff Hill Cove in South Kingstown and Watch Hill in Westerly (two specimens). A search of the Brown University herbarium yielded one sample from Block Island, but with no specific location. Four locations obtained from the KIRI Herbarium were not specific enough to use. Five locations were obtained from samples from the Providence College Herbarium: Briggs Beach in Little Compton, Sakonnet Point in Little Compton, Beach Avenue in Narragansett, Iron Hill Mine in Cumberland, and Sapowet Marsh in Tiverton. Sampling locations obtained from herbarium samples were surveyed with the methods described below.

We published an article in the Rhode Island Natural History Survey (RINHS) semi-annual newsletter asking for information on possible native *P. australis* populations within the state (Lambert 2002). This article and a presentation at the RINHS Annual Conference in March 2002 generated information on four sites with potentially native *P. australis* stands: Worden Pond in South Kingstown, Trustom Pond in South Kingstown, Galilee salt marsh (southern end) in Narragansett, and Quonochontaug Pond in Charlestown. These plant populations were surveyed with the methods described below.

Collection and genetic analysis

All *P. australis* stands were field-screened for native or introduced status using morphological characteristics (Blossey 2005; refer to URL http://www.invasive.plants.net for characteristics). As many characteristics as possible were used in combination when analyzing plants, but we found that stem height, stem color, leaf color, presence/absence of stem fungus, and inflorescence density were the most diagnostic. The coordinates of all surveyed stands were recorded using a Trex® GPS (Garmin LTD, Olathe, KS). Stands with either native characteristics or questionable characteristics (could not unambiguously be deemed exotic) were collected and returned to the laboratory for genetic analysis (see Table 1). Collected samples were placed in plastic Ziploc® bags and held at -20 °C until analysis.

To isolate genomic DNA, a 2-cm^2 sample of leaf tissue was ground to powder in liquid nitrogen. The ground tissue was then incubated at 65 °C in 0.05% SDS Buffer for 30 min. After adding 8 M potassium acetate and vortexing, the solution was incubated at 4 °C for 30 min., and samples were spun at 10,000 rpm for 5 min. The upper phase was removed, and DNA was precipitated with cold 100% ethanol at 20 °C overnight. Samples were then centrifuged at 10,000 rpm for 5 min., and the resulting pellets were resuspended in distilled water. Population origin (native vs. exotic) was determined using the RFLP methods of Saltonstall (2003b).

Table 1. Locations of native and exotic *P. australis* populations used in this study. Columns 2–5 are attribute data in the GIS database available at http://www.uri.edu/cels/pls/biocontrol/phrag.html. Coordinates are given in UTM zone 19. Native or introduced status (origin) was determined using either morphological characteristics (M) or genetic analysis (G).

Location	Habitat	East	North	Origin	Population determination
Ballard's Beach, Block Island	Upland	285756	4560884	Non-native	G
Beach Avenue (BIAD3), Block Island	Salt pond	284704	4561784	Native	G
Beavertail State Park, Jamestown	Rocky coast	299593	4591509	Non-native	M
BI Conservancy exotic, Block Island	Salt marsh/tidal pond	284627	4561840	Non-native	M
BI Conservancy native, Block Island	Salt marsh/tidal pond	284607	4561865	Native	G
BI Dump, Block Island	Sandy beach	283851	4565144	Non-native	G
Black Point, Narragansett	Rocky coast	293879	4585536	Non-native	G
Brigg's Beach, Little Compton	Sandy beach	319827	4593964	Non-native	G
Calf Pasture Point, North Kingstown	Sandy beach	299815	4611660	Non-native	M
Canada Pond, North Providence	Freshwater pond edge	298385	4637550	Non-native	M
Center Road, Block Island	Freshwater pond edge	283221	4560692	Non-native	M
Champlin Road, Block Island	Salt marsh/brackish	282972	4562668	Non-native	M
Charlestown Beach, Charlestown	Saltwater pond edge	280321	4582473	Non-native	M
Chopmist Hill, Scituate	Freshwater swamp	278181	4633745	Non-native	M
Spring St., Block Island	Upland	286139	4560197	Non-native	M
Corn Neck Road, Block Island	Saltwater pond edge	284707	4562000	Non-native	G
Freshpond Greenway	Upland	283448	4560004	Non-native	M
Galilee salt marsh, Galilee	Salt marsh	290698	4583934	Non-native	M
Golf course, Little Compton	Upland	317500	4594350	Non-native	G
Grace Point, Block Island	Sandy beach	281590	4562348	Non-native	M
Harbor Road, Block Island	Roadside drainage ditch/salt marsh	284870	4561294	Non-native	M
Harbor Road, Block Island	Upland, salt marsh edge	285009	4561331	Non-native	M
Hull's Cove, Jamestown	Salt marsh/rocky	300394	4593007	Non-native	M
Little Compton	Freshwater pond	317335	4599098	Non-native	G

Table 1, continued.

Location	Habitat	East	North	Origin	Population determination
Mosquito Beach, Block Island	Salt marsh	284551	4562895	Non-native	G
Old Harbor Point, Block Island	Bluffs	286326	4559328	Non-native	M
Newton Avenue, Narragansett	Rocky coast	294925	4587459	Non-native	M
North Scituate	Roadside drainage ditch/freshwater marsh	286001	4637304	Non-native	M
North Smithfield	Freshwater swamp	290097	4649913	Non-native	M
Ocean Avenue (near New Harbor), BI	Upland	284089	4561993	Non-native	M
Ocean View Pavilion, Block Island	Upland	285676	4560874	Non-native	G
Old Harbor, Block Island	Upland	285576	4561045	Non-native	G
Portsmouth	Dry/roadside	313963	4611643	Non-native	M
Providence (Onlyville)	River edge	296263	4632865	Non-native	M
Providence (West End)	Roadside drainage ditch	299209	4634714	Non-native	M
Prudence Island, Portsmouth	Rocky/sandy beach	304634	4611647	Non-native	M
Quonochontaug Pond, Charlestown	Saltwater pond edge	273186	4580619	Non-native	G
Routes 117/102, Coventry	Roadside drainage ditch	275761	4619172	Non-native	M
Rueker Wildlife Refuge, Tiverton	Salt marsh	316344	4606909	Non-native	G
Ryan Park, North Kingstown	Freshwater stream	293540	4603620	Non-native	M
Sachem Pond, Block Island	Pond edge	284612	4566915	Non-native	G
Sachuest Point, Tiverton	Sandy beach	312224	4594925	Non-native	M
Schoolhouse Pond, Charlestown	Freshwater pond (submerged)	277225	4586755	Non-native	G
Settlers Rock, Block Island	Sandy beach	285004	4566834	Non-native	G
Smithfield	Freshwater swamp	289642	4638545	Non-native	M
Sprague Park, Narragansett	Freshwater pond edge	293728	4589922	Non-native	M
Town Beach, Block Island	Salt pond	284531	4562322	Native	G
Town Beach, Little Compton	Saltwater pond edge	321524	4595803	Non-native	G
Trustom Pond, South Kingstown	Tidal pond edge/dry	284561	4583271	Non-native	G
Worden Pond, South Kingstown	Freshwater pond (submerged)	285166	4589548	Non-native	G

GIS mapping

Arcview 8.2 (ESRI, Inc., Redlands, CA) was used to map the distribution of native and exotic *P. australis*. State- and town-boundary data and orthophotographs from the Rhode Island Geographical Information System were used as base layers. *Phragmites australis* locations were added as points, and an attribute table (see Table 1) was created for each point using the following attributes: coordinates (in UTM zone 19), haplotype, and habitat type (freshwater pond, freshwater-pond edge, freshwater swamp, river edge, rocky coast, roadside drainage ditch, salt marsh, saltwater-pond edge, sandy beach, upland). GIS data in geodatabase format (.mdb) and attribute data for all locations, as well as distribution maps in jpeg format, are publicly available through the University of Rhode Island's Biological Control Lab website at http://www.uri.edu/cels/pls/biocontrol/phrag.html or the RIVR Lab website at http://rivrlab.msi.vcsb.edu.

Results and Discussion

Haplotype distribution

Both native and exotic *P. australis* populations were found in Rhode Island (Fig. 1, Table 1). The native populations were found only on the

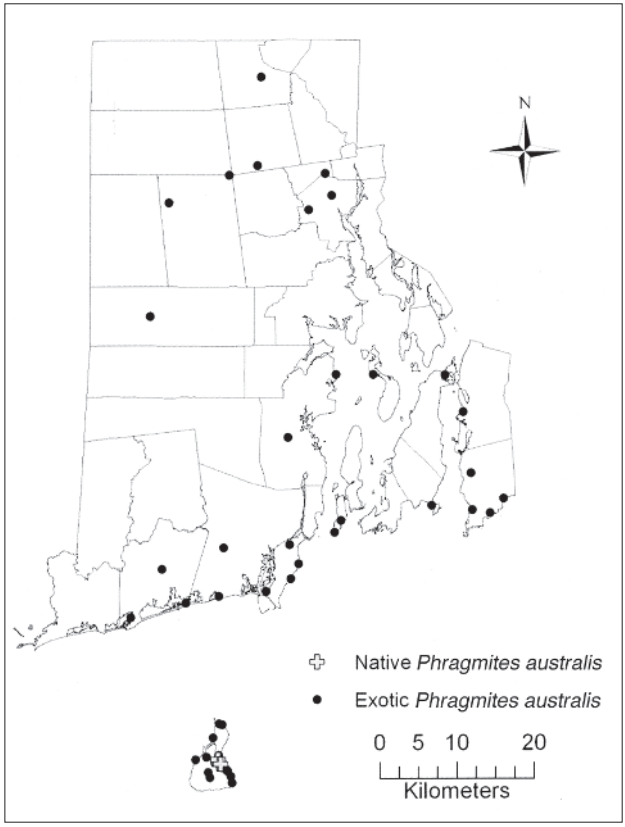

Figure 1. Map showing native and exotic populations of *P. australis* in Rhode Island. The map base layer was derived from a Rhode Island state and town boundary shape file available through the Rhode Island Geographic Information System. Native and exotic population coordinates were added as point data. Data and related attributes are available at http://www.uri.edu/cels/pls/biocontrol/phrag.html.

eastern side of Block Island growing along an extensive tidal marsh (Fig. 2). No native populations were found on the mainland, but exotic *P. australis* was present throughout the sampling area, with greatest abundance in coastal areas. Through chloroplast DNA sequencing, the native population at the Block Island Conservancy was found to be a previously unidentified native haplotype (AB; K. Saltonstall, pers. comm.). The other native populations were tested by RFLP analysis, and have the same morphological characteristics as the native Block Island Conservancy stand.

Although there is exotic *P. australis* present on Block Island, the native form has not yet been extirpated. Block Island has experienced relatively little recent shoreline development (S. Comings, The Nature Conservancy, Block Island, RI, pers. comm.), whereas in mainland Rhode Island, coastal development has led to nitrogen enrichment in salt marshes, "driving" the growth of exotic *P. australis* (Bertness et al. 2002). Several of the native populations on Block Island are growing in areas where little anthropogenic modification has taken place. Most of the exotic populations on the Island are growing in the more disturbed areas. At two sites that have been disturbed, the exotic haplotype is now present and expanding into native stands.

The town-beach site has the largest native stand, covering approximately one hectare. This stand is situated on the edge of a tidal marsh, where the pore water can reach salinities as high as 27% (A.M. Lambert, unpubl. data).

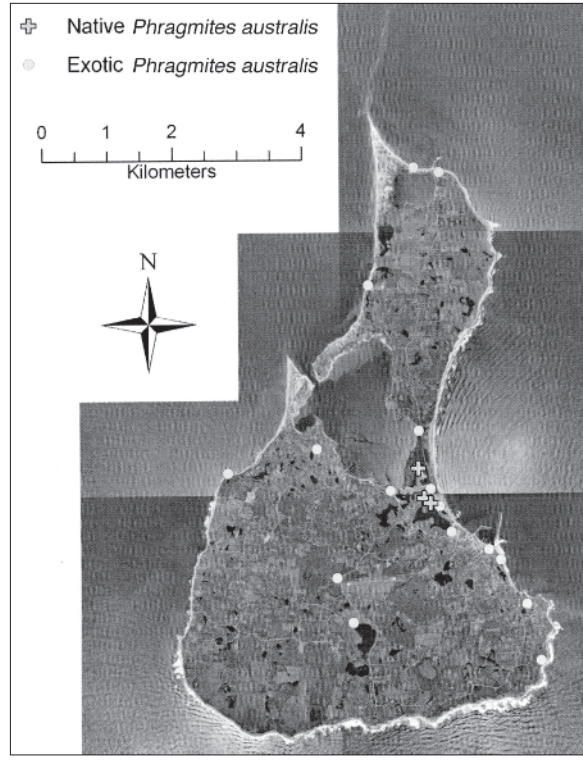

Figure 2. Map showing native and exotic *P. australis* populations on Block Island, RI. The map base layer was derived from 1997 Rhode Island Department of Transportation digital orthophotography available through the Rhode Island Geographic Information System. Native and exotic population coordinates were added as point data. Data and related attributes are available at http://www.uri.edu/cels/pls/biocontrol/phrag.html.

There is no exotic *P. australis* at this site. At the Block Island Conservancy site, the native *P. australis* population covers about 0.6 hectare and is situated along another edge of the same tidal marsh. At this site, there is an adjacent exotic *P. australis* stand (toward the upland edge) within four meters of this native stand. At the Block Island Conservancy site, we are using permanent plots to monitor the yearly growth of the native and exotic populations. Over the past three years, the exotic stand has expanded toward the native stand by two meters (A.M. Lambert, unpubl. data). The Beach Avenue stand is a small, native stand along the side of a road that runs over the tidal marsh. The stand covers approximately 0.08 hectare and has no exotic *P. australis* nearby. The only other native stand is located on private property; however, we were not given permission to publish the location of this stand. This native population is being over-run by an expanding exotic population (A.M. Lambert, pers. observ.).

As we show in this study, more intensive sampling on smaller spatial scales can uncover other native stands and possibly additional native haplotypes. This information will increase our understanding of the level of gene flow among native haplotypes (Saltonstall 2003c), and help us identify where stands of native populations are expanding (Lynch and Saltonstall 2002) or where they are being displaced by the exotic. Also, a more complete record of native population distributions will enable future control efforts to target only exotic *P. australis*.

GIS database

All data from this study are downloadable in geodatabase format (a common GIS file format; ESRI, Inc.) and are available at http://www.uri.edu/cels/pls/biocontrol/phrag.html or http://rivrlab.msi.vcsb.edu. Data files are also available through email from the author. This database is only a "representative" subset of populations of *P. australis* in Rhode Island. We are incorporating more stands into the database as they are screened. We encourage conservation scientists and managers throughout New England to contribute to this database by sending native and exotic population coordinates and attribute data for each location to lambert@msi.ucsb.edu. This information will be incorporated into the current database, which will be updated quarterly.

Because of the severe environmental and economic effects of invasive species such as *P. australis*, scientists, resource managers, and governmental agencies are recognizing the need for a global system for tracking the spread, ecosystem and economic damage, control methods, and biology of invasive species (Ricciardi et al. 2000). Ricciardi et al. (2000) called for a global information system for gathering all available information on invasive species and making this information available through the Internet. Our GIS dataset is meant to serve this purpose. Because it is easily downloaded through the Internet, conservation managers can access it for mapping of populations in areas under consideration for conservation or control programs. The database can also be expanded or incorporated into other GIS databases to cover other regions and other invasive-species research. We are

currently expanding this database to include polygon data, which spatially portray stand size and shape. These data can be used to study the expansion of exotic populations into native populations and track the resulting temporal changes in biomass and biodiversity. We are also looking to incorporate environmental variables, such as soil salinity and tidal regimes, to help elucidate the factors that are causing the replacement of the native populations by the exotic haplotype over time.

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