Element Stewardship Abstract

Phragmites australis (*P. communis*): Threats, Management, and Monitoring

Marianne Marks
The Nature Conservancy
Eastern Regional Office
210 Devonshire Street
Boston, Massachusetts 02110

Beth Lapin
The Nature Conservancy
Connecticut Field Office
55 High Street
Middletown, Connecticut 06457

John Randall
The Nature Conservancy
13501 Franklin Blvd.
Galt, California 95632

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INTRODUCTION

Phagmites (*Phragmites australis* [Cav.] Trin. ex Steud.) is a widespread species that can invade or dominate wetland communities. This species was long known as *Phragmites communis* (L.) Trin. However, *P. australis* is the earliest available valid name and therefore the correct name (Clayton 1968). Other synonyms that have been used for this species are *Phragmites communis* variety *berlandieri* (Fourn.) Fern. and *Phragmites phragmites* (L.) Karst. (Kartesz and Kartesz 1980).

The name *Phragmites* is derived from the Greek word for fence, *phragma*, in reference to the plant's fencelike growth along streams. Common names for this species are reed, common reed, roseau cane (Louisiana), carrizillo (Mexico), and carrizo (Mexico).

THREATS POSED BY *P. AUSTRALIS*

Phragmites australis can be regarded as a stable, natural component of a wetland community if the habitat is pristine and the population does not appear to be expanding. Many native populations of *P. australis* are benign in that they pose little or no threat to other species and should be left intact. Examples of areas with stable, native populations include sea-level fens in Delaware and Virginia and along Mattagota Stream in Maine (Rawinski 1985, pers. com. 1992). In Europe, a healthy reed belt is defined as a "homogeneous, dense or sparse stand with no gaps in its inner parts, with an evenly formed lakeside borderline without aisles, shaping a uniform fringe or large lobes, stalk length decreasing gradually at the lakeside border, but all stalks of one stand of similar height; at the landside edge the reeds are replaced by sedge or woodland communities or by unfertilized grasslands" (Ostendorp 1989).

Stable populations may be difficult to distinguish from invasive populations; but to arrive at a determination, one should examine such factors as site disturbance and the earliest collection dates of the species. If available, old and recent aerial photos can be compared to determine whether stands in a given area are expanding or not (Klockner, pers. com. 1985).

Phragmites australis is a problem when and where stands appear to be spreading while other species typical of the community are diminishing. Disturbances or stresses such as pollution, alteration of the natural hydrologic regime, dredging, and increased sedimentation favor invasion and continued spread of *P. australis* (Roman et al. 1984). Other factors that may have favored recent invasion and spread of *P. australis* include increases in soil salinity (from fresh to brackish) and nutrient concentrations, especially nitrate, and the introduction of a more invasive genotype(s) from the Old World (Metzler and Rozsa 1987, McNabb and Batterson 1991; see "Global Range" below for further discussion).

Michael Lefor asserts that one reason for the general spread of *P. australis* has been the destabilization of the landscape (pers. com. 1993). In urban landscapes water is apt to collect in larger volumes and pass through more quickly (flashily) than formerly. This tends to destabilize substrates, leaving bare soil open for colonization. Watersheds throughout eastern North America are flashier owing to the proliferation of paved surfaces, lawns, and roofs and the fact that upstream wetlands are largely filled with postsettlement/post-agriculture sediments from initial land-clearing operations.

Many Atlantic Coast wetland systems have been invaded by *P. australis* as a result of tidal restrictions imposed by roads, water impoundments, dikes, and tide gates. Tide gates have been installed in order to drain marshes to harvest salt hay, to control mosquito breeding, and, most recently, to protect coastal development from flooding during storms. This alteration of marsh systems may favor *P. australis* invasion by reducing tidal action and soil water salinity and lowering water tables.

Phragmites australis invasions may threaten wildlife because they alter the structure and function (wildlife support) of relatively diverse *Spartina* marshes (Roman et al. 1984). This is a problem in many of the eastern coastal national fish and wildlife refuges, including Brigantine in New Jersey, Prime Hook and Bombay Hook in Delaware, Tinicum in Pennsylvania, Chincoteague in Virginia, and Trustom Pond in Rhode Island.

Phragmites australis invasions also increase the potential for marsh fires during the winter, when the aboveground portions of the plant die and dry out (Reimer 1973). Dense congregations of redwinged blackbirds, which nest in *P. australis* stands preferentially, increase chances of airplane accidents nearby. The monitoring and control of mosquito breeding is nearly impossible in dense *P. australis* stands (Hellings and Gallagher 1992). In addition, *P. australis* invasions can also have adverse aesthetic impacts. In Boston's Back Bay Fens, dense stands have obscured vistas intended by the park's designer, Frederick Law Olmstead (Penko, pers. com. 1993).

GLOBAL RANGE

Phragmites australis is found on every continent except Antarctica and may have the widest distribution of any flowering plant (Tucker 1990). It is common in and near freshwater, brackish, and alkaline wetlands in the temperate zones worldwide. It may also be found in some tropical wetlands but is absent from the Amazon Basin and central Africa. It is widespread in the United States, typically growing in marshes, swamps, fens, and prairie potholes, usually inhabiting the marsh-upland interface where it may form continuous belts (Roman et al. 1984).

Because *P. australis* has invaded and formed near-monotypic stands in some North American wetlands only in recent decades, there has been some debate as to whether it is indigenous to this continent. Convincing evidence that it was here long before European contact is now available from at least two sources. Niering and Warren (1977) found remains of *P. australis* in cores of 3000-year-old peat from tidal marshes in Connecticut. Identifiable *P. australis* remains dating from 600 to 900 A.D. and constituting parts of a twined mat and other woven objects were found during archaeological investigations of Anasazi sites in southwestern Colorado (Breternitz et al. 1986, Kane and Gross 1986).

There is some suspicion that, although the species *P. australis* is indigenous to North America, a new, more invasive genotype(s) was introduced from the Old World (Metzler and Rozsa 1987). Hauber et al. (1991) found that invasive *P. australis* populations in the Mississippi River Delta differed genetically from a more stable population near New Orleans. They also examined populations elsewhere on the Gulf Coast, from extreme southern Texas to the Florida Panhandle, and found no genetic differences between those populations and the one near New Orleans (Hauber, pers. com. 1992). This increased their suspicion that the invasive biotypes were introduced to the Delta from somewhere outside the Gulf relatively recently.

Phragmites australis is frequently regarded as an aggressive, unwanted invader in the East and upper Midwest. It has also earned this reputation in the Mississippi River Delta of southern Louisiana, where over the last 50 years it has displaced species that provided valuable forage for wildlife, particularly migratory waterfowl (Hauber et al. 1991). In other parts of coastal Louisiana, however, *P. australis* seems to be declining as a result of increasing saltwater intrusion in the brackish marshes it occupies. It is apparently declining in Texas as well owing to invasion of its habitat by the alien grass *Arundo donax* (Poole, pers. com. 1985). Similarly, *P. australis* is present in the Pacific states but is not regarded as a problem there. In fact, throughout the western United States there is some concern over decreases in the species habitat and losses of populations.

HABITAT

Phragmites australis is especially common in alkaline and brackish (slightly saline) environments (Haslam 1972, 1971b), and can thrive in highly acidic wetlands (Rawinski, pers. com. 1985). However, *P. australis* does not require, nor even prefer, these habitats to freshwater areas. Its growth is greater in fresh water but it may be outcompeted in these areas by other species that cannot tolerate brackish, alkaline, or acidic waters. It is often found in association with other wetland plants including species from the following genera: *Spartina, Carex, Nymphaea, Typha, Glyceria, Juncus, Myrica, Triglochin, Calamagrostis, Galium,* and *Phalaris* (Howard et al. 1978).

Phragmites australis occurs in disturbed areas as well as pristine sites. It is especially common along railroad tracks, roadside ditches, and piles of dredge spoil, wherever even slight depressions hold water (Ricciuti 1983). Penko (pers. com. 1993) has observed stunted *P. australis* growing on acidic tailings (pH 2.9) from an abandoned copper mine in Vermont. Various types of human manipulation and disturbance are thought to promote *P. australis* (Roman et al. 1984). For example, restriction of the tidal inundation of a marsh may result in a lowering of the water table, which may in turn favor *P. australis*. Likewise, sedimentation may promote the spread of *P. australis* by elevating a marsh's substrate surface and effectively reducing the frequency of tidal inundation (Klockner, pers. com. 1985).

A number of explanations have been proposed to account for the recent dramatic increases in *P. australis* populations in the northeastern and Great Lakes States. As noted above, habitat manipulations and disturbances caused by humans are thought to have a role. In some areas *P. australis* may also have been promoted by the increases in soil salinity that result when deicing salt washes off roads and into nearby ditches and wetlands (McNabb and Batterson 1991). On the other hand, bare patches of road sand washed into ditches and wetlands may be of greater importance. *Phragmites australis* seeds are shed from November through January and so may be among the first propagules to reach these sites. If the seeds germinate and become established the young plants will usually persist for at least two years in a small, rather inconspicuous stage, resembling many other grasses. Later, perhaps after the input of nutrients, they may take off and assume the tall growth form that makes the species easily identifiable. Increases in soil nutrient concentrations may result from runoff from farms and urban areas. Increases in nutrient concentrations, especially nitrates, have been suggested as a primary cause for increases in *P. australis* populations. Ironically, eutrophication and increases in nitrate levels are sometimes blamed for the decline of *P. australis* populations in Europe (Den Hartog et al. 1989).

BIOLOGY-ECOLOGY

Phragmites australis is typically the dominant species in areas that it occupies. It is capable of vigorous vegetative reproduction and often forms dense, virtually monospecific stands. Hara et al. (1993) classify sparse stands as those with densities of less than 100 culms/m^2 and dense stands as those with densities of up to about 200 culms/m^2 in wet areas or up to 300 culms/m^2 in dry areas. Mammalian and avian numbers and diversity in the dense stands are typically low (Jones and Lehman 1987). Newly opened sites may be colonized by seed or by rhizome fragments carried to the area by humans — in soils and on machinery during construction — or naturally in floodwaters.

The plants generally flower and set seed between July and September and may produce great quantities of seed. In the Northeast, seeds are dispersed between November and January. However, in some cases, most or all of the seed produced is not viable (Tucker 1990). The seeds are normally dispersed by wind but may be transported by birds such as red-winged blackbirds that nest among the reeds (Haslam 1972). Following seed set, nutrients are translocated down into the rhizomes and the aboveground portions of the plant die back for the season (Haslam 1968).

Temperature, salinity, and water levels affect seed germination. Water depths of more than 5 cm and salinities above 20 ppt (2%) prevent germination (Kim et al. 1985, Tucker 1990). Germination is not affected by salinities below 10 ppt (1%) but declines at higher salinities. Percentage germination increases with increasing temperature from 16 to 25 °C, while the time required to germinate decreases from 25 to 10 days over the same temperature range. Barry Truitt (pers. com. 1992) has observed that areas covered by thick mats of wrack washed up during storms and high water events are frequently colonized by *P. australis* on the Virginia Coast Reserve. It is not clear whether it establishes from rhizome pieces washed in with the wrack or from seed that blows in later.

Once a new stand of *P. australis* takes hold it spreads, predominantly through vegetative reproduction. Individual rhizomes live for three to six years and buds develop at the base of the vertical type late in the summer each year. These buds mature and typically grow about 1 m (up to 10 m in newly colonized, nutrient-rich areas) horizontally before terminating in an upward apex and going dormant until spring. The apex then grows upward into a vertical rhizome which in turn produces buds that will form more vertical rhizomes. Vertical rhizomes also produce horizontal rhizome buds, completing the vegetative cycle. These rhizomes provide a large absorbent surface that brings the plant nutrients from the aquatic medium (Chuchoza and Arbuzova 1970). The aerial shoots arise from the rhizomes. They are most vigorous at the periphery of a stand, where they arise from horizontal rhizomes rather than old verticals (Haslam 1972).

Salinity and depth to the water table are among the factors that control the distribution and performance of *P. australis*. Maximum salinity tolerances vary from population to population; reported maxima range from 12 ppt (1.2%) in Britain to 29 ppt in New York State and 40 ppt on the Red Sea coast (Hocking et al. 1983). Dense stands normally lose more water through evapotranspiration than is supplied by rain (Haslam 1970). However, rhizomes can reach down almost 2 m below ground, their roots penetrating even deeper, allowing the plant to reach low-lying groundwater (Haslam 1970). Killing frosts may knock the plants back temporarily but can ultimately increase stand densities by stimulating bud development (Haslam 1968).

Phragmites australis has a low tolerance for wave and current action, which can break its culms (vertical stems) and impede bud formation in the rhizomes (Haslam 1970). It can survive, and in fact thrive, in stagnant waters where the sediments are poorly aerated at best (Haslam 1970). Air spaces in the aboveground stems and in the rhizomes themselves assure the underground parts of the plant with a relatively fresh supply of air. This characteristic and the species' salinity tolerance allow it to grow where few others can survive (Haslam 1970). In addition, the buildup of litter from the aerial shoots within stands prevents or discourages other species from germinating and becoming established (Haslam 1971a). The rhizomes and adventitious roots themselves form dense mats that further discourage competitors. These characteristics are what enable *P. australis* to spread, push other species out, and form monotypic stands.

Such stands may alter the wetlands they colonize, eliminating habitat for valued animal species. On the other hand, the abundant cover of litter in *P. australis* stands may provide habitat for some small mammals, insects, and reptiles. The aerial stems provide nesting sites for several species of birds, and song sparrows have been seen eating *Phragmites* seeds (Klockner, pers. com. 1985). Muskrats (*Ondatra zibethicus*) use *P. australis* for emergency cover when low-lying marshes are swept by storm tides and for food when better habitats are overpopulated (Lynch et al. 1947).

Studies conducted in Europe indicate that gall-forming and stem-boring insects may significantly reduce growth of *P. australis* (Durska 1970, Pokorny 1971). Skuhravy (1978) estimated that roughly one-third of the stems in a stand may be damaged, reducing stand productivity by 10-20%. Mook and van der Toorn (1982) found that yields were reduced by 25–60% in stands heavily infested with lepidopteran stem- or rhizome-borers. Hayden (1947) suggested that aphids (*Hyalopterus pruni*) heavily damaged a *P. australis* stand in Iowa. On the other hand, work in Europe by Pintera (1971) indicated that although high densities of aphids may bring about reductions in *P. australis* shoot height and leaf area, they have little effect on shoot weight. Like other emergent macrophytes, *P. australis* has tough leaves and appears to suffer little grazing by leaf-chewing insects (Penko 1985).

As mentioned above, there is great concern about recent declines in *P. australis* in Europe, where the species is still used for thatch. In fact, the journal *Aquatic Botany* devoted an entire issue (Vol. 35, no.1, September 1989) to this subject. Factors believed responsible for the declines include habitat destruction and manipulation of hydrologic regimes by humans, grazing, sedimentation, and decreased water quality (eutrophication) (Ostendorp 1989).

Detailed reviews of the ecology and physiological ecology of *P. australis* are provided by Haslam (1972, 1973) and Hocking et al. (1983), and an extensive bibliography is provided by van der Merff et al. (1987).

RECOVERY POTENTIAL

Areas that have been invaded by *P. australis* have excellent potential for recovery. Management programs have proven that *P. australis* can be controlled and natural vegetation will return. However, monitoring is imperative because *P. australis* tends to reinvade; control techniques may need to be applied several times or, perhaps, in perpetuity. It is also important to note that some areas have been so heavily manipulated and degraded that it may be impossible to eliminate *P. australis* from them. For example, it may be especially difficult to control *P. australis* in freshwater impoundments that were previously salt marshes.

MONITORING REQUIREMENTS

Phragmites australis populations require close monitoring to determine whether they are increasing in area or not. Populations that are growing may quickly threaten or even eliminate rare elements. Monitoring provides the data needed to decide if control measures are necessary. If and when a control program is begun it is important to monitor targeted populations so that the program's effectiveness can be determined. If it is possible to leave control areas untreated without jeopardizing the success of the control program, these should be monitored as well for comparison. It is imperative to continue monitoring even if a control program succeeds initially, because *P. australis* may reinvade and the sooner this is detected the easier it will be to combat.

MONITORING PROCEDURES

To assess if a *P. australis* colony is spreading, quantitative measurements should be made of percentage of aerial cover, stem density, and culm height, especially at the periphery of the stand. Annual data should be compared to detect if the colony is expanding and the stand is gaining vigor. Inventories of the vegetation in and near the colony should also be carried out to determine whether declines in species diversity are occurring.

In Europe, reed declines have been documented by comparing areas covered by *P. australis* colonies on up-to-date maps or aerial photographs with older sources, monitoring permanent quadrats within or at the border of the reed belt, and mapping the stubble fields left after die-back (Ostendorp 1989). In lakes (Stark and Dienst 1989), wooden poles 5 m apart were connected with string and the numbers of reed stalks directly below the strings were counted each year in the spring.

MANAGEMENT PROGRAMS

Cultural, mechanical, and chemical methods can be used to control *P. australis*. The factors that are believed responsible for the alarming decreases of *P. australis* beds in Europe and Texas, including habitat destruction, increased soil nitrate levels, and eutrophication (Boar et al. 1989, Ostendorp 1989, Sukopp and Markstein 1989), are not appropriate as management tools in natural areas.

Biological Control

Biological control does not appear to be an option at this time. No organisms that significantly damage *P. australis* but do not feed on other plant species have been identified. Naturally occurring parasites have not proven to be successful controls (Tscharntke 1988, Mook and van der Toorn 1982, van der Toorn and Mook 1982). In addition, some of the arthropods that feed on *P. australis* are killed by winter fires and thus would likely be eliminated from the systems where prescribed fires are used. Coots, nutria, and muskrats may feed on *P. australis* but appear to have limited impacts on its populations (Cross and Fleming 1989).

Burning

Prescribed burning does not reduce the growing ability of *P. australis* unless root burn occurs. Root burn seldom occurs, however, because the rhizomes are usually covered by a layer of soil, mud, and/or water. Fires in *P. australis* stands are dangerous because this species can cause spot-fires over 100 feet away (Beall 1984). Burning does remove accumulated *P. australis* leaf litter, allowing seeds of other species to germinate. Prescribed burning has been used with success after chemical treatment for this purpose at Brigantine National Wildlife Refuge, New Jersey (Beall 1984) and in Delaware (Lehman, pers. com. 1992). Occasional burning has been used in Delaware in conjunction with intensive spraying and water level management.

At Wallops Island, Virginia, a small (100-foot x 400-foot) brackish to saline to dry wetland was burned November 1990 to control *P. australis* (M. Ailes, pers. com. 1992). A variety of other species appeared in the year following the burn, but they grew "leggy" while the *P. australis* remained vigorous. A second winter burn is planned and monitoring of transects will continue (there are no pretreatment data).

At Wertheim National Wildlife Refuge in New York, a 20- to 30-acre freshwater impoundment was drained in the fall of 1989, burned the following winter, and then reflooded (Parris, pers. com. 1991). *Phragmites australis* was eliminated from the half of the marsh that was treated and the area remained free of the grass through 1992.

According to Cross and Fleming (1989), late-summer burns may be effective, but winter and spring burning may in fact increase the densities of spring crops. Thompson and Shay (1985) performed experimental burn treatments on Delta Marsh, Manitoba. They found that spring, summer, and fall burns resulted in higher total shoot densities and lower mean shoot weights than on controls primarily as a result of greater densities of shorter, thinner vegetative shoots. Shoot biomass was greater in spring-burned and fall-burned plots than in control areas but less on summer-burned plots. They also found that belowground production increased following spring and fall burns but not following summer burns. The increase in light availability following burns generally appears to benefit *P. australis*. A variety of understory responses to these burns was noted. For example, summer burns increased species diversity, richness, and evenness, although certain species declined (Thompson and Shay 1985).

In Connecticut late-spring burns followed by manual flooding with salt water was successful in reducing *P. australis* height and density (Steinke, pers. com. 1992). After three years, the fuel load was exhausted; the process was very expensive and self-regulating tide gates were installed instead (see "Manipulation of Water Level and Salinity").

In Europe, experimental removal of litter in winter resulted in doubling the aboveground biomass (Graneli 1989). Increased light availability at the soil surface and aeration of the soil around the rhizomes may have been responsible for this increase. Burning in the winter in an experimental field caused little damage, while burning during the emergence period led to the death of the majority of *P. australis* shoots (van der Toorn and Mook 1982).

Chemical Control

Rodeo™, an aqueous solution of the isopropylamine salt of glyphosate, is registered for use over water and is commonly used for *P. australis* control. This herbicide is not selective and will kill grasses and broadleaved plants alike. Tests indicate that it is virtually nontoxic to aquatic animals. It should be noted that many of these tests were performed by or for the company that manufactures Rodeo. Bioconcentration values for glyphosate in fish tissues were insignificant. Since glyphosate does not volatilize, it will not vaporize from a treated site and move to a nontarget area (Comes et al. 1976, Folmar et al. 1979, Brandt 1983, Monsanto 1985).

Rodeo must be mixed with water and a surfactant that allows it to stick to and subsequently be absorbed by the plant (Beall 1984). Rodeo should not by applied during windy conditions, as the spray will drift (I. Ailes, pers. com. 1985). It also should not be applied if rain is forecast within 12 hours because it will wash away before it has a chance to act (Daly 1984). Application rates may vary; as one example, effective control of *P. australis* in a Delaware marsh was achieved with 4 pints of concentrate /acre (Lehman, pers. com. 1992).

Application of Rodeo must take place after the tasseling stage when the plant is supplying nutrients to the rhizome. At this time, when Rodeo is sprayed onto the foliage of aquatic weeds, it translocates into the roots. Rodeo causes gradual wilting, yellowing, browning, and deterioration of the plant. Studies on tasseling at the Augustine Tidal area in Port Penn, Delaware, indicated that tasseling in a stand is never 100%, but that it is possible to spray when 94% of the plants are tasseling. In dense stands, subdominant plants are protected by the thick canopy and thus may not receive adequate herbicide. For these reasons, touch-up work will be necessary (Lehman 1984).

At Brigantine National Wildlife Refuge, Rodeo was applied aerially after the plants tasseled in late August. The application resulted in 90% success. The following February, a fast-moving prescribed burn was carried out to remove litter, exposing the seedbed for reestablishment of marsh vegetation. However funding was not available for several years and *P. australis* has returned to 90% of the previously treated areas (Beall, pers. com. 1991). Treatment was resumed in fall 1991.

In September 1983, at Prime Hook Wildlife Refuge in Delaware, 500 acres of freshwater impoundments were sprayed with Rodeo from a helicopter for *P. australis* control. The plants yellowed within 10 days. The following May aerial and ground evaluations of the sprayed area revealed 98% kill of *P. australis* (Daly 1984). In addition to applying herbicide, Prime Hook manipulates water levels with a stop log to stress *P. australis*; winter water levels are held at an elevation of 2.8 feet msl until June, when water would otherwise be held at 2.2 feet msl. The combined spraying and water management approach was successful and many aquatic plants returned. A regime of spraying in August–September for two years followed by flooding was used through 1991 (Daly, pers. com. 1991). Annual costs of *P. australis* control are $20,000 at Prime Hook (1000 acres) and $3000 at Bombay Hook (20–60 acres); monitoring costs, which include reading vegetation transects for species presence and density each September, are not included in the cost.

Aerial spraying has been used since 1983 in many Delaware state wildlife refuges (Lehman, pers. com. 1992). Using Rodeo, the state sprays freshwater and brackish impoundments, brackish marshes, and salt marshes from early September to early October; this is combined with winter burns between the first and second year of spraying. Areas will be spot-treated whenever needed after that. The herbicide treatments consist of 4 pints/acre the first year and 2 pints/acre the second, with an average cost of $65/acre. The state has arranged cost-sharing programs with private landowners, in which the state pays half the spraying cost with a willing owner. Desirable native vegetation usually returns after spraying; no revegetation is done. Occasionally, sprayed sites become open mud flats that are eventually repopulated by *P. australis.*

At Chincoteague National Wildlife refuge, an aerial spraying program initiated in 1986 in an 18-mile-long freshwater impoundment was terminated because of budget cuts. *Phragmites australis* quickly reclaimed the area, estimated to be 100–150 acres total in small scattered stands. In September 1991, spraying with Rodeo began again and resulted in 85% kill. Spraying of remaining areas occurred in September 1992, killing 79% of the remaining *P. australis.* There has been no additional spraying; there is some *P. australis* in some of the smaller impoundments. Follow-up ground spot-spraying may occur in 1994 or 1995 as needed. Because the area is impounded, the water level usually is lower in the spring, which helps prevent *P. australis* regrowth (I. Ailes, pers. com. 1991, 1994).

Herbicides are used at Tinicum Environmental Center (Pennsylvania), because other control options are limited. Unplanned burns do occur, but prescribed burns are not allowed owing to the proximity to the highway and airport. Tinicum was recently granted $2 million to restore an 18-acre site. Here they will be altering the elevation of the marsh, seeding with native plants, and monitoring the results (Nugent, pers. com. 1991).

At Parker National Wildlife Refuge, an aerial spraying program (annual budget $5000) for 50 acres of a 100-acre freshwater impoundment began in mid-August 1991. A winter burn was anticipated and a second year of spraying was planned. Results will be monitored using aerial photos to delineate the boundaries of the *P. australis* clones. A nearby tower also provides a suitable viewing point to observe progress (Healey, pers. com. 1992).

In more fragile situations where *P. australis* is threatening a rare plant or community, aerial spray techniques are inappropriate because such large-scale application could kill the community that the entire operation was designed to protect. Glyphosate can be applied to specific plants and areas by hand with a backpack sprayer. Wayne Klockner of The Nature Conservancy's Maryland Field Office was successful in eliminating most *P. australis* at the Nassawango preserve by applying glyphosate by hand with a backpack sprayer (Klockner, pers. com. 1985). The control program there began in 1983; actual spraying is conducted along the power-line right-of-way by Delmarva Power (Droege, pers. com. 1991). Delmarva Power generally sprays from trucks, backpacks, or helicopter, depending on the accessibility of the area and presence of rare plants nearby (Johnstone, pers. com. 1991). They use Rodeo in tidal areas and Accord™ (another glyphosate product) in nontidal areas from mid-August to mid-October, when seeds are ripening. They spray intensively the first year and conduct touch-up spraying the second year, which eliminates 90–95% of the plants. They then return every three years to eliminate any new plants. Plants are not sprayed if they are not tasseling and are short.

Rodeo was used at The Nature Conservancy's Cape May Meadows (New Jersey) in 1989, 1990, and 1991. It was applied with a 30-gallon gas-powered tank with spray nozzle mounted on a truck, Indian pump sprayers, 2.5-gallon hand-held sprayers, and wick applicators (Johnson, pers. com. 1991). Most, if not all, of the treated *P. australis* in this 20-acre area were killed; plants found in the area following treatment were shorter and the stand was less dense (determined visually). The dead stalks remained, however, and blocked views from the trail.

In Connecticut a 5-m x 23-m patch of *P. australis* was treated in late August–early September with a hand-held sprayer of Rodeo (1988 and 1989) and Roundup (1990 and 1991) for four years. The *P. australis* is shorter and less dense at the site, but it is still present (Lapin pers. obs.). Actions to supplement and enhance herbicide applications, including the removal of tassels (1991) and removal of dead stalks (planned 1992), have been and will be taken.

Other chemicals have been used on *P. australis* and are described in Cross and Fleming (1989).

Cutting

Cutting has been used successfully to control *P. australis.* Since it is a grass, cutting several times during a season at the wrong times may increase stand density (Osterbrock 1984). However, if it is cut just before the end of July, most of the food reserves produced that season are removed with the aerial portion of the plant, reducing the plant's vigor. This regime may eliminate a colony if carried out annually for several years. Care must be taken to remove cut shoots to prevent their sprouting and forming stolons (Osterbrock 1984). In the Arcola Creek Preserve in Ohio, cutting reduced the vigor of the *P. australis* colony. Also in Ohio, at Morgan Swamp, cutting began in middle to late July (before tassel set) in 1989 around a gas well in a freshwater wetland (Seidel, pers. com. 1991). The preferred tool was an old-fashioned hedge trimmer with an 8-inch flat blade with serrations and manufactured by Union Fork and Hoe. The trimmers worked better than loppers and were safer than sickles; a circular blade on a weed-whacker was also used and proved to be faster and good for staff, but it was more dangerous for volunteers and detracted from the atmosphere of the workday (Huffman, pers. com. 1992).

Small patches (10 feet x 50 feet) in a New York freshwater system were cut at the end of July or the beginning of August for two successive years with positive results (Schneider, pers. com. 1990). The hand-cut material was removed from the site and thrown on a brush pile (unfortunately it was located too close to the water and returned to the system).

Massachusetts Audubon staff have cut the perimeter around a 0.25-acre *P. australis* patch at the end of July since 1986 in a freshwater wetland at Daniel Webster Preserve in Marshfield, Massachussetts (Anderson, pers. com. 1992). They have monitored their success in keeping the species from spreading using a map and hand compass.

Stands of *P. australis* of less than 1 acre in extent that block views in Everglades National Park are cut just before the onset of the rainy season. The rise in water elevation from the rains that follow stresses the roots of the plant. This works to a degree, but *P. australis* returns (Dowlen, pers. com. 1985).

At Post Island Marsh, in Quincy, Massachusetts, the town used small Bobcats with lawnmower clippers mounted on the buckets with a flexible cable to cut an area with 75% cover of *P. australis* and 20–25 feet of muck (Wheelwright, pers. com. 1991, 1994; Dobberteen pers. com. 1991). Cutting this 10-acre plot three times during the summer (April, June, August) cost $150,000. The cut material was stockpiled nearby, where it was to be burned in the winter, but it was washed away in a severe storm. In winter 1992, the town openned the tide gate and allowed flushing to prevent further return of *P. australis.* Two cuttings were performed in the summer of 1992 with hand-held weed-whackers, and three cuttings occurred in 1993. By 1994, *P. australis* had been reduced by 40%, with most of the remaining plants being 2–4 inches in height. Native vegetation is returning naturally to the site.

Cutting culms to 6 inches followed by addition of rock salt on a 10-foot x 10-foot patch appeared to have reduced the height and density of *P. australis* in a salt marsh in Greenwich, Connecticut (Jontos and Allan 1984). Continued observations indicated that this trend continues (Jontos, pers. com. 1992).

In a freshwater tidal wetland in Connecticut, cutting below the first leaf of *P. australis* plants at the end of July in 1986 and 1989 through 1993, around the perimeter of a 1-acre patch, has prevented subsequent expansion of the patch. Monitoring using aerial photos taken at five-year intervals indicated that the control effort was a success. Cutting was done with hand-held cutters and gas-powered hedge trimmers, which were very efficient. Cut material was removed from the site and allowed to decompose on upland areas. In a second area in a calcareous wetland, similar efforts in 1990–1992 were monitored by placing red survey wires around the perimeter of the patch. Visual observations indicate a cessation in or limited amount of *P. australis* expansion.

In Europe, Weisner and Graneli (1989) found that oxygen transport was reduced by cutting the culms above and below the water surface; cutting below the water in June almost totally inhibited regrowth of shoots the following summer, while cutting above water reduced regrowth of shoots. Cutting in August did not reduce growth the following summer. Cutting in sandy substrates was minimally effective, while cutting on calcareous muds caused decreases in oxygen levels.

Grazing, Dredging, and Draining

Grazing, dredging, and draining are other methods that have often been used to reduce stand vigor (Howard et al. 1978). However, draining and dredging are not appropriate for use on most preserves (Osterbrock 1984).

Grazing may trample the rhizomes and reduce vigor but the results are limited (Cross and Fleming 1989). Van Deursen and Drost (1990) found that cattle consumed 67–98% of aboveground biomass; in a four-year study, they found that reed populations may reach new equilibria under grazing regimes.

Manipulation of Water Level and Salinity

A self-regulating tide gate that reintroduced saltwater tidal action was used to help restore a diked marsh in Fairfield, Connecticut (Bongiorno et al. 1984, Steinke pers. com. 1992). A 1- to 3-foot reduction in stem height resulted over each of three years. In addition, plant density declined dramatically from 11.3 plants/m^2 in 1980 to 3.3 plants/m^2 the following year. In following years, *P. australis* continued to decline, although less dramatically. In addition to the decreased height and density of the *P. australis* stands, typical marsh flora including *Salicornia, Distichilis, Spartina alterniflora,* and *S. patens* returned. Depending on topography and elevation, *P. australis* was eliminated in large areas and continued to remain short and sparse in other areas through 1992. Hence, reintroduced tidal action and salinity can reduce *P. australis* vigor and restore the vegetative community's integrity. This technique has been implemented successfully in other degraded former salt marshes in Connecticut (Rozsa, pers. com. 1992).

Flooding can be used to control *P. australis* when 3 feet of water covers the rhizome for an extended period during the growing season, usually four months (Beall 1984). However, many areas cannot be flooded to such depths. Furthermore, flooding could destroy the communities or plants targeted for protection.

Open Marsh Water Management (OMWM) has been used as a method to control *P. australis.* Plugging of ditches and addition of culverts to raise the soil salinities appears to have caused *P. australis* die-back over the last four growing seasons at Fireplace Neck, New York (Niniviaggi, pers. com. 1991, Rozsa, pers. com. 1992).

Hellings and Gallagher (1992) found that *P. australis* was negatively impacted by increasing salinity and increased flooding. They also found that cutting and subsequent flooding also reduced growth and survival in outdoor experiments. They suggest that *P. australis* may be controlled by increasing flooding and salinity levels. Matoh et al. (1988) also found reduction in vigor with increased salinity. However death apparently occurred only when cutting was combined with brackish flooding (Hellings and Gallagher 1992).

In Europe, episodic freshwater flooding occurring early in the growing season has been suggested as one of the reasons for reed population declines (Ostendorp 1991). McKee et al. (1989) investigated root metabolic changes due to freshwater flooding and labeled *P. australis* as a flood-tolerant species.

Mowing, Disking, and Pulling

Beall (1984) discouraged mowing and disking. Mowing only affects the aboveground portion of the plant, so mowing would have to occur annually. To remove the rhizome, disking could be employed. However, disking could potentially result in an increase of *P. australis,* since pieces of the rhizome can produce new plants. Cross and Fleming (1989) described successful mowing regimes of several-year duration during the summer (August and September) and disking in summer or fall.

In Cape May Meadows, New Jersey, a brackish to freshwater nontidal sandy area, an attempt was made to remove rhizomes by pulling to a depth of 3 feet (Johnson, pers. com. 1991). This resulted in a very sparse *P. australis* stand the following year. The work was very labor-intensive (using 130 people-hours to cover a 50-ft^2 patch) and could be applied best to sandy soils.

At Constitution Marsh, New York, a 10-ft^2 area was dug; both mud and rhizomes were disposed off site. Although no *P. australis* returned, it took 28 people hours to clear this small area, and there was a problem with disposal of the mud and rhizomes (Rod, pers. com. 1994).

In a private yard, *P. australis* was mowed and a thin layer of soil and grass seed was added. This was mowed weekly over the course of the summer. In the second summer shoots of *P. australis* occurred around the edges. The rhizomes were decomposing after this treatment (M. Ailes, pers. com. 1992).

Plastic Mulch

A 12-m x 17-m piece of clear plastic, 6-mil thickness, weighing 51.8 kg, was carried into a North Carolina marsh by air and held in place by sandbags (Boone et al. 1987, 1988). Plants were initially cut to 6–8 inches with a hand-pushed bush hog (Boone, pers. com. 1991) or a weed-eater with blade, with an area of 20 x 20 m taking several days to cut. The cut material was left and the plastic put over the area. The high temperatures under the plastic caused die-off of *P. australis* in 3–4 days. After 8–10 weeks, the plastic deteriorated. The rhizomes appeared to have died back, but the project was of short duration and the results were not monitored the following year (Boone, pers. com. 1991). Turner (pers. com. 1992) noted that follow-ups in subsequent years indicated *P. australis* returned but not as densely. Plastic management in each 12-m x 12-m plot took an average of 53 hours, compared with 17 hours to cut and 3 hours to burn (Boone et al. 1987).

Clear plastic in two narrow swaths (70 m x 20 m) was placed along the edge of a tidal brackish pond after *P. australis* was hand cut at the end of July 1991 (Anderson, pers. com. 1992). One plot, in total sun, had a complete kill of *P. australis* in 10 days, while the plot in partial shade had a partial kill. It is unknown how the plastic was kept in place or what was done with the cut material.

Both clear and black plastic were used on 50-foot-diameter circular areas at Constitution Marsh in New York in 1990 and 1991 (Keene, pers. com. 1991). Although there was difficulty due to tidal influence, the plastic was weighted down with rocks and appeared to kill what was under it. In November 1991, a hole cut in the middle of the black plastic provided the opportunity for cattail shoots to germinate. The black plastic was removed in late summer of 1992 and the areas were revegetated with a diverse growth of native species, with some *P. australis* stalks around the edges, which were cut in 1992 and 1993. A second spot was covered with black plastic in summer 1991. The plastic was removed in spring 1992; *P. australis* was 90% eradicated, with clumps remaining around the edges. These clumps were hand cut and dug in 1993, and as of 1994, there were no *P. australis* plants at this site (Rod, pers. com. 1992, 1994). The black plastic appeared to be more effective than clear plastic (Rod, pers. com. 1992).

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REFERENCES

Ailes, I. 1985. Biologist, Chincoteague National Wildlife Refuge. Telephone conversation with Marianne Marks.

Ailes, I. 1991. Biologist, Chincoteague National Wildlife Refuge. Telephone conversation with Beth Lapin, November 1991.

Ailes, I. 1994. Biologist, Chincoteague National Wildlife Refuge. Telephone conversation with Beth Lapin, March 1994.

Ailes, M. 1992. Ecologist, U.S. Navy. Telephone conversation with Beth Lapin, January 1992.

Anderson, J. 1992. Biologist, Massachusetts Audubon Society. Telephone conversation with Beth Lapin, January 1992.

Beall, D.L. 1984. Brigantine Division — Marsh vegetation rehabilitation — chemical control of phragmites. Unpublished report by U.S. Fish and Wildlife Service, Oceanville, N.J. 8 p.

Beall, D. 1991. Refuge Manager, Brigantine National Wildlife Refuge. Telephone conversation with Beth Lapin, November 1991.

Boar, R.R., C.E. Crook, and B. Moss. 1989. Regression of *Phragmites australis* reedswamps and recent changes of water chemistry in the Norfolk Broadland, England. Aquatic Botany 35:41-55.

Bongiorno, S.F., J.R. Trautman, T.J. Steinke, S. Kawa-Raymond, and D. Warner. 1984. A study of restoration in Pine Creek Salt Marsh Fairfield, Connecticut. *In* F.J. Webb, ed., Proceedings of the 11th Annual Conference in Wetlands Restoration and Creation, Hillsborough Community College, Tampa, Fla.

Boone, J. 1991. University of Georgia, Athens. Telephone conversation with Beth Lapin, November 1991.

Boone, J., E. Furbish, and K. Turner. 1987. Control of *Phragmites communis*: results of burning, cutting, and covering with plastic in a North Carolina marsh. Cooperative Park Service Unit Technical Report 41, U.S. Department of the Interior, National Park Service, Athens, Ga. 15 p.

Boone, J., E. Furbish, K. Turner, and S. Bratton. 1988. Clear plastic. A non-chemical herbicide. Restoration and Management Notes 6:101.

Brandt, S.J. 1983. A health and environmental report on Rodeo herbicide. Monsanto Agricultural Products Company, St. Louis, Mo. 3 p.

Breternitz, D.A., C.K. Robinson, and G.T. Gross. 1986. Dolores archaeological program: final synthetic report. U.S. Department of the Interior, Bureau of Reclamation, Denver, Colo.

Chuzhoza, A.P. and L.Y. Arbuzova. 1970. Specific morphological and biological features of aquatic adventitious roots in *Phragmites communis*. Trin. Botanichniyi Zhurnal (Kiev) 55:1473-1480.

Clayton, W.D. 1968. The correct name of the common reed. Taxon 17:157-158.

Comes, R.D., V.F. Bruns, and A.D. Kelly. 1976. Residues and persistence of glyphosate in irrigation water. Weed Science 24:47-58.

Cross, D.H. and K.L. Fleming. 1989. Control of *Phragmites* or common reed. U.S. Fish and Wildlife Leaflet 13.4.12. U.S. Department of the Interior, Fish and Wildlife Service, Washington, D.C. 5 p.

Daly, P.D. 1984. Prime Hook Narrative Report. Unpublished report by U.S. Department of the Interior, Fish and Wildlife Service. 15 p.

Daly, P.D. 1991. Refuge manager, Bombay Hook, Prime Hook National Wildlife Refuges. Telephone conversation with Beth Lapin, November 1991.

Den Hartog, C. J. Kvet, and H. Sukopp. 1989. Reed. A common species in decline. Aquatic Botany 35:1-4.

Dobberteen, R. 1991. Wildlife biologist, Lelito Environmental Consultants, Peabody, Mass. Telephone conversation with Beth Lapin, November 1991.

Dowlen, D. 1985. Everglades National Park, Fla. Telephone conversation with Marianne Marks.

Droege, M. 1991. Stewardship Director, Maryland Office, The Nature Conservancy. Telephone conversation with Beth Lapin, November 1991.

Durska, B. 1970. Changes in the reed *(Phragmites communis* Trin.) condition caused by diseases of fungal and animal origin. Polish Archives of Hydrobiologie 17:373-396.

Folmar, L.C., H.O. Sanders, and A.M. Julin. 1979. Toxicity of the herbicide glyphosate and several of its formulations to fish and aquatic invertebrates. Archives of Environmental Contamination and Toxicology 8:269-278.

Graneli, W. 1989. Influence of standing litter on shoot production in reed, *Phragmites australis* (Cav.) Trin. Ex Steudel. Aquatic Botany 35:99-109.

Hara, T., J. van der Toorn, and J.H. Mook. 1993. Growth dynamics and size structure of shoots of *Phragmites australis*, a clonal plant. Journal of Ecology 81:47-60.

Haslam, S.M. 1968. The biology of reed (*Phragmites communis*) in relation to its control. Pp. 382-397 *in* Proceedings of the Ninth British Weed Control Conference.

Haslam, S.M. 1970. The performance of *Phragmites communis* Trin. in relation to water supply. Annals of Botany (n.s.) 34:867-877.

Haslam, S.M. 1971a. Community regulation in *Phragmites communis* Trin. I. Monodominant stands. Journal of Ecology 59:65-73.

Haslam, S.M. 1971b. The development and establishment of young plants of *Phragmites communis* Trin. Annals of Botany (n.s.) 35:1059-1072.

Haslam, S.M. 1972. *Phragmites communis* Trin.: biological flora of the British Isles. Journal of Ecology 60:585-610.

Haslam, S.M. 1973. Some aspects of the life history and autecology of *Phragmites communis* Trin. Polish Archives of Hydrobiologie 2079-100.

Hauber, D. 1992. Faculty member, Department of Biological Sciences, Loyola University, New Orleans, La. Telephone conversation with John Randall, September 1992.

Hauber, D.P., D.A. White, S.P. Powers, and F.R. DeFrancesch. 1991. Isozyme variation and correspondence with unusual infrared reflectance patterns in *Phragmites australis* (Poaceae). Plant Systematics and Evolution 178:1-8.

Hayden, A. 1947. Notes on destructive factors operating among the emergent plants of the Ruthven area in the summer of 1947. Quarterly Report of the Iowa Cooperative Wildlife Research Unit 44:331-343.

Healey, J. 1992. Biologist, Parker National Wildlife Refuge. Telephone conversation with Beth Lapin, January 1992.

Hellings, S.E. and J.L. Gallagher. 1992. The effects of salinity and flooding on *Phragmites australis*. Journal of Applied Ecology 29:41-49.

Hocking, P.J., C.M. Finlayson, and A.J. Chick. 1983. The biology of Australian weeds. 12. *Phragmites australis* (Cav.) Trin. ex Steud. Journal of the Australian Institute of Agricultural Science 123-132.

Howard, R., D.G. Rhodes, and J.W. Simmers. 1978. A review of the biology and potential control techniques for *Phragmites australis*. U.S. Army Engineer Waterway Experiment Station, Vicksburg, Miss. 80 p.

Huffman, Mary. 1992. Project Director, Lake Wales Project, Florida, The Nature Conservancy. Telephone conversation with Beth Lapin, January 1992.

Johnson, E. 1991. Stewardship Director, New Jersey Field Office, The Nature Conservancy. Telephone conversation with Beth Lapin, November 1991.

Johnstone, R. 1991. Delmarva Power. Telephone conversation with Beth Lapin, November 1991.

Jones, W.L. and W.C. Lehman. 1987. *Phragmites* control and revegetation following aerial applications of glyphosate in Delaware. *In* W.R. Whitman and W.H. Meredith, eds., Waterfowl and Wetlands Symposium, Delaware Department of Natural Resources and Environmental Control, Dover.

Jontos, R. Jr. 1992. Consultant, Land-Tech Consultants. Telephone conversation with Beth Lapin, January 1992.

Jontos, R. Jr. and C.P. Allan. 1984. Test salt to control *Phragmites* in salt marsh restoration (Connecticut). Restoration and Management Notes 2:32.

Kane, A.E. and G.T. Gross. 1986. Anasazi communities at Dolores: early Anasazi sites in the Sagehen Flats area. Denver. 985 p.

Kartesz, J.T. and R. Kartesz. 1980. A Synonomized Checklist of the Vascular Flora of the United States, Canada, and Greenland. Volume II: the Biota of North America. The University of North Carolina Press, Chapel Hill. 498 p.

Keene, C. 1991. Biologist, Museum of Hudson Highlands. Telephone conversation with Beth Lapin, November 1991.

Kim, K.S., Y.S. Moon, and C.K. Lim. 1985. Effect of NaCl on germination of *Atriplex gmelini* and *Phragmites communis*. Korean Journal of Botany 28:253-259.

Klockner, W. 1985. Stewardship Director, Maryland Chapter, The Nature Conservancy. Telephone conversation with Marianne Marks, June 1985.

Lefor, M.W. 1993. Wetland biologist, University of Connecticut. Letter to John M. Randall, March 1993.

Lehman, W.C. 1984. Project Benchmark. Ecological factors governing growth of *Phragmites* and preliminary investigation of *Phragmites* control with glyphosate. Delaware Division of Fish and Wildlife, Dover. 30 p.

Lehman, W.C. 1992. Biologist, Delaware Division of Fish and Wildlife. Telephone conversation with Beth Lapin, January 1992.

Lynch, J.J., T. O'Neill, and D.E. Lay. 1947. Management and significance of damage by geese and muskrats to Gulf Coast marshes. Journal of Wildlife Management 11:50-76.

Matoh, T., M. Matsushita, and E. Takahashi. 1988. Salt tolerance of the reed plant *Phragmites communis*. Physiologia Plantarum 72:8-14.

McKee, K.L., I.A. Mendelssohn, and D.M. Burdick. 1989. Effect of long-term flooding on root metabolic response in five freshwater marsh plant species. Canadian Journal of Botany 67:3446-3452.

McNabb, C.D. and T.R. Batterson. 1991. Occurrence of the common reed, *Phragmites australis*, along roadsides in Lower Michigan. Michigan Academician 23:211-220.

Metzler, K. and R. Rozsa. 1987. Additional notes on the tidal wetlands of the Connecticut River. Connecticut Botanical Society Newsletter 15:1-6.

Monsanto Co. 1985. Rodeo aquatic herbicide; complete directions for use in aquatic sites. Monsanto Co., St. Louis, Mo.

Mook, J.H. and J. van der Toorn. 1982. The influence of environmental factors and management on stands of *Phragmites australis*. II. Effects on yield and its relationships with shoot density. Journal of Applied Ecology 19:501-517.

Niering, W.A. and R.S. Warren. 1977. Our dynamic tidal marshes: vegetation changes as revealed by peat analysis. Connecticut Arboretum Bulletin 12. 22 p.

Niniviaggi, D. 1991. Marine resources specialist, Bureau of Marine Habitat Protection, Department of Environmental Conservation, Stony Brook, N.Y. Telephone conversation with Beth Lapin, November 1991.

Nugent, R. 1991. Director, Tinicum Environmental Center in John Hindes National Wildlife Refuge, Penn. Telephone conversation with Beth Lapin, November 1991.

Ostendorp, W. 1989. "Die-back" of reeds in Europe — a critical review of literature. Aquatic Botany 35:5-26.

Ostendorp, W. 1991. Damage by episodic flooding to *Phragmites* reeds in a prealpine lake: proposal of a model. Oecologia 86:119-124.

Osterbrock, A.J. 1984. *Phragmites australis*. The problem and potential solutions. Ohio Field Office, Stewardship. 8 p.

Parris, R. 1991. Biologist, Wertheim National Wildlife Refuge, Shirley, N.Y. Telephone conversation with Beth Lapin, November 1991.

Penko, J.M. 1985. Ecological studies of *Typha* in Minnesota: *Typha*-insect interactions, and the productivity of floating stands. M.S. thesis, University of Minnesota, .

Penko, J.M. 1993. Ecologist, U.S. Army Corps of Engineers, Waltham, Mass. Letter to John M. Randall, April 1993.

Pintera, A. 1971. Some observations on mealy plum aphid, *Hyalopterus pruni* Geoffi, occurring on reeds. Hidrobiologia (Bucharest) 12:293-295.

Pokorny, V. 1971. Flies of the genus *Lipara meigen* on common reed. Hidrobiologia (Bucharest) 12:287-292.

Poole, J. 1985. Botanist, Texas Natural Heritage Program, The Nature Conservancy. Letter to Marianne Marks, March 1985.

Raicu, P., S. Staicu, V. Stoian, and T. Roman. 1972. *Phragmites communis* Trin. complement in the Danube Delta. Hydrobiologia 39:83-89.

Rawinski, T. 1985. Common reed (*Phragmites australis*) in a select group of New York/ New England natural areas, an overview. Unpublished report of the Eastern Heritage Task Force, The Nature Conservancy. 6 p.

Rawinski, T. 1985. Ecologist, Eastern Heritage Task Force, The Nature Conservancy. Conversation with Marianne Marks, July 1985.

Reimer, D.N. 1973. Effects of rate, spray volume, and surfactant on the control of *Phragmites* with glyphosate. Proceedings of the New England Weed Science Society 27:101-104.

Ricciuti, E.R. 1983. The all too common, common reed. Audubon Magazine, September.

Rod, J. 1992. Manager, Constitution Marsh, National Audubon Society. Telephone conversation with Beth Lapin, February 1992.

Rod, J. 1994. Manager, Constitution Marsh, National Audubon Society. Telephone conversation with Beth Lapin, March 1994.

Roman, C.T., W.A. Niering, and R.S. Warren. 1984. Salt marsh vegetation change in response to tidal restriction. Environmental Management 8:141-150.

Rozsa, R. 1992. Biologist, Connecticut Department of Environmental Protection. Telephone conversation with Beth Lapin, August 1992.

Schneider, K. 1990. Coordinator, New York Heritage Program. Telephone conversation with Beth Lapin, October 1990.

Seidel, T. 1991. Stewardship and Volunteer Coordinator, Ohio Office, The Nature Conservancy. Telephone conversation with Beth Lapin, November 1991.

Skuhravy, V. 1978. Invertebrates: destroyers of the common reed. Pp. 376-388 *in* D. Dykyjova and J. Kvet, eds., Pond Littoral Ecosystems Structure and Functioning. Springer-Verlag, New York.

Sorrie, B. 1985. Botanist, Massachusetts Natural Heritage Program. Letter to Marianne Marks, April 1985.

Stark, H. and M. Dienst. 1989. Dynamics of lakeside reed belts at Lake Constance (Untersee) from 1984 to 1987. Aquatic Botany 35:63-70.

Steinke, T. 1992. Conservation Commissioner, Fairfield, Conn. Telephone conversation with Beth Lapin, August 1992.

Sukopp, H. and B. Markstein. 1989. Changes of the reed beds along the Berlin Havel, 1962–1987. Aquatic Botany 35:27-39.

Thompson. D.J. and J.M. Shay. 1985. The effects of fire on *Phragmites australis* in the Delta Marsh, Manitoba. Canadian Journal of Botany 63:1964-1869.

Truitt, Barry. 1992. Steward, Virginia Coast Reserve, Nassawadox, Va. Interview with John Randall, December 1992.

Tscharntke, T. 1988. Variability of the grass *Phragmites australis* in relation to the behavior and mortality of the gall-inducing midge *Giraudiella inclusa* (Diptera, Cecidomyiidae). Oecologia 76:504-512.

Tucker, G.C. 1990. The genera of Arundinoideae (Gramineae) in the southeastern United States. Journal of the Arnold Arboretum 71:145-177.

Turner, K. 1992. Chief of Resource Management, Lake Mead Recreation Area, Nevada. Telephone conversation with Beth Lapin, January 1992.

van der Merff, M., J.W. Simmers, and S.H. Kay. 1987. Biology, management and utilization of common reed *Phragmites australis*. U.S. Army report, Contract number DAJA45-86-M-0482. 101 pp.

van der Toorn, J. and J. H. Mook. 1982. The influence of environmental factors and management on stands of *Phragmites australis*. I. Effects of burning, frost and insect damage on shoot density and shoot size. Journal of Applied Ecology 19:477-499.

van Deursen, E.J.M. and H.J. Drost. 1990. Defoliation and treading by cattle of reed *Phragmites australis*. Journal of Applied Ecology 27:284-297.

Weisner, S.E.B. and W. Graneli. 1989. Influence of substrate conditions on the growth of *Phragmites australis* after a reduction in oxygen transport to below-ground parts. Aquatic Botany 35:71-80.

Wheelwright, M. 1991. Department of Public Works, Quincy, Mass. Telephone conversation with Beth Lapin, November 1991.

Wheelwright, M. 1994. Department of Public Works, Quincy, Mass. Telephone conversation with Beth Lapin, April 1994.

Young, J. 1985. Land Steward Florida Field Office (formerly, Stewardship Director, Ohio Field Office), The Nature Conservancy. Telephone Conversation with Marianne Marks, May 1985.