The interaction between science and policy in the control of *Phragmites* in oligohaline marshes of Delaware Bay

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Abstract

Public Service Enterprise Group of New Jersey restored Delaware Bay marshes to enhance fish production as part of a mitigation negotiated in a company's NJPDES permit.   Restoration meant control of an introduced type of the common reed, *Phragmites,* that had displaced *Spartina alterniflora* and *S. patens. Phragmites* dominance altered the function and structure of these brackish marshes and reduced habitat value by raising and flattening marsh surface and covering smaller tidal creeks. A common control technique is to use an herbicide – Glyphosate, but public concern about herbicide use resulted in an agreement between PSEG and NJ regulators to test other methods for reed control and limit the amount of herbicide used. Experiments with methods of *Phragmites* control indicate that herbicide application over three or more growing seasons, concentrating in an area until control was complete, is the most effective control method.

In the 1970s and 1980s, state environmental agencies and USEPA began to evaluate the effect of power plants' cooling water intake structures on fish populations in estuaries, the coastal ocean, rivers or lakes. The State of New Jersey, in issuing the New Jersey Pollutant Discharge Elimination System ("NJPDES") Permits for the Salem Generating Station in September 1994 following lengthy negoitiations, required physical modifications to intake structures and mitigation for perceived effects of power plant activities on fish eggs and larvae. Public Service Enterprise Group of New Jersey (PSEG) owns and operates Salem Station in Salem, NJ on the edge of Delaware Bay. The permit required that PSEG, as one part of the mitigation process, restore up to 10,000 acres of diked salt hay farms and/or *Phragmites* dominated tidal wetlands "so as to become functional salt marsh." The restoration effort, called the Estuary Enhancement Program or EEP, was designed to offset potential negative impacts of Salem's operations on fish and other aquatic species in Delaware Bay. An interaction between science and policy in the restoration of *Phragmites* dominated marshes is discussed here.

The reed, *Phragmites australis*, was historically a common species in brackish marshes along much of the northeast coast of the U.S., including those in upper Delaware Bay. Until the 1970s, *Phragmites* was generally located on the upper edge of marshes dominated by *Spartina patens* and *S. alterniflora*. *Phragmites* shared this upper edge with other marsh edge plants such as high-tide bush (*Iva frutescens)* and groundsel tree (*Baccharis halimifolia)*. However, in the past 30 to 40 years, the vegetative diverse brackish marshes have changed dramatically. This change is due to a cryptic invasion. A type of *Phragmites* from Europe, differing from the native form only slightly in appearance, was introduced into North America and has taken over the habitat of the native *Phragmites.* It has proven to be much more invasive than the native form (Saltonstall 2002) and consequently occupies much more of the marsh ecosystem than the native reed did. The invasion has turned diverse marshes into monocultures of *Phragmites* (Figure 1).

The result has been changes in both marsh structure and function. Salt marsh functions important in this instance include nursery areas for juvenile fish, primary production, production of fish food, and bird habitat. Salt marsh structures associated with these functions include existence of tidal streams and rivulets providing access to the marsh for aquatic organisms, amount of marsh/water edge and vegetation type and coverage. Salt marshes are inherently changeable, evolving landscapes, balanced between the ocean and the upland in protected coastal areas, subject to modification by storms and migrating with changes in sea level. Since observing the evolution from *Spartina*-dominated marshes to *Phragmites*-dominated marshes, the scientific community has studied changes in function. We now know that *Phragmites* contributes carbon and energy to the marsh food web as shown by stable isotope studies (e.g. Weinstein et al.2000). But what about the function of these marshes related to fish? The marsh killifish, mummichog (*Fundulus heteroclitus*) is the most abundant resident fish on the marsh and a base of the trophic relay that moves marsh production into estuarine fish populations (Kneib 1997). Able and Hagan (2003) and Fell *et al.* (2003) have shown that marshes where *Phragmites* has become the dominant vegetation are much less suitable for reproduction of mummichog than are *Spartina* marshes.

Phragmites dominated marshes are structurally different from those dominated by *Spartina*. The invasive reed reduces the topographical variability of the marsh plain (Windham and Lathrop 1995) that provides larval fish habitat. The reed's roots and rhizomes bridge marsh creeks up to about 1.5 meters in width (Figure 2)(personal observations). This makes it more difficult for fishes to move in and out of the marsh, which, in turn, affects it nursery value for these animals (Minello et al. 2003). *Phragmites* growth also steepens creek banks, reducing the gentle slopes on the insides of creek bends that provide feeding areas for birds and refuge for small fishes. Removal of *Phragmites* reverses the processes and restores marshes to their previous condition, although restoration of sediment characteristics takes longer than revegetation. Figure 3 shows an area where *Phragmites* was killed which was then in the early stages of revegetation with *Spartina alterniflora*. Figure 4 shows the early stages of re-establishment of a marsh creek that had been bridged by *Phragmites* rhizomes and was then reopening after the *Phragmites* was killed, the rhizomes decomposed and the covering of the creek began to disappear (personal observations).

PSEG began the *Phragmites* control program with aerial application, using helicopters, of the herbicide Glyphosate. They followed the example of the Delaware Department of Natural Resources, which had been using this method for some years. It was difficult to extract information on application rates and frequency from Delaware DNR's records to project accurately the time it would take to reduce *Phragmites* stands. As a result PSEG was overly optimistic about how long *Phragmites* control would take. Initial spraying killed the above ground plant parts of the reeds and the immediate rhizomes from which they grew, but did not kill all the older rhizomes or those more distant from the aboveground stems. Without further spraying, surviving rhizomes, which had been released from apical dominance, restored the *Phragmites* monoculture almost completely within two to three years in several areas. Clearly a different herbicide application program was necessary.

Because the EEP program was geographically extensive, involving thousands of acres in Delaware and New Jersey, and highly visible, both literally and politically, the challenges of *Phragmites* control and herbicides use were widely known. As it became apparent that a single application of herbicide was not effective in restoring *Phragmites* dominated marshes, public concern about the herbicide application program became more vocal. EEP's advisory board, consisting of independent scientists, state and federal regulators, met regularly to discuss the *Phragmites* restoration projects at open public meetings. At these meetings, experts explained at length that the risk assessments of Glyphosate (and the detergents used with it as spreading/penetrating agents) showed low probability of either a hazard to humans or to the environment (see Williams et al. 2000; Solomon and Thompson 2003).

Increasing opposition from citizens concerned about herbicide use occurred despite the technical data and analysis provided. New Jersey regulators had to respond. The first step, agreed to by NJDEP and PSEG, was a public forum to discuss the safety of Glyphosate and the detergents used with it. Invited experts and PSEG consultants were seated on one side of the room facing the concerned citizens and their consultants. The League of Women Voters ran the meeting. The rules were that each side could speak for just three minutes and then the other side got three minutes for rebuttal. The antiherbicide people had no trouble making their point, short sound bites opposing herbicide use, over and over within their three-minute period. The scientists, committed to thorough explanation of highly technical material, were unable to convey their conclusions in three-minute segments and were cut off in mid-sentence again and again. While some of the public in the audience said they were satisfied, the opposition continued to voice their concerns.

As a result of opposition from a small number of concerned citizens, a new agreement was negotiated between PSEG and the NJ regulators. The amounts of herbicide that could be used were reduced and a test program was established to study whether or not other techniques would control *Phragmites*. The EEP technical staff developed a matrix of control techniques to be studied over time at experimental plots. The techniques included mowing, rhizome ripping, surface scarification and grazing.

- EEP experimented with annual mowing, annual mowing in combination with herbicide application, and mowing three or four times a year. The theory behind this technique was that mowed *Phragmites* would not have enough surface area for photosynthesizing adequate energy to support the extensive below ground portion of the plant.
- On other test areas, EEP experimented with rhizome ripping. This involved using a modified tractor to drag discs or vertical bars through the sediment to cut the rhizomes. The technique was tried both with and without herbicide. The theory behind this technique was that cutting rhizomes allowed seawater to enter and drown the rhizome at high tide. It could also release dormant buds on rhizomes

from apical dominance, cause them to sprout and make them susceptible to herbicide.

- In a subset of mowed and sprayed plots, the sediment surface was scarified to encourage trapping seeds of other, more desirable, marsh plants. The theory was that, given a more hospitable environment, other plants would naturally fill in those areas where *Phragmites* had been weakened by mowing/spraying.
- Goats were introduced to the upland edge of some *Phragmites* stands on the theory that grazing goats would reduce the stands of reeds.

All test treatments were replicated and continued for at least two years. The final results of these trials are not yet analyzed statistically, but preliminary indications are that no technique gave good control without the use of herbicides. Considering the cost and danger involved with use of equipment on the marsh surface, the nuisance of maintaining a healthy population of goats, and the size of the marshes to be managed, it likely that use of herbicide alone will be the preferred technique (measured by area freed from reed per year) and the most cost-effective means of *Phragmites* control on the surface of a tidal marsh.

During the test program, herbicide applications were continued, but at a restricted rate. This made it impossible for EEP to spray the entire area of any of the restoration sites. Their approach was modified to concentrate on selected areas at each site and spray them every year until complete *Phragmites* control was achieved. PSEG considered this approach more likely to achieve restoration than inadequate spraying of the entire area. This conclusion is supported by modeling (Turner and Warren 2003) and by experience at these and other restoration sites both fresh and brackish (Ailstock *et al.* 2001, Warren *et al.* 2001). EEP noted that the amount of herbicide needed to treat an area declined each year as the standing stock of *Phragmites* declined in height and density. In most areas, ground and/or boat application were substituted for aerial spraying. The exceptions were those areas where the surface sediments were so soft as to cause safety concerns for the applicators. Since most of the selected areas being treated are isolated from other *Phragmites* stands by tidal creeks too wide (over 10m) for *Phragmites* runners to cross, once complete control is achieved, the only maintenance needed will be monitoring for occasional invasion of viable rhizomes, such as may be brought on site by ice rafting or after severe storms. Because the restoration process restores marsh structure and hydrology, it is highly unlikely that *Phragmites* will be reintroduced by seeds. Wijte and Gallagher (1996) have shown the seeds fail to germinate on the saturated soils of salt marshes. The other potential locations for reinvasion are the remnant levees or dikes on which *Phragmites* seedlings originally got a foothold. Most of these features have either eroded naturally or were leveled by PSEG.

New Jersey regulators and PSEG reached a compromise on the process for restoring *Phragmites* dominated salt marshes that reflected inclusion of public concern. While the restoration will take longer than originally planned, the final result -- restoration of formerly *Phragmites* dominated marshes to marshes dominated by *Spartina* and other desirable marsh plants, will satisfy the purpose of both the company and the regulators.

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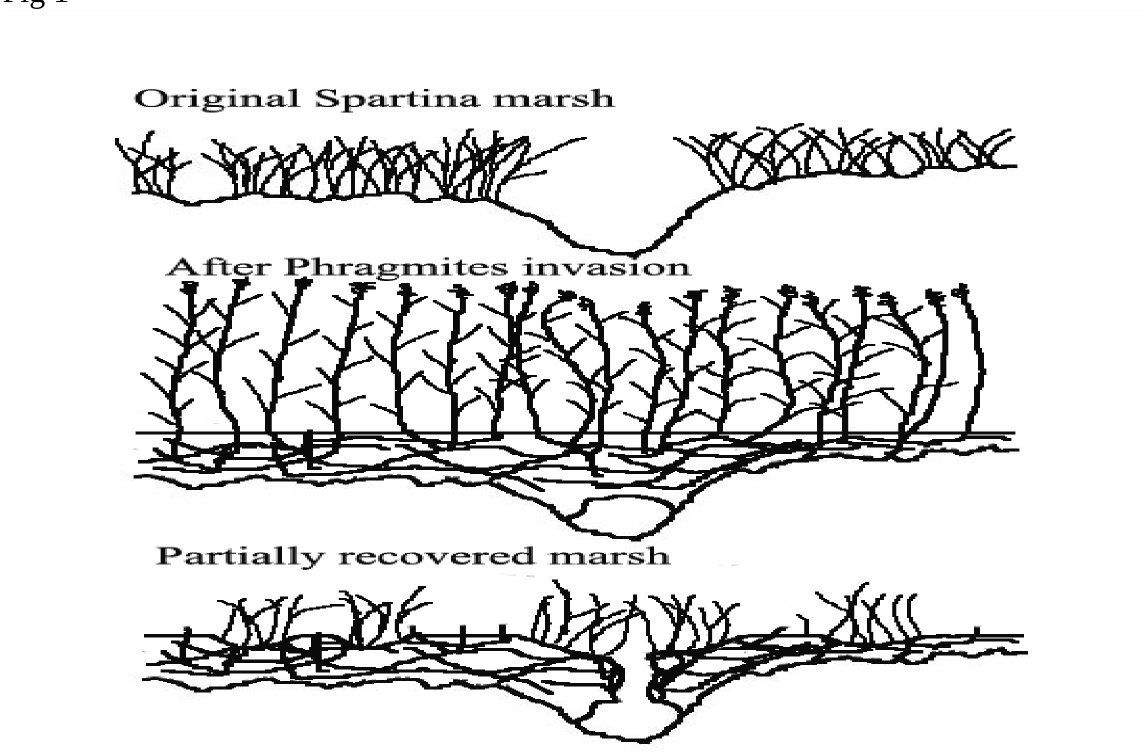
Figure 1. Aerial view of monoculture of *Phragmites* in an oligohaline marsh on Delaware Bay.

Figure 2. Cartoon of marsh cross-section before *Phragmites* invasion, as a *Phragmites* monoculture, and partially recovered after *Phragmites* removal.

Figure 3. A site in the foreground which in the process of revegetating with *Spartina* while an adjacent site in the background separated by a broad tidal creek has not been treated and contains *Phragmites* as used to exist in the foreground.

Figure 4. Tidal creek beginning to open after *Phragmites* has been removed. Invasion of *Spartina alterniflora* is just beginning.

Fig 1



Original Spartina marsh
After Phragmites invasion
Partially recovered marsh

Fig 2


Fig 3

Fig 4