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Manual Control of *Phragmites australis* in Freshwater Ponds of Cape Cod National Seashore, Massachusetts, USA

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INTRODUCTION

The non-native, invasive genotype of the common reed (*Phragmites australis* (Cav.) Trin. ex Steudel) has become a problem of significant proportions throughout wetlands of North America (Saltonstall 2001). Although attempts to suppress or eradicate *Phragmites* have utilized a wide variety of techniques, herbicides have generally been most effective (Marks et al. 1994). However, their use may be infeasible due to policy, political, or ecological concerns and alternative techniques are often sought.

In non-tidal, freshwater environments, *Phragmites* may occasionally experience lengthy periods of flooding. Although well-adapted for growth in anaerobic substrates, extreme flooding results in increased metabolic demands associated with the transport of oxygen from aerial parts to the roots (McKee et al. 1989). In 2003, Cape Cod experienced record amounts of rainfall that resulted in extremely high water levels. In the spring, mid-summer, and late summer of that year we attempted to opportunistically control *Phragmites* in five freshwater ponds within Cape Cod National Seashore (CCNS) by repeatedly severing stems underwater, at ground level. Based on previous studies on the effects of underwater cutting (Husak 1978, Weisner and Graneli 1989, Hellings and Gallagher 1992, Rolletschek et al. 1998, 1999, Rolletschek and Hartzendorf 2000, Asaeda et al. 2003), we hypothesized that the stress of root oxygen deprivation and forced depletion of carbohydrate reserves during re-growth might be sufficient to induce substantial mortality in this particular setting.

MATERIALS AND METHODS

Five freshwater ponds within CCNS that had been invaded by *Phragmites* (Long, Round, Snow, Ryder, and Great) were randomly selected for treatment. Since there were no other spatially discrete stands of *Phragmites* that could serve as within-

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pond controls, untreated populations at nearby Bennett and Herring Ponds were also monitored to assess how water level alone may have influenced growth during the study period.

At each site, three permanent 0.25 m² sampling plots were randomly established within each stand and marked with PVC pipe. Because the study was begun in the early spring of

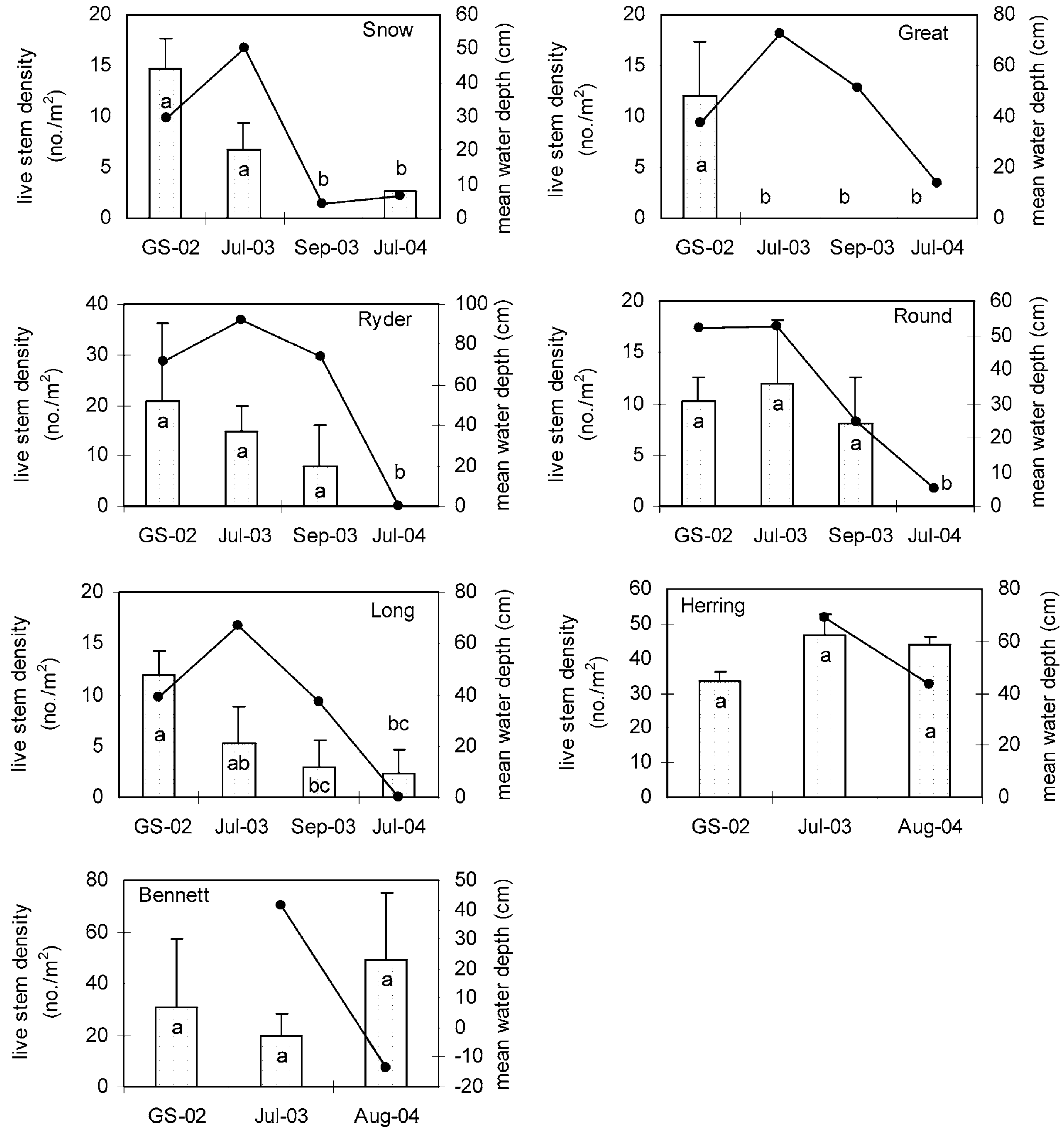

Figure 1. Changes in *Phragmites* live stem densities (histograms corresponding to left y-axis) following repeated underwater removal of stems and mean water levels (line graph corresponding to right y-axis) in plots (GS-02 = calculated values for the growing season of 2002; histograms with shared letters are statistically equal and vice versa; error bars represent standard error of the mean).

2003 (when no live stems were present) estimates of pre-treatment live stem densities were obtained by dividing the total number of over-wintering (dead) stems by three (i.e., one third of the stems were assumed to be live stems from 2002, the other two thirds represent growth from 2001 and 2000). For the reference stands, the entire population of dead stems was assumed to represent the live stem population during 2002, even though in reality some portion was from 2001. In this way, estimates would err on the high side, increasing the probability that even minor reductions from high water conditions would be detected.

On April 3, 2003, following the acquisition of data on initial stand characteristics, all *Phragmites* stems in each population were manually broken underwater and removed from the ponds. This was accomplished by grasping the stem with both hands and kicking sideways, which snaps the stem off near or at its base—a method that actually proved easier than using cutting tools. Removal treatments were repeated on June 9 and September 1, 2003. Prior to each treatment and in the following growing season (2004) live stem densities were enumerated directly and water depths within each permanent plot were recorded with a meter stick.

In addition to plot data, the circumference (c) of each treatment stand was measured to the nearest meter and stand size calculated as $\pi(c/2\pi)^2$. To estimate the initial population of live stems on an entire stand basis, mean stem densities from the permanent plots (number of live stems/m^2) were multiplied by stand area. Subsequently, all re-growing stems were counted, with the exception of the untreated Herring Pond stand where, due to its large size, the final stem total also was determined indirectly as described above.

To analyze treatment effects within each pond, log-transformed stem density values were compared along the timeline of the study using one-way Analysis of Variance (ANOVA) followed by Tukey's Tests ($\alpha = 0.05$).

RESULTS AND DISCUSSION

In March, more than 30 cm of water covered the plots in all the ponds. Water levels continued to rise until the end of June (Figure 1), after which a steady decline occurred. The following spring maxima were much lower than in 2003. By the end of the study period (July 2004) the plots at Round, Snow, and Bennett Pond had gone dry, whereas all others had water depths between 0 (Long Pond) and 43 cm (Herring Pond).

Approximately 1.5 years after initial treatment, *Phragmites* was absent from all plots in Great, Ryder, and Round Pond (Figure 1). Re-growth occurred in one plot at Snow Pond but stem densities were significantly lower than in July 2003 and the previous growing season. In Long Pond, stem densities in July 2004 were statistically different only from pre-treatment values. In the two reference stands, live stem densities increased although the changes were not statistically significant. With respect to whole stands, large reductions in the total number of stems occurred at all but the reference sites (Figure 2). Long and Round Ponds showed the least amount of decline (<70%), while populations in Snow, Great, and Ryder Pond decreased by >90% (Figure 1). *Phragmites* at Herring Pond showed very little change in the estimated number of total stems, while Bennett Pond (an incipient population) increased by 43%.

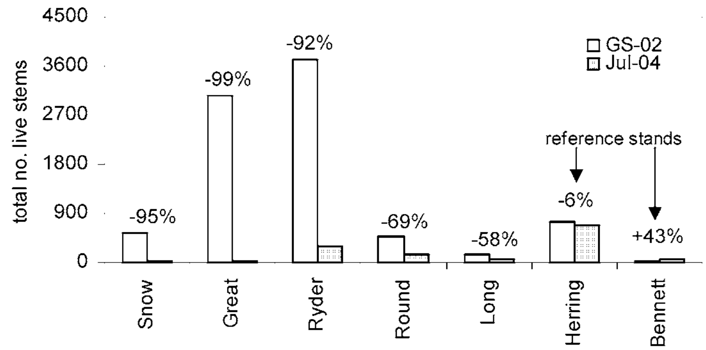

Figure 2. Number of live stems within whole stands before and after treatment (percent values indicate increase or decrease in total population size; GS-02 = calculated values for the growing season of 2002).

In conclusion, repeated underwater breakage and removal of stems significantly reduced *Phragmites* population size the following year. No stems re-emerged in 12 out of 15 permanent plots while reductions in total stand size ranged between 59% and 99%. The changes are the direct result of removal treatments since high water levels alone did not reduce stem densities in either of the reference stands. In the absence of such treatment, periods of deep water alone are likely to result in phenotypic changes or reduced rates of expansion rather than a general population decline (Clevering 1998, Cross and Flemming 2000, Vretare et al. 2001, Wilcox et al. 2003).

In the five CCNS ponds where *Phragmites* was treated, water covered the tops of the broken stems long enough to induce substantial mortality. Thus, a prolonged period of high water appears to be a pre-requisite for success in using this method. It stands to reason, however, that populations spanning a greater elevation range may be more difficult to control since individuals at the upland edge may experience very shallow water or no flooding at all. In this study, plants that grew back were typically those at the highest elevations. In general, there are a variety of factors, both logistical and ecological, that can influence the success of this control method. As such, further studies on success and failure rates from diverse settings and conditions would be of considerable value in further evaluating and improving this technique.

ACKNOWLEDGMENTS

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