# Common reed (*Phragmites australis*) harvest as a control method in a Neotropical wetland in Western México

# Cosecha de carrizo (*Phragmites australis*) como método de control en un humedal del occidente de México

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## ABSTRACT

Common reed (*Phragmites australis*) has invaded wetlands worldwide and displaced native vegetation and wildlife. Control measures include herbicides, but their use can cause negative environmental impacts. An alternative is to harvest aerial biomass. We tested harvest as a control for common reed in Mintzita springs, Michoacán in Western Mexico. Results showed that harvest increased native plant species establishment, and that species richness varied with harvesting method. In plots where reed was completely removed every two months, 9 native species established, the same number as in plots where all reed biomass was removed if at least one stem was 2 m tall at the harvest date. When only reed stems 2m or taller where removed, 6 species established, whereas, in control plots only three species established. Species composition correlated with harvesting method (ANOSIM, R=0.4514, $p < 0.01$). Harvest reduced resprouting measured as standing biomass ($F_{(3,20)} = 27$, $p < 0.000001$). After one year of treatment, full removal plots had the lowest aerial dry biomass (108 ± 15 g) followed by plots with full removal once a reed stem was at least 2m tall (197 ± 81 g), followed by plots where only 2 m or taller stems were removed (593 ± 466 g) and control (3296 ± 232 g). Several reed plants died after the first year of the experiment. Although more trials and long term follow up are needed, our results suggest that harvest can be an efficient control method for reed-infested wetlands in Western Mexico.

**Key words:** Herbicide, native species, removal, restoration, water supply.

## RESUMEN

El carrizo (*Phragmites australis*) invade humedales a nivel mundial y desplaza a especies nativas. Se controla con herbicidas pero ésto puede causar impactos ambientales negativos. Una alternativa es la cosecha de la biomasa aérea, la cual se probó en los humedales del manantial de la Mintzita, Michoacán, en el occidente de México. La cosecha incrementa el establecimiento de especies nativas, pero la riqueza de especies varía en función del método de cosecha. En parcelas en donde el carrizo se removió completamente cada dos meses, 9 especies nativas se establecieron, el mismo número que en parcelas en donde se removió el carrizo cuando un tallo alcanzara los 2 m de altura. En parcelas en donde sólo se removieron tallos de dos metros de altura o más, se establecieron 6 especies, y sólo tres en las parcelas control. La composición de especies y la capacidad de retoñar del carrizo ($F_{(3,20)} = 27$, $p < 0.000001$), se correlacionaron con el método de cosecha. Después de tan sólo un año, las parcelas de remoción total presentaron la menor biomasa (108 ± 15 g) seguida por la remoción total cuando un tallo alcanzara los dos metros de altura (197 ± 81 g), el tratamiento de remoción de tallos > 2 m (593 ± 466 g) y el control (3296 ± 232 g). Aunque se requieren ensayos de largo plazo en sitios invadidos, estos resultados sugieren que la cosecha de carrizo puede ser una medida de control eficiente en humedales invadidos en el occidente de México.

**Palabras clave:** Especies nativas, fuente de agua, herbicida, remoción, restauración.

## INTRODUCTION

Plant invasions displace native species, alter key ecosystem functions and are a main cause of biodiversity decline (Mack *et al.*, 2000). In wetlands, most invasions are fostered by human induced changes in disturbance regimes and nutrient loads (Alpert *et al.,* 2000; D´Antonio, 1993; Thompson *et al.*, 2001). Once established, invasive plant species can alter environmental conditions and the intensity and nature of biotic interactions (D´Antonio & Vitousek, 1992; Goldberg, 1990; Gordon, 1998; Vitousek *et al.*, 1987), resulting in dramatic changes in the composition of native communities (Howard & Goldberg, 2001; Reader& Bonser, 1993).

Common reed *(Phragmites australis* Cav. Trin ex. Steud.*)* is a coarse perennial grass with a worldwide distribution. It is common in brackish and freshwater wetlands (Gleason & Cronquist, 1963) especially in disturbed habitats along water bodies (Ailstock *et al.*, 2001Marks *et al.*, 1994; Saltonstall, 2002). It has been suggested that this species turns invasive after human induced changes in disturbance regimes, particularly changes in hydrological and nutrient regimes as well as salinity (Marks *et al.*, 1994).

Our experimental area, the Mintzita wetland complex, is located to the south of the city of Morelia, the capital of the state of Michoacán, México. The dominant species are cattail (*Typha domingensis* Presl.) and chairmaker's bulrush (*Schoenoplectus americanus* (Pers.) Volkart ex Schinz *et* Keller). Two major impacts on the wetlands are nitrogen inputs from the watershed and phosphorus release from fires (Escutia-Lara *et al.*, 2009). In recent years, *P. australis* has increased its cover in the wetlands, displacing native vegetation and altering hydrological regimes. Elsewhere, after invasion by *P. australis,* control measures were necessary to reduce its negative effects on natural wetland communities (Ailstock *et al.,* 2001). The Mintzita springs provides water for 300,000 inhabitants of Morelia and conservation and restoration of the area is required, including *P. australis* control.

*Phragmites australis* control has been done by applying herbicides, mostly glyphosate, to affected areas (Back & Holomuzki, 2008; Mozdzer *et al.*, 2008; Turner & Warren, 2003), but use of glyphosate can have the undersired environmental impact of causing damage to non target species (Tsiu & Chu, 2007). Furthermore, glyphosate, is no longer considered completely safe for humans (Williams *et al.*, 2000), because in recent studies it has been suggested that long term exposure to some formulations might pose risks to human health (Romano *et al.*, 2010). Since there are no official guidelines or norms regarding the use of herbicides in Mexican wetlands, and to avoid potential hazards to human populations, information on alternative reed control methods is needed. This is especially true for wetlands that provide drinking water, such as the Mintzita springs, that provide up to 40% of the water of the city of Morelia. One alternative control measure is the removal of aerial biomass, because eliminating the photosynthetic tissues of the plant can reduce posterior growth and spread of the species (Asaeda & Karunaratne, 2000). In some areas, harvesting during late summer has no effect because reserves have already accumulated in plant tissues (Husak ,1978), whereas harvesting after winter, when the plant has already sprouted, can have a considerable effect because the plant has low reserves (Karunaratne *et al.*, 2004), also continuous harvesting can significantly reduce *P. australis* biomass (Asaeda & Karunarante, 2000; Cizkova *et al.*, 1996; Rajapakse *et al.*, 2006; Van der Putten *et al.*, 1997). Therefore, it is necessary to determine the optimal harvesting regime depending on regional conditions (Ostendorp, 1995; Rajapake *et al.*, 2006). We compared the effect of four harvesting treatments in an area invaded by *P. australis* within Mintzita springs on native species establishment, in order to assess its management potential. Harvesting treatments simulated existing practice. Traditionally, stems are used for handcrafts, as well as for other purposes. Usually, only stems 2 m or taller are harvested (Gerritsen *et al.*, 2009), but removal of all stems can also be observed (Lindig-Cisneros, pers. obs.). Therefore, harvest of reed aerial biomass is socially accepted and provides an economic benefit.

## MATERIALS AND METHODS

An area invaded by *P. australis* was selected within the Mintzita wetlands (101°17'47" W, 19°38'43" N) for a harvesting experiment in 2009. The area has been studied for the last 5 years by biannual plant composition sampling of 30, 1 $m^2$ permanent plots across the water depth gradient (Escutia-Lara *et al.*, 2009). In our study site, *P. australis* grows all year round, although growth peaks during summer and slows from October to February, when some leaves senesce and isolated stems die. Within a *P. australis* invaded area where the water level did not varied significantly and was between soil level and 10 cm above it, all live and dead stems were removed at the beginning of the 2009 growing season (February), cut stems were not submerged after removal. Four harvesting treatments were chosen: 1) harvesting all stems every 60 days, 2) harvesting only stems that were 2 m or taller every 60 days, 3) when one stem reached 2 m tall harvesting all stems every 60 days, 4) and a no harvesting treatment as control (Table 1). Each treatment had 6 replicates, each in one 1 $m^2$ plot. Plots were placed at random leaving 50 cm between plots. Plant species cover by plot was recorded as percentage every 30 days, by dividing each plot in square decimeters and recording presence-absence in each, for a year and *P. australis* stem height was also evaluated by measuring all stems in the plots.

*Phragmites australis* response to the experimental treatments was analyzed by means of ANOVA with R software (R. Development Core Team, 2010), for all tests compliance with assumptions of homogeneity of variances and normality was checked. Species composition as affected by the treatments was tested with ANOSIM on a Bray-Curtis distance matrix (Manly, 2000) using vegan in R (Oksanen *et al.*, 2009). Comparison of species composition in reed-invaded plots with the composition of not-invaded plots within the same water depth area of the wetlands was done using the data of the permanent plots that have been monitored since 2005 (Escutia-Lara *et al.*, 2009) through a similarity analysis with Jaccard's index for presence-absence data using MVSP software (Kovach Computing Services, 1998.)

## RESULTS

Sixty days after initial removal of *Phragmites australis* live and dead stems in february 2009, plots showed vigorous sprouting of this species and a few individuals of other species. After 60 additional days, 4 species were observed (Table 2): *Hidrocotyle verticillata* Thunb., *Typha domingensis* and *Eupatorium rugosum* Kunth., and in one plot an individual of *Schoenoplectus americanus.* Throughout the experiment only a few individuals of *Hidrocotyle verticillata, Typha domingensis* and *Eupatorium rugosum* were found in control plots.

It was during June (120 days after the experiment started), at the beginning of the rainy season, that *P. australis* height (Fig. 1) as well as cover started to diverge between treatments, for example, only 10 plots had more than 50% cover (Table 2). Also, two new species were recorded in the plots, *Galium trifidium* L. in 23 plots and *Polygonum hidropiperoides* Michx. in two plots. In August (180 days after initial harvest), *Schoenoplectus americanus* was present in 6 plots and *Carex comosa* Booth was recorded for the first time in one plot. In the following months more species were recorded and most native species increased their cover, and seasonal changes in cover were also evident (Table 2). Using the October cover data, the month when more species were present at the end of the rainy season, Bray-Curtis distances correlated with removal treatments (ANOSIM, R=0.4514, $p$=0.0099).

Table 1. Number of plots harvested of each treatment at each harvesting interval (in days after the experiment was started).

| Treatments | 60 days | 120 days | 180 days | 240 days | 300 days |
|---|---|---|---|---|---|
| Control (D) | 0 | 0 | 0 | 0 | 6 |
| A | 6 | 6 | 6 | 6 | 6 |
| B | 0 | 6 | 6 | 5 | 5 |
| C | 0 | 6 | 6 | 4 | 1 |

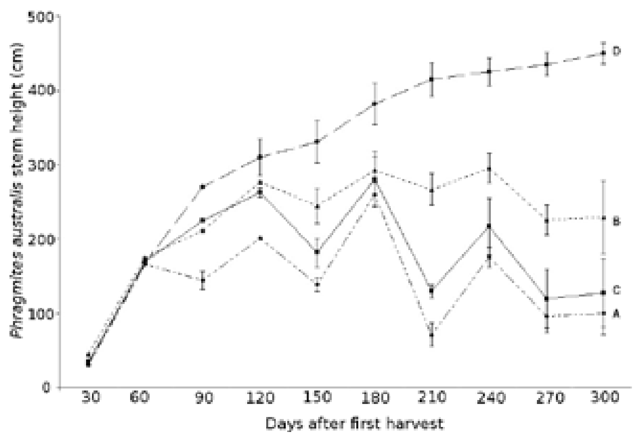


Figure 1. *Phragmites australis* mean stem height by treatment during the duration of the experiment. Treatments were: (A) removal of all *P. australis* stems every two months, (B) removal of stems 2 m or taller every two months, (C) removal of all stems if at least one reached 2 m in height, and (D) control.

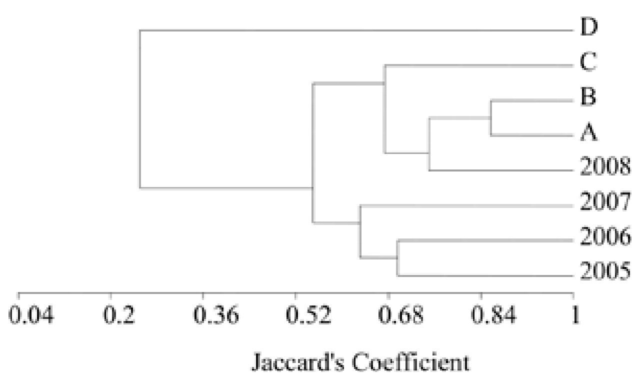


Figure 2. A comparison of experimental and permanent plots (evaluated from 2005 to 2008) using cluster agglomerative analysis based on Jaccquard's distance between plot's species composition. Treatments in 2009 were: (A) removal of all *P. australis* stems every two months, (B) removal of stems 2 m or taller every two months, (C) removal of all stems if at least one reached 2 m in height, and (D) control.

Table 2. Cover (%) of *Phragmites australis* and native species present in the experimental plots at each harvest date after the initial harvest in February 2009. Treatments where: A) removal of all *P. australis* stems every two months, B) removal of stems 2 m or taller every two months, C) removal of all stems if at least one reached 2 m in height. Control plots not shown because only a few individuals of *Hidrocotaly verticillata, Typha domingensis* and *Eupatorium rugosum* were found all along the experiment.

| | | Days after initial harvest | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Species | Treatment | 60 | 90 | 120 | 150 | 180 | 210 | 240 | 270 | 300 |
| *Phragmites australis* Cav. Trin ex. Steud. | A | 83 | 30 | 45 | 31 | 37 | 18 | 24 | 21 | 21 |
| | B | 84 | 55 | 42 | 43 | 42 | 43 | 44 | 45 | 45 |
| | C | 84 | 47 | 59 | 38 | 39 | 33 | 27 | 21 | 21 |
| *Carex comosa* Booth | A | | | | | | | | 1 | 1 |
| | B | | | | 1 | 2 | 2 | 2 | 2 | 2 |
| | C | | | | | | | | | |
| *Cyperus niger* Ruiz *et* Pav. | A | | | | | | | | | |
| | B | | | | | | | | 1 | |
| | C | | | | | | | | 1 | 1 |
| *Epilobium ciliatum* Raf. | A | | | | | | | | | 1 |
| | B | | | | | | | | | |
| | C | | | | | | | | | |
| *Eupatorium rugosum* Kunth | A | 3 | | | 2 | 4 | 13 | 9 | 19 | 19 |
| | B | 3 | | | 3 | 4 | 6 | 5 | 13 | 13 |
| | C | 3 | 1 | 1 | 2 | 6 | 5 | 8 | 17 | 16 |
| *Galium trifidium* L. | A | 0 | 11 | 15 | 20 | 2 | 1 | | 3 | 3 |
| | B | 0 | 12 | 15 | 19 | 3 | 2 | | | |
| | C | | 17 | 6 | 13 | 4 | 2 | 3 | 6 | 7 |
| *Hidrocotyle verticillata* Thunb. | A | 8 | 49 | 30 | 33 | 33 | 34 | 36 | 28 | 28 |
| | B | 8 | 21 | 34 | 20 | 29 | 27 | 24 | 18 | 18 |
| | C | 8 | 27 | 25 | 34 | 31 | 30 | 35 | 38 | 38 |
| *Mimulus glabratus* Kunth | A | | | | | | | 1 | 3 | 3 |
| | B | | | | | | | 1 | 2 | 2 |
| | C | | | | | | | 3 | | |
| *Poaceae* 1 | A | | | | | | | | | |
| | B | | | | | | | | 1 | 1 |
| | C | | | | | | | | | |
| *Poaceae* 2 | A | | | | | | | | 1 | |
| | B | | | | | | | | 1 | 1 |
| | C | | | | | | | | | |
| *Polygonum hydropiperoides* Michx. | A | | | 2 | 2 | 3 | 3 | 6 | 5 | 5 |
| | B | | | 2 | 2 | 1 | 2 | 4 | 2 | 2 |
| | C | | | 1 | 4 | 3 | 3 | 6 | 3 | 3 |
| *Rorippa palustris* (L.) Besser | A | | | | 1 | 1 | | 3 | | |
| | B | | | | | 2 | 1 | 2 | | |
| | C | | | | 1 | | 1 | 1 | | |
| *Schoenoplectus americanus* (Pers.) Volkart ex Schinz *et* R. Keller | A | 1 | | | | | | | 3 | 4 |
| | B | | | | | | | | 2 | 3 |
| | C | | | | | | | | | |
| *Typha domingensis* Pers. | A | 5 | 11 | 8 | 13 | 22 | 32 | 22 | 18 | 18 |
| | B | 5 | 12 | 8 | 13 | 18 | 19 | 18 | 15 | 15 |
| | C | 5 | 9 | 8 | 8 | 18 | 26 | 21 | 14 | 14 |

A comparison of experimental and permanent plots (evaluated from 2005 to 2008) using cluster agglomerative analysis based on Jaccquard's distance between plot's species composition shows that removal treatments are closer to permanent plots evaluated in 2008 (Fig. 2). Control plots do not clustered with other treatment or permanent plots evaluated in 2005 and 2006 that are clustered together, because they share 16 of the 21 species present in the study area and are similar to plots evaluated in 2007 because these plots share 12 species of 21 with those of 2005 and 2006. At the end of the experiment, treatment A (complete removal) had 9 species and also treatment B (removal of all stems when at least one reached 2 m in height) being the most similar, and close to treatment C (only stems 2 m high or taller removed) plots that had 6 species .

Trends in species composition were correlated with removal treatments because *P. australis* became less abundant in harvested treatments, in particular the treatment of full removal every 60 days, and differences were found at the end of the removal experiment. Treatment A, full removal, had the lowest aerial dry biomass of all treatments at the end of the experiment (108 ± 15 g) followed by treatment C, full removal once a stem reached 2 m in height (197 ± 81 g ), treatment B, where only 2 m or higher stems were removed (593 ± 466 g) and finally control (3296 ± 232 g). The differences among treatments were significant ($F_{(3,20)} = 92$, $p < 0.000001$). Differences in height among treatments (A = 83 ± 33 cm, B = 225 ± 121 cm, C = 100 ± 80 cm, D = 437 ± 35 cm), were also significant ($F_{(3,20)} = 27$, $p < 0.000001$). All *P. australis* plants died in 3 plots.

## DISCUSSION

Harvesting of *Phragmites australis* reduced sprouting and aerial biomass accumulation as other experiments have shown (Asaeda & Kurunaratne, 2000; Healy *et al.*, 2007; Husak, 1978; Karunaratne *et al.*, 2004; Rajapakse *et al.*, 2006; van der Putten *et al.*, 1997), and native species were able to colonize harvested plots. When comparing, using a dendrogram, native species present in the experimental plots with those of the permanent plots within the adjacent area of the wetland it was noticeable that permanent plots from 2005 to 2007 clustered together. Plots monitored in 2008 clustered with harvest treatments. The Mintzita wetlands have been subjected to increased human disturbance in the last decade changing species composition in our permanent plots (Escutia-Lara *et al.*, 2009). In fact, permanent plots were not evaluated in 2009 because a provoked fire burned them just weeks before the scheduled sampling date. Harvest treatments, in particular full removal (A) and removal of stems 2 m in height or taller (B), clustered with plots evaluated in 2008, the closest sampling date of the permanent plots. Harvesting of all *P. australis* stems when at least one of them reached 2 m in height (treatment C) was not as close in species composition to permanent plots, probably because the harvest date of a particular plot was not necessarily the same as in treatment A. Therefore, the amounts of biomass removed were more variable, as reflected in the last harvest date, when this treatment was the most variable of all.

For management of *P. australis* in our study area, several conclusions can be reached. First, there is not optimal season for removal, unlike in other areas where this species is present (Asaeda *et al.*, 2002; Asaeda & Karunaratne, 2000; Bjorndahl, 1985; Gryseels, 1989a; Gryseels, 1989b; Husak, 1978). Second, it is important to note that the area intervened in this study was small, nevertheless, because removal is done manually, damage to the soil would be minimal even in larger projects. Also, in larger project where propagules might no be available planting of desired species might be needed.

Third, although all harvest treatments allow native species to establish, species composition in harvested treatments that are similar to the traditional use of the species (Gerritsen *et al.*, 2009) are more similar to the composition of the natural wetland. Therefore, harvesting can be an efficient control method of this species in infested wetlands in Western Mexico because local human populations already use the resource following a method that can be adapted for control.

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