

Determining the timing of willow shrub dieback using epicormic shoots

Kristen M. Kaczynski · David J. Cooper

Received: 15 May 2014 / Accepted: 20 August 2014
© Springer Science+Business Media Dordrecht 2014

Abstract Riparian willows are declining throughout the Rocky Mountains, USA. Dendrochronological methods can be used to age dieback and disturbance dates in trees, however, these methods are not suitable for multi-stemmed shrub species. We present a new method for aging willow dieback using epicormic shoots and compare our findings with an aerial photo analysis of our riparian valley study site in Rocky Mountain National Park. Epicormic shoots initiate when stem wounding affects the apical meristem. We determined the date of stem death by comparing the age of the dead stem above a wound with the age of the live stem below a wound. Epicormic shoots initiated below wounds an average of 2 years prior to stem death, suggesting that it takes stems 2 years to die after being wounded. Aerial photo analysis demonstrated a sharp decline in willow canopy cover across the valley and we show a coinciding increase in epicormic shoots during the period of willow canopy decline. This was followed by a decrease in the number of epicormic shoots formed per year as the number of tall stems able to produce epicormic shoots has decreased. Age analysis of epicormic shoots is a promising new

method for examining local scale willow dieback and decline.

Keywords Stem aging · Stem growth · Epicormic shoot · *Salix* spp. · Willow

Introduction

The decline of woody riparian vegetation has been reported throughout the western United States (Busch and Smith 1995; Obedzinski et al. 2001; Williams and Cooper 2005). The likely causes include natural and anthropogenic processes including dams and water diversions (Merritt and Cooper 2000), groundwater depletion (Lite and Stromberg 2005; Hultine et al. 2010), exotic plant species invasions (Reynolds and Cooper 2010), pathogens (Nossov et al. 2011; Kaczynski and Cooper 2013), and native ungulate herbivory (Peinetti et al. 2002; Wolf et al. 2007). Shrub willows (*Salix* spp.) that dominate riparian zones in the mountainous western U.S. have declined precipitously (Peinetti et al. 2002; Kaczynski et al. 2014). Elk (*Cervus canadensis*) and moose (*Alces alces*) browse riparian willows (Hobbs et al. 1981; Kufeld 1994) and in some areas have created and maintain short stature willows that negatively affect other species, for example reducing songbird breeding and nesting habitat (Baril et al. 2011). Red naped sapsuckers (*Sphyrapicus nuchalis*, hereafter

K. M. Kaczynski (✉) · D. J. Cooper
Graduate Degree Program in Ecology and Department of
Forest and Rangeland Stewardship, Colorado State
University, 1472 Campus Delivery, Fort Collins,
CO 80523, USA
e-mail: kristen.kaczynski@colostate.edu

sapsucker) influence willows by creating sap wells that facilitate infection by the fungus *Valsa sordida* (Cytospora canker) resulting in the death of stems above the wound (Kaczynski et al. 2014).

Determining the timing of individual plant and plant species declines can be informed by the analysis of repeat aerial photography (Peinetti et al. 2002). However, many years to decades typically occur between photographs making it impossible to accurately identify the timing of dieback. The use of dendrochronology in aging tree death and dates of disturbance events is widely used (Speer 2010), but identifying the age of dead stems is difficult with multi-stemmed shrubs. Stems on one plant may grow at different rates and dendrochronological methods for cross dating are not suitable. However, stems have a compensatory response to disturbance with individual stems producing epicormic shoots from lateral meristems when the apical meristem is damaged (Meier et al. 2012). This mechanism for regrowth after fire or herbivory occurs during the year of disturbance and is common for willows (Zvereva and Kozlov 2001; Stromberg and Rychener 2010). Our previous research has demonstrated that 68 % of sapsucker wounded stems produced epicormic shoots the year of wounding (Kaczynski et al. 2014).

We introduce a new method to identify the timing of plant level stem dieback on shrub willows. The aging of epicormic shoots can be used to determine years when stems are damaged and the year the apical meristem is injured and dies. We compare this method to aerial photo analysis of willow dieback the same riparian valley. Finally, we suggest some applications of this method for management of wetland ecosystems.

Materials and methods

Study area description

The Kawuneeche Valley study area encompasses a 12.5 km reach of the Colorado River headwaters within Rocky Mountain National Park (RMNP) (40°22'N and 105°51'W). The valley ranges from 0.4 to 1.6 km wide with a mean elevation of 2,686 m. Mean annual precipitation is 640 mm with 42 % falling as snow at the Phantom Valley SNOTEL station (CO05J04S, elevation 2,750 m) and 885 mm

with 84 % falling as snow at the Lake Irene SNOTEL station (CO05J10S, elevation 3,260 m). The long-term mean December and July air temperatures in the valley are -9.6 and 12.4 °C. The valley hydrologic regime is characterized by spring snowmelt driven floods and low later summer flows. Beaver dams along the Colorado River may divert up to 70 % of the flow from the channel onto the floodplain (Westbrook et al. 2006). However, within the last decade, there has been a decline in beaver and few beavers occur likely due to the lack of suitable tall willows for food and dam construction. Vegetation in the valley includes riparian shrublands dominated by *Salix monticola*, *S. geyeriana*, *S. drummondiana*, wet meadows dominated by *Deschampsia cespitosa* and *Calamagrostis canadensis*, and peat-accumulating fens dominated by *S. planifolia* and *Carex aquatilis*. Hillslope vegetation is dominated by *Pinus contorta*, *Picea engelmannii* and *Abies lasiocarpa*. Plant nomenclature follows Weber and Wittmann (2012).

Dating initiation years of epicormic shoots

Seventy stems with sapsucker wounds, apical meristem dieback and epicormic shoots present below the wound, were collected in the study area in June 2010 and 2011. All stems were independent and collected from different plants of the four dominant tall willow species: *S. monticola*, *S. geyeriana*, *S. drummondiana* and *S. planifolia*. The epicormic shoot was removed at its base adjacent to the main stem, and a cross section mounted, sanded and the number of growth increments on the shoot counted to determine the number of years since its initiation (Fig. 1). In addition, we collected a cross section of the stem at or just above and below the sapsucker wound, and these sections were similarly analyzed. All stem sections were sanded and growth increments counted (Fig. 1).

The date of epicormic stem initiation was determined by counting growth increments on the epicormic stem and subtracting the total from the year of the outer ring (for stems collected in 2010, this was 2009 and for stems collected in 2011, this was 2010). Because we found that epicormic shoots initiate the year of stem disturbance (Kaczynski et al. 2014) the number of years from injury to death of the dead stem was determined by subtracting the number of growth increments on the dead stem from the number of growth increments on the epicormic stem (Eq 1).

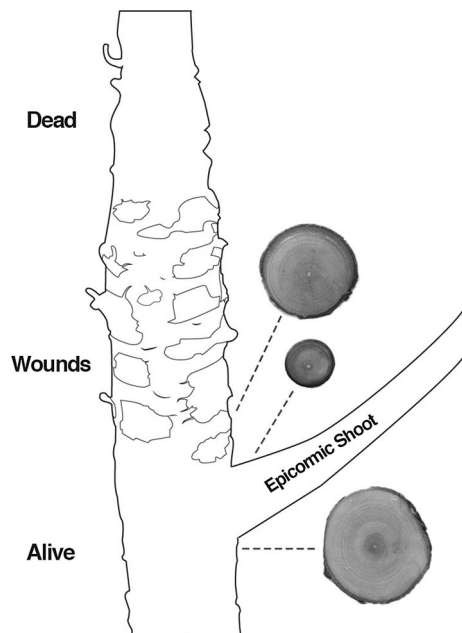


Fig. 1 Schematic of a sampled willow stem. *Stem above* wound was dead, *stem below* wound was alive and an epicormic shoot had initiated below the wound. *Dotted lines* depict where stem was cross sectioned for aging. (Figure created by Elijah Joe Cooper)

$$\begin{aligned} \text{Years from injury to stem death} \\ = \text{Age}_{\text{epicormic shoot}} - \text{Age}_{\text{dead stem}} \end{aligned} \quad (1)$$

Due to the close proximity of the live and dead stem sections (approximately 5 cm apart), we assumed that the difference in the ring count from the live stem and the dead stem was due to the stem's death. The year of stem death was determined by adding the number of growth increments from the live stem and the dead stem, and subtracting this from the year of the outer ring on the live stem (for stems collected in 2010, this ring was 2009 and for stems collected in 2011, this was 2010) (Eq 2).

$$\text{Year}_{\text{death}} = \text{Year}_{\text{outer ring}} - \text{Age}_{\text{live stem}} + \text{Age}_{\text{dead stem}} \quad (2)$$

Methods for the aerial photo analysis are described in Kaczynski et al. (2014). There is a gap in aerial photo coverage between 2001 and 2005, when the large decrease in willow cover occurred. We compared the timing of willow stem death determined through dating epicormic shoots with the timing of willow cover decline as quantified using aerial photo analysis.

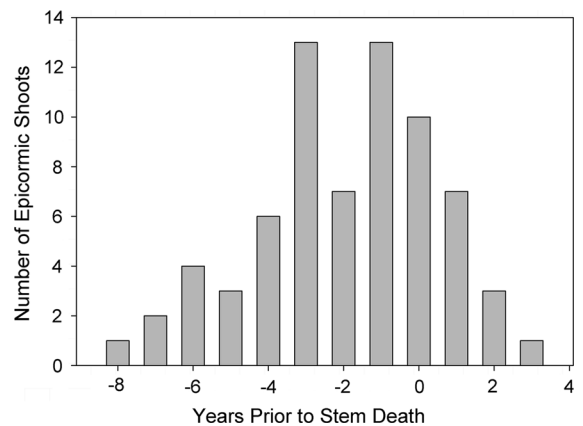


Fig. 2 Epicormic shoot initiation prior to stem death. *Negative numbers* indicate epicormic shoot initiated prior to stem death

Results

Shoots initiated an average of two years prior to stem death above the wound (Fig. 2) indicating that most stems did not die immediately following disturbance. Sixty two percent of stems died the year of stem disturbance to three years after disturbance.

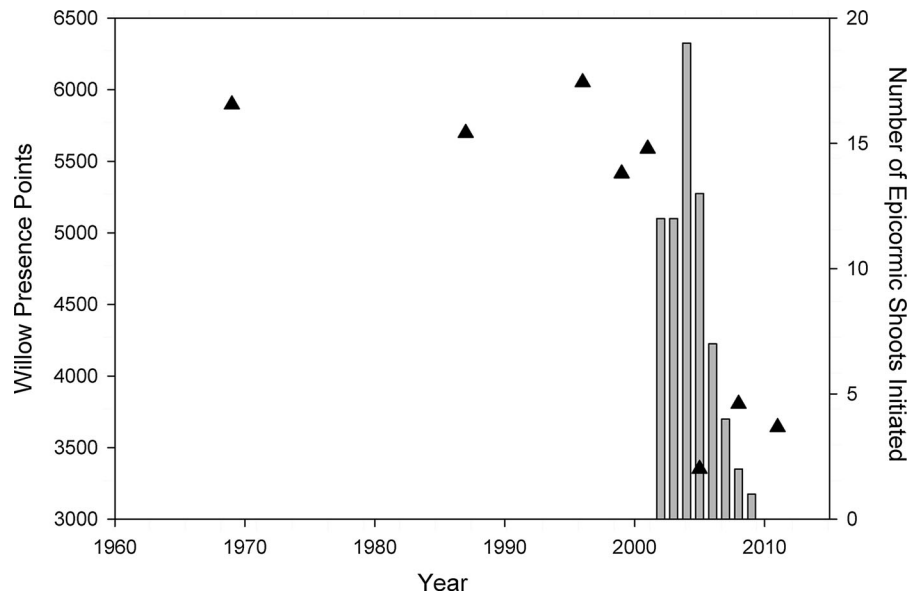
The sharp decline in epicormic shoot initiation after 2005 coincided with the decrease in willow cover in the valley identified using aerial photographs (Fig. 3). Seventy five percent of epicormic shoots initiated between 2001 and 2005 indicating that tall willow stems were experiencing high levels of disturbance during this period resulting in apical meristem death. In addition, 70 % of sampled stems died between 2003 and 2007.

Discussion

Dendrochronology and the cross-dating of growth increments are often used to measure tree growth and forest dynamics, including years since disturbance and tree deaths (Speer 2010). To date, no study has examined the temporal dynamics of shrub willow diebacks, because each stem can be a different age. We have presented a method for identifying the year stems were first disturbed and the year they died using epicormic shoot initiation.

Epicormic shoots are prevalent on many tree and shrub species and arise in response to a stem

Fig. 3 Willow presence points (*triangles*) as quantified through aerial photo analysis (Kaczynski et al. 2014). *Bars* are numbers of epicormic shoots initiated. Decrease in epicormic shoot initiation follows decrease in willow cover in the study area



disturbance that initiates stress on the apical meristem. Wilson (1997) investigated the response of understory stems to bending and demonstrated that epicormic shoots developed on the majority of his study species during the first year. Remphrey and Davidson (1992) observed an increase in epicormic shoot production in *Fraxinus pennsylvanica* corresponding with an increase in mortality of older shoots. On our study willows, stem death occurred on average 2 years after epicormic shoot initiation.

In our study area willow community canopy cover was stable for at least the 40 years prior to 2001 based on air photo records. The initiation of each epicormic shoot occurred the year the main stem was stressed or disturbed. This indicated that in the time period between 2001 and 2005 when aerial photos for the site are lacking, epicormic shoot initiation was highest, indicating apical meristem and willow canopy dieback.

Willow stem dieback and epicormic shoot development is a natural process in willow stands, as sapsuckers are an integral part of these riparian ecosystems and drivers of stem dieback. However, historically stems that died likely were replaced by epicormic shoots that reached full height in several years (Kaczynski et al. 2014). Increased ungulate browsing, potentially due to the increasing presence of resident moose after 2001 led to a change in the processes shaping willow ecosystems (Kaczynski and Cooper 2013). Ungulates browse the epicormic

shoots, preventing them from attaining full height, producing plants that are of short stature.

Analysis and aging of epicormic shoots is an important method for determining the timing of shrub stem dieback. We validated these methods on species of the genus *Salix*, however, it is possible that these methods could be used successfully on other species of riparian shrubs, such as *Populus* spp. and could further our understanding of riparian ecosystem management. We have demonstrated the effectiveness of epicormic shoots in determining years of disturbance, damage and subsequent dieback to the apical meristem. Researchers may find this method useful for providing insight into the timing and cause of stand change under increased ungulate browsing, fungal infection, the timing of beaver cutting or purposefully cutting by humans.

Acknowledgments The study was funded by the National Park Service RMNP, Rocky Mountain Nature Association and a George Melendez Wright climate change fellowship through the National Park Service Climate Change program. We thank J. Visty, J. Connor and B. Bobowski at RMNP for logistical and financial support. We also thank A. Carlson for help in the field and processing the stem sections. E. Gage provided helpful comments on an earlier draft.

References

- Baril LM, Hansen AJ, Renkin R, Lawrence R (2011) Songbird response to increased willow (*Salix* spp.) growth in Yellowstone's northern range. *Ecol Appl* 21:2283–2296

- Busch DE, Smith SD (1995) Mechanisms associated with decline of woody species in riparian ecosystems of the southwestern US. *Ecol Monogr* 65:347–370
- Hobbs NT, Baker DL, Ellis JE, Swift DM (1981) Composition and quality of elk winter diets in Colorado. *J Wildl Manag* 45:156–171
- Hultine K, Bush S, Ehleringer J (2010) Ecophysiology of riparian cottonwood and willow before, during, and after two years of soil water removal. *Ecol Appl* 20:347–361
- Kaczynski KM, Cooper DJ (2013) Susceptibility of *Salix monticola* to Cytospora canker under increased temperatures and decreased water levels. *For Ecol Manag* 305:223–228
- Kaczynski KM, Cooper DJ, Jacobi WR (2014) Interactions of sapsuckers and Cytospora canker can facilitate decline of riparian willows. *Botany* 92:485–493
- Kufeld RC (1994) Status and management of moose in Colorado. *Alces* 30:41–44
- Lite S, Stromberg J (2005) Surface water and ground-water thresholds for maintaining *Populus-Salix* forests, San Pedro River, Arizona. *Biol Conser* 125:153–167
- Meier AR, Saunders MR, Michler CH (2012) Epicormic buds in trees: a review of bud establishment, development and dormancy release. *Tree Physiol* 32:565–584
- Merritt DM, Cooper DJ (2000) Riparian vegetation and channel change in response to river regulation: a comparative study of regulated and unregulated streams in the Green River Basin, USA. *Regul Rivers: Res Manag* 16:543–564
- Nossov DR, Hollingsworth TN, Ruess RW, Kielland K (2011) Development of *Alnus tenuifolia* stands on an Alaskan floodplain: patterns of recruitment, disease and succession. *J Ecol* 99:621–633
- Obedzinski RA, Shaw C, Neary DG (2001) Declining woody vegetation in riparian ecosystems of the western United States. *Wes J Appl For* 16:169–181
- Peinetti HR, Kalkhan MA, Coughenour MB (2002) Long-term changes in willow spatial distribution on the elk winter range of Rocky Mountain National Park (USA). *Landsc Ecol* 17:341–354
- Remphey W, Davidson C (1992) Spatiotemporal distribution of epicormic shoots and their architecture in branches of *Fraxinus pennsylvanica*. *Can J For Res* 22:336–340
- Reynolds LV, Cooper DJ (2010) Environmental tolerance of an invasive riparian tree and its potential for continued spread in the southwestern US. *J Veg Sci* 21:733–743
- Speer JH (2010) Fundamentals of tree-ring research. University of Arizona Press, Tucson
- Stromberg JC, Rychener TJ (2010) Effects of fire on riparian forests along a free-flowing dryland river. *Wetlands* 30:75–86
- Weber WA, Wittmann RC (2012) Colorado flora. University Press of Colorado, Boulder
- Westbrook CJ, Cooper DJ, Baker BW (2006) Beaver dams and overbank floods influence groundwater-surface water interactions of a Rocky Mountain riparian area. *Water Resour Res* 42:W06404. doi:10.1029/2005WR004560
- Williams CA, Cooper DJ (2005) Mechanisms of riparian cottonwood decline along regulated rivers. *Ecosystems* 8:382–395
- Wilson BF (1997) Response to stem bending in forest shrubs: stem or shoot reorientation and shoot release. *Can J Bot* 75:1643–1648
- Wolf EC, Cooper DJ, Hobbs NT (2007) Hydrologic regime and herbivory stabilize an alternative state in Yellowstone National Park. *Ecol Appl* 17:1572–1587
- Zvereva E, Kozlov M (2001) Effects of pollution-induced habitat disturbance on the response of willows to simulated herbivory. *J Ecol* 89:21–30