Research Reports

Paper birch: Sentinels of climate change in the Niobrara River Valley, Nebraska

By Esther D. Stroh

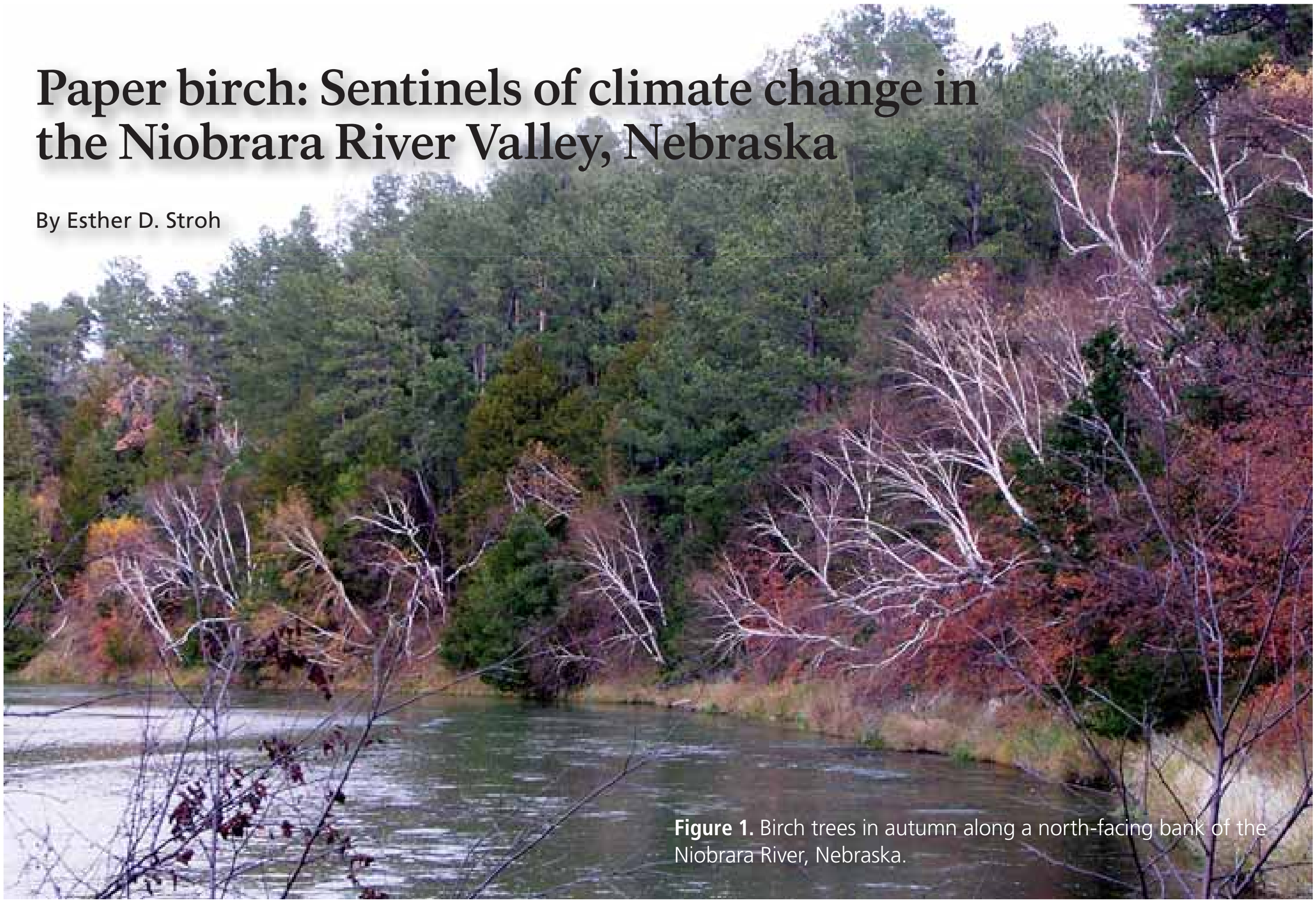

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Figure 1. Birch trees in autumn along a north-facing bank of the Niobrara River, Nebraska.

THE NIOBRARA NATIONAL SCENIC River, in north-central Nebraska, is known for encompassing a wide mix of species at or beyond their typical geographic ranges. Plants representative of eastern and western forests and several prairie types are maintained by localized microclimates that change abruptly with differences in topography, soils, slope, and moisture (Kaul et al. 1988). For example, paper birch trees (*Betula papyrifera* Marsh) can be found on north-facing slopes on the south bank of the river and in small protected canyons on both the north and south sides of the river (fig. 1). Paper birch is typically an important component of boreal forests, but here in the middle of the Great Plains, remnant populations remind us that the area once supported a very different mix of vegetation under different climatic regimes. Birch populations are believed to have persisted in the Niobrara River Valley since the end of the Wisconsin glaciation, when conditions supported boreal species (Wright 1970).

Paper birch rarely occurs naturally where average July temperatures exceed 21°C (70°F; USDA 1965). The average July temperature in Valentine, Nebraska, 4 km (2.5 mi) from the nearest birch trees,

Abstract

The Niobrara River Valley in the northern Great Plains supports scattered stands of paper birch (*Betula papyrifera* Marsh), a species more typical of boreal forests. These birch stands are considered to be relictual populations that have persisted since the end of the Wisconsin glaciation. Localized summer microclimates have likely facilitated the persistence of birch populations in a region otherwise unsuitable for the species. Dieback of canopy-sized birch has been observed throughout the valley in recent years, although no onset dates are documented. Changes in spring weather patterns may be causing rootlet injury so that trees die in spite of the still-cool summer microclimates. Current weather patterns, combined with little evidence of recruitment of young birch and great geographic distances from potential immigrant sources, make the future persistence of birch in the Niobrara River Valley stands uncertain.

Key words

Betula papyrifera, climate change, crown dieback, Niobrara National Scenic River, paper birch, relict plant populations

is 23°C (73°F; National Weather Service 2008). However, relict populations can persist for thousands of years outside of their typical range in sites with favorable microclimates (Stebbins and Major 1965). Presumably, microclimates in birch sites have maintained birch populations for roughly 10,000 years. However, resource managers have observed many dead or dying birch trees in recent years (fig. 2); in some sites, nearly all trees have died. Why are they dying now after such a long presence in the Niobrara Valley?

Background

Widespread dieback of paper birch has been observed in other areas, and these events have been associated with atypical weather patterns. For example, from 1935 to 1945 in Maine and Nova Scotia, 67% of paper and yellow birch (*Betula alleghaniensis* Britt) died and 15% of remaining trees were dying (Nash and Duda 1951). Later, this dieback event was attributed to low winter temperatures, late spring freezes, years with below-average winter snow cover, combined with below-average temperatures and years with above-average spring temperatures (Greenidge 1953; Braathe 1995). Plant developmental stages such as flowering and bud burst typically occur after a certain amount of heat accumulation in the spring, also known as growing degree days (GDD). Some crops and native plants can be injured if a hard freeze occurs after plants have reached certain early growth stages. Crown dieback in birch is an expression of rootlet mortality, and shallow birch roots can be injured by thawing and then refreezing. Specifically, a spring thaw-freeze cycle of March growing degree days greater than 50°C (equivalent to GDD greater than 90°F), followed by April or May temperatures below −4°C (25°F), can induce root injury and subsequent crown dieback in paper birch (Braathe 1995). Damaged birch roots are less able to provide sufficient pressure to refill the stem xylem with sap in the spring, and the tree begins to die from the tips of the branches back to the main stem. These are the symptoms presented by the Niobrara birch trees.

Methods

Could atypical weather patterns in recent years explain dieback of the Niobrara birch trees? We used data loggers to record air temperature every half hour from June 2005 through October 2007 in 12 birch stands and compared these data against concurrent and historical data from the National Weather Service station in Valentine, Nebraska. We also assessed percentage of canopy dieback of 248 birch trees growing in these and 13 additional sites along approximately 68 km (42 mi) of the Niobrara River (fig. 3). Most sites were located on the south bank of the river on north-facing slopes or in north-facing canyons near the riverbank; a few stands were on the north side of the river in protected small canyons. Our results are reported in Stroh and Miller (2009).

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Figure 2. Dead and dying stems of paper birch amid apparently healthy stems.

Findings and discussion

We used the entire period of record available from the Valentine weather station (1948–2007) and simply divided it into two 30-year periods. We found that frequency of thaw-freeze conditions capable of inducing crown dieback increased significantly from 1978 to 2007 (the second half of the period of record) compared with 1948 to 1976, the first half of the period of record. From 1948 to 1976, 7 out of 30 years (23%) met the combination of a warm March followed by a cold snap in April or May; from 1977 to 2007, 15 out of 30 years (50%) met these conditions, a significant difference in proportion ($z = -2.179$, $p = 0.029$; Stroh and Miller 2009). Importantly, average April and May minimum temperatures in both periods were identical; increasing frequency of warm spells in March contributes to increased frequency of conditions that can induce rootlet injury in birch trees.

We also found microclimate differences among types of birch sites and among birch sites as compared with the Valentine weather station. During the crucial spring months, maximum temperatures were higher and minimum temperatures were lower in birch sites on the north side of the river than in those on the south side.

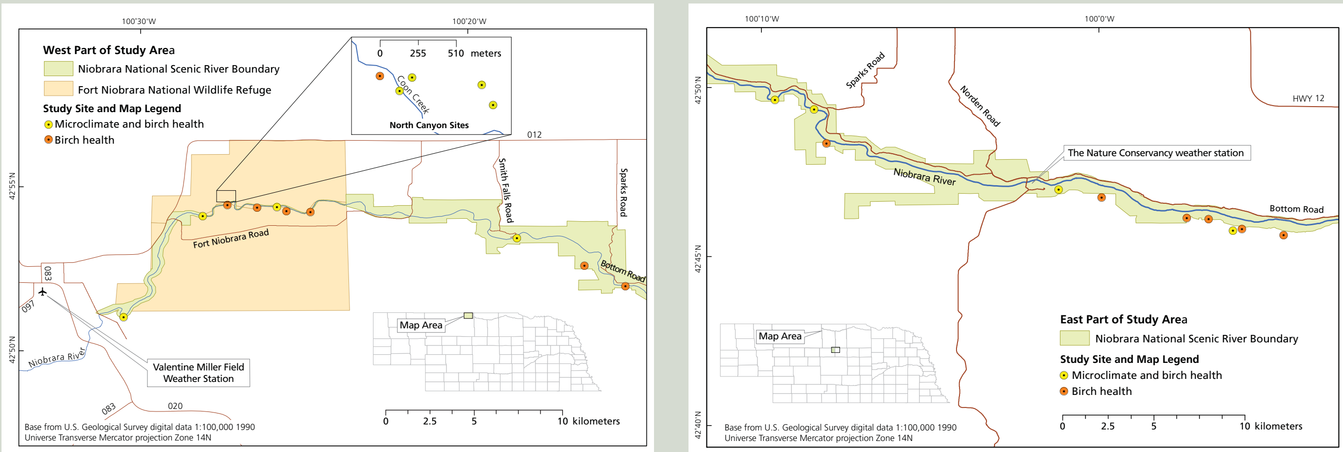

Figure 3. Western (left) and eastern (right) portions of study area showing study site locations. Modified from Stroh and Miller 2009.

Consequently, spring thaw-freeze conditions capable of inducing rootlet injury are likely more frequent in north bank sites; this is probably one reason why birch stands are less common there and why trees there are in worse condition (Stroh and Miller 2009). Meanwhile, spring maximum and minimum temperatures in birch stands on the south side of the river were not significantly different from conditions at Valentine. Thus spring temperatures recorded at Valentine are good predictors of when thaw-freeze conditions might be injurious to trees in these sites.

In summer months, mean daily temperature in all birch sites was about 2°C (3.6°F) cooler than in Valentine. During the study, all birch sites exhibited mean daily temperatures of approximately 22°C (72°F), as opposed to 24°C (75°F) at Valentine. Therefore, summer conditions in all birch sites were close to the 21°C (70°F) average July temperature range limit for birch (USDA 1965). Summer microclimates in these birch stands have likely facilitated the persistence of birch populations in a region otherwise unsuitable for the species and still appear to be close to the temperature limit for birch. Unfortunately, changes in spring weather patterns recorded at Valentine and reflected in birch sites may be causing rootlet injury so that trees die in spite of the still-cool summer microclimates.

Our study looked at weather patterns in a small area and cannot be interpreted as evidence of climate change. However, annual mean temperature in the Great Plains has increased about 0.8°C (1.5°F) compared to the 1960s and 1970s; spring temperatures are projected with 95% likelihood to increase within the next two decades by approximately 0.3 to 2.2°C (0.5 to 3.9°F; USGCRP 2009). Our findings (Stroh and Miller 2009) of significantly warmer March temperatures in the period 1978–2007 as compared to 1948–1977 are consistent with these observations and projections.

Increasing frequency of warm spells in March contributes to increased frequency of conditions that can induce rootlet injury in birch trees.

Although widespread birch dieback is known from other locations, Niobrara River Valley birch populations are isolated and far removed from potential immigrant sources. A large population decline in the context of increased frequency of potentially injurious climatic events will make population recovery more difficult now than in the years 1948–1977, when thaw-freeze conditions were less frequent. These conditions, combined with little evidence of recruitment of young birch and great geographic distance from potential immigrant sources, make future persistence of paper birch populations in the valley uncertain.

Although many trees will likely continue to die or die back, individual trees might improve if living stump sprouts continued to grow. We encountered only a handful of birch saplings in our study (Stroh and Miller 2009); nearly all the mature trees we observed consisted of multiple stems emanating from a common root system, evidence of vegetative reproduction. Smaller subcanopy birch trees die back at lower rates than more exposed canopy trees (Nash and Duda 1951); small trees may be able to survive even if warm spring weather continues to occur for some time. Assisted recruitment activities, such as propagating and planting birch trees, could help establish young trees that may grow to maturity, maintaining a seed source for future natural recruitment. Persistence via vegetative reproduction is common in relict populations; they can maintain themselves for many generations even with extremely rare recruitment events via sexual reproduction (Eriksson 1996). However, maintaining or reestablishing populations of canopy-sized trees may depend on a reduction in frequency of warm springs observed in recent years.

Management implications

National parks and other protected areas often encompass regionally unique habitat and therefore frequently harbor relict or disjunct plant populations. Typically, the farther a disjunct or relict population is from its core range, especially if it occupies unusual or unique habitat, the more likely it is to be on a different evolutionary trajectory (Leppig and White 2006). Consequently, relict and disjunct populations are likely to be ecologically and genetically distinct from core populations. Such populations are more susceptible to extirpation because they are usually isolated and small, but are also potentially important for speciation and preservation of evolutionary potential (Lesica and Allendorf 1995). The decline in paper birch populations in the Niobrara River Valley offers resource managers, policymakers, and the public the opportunity to weigh intervention costs against other resource management costs, the risk of failure, and benefits of maintaining species, ecological, and genetic diversity along with the evolutionary potential of species. In the case of the Niobrara Valley birch, loss of this species would eliminate the principal component of the boreal ecosystem represented in the valley, regionally known as the biological crossroads of the Great Plains. Leppig and White (2006) identified approaches to assess conservation value of relict or disjunct populations, including those with local cultural value. Birch populations along the Niobrara Scenic River in Nebraska present an excellent opportunity to incorporate biological and cultural values of relict populations into regional conservation planning efforts.

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About the author

Esther D. Stroh *is an ecologist with the U.S. Geological Survey, Columbia Environmental Research Center, 4200 New Haven Road, Columbia, MO 65201. She can be reached at estroh@usgs.gov.*

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