Forest Ecology and Management 347 (2015) 83–95

Contents lists available at ScienceDirect

Forest Ecology and Management

journal homepage: www.elsevier.com/locate/foreco

Tree-ring response of jack pine and scots pine to budworm defoliation in central Canada

J.R.M. Robson, F. Conciatori, J.C. Tardif *, K. Knowles

Centre for Forest Interdisciplinary Research (C-FIR), University of Winnipeg, Environmental Studies and Sciences, 515 Portage Avenue, Winnipeg, Manitoba R3B 2E9, Canada

ARTICLE INFO

Article history:
Received 31 August 2014
Received in revised form 20 February 2015
Accepted 9 March 2015
Available online 26 March 2015

Keywords:
Dendrochronology
Climate change
Insect outbreak
Plantation forestry
Exotic tree species
Pine sawfly

ABSTRACT

Insect outbreaks constitute major disturbances and global climate changes are expected to increase their frequency and severity. In Canada, an increase in outbreak severity of the jack pine budworm is expected as a consequence of more frequent droughts associated with climate changes. In this study, the impact of jack pine budworm defoliation on radial growth was assessed on two host species: jack pine (*Pinus banksiana* Lamb.) and scots pine (*Pinus sylvestris* L.). Standard tree-ring chronologies were developed for each host species in thirteen plantations established in the early 20th century and located in Spruce Woods Provincial Forest (central Canada). Radial growth suppressions caused by jack pine budworm defoliation were identified using a host and non-host comparison and calibrated against historical outbreak records. Five periods of major growth suppression were identified (1956–1958, 1966–1968, 1974–1977, 1979–1980 and 1984–1986) that matched historical jack pine budworm outbreaks. An annual tree-ring signature made up of a tree ring with thin latewood followed by a narrow ring most often characterized these growth suppressions. The occurrence of missing rings also increased during outbreaks. Based on the timing of suppression, jack pine was the initial host with scots pine often showing a one year lag in suppression. However, scots pine may be more sensitive to jack pine budworm defoliation as indicated by the abundance of missing rings during outbreak years. In the study area, jack pine budworm outbreaks were generally associated with the occurrence of dry summers and cool May temperatures. No outbreak occurred in the study area since the mid-1980s. The occurrence of droughts that were not synchronized with cool May temperatures suggests that warmer springs associated with climate changes could alter the phenological synchrony between the jack pine budworm and its host trees species. Future research should attempt to (i) relate the results of this study to natural forest stands where management practices (and non-native tree species) have not influenced the natural jack pine budworm population dynamics, (ii) assess the spatial dynamics of these outbreaks using a network of tree-ring chronologies and (iii) reconstruct outbreaks prior to historical surveys. Such research would help develop a better understanding of insect population dynamics and subsequent impacts on both European and North American forests under future climate changes.

1. Introduction

Insect outbreaks constitute major forest disturbances causing important volume loss and tree mortality in forests around the world (Haack and Byler, 1993; Fleming, 2000; Netherer and Schopf, 2010). In the scots pine (*Pinus sylvestris* L.) forests of northern Europe the most widespread outbreaks are from the large pine sawfly (*Diprion pini* L.) with growth losses and mortality rates recorded as high as 94% and 30% respectively (Lyytikäinen-Saarenmaa and Tomppo, 2002; Lyytikäinen-Saarenmaa et al., 2003). In North America's boreal forests, insect outbreaks cause the greatest loss in forest volume compared to any other forest disturbance including fire (Haack and Byler, 1993; Fleming, 2000; Bogdanski, 2008). Among these insects, the jack pine budworm (JPBW, *Choristoneura pinus pinus* Free., Order: Lepidoptera, Family: Tortricidae), a major defoliator of jack pine (*Pinus banksiana* Lamb.), causes repeated damage in commercially valuable stands. During the most widespread and severe JPBW outbreak recorded in central Canada (1982–1987) the forested area impaired by severe damage from JPBW defoliation reached over two million hectares in the province of Manitoba by 1985 (Volney, 1988; Grandmaison, 1991, 1993). The reduced volume and mortality associated with severe defoliation during periodic JPBW outbreaks rapidly lowers timber quality, reduces available harvest volume by as much as one third and can double the time

* Corresponding author. Tel.: +1 204 786 9475.
E-mail address: j.tardif@uwinnipeg.ca (J.C. Tardif).

http://dx.doi.org/10.1016/j.foreco.2015.03.018
0378-1127/

for a stand to reach a merchantable harvest size (Clancy et al., 1980; Moody and Amirault, 1992). Furthermore, both forest fire suppression and the predicted increase in drought stress under future climate change scenarios may lead to older stands with higher staminate cone abundance thus leading to more frequent and severe JPBW outbreaks (Volney, 1988; McCullough, 2000; Volney and Fleming, 2000).

1.1. Jack pine budworm (JPBW)

The JPBW is found throughout the entire range of its main host, jack pine, which has the largest natural range of any northern pine species in Canada (Freeman, 1953; Rudolph and Laidly, 1990; McCullough, 2000). The range of jack pine (Fig. 1) spreads across Canada from the Northwest Territories to Nova Scotia and also extends south to Minnesota, Wisconsin, Michigan and New York in the United States (Rudolph and Laidly, 1990; Conway et al., 1999b). Within its range the JPBW also defoliates scots pine, red pine (*Pinus resinosa* Ait.) and white pine (*Pinus strobus* L.) (Hodson and Zehngraff, 1946; Kulman et al., 1963; Reeks, 1971; McCullough, 2000). Scots pine is a non-native species that was introduced to North America during European settlement in the 17th century (Skilling, 1990). Severe JPBW defoliation has also been observed in non-native lodgepole pine (*Pinus contorta* Dougl. ex. Loud.) plantations in southwestern Manitoba (Brandt and McDowall, 1968; Walker, 1990).

The JPBW completes one lifecycle generation within 12 months over the course of two summers. The JPBW has seven distinct larval instars that cumulate with an adult moth (Nealis, 1995; McCullough, 2000). The adult moth is a short-lived phase that does not damage host trees but functions in reproduction and dispersal (McCullough, 2000). In the first year, the moth will lay eggs on host trees. The first instar larvae will emerge from the egg, spin a hibernaculum for winter diapause, molt and over winter as second instar larvae. Very little feeding occurs in the first year (McCullough, 2000). Between May and June of the second year, second instar larvae emerge from the hibernaculum and move into staminate cones to feed on pollen (Nealis and Lomic, 1994; Nealis, 1995; McCullough, 2000). By the time the pollen supply is exhausted, bud-break has usually occurred and the larvae will begin to feed on the current year's foliage. During an outbreak, high populations of the JPBW larvae will also feed on the previous year's foliage with the sixth and seventh larval instars doing the most damage (Clancy et al., 1980; Nealis et al., 1997). In mid-July the seventh instar larvae will pupate and adult moths will emerge within two weeks to begin the cycle again (McCullough, 2000).

Both larval development and survival in JPBW are influenced by climate conditions (Clancy et al., 1980; Ives, 1981; Volney, 1988; Nealis, 1990; Nealis et al., 1997). Extreme temperature fluctuations during the winter diapause were associated with high larvae mortality (Lysyk, 1989; Nealis, 1995). Warm dry conditions throughout the development stages of the larvae and pupae will favour higher survival rates (Clancy et al., 1980; Ives, 1981). However, research on the direct relationship between JPBW population survival and climate is sparse (Nealis, 1995; Volney and Fleming, 2000, 2007).

1.2. JPBW outbreaks

Jack pine budworm outbreaks have been recorded throughout the range of jack pine in both Canada and the United States (Kulman et al., 1963; Clancy et al., 1980; Volney, 1988). In Canada, large periodic JPBW outbreaks have mainly been reported for the central region including eastern Saskatchewan, Manitoba and northwestern Ontario (Fig. 1, Ives, 1981; Volney, 1988; Fleming, 2000). In Manitoba and Saskatchewan, populations of JPBW have been detected every year from 1937 to 1986 except 1980 and 1981 (Volney, 1988). Analysis by Volney (1988) indicated six major outbreaks within Manitoba with peaks in severity occurring in 1938, 1944, 1948, 1965, 1979 and 1985. Outbreaks usually last from one to four years with no more than two years of severe defoliation at the local scale (Clancy et al., 1980; Volney, 1988; McCullough et al., 1996; Kouki et al., 1997). In general, the interval

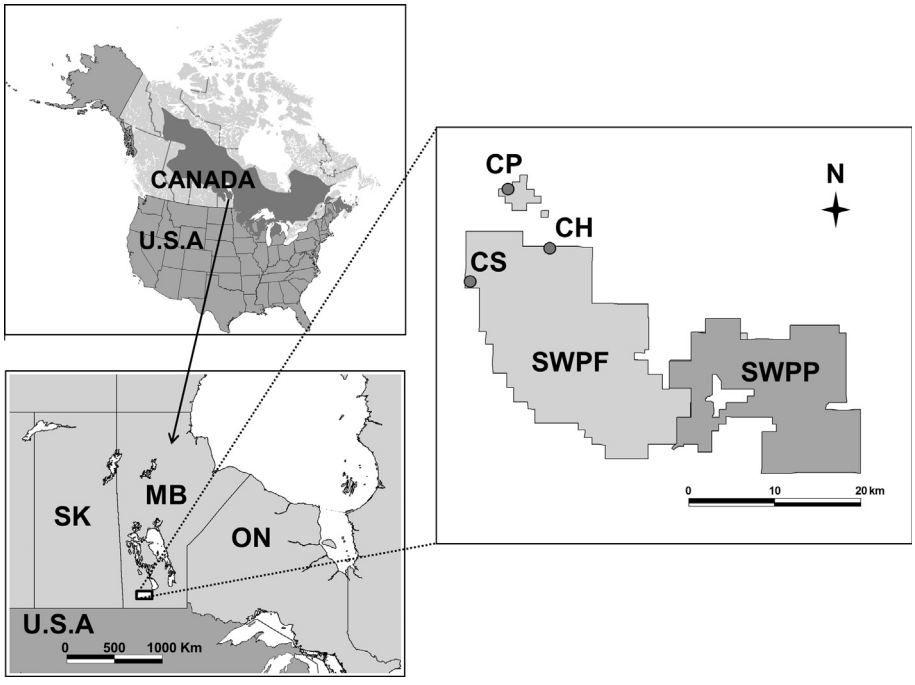

Fig. 1. Map of North America indicating the range of jack pine distribution (top left). Map of central Canada showing location of Manitoba, of Spruce Woods Provincial Forest (SWPF) and of Spruce Woods Provincial Park (SWPP) within SWPF (bottom left). Locations of plantation regions within SWPF (right): Camp Picnic (CP), Camp Hughes (CH), and Camp Shilo (CS).