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RESEARCH REPORT

FIRE HISTORY IN EUROPEAN BLACK PINE (*PINUS NIGRA* ARN.) FORESTS OF THE VALIA KALDA, PINDUS MOUNTAINS, GREECE

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ABSTRACT

The past fire regime of European black pine (*Pinus nigra* Arn.) forests in Valia Kalda in Greece was investigated by standard dendrochronology methods. The sampled trees contained a record of fires from the early 14th Century through the late 19th Century with the last fire recorded in 1891. Evidence of non-lethal surface fires over the past seven centuries suggests that in addition to its destructive power, fire also plays a role in ecological functioning of the region. This is the first fire history study in Greece and can provide a basis for development of the first fire history network in the region. It also provides insight and perspective that may be useful for planning and justifying future ecosystem management programs.

Keywords: fire history, tree rings, dendrochronology, European black pine, *Pinus nigra* Arn., Greece.

INTRODUCTION

Wildland fires are considered a common and destructive disturbance in the Mediterranean Basin. Because of the climate and vegetation, Mediterranean ecosystems have always been subjected to fire, and, thus, burning has become part of their dynamic natural equilibrium (Moreno and Oechel 1994). Greece has a long history of forest fires extending from before the birth of the modern country in 1830. During the period 1980–2000, an average of *ca.* 53,000 ha burned by 1,500 forest fires annually. The average fire size was 35 ha, which is the highest in Europe (Dimitrakopoulos and Mitsopoulos 2006).

Managing forests to account for the effects of fires requires knowledge of the frequency and distribution of the historical fire occurrence and its relationship with potential causative agents such as climate and forest management (Covington *et al.* 1997). Given that the instrumental record of climate in Greece is less than 100 years long and climate fluctuations that may influence fire frequency and behavior can last several decades, information on longer time scales must be sought from historical documents, natural archives, and other sources such as tree rings (Swetnam and Betancourt 1998). Surface fires in Mediterranean and semi-arid forest environments often result in non-lethal scarring of living trees caused by the "cooking" of the wood-producing cambium immediately under the bark. These fire-scarred trees can provide a record of fire occurrence over many centuries. Fires can be dated to the calendar year and often season of their occurrence by tree-ring dating (Baisan and Swetnam 1990). It is possible to build a history of the timing and spatial extent of forest fire by sampling many trees across a region (Swetnam and Baisan 1996; Touchan *et al.* 1996). Numerous studies have been conducted in North America to investigate historic fire regimes

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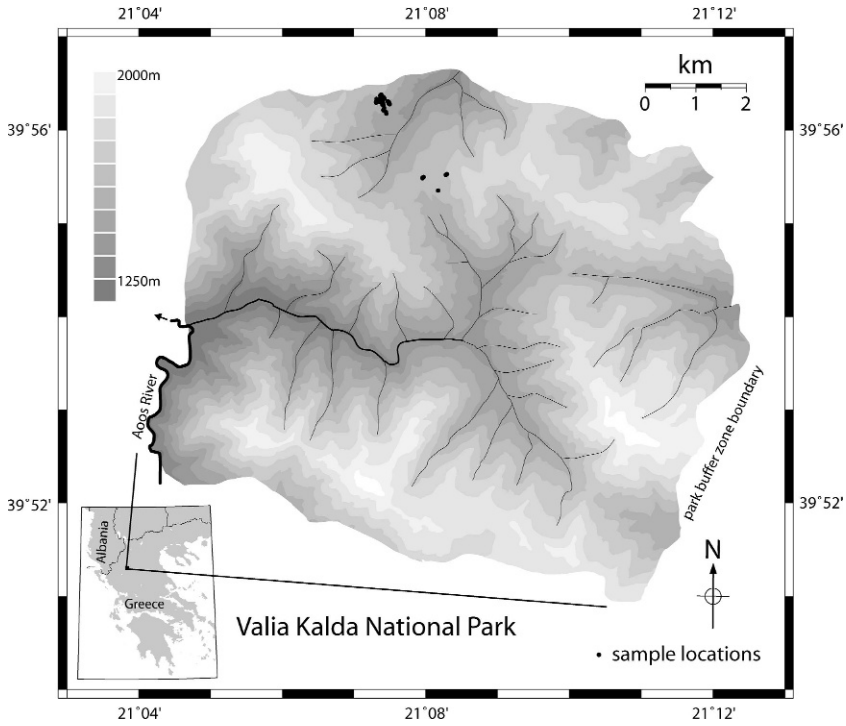

Figure 1. Location of the study area Valia Kalda. Map re-drawn after Figure of Tzanou *et al.* (2008).

using dendrochronology (Baisan and Swetnam 1990; Swetnam and Baisan 1996; Touchan *et al.* 1996; Brown and Baxter 2003; Swetnam *et al.* 2009). However, fire history in the eastern Mediterranean region is poorly developed. Dendrochronology can provide valuable insight into historical fire frequency, intensity, and distribution in the region and its role in local forest ecology.

We investigated the past fire regime of the European black pine (*Pinus nigra*) forest in Valia Kalda in northern Greece in this study. Here, we demonstrate for the first time the use of dendrochronology for documenting and reconstructing forest disturbance by fire in this region.

MATERIALS AND METHODS

Study Area

The National Forest of "Valia Kalda" in Pindus Mountains is located in northwestern Greece (39°54′N, 21°07′E) and covers an area of 6,868 ha (Figure 1). The National Forest was established in 1966 and is considered one of the most important protected areas for the maintenance of mountainous biodiversity and ecosystem integrity at the national level. The study area is within the protected core of 3,294 ha that has been declared a "biogenetic reserve" by the European Council. Total annual rainfall ranges from 1,000–1,800 mm. Temperatures vary with elevation, remaining below 20°C at upper altitudes. The mean monthly temperatures vary between 0.9° and 21.4°C. Open forests of European black pine and common beech (*Fagus sylvatica* L.) cover the park's lower and middle altitudes 1,000 to 1,600 m a.s.l. with several of the European black pine trees sampled within four hectares being more than 700 years old. Balkan pine (*Pinus heldreichii* Christ.) woodland is dominant at higher altitudes of 1,600 to 1,900 m a.s.l.

Sampled trees are part of an open forest stand of European black pine covering ca. 4 ha at the core of the National Park of Valia Kalda. The stand occupies a hillside with a southern aspect, medium to steep slope (30–40%) with understory vegetation of *Juniperus* sp. and herbaceous vege-

tation covering about 60–70% of the total surface area. Before the area was declared a National Park, intensive goat grazing and selective logging were the traditional human activities during the 19th and early 20th Centuries.

Black pine occupies low to middle elevations (200–1,600 m a.s.l.) in continental Greece and forms pure or mixed stands with other conifers. Cone maturity and seed dispersal takes place between March and May. This is considered an adaptive strategy in order for the seeds to be protected inside the soil when the intense summer fires occur. Black pine shows almost no regeneration after crown fire, does not produce serotinous cones, and its seeds are not able to resist the high temperatures attained during intense summer wildfires. Moreover, the short dispersal distance of black pine, does not allow effective colonization from unburned edges. However, European black pine is a long-lived tree with a thick bark, and it can grow tall with few branches in the lower part, thus surviving surface fires. Indeed, fire scars on living old trees are frequent, suggesting that they naturally support surface fires (Pausas *et al.* 2008).

Methods

Increment cores were taken from 70 living trees, and 24 full cross-sections were obtained from stumps and logs in Valia Kalda during 2009–2010. Eight fire-scarred trees were collected at the same time within an area of four hectares. Full or partial cross-sections from fire-scarred boles of downed logs, snags, and stumps were cut with a chainsaw. Partial sections were also taken from living trees as described by Arno and Sneck (1977). The primary criterion for sample tree selection was the presence of a maximum number of well-preserved scars showing evidence of fire according to the number of healing ridges observed on the scarred surface (Baisan and Swetnam 1990).

The samples were fine-sanded and crossdated in the laboratory using standard dendrochronological techniques (Stokes and Smiley 1968). The width of each annual ring on the cores and cross-sections was measured to the nearest 0.01 mm. Visual and graphical crossdating was confirmed by statistical pattern matching (Holmes 1983).

We identified the intra-ring position of fire scars to infer approximate timing of individual fires relative to the growing season of the trees (Baisan and Swetnam 1990). All fire-scar dates from individual trees were compiled into master chronologies to examine both temporal patterns of past fire occurrence. The FHX2 fire history analysis program (Grissino-Mayer 2001) was used to compute descriptive statistics. These statistics included fire frequency (number of fires per time period), fire-scar index ([number of trees scarred ÷ Number of trees sampled] × 100), Weibull median probability intervals (WMPI), maximum and minimum fire interval (Max. FI and Min. FI), and standard deviation (STD) of fire intervals.

RESULTS AND DISCUSSION

The length of the tree-ring chronology developed from this stand was 815 years (1196–2010). The series intercorrelation using the COFECHA program (Holmes 1983) is 0.63; the output statistics demonstrate strong crossdating. Successful crossdating requires that a common climatic signal be reflected in tree growth, and the signal here was sufficiently robust to allow reliable dating of remnant wood samples. The mean sample segment length was 354 years.

Of the 24 sections collected, eight crossdated trees contained a record of fires from the early 14th Century through the late 19th Century with the last fire recorded in 1891 (Figures 2 and 3). We determined that all the fires occurred during the period of active tree growth, forming mid-early-wood to latewood scars representing fires occurring during the period from mid-summer to early fall. Although the number of samples obtained was not sufficient to fully assess fire frequency in the area, the samples do document fire occurrence throughout the period of record. The first identified fire scar was formed in AD 1309, and a fire in AD 1437 scarred four of the eight trees sampled (Figure 3). Although individual trees showed scarring indicative of significant wounding, scars were not generally coincident between trees. This finding suggests that unknown local factors (*i.e.* possibly fuel accumulation around individual stems) at the tree-level were responsible

Figure 2. Dated fire scars shown on a *Pinus nigra* cross-section, sample RAK-42.

for the severity of wounding as opposed to stand-level fire intensities that may have been typically low, and unlikely to cause extensive wounding of these thick-barked pines. There was some evidence that tree establishment and recruitment could be related to disturbances such as high intensity fire, as groups of trees with similar pith ages were noted among those we sampled. Taken together, the combined evidence suggests that fire has been a persistent factor in the development and ecology of the current forest stands, likely affecting both forest structure and recruitment patterns.

The notion that forest fires are only an artifact of recent history rather than a persistent characteristic of the region can be clearly rejected based on the data presented in this paper. Although the exact character of the local fire regime and its ecological role in this black pine forest cannot be determined from such a limited sample, the evidence presented illustrates the potential and utility of further study to more fully describe and explain the role of fire in northern Greece. Our success in locating and collecting samples of old wood containing fire evidence covering the past seven centuries demonstrates that such studies are possible despite the long history of forest utilization in this region. The longer perspective offered by dendrochronology is particularly suited to providing an understanding

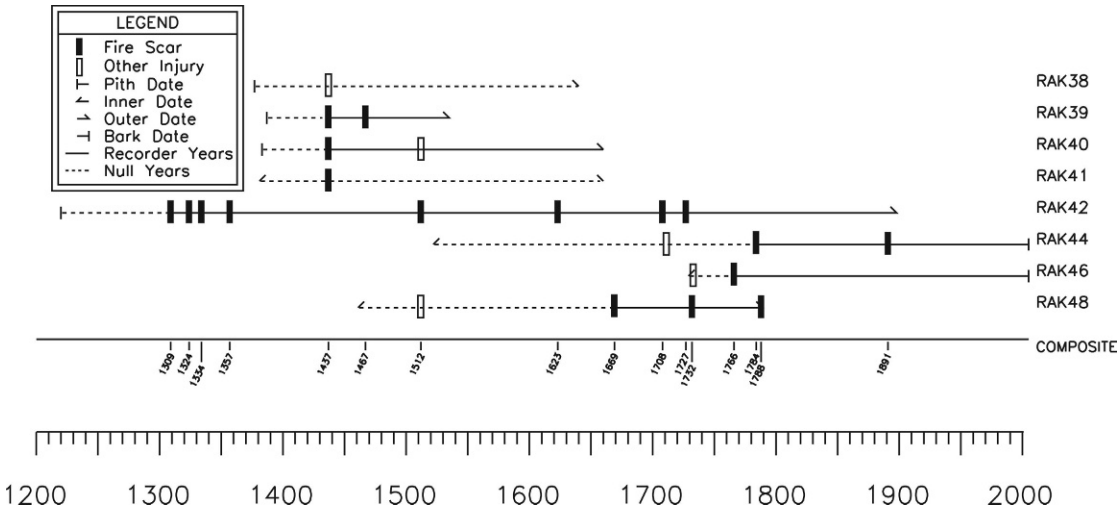

Figure 3. Composite of fire history chart. Horizontal lines are maximum life span of trees. Vertical bars are fire dates recorded by the trees.

of ecological changes that may have occurred in the recent past.

CONCLUSION

This study provides a basis for development of the first dendrochronologically based fire history in Greece. It is also a baseline for planning and justifying future ecosystem management programs. Such information will offer a quantitative measure of the frequency of past fire regimes. Local dendrochronology studies are a first step toward building regional networks to address issues regarding the understanding and management of fire regimes in the region and possible linkages to regional climate and climatic change. The outcome from research of this nature will include the identification of key issues for technical cooperation between the countries affected by catastrophic fires and a prioritization of this issue for follow up action.

Similar to the Fule *et al.* (2008) findings for old-growth European black pine forests in eastern Spain, this study presents direct evidence of fire's persistent long-term role in the forests of northern Greece. Evidence of recurrent non-lethal surface fires over the past seven centuries suggests that in addition to its destructive power, fire also plays a role in the ecological functioning of the region. As it is unlikely that fire can ever be eliminated by human efforts, an ecological perspective that recognizes and manages fire's long-term role in the region can be a more beneficial and cost-effective approach than simply attempting to exclude it.

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