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ORIGINAL PAPER

Environmental change in Garry oak (*Quercus garryana*) ecosystems: the evolution of an eco-cultural landscape

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Abstract Globally, colonialism resulted in the suppression of aboriginal land management practices, abetted by the concept of *terra nullius*, "belonging to no one"; the belief that aboriginal people had little influence on or ownership of the land. Until recently, this ideology was entrenched in resource management and policy. Traditional ecological knowledge, historical ecology, archaeology, and palaeoecological research have shown these assumptions to be wrong. In this paper we take a multidisciplinary approach (biogeography, paleoecology, dendrochronology, and bioclimatic envelope modeling) to better understand the role of climate and fire in the formation of eco-cultural landscapes. We synthesize results from pollen and charcoal analysis in Garry oak ecosystems that indicate there were continuous and frequent prescribed burning events, with more severe fires occurring every 26–41 years in southwest British Columbia throughout the Anthropocene ($\sim$last 250 years) that substantially altered forest structure and composition. These results are consistent with stand age reconstructions in BC and Washington with Garry oak establishment beginning $\sim$1850 AD, corresponding with modern fire exclusion, aboriginal population decline, and end of the Little Ice Age. Douglas-fir recruitment has been continuous since $\sim$1900, with succession of oak woodland to closed conifer forest at most sites. These findings indicate that the structure of many Garry oak ecosystems have been profoundly influenced by eco-cultural practices. Overwhelming evidence indicates that in many cases these ecosystems are dependent on prescribed fire for their open structure. In

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the absence of aboriginal land-management practices, active management will be necessary to maintain Garry oak woodland.

Keywords British Columbia · Eco-cultural landscapes · Ecological restoration · Environmental change · Fire history · Garry oak · Indigenous people land practices · Paleoecology

Introduction

Understanding the complex nature of Garry oak (aka Oregon white oak; *Quercus garryana*) ecosystems and threats facing their continued existence has been the topic of many recovery actions throughout the Pacific Northwest of North America and has resulted in a number of papers at the technical and peer-reviewed level (Pellatt et al. 2007 ; Dunwiddie et al. 2011; Devine et al. 2013; McCune et al. 2013). These papers have highlighted pressing conservation issues such as landscape fragmentation, invasive species, herbivory, and the role of aboriginal land management using fire (MacDougall et al. 2004; Gedalof et al. 2006; Lea 2006; Pellatt et al. 2007; Gonzales and Arcese 2008; Dunwiddie et al. 2011; Bennett et al. 2012). Unfortunately there seems to be a global disconnect between academic research and actual ecosystem restoration activities (Suding 2011). Even where active management is being applied in the attempt to maintain or restore ecosystems, site selection and restoration techniques tend to be opportunistic, with limited consideration given to eco-cultural and climatic influences on present and future Garry oak ecosystem range (Pellatt et al. 2012; Götmark 2013) .

Dunwiddie and Bakker (2011) identified habitat loss and fragmentation, successional transition from open to forested conditions, and invasive species as the greatest threats to Garry oak ecosystems. They felt that the future challenges to be tackled by the management and scientific community include the reestablishment of prescribed burning, aboriginal plant harvest techniques (i.e., Camas bulbs), the need for climate change models that addressed Garry oak ecosystem adaptation at a scale relevant to land managers, and the selection of sites for restoration based on knowledge of their natural range of variability while being cognisant of the emergence of novel ecosystems. The role of climate change on these ecosystems has also been examined (Bachelet et al. 2011; Pellatt et al. 2012), highlighting the importance of securing habitat that will be suitable for Garry oak ecosystems in the future if they are to persist amongst a populated, fragmented landscape, but it may be that more interventionist measures will be required to assist with Garry oak ecosystem migration. Nested in these conservation and scenario-based activities, there is a need to understand the natural range of variability of ecosystems, ecological trajectories, and why an understanding of historical ecology and paleoecology is necessary for the long-term success of conservation and ecological restoration efforts (Delcourt and Delcourt 1997; Bjorkman and Vellend 2010; Dunwiddie et al. 2011; McCune et al. 2013).

Dunwiddie et al. (2011) in a recent overview on Garry oak ecosystems (Special Issue Northwest Science Volume 85, 2011) highlight that studies examining the historical ecology and stand dynamics of Garry oak ecosystems (e.g., Gedalof et al. 2006; Pellatt et al. 2007; Smith 2007; Sprenger and Dunwiddie 2011) “are beginning to provide the in-depth understanding of historical conditions that is a key first step in mapping out restoration goals and strategies”. Building on this idea, one of the key challenges for ecosystem scientists will be to integrate the longer fire and vegetation history records based on pollen and charcoal analysis (McCoy 2006) with the more recent fire and stand age/structure based on dendroecological studies, and emerging work based on soil and phytolith analyses (Hegarty et al. 2011; McCune and Pellatt 2013). Studies examining historical changes of Garry oak ecosystems and how these changes are related to a number of complex factors such as human land-use, climate, forest fire and stand dynamics will greatly enhance our interpretation of ecosystem structure and function. In addition, a better understanding of historic aboriginal land-use is also crucial for current ecosystem management and restoration efforts.

To assist land managers and restoration practitioners in better understanding the long-term dynamics of ecosystems, along with the environmental and cultural influences that shape them, we undertake a multi-disciplinary synthesis that examines vegetation change in Canada's Garry Oak (*Quercus garryana*) ecosystems through the Holocene period, from deglaciation to the present. We examine and synthesize how climate, pre-contact land management practices, and European colonization, as drivers of ecological change have influenced and continue to influence this particular landscape. To do this, we tie together ecology, paleoecology, bioclimatic envelope modelling, and historical ecology. Fire-adapted and now endangered due to fire exclusion, agriculture, fragmentation, urbanization, and invasive species infestation; Garry oak ecosystems in Canada are examples of oak savannahs across North America, and are also representative of the global phenomena of unprecedented anthropogenic ecosystem degradation and species decline (Barnosky et al. 2011).

Study region and biogeography

Garry oak is a broadleaved deciduous hardwood tree common along the Pacific Coast of the USA and occurs in south coastal British Columbia. It has the longest north–south distribution among western oak species, occurring from Vancouver Island, Canada, to south-central California, USA (Fig. 1a). It is the only native oak in British Columbia and Washington and is the principal oak species in Oregon (Stein 1990). Garry oak ecosystems occur within the Coastal Douglas-Fir biogeoclimatic zone in the eastern and southernmost parts of Vancouver Island, on the adjacent Gulf islands from near sea level to approximately 200 m, and at two isolated locales in the Fraser Valley and Fraser Canyon on the BC mainland (Fig. 1a). Many plant communities within the historic range of Garry oak depend on periodic disturbance to retain their open structure. It is believed that many Garry oak ecosystem sites were maintained by disturbance processes, such as annual periods of saturation, wildfire, or possibly by cultural management practices, including plant resource harvesting and prescribed burning (Boyd 1999a; Whitlock and Knox 2002). Pollen analysis of Holocene pollen records indicate that the range of Garry oak has not expanded northward beyond its current extent since the late Pleistocene (Pellatt 2002; Marsico et al. 2009) likely because the rugged topography of the Coast Mountains to the north inhibited range expansion supporting little physical and climatically suitable habitat.

Fire and humans in Garry oak ecosystems

The fire-adapted nature of plants in Garry oak ecosystems indicate there has been a long association with fire. Analyses of fossil pollen in marine sediments of Saanich Inlet indicate that Garry oak savannah reached its maximum extent in coastal British Columbia ~7500 years before present (BP) (Pellatt et al. 2001), when climate was 2 to 4°C warmer

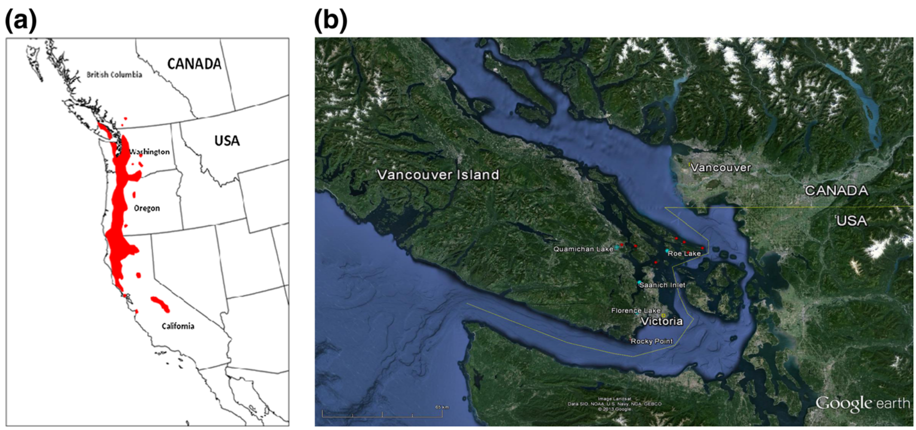

Fig. 1 **a** Map showing Garry oak distribution (map © Province of British Columbia). **b** Salish Sea Region of southwest British Columbia showing the location of pollen, charcoal, and tree ring study sites. *Blue dots* represent study sites for pollen and charcoal analyses. *Red dots* represent tree ring study sites

than present (Walker and Pellatt 2003). In the Willamette Valley and San Juan Islands, Garry oak savannahs are believed to have established more than 6,000 years BP (Boyd 1986; Weiser and Lepofsky 2009). Despite the onset ~3,800 years ago of cooler, wetter conditions that favoured development of woodland and closed forests in the Pacific Northwest of North America, oak savannahs have persisted to the present (Pellatt et al. 2001). Boyd (1986) notes that lightning-ignited fires do not occur frequently enough in the Willamette Valley to account for the continuation of oak savannah. He and others conclude that cultural burning is the most likely factor responsible for maintaining the savannah structure since 3800 BP that persists there today (Habeck 1961; Johannessen et al. 1971). In contrast to this view, Whitlock and Knox (2002) suggest that lightning played a more important role during the early- to mid-1800s than today, and that lightning and fire were common in the early autumn in the Willamette Valley oak savannah. In all likelihood the establishment of Garry oak ecosystems was the result of both climate and aboriginal landscape practices (Pellatt et al. 2001; Pellatt et al. 2007; Dunwiddie et al. 2011; McCune et al. 2013).

Nonetheless, evidence from Vancouver Island indicates that humans rather than lightning may have been responsible for burning the landscape. From 2000 BP until the twenty-first century, cool, moist climate conditions prevailed and fire activity on southern Vancouver Island was generally low (Brown and Hebda 2002; Gavin et al. 2003). Despite these conditions, sites on southeastern Vancouver Island record an increase in fire activity during this period (Allen 1995; Brown and Hebda 2002; Gavin et al. 2003). Besides being in the rain shadow of the Olympic and Insular Mountain ranges, broad scale climate conditions at southeastern Vancouver Island were not appreciably different from the surrounding region. The difference in fire regime may therefore be partially attributable to cultural burning (Allen 1995; Brown 1998). Many researchers (Boyd 1986; Tveten and Fonda 1999), and accounts in historical journal materials (British Columbia Historical Society 1974; Dougan 1973; Duffus 2003; The Pioneer 1986) have concluded that aboriginal people used fire to manage food resources, most notably to increase yields of root vegetables (i.e., Camas), berries, seeds (Turner 1999), and forage species (Agee 1993; Turner 1999). Empirical evidence suggests that, on southeastern Vancouver Island and the Gulf Islands, this has been the case for millennia (MacDougall et al. 2004). The aboriginal population in the Salish Sea region of BC (Fig. 1b), before the arrival of Europeans is estimated to have ranged from 77,000 to over a million prior to decimation by disease introduced by Europeans (Duff 1997; Ames and Maschner 1999; Boyd 1999b). By the late Holocene, when climate favoured succession of oak savannah to forest, many generations of people over thousands of years would have observed the role and importance of fire in maintaining savannah and woodland structure.

Historical accounts indicate that Garry oak ecosystems were ignited in late summer and fall (Boyd 1986; Fuchs 2001; Turner 1999). By the mid-1800s, however, as Europeans began clearing portions of southeastern Vancouver Island for agriculture, large fires were commonly observed (Grant 1857; Maslovat 2002). It is unclear whether the constant veil of summer smoke reported during this time originated from lightning strikes, from fires lit by aboriginal peoples, or from the settlers themselves who burned for cultivation and after logging. Europeans restricted cultural burning in southwestern BC through the Bush Fire Act of 1874 (MacDonald 1929). In less than 100 years, European settlement, followed by fire exclusion, disrupted the fire regime in virtually all western North American oak ecosystems that have been studied (Pyne 1982).

Palaeoecological context

Early to mid-Holocene

The Holocene climate along south coastal British Columbia has varied considerably over the last 12,000 years (Mathewes 1985;Hebda 1995; Walker and Pellatt 2003). After deglaciation, warm dry conditions occurred on southeastern Vancouver Island (11,450–8,300 BP) and were typical of climate throughout the coast of BC at the time (Walker and Pellatt 2003), with frequent fires also occurring in the Fraser Valley (Mathewes 1973). These conditions supported Douglas-fir (*Pseudotsuga menziesii*) parkland with abundant grasses (Poaceae) and bracken fern (*Pterdium*) (Pellatt et al. 2001) (Fig. 2). These and other species present in the pollen record indicate a relatively warm/dry climate with frequent disturbance, likely fire. Garry oak arrives curiously late along the south BC coast ($\sim$8300 BP), but quickly increases in abundance after its arrival (Allen 1995; Heusser 1983; Pellatt et al. 2001). Although maximum summer temperature for the Holocene occurred between 11,000 to $\sim$8000 BP (Mathewes and Heusser 1981; Rosenberg et al. 2004), oak pollen was rare prior to 8300 BP and peaked at 8000 BP or later on southern Vancouver Island (Allen 1995; Heusser 1983; Pellatt et al. 2001). A slow northward migration across the southern Gulf Islands to Vancouver Island, and thus, a long time lag following climatic change, offers a possible explanation for this species' late arrival.

The low abundance of Garry oak on Vancouver Island during the early Holocene despite higher summer temperatures may be due to cooler winter temperatures. Greater seasonality may have been an important feature of early Holocene climate (Kutzbach et al. 1998; Walker and Pellatt 2003). Pellatt et al. (2001) also note that Garry oak persists into the late Holocene, when summer temperatures are thought to have cooled significantly from early Holocene maximums. Pellatt et al. (2001) speculate that aboriginal burning practices may have played an important role in maintaining the oak savannah on southernmost Vancouver Island over the last 3800 years, despite less favorable climatic conditions (Walker and Pellatt 2003). This interpretation is supported by the increasing frequency of radiocarbon dated materials from archaeological sites within the range of

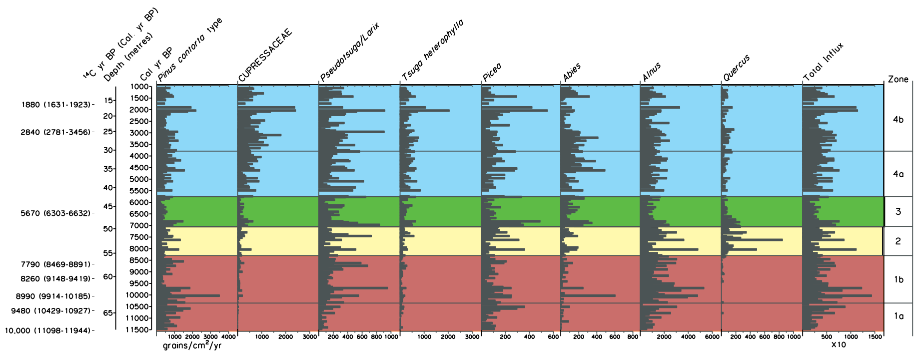

Fig. 2 Simplified Pollen Accumulation Rate (grains/cm/year) Diagram from Saanich Inlet, BC. *Red* (*Zones 1a* and *1b*) represents conditions that are warmer, dryer and more continental than present, yellow (*Zone 2*) is warmer and wetter, *green* (*Zone 3*) is a transitional cooling phase, and *blue* (*Zone 4a* and *4b*) represents the establishment of conditions more typical of the present day. Note that oak (*Quercus*) pollen rapidly increase around 8000 BP, subsequently declines, then again increases in the late Holocene. The persistence in the late Holocene corresponds with a subsequent increase of typical temperate rain forest species such as cedar (Cupressaceae), western hemlock (*Tsuga heterophylla*), and spruce (*Picea*). The *x* axis shows radiocarbon years before present (with 95 % confidence limits), depth (m), and calibrated years before present

Garry oak in British Columbia beginning about 3400 years ago and again after 2000 years ago (McCune et al. 2013).

Recent past—the Anthropocene (~last 250 years)

Of particular interest in understanding Garry oak ecosystems in southern British Columbia is the frequency of fire on Vancouver Island and the southern Gulf islands (McCoy 2006; Pellatt et al. 2007). McCoy (2006) examined pollen and charcoal for three sites in the region to determine the vegetation and fire history for the region during the Anthopocene (Crutzen and Stoermer 2000). The charcoal analyses provide evidence of fire history synchrony among the three sites, and also within the broader region of the Pacific Northwest. Figure 3 presents a comparison of the data derived from charcoal analysis from lake sediments to determine the fire history of 3 study sites (Roe Lake, Pender Island, BC; Quamichan and Florence lakes, Vancouver Island BC) (Fig. 1b) for the period from 1745 to present. The figure shows fire events we interpreted as roughly coeval (within ~10 years). Table 1 shows approximate years of fire events at Quamichan, Florence, and Roe lakes, and differences in years of fire events that are interpreted as coeval among sites. These results also show a degree of synchrony with fire events at sites elsewhere in the Pacific Northwest (Howe 1915, Eis 1962, Schmidt 1970, Daniels et al. 1995, Gavin et al. 2003, Weisberg 2003, Parminter 2004).

This research is consistent with change in savannah/forest structure based on pollen and the charcoal record in adjacent Washington State (Walsh et al. 2010; Dunwiddie et al. 2011). Changes in forest community structure based on pollen and charcoal analyses correspond with termination of the Little Ice Age, decimation of aboriginal populations due to disease (smallpox epidemics), fire suppression, and European colonization. The pollen and charcoal records also show recent change in forest structure due to logging, clearing and settlement reflecting change in natural resource management practices and the displacement of aboriginal people and their land practices. McCoy (2006) also aimed to

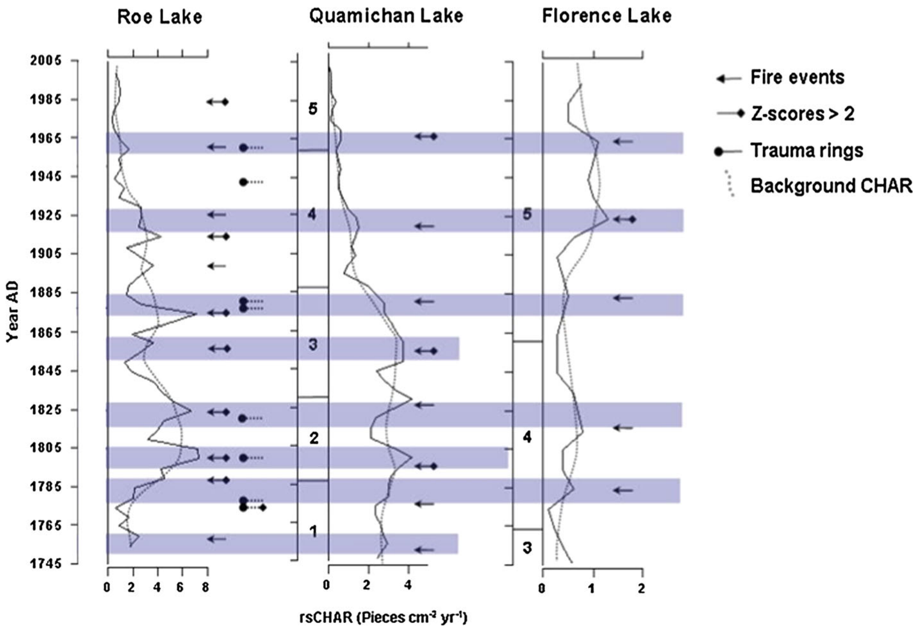

Fig. 3 Comparison of pollen zones and re-sampled charcoal accumulation rate (rsCHAR) fire history for Roe Lake and Quamichan Lake, and upper (1745–2003) fire history for Florence Lake. Grey bars span ~10 years and highlight fire events that appear coeval ±10 years (McCoy 2006)

Table 1 Years of fire events identified from re-sampled charcoal accumulation rate for 1745 to present at Roe Lake (RL), Quamichan Lake (QL), and Florence Lake (FL), and differences in years of fire events among sites that are interpreted as coeval (McCoy 2006)

Sites and years of fire events			Differences in years of coeval fire events among sites		
RL	QL	FL	RL-QL	RL-FL	QL-FL
1984					
1959	1969	1955	10	4	14
1924	1919	1925	5	1	4
1914					
1894					
1870	1879	1880	9	10	1
1859	1849			10	
1820	1824		4		
		1815			
1800	1798		2		
1789	1779	1785	10	4	6
1759	1754			5	

determine a mean fire return interval (MFRI), or average number of fires within a designated area during a specified time (Agee 1993; CIFFC 2002), for each site. An MFRI can be used to define a natural range of variability for fire frequency, which in turn can help refine restoration management strategies (Higuera et al. 2005). MFRIs for Quamichan, Roe and Florence Lakes were 26, 27 and 41 years respectively. Frequent prescribed burning in the Pacific Northwest has been inferred from tree ring and charcoal records, ranging from 3 to 80 years (Agee and Dunwiddie 1984; McCoy 2006; Walsh et al. 2010; Sprenger and Dunwiddie 2011). These data are important in establishing the scientific foundation for prescribed burning in coastal ecosystems and may well be underestimated in frequency due to the low intensity nature of frequent burning in meadow environments (Agee 1993).

Stand age and tree ring records

The tree ring record of Garry oak and associated trees offers the opportunity to examine how the cumulative impacts of fire exclusion, climate change, species introductions, and other land management practices have affected the structure and composition of Garry oak ecosystems. Dendroecological analyses of Garry oak are relatively uncommon due to the hardness of the tree, and its presumed low potential for dendroclimatic studies. Nonetheless, studies have been undertaken, and their results reveal several recent important changes to Garry oak ecosystems.

Gedalof et al. (2006) examined changes in stand structure and composition at Canadian Forces Base Rocky Point on southern Vancouver Island in a 0.9 ha plot using tree-ring analysis and historical techniques (i.e., historical air photographs and documents) (Fig. 1b). They found that the site was largely tree-free at the time of European contact, with the exception of a few oaks that established in the early eighteenth century. Following displacement of the aboriginal people who occupied the site there was a sudden and rapid increase in the establishment of Garry oak trees that lasted from ~1850 to 1940, and peaked in the 1880s (Fig. 4). This pulse of early establishment probably initially included many stems that were episodically top-killed by fire, but that resprouted from a surviving root the following year (Hibbs and Yoder 2007). This early pulse of establishment by Garry oak was followed by establishment of a range of coniferous species—in particular Douglas-fir, but also grand fir (*Abies grandis*), and shore pine (*Pinus contorta*). Although there are many seedlings present at the site today, there is no evidence of a Garry oak tree having been recruited to the overstorey since ~1950, and there are almost no saplings present at the site. In contrast, conifer encroachment is ongoing, and in parts of the study area where density is high, understorey exclusion is occurring and overstorey Gary oak trees are dying.

Smith (2007) extended this analysis to evaluate how ubiquitous this pattern is in southwestern Vancouver Island and the southern Gulf Islands in BC. She examined stand composition at an additional eight sites representing a range of edaphic conditions, and found that oak seedling establishment is generally high throughout the distribution of Garry oak in BC, with the exception of sites with especially thin, rocky soils (Fig. 5). However, subsequent recruitment to the overstorey is very rare. In fact, the only locations where overstorey recruitment occurred since ca. 1950 are on some small island sites where large herbivores are presumably absent. These island sites generally also have a low proportion of invasive species, thin rocky soils, and dense patches of Garry oak trees that appear to be reproducing vegetatively rather than from seed.

These results indicate that Garry oak recruitment is not ongoing, but instead forms an early post-fire cohort, whereas Douglas-fir recruitment is continuous and ongoing. As Garry oak is slower growing than Douglas-fir, it can be quickly overtopped despite its “head-start”, resulting in cessation of oak recruitment. Douglas-fir, in contrast, is able to

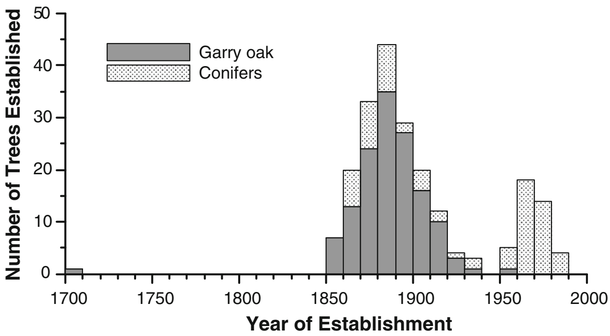

Fig. 4 Number of overstorey trees recruited at Rocky Point by decade (after Gedalof et al. 2006)

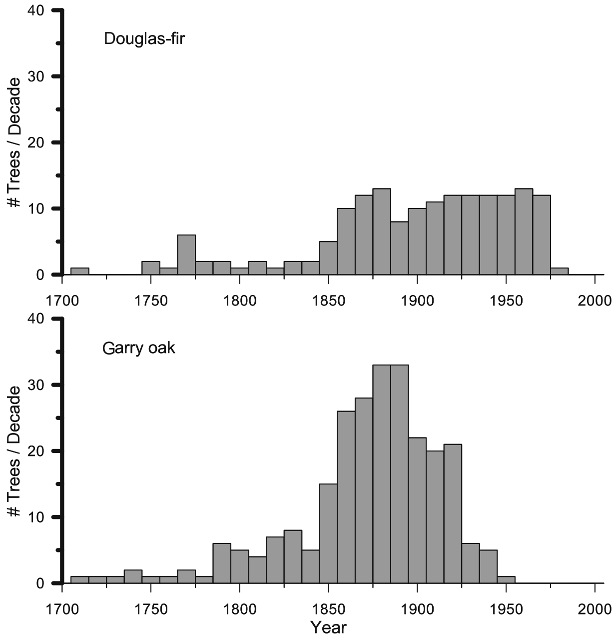

Fig. 5 Combined establishment dates for Douglas-fir and Garry oak trees at eight sites on southern Vancouver Island and the southern Gulf Islands, BC, Canada. (Smith 2007)

continue establishing in shadier conditions, and its seedling development is potentially facilitated by the oak overstorey. Most sites show this pattern in stand structure, with the majority of the older trees within the plots being Garry oak and younger trees being Douglas-fir. Sites with deeper soils, gentler slopes, and/or more adjacent conifer forest had higher levels of conifer recruitment following oak establishment, which is expected based on the understanding that Garry oak ecosystems can be considered climax ecosystems on more xeric sites, and seral ecosystems on more mesic, nutrient-rich sites (Stein 1990).

Garry oak extent, climate suitability and conservation goals

As in the past, current and future climate change will no doubt impact the structure of, and processes affecting, Garry oak ecosystems throughout western North America. In addition to understanding the past and current stressors affecting Garry oak ecosystems, we need to understand how these species and ecosystems will adapt under different climate scenarios throughout their range. If long-term biodiversity conservation goals in the context of climate change adaptation are to be achieved, the spatial and temporal connectivity of landscapes will be essential for ecosystem migration. Understanding how Garry oak responds to future climate scenarios at scales relevant to land managers is an important planning tool for conservation managers providing the opportunity to identify temporally connected migration corridors (areas where climate remains continuously suitable over time), as well as additional areas that are expected to be necessary to maintain Garry oak populations over the next century.

Climate Change scenarios (Bachelet et al. 2011) and a down-scaled bioclimatic envelope model (Pellatt et al. 2012) have been used to identify areas projected to maintain climatic suitability over time. Pellatt et al. (2012) generated scenarios that examine temporally connected areas that persist throughout the twenty-first century for Garry oak, and the extent of overlap between these temporally connected regions and existing protected areas.

Garry oak is used as a representative species for Garry oak ecosystems as its range is well-known and overall is limited by climate. The results of the bioclimatic envelope modelling indicate climatically suitable Garry oak habitat is projected to increase marginally, mostly in the United States of America, but in order for adaptation and migration to occur there is a need to secure manageable, connected landscapes (Nantal et al. 2014). At present models indicate that only 6.6 to 7.3 % will remain continuously suitable (temporally connected) in protected landscapes between 2010 and 2099 (Fig. 6; based on CGCM2-A2 model-scenario) highlighting the need for coordinated conservation efforts on public and private lands. Of particular interest to conservation ecologists, is that even though there is an expansion of climatically suitable Garry oak habitat to the east of the Cascade Mountains (Washington and Oregon), very little expansion is expected to occur northward in Canada (Pellatt et al. 2012).

Conclusions

The findings presented here highlight the importance of aboriginal land management practices in the evolution of eco-cultural landscapes. Nested within the overarching influence of climate, the role of aboriginal, and subsequently post-colonial settlement and resource use has influenced many Garry oak ecosystems in southern British Columbia and the Pacific Northwest of North America; in particular is the important role of fire in maintaining Garry oak ecosystems prior to the mid-twentieth century. The paleoecological record illustrates the rate and magnitude of ecosystem change in the past, showing that the forests in the region have experienced drastic changes in structure due to temperature changes of up to 4 °C in the past (Walker and Pellatt 2003). Past ecosystem change has responded rapidly to climate change, hence when this information is coupled with bioclimate envelope modelling, it serves as an indicator of the impact anthropogenic climate change may have in the future (Pellatt et al. 2001).

Even though extensive climate change has occurred in southwest British Columbia throughout the Holocene, the northernmost extent of the range of Garry oak has remained relatively static (Pellatt 2002; Marsico et al. 2009) and is predicted to continue to be limited in its northern expansion based on bioclimate envelope models (Pellatt et al. 2012). Palaeoecological studies indicate that as temperate coniferous rainforest was increasing in the region, the persistence of oak woodland and savannah habitat and the evidence of fire

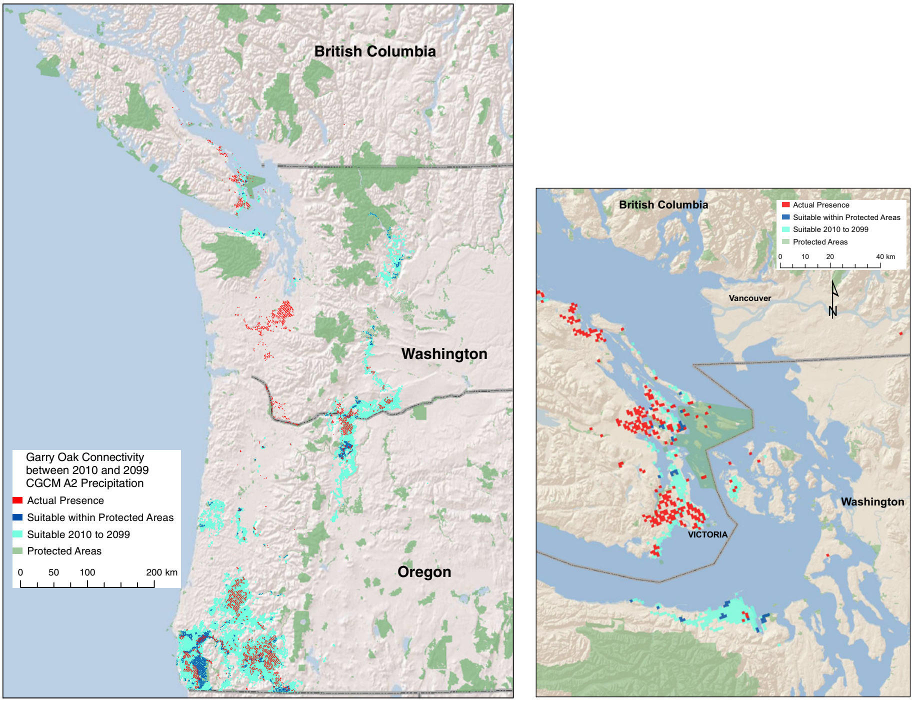

Fig. 6 Climatically suitable habitat for Garry oak using CGCM2 scenario A2 (temporally connected) between 2010 and 2099. *Green* represents the location of protected areas. *Light blue* represents temporally connected Garry oak habitat. *Dark blue* represents temporally connected Garry oak habitat within existing protected areas. *Red* represents actual occurrence of Garry oak

alludes to a role of aboriginal landscape management in maintaining these ecosystems (Pellatt et al. 2001; Brown and Hebda 2002). Nested within the broadscale ecosystem changes driven by climate is the presence of people on the landscape. Garry oak ecosystems in British Columbia are the result of a warmer/dryer climate in the past but many have been perpetuated by aboriginal burning and land-use practices over the past 3000 years (Pellatt et al. 2001; McCune et al. 2013).

Recent oak establishment since ~1850 corresponds with fire suppression, aboriginal population decline, the end of the Little Ice Age, and European colonization (Boyd 1999b). Oak recruitment was continuous from ~1850 to early 1900s and virtually no recruitment has occurred since 1940. Douglas-fir recruitment has been continuous since ~1900; hence conifer exclusion of Garry oak sapling success is evident. The change in disturbance regimes in Garry oak ecosystems has these systems on an ecological trajectory that, without intervention, will result in conifer domination.

Recent work gives greater recognition to aboriginal influence on the structure of many ecosystems (White et al. 2011), including those associated with Garry oak, and that fire is important in the structure and function of these ecosystems regardless of whether they experienced prescribed fire or natural ignition sources. By incorporating aboriginal land use practices into the active management of remaining Garry oak ecosystems, restoration or intervention activities (Hobbs et al. 2011) may be more successful than they are at present (Dunwiddie and Bakker 2011; Götmark 2013). Even with active management, ecological intervention will be necessary to maintain mixed age class Garry oak ecosystems over the next century—especially in Canada. Given that the Intergovernmental Panel on Climate Change (Pachauri and Reisinger 2007) has concluded that Earth's climate is very likely changing at a pace unprecedented in the last 10,000 years, this leads us to wonder how we can best protect the value of our lands and renewable resources for both ourselves and for future generations?

It is crucial for palaeoecologists to tackle issues associated with conservation ecology (Froyd and Willis 2008). In particular, paleoecology can contribute to a better understanding of the relationship between climate and ecosystem response in the context of natural range of variability and ecological thresholds. Given that most of the available literature on ecosystems is focused on timescales less than 50 years, palaeoecological studies focusing on longer time horizons and ecological questions are useful (Froyd and Willis 2008). This is especially important in future conservation efforts as novel ecosystems may become the norm given climate change (Williams et al. 2007; Hobbs et al. 2009). Strategic site selection for Garry oak ecosystems under future climate scenarios (Pellatt et al. 2012) will likely involve the alteration of future ecosystems in order to maintain many of the ecosystems that we value today. Hence lessons learned from the past regarding Garry oak ecosystem structure and function, aboriginal land use, and fire show us that many Garry oak associated ecosystems are eco-cultural in origin. We also can see from the conditions of these ecosystems today and where they may persist in the future, that ecological intervention activities may be necessary for their persistence and even with our active management activities, these systems will be different than they were in the past.

Just as importantly we seek to stress the need to accept and incorporate traditional land-use practices into ecosystem management activities because our study area was not *terra nullius* (Lindqvist 2007); it was the result of an eco-cultural interaction. Understanding ecological processes (past and possible futures) is critical in determining the feasibility of long-term recovery or future ecological trajectories (Karlsson et al. 2007). If we fail to understand, and in many cases emulate, these processes then we will become gardeners, maintaining fragments of a past ecosystem that represents a depauperate assemblage of its former richness.

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