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Article

Fire Exclusion Destroys Habitats for At-Risk Species in a British Columbia Protected Area

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Abstract: Fire exclusion and suppression has altered the composition and structure of Garry oak and associated ecosystems in British Columbia. The absence of frequent low severity ground fires has been one of the main contributors to dense patches of non-native grasses, shrubs, and encroaching Douglas-fir trees in historical Garry oak dominated meadows. This case study uses remote sensing and dendrochronology to reconstruct the stand dynamics and long-term fire history of a Garry oak meadow situated within Helliwell Provincial Park located on Hornby Island, British Columbia. The Garry oak habitat in Helliwell Park has decreased by 50% since 1950 due to conifer encroachment. Lower densities and mortalities of Garry oak trees were associated with the presence of overstory Douglas-fir trees. To slow conifer encroachment into the remaining Garry oak meadows, we recommend that mechanical thinning of Douglas-fir be followed by a prescribed burning program. Reintroducing fire to Garry oak ecosystems can restore and maintain populations of plants, mammals, and insects that rely on these fire resilient habitats.

Keywords: British Columbia; conifer encroachment; ecosystem restoration; fire exclusion; Garry oak ecosystems; species at risk; parks and protected areas

1. Introduction

Understanding the ecological and cultural history of ecosystems is important when developing management objectives, restoration strategies, and long-term monitoring [1–5]. For example, prior to a government ban on cultural burning practices in British Columbia in the 1920s, coastal First Nations intentionally set low severity ground fires to support the growth of fire adapted species (organisms with life history strategies that tolerate fire [6]), such as camas (*Camas* spp.), and increase fodder for game, such as deer [7–9]. Frequent burning was also used to decrease the amount of fuels surrounding habitation sites and remove fast growing Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco) and shore pine trees (*Pinus contorta var. contorta* Douglas ex Louden) [8,10,11]. Due to millennia of fire management by First Nations, Garry oak (*Quercus garryana* Dougl. ex Hook.) ecosystems are fire resilient (recover quickly from fire disturbance [12]) and require frequent low severity ground fires to maintain the species that historically live in these meadow habitats [13–15]. Widespread fire suppression and ongoing exclusion have resulted in the encroachment of Douglas-fir dominated forests and encouraged the growth of fire intolerant non-native species in Garry oak and associated ecosystems in the Pacific Northwest [8,11,15–18].

Currently, Garry oak ecosystems cover less than 5% of British Columbia, but these ecosystems contain among the greatest proportions of species-at-risk in the province [19]. Almost all remaining Garry oak and associated ecosystems have been directly impacted by roads, agriculture, and urban development [20]. This loss of habitat has put over 100 Garry oak associated species at risk [19], including the Taylor's Checkerspot butterfly (*Euphydryas editha taylori*), whose populations have declined drastically over the past century [19,21,22]. The Taylor's Checkerspot butterfly was historically recorded in the southeast portion of British Columbia where Garry oak meadows are located [23–25]. For some time, a 1996 sighting of Taylor's Checkerspot in the Helliwell Provincial Park on Hornby Island was presumed to be the last evidence of the species in Canada. [24]. Fortunately, in 2005, a small sub-population (15 individuals) was found on nearby Denman Island [25]. This species is still listed as endangered, and the Denman Island population is one of only two known in Canada [21,25]. BC Parks and community organizers are planning to reintroduce Taylor's Checkerspot butterflies to Helliwell park in 2020 [26].

The loss of food plants due to encroaching conifers into open meadow habitats is hypothesized to be the primary factor contributing to the decline of Taylor's Checkerspot butterflies in British Columbia [22,26]. The absence of frequent fire activity has affected the presence of nectar bearing plants and shrubs that depend on open meadows with few overstory conifers [27–29]. The spatial extent of ephemeral wetlands associated with Garry oak meadows has also decreased during the 20th century as a result of Douglas-fir encroachment [30]. Once established, mature Douglas-fir trees significantly lower the water table and dry out soils [30]. This can contribute to a competition for moisture between Garry oak and Douglas-fir, and fast-growing and taller Douglas-fir can achieve dominant canopy positions, ultimately shading out both mature and sapling Garry oak trees [31].

The purpose of this study is to understand the stand dynamics and fire history of a maritime meadow situated within a Garry oak ecosystem (including historical Taylor's Checkerspot butterfly habitat), located in Helliwell Provincial Park on Hornby Island, British Columbia. We used a range of methods and analytical tools, such as reviewing historical documents and aerial photographs, dendrochronology, and spatial analyses, to assess forest stand composition and structure. We also mapped the extent of a north-south sedge dominated wetland complex to assess the suitability of habitat for the reintroduction of the Taylor's Checkerspot butterfly. Our study provides a habitat assessment to inform management and restoration actions in Helliwell Provincial Park that can be applied to threatened Garry oak and associated ecosystems across the Pacific Northwest.

2. Materials and Methods

2.1. Study Area

The study area is situated in Helliwell Provincial Park, which is located on the southeast side of Hornby Island, British Columbia (approximately 49°31′ latitude and 124°35′ longitude) in the Strait of Georgia (Figure 1). Helliwell Provincial Park encompasses 2872 ha, 2.5% (69 ha) of which is upland and 97.5% (2803 ha) is marine habitat [32]. The park lies within the Coastal Douglas-fir moist maritime (CDFmm) biogeoclimatic subzone, which is characterized by warm, dry summers and mild, wet winters (mean annual temperature 9.9 °C; mean annual precipitation 955 mm) [33]. The ecosystems encompassed in this subzone range from mature coastal Douglas-fir forests to Garry oak meadows, riparian wetlands, and coastal cliffs [33].

The 69 ha of upland terrestrial habitat in Helliwell Provincial Park is comprised of diverse habitats including mature Douglas-fir forests, mixed woodlands, sedge dominated wetlands, coastal bluffs, and Garry oak meadows. The Garry oak meadows are among the northernmost Garry oak populations found in British Columbia [19,26]. Garry oak ecosystems within the park provide a habitat for five red-listed and nine blue-listed vascular plants [22]. Additionally, Helliwell Park provides a habitat for five rare mammals, twenty rare birds, and two rare invertebrates [22].

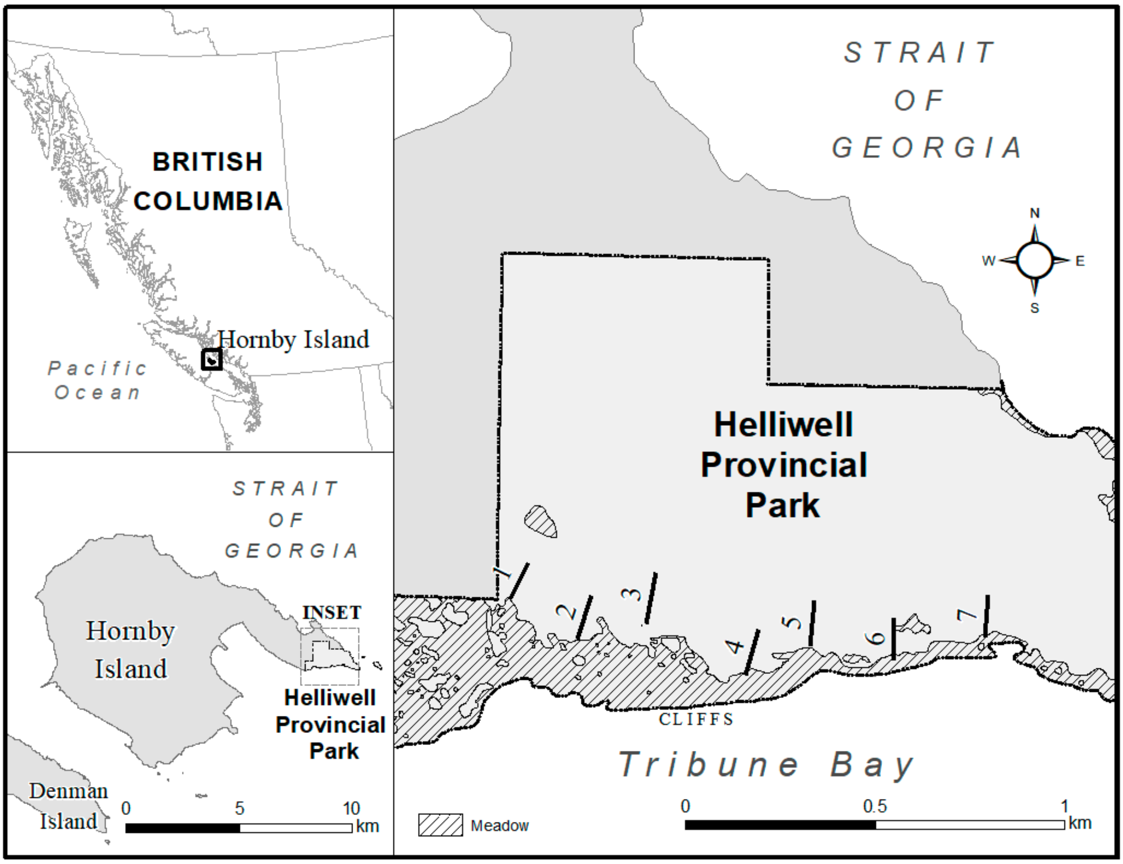

Figure 1. The location of seven 6 × 75 metre belt transects on the southwest portion of Helliwell Provincial Park located on Hornby Island, British Columbia, Canada.

2.2. Reconstructing Historical and Contemporary Forest Structure Via Belt Transects

A Garry oak meadow transitioning to a Douglas-fir dominated woodland was the focal area for our study in Helliwell Provincial Park (Figure 1). The study area extended from the open meadow (containing scattered individual Garry oak, Douglas-fir, and shore pine trees) into an encroaching Douglas-fir dominated forest. To capture the presence and abundance of the six dominant tree species growing along a moisture gradient, we surveyed seven belt transects (6 × 75 m) over a 1500 m stretch of forest, starting at the west (49°31′6.9″) corner of the park and running east (49°31′4.7″). Belt transects ran perpendicular to the coastline and were selected within a stratified random sampling design at the present-day forest edge (to effectively sample upland meadow and wetland sites; Figure 1).

Within each belt transect, two 5 mm increment cores were sampled from every fifth tree of the species Douglas-fir, shore pine, and western redcedar [*Thuja plicata* Donn ex D. Don.]) that were greater than 15 cm dbh. These species were selected because they are the most common in the study area. Tree cores were sampled as close to the ground level as possible and from bark to pith perpendicular to the slope to avoid reaction wood and to accurately estimate the decade of tree establishment [34]. Although we were not able to core every tree in each transect the age, number, health, dbh, and species of every tree greater than 15 cm dbh was recorded. The number and type of trees present were used to estimate the abundance of stems per hectare and the composition of forest canopy [34]. Tree whorls on every fifth sapling (>7.5 cm dbh; <15 cm dbh) were counted to estimate the age of tree saplings, and estimates of sapling ages were verified by counting rings on the stumps of trees that had been recently thinned outside of the study area. The composition and abundance of all living and dead trees per hectare was calculated in each belt transect for comparison.

In the laboratory, tree cores were mounted on boards and sanded with progressively finer sandpaper to a 600 grit finish. Tree cores were processed using standard dendrochronological techniques [35].

Samples were first visually crossdated, and then statistically verified using the computer program COFECHA [36]. To accurately determine the decade of tree establishment, we estimated the number of tree rings missing from the sample by measuring the curvature of the innermost ring using a transparent template and dividing the radius of the missing growth portion by the average growth rate during its period of early development [37]. For age structure analyses, we binned trees >15 cm dbh together by decade to reduce uncertainty in the time needed to reach the coring height [38].

2.3. *Reconstructing Historical and Contemporary Forest Structure Via Remote Sensing*

Interpretation of historical maps and aerial photographs (extending to 1950) were used to assess changes in land-use patterns and conifer densities in the park since 1875. Air photos of Helliwell Provincial Park containing data for all available dates were acquired from GeoBC. Air photos were georeferenced to Bing Satellite Imagery© with an estimated accuracy of ~5 m, and five to ten control points were used to situate each photo. Air photos were then digitized in ArcMap 10.5.1, and a layer was created for each year [39]. Individual trees were not digitized unless they were encompassed by dense brush, resulting in an uninhabitable location for native forbs and grasses (which represent Taylor's Checkerspot forage). The forested area was subtracted from the entirety of the park polygon to assess the meadow extent and the remaining polygons were calculated for each year. To verify field surveys, mapping analyses focused primarily on the west side of the park adjacent to the present day Garry oak meadow. For map clarity, four years (1952, 1972, 1996, and 2014), at approximately twenty-year intervals across six decades, were selected to assess land-use changes and calculate the historic Garry oak meadow extent.

2.4. *Reconstructing Fire Dynamics in Helliwell Provincial Park*

To reconstruct the fire history of the park, we systematically searched all old growth trees (estimated by dbh, branch size and height) for the presence of superficial fire scars, which are lobed folds of bark generally found near the tree base [40]. We also cored five large diameter Douglas-fir trees located in the southern corner of the park to age the old growth Douglas-fir.

2.5. *Statistical Analyses*

All data were analyzed in R Version 1.0.136 [41]. The abundance and location of trees along belt transects, species, and stand age were compared using the Kruskal–Wallis test for non-parametric data. A contingency test was used to test the association between the presence of dead Garry oak and living Douglas-fir trees.

3. Results

3.1. *Reconstructing Historical and Contemporary Forest Structure Via Belt Transects*

Belt transects contained Douglas-fir, shore pine, and Garry oak trees in drier upland sites and Pacific crabapple (*Malus fusca* [Raf.] C. K. Schneid), aspen (*Populus tremuloides* Michx.), and western redcedar in wetter sites (Figure 2). There was no significant difference in the species composition (Kruskal–Wallis chi-squared = 4.8214, df = 2, p-value = 0.08975), dbh (Kruskal–Wallis chi-squared = 212.8083, df = 225, p-value = 0.7102) and height (Kruskal–Wallis chi-squared = 186.8888, df = 168, p-value = 0.1514) of the trees in each belt transect.

The median number of Douglas-fir stems in the transects was 902 trees per hectare, followed by shore pine at 88 trees per hectare, and Garry oak at 44 trees per hectare. A greater number of Douglas-fir trees were found in the first 0–15 m of transects running from the meadow and present-day forest edge (Kruskal–Wallis chi-squared = 4, df = 4, p-value = 0.04; Figure 2). There was no significant difference in the density of stems per hectare between the six belt transects (Kruskal–Wallis chi-squared = 6, df = 6, p-value = 0.4232) or age (Kruskal–Wallis chi-squared = 12.5905, df = 9, p-value = 0.182).

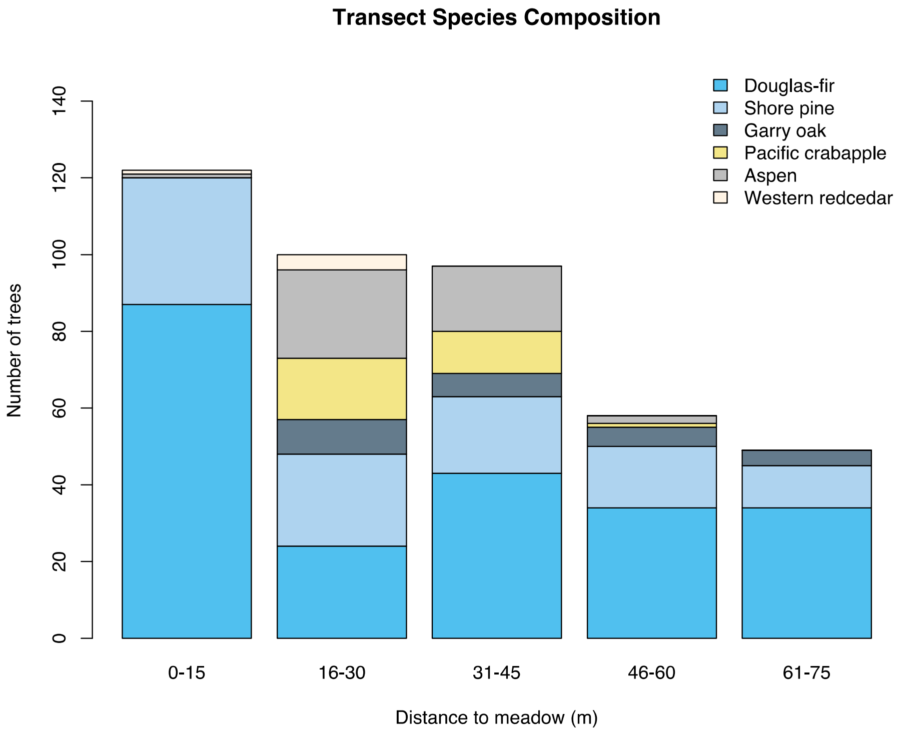

Figure 2. The composition and abundance of the six species of trees located in seven belt transects along a gradient of Garry oak maritime meadow transitioning to woodland. The greatest numbers of trees, specifically Douglas-fir trees, were located in the western Garry oak meadow at the present day forest edge.

Tree ring analyses show that the majority (85%) of trees have been established on the western meadow edge since 1950 (Figure 3), and the meadow edge (0–15 m) of transects is comprised of fast growing Douglas-fir and shore pine saplings (Figure 2). Counting of branch whorls confirmed that Douglas-fir trees can reach heights of 3 m in less than 10 years.

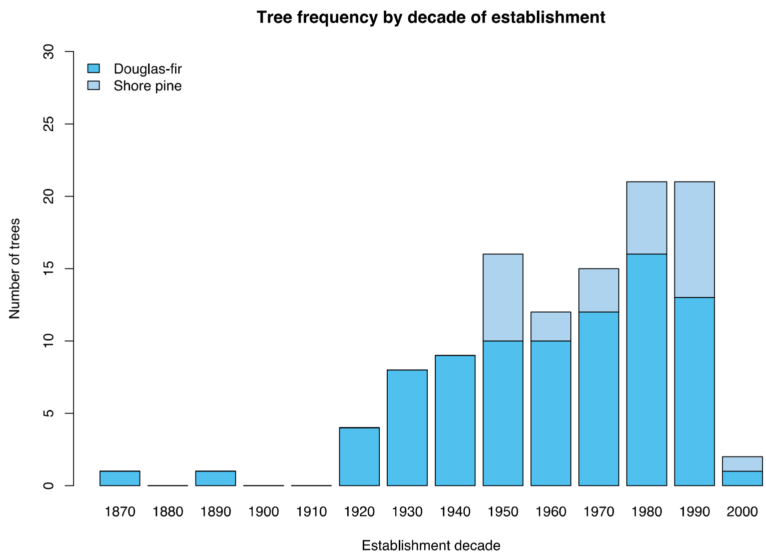

Figure 3. The number of Douglas-fir (dark blue) and shore pine (light blue) trees along with their decade of establishment from every fifth tree (greater than 15 cm diameter at breast height [dbh]) sampled from seven belt transects.

Fifty-three percent of Garry oak trees sampled were dead and located in the transitional zone (0–15 m) proximal to the Garry oak meadow (Figure 2). Dead Garry oak trees were not independent of the presence of overstory Douglas-fir trees (Chi-squared= 28.4938, df = 1, p-value < 0.0001; Figure 4).

Figure 4. Garry oak trees located at the present-day forest edge are experiencing overhead shading, infilling and subsequent mortalities (likely due to encroaching Douglas-fir and shore pine trees).

3.2. Reconstructing Historical and Contemporary Forest Structure Via Remote Sensing

The total area of the Garry oak meadow in Helliwell Provincial Park has decreased more than 50% since 1952 (Figure 5; Table 1). The extent of the Garry oak meadow was largest in 1952, encompassing a large portion of the southeast corner of the park, as well as several large patches to the west and northwest regions of the park (Figure 5). In the 1960s, several patches of isolated young Douglas-fir and shore pine trees established in the southeast portion of the park. By 1972, the large Garry oak meadow in the west and northwest portion of the park was infilled with Douglas-fir trees. In 1996 several small patches of Garry oak meadows were re-established in the interior of the park following a >10 hectare fire from an escaped campfire in 1985 [42].

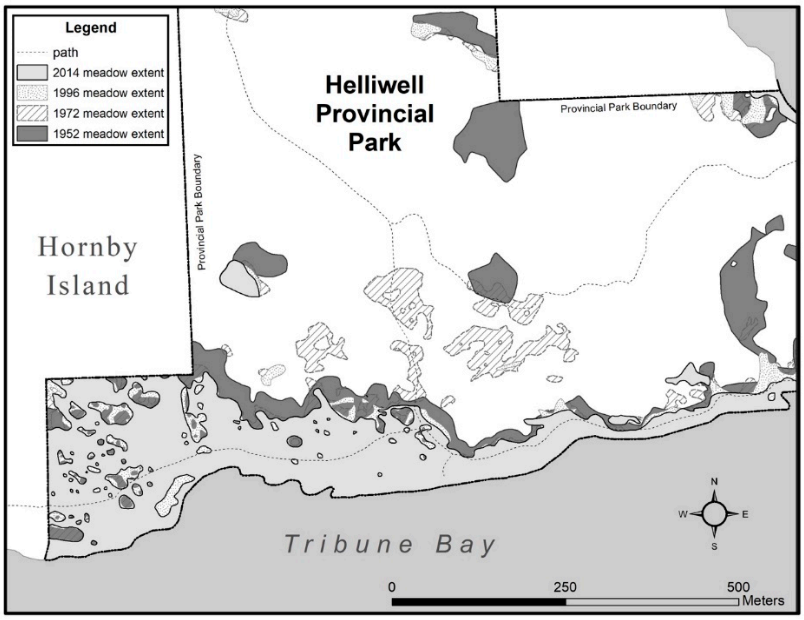

Figure 5. Repeat Aerial photographs from 1952 to 2014 depict spatial changes in the extent of the Garry oak maritime meadow located in the southwest corner of Helliwell Park on Hornby Island, British Columbia, Canada.

Table 1. The year, scale, focal length, media type, and source of air imagery used to map spatial changes in the historic Garry oak meadow in Helliwell Provincial Park, British Columbia, Canada.

Year	Meadow Extent (m^2)	Reference	Scale	Focal Length	Media
2014	93,968	08bcd14101_105_25_8bit_rgb	"1:20,000"	80 mm	Digital—Colour
2000	136,265	Bing Imagery			Image Service
1996	155,650	bcb96016_222	"1:40,000"	153 mm	Film—BW
1988	170,045	bcc835_215	"1:10,000"	305 mm	Film—Colour
1980	166,108	BC80102_164	"1:20,000"	153 mm	Film—BW
1972	194,948	BC7406_197	"1:15,000"	305 mm	Film—BW
1968	197,286	BC7077_109	"1:16,000"	305 mm	Film—BW
1964	219,693	BC5097_089	"1:31,680"	153 mm	Film—BW
1952	211,519	BC1499_058	"1:40,000"		Film—BW

By 2014, these interior patches were again infilled with Douglas-fir and shore pine and several new patches of Douglas-fir trees had established in the southeast portion of the Garry oak meadow (Figure 5). Since 1952, the present-day forest edge has encroached 125 m into the historic Garry oak meadow (Table 1). The rate of encroachment into the Garry oak meadow since 1952 is 0.53 m per year.

3.3. Reconstructing Fire Dynamics in Helliwell Provincial Park

Systematic field surveys revealed that very few fire-scarred trees were present within the park. We attempted to core several (n = 5) large diameter (>100 cm dbh) trees. However, complacent ring widths and heart rot rendered fire reconstructions impossible [34]. The oldest tree successfully cored with an increment borer in Helliwell Provincial Park was established at the beginning of the 18th century (Supplementary Materials Figure S2).

4. Discussion

Our results indicate that Helliwell Provincial Park has experienced significant decreases in the area of Garry oak meadows since the beginning of the 20th century. Douglas-fir dominated conifer forests have substantially encroached into the meadow, potentially affecting the amount of habitat available for Taylor's Checkerspot butterfly breeding and foraging.

Fire exclusion, substantial logging followed by land clearing, and livestock grazing occurred in the park region from the 1900s through to the 1960s [43]. Following the establishment of the provincial park in 1966, several roads were constructed, and a subdivision was built on the western park boundary (Figure 1). Helliwell is a popular park, drawing upwards of 60,000 visitors per year (when last censused in 2001) [43]. Many of these visits are concentrated in the summer months when the population of Hornby Island quadruples [44]. The popularity of the park has resulted in human disturbances such as trampling, escaped campfires, and the introduction of invasive plant species [43], all factors which may have contributed to the decline of Taylor's Checkerspot butterfly populations.

Our results reveal important information about current stand composition and conifer encroachment in the park, which can be used to infer future forest composition. First, conifer encroachment is occurring fastest in the west and northwest areas of the park adjacent to the largest remaining Garry oak meadow and wetland area (Figure 5). Second, living Garry oak seedlings and saplings are only present when overstory conifers are absent, and no Garry oak saplings were present in forested areas with Douglas-fir dominated canopies (Figure 2). Third, more than half of the Garry oak trees located in the belt transect were dead, likely due to conifer encroachment and the associated effects of shading and water table drawdown (Figure 4). The greatest number of trees >15 cm dbh occur at the present-day forest edge proximal to the Garry oak meadow along the northwest boundary of the park (Figure 1). This transitional forest edge (0–15 m) is comprised of fast-growing Douglas-fir and shore pine trees (Figure 2).

There has been significant encroachment of conifers in the Garry oak meadow area since it was first mapped in 1875 (Supplementary Materials Figures S1 and S3). Digitization and analyses of historical aerial photographs (1952–2014) indicate that conifer encroachment is ubiquitous along the southern present-day meadow-forest transitional boundary (Figure 5). These findings are consistent with other aerial imagery analyses of similar ecosystems, which found that conifer infilling was pervasive along forest boundaries in the absence of fire on southern Vancouver Island [13]. By as early as the 1970s, there was evidence of a closed canopy forest over much of the northwest Garry oak meadow as well as infilling of conifers in western coastal bluff areas. The establishment of island like patches of Douglas-fir and shore pine trees in the southeast portion of the meadow has rapidly reduced Garry oak meadow habitat (Supplementary Materials Figure S4). The meadow area adjacent to the study area is currently undergoing forest thinning and replanting of native vegetation to restore habitat to the desired <20% canopy cover for the proposed reintroduction of the Taylor's Checkerspot butterfly in the year 2020 [26].

The oldest tree successfully cored with an increment borer in Helliwell Provincial Park was established at the beginning of the 18th century (Supplementary Materials Figure S2). This tree was part of a stand of approximately 50 old growth (>250 years) Douglas-fir trees located in the southeast portion of the park. The majority of Douglas-fir tree establishment occurred after 1910, and continuous recruitment of Douglas-fir and shore pine trees has occurred in the park through the 20th century (Figure 5). Douglas-fir and shore pine trees have also experienced pulses of recruitment likely associated with the cessation of livestock grazing the 1960s [43]. Accidental and lightning caused fire ignitions also contribute to early successional forests dominated by Douglas-fir and shore pine trees as exemplified by the loss of a large portion of the Garry oak meadow following an escaped campfire in 1985 that burned several hectares of forest (Figure 5; Supplementary Materials Figure S3).

Fire suppression and the subsequent encroachment of Douglas-fir and shore pine trees into Garry oak meadows has created significant management challenges such as maintaining native plants and animals that depend upon these once fire resilient ecosystems [45]. Fire suppression results in conifer encroachment to grassland and wetland areas, changing the soil chemistry and the organic matter composition on the forest floor, which enables the growth of some species, and inhibits the growth of others [13]. Fire suppression has increased fuel loads, created dense shrub layers, and increased the risk of high severity fire activity (Supplementary Materials Figure S5). Introduced invasive grasses and weedy forb species can accumulate in higher densities in disturbed areas (trails, roads, and forest edges) and dry faster than native plant species [46]. Invasive grasses, forbs, and shrubs are prevalent in Helliwell Provincial Park in coastal bluffs, meadows, woodlands, and wetland areas [23]. Invasive shrubs, grasses, and vines can affect the rate of fire spread, flame length, and the resilience of native species to fire activity [46]. The presence of these invasive species has the potential to increase the fire hazard in the park, as species like English holly (*llex aquifolium*) and English Ivy (*Hedera helix*) could be more flammable than native plants [47,48].

Garry oak ecosystems retain the majority of larger diameter fuels within the canopy layer and do not easily ignite except when leaf tissue moisture is low [48]. Burning Garry oak meadows every few years was likely a common practice by coastal First Nations to maintain habitat for camas (*Camassia* spp.) and other important food species [9,10]. These low severity fires consumed available fuels, often leaving no evidence of fire on the landscapes [10]. The lack of fire-scarred trees suggest that fire activity was likely suppressed prior to widespread fire suppression policies implemented in British Columbia in the 1920s [8]. Historic documents indicate that First Nations populations on Hornby Island were significantly affected by three smallpox epidemics, and it has been estimated that Helliwell Park might not have experienced cultural fire activity in approximately 100 years [43]. A long history of commercial logging on Hornby Island has also decreased the extent of old growth trees containing fire scars [43]. Unfortunately, the lack of fire evidence in the form of living fire scarred trees limits the potential to reconstruct historical fire activity in the park [8]. Soil charcoal analysis, fossil pollen analysis, and more ethnohistorical research and traditional ecological knowledge is required to understand the fire history of Helliwell Provincial Park [49,50], including the spatial and temporal characteristics of historic burning by First Nations.

Accidental fire ignitions by park visitors pose the greatest large-scale management risk to the park, as the fuel profile and flammability of species has significantly changed since frequent burning by First Nations historically occurred in the park [9,13]. The success of reintroducing fire into Garry oak ecosystems is largely dependent on site preparation, such as clearing ground fuels and removing flammable invasive plants prior to implementing prescribed burning programs [51–53]. Ecosystems with deep, organically enriched soils have been shown to be more resilient to prescribed fire at three-year intervals [13,15]. However, maritime meadow ecosystems such as the Garry oak meadow and transitional forests in Helliwell Provincial Park contain relatively shallow mineral soils with low native species richness [30]. Even low severity fires have the potential to destabilize soils and allow invasive species to establish [23,30]. Long-term site monitoring should be employed to address the knowledge gap regarding the effects of prescribed fire on soil composition and stability.

The encroachment of conifer species also complicates the success of prescribed burning, because the presence of Douglas-fir stands decrease understory light, which restricts the establishment of perennial herbaceous species and native grasses [52]. Conifer species also impact the microclimate of the forest floor, saturating and cooling soils, which can extinguish low severity ground fires [54]. Fortunately, thinning encroaching conifers can decrease the competitive pressure on native herbaceous and grass species while creating a desirable microclimate for propagation and suitable prescribed burning pre-conditions [15,30,55]. A mixed restoration plan of monitoring, clearing, thinning, and burning would provide the best opportunity to allow native grassland species, such as the forbs and perennials favoured by the Taylor's Checkerspot butterfly, to establish and will be an important step towards the long-term recovery of the Garry oak meadow.

A successful fire prescription program will include partnering with local community members and First Nations, as well as incorporating traditional ecological knowledge to determine the socio-ecological objectives desired in a restoration plan for the Park [53]. After pre-fire treatments, such as clearing and thinning, several small spot burns (10 × 10 m) could provide a preliminary assessment of the effects of low severity ground fires on native plant propagation and the abundance and persistence of invasive species. With local public support and support from a diverse portfolio of stakeholders, such as First Nations partners, BC Parks, Parks Canada (who have experience with prescribed burns in Garry oak ecosystems in Gulf Islands National Park; see below), and the Garry Oak Ecosystem Recovery Team, this program could be expanded to prescribed burning of one-hectare sites in the Garry oak meadow. Long-term monitoring and repeat prescribed burns are required to re-establish fire tolerant native plants, which may be lying dormant within the soil [23], restore biogeochemical cycling, and enhance Garry oak seedling regeneration [15,51].

There are several examples of successful prescribed burning programs in Garry oak ecosystems that combine ecological, cultural, and social values. A Parks Canada (Gulf Islands National Park Reserve) restoration and prescribed burning program was initiated on Tumbo Island, a small, uninhabited island north of Saturna Island, British Columbia. In September 2016 four 50 × 50 m plots (totaling one hectare in area) were burnt [56]. The prescribed burn created more open forest floor and removed 150 years of ground fuel [56]. In addition to the Tumbo Island project, there are many other established prescribed burning programs in Garry oak ecosystems including: Willamette Valley, Oregon [57], Cowichan Nature Preserve, British Columbia [58], Redwood National Park, California [59], and in the San Juan Islands, Washington [60]. These fire restoration programs provide important information on how to successfully reintroduce fire in populated areas with complex disturbance histories and management concerns and could serve as models for the re-introduction of prescribed burning in Helliwell Provincial Park.

5. Conclusions

Because of the decline in their habitat's extent and quality [61], Garry oak ecosystems are often targets for restoration and species management in Canada. The reintroduction of fire through prescribed burning is an effective, timely, and practical restoration technique to enhance ongoing Garry oak meadow habitat restoration in Helliwell Provincial Park. Establishing a prescribed burning program also supports several long-term goals in the park, such as decreasing the risk of future high severity interface fires, supporting the re-establishment of fire adapted native grasses, and restoring Garry oak meadow habitat for several threatened and critically endangered species such as the Taylor's Checkerspot butterfly [15]. A comprehensive proposal for a prescribed burning program that combines traditional ecological and local knowledge with current wildfire science could help engage stakeholders with proposed fire restoration efforts [30,53]. Garry oak ecosystems are one of the most damaged ecosystems in North America [21,62], and restoration activities in these ecosystems contribute to the recovery of areas containing some of the highest densities of species at risk in Canada.

Supplementary Materials: Supplementary materials are available online at http://www.mdpi.com/2571-6255/2/3/48/s1. Figure S1. A hand drawn map of what is presently known as Helliwell Park and surrounding areas on Hornby Island, B.C. completed in 1875 by field surveyor Joseph Carey; Figure S2. The oldest tree cored in the park is a Douglas-fir estimated to have established in 1710. This tree is part of a stand of old-growth trees located in the southeast corner of the park; Figure S3. This high-density patch of shore pine established after the 1985 fire, which burned several hectares in the northern portion of the park; Figure S4. Ongoing restoration efforts aim to thin high-density patches of encroaching Douglas-fir in the western Garry oak meadow. The majority of high-density patches of trees established within the last 30 years; Figure S5. Fuel-loading in the shrub layer increases the risk of high-severity, stand replacing fires in the park. Pictured here is an accumulation of windfall and downed coarse woody debris in transect five. Datasets will be made available through the Dryad repository.

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Conflicts of Interest: The authors declare no conflict of interest.

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