Garry oak acorn production at the Swan Lake Christmas Hill Nature Sanctuary, Saanich BC
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Introduction

Garry oak (Quercus garryana) occurs in restricted areas of southwestern British Columbia, especially on southern and eastern Vancouver Island and the Gulf Islands, and south through drier areas of western Washington and Oregon and northern California. Garry oak growing sites range from relatively dry and rocky to relatively moist, fertile, and with deep soils. Its establishment and persistence, along with associated understory vegetation, is favored by periodic burning as traditionally practiced by First Nations. Garry oak is most productive on relatively moist and fertile sites. However, its abundance on those sites has been greatly reduced by land use changes occurring with European settlement beginning in the mid-1800s. These land use changes include cessation of periodic burning by First Nations (e.g., Hoffman et al. 2019), woodland conversion to farmland, and urbanization. Reductions in Garry oak-dominated ecosystems have been especially pronounced on southern Vancouver Island, the Puget Sound lowlands, and the Willamette Valley.

Although much Garry oak habitat has been lost to settlement and land use changes, growing seasons in the region are predicted to get hotter and drier with climate change. Because Garry oak is thought to be more drought-tolerant than its primary coniferous associate Douglas-fir (Hahm et al 2018), it may establish and persist on some sites now dominated by Douglas-fir as drought increasingly impacts Douglas-fir. Ultimately, the ability of Garry oak to colonize and establish on those sites will also depend on disturbance regimes, timely production and dispersal of acorns and emergence and survival of seedlings, and the ability of older trees to tolerate climatic extremes and changes in pest abundance and dynamics.

Acorn production by Garry oak is important to document and understand. Reproduction depends on the production of viable acorns and their emergence and their subsequent establishment. Acorns are also an important food for many species. Acorn production is known to vary from year to year. This is not surprising; reproductive bud initiation, pollination, and the development of mature viable acorns require appropriate weather conditions over a 15- month period spanning two growing seasons (Peter and Harrington 2009) and significant energy, mineral nutrients, and available moisture. Resource demands associated with large acorn crops may be sufficient to reduce stem diameter growth of oaks. Understanding how Garry oak acorn production varies with external (weather, site, and stand) conditions, and internal factors such as tree age and vigor can help explain how Garry oak persists on the landscape now and under future climates, along with its role in the food web.

Methods

To better understand patterns of acorn production by Garry oak, the US Forest Service Forestry Sciences Laboratory (FSL) in Olympia Washington initiated a long-term range-wide study of acorn production in 1998. Objectives were to document acorn production over time on the same trees across a range of sites, stand conditions, tree ages and vigor. FSL researchers designed the study and analyzed data; much of the data were collected by volunteer “community scientists” and then submitted annually to the researchers for analysis. Ultimately, approximately 900 trees were regularly assessed sampled from Courtenay BC in the north to Medford Oregon in the south (Peter and Harrington 2009).

The Swan Lake- Christmas Hill sample trees are among ca. 200 trees initially selected for study on Vancouver Island, from Courtenay to Metchosin, beginning in 2002. Twelve trees (or separate stems above 1.3m height) were selected south of the summit on Christmas Hill and 15 near the path on the northeast side of Swan Lake. Two trees in Rainbow Park were also selected, providing a range of site conditions in the Swan Lake area. Similar within-location site contrasts were also made elsewhere on the Vancouver Island.

Site data were collected when the study was begun and included tree location (UTMs and field notes to allow relocation), elevation, slope and aspect, amount of visible rock at the soil surface, and notes on understory vegetation. Tree location notes are attached in Appendix A. Tree growth data were collected at the beginning of the study and included age (if known or inferable), height, diameter at 1.3m height, crown width, crown shape, and the proportion of crown impacted by adjacent trees of similar or greater height. These measurements were originally intended to be repeated at 5-year intervals. Height measurements of the Vancouver Island trees were difficult to repeat at 5-year intervals, but diameter measurements were repeated at yearly intervals from 2013 onward as they were easy and aided in relocating untagged survey trees.

Data on acorn crops and tree vigor were collected yearly between mid-August and early September when acorns were fully developed but prior to acorn drop or collection by acorn consumers. Tree vigor was assigned to one of three classes and acorn crop size to one of four (Table 1; Graves 1980). Acorn production class is relative to the size of the tree; hence a large-crowned tree with an acorn production class of 3 would produce more acorns in absolute terms than a much smaller tree also with an acorn production class. Acorn surveys were conducted at Christmas Hill from 2002 through 2022, except for 2021; surveys were conducted at Swan Lake from 2002 through 2020.

Results

It was apparent early in the study that acorn crop surveys were difficult for trees growing in dense stands. For accurate estimates, one needs a view of the outside of the crown from a distance and ideally with the sun behind the surveyor. Acorns are not easily seen from beneath the tree crown in productive dense stands. Hence, apparent differences in acorn production between trees growing in the open versus those in dense stands with tall trees and small high crowns may be due to different stand conditions (resource availability) or to inconsistent survey technique. The Christmas Hill oaks were open-grown and relatively small so acorns were readily visible; the crowns of Swan Lake oaks were completely or largely visible under appropriate lighting, but acorn production may have been underestimated in some years.

Acorn production was consistently less in the Christmas Hill trees than in the Swan Lake trees. “Good” (i.e., acorn class 3 or 4) acorn production occurred in only 7 of 20 years and in a maximum of 20% of trees. None of the “good” producers were in class 4; in 4 years, the production was borderline between classes 2 and 3. Relatively high years for acorn production were 2004, 2009, 2012, and 2019. No acorns were observed in 2003, 2010, 2015, and 2018 (Figure 1a). In some years, acorns were initiated but did not develop to maturity (i.e., acorns were small and brown).

At Swan Lake, good acorn production occurred in some trees in all but 4 of 19 years (only two trees were surveyed in 2017). The highest production (> 40 % of trees in class 3 or 4) occurred in 2004, 2009, 2012, 2014 and 2016. Acorns were produced by at least some trees in all years (Figure 1b).

Sampled trees were also smaller and mean diameter increment less at Christmas Hill than at Swan Lake (Figure 2), consistent with reduced crown health (Christmas Hill mean health class by year ranged from 1.9 to 2.8; Swan Lake mean health class by year ranged from 1.8 to 2.3). Mean acorn production per tree over the sample period increased with mean diameter increment, in other words, healthier and more vigorous trees generally produced more acorns.

Variation in acorn production with weather or stand and site conditions hasn't been examined for the Christmas Hill, Swan Lake or other sample trees on Vancouver Island. Based on 8 years of surveys across the range of Garry oak, Peter and Harrington (2009) suggested that acorn production decreased with higher winter temperature and spring precipitation and might also be decreased by low soil moisture during summer. The latter would be consistent with less frequent years of "good" production in rocky and shallow sites such as Christmas Hill, compared with the deeper soil sites near Swan Lake. In the more productive deeper soil sites, shading by adjacent large trees may constrain reproductive bud initiation and, ultimately acorn production.

Hahm, W. J., W. E. Dietrich, and T. E. Dawson. 2018. Controls on the distribution and resilience of Quercus garryana: ecophysiological evidence of oak's water-limitation tolerance. Ecosphere 9(5):e02218. 10.1002/ecs2.2218

Peter, D.H. and C.A. Harrington 2009. Synchronicity and geographic variation in Oregon white oak acorn production in the Pacific Northwest. Northwest Science 83:117.

Table 1. Coding for tree health and acorn production

Health codes

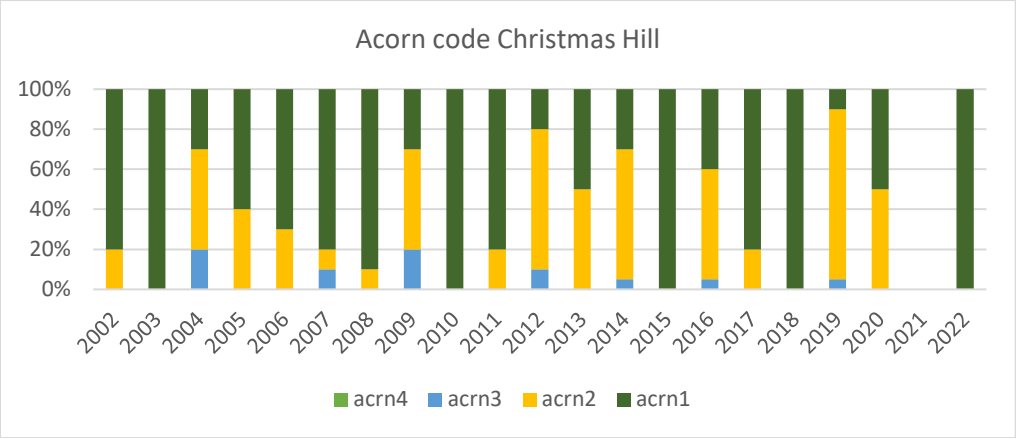
1. Tree healthy, all bark and major limbs present and alive, no visible rot, full crown of healthy leaves
2. Tree healthy but has one or more of: missing bark, broken major limbs, visible rot
3. Tree appears unhealthy-- much visible rot, sparse foliage, major branches broken or dead

Acorn abundance codes

1. No acorns visible
2. One or more fully-developed acorn visible after close inspection
3. Acorns readily visible all around tree and borne predominantly singly
4. Acorns typically in clusters of two or more, all around the tree. Limbs often bend from the weight of acorns

Figure 1. Percentage of trees by acorn production class and year at (a) Christmas Hill and (b) Swan Lake. Acorn codes 1,2,3,4 shown as acrn1, acrn2, acrn3, and acrn4, where acrn1 represents no acorns and acrn4 represents abundant acorn production.

(a)



(b)

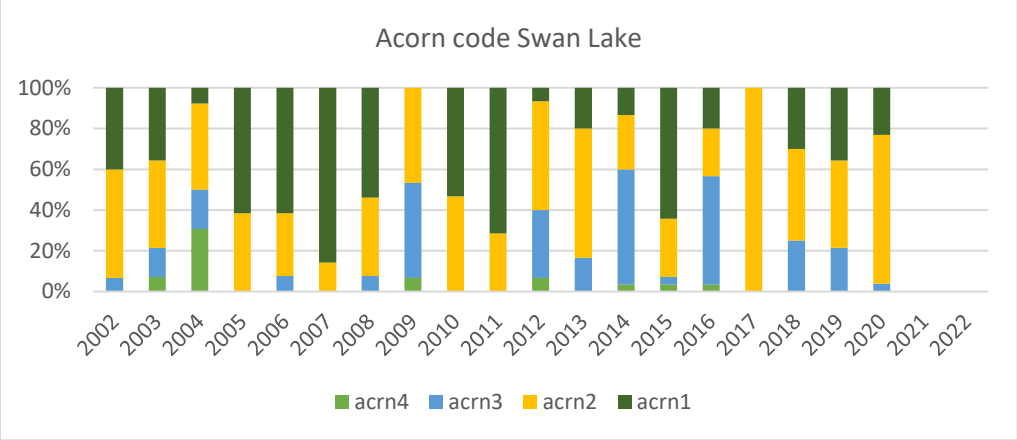
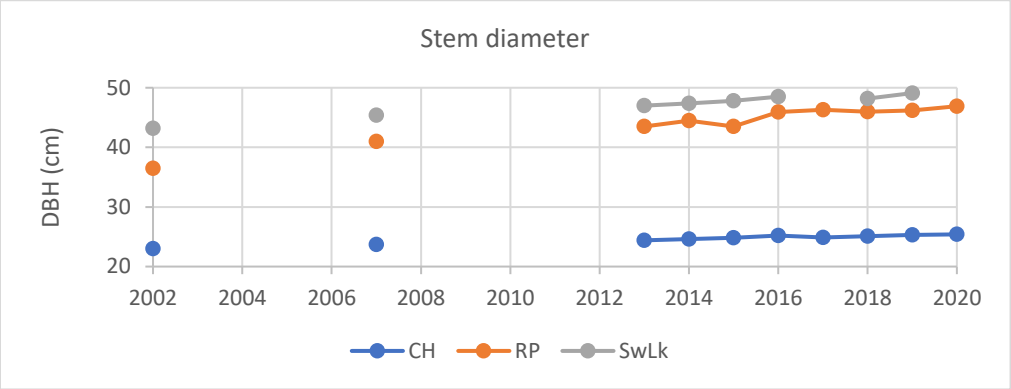


Figure 2. (a) Mean stem diameter (ca. 1.3m height) and **(b)** tree height by year at Christmas Hill (CH), Rainbow Park (RP), and Swan Lake (SwLk).

(a)



(b)

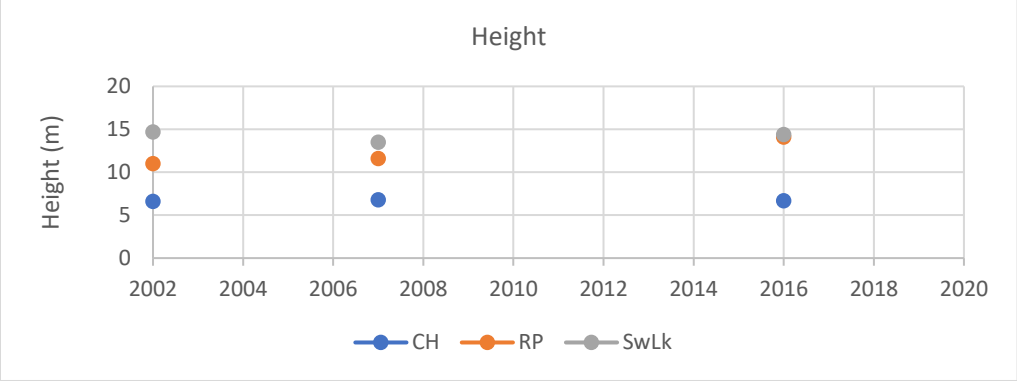
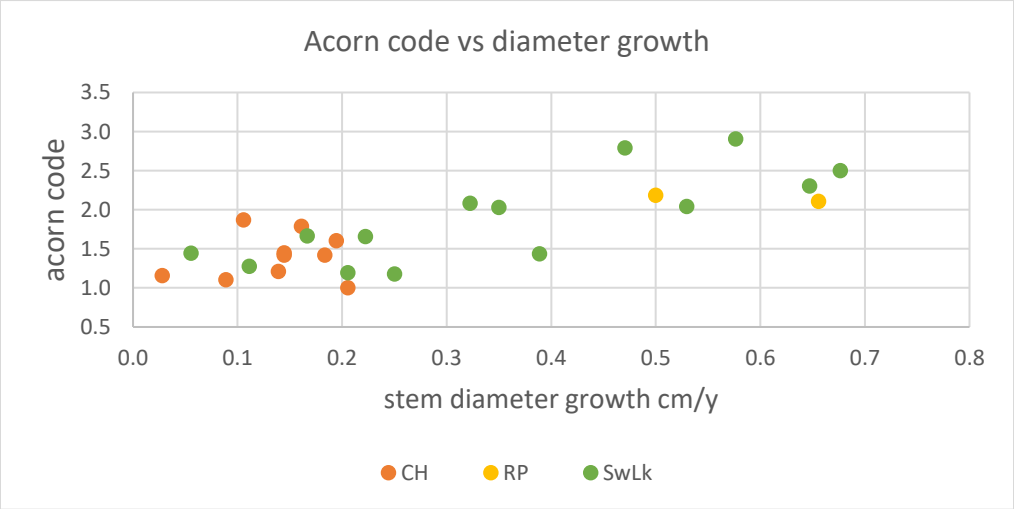


Figure 3. Mean acorn production per tree versus mean stem diameter increment for individual trees at Christmas Hill (CH), Rainbow Park (RP) and Swan Lake (SwLk)



Appendix A. Acorn survey tree locations (UTMs and field notes) Christmas Hill and Swan Lake. **Location data need rechecking.**

ChristmasHill

Tree#	UTM	Easting	Northing	Location notes (relative to centre of flat rock outcrop between summit and vernal pool)
1	10U	472176	5368993	18m @270° closer one
	10U	472176	5368993	
2	10U	472168	5368981	31m@240° W end vernal pool
3	10U	472180	5368964	30m@210° W most of pair
4	10U	472194	5368953	42m@180° largest of pair
5	10U	472202	5368972	21m@156° 3m from fence
6	10U	472207	5368986	E end of rock 120°
7	10U	472220	5369008	2nd tree in line N of trail @60°
8	10U	472198	5369017	double stem _m@ 10°
	10U	472198	5369003	
9	10U	472192	5369003	0° right of steps, largest of clump
10	10U	472174	5369007	320° by trail below big rock

Swan Lake

Tree#	UTM	Easting	Northing	Location notes
1	10U	472705	5368059	open-grown E side sanctuary west of loop trail
2	10U	472720	5368166	double stem S side (downslope) of trail
	10U	472720	5368166	
3	10U	472724	5368175	7m 250° from #2 downslope of trail
4	10U	472724	5368175	2m 300° from #3 downslope of trail
5	10U	472708	5368188	tree cut down 2004
6	10U	472695	5368184	5m 190° from #7
	10U	472695	5368184	
7	10U	472698	5368189	11m 210° from #8
8	10U	472706	5368202	11m 30° from #7
9	10U	472700	5368197	6m 290° from #8 upslope of trail
10	10U	472688	5368211	9m 340° from #9 upslope of trail
	10U	472688	5368211	
11	10U	472683	5368201	21m 243° from #10 stand edge downslope of trail
	10U	472683	5368201	
	10U	472683	5368201	
12	10U	472622	5368220	at trail access end of NelthorpeSt