U.S. Fish & Wildlife Service

Development of Protocols for Monitoring Phenology and Abundance of Berries Important to Brown Bear in the Kodiak Archipelago, Alaska

Pilot Study Final Report

Bill Pyle and Daniel Hernandez

Bill Pyle / USFWS

Kodiak National Wildlife Refuge, Kodiak, Alaska

November 2017

Citation:

Pyle B, Hernandez D. 2017. Development of protocols for monitoring phenology and abundance of berries important to brown bear in the Kodiak Archipelago, Alaska: pilot study final report. Refuge report 2017.4. U.S. Fish and Wildlife Service, Kodiak National Wildlife Refuge, Kodiak, AK.

Keywords: Kodiak Archipelago, brown bear, red elderberry (*Sambucus racemosa*), salmonberry (*Rubus spectabilis*), oval-leaf blueberry (*Vaccinium ovalifolium*), and devilsclub (*Oplopanax horridus*), berry abundance, plant phenology, phenophase.

Disclaimer: The findings and conclusions in this report are those of the authors and do not necessarily represent the views of the U.S. Fish and Wildlife Service. The use of trade names of commercial products does not constitute endorsement or recommendation for use by the federal government.

TABLE OF CONTENTS

EXECUTIVE SUMMARY **7**
INTRODUCTION **9**
PROBLEM STATEMENT **10**
OBJECTIVES **11**
METHODS **11**
STUDY AREA 11
STUDY SITE AND FOCAL SPECIES SELECTION 12
PHENOLOGY MONITORING 12
PLOT-BASED BERRY ABUNDANCE MONITORING 13
ANALYSIS OF PLOT DATA 16
TEMPERATURE MONITORING 17
RESULTS AND DISCUSSION **17**
PHENOLOGY MONITORING 17
PLOT-BASED BERRY ABUNDANCE MONITORING 18
TEMPERATURE MONITORING 19
CONCLUSION **20**
RECOMMENDATIONS **20**
PHENOLOGY MONITORING 20
PLOT-BASED BERRY ABUNDANCE MONITORING 21
TEMPERATURE MONITORING 21
DATA ANALYSIS 22
ACKNOWLEDGEMENTS **22**
LITERATURE CITED **23**

LIST OF TABLES

Table 1. Characteristics of red elderberry (*Sambucus racemosa*) index sites, Kodiak Island, Alaska, 2015-2016.. 26

Table 2. Characteristics of salmonberry (*Rubus spectabilis*) index sites, Kodiak Island, Alaska, 2015-2016.. 27

Table 3. Characteristics of oval-leafed blueberry (*Vaccinium ovalifolium*), Road System index site, northeastern Kodiak Island, Alaska, 2015-2016. 27

Table 4. Characteristics of devilsclub (*Oplopanax horridus*) plots, Road System index site, northeastern Kodiak Island, Alaska, 2015-2016. 28

LIST OF FIGURES

Figure 1. Area, sites, and plots of study of four focal species of berry-producing shrubs,No table of figures entries found. Kodiak Island, Alaska, 2015-2016. 29

Figure 2. Sites monitored for phenology of berry-producing shrub species on Kodiak Island (2015 & 2016) and Afognak Island (2016), Alaska. 30

Figure 3. Plot layouts in red elderberry (*Sambucus racemosa*) and devilsclub (*Oplopanax horridus*), Kodiak Island, Alaska. 31

Figure 4. Guide for estimation of relative abundance of red elderberry (*Sambucus racemosa*) fruit. 32

Figure 5. Guide for field estimation of relative abundance of devilsclub (*Oplopanax horridus*). Actual percentage fruit per cluster listed in lower right corner of each image.33

Figure 6. Plot layout in salmonberry (*Rubus spectabilis)*, Kodiak Island, Alaska. 34

Figure 7. Regression of salmonberry (*Rubus spectabilis*) fruit length and drupelet number, Kodiak Island, Alaska, 2016. 34

Figure 8. Guide for field estimation of relative quality of salmonberry (*Rubus spectabilis*) fruit.. 35

Figure 9. Plot layout in oval-leaf blueberry (*Vaccinium ovalifolium*), Kodiak Island, Alaska. 36

Figure 10. Timing and duration of ripe fruit and maximum abundance of ripe fruit of four berry-producing shrub species in four lowland monitoring sites of the Kodiak Archipelago, Alaska, 2016. 36

Figure 11. Timing and duration of selected phenophases of red elderberry (*Sambucus racemosa)* in 2015 and 2016, Camp Island area of Karluk Lake, Kodiak Island, Alaska.37

Figure 12. Timing and duration of major phenophases in red elderberry (*Sambucus racemosa*), Camp Island area of Kodiak Island, Alaska, 2016. 37

Figure 13. Timing and duration of major phenophases in salmonberry (*Rubus spectabilis*), Camp Island area of Kodiak Island, Alaska, 2016. 38

Figure 14. Actual and potential number of devilsclub (*Opoplanax horridus*) fruit per cluster (n=43 clusters of 30 plants), Kodiak Island, Alaska. 39

Figure 15. Regression of devilsclub (*Oplopanax horridus*) fruit cluster diameter and potential number of fruit per cluster, Kodiak Island, Alaska, 2016. 39

Figure 16. Representative pattern of mean monthly air-soil temperature relationship of monitoring plots, Kodiak Island, Alaska, October 2015-September 2016. 40

Figure 17. Comparison of long-term (1981-2010) mean December-February air temperature (°C) at Kodiak State Airport (KSA), with short-term (2015-2016) mean December-February air temperature (°C) at KSA and berry study sites, Kodiak Island, Alaska. 40

LIST OF APPENDICES

Appendix A. Preliminary field protocol for phenology monitoring of selected berry-producing shrub species with white-flash equipped trail cameras in the Kodiak Archipelago, Alaska.……..35

Appendix B. Guidelines for interpretation of trail camera images in classification of phenology of selected berry-producing shrub species in the Kodiak Archipelago, Alaska.……...40

Appendix C. Red elderberry (*Sambucus racemosa*) fruit cluster data systematically collected on nearly ripe fruit to support development of field estimation of fruit abundance (percentage fruit/cluster), Kodiak Island, Alaska, 2015……..43

Appendix D. Red elderberry (*Sambucus racemosa*) fruit cluster data, Kodiak Island, Alaska, 2015. Data specifically collected from clusters protected with netting to evaluate potential change between immature and ripe fruit in cluster dimensions…….45

Appendix E. Devilclub (*Oplopanax horridus*) fruit cluster data, Kodiak Island, Alaska, 2016……..….46

Appendix F. Devilclub (*Oplopanax horridus*) structural data, Kodiak Island, Alaska, 2016. Plants were systematically selected to represent a wide range of size, age, and fruit abundance……..48

Appendix G. Salmonberry (*Rubus spectabilis*) data systematically collected on nearly ripe and ripe fruit to support development of field estimation of fruit quality……..49

Appendix H. Results of Wilcoxin paired-sample test of difference between years in selected characteristics of berry-producing species, 2015-2016, expressed as probability-value (sample size1)……..…….52

Appendix I. Mean monthly air temperature (°C) and soil temperature (°C) at red elderberry (*Sambucus racemos*a) study plots, Kodiak Island, Alaska…….…..53

Appendix J. Mean monthly air temperature (°C) and soil temperature (°C) at salmonberry (*Rubus spectabilis*) study plots, Kodiak Island, Alaska……55

Appendix K. Mean monthly air temperature (°C) and soil temperature (°C) at oval-leaf blueberry (*Vaccinium ovalifolium*) plots, road system study site, Kodiak Island, Alaska……57

Appendix L. Mean monthly air temperature (°C) and soil temperature (°C) at devilsclub (*Oplopanax horridus*) plots, road system study site, Kodiak Island, Alaska……....57

Appendix M. Phenophases1 of selected berry-producing shrubs, Kodiak Island, Alaska, 2015-2016……..58

Development of Protocols for Monitoring Phenology and Abundance of Berries Important to Brown Bear of the Kodiak Archipelago, Alaska

Pilot Study Final Report

Bill Pyle and Daniel Hernandez[1]

Executive Summary

We conducted a two-year pilot study in 2015-2016 to evaluate methods of monitoring phenology and abundance of red elderberry (*Sambucus racemosa*), salmonberry (*Rubus spectabilis*), oval-leaf blueberry (*Vaccinium ovalifolium*), and devilsclub (*Oplopanax horridus*) on Kodiak Island. Following review of technical literature and completion of a pilot-study plan, we developed and tested monitoring methods at an operational scale in four study sites. This report emphasizes method description given the method development focus of study.

Following reconnaissance surveys, we established plots in four study sites: Red Lake, Karluk Lake, Uganik Lake, and the roaded area near the city of Kodiak. Selected individual plants (elderberry, devilsclub) and transects (salmonberry, blueberry) were marked to enable repeated sampling among years. We measured structural characteristic of shrub stands and, following development of indices of fruit abundance and quality, collected these data near the onset of fruit ripening (elderberry, devilsclub) and after onset of fruit ripening (salmonberry, blueberry). Where data series for both years were collected, difference between years was evaluated with the Wilcoxin paired-sample test; significance level was set at $p \leq 0.10$. Interpretation of results was constrained by limited duration of study and understanding of temporal variation in berry abundance, structural characteristics, and their interaction with environmental factors.

We developed protocol for automated collection of phenology data with timelapse cameras, and for interpretation of acquired imagery in accordance with a national protocol for classification of phenology data. Phenology of elderberry and salmonberry differed between 2015 and 2016. Compared to 2015, elderberry flowered 10 days earlier in 2016 (May 19) and fruit reddened 10 days earlier (July 9). Whereas first ripe salmonberry was observed on 6 July 2015, first ripe salmonberry was observed 9 days earlier in 2016. For both species, differences in phenology between years were attributed to cumulative differences in winter-spring temperatures. Specifically, mean January-July temperature deviated by +2°C in 2015 and +2.8°C in 2016 compared to the long-term (1981 – 2010) average recorded by the National Weather Service at Kodiak State Airport.

We observed increased elderberry abundance in 2016 at three of four study sites. Compared to 2015, significantly greater fruit clusters per plant were observed in 2016 at the roaded area ($p = 0.046$) and Karluk Lake ($p = 0.003$), while significantly greater percentage fruit per cluster were observed at Uganik Lake (*p*

= 0.040) and Karluk Lake (p = 0.010). While structural characteristics varied among study sites and years, only basal diameter exhibited a significant and consistent difference (i.e., increased diameter, p = 0.073 to p = 0.000) across study sites.

Salmonberry foliage height, foliar cover, and fruit density were greater in 2016 compared to 2015. The difference between years was significant in fruit density at Karluk Lake (p = 0.000) and Red Lake (p = 0.000). However, fruit quality was seemingly suboptimal in 2016 at all study sites. Specifically, percentage medium- to large-sized fruit—sizes presumably preferred by foraging brown bear—composed less than 25% of fruit at the time of sampling. We are uncertain why fruit quality appeared suboptimal but suspect it reflected incomplete pollination, a limiting factor described for closely-related raspberry (*R. ideaus*) in reviewed technical reports.

Restricted distribution of accessible oval-leafed blueberry and devilsclub stands limited sampling to the roaded study site. We observed significantly greater blueberry foliage height (p = 0.002), foliage cover (p = 0.002), and fruit density (p = 0.097) in 2016 compared to 2015. We suspect that increased fruit density may be attributed to optimal temperature, precipitation, and pollination activity—factors affecting closely-related highbush blueberry (*V. corymbosum*) in reviewed technical reports. Devilsclub basal diameter was significantly greater in 2016 (p = 0.020) than 2015. However, none of the other five sampled devilsclub characteristics including fruit clusters per plant differed between years. We speculated that the low percentage fruit per cluster observed in 2016 may be related to several factors including deficient pollination, flower predation, or unfavorable temperature and precipitation during and prior to the growing season.

Given the design and outcomes of pilot study, operational monitoring can be immediately implemented to continue collection of elderberry and salmonberry data in established study sites. Meaningful monitoring of blueberry and devilsclub will require establishment of partnerships to continue data collection in the existing roaded study site, and to collect data in an additional study site(s) at Afognak Island, where the species are most represented. Utility of monitoring results will increase as the time-series of data expands and advanced analytical methods are applied to assess patterns and trends in phenology, berry abundance, structural characteristics of berry-producing shrubs, interacting environmental factors, and their relationship to variation in brown bear habitat use and population characteristics. We conclude the report with recommendations on engagement of partnering organizations, data analyses, and monitoring phenology and abundance of berries and berry-producing shrubs.

[1]**Authors:** Bill Pyle and Daniel Hernandez, U. S. Fish and Wildlife Service, Kodiak National Wildlife Refuge, 1390 Buskin River Road, Kodiak, AK. Direct correspondence to: Bill_Pyle@fws.gov, (907) 487-0228.

INTRODUCTION

The location, abundance, timing, and accessibility of various seasonal foods influence brown bear (*Ursus arctos*) movements and habitat use (Berns et al. 1980; Barnes 1990; Deacy et al. 2017). In the Kodiak Archipelago, regional differences in brown bear diets and habitat use likely reflected regional differences in availability of different food sources (Van Daele et al. 2013). Specifically, habitat use by Kodiak brown bear (*U. arctos middendorffi*) was generally regulated by the availability of three primary food sources: succulent new growth of herbaceous vegetation, salmon, and fruit of berry-producing shrub species (Troyer and Hensel 1969).

Fruit is an essential component of the diet of brown bear (Erlenbach et al. 2014; Robbins et al. 2007). Erlenbach et al. (2014) experimentally evaluated the influence of different diets (e.g., salmon, fruit, mixed salmon-fruit) on the efficiency of weight gain in brown bear. Although bears preferred foods high in lipids such as salmon, diets composed of both lipid sources (e.g., salmon) and carbohydrate sources (e.g., fruit) maximized weight gain efficiency.

In the Kodiak Archipelago, the importance of dietary fruit to brown bear has been inferred from analysis of telemetry relocation data and scats over the last four decades. Study results consistently indicated that adult female bears usually shifted habitat use from the vicinity of salmon-spawning streams in valley bottoms to adjacent mountain slopes when red elderberry (*Sambucus racemosa*) ripened (Troyer and Hensel 1969; Berns et al. 1980; Barnes 1990; Sorum 2013; Deacy et al. 2017). Use of mountain areas supporting extensive elderberry was sustained for up to a month through the duration of fruit availability. However, in years of apparent low abundance of berries, bears continued to occupy the vicinity of salmon spawning streams, or foraged on other types of vegetation, such as Nootka lupine (*Lupinus nootkatensis*) and ground cone (*Boschniakia rossica*) (Sorum 2013).

Despite apparent low production and reduced availability, salmonberry (*Rubus spectabilis*) and elderberry collectively comprised 11% (5 – 21%) of the diet of eight single adult females in southwest Kodiak Island during early August-early October 2011 (Sorum 2013). Van Daele et al.'s (2013) analyses of stable isotope signatures in hair samples of 485 bears revealed that composition of dietary plant matter, which included berries, was highest in dependent cubs (53%) and subadults (30%) and lowest in adult females (25%) and males (13%). Clark (1957) collected 140 scats during mid-August through mid-October in the Karluk Lake area; 69% contained residual high-bush cranberry (*Viburnum edule*) fruit and 17% contained residual elderberry fruit.

Anecdotal evidence suggests that the survival and productivity of brown bear could be diminished following years of minimal availability of fruit. On Kodiak Island, fewer adult females with cubs and fewer cubs were observed following years of apparent low production in berries and/or berries and salmon (Kodiak NWR, unpublished data). Presumably, insufficient fruit intake can adversely impact body condition and reproductive output, as described for black bear (Rogers 1976). Furthermore, low fruit supply could prompt increased movements, energy demand, and safety risk to bears searching for food in novel areas. Kodiak-based biologists have observed increased rates of adverse encounters and number of bears killed in Defense of Life and Property during years of extensive failure in the berry crop (Van Daele 2001).

Berries produced by at least 10 shrub species likely serve as food and energy sources to brown bear of the Kodiak Archipelago. No studies have systematically evaluated the nutrient content and digestibility of berries of berry-producing shrub species in the archipelago. However, Pritchard and Robbins (1990) assessed nutrient content and digestibility of berries of 16 species including several that occur in the archipelago. In general, berry species differed in digestibility, which declined as the fraction of fiber increased. For example, blueberry (*Vaccinium spp*.), the most digestible species, had the greatest digestibility (72%) and least dietary fiber (21%). In contrast, crowberry (*Empetrum nigrum*), devilsclub, and red elderberry exhibited intermediate digestibility (48–58%) and dietary fiber (35 – 38%). Despite differences in digestibility, blueberry and elderberry had similar total energy value—derived primarily from carbohydrate sugars in blueberry and carbohydrates, fats, and proteins in elderberry (Usui et al. 1994).

Review of technical papers indicated that variation in cover and geographic distribution of berry-producing shrub species is regulated by many factors including climate (Cook et al. 2009), solar radiation as influenced by overstory crown closure (Wender et al. 2004; Suring et al. 2008), soil characteristics (Ilhalainen et al. 2003), mammal and bird frugivory (Conrad and McDonough 1972; Traveset and Willson 1997), and intra- and interspecific competition (Conrad and McDonough 1972; Tappeiner et al. 2001; Wender et al. 2004). Within sites, year-to-year variation in berry abundance was related primarily to variation in plant age (Wender et al. 2004), extent of berry production the previous year (Howe et al. 2012), and climate (Conrad and McDonough 1972; Cook et al 2009; Holden et al. 2012). Climatic effects may include time-limited events such as a severe late frost (Conrad and McDonough 1972), and interactive variation of temperature levels and precipitation amounts during spring and summer of the current and previous two years (Krebs et al. 2009). Papers that described climatic effects consistently demonstrated various species-specific relationships (Krebs et al. 2009; Holden et al. 2012).

Additional factors may account for differences in the relative importance of berry-producing shrub species to brown bear. It is known that many of the most common species differ in distribution and abundance across the Kodiak Archipelago (Fleming and Spencer 2007). It seems likely that interspecific differences in fruit density and clustering partly account for interspecific differences in relative importance to brown bear (Welch et al. 1997). However, no studies we reviewed reported the extent of bear intake and relative use of berries of different species in the archipelago.

Problem Statement

Given available information, it appears likely that variation in the abundance of fruit influences the nutritional condition, productivity, and survival of Kodiak brown bear. Because of these presumed influences, fruit could be collectively considered as a primary seasonal food—one that partly regulates the quality of bear habitat and potential size and productivity of the bear population. Yet the absence of systematic monitoring of fruit has confounded managers charged with monitoring and conserving the bear population and its habitat. Biologists can only speculate about fruit abundance and its relationship to bear habitat use and productivity, as well as weather and climate influence on fruit abundance. To address this gap, we evaluated methods for

monitoring phenology of selected berry-producing species, relative abundance of berries, and influence of temperature on phenology and berry abundance.

Purposes of this study are supported by recommendations and objectives of agency management plans. A stakeholder committee recommended documentation of abundance and availability of vegetation in representative habitats in a locally developed bear management plan (ADF&G 2002). The Kodiak National Wildlife Refuge, hereafter referenced as "Refuge", listed development and implementation of systematic monitoring of berry supplies as objectives in its Comprehensive Conservation Plan (USFWS 2008) and Wildlife Inventory and Monitoring Plan (Cobb et al. 2014). Most recently, public- and private-sector stakeholders met and agreed on the need to establish systematic monitoring of berry supplies following initial testing and selection of methods.

Objectives

1. Evaluate methods to estimate relative abundance of red elderberry, salmonberry, oval-leaf blueberry, and devilsclub berries, as well as structural characteristics of stands of these species.

2. Evaluate methods of monitoring phenology of red elderberry, salmonberry, oval-leaf blueberry, and devilsclub.

Methods

Study Area

The geography of Kodiak Island is mountainous. The main mountain axis trends northeast to southwest and elevations commonly range between 500–800m with highest peaks slightly exceeding 1,200m. Geomorphology exhibits extensive evidence of glaciation during the Pleistocene (Mann and Petit 1994). The island area is dissected by fiords, bays, and stream valleys. The generally wet and cool climate is indicative of high latitude (58°N), proximate North Pacific Ocean, and frequent storms between October and March. Data recorded by the National Weather Service at the Kodiak State Airport situated in NE Kodiak Island indicated a long-term (1981–2010) mean annual temperature of 2.08°C (-0.86° to 12.86°C monthly mean range), mean monthly minimum temperature range of -1.84° to -3.17°C between November and March, mean total annual precipitation of 198cm, and mean total annual snowfall of 175cm with measurable snow usually recorded between October and May. The least precipitation was recorded in August (11.6cm) and, the most was recorded in December (22.2cm). Total annual precipitation exhibited considerable variation across the island area. For example, Larsen Bay, a town located on the west side of Kodiak Island, received less than half the total annual precipitation of Old Harbor, a town located on the east side of Kodiak Island (Karlstrom and Ball 1969). This difference has been attributed to the southerly source of prevailing storm winds coupled with the precipitation-blocking effect of mountains spanning the axis of Kodiak Island.

Study site and focal species selection

We selected four study sites on Kodiak Island including uplands adjacent to Red Lake, Karluk Lake, Uganik Lake, and roaded area of NE Kodiak Island (Figure 1). A primary reason for multiple study sites was to facilitate eventual operational application of study results by accounting for possible influence of geographic variation in vegetation characteristics during methods development. Additional selection factors included management interests of the Refuge, the primary sponsoring organization, results of stakeholder meeting discussion, and the senior author's general knowledge of the distribution, abundance, and accessibility of four focal species—red elderberry, salmonberry, oval-leaf blueberry (*V. ovalifolium*), and devilsclub (*Oplopanax horridus*) on Kodiak Island.

Collectively, land ownership of study sites included a mixture of public land (e.g., Refuge, U.S. Coast Guard, State of Alaska) and large parcels of private land (e.g., various Native Corporations). We received permission from Alaska State Parks, Lesnoi Inc., and Ouzinkie Inc., to access and conduct study activities on their lands in NE Kodiak Island. We transported field crews via floatplane to access roadless study sites on Refuge lands. Within these sites, uplands harboring focal species were accessed via foot travel and/or a combination of small watercraft and foot travel. In the roaded study site, areas were accessed via vehicle and foot tavel. To maximize efficiency, we restricted field operations to uplands within 2km of lakes, roads, and/or trails.

Fleming and Spencer (2007) classified and mapped land cover of the Kodiak Archipelago. Red elderberry and salmonberry dominated cover in four widely distributed communities that occupied well-drained soils of rolling terrain and lower mountain slopes between 10 and 300m elevations. Oval-leaf blueberry and devilsclub are primarily distributed in lowlands of Afognak Island and northern Kodiak Island, often near sites that support salmonberry and elderberry. Although focal species often occurred in low density in places dominated by other plant species, they also occurred in comparatively high densities as overstory or understory cover-dominants. Study plots were located in stands where a focal berry-producing species dominated understory or overstory vegetation cover. Nomenclature of plants follows standards and conventions of the USDA Natural Resources Conservation Service (USDA, NRCS 2016).

Phenology monitoring

Digital photos to assess plant phenology were recorded hourly between 1200-1800 and 0000-0300 from April – September using remotely triggered game cameras (Bird Cam Pro, TimelapeCam Pro, Bushnell Trophy Cam HD Aggressor). From October – March, cameras on Kodiak Island were re-programmed to collect 2 photos daily (1 night, 1 day). Cameras were mounted on T-posts positioned to obtain an unobscured photo of each focal plant, and located in routinely accessed areas of the Camp Island vicinity of Karluk Lake, roaded study site, and in 2016, eastern Afognak Island (Figure 2). Guidelines were developed to facilitate management of cameras in the field and management of data in the office. Specifically, we developed guidelines to facilitate operation and installation of phenocams (Appendix A), and consistent organization, interpretation, and classification of phenocam images (Appendix B).

In most cases, plants of the same species occurred adjacent to and behind the plant(s) targeted by timelapse cameras. To maximize consistency of classification, we chose a single image from each species-site batch and annotated a copy of this image with a description of the evaluated plant or, in the case of salmonberry, patch area.

To assess phenophase, we followed Moussus et al. (2010) and reviewed a subsample of 1 – 3 images acquired at 3-d intervals for each species. A phenophase is defined as "...an observable stage or phase in the annual life cycle of a plant or animal that can be characterized by a start and an end point" (Denny et al. 2014). We classified phenophase occurrence (e.g., flowering, fruiting, etc.) and phenophase, status (i.e., percentage open flowers) in accordance with USA National Phenology Network (USANPN) species-specific protocols. Where a profile was not available for a focal species, we substituted a profile of a related species, such as bog blueberry (*V. uliginosum*) for oval-leafed blueberry. In 2016, we added a level to the classification "ripe fruit abundance" as recommended in the 2015 progress report.

Plot-based berry abundance monitoring

During May-July 2015, we surveyed study sites for stands of focal species. We recorded GPS locations of candidate plots where focal species commonly occurred or dominated overstory or understory vegetation cover and, in the roaded area, were readily accessed hiking from a nearby road or trail. Upon survey conclusion, we randomly select a subset of three plots per study site where a focal species was adequately represented.

To facilitate re-location, we installed a witness post (i.e., 1m-long rebar) at each plot and affixed a metal tag with the inscribed 6-character alphanumeric plot name. The first two characters denoted the study site (KL – Karluk Lake);, the next two denoted species (EB – elderberry); and the final two denoted the stand number assigned during the reconnaissance survey.

We derived plot elevations from GPS, measured slope grade (°) with clinometer, and assessed structural features (e.g., stem diameter, canopy volume, foliage cover) of focal species. In general, methods applied to species bearing fruit in clusters (e.g., red elderberry, devilsclub) differed from methods applied to species bearing individual fruit dispersed through the shrub (e.g., salmonberry, oval-leaf blueberry) as detailed below.

Red Elderberry. The following steps were applied to establish plots and select 10 sample plants within each plot. At Karluk Lake and Uganik Lake, we delineated a baseline along a stand edge parallel to the slope axis, randomly selected a point along the baseline, and established a 30m-long transect that extended through the stand perpendicular to the slope axis. Where a stand exceeded 60m width, the baseline was positioned in the center of the stand, and transect direction was determined by coin toss. On each transect, we selected 10 elderberry plants nearest to 10 randomly selected distances and sides (left or right) of transect (Figure 3).

At Red Lake and the roaded study site, areas with small elderberry stands, we applied an alternative selection method. We extended two tape measures at 90° angles adjacent to the stand, randomly selected a coordinate pair (X, Y), navigated to the coordinate, and selected the nearest elderberry plant. Sample plants were marked with metal tags inscribed with abbreviated site, plot, plant number, and transect distance or coordinate pair information (Figure 3).

We established one plot at Red Lake, and three plots in each of Karluk, Uganik, and roaded study sites between 2 June and 19 July 2015. In all but two of 10 total plots, relatively high densities of elderberry plants formed a closed overstory canopy. Mean elevation was 69m (6 – 175m range), slope aspect varied, and slope grade ranged from 0 – 31°. Sampling occurred primarily in July immediately before fruit ripened.

On transect-based plots we enumerated elderberry plants in a 3m-strip centered on the transect line to support derivation of elderberry density. At Red Lake and the roaded study site, elderberry density was derived from the point-quarter method (Cottam and Curtis 1956). Because elderberry exhibits clonal growth most plants of stands are interconnected, usually by roots but occasionally by near-ground aerial stems. Rules applied to identify an individual plant included: (1) a group of stems affixed to a single root crown; and (2) two groups of stems affixed to two root crowns interconnected by an aerial horizontal stem. In 2016, we loosely wrapped a single strand of .20-gauge wire around the base of each sample plant to facilitate consistent identification between years.

Data collected for each elderberry included basal diameter; diameter at breast height; shrub height; maximum canopy width; width perpendicular to maximum width; number of fruit clusters; and dimensions of a subsample of fruit clusters, usually three, including cluster length base to apex, maximum width, width perpendicular to maximum width. Volume of shrub canopy and fruit clusters was derived from multiplication of dimensional height and width data. We used calipers to measure basal diameter of the largest stem just above the root crown and the largest stem at breast height (1.3m above ground). Shrub height was measured as the vertical distance between the highest foliage and the soil surface. To minimize bias of height measurements on slope, we estimated a horizontal plane extending from the plant base, and measuring the vertical distance between the maximum canopy height and a horizontal plane extending from the plant base.

We visually estimated percentage fruit per fruit cluster to the nearest tenth increment. For example, an estimate of 100% denoted that all cluster pedicels were completely occupied by fruit. Lower value estimates were associated with missing fruit as visually apparent from fruitless pedicels. To improve precision of estimates, we developed an accessory field guide in 2015 (Figure 4). Data used to support guide development was derived from 25 clusters collected just prior to fruit ripening (Appendices C & D). We photographed clusters, measured length and maximum width in two dimensions to derive volume; and carefully counted present and absent fruit, where absence was indicated by empty pedicels. Because the guide was developed after plots were sampled in 2015, it was not used to facilitate estimation of fruit per fruit cluster until 2016.

Devilsclub. We located and mapped devilsclub stands near trails and roads in the roaded study site. We established and sampled two study plots at Fort Abercrombie State Park when devilsclub fruit initially ripened in late July 2016 and early August 2015. In both plot vicinities, devilsclub was the primary understory shrub species within mature Sitka spruce (*Picea sitchensis*) forest. Plot site aspect ranged from NE – NNE, slope grade ranged from 3 – 6°, and elevation ranged from 5 – 9m. The process of study plant selection and data collection mirrored

the process applied to elderberry plots sampled in roaded study site (Figure 3). Since devilsclub generally supports ≤ 3 fruit clusters/plant, dimensions of all clusters were measured.

In July 2016, we developed and applied an accessory field guide to estimate percentage fruit per fruit cluster (Figure 5). Data used to support guide development was derived from 43 clusters collected when fruit ripened (Appendices E & F). We photographed clusters, measured length and maximum width in one dimensions to derive volume; and carefully counted fruit present and absent, the latter indicated by fruitless pedicels. We defined 'potential fruit' as the sum of present and absent fruit.

Salmonberry. Study plots were established in Karluk Lake, Red Lake, and roaded study sites. Before plots were established, we tested methods in a salmonberry stand at Kodiak Refuge headquarters. We evaluated the coefficient of variation (CV) of the mean and standard deviation of fruit counts derived from three transects where (1) size of subplot differed (0.2 x 0.25m, 0.2 x 0.5m) and (2) number of subplots/transect differed (10, 20). Both CVs of mean and error estimates were substantially larger for counts of berries in the small subplot compared to the large subplot. Increase in sample size beyond 10 subplots/transect slightly increased CVs of estimated mean and error indicating minimal reduction in accuracy and precision. We concluded that data collected from three transects, each comprised of 10 subplots, would provide sufficiently accurate and precise bases for estimation of mean number of fruit. Additionally, we determined that an inter-transect distance minimum of 3m and an inter-subplot distance minimum of 1m were required to avoid observer disturbance to adjacent transects and subplots, respectively.

The following procedures were applied to establish plots and transects in salmonberry stands. We extended a tape measure across and parallel to the upslope edge of the stand requiring a minimum stand width ≥ 11m to accommodate 10-m transect distances. Transect starting locations were randomly selected on a baseline that extended down the slope axis. Following random selection of the origin the first transect, origins of subsequent transects were systematically set at 3-m distance (Figure 6). For example, if a baseline was 9m long and 5m was randomly chosen for the first transect, the second and third transects were set at 2m and 8m along the baseline, respectively.

Ten subplots, each 0.2 x 0.5m, were systematically arrayed at meter intervals between 1 – 10m of each transect. Each subplot was positioned with the long axis parallel and adjacent to the upslope transect edge, while the observer was positioned downslope of the transect. Collected subplot data included maximum height of salmonberry foliage nearest to each meter interval; percentage salmonberry foliar cover estimated to the nearest 5%; fruit number; and in 2016, fruit quality. Transects were extended as necessary to accommodate replacement subplots where subplot foliar cover was 0% or apparently displaced by large mammals (e.g., trailing).

Field observations suggested that the value of salmonberry as a bear foraging resource would be influenced by both number and quality of fruit (Pyle and Hernandez 2016). Analysis of 66 mature salmonberries collected in 2015 at Refuge Headquarters revealed that drupelet number ranged from 5 – 109 ($\bar{x}$ = 40, SD = 22). Examination of corresponding digital images indicated that berries with fewer than 30 drupelets appeared diminutive because the limited number of

drupelets incompletely occupied the fruit stem core. In 2016, we collected 80 ripe salmonberries of various sizes, measured dimensions, counted drupelets, and weighed samples (Appendix G). Correlation analysis identified a relatively strong functional relationship ($R^2 = 0.75$) between berry size (length) and drupelet number (Figure 7). In response, we derived four classes including: no fruit, small-sized fruit (≤ 30 drupelets), medium-sized fruit (31 – 50 drupelets), and large-sized fruit (≥ 51 drupelets). Results were applied in an accessory field guide to facilitate estimation of fruit quality (Figure 8).

We sampled salmonberry during July of 2015-2016 when most salmonberry fruit had ripened but before significant fruit loss, as indicated by empty pedicels. Mean plot elevation was 115m (11 – 229m range), slope aspect varied, and slope grade ranged from 10 – 42°. Due probably to high salmonberry density and foliar cover, associated herbaceous species were uncommon. Characteristics of plots seemingly typified salmonberry where it occurs in high density at sites of relatively low elevation (i.e., ≤ 300m).

Oval-leaf Blueberry. Among six areas of the roaded study site identified with blueberry cover, only three had sufficient area and densities of blueberry to support sampling and, therefore, each of these was selected as a study plot. Following plot selection, we applied procedures described by Holden et al. (2012). A baseline was established along the short axis of each blueberry stand. Transect origin was randomly selected from a meter increment between 3 – 7m along the baseline. From the origin, a transect was extended 50m parallel to the long axis of the stand, rebar was installed at 0 and 50m points, and coordinates were recorded (Figure 9). Orientation of sampling along each transect (L, R) was determined by coin flip. At 0.5-m intervals, berries were enumerated within a 0.2 x 0.2m subplot stationed on the ground or over the shrub and adjacent to each transect. Percentage foliar cover of blueberry was recorded at each subplot, as well as height of foliage at each 0.5m-increment. When 0% cover was observed in a subplot, no data was collected and the subplot was advanced to the next sampling increment. Since the objective was collection of a minimum of 50 subplots where blueberry foliage cover ≥ 0%, we extended the total sampling distance as necessary. Actual distance ranged from 24.5 – 43.5m among the three study plots in 2015. Evaluation of the effect of cumulative observations on variance (SD) of blueberry foliar cover revealed that variance was minimized where sample size ≥ 30 subplots.

Plot sites were convex-shaped, minimally-sloping (< 3°) ridgelines where mean elevation was 17m (11 - 27m range). Plots were sampled in late July 2016 and early August 2015 after onset of fruit ripening.

Analysis of plot data

We performed exploratory data analysis, generated summary statistics and applied a two-tailed Wilcoxin paired-sample test (Zar 1984) to assess whether vegetation characteristics of plots differed between 2015 and 2016. Selection of this procedure was based on occurrence of paired dependent and continuous data that, in many cases, did not meet assumptions of normality, as revealed in exploratory data plots. Test results were excluded from presentation for data acquired from a single elderberry plot at Red Lake (n = 10 plants). Additionally, some parameters were excluded from analyses because only one year of data was available (e.g., elderberry density,

fruit per fruit cluster). Complete test results are reported in Appendix H. Significance level was set at $p \leq 0.10$.

We did not assess whether vegetation characteristics differed among study sites within year since these are more effectively addressed when methods of data collection have been approved, standardized, and implemented for three or more years. In the concluding recommendation section, we present two scientist's perspectives on future analytical approaches.

Temperature monitoring

We deployed automated temperature dataloggers on study plots to (1) facilitate understanding of the association between temperature, phenology, and fruit availability, and (2) evaluate whether low-cost sensors could withstand field conditions and reliably collect year-round data. Prior to deployment, each waterproofed Thermochron® iButton datalogger was programmed to record temperature at 4-h or 6-h intervals with interval duration determined by iButton model and storage capacity. At each plot, a datalogger was mounted 1-m above the ground on the north side of a alder or spruce within or adjacent to the plot. Another datalogger was buried 10cm beneath the soil surface below the tree-mounted datalogger. The burial site was discretely marked with flagging. GPS coordinates were recorded for each temperature monitoring site.

Data was collected at 26 plots of 4 study sites plus two sites with dedicated phenology monitoring between July 2015 and September 2016. Data recorded by dataloggers was downloaded in spring and fall of 2016. Daily and monthly mean temperatures were calculated.

We analyzed the relationship between mean monthly soil and air temperature data of study plots, and mean monthly air temperature data acquired at study sites and Kodiak State Airport, the regional climate monitoring station administered by the National Weather Service. Mean monthly air and soil temperatures are reported in Appendices I – L. Although we describe the possible influence of temperature on vegetative characteristics, especially phenology, data analyses were limited. Primary reasons included: (1) limited scope of temperature and vegetation data (12 – 14 months); (2) some inconsistencies in temperature data (e.g., missing data) due to animal removal of some dataloggers; and (3) data gaps created by exceedance of Ibutton logger storage capacity due to inability to access remote sites before exceedance occurred. We address these issues in recommendations.

Results and Discussion

Phenology monitoring

Phenology of elderberry and salmonberry differed between 2015 and 2016. Compared to 2015, elderberry first flowered 10 days earlier in 2016 (May 19) and fruit first reddened 10 days earlier (July 9). Whereas the first ripe salmonberry fruit were observed 6 July 2015, the first ripe fruit were observed nine days earlier in 2016 (June 27). For both species, differences in phenology between years were attributed to cumulative differences in winter-spring temperatures. Specifically, mean January-July temperature deviated by +2.0°C in 2015 and +2.8°C in 2016 compared to the long-term (1981 – 2010) mean recorded at the Kodiak State Airport. These

seasonal exceedances were indicative of annual exceedances: 2015 and 2016 ranked as the third and first highest recorded mean annual temperatures, respectively.

Analysis was constrained because of the limited number of years of data, and by operational issues. Nonetheless, we present a few charts to illustrate some of the basic types of information yielded from phenology monitoring. These include description of major phenology phases across the growing season (Figure 10); comparison between years of selected species and phenology phases (Figure 11); and depiction of major phenology phases of elderberry and salmonberry across the 2016 growing season (Figures 12 and 13). Additional results for all sites and species monitored are reported in Appendix M.

Increased resolution (20mp) of cameras purchased and deployed in 2016 (TimelapseCam Pro) improved image classification efficiency and accuracy. In the future, data gaps resulting from faulty field operations can be avoided through field staff training and adherence to newly developed data collection standards. Continued future acquisition of phenology and temperature data should enable modeling the phenology-temperature relationship to describe trend and in-season prediction of the onset of ripened berry availability to brown bear.

Plot-based berry abundance monitoring

Red elderberry. We observed increased abundance of fruit in 2016 at three of four study sites (Table 1). Compared to 2015, significantly greater fruit clusters per plant were observed in 2016 at the roaded area ($p = 0.046$) and Karluk Lake ($p = 0.003$), while significantly greater percentage fruit per cluster were observed at Uganik Lake ($p = 0.040$) and Karluk Lake ($p = 0.010$). While structural characteristics varied among study sites and years, only basal diameter exhibited a significant and consistent difference across study sites (i.e., increased diameter, range $p = 0.073 – p = 0.000$).

Since no evidence of over-winter stem mortality was observed in 2016, we expected that various size characteristics, such as DBH, height, and canopy volume, would exhibit minimal non-significant change or, alternatively, size increase consistent with continued age-growth between years. We did not expect to observe significant decrease in size characteristics, such as total height and canopy height in the Road System study site and canopy volume at Karluk Lake. We attributed size decreases to inconsistent measurement methods within and between years. In response, we adjusted methods in 2016. For example we surrounded bases of sample plants with wire to ensure precise identification and subsequent measurements of structural characteristics.

Analysis of the potential number of fruit aggregated in clusters, where potential is determined by the combination of cluster pedicels with and without fruit, indicated a mean of 292 fruits per cluster (112 SD; 44 – 532 range; n = 64 clusters). Correlation analysis revealed a moderately strong functional relationship between fruit per cluster and cluster volume ($R^2 = 0.62$).

Salmonberry. Salmonberry foliage height, foliar cover, and fruit density were greater in 2016 compared to 2015 (Table 2). The difference between years was significant in fruit density at Karluk Lake ($p = 0.000$) and Red Lake ($p = 0.000$). However, fruit quality was seemingly suboptimal in 2016 at all study sites. Specifically, percentage medium- to large-sized fruit—sizes

presumably preferred by foraging brown bear—composed less than 25% of fruit at the time of sampling.

We are uncertain why fruit quality appeared suboptimal but suspect it reflected incomplete pollination. As indicated in phenology observations, flowering occurred early—probably substantially earlier than normal due to exceptionally mild winter-spring 2015 – 2016 temperatures. Perhaps incomplete pollination resulted from insufficient number of pollinators accustomed to later emergence and flower availability. On the other hand, we noted that salmonberry flowers appeared prolific, and flowering prolonged, in 2016. Perhaps supply of flowers—each with about 45 – 65 ovaries requiring pollination—exceeded the number of available pollinators. In raspberry (*Rubus ideaus*), flowers require insect pollination to facilitate complete fruit development (Richards 2001), and inadequate pollination reduces the size, weight, and quality of fruit (Cane 2005).

Oval-leaf blueberry. We observed significantly greater blueberry foliage height ($p = 0.002$), foliage cover ($p = 0.002$), and fruit density ($p = 0.097$) in 2016 compared to 2015 (Table 3). We attributed to optimal temperature, precipitation, and pollination activity—factors affecting closely-related highbush blueberry (*V. corymbosum*). In commercially-cultivated highbush blueberry (*V. corymbosum*), weather conditions during flowering influence the level of pollination activity (Tuell and Isaacs 2010), and level of pollination activity corresponded with the extent of fruit and seed development (MacKenzie 1997). We found only one empty fruit pedicel in 2015 and none in 2016, which suggested that most flowers produced fruit or that fruit loss was negligible up to the time of observation.

Devilsclub. Devilsclub basal diameter was significantly greater in 2016 ($p = 0.020$) than 2015 (Table 4). However, none of the other five sampled devilsclub characteristics including fruit clusters per plant differed between years. We speculated that the low percentage fruit per cluster observed in 2016 may be related to several factors including deficient pollination, flower predation, or unfavorable temperature and precipitation during and prior to the growing season. Results for devilsclub must be viewed with caution because of the small sample size and restricted geographic scope of plots.

Analysis of collected fruit clusters revealed that they bore fewer fruit than potential, as indicated by the difference between present fruit and empty fruit pedicels (Figure 10). On average clusters supported 317 fruit, with a potential of 378 (177 SD; 33 – 845 range; n = 58 clusters). Correlation analysis indicated a moderately strong functional relationship ($R^2 = 0.64$) between maximum cluster diameter and potential number of fruit (Figure 14).

Temperature monitoring

Site-specific paired air and soil temperature data were highly correlated ($R^2 = 0.97$; n = 251). This result likely reflected the accuracy of recording instruments and consistency in operational methods. Air-soil temperature data exhibited a consistent pattern of intra-annual variation (Figure 12). Whereas, mean air temperature was 1 – 2°C higher than soil temperature in summer, it was 1 – 2°C lower than soil temperature in winter. Correspondingly, air temperature exhibited greater magnitude of annual variation than soil temperature. Apparently, the soil medium acted to limit temperature variation compared to the air medium.

Monthly mean air temperature, October 2015 – September 2016, was highly correlated between study plots and the regional monitoring station at Kodiak State Airport (R^2 range = 0.990 – 0.997; n = 15 plots of 4 study sites). Mean winter air temperature, December 2015 – February 2016, exceeded the long-term (1981 – 2010) mean by 2.6°C recorded at the Kodiak State Airport (Figure 13). It is likely that this magnitude of exceedance occurred throughout Kodiak Island, given the previously described correlation in air temperature between the Airport monitoring site and sites monitored in this study.

Mean winter air temperature 2015 – 2016 differed slightly among the regional monitoring station, study sites, and between plots within the road-connected study site (Figure 13). Temperature differed least at study sites closest to the regional station. Because of proximity to ocean, lower-elevation coastal sites (i.e., Airport, road system) likely exhibit greater intra-annual variation in temperature than higher-elevation interior sites (i.e., Uganik Lake, Karluk Lake, Red Lake). Within the road-connected study site, mean winter temperature apparently differed between vegetation cover types. Specifically, mean temperature was greater in inside Sitka spruce forest (e.g., devilsclub, blueberry) compared to outside spruce forest (e.g., elderberry, salmonberry). We attributed this apparent difference primarily to the potential temperature buffering influence of spruce forest canopy.

Conclusion

We developed methods to reliably monitor phenology and berry abundance of red elderberry, salmonberry, oval-leaf blueberry, and devilsclub. Considerable time and energy was dedicated to development and testing of data collection methods given the absence of relevant methods described in technical reports, except for blueberry. Given the design and outcomes of pilot study, operational monitoring can be immediately implemented to continue collection of elderberry and salmonberry data in established study sites. Meaningful monitoring of blueberry and devilsclub will require establishment of partnerships to continue data collection in the existing roaded study site, and to collect data in an additional study site(s) at Afognak Island, where the species are most represented. Utility of monitoring results will increase as the time-series of data expands and advanced analytical methods are applied to assess patterns and trends in phenology, berry abundance, structural characteristics of berry-producing shrubs, interacting environmental factors, and their relationship to variation in brown bear habitat use and population characteristics.

Recommendations

Phenology monitoring

Continue camera-based monitoring of focal species at selected sites.

Partner with interested organizations and individuals to expand the scope of data collection, including opportunity to collect data by either timelapse camera or direct observation.

Designate a coordinator to facilitate partner data collection; ensure consistent partner application of data collection protocols; compile and manage data; and serve data to cooperating parties responsible for analyses.

Periodically submit copies of data to the USA National Phenology Network to promote its accessibility to the science community and public.

Replace timelapse cameras when new models become available that produce images of substantially greater resolution, while maintaining white-flash capability for nighttime image acquisition.

Complete "species profiles" to facilitate both standardized interpretation of phenology and status in the field and office. Pattern development of profiles, which includes images representing phenophases and accompanying narrative descriptions, after the template jointly developed by the USA National Phenology Network and National Park Service.

Deploy motion-activated game cameras to ascertain whether insects and birds forage on immature elderberry fruit, and to document animal foraging on ripe fruit of the range of focal species.

Plot-based berry abundance monitoring

Implement long-term monitoring of red elderberry and salmonberry in the current suite of Refuge and non-Refuge study sites.

Adjust annual timing of plot sampling, as necessary, to occur immediately prior to fruit reddening in elderberry plots and during initial fruit color alteration in salmonberry plots.

Determine whether monitoring should continue of blueberry and devilsclub and, if so, by whom and to what extent. Should scope be limited to roaded area or to include an additional study site(s) on Afognak Island?

Discontinue data collection for plant structural characteristics that cannot be consistently collected (e.g., DBH of devilsclub) or may have minimal value in long-term analyses (e.g., fruit cluster dimensions, etc.).

Develop a formal protocol for collection, management, storage, analyses, and interpretation of plot-based data.

Temperature Monitoring

To promote efficiency and data continuity, replace iButtons with Hobo®TidbiTs in the remote (Refuge) plots.

To minimize animal damage and removal, camouflage paint air temperature dataloggers deployed adjacent to tree trunks, and wire soil temperature dataloggers to rebar stake in ground.

Data Analysis

Accumulation of additional years of data will increase the depth, breadth, and utility of interpretations based on application of various modeling approaches and statistical procedures. In the short-term, analyses will focus on modeling interannual variation and trend in focal plant species phenology, berry relative abundance, and plant structural characteristics. In the long-term, analyses also will include evaluation of relationships to bear population metrics and interactions with climate and herbivory (e.g., barking) of Sitka-black tailed deer. Below is a summary of recommendations provided by consulted scientists affiliated with USGS and the University of Alaska, Fairbanks.

Question: Are there differences in phenology between years and do different species show similar shifts between years?

Approach: Apply ANOVA to evaluate whether the Julian date of an early season event, such as peak flowering, differs within and among species and years. Difference in magnitude of shifts would be identified by significance of interactions.

Question: How well does early season phenology explain later season phenology?

Approach: Apply ANOVA to evaluate whether the number of days between events, such as peak flowering and fruiting, differs among species and years. If differences are identified, examine relationship to cumulative degree days, a proxy for temperature, between the same two events.

Question: Does berry abundance (or other characteristics) differ within site among years?

Approach: Apply ANOVA or Generalized Linear Mixed Model (GLMM) to evaluate differences in berry abundance or other selected characteristic within and among study sites and years.

Question: Can differences in fruit abundance (or other characteristics) be explained by environmental variation?

Approach: As described by Burnham and Anderson (2002), apply the Aikaike Information Criterion (AIC), a model selection approach to estimate the relative importance of environmental variables, such as temperature) in explaining variation in a response variable, such as site-level mean fruit abundance. Alternatively, GLMM could be applied where a group of plots or sites is the focus, or Principal Components Analysis (Jolliffe 2014) could be used to determine the most important subset of explanatory variables.

Acknowledgements

This study benefitted from reviews, comments, and recommendations afforded by Amy Miller (National Park Service), Anne Marie La Rosa (US Fish and Wildlife Service), Christa Mulder (University of Alaska Fairbanks), Jason Bunch (Kodiak Backcountry Adventures), John Crye (Alaska Department of Fish and Game), Larry Van Daele (Kodiak Brown Bear Center), Nathan Svoboda (Alaska Department of Fish and Game), Rachel Loehmann (US Gelogical Survey), Richard Rohrer (Rohrer Bear Camp), Taal Levi (Oregon State University), William Leacock (US

Fish and Wildlife Service), and Victor Barnes Jr. (Kodiak Brown Bear Trust). We thank Anne Marie La Rosa (Manager of Kodiak Refuge), Tevis Underwood (Deputy Refuge Manager), Diane Granfors (Coordinator of the Service's Inventory and Monitoring Program in the Alaska Region), and Nathan Svoboda for provision of funds to support study personnel, field operations, and report preparation.

Literature Cited

[ADFG] Alaska Department of Fish and Game. 2002. Kodiak Archipelago brown bear management plan. Anchorage, AK.

Barnes Jr VG. 1990. The influence of salmon availability on movements and range of brown bears on southwest Kodiak Island. Int. Conf. Bear Res. and Manage. 8: 305-313.

Berns VD, Atwell GC, Boone DL. 1980. Brown bear movements and habitat use at Karluk Lake, Kodiak Island. Int. Conf. Bear Res. and Manage. 4:293-296.

Burnham KP, Anderson DR. 2002. Model Selection and Multimodel Inference: A Practical Information-Theoretic Approach (2nd ed.), Springer-Verlag, ISBN 0-387-95364-7.

Cane JH. 2005. Pollination potential of the bee *Osmia aglaia* for cultivated red raspberries and blackberries (*Rubus*: Rosaceae). HortScience 40:1705-1708.

Clark WK. 1957. Seasonal food habitats of the Kodiak bear. Trans. North Amer. Wildl. Conf. 22:145-151.

Cobb MA, Pyle B, Corcoran R, Leacock W. 2014. Wildlife inventory and monitoring plan. Unpublished report. U.S. Fish and Wildlife Service Kodiak National Wildlife Refuge, Kodiak, AK.

Conrad PW, McDonough WT. 1972. Growth and reproduction of red elderberry on subalpine rangeland in Utah. Northwest Science 46:140-148.

Cook BI, Terando Cook ER, Huth PC, Thompson JE, Forster A, Smiley D. 2008. A cross-taxa phonological dataset from Mohonk Lake, NY and its relationship to climate. Int. J. Climatol. 28:1369-1383.

Cottam C, Curtis JT. 1956. The use of distance measures in phytosociological sampling. Ecology 37:451-460.

Deacy W, Leacock W, Armstrong JB, Stanford JA. 2016. Kodiak brown bears surf the salmon red wave: Direct evidence from GPS collared individuals. Ecology 91:1091-1098.

Deacy WW, Armstrong JB, Leacock WB, Robbins CT, Gustine DD, Ward EJ, Erlenbach JA, Stanford JA. 2017. Phenological synchronization disrupts trophic interactions between Kodiak brown bears and salmon. Proc. National Academy of Sciences 114:10432-10437. www.pnas.org/cgi/doi/10.1073/pnas.1705248114

Denny EG, Gerst KL, Miller-Rushing A, Tierney GL, Crimmins TM, Enquist CAF, Guertin P, Rosemart AH, Schwartz MD, Thomas KA, Weltzin JF. 2014. Standardized phenology monitoring methods to track plant and animal activity for science and resource management applications. Int J Biometeorol 58:591-601. DOI 10.1007/s00484-014-0789-5

Erlenbach JA, Rode KD, Raubenheimer D, Robbins CT. 2014. Macronutrient optimization and energy maximization determine diets of brown bears. J. Mammology 95:160-168.

Fleming MD, Spencer P. 2007. Kodiak Archipelago land cover classification users guide. Anchorage, Alaska: U.S. Geological Survey, Alaska Science Center, Anchorage.

Hamilton AN, Bunnell FL. 1987. Foraging strategies of coastal grizzly bears in the Kimsquit River valley, British Columbia. Int. Conf. Bear Res. and Manage. 7:187-197.

Holden ZA, Kasworm WF, Servheen C, Hahn B, Dobrowski S. 2012. Sensitivity of berry productivity to climatic variation in the Cabinet-Yaak Grizzly Bear recovery zone, northwest United States, 1989-2010. Wildl. Soc. Bull. 36:226-231.

Howe EJ, Obbard ME, Bowman J. 2012. Prior reproduction and weather affect berry crops in central Ontario, Canada. Popul. Ecol. 54:347-356.

Ilhalainen M, Salo K, Pukkala T. 2003. Empirical prediction modesl for Vaccinium myrtillus and V. vitis-idaea berry yields in North Karelia, Finland. Silva Fennica 37:95-108.

Jolliffe, I. 2014. Principal Component Analysis. Wiley StatsRef: Statistics Reference Online. DOI: 10.1002/9781118445112.stat06472.

Krebs CJ. Boonstra R, Cowcill K, Kenney AJ. 2009. Climatic determinants of berry crops in the boreal forest of southwestern Yukon. Botany 87:401-408.

Lashley MA, Thompson JR, Chitwood MA, DePemo CS, Moorman CE. 2014. Evaluation of methods to estimate understory fruit biomass. Plos One e96898.

Lee K. 2017. The importance of pollinators. http://fruit.cfans.umn.edu/pollination/

Lutes DC, Keane RE, Caratti JF, Key CH, Benson NC, Sutherland S, Gangi L. 2006. Fire effects monitoring and inventory system (FIREMON). U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station Gen. Tech. Rep. RMRS-GTR-164-CD. Fort Collins, CO.

Karlstrom TNW, Ball GE (eds.). 1969. The Kodiak Island Refugium: its geology, flora, fauna, and history. The Boreal Institute, University of Alberta, Ryerson Press.

MacKenzie KE. 1997. Pollination requirements of three highbush blueberry (*Vaccinium corymbosum* L.) cultivars. J. Amer. Soc. Hort. Sci. 122:891-896.

Mann DH, Petit DM. 1994. Extent and timing of the last glacial maximum in southwestern Alaska. Quarternary Research 42:136-148.

Matthews ER, Gerst Kl, Mazer SJ, Brigham C, Evenden A, Forrestel A, Haggerty B, Haukltain S, Hoines J, Samuels S, Villaba F. 2014. California Phenology Project (CPP) plant phenological monitoring protocol: Version 1. Natural Resources Report NPS/PWR/NRR—2014/763. National Park Service, Fort Collins, CO.

Moussus JP, Julliard R, Jiguet F. 2010. Featuring 10 phenological estimators using simulated data. Methods in Ecology and Evolution 1: 140-150. DOI 10.1111/j.2041-210X.2010.00020.x

Pritchard GT, Robbins CT. 1990 Digestive and metabolic efficiencies of grizzly and black bears. Can. J. Zoology 68:1645-1651.

Pyle B, Hernandez D. 2016. Development of protocols for monitoring relative abundance of berries important to brown bear of the Kodiak Archipelago, Alaska: pilot study progress report. Refuge report 2017.2. U.S. Fish and Wildlife Service, Kodiak National Wildlife Refuge, Kodiak, AK.

Richards AJ. 2001. Does low biodiversity resulting from modern agricultural practice affect crop pollination and yield? Annals of Botany 88: 165-172.

Robbins CT, Fortin JK, Rode KD, Farley SD, Shipley LA, Felicetti LA. 2007. Optimizing protein intake as a foraging strategy to maximize mass gain in an omnivore. Oikos 116:1675-1682.

Rogers L. 1976. Effects of mast and berry crop failures on survival, growth, and reproductive success of black bears. Trans. North Amer. Wildl. Conference 41:431-438.

Sorum M. 2013. Behavior-specific resource selection by Kodiak brown bears. MS Thesis. Univ. Idaho, Moscow.

Suring LH, GoldStein MI, Howell SM, Nations CS. 2008. Response of the cover of berry-producing species to ecological factors on the Kenai Peninsula, Alaska, USA. Can. J. For. Res. 38:1244-1259.

Tappeiner II JC, Zasada JC, Huffman DW, Ganio LM. 2001. Salmonberry and salal annual aerial stem production: the maintenance of shrub cover in forest stands. Can. J. For. Res. 31:1629-1638.

Tierney GB, Mitchell a, Miller-Rushing J, Katz E, Denny C, Brauer T, Donovan AD, Richardson M, Toomey A, Kozlowski J, Weltzin K, Gerst E, Sharron O, Sonnentag F. 2013. Phenology monitoring protocol: Northeast Temperate Network. Natural Resources Report NPS/NETN/NRR—2013/681. National Park Service, Fort Collins, CO.

Traveset A, Willson MF. 1997. Effects of birds and bears on seed germination of fleshy-fruited plants in a temperate rainforest in Southeast Alaska. Oikos 80:8 9-95.

Troyer WA, Hensel RJ. 1969. The brown bear of Kodiak Island. Unpublished report. USFWS Kodiak National Wildlife Refuge, Kodiak, AK.

Tuell JK, Isaacs R. 2010. Weather during bloom affects pollination and yield of highbush blueberry. J. Econ. Entomol. 103:557-562

Usui M, Kakuda Y, Kevan PG. 1994. Composition and energy values of wild fruits from boreal forest of northern Ontario. Can. J. Plant Sci. 74:581-587.

USDA, NRCS. 2016. The PLANTS Database (http://plants.usda.gov, 11 January 2016). National Plant Data Team, Greensboro, NC 27401-4901 USA.

[USFWS] U.S. Fish and Wildlife Service. 2007a. Revised comprehensive conservation plan and environmental impact statement: Kodiak National Wildlife Refuge. Anchorage, Alaska: U.S. Fish and Wildlife Service.

Van Daele LJ. 2001. Brown bear management report of survey and inventory activities 1 July 1998-30 June 2000 (game management unit 8). Pp 75-99 in: Healy C, ed. Project 4.0. Alaska Department of Fish and Game, Juneau.

Van Daele LJ, Barnes Jr VG, Belant JL. 2012. Ecological flexibility of brown bears on Kodiak Island, Alaska. Ursus 23:21-29.

Van Daele MB, Robbins CT, Semmens BX, Ward EJ, Van Daele LJ, Leacock WB. 2013. Salmon consumption by Kodiak brown bear with ecosystem management implications. Can. J. Zool. 91:164-174.

Welch CA, Keay J, Kendall KC, Robbins CT. 1997. Constraints on frugivory by bears. Ecology 78:1105-1119.

Wender BW, Harrington CA, Tappeiner II JC. 2004. Flower and fruit production of understory shrubs in western Washington and Oregon. Northwest Sci. 78:124-140.

Zar JH. 1984. Biostatistical Analysis. Prentice-Hall, Inc. Englewood Cliffs, NJ.

Table 1. Characteristics of red elderberry (*Sambucus racemosa*) index sites, Kodiak Island, Alaska, 2015-2016.[1] Bold-faced values within study site and column denote significant between-year difference ($p \leq 0.10$).

Characteristic & Year	Road System $\bar{x}$ (SD)	Uganik Lake $\bar{x}$ (SD)	Karluk Lake $\bar{x}$ (SD)	Red Lake[2] $\bar{x}$ (SD)
Density (plants/0.1 ha)				
2015	no data	91 (45)	102 (21)	no data
2016	121 (54)	110 (64)	141 (51)	91
Basal Diameter (mm)				
2015	**58.1 (43.6)**	**45.3 (34.9)**	**28.2 (21.3)**	26.6 (22.6)
2016	**73.8 (64.7)**	**53.7 (44.0)**	**41.8 (19.5)**	38.9 (29.9)
Diameter Breast Height (mm)				
2015	31.3 (32.8)	21.3 (19.7)	**12.5 (4.3)**	14.2 (7.4)
2016	29.9 (31.0)	18.1 (9.9)	**14.8 (3.9)**	12.4 (4.8)
Total Height (m)				
2015	**2.2 (0.8)**	2.2 (0.6)	**2.2 (0.4)**	2.0 (0.3)
2016	**2.1 (0.8)**	2.3 (0.6)	**2.3 (0.3)**	1.9 (0.3)
Canopy Volume (m^3)				
2015	12.5 (13.8)	**14.4 (16.9)**	**15.3 (31.6)**	6.0 (4.)
2016	14.8 (16.4)	**22.3 (25.5)**	**14.3 (16.2)**	8.8 (6.0)
Fruit Clusters/Plant (no.)				
2015	**30 (56)**	83 (181)	**26 (29)**	22 (25)
2016	**47 (76)**	69 (110)	**43 (44)**	30 (34)
Fruit/Cluster (%)				
2015	incomplete data	**67 (37)**	**86 (12)**	82 (10)
2016	76 (18)	**75 (34)**	**93 (5)**	85 (10)
Cluster Volume (mm^3)				
2015	459 (259)	**240 (79)**	309 (161)	523 (303)
2016	463 (168)	**317 (137)**	338 (187)	506 (193)

[1]Measurements and estimates acquired yearly from 10 plants in each of 3 plots per site.
[2]Small sample size precluded testing.

Table 2. Characteristics of salmonberry (*Rubus spectabilis*) index sites, Kodiak Island, Alaska, 2015-2016. Bold-faced values within study site and column denote significant between-year difference ($p \leq 0.10$).

Characteristic & Year	Road System $\bar{x}$ (SD)	Karluk Lake $\bar{x}$ (SD)	Red Lake $\bar{x}$ (SD)
Foliage Height (m)			
2015	1.26 (0.41)	**0.90 (0.33)**	1.06 (0.33)
2016	1.25 (0.37)	**1.11 (0.22)**	1.21 (0.28)
Foliar Cover (%)			
2015	**95 (11)**	**79 (29)**	**89 (18)**
2016	**98 (7)**	**92 (20)**	**96 (13)**
Fruit Density (m^2)[1]			
2015	36.8 (36.2)	**35.6 (36.7)**	**41.1 (39.9)**
2016	45.5 (60.0)	**84.7 (66.9)**	**139.7 (93.5)**
Fruit quality (2016)[2]			
Aborted flower (%)	18 (20)	17 (8)	19 (8)
Small-size (%)	75 (19)	64 (7)	60 (16)
Medium-size (%)	7 (5)	18 (9)	16 (17)
Large-size (%)	0 (0)	1 (1)	4 (8)

[1]Exludes subplots missing salmonberry foliar cover. Mean and SD weighted by percentage foliar cover (plots) and number of fruits per plot (site).
[2]Based on relationship between berry length and berry drupelet number. We suspect that brown bear do not selectively feed on small-sized fruit composed of 1-30 drupelets.

Table 3. Characteristics of oval-leafed blueberry (*Vaccinium ovalifolium*), Road System index site, northeastern Kodiak Island, Alaska, 2015-2016. Bold-faced values within row denote significant between-year difference ($p \leq 0.10$).

Characteristic	2015 $\bar{x}$ (SD)	2016 $\bar{x}$ (SD)
Foliage Height (m)	**0.86 (0.28)**	**0.95 (0.27)**
Foliar Cover (%)	**58 (27)**	**65 (25)**
Fruit Density (m^2)[1]	**92.0 (135.9)**	**122.2 (159.2)**

[1]Excludes subplots missing blueberry foliar cover. Mean and SD weighted by percentage foliar cover (plots) and number of fruits per plot (site).

Table 4. Characteristics of devilsclub (*Oplopanax horridus*) plots, Road System index site, northeastern Kodiak Island, Alaska, 2015-2016.[1] Bold-faced values within row denote significant between-year difference ($p \leq 0.10$).

Characteristic	2015 $\bar{x}$ (SD)	2016 $\bar{x}$ (SD)
Density (plants/0.1 ha)	--	120 (54)
Basal diameter (mm)	**25.1 (7.0)**	**27.8 (9.6)**
Shrub height (m)	1.16 (0.36)	1.11 (0.39)
Canopy volume (m^3)	0.38 (0.25)	0.43 (0.41)
Fruit clusters/plant (no.)[2]	1.1 (0.8)	1.2 (1.0)
Fruit cluster volume (mm^3)[3]	163 (123)	196 (194)
Fruit/cluster (%)[4]	--	23 (7)

[1]Measurements and estimates acquired yearly from 10 plants in each of 2 plots.
[2]Analysis included plants with and without fruit clusters.
[3] Site mean and SD weighted by no. clusters per plot.
[4]Mean and SD weighted by no. clusters per plant.

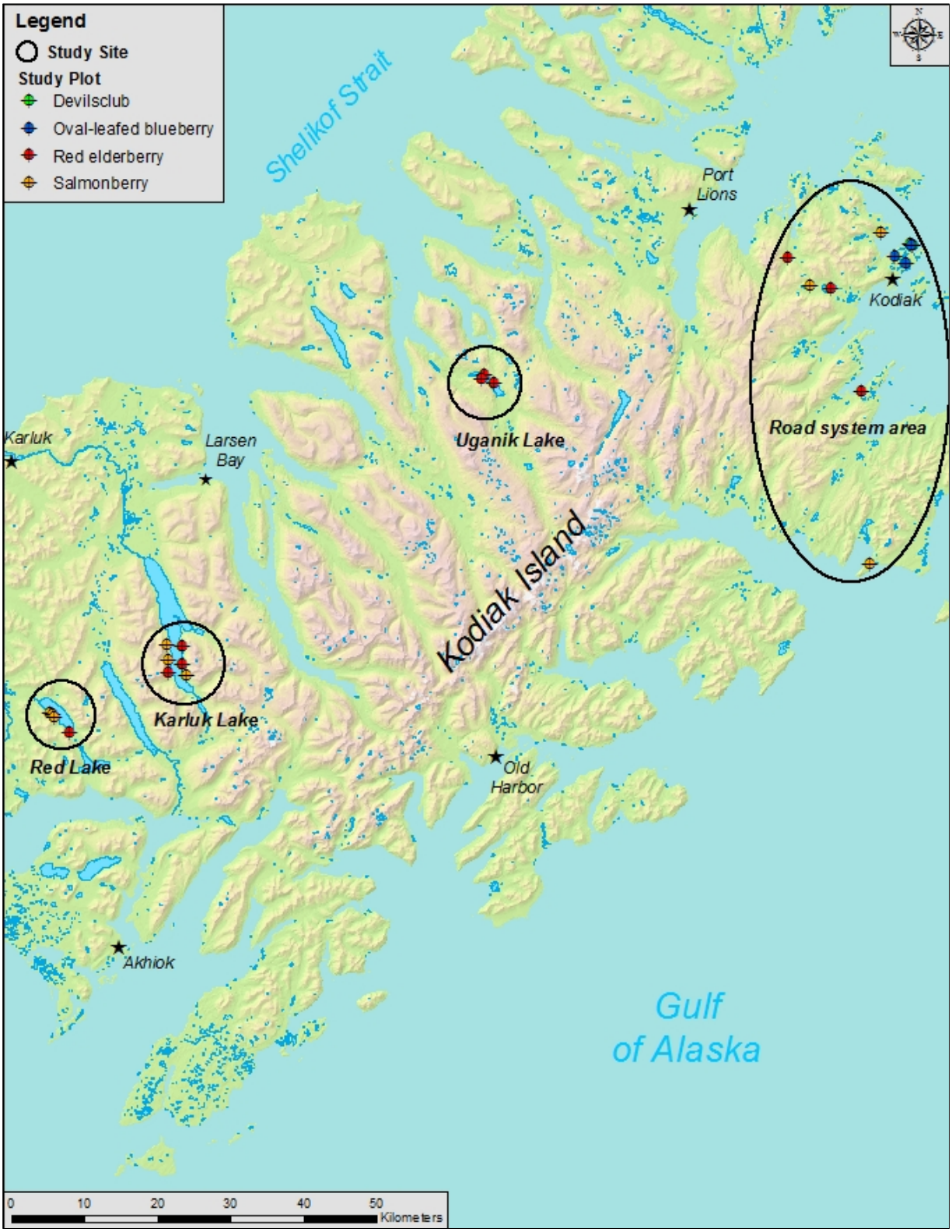

Figure 1. Area, sites, and plots of study of four focal species of berry-producing shrubs, Kodiak Island, Alaska, 2015-2016.

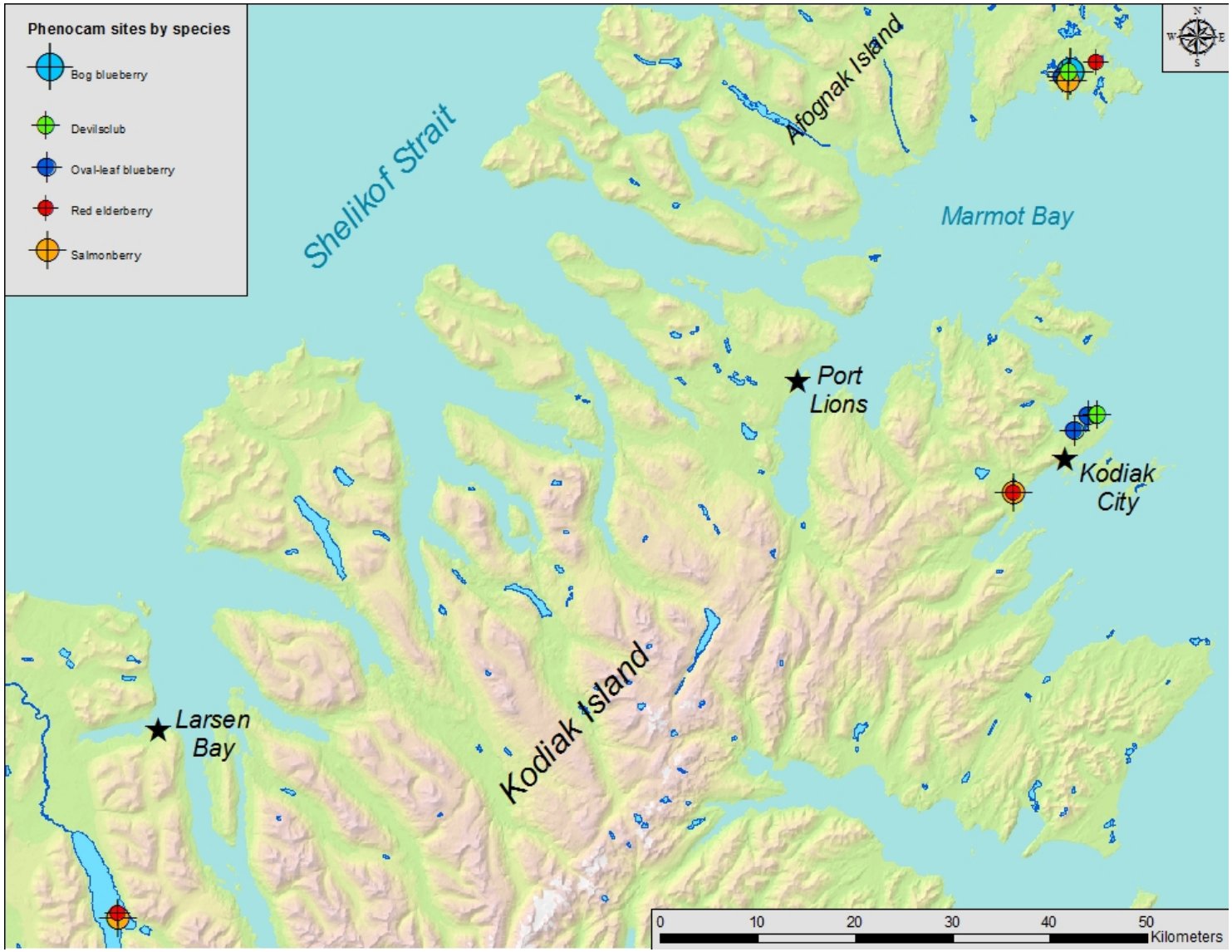

Figure 2. Sites monitored for phenology of berry-producing shrub species on Kodiak Island (2015 & 2016) and Afognak Island (2016), Alaska.

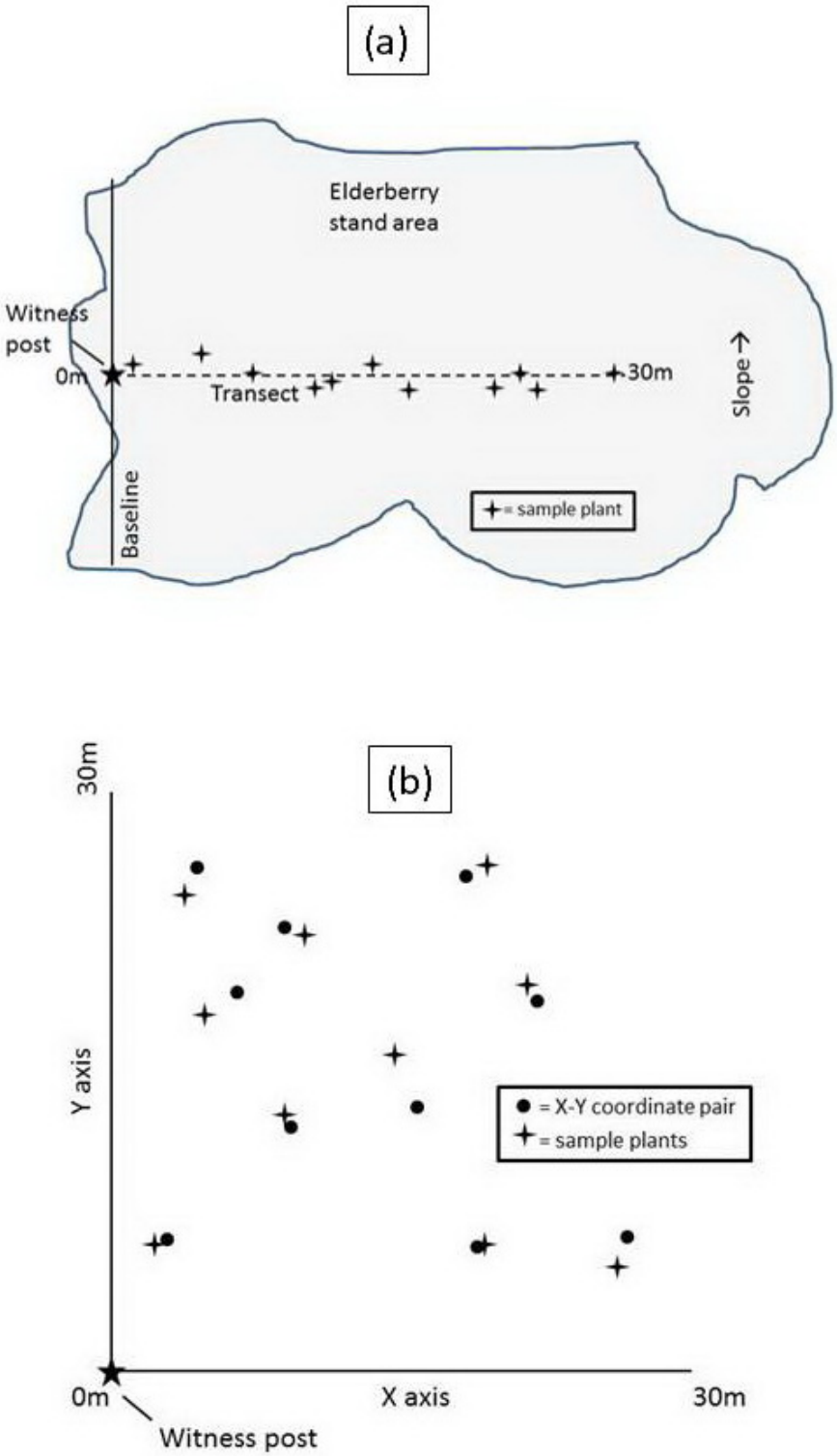

Figure 3. Plot layouts in red elderberry (*Sambucus racemosa*) and devilsclub (*Oplopanax horridus*), Kodiak Island, Alaska. Layout (a) was applied to relatively large and dense elderberry stands; layout (b) was applied to smaller, low density elderberry and devilsclub stands.

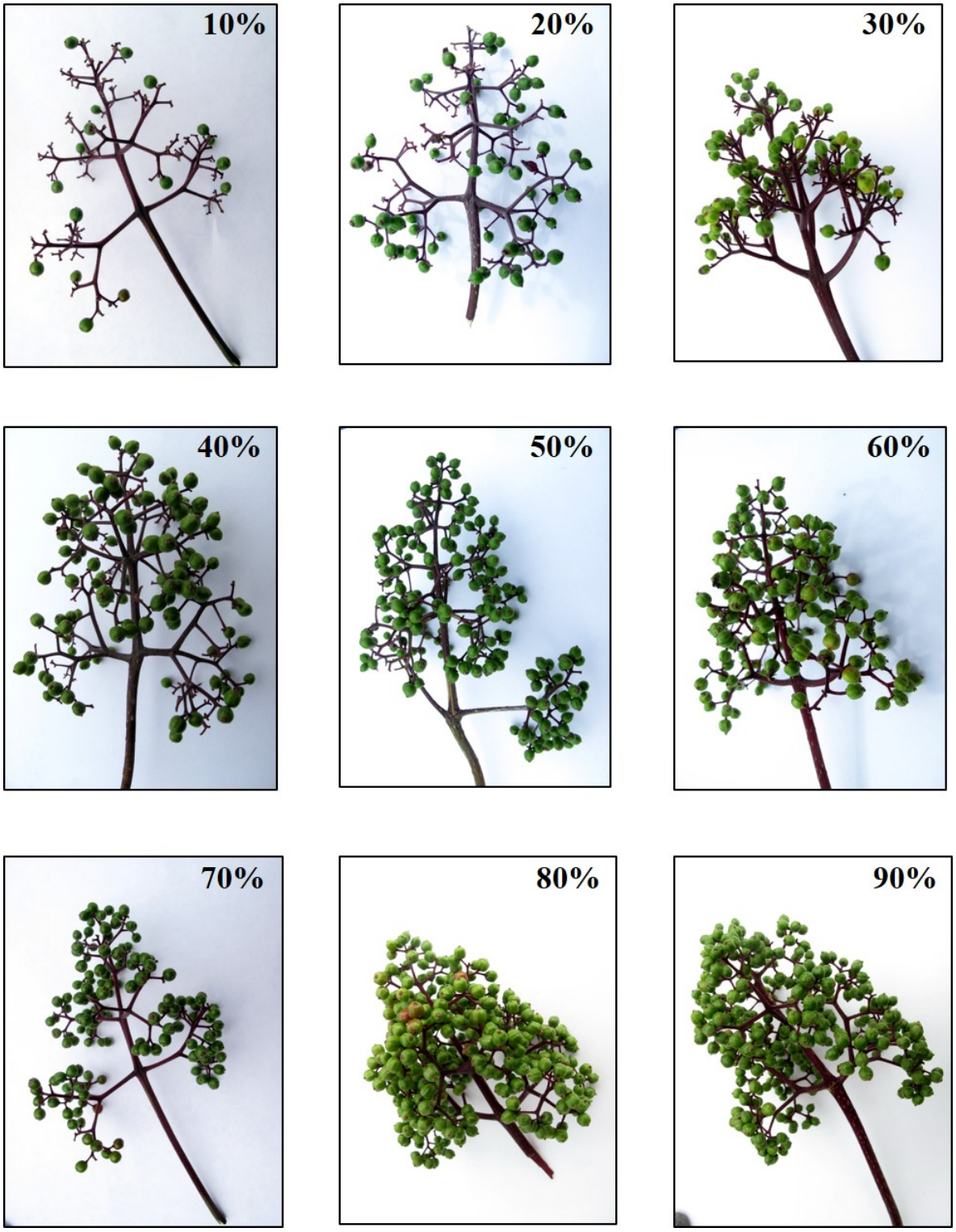

Figure 4. Guide for estimation of relative abundance of red elderberry (*Sambucus racemosa*) fruit. Actual percentage fruit per cluster listed in upper right corner of each image.

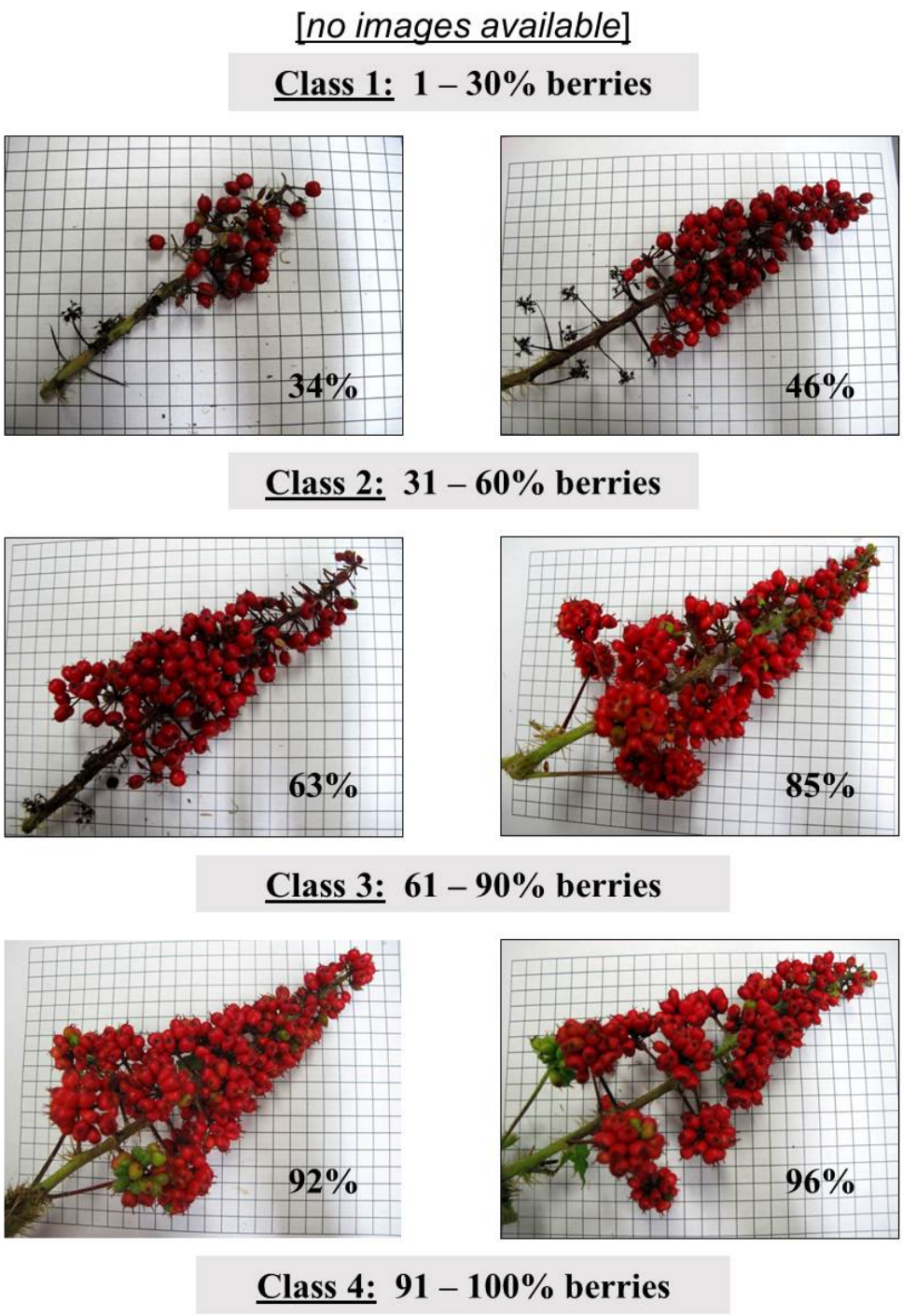

Figure 5. Guide for field estimation of relative abundance of devilsclub (*Oplopanax horridus*). Actual percentage fruit per cluster listed in lower right corner of each image.

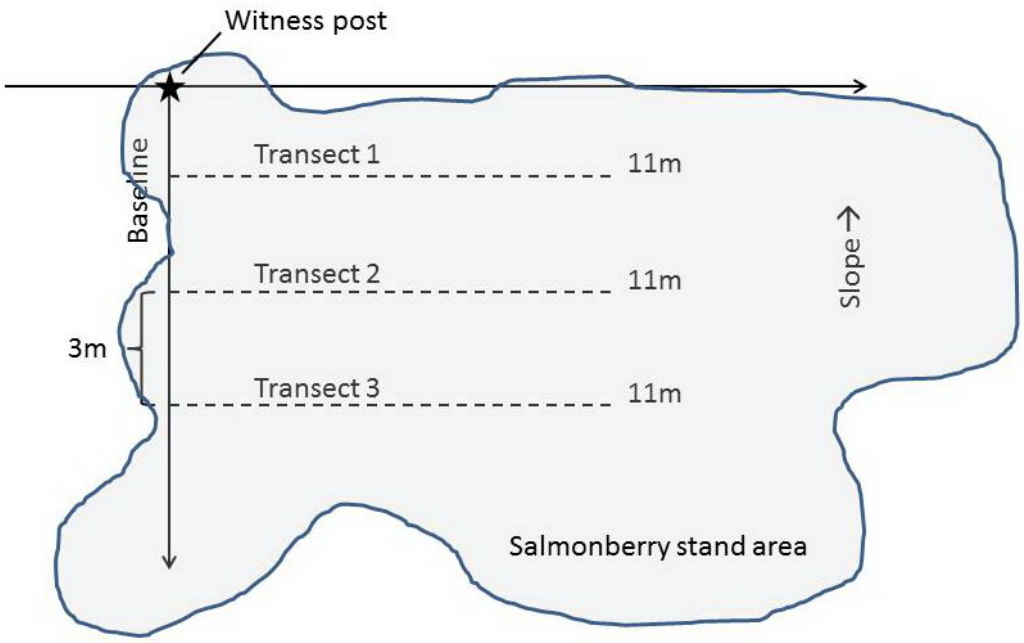

Figure 6. Plot layout in salmonberry (*Rubus spectabilis)*, Kodiak Island, Alaska.

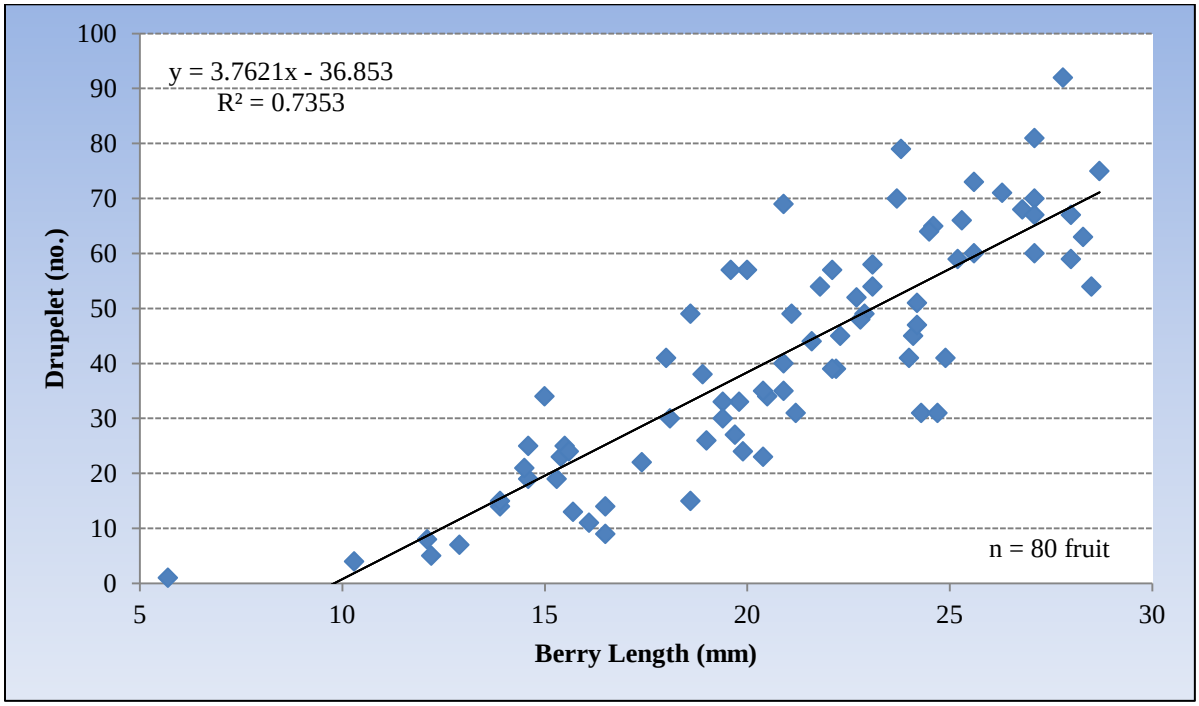

Figure 7. Regression of salmonberry (*Rubus spectabilis*) fruit length and drupelet number, Kodiak Island, Alaska, 2016. Drupelet number increases by about 18 every 5mm increase in berry length.

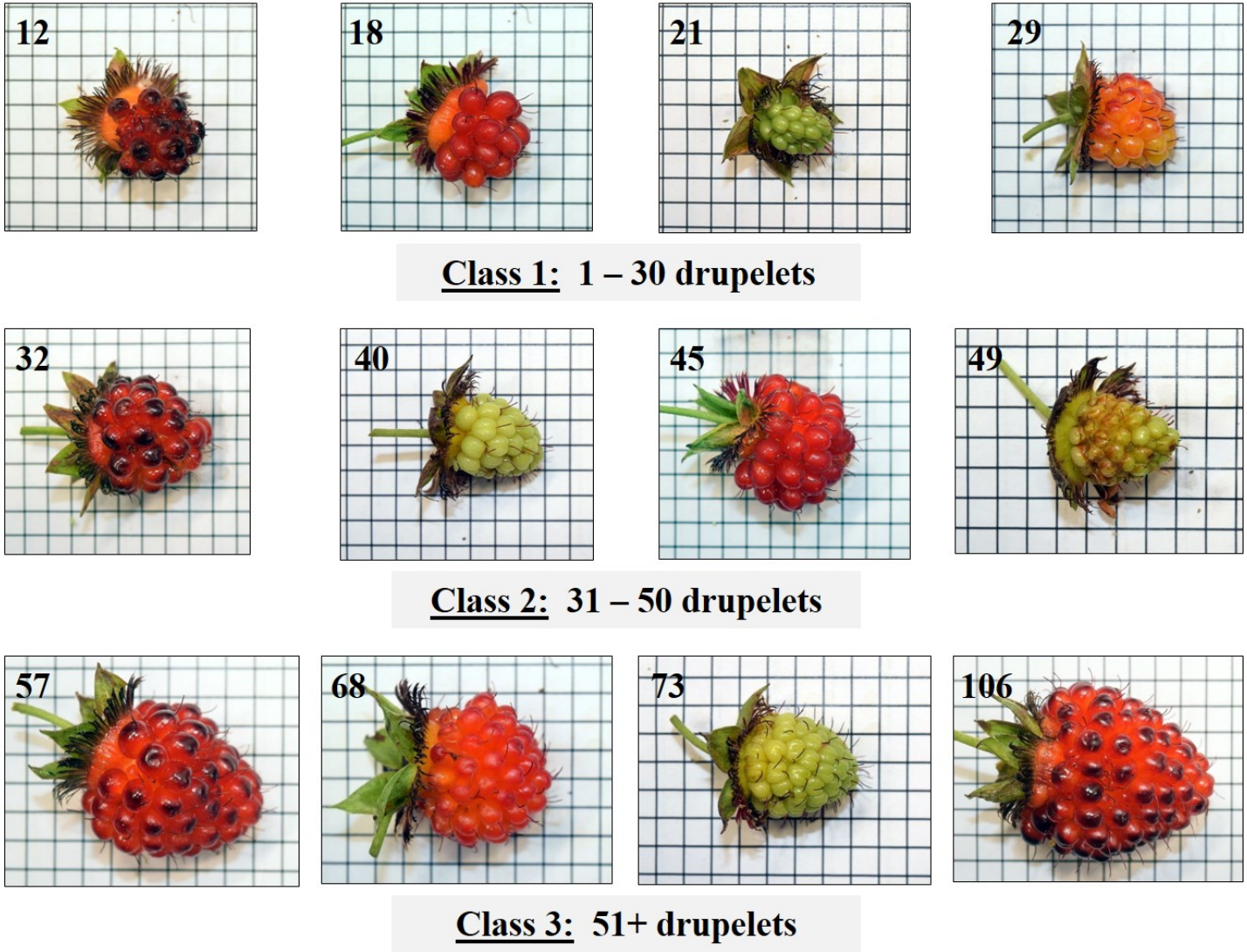

Figure 8. Guide for field estimation of relative quality of salmonberry (*Rubus spectabilis*) fruit. Actual drupelet number per berry listed in upper left corner of each image.

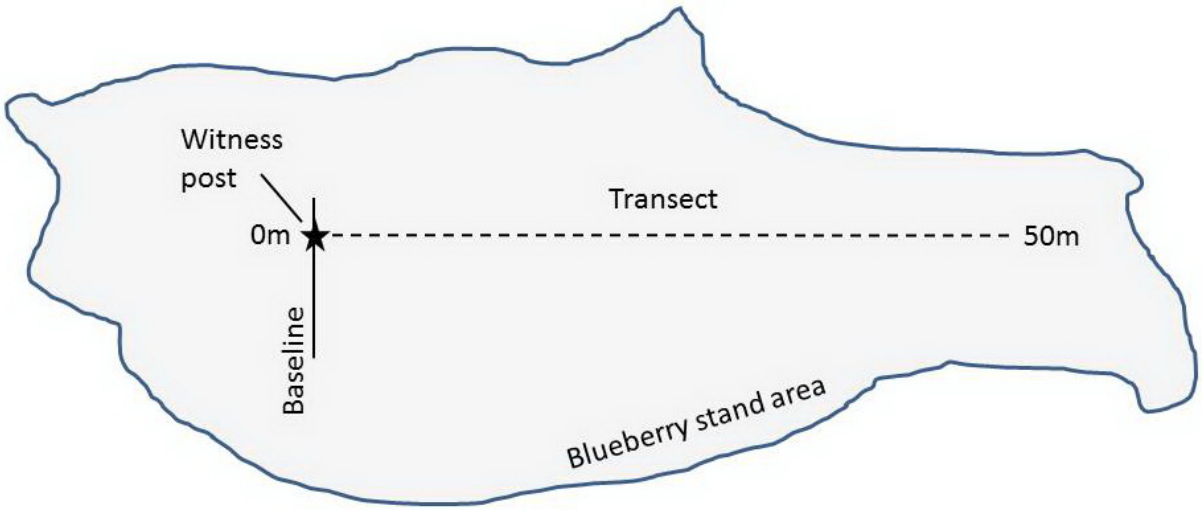

Figure 9. Plot layout in oval-leaf blueberry (*Vaccinium ovalifolium*), Kodiak Island, Alaska.

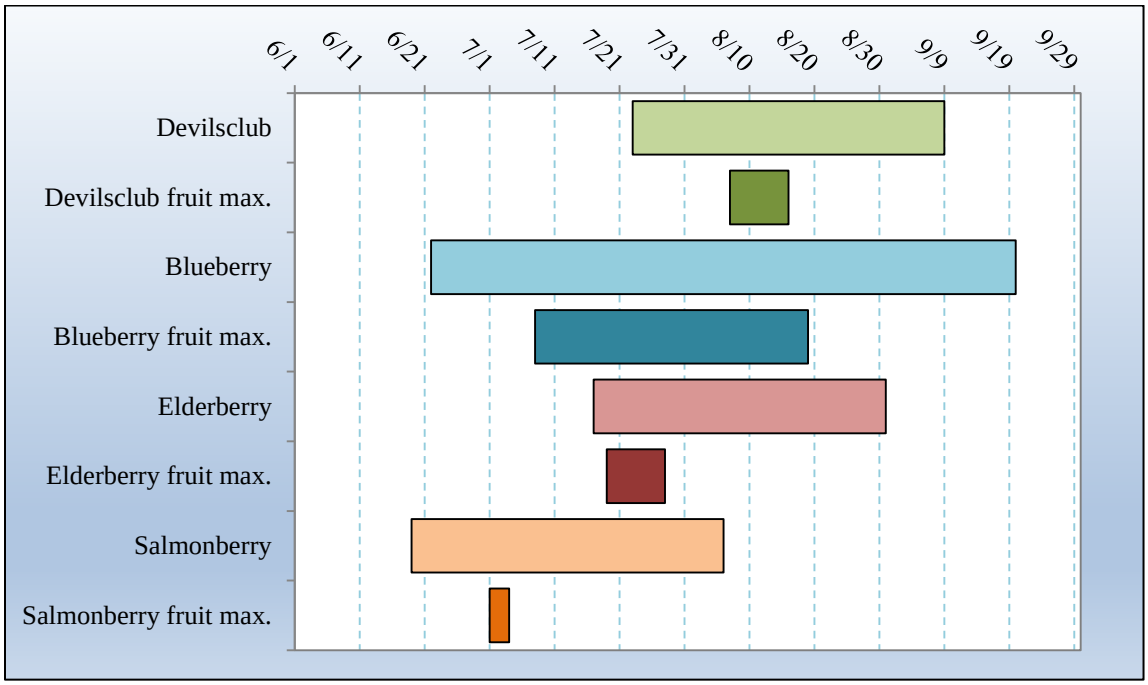

Figure 10. Timing and duration of ripe fruit and maximum abundance of ripe fruit of four berry-producing shrub species in four lowland monitoring sites of the Kodiak Archipelago, Alaska, 2016.

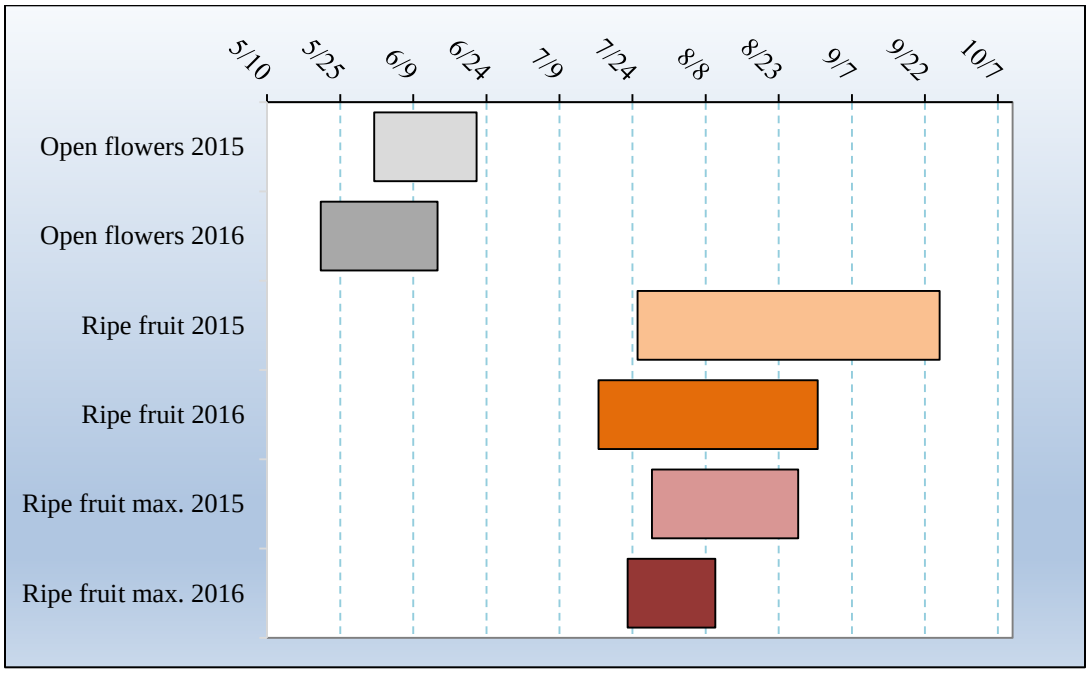

Figure 11. Timing and duration of selected phenophases of red elderberry (*Sambucus racemosa)* in 2015 and 2016, Camp Island area of Karluk Lake, Kodiak Island, Alaska.

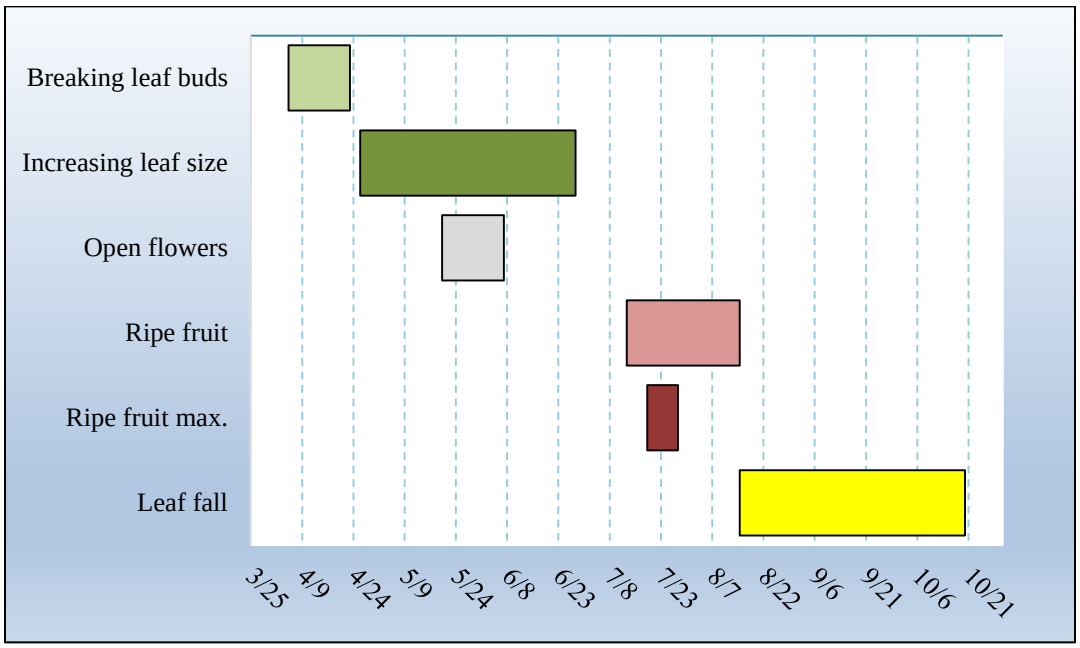

Figure 12. Timing and duration of major phenophases in red elderberry (*Sambucus racemosa*), Camp Island area of Kodiak Island, Alaska, 2016.

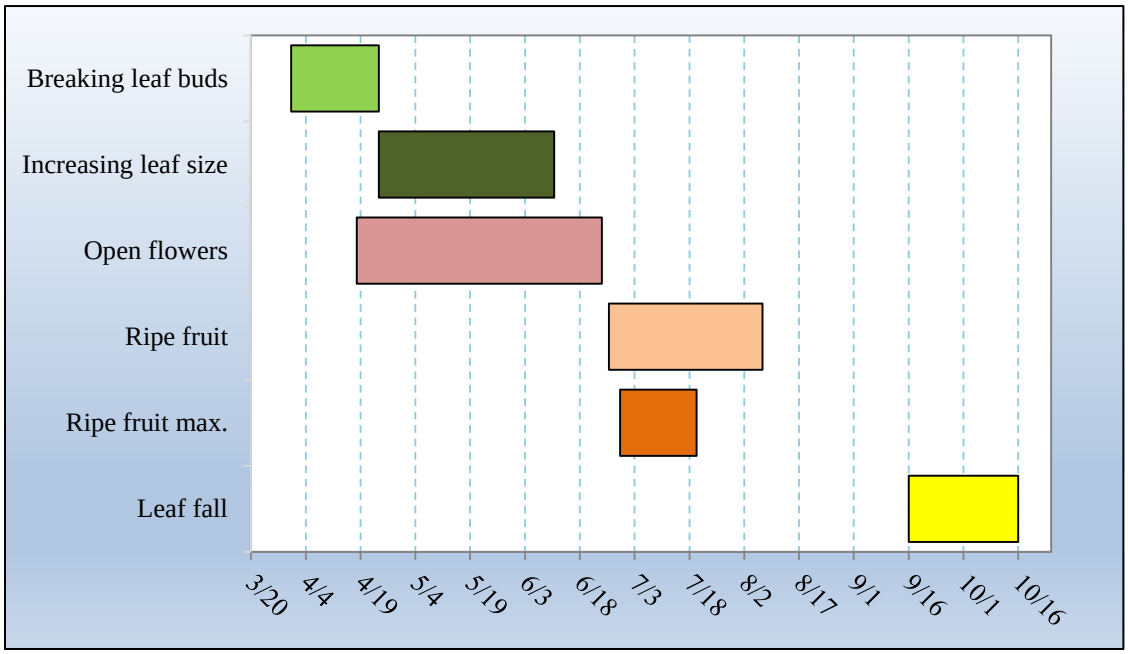

Figure 13. Timing and duration of major phenophases in salmonberry (*Rubus spectabilis*), Camp Island area of Kodiak Island, Alaska, 2016.

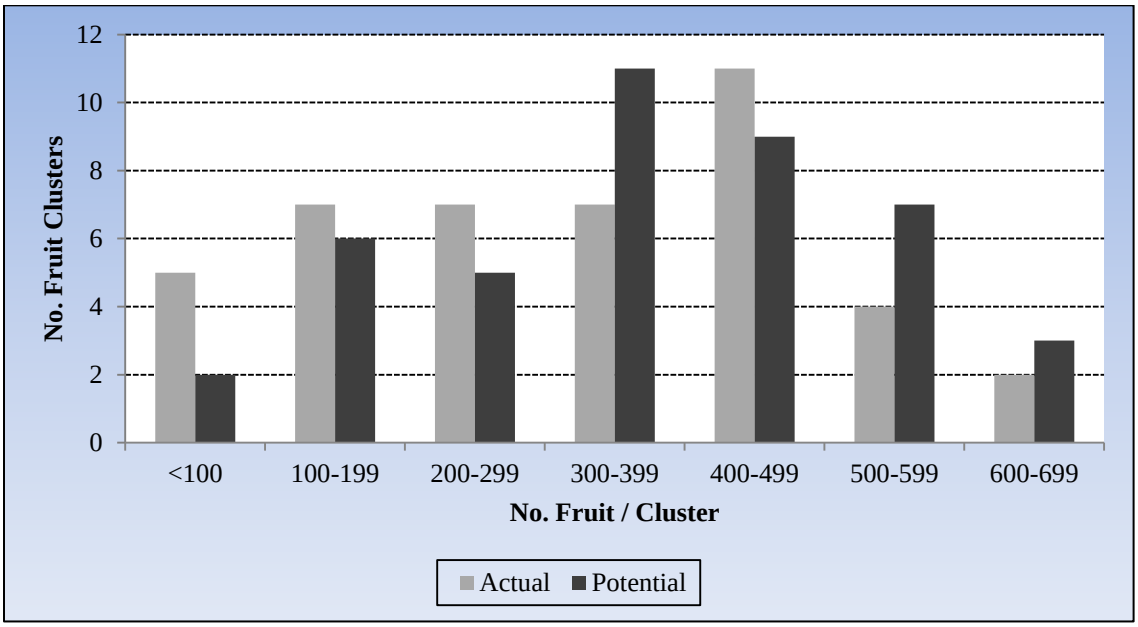

Figure 14. Actual and potential number of devilsclub (*Opoplanax horridus*) fruit per cluster (n=43 clusters of 30 plants), Kodiak Island, Alaska.

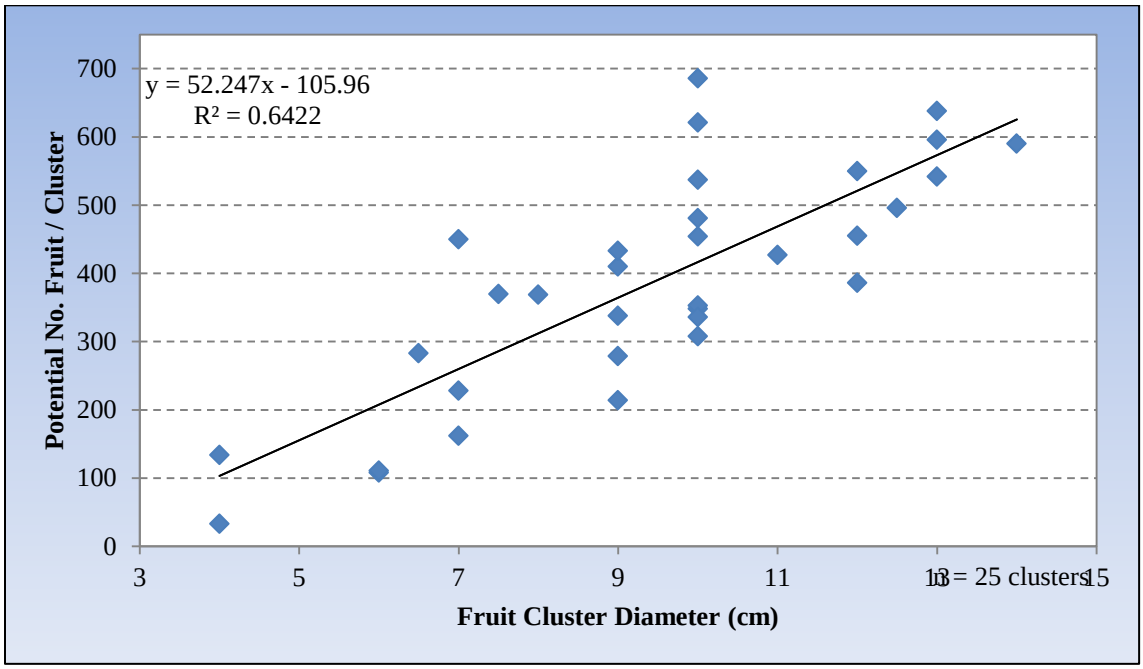

Figure 15. Regression of devilsclub (*Oplopanax horridus*) fruit cluster diameter and potential number of fruit per cluster, Kodiak Island, Alaska, 2016. Potential fruit number increases by about 100 every 2cm increase in cluster diameter.

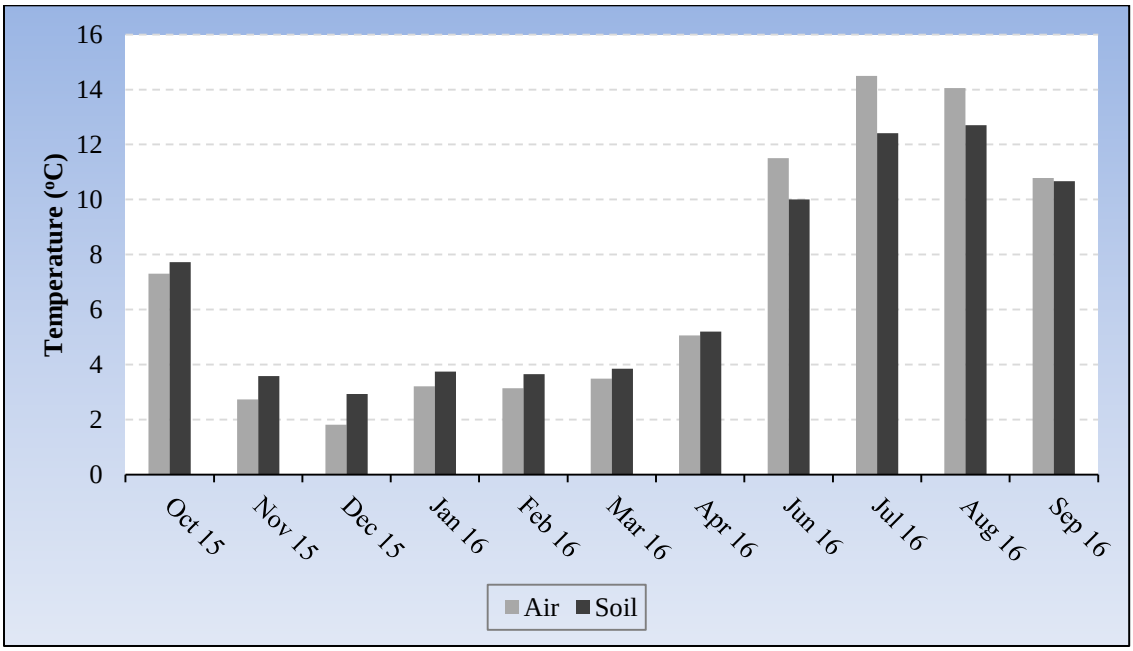

Figure 16. Representative pattern of mean monthly air-soil temperature relationship of monitoring plots, Kodiak Island, Alaska, October 2015-September 2016. Data derived from a devilsclub (*Oplopanax horridus*) plot in roaded area of northeastern Kodiak Island.

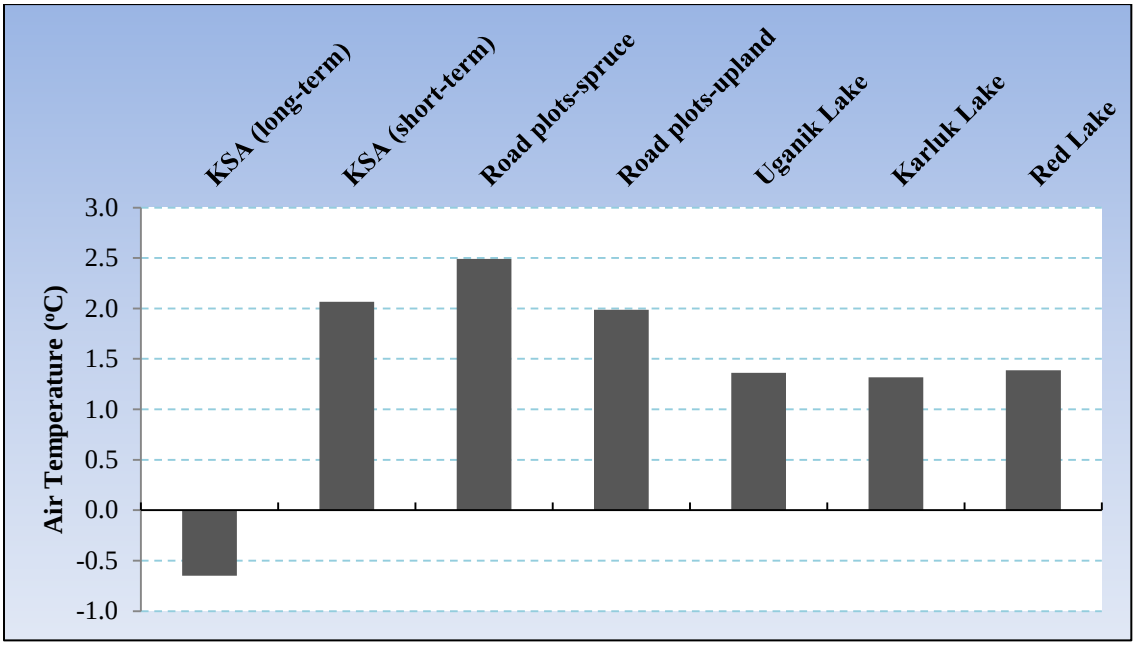

Figure 17. Comparison of long-term (1981-2010) mean December-February air temperature (°C) at Kodiak State Airport (KSA), with short-term (2015-2016) mean December-February air temperature (°C) at KSA and berry study sites, Kodiak Island, Alaska.

Appendix A. Preliminary field protocol for phenology monitoring of selected berry-producing shrub species with white-flash equipped trail cameras in the Kodiak Archipelago, Alaska.

1. Camera familiarization. Read the camera manual. Familiarize yourself with programming operations (via setup mode) and variation in resolution (detail) at different distances. The objective is to capture as large an area as possible of a shrub(s) canopy at sufficient resolution to discriminate detail as small as 0.5 centimeter (~3/8 inch) scale. For purposes of phenology classification using a Wingscapes® TimelapseCam Pro (Figures A-1 & 2), the best distance is 2-3 meters (6.5-10 feet) between the camera and center of targeted shrub. Also become familiar with how to target the cameras to acquire a specific area in an image frame (e.g., sight over top center for center of image frame). To assess whether you're imaging the right area and using the right focus, take some test shots and review these in playback mode on the camera, on a handheld digital camera using the zoom function as needed, or on a laptop computer. Finally, set the date and time (AK standard time, not savings time) while in camera setup mode.

2. Prepare for camera field deployment. Determine how you will mount the camera in the field and what supplies you'll need to mount the camera. Greatest flexibility is provided by mounting the camera on a steel T-post. Options for securing the camera to the T-post include:

- Strap to post with the webbing strap supplied with the camera
- Custom-build a camera bracket or purchase brackets and swivel mounts specially designed for trail cams. For examples see http://www.murphymetalart.com/trailcamera.html and https://www.chasingame.com/product-category/mounting-brackets/ (Figures A-3, 4 & 5)

Although the camera is supplied with a bracket for mounting the camera to a small tree or tree limb, in most cases, the availability of suitable trees close to camera-targeted shrubs, is often limited except, in some cases, where they occur near forest-inhabiting devilsclub and blueberry.

Supplies needed for mounting in the field (T-post setup with metal bracket & swivel ball mount)

- Post-pounder or sledgehammer for driving T-post & T-post
- Timelapse camera
- AA batteries (8)
- SD card (16-32 gb)
- Camera bracket
- 8 or 10" zip ties (fasten camera to bracket)
- Measurement tape or ruler (measure camera to target shrub distance to set camera focus)
- Digital camera (take a picture of mounted camera and target shrub)
- GPS (record the coordinates of the camera site)
- Survey flagging (used as needed to establish bulls eye for positioning center of photo frame)
- Desiccant pack (mount over label of inside camera so pack rests on the view frame)
- (Follow-up maintenance only): spare camera, batteries, SD card, desiccant pack, electric tape (if you're performing a maintenance check)

3. Field deployment of the camera. Select the shrub you want to monitor.

- Deploy camera in early spring where possible (March-April) to enable monitoring the entire growing season from initial burst of leaf buds to total leaf fall. At minimum, deploy before flowering occurs (e.g., oval-leaf blueberry early March; salmonberry mid-April; elderberry mid-May; devilsclub late May).
- Select a shrub species for camera monitoring. Be advised that the size of some of the plant species and visibility of key parts (flowers, fruit) will change dramatically over the growing season. Guidelines follow:
    - Select a site where the shrub is positioned in north (NW-NE) of the post-mounted camera. This will minimize image distortion from sun glare.
    - Where possible, select a site where the camera is positioned upslope or above (tree-mounted) the targeted shrub. This will maximize the visibility of flowers and fruit while minimizing the effect of concealing plant growth between the camera and target shrub.
    - Select a site where vegetation growth between the camera and target shrub will not block the camera view. However, extent of blocking growth may not be obvious till later in growing season.

- Drive the T-post, fasten the camera to the bracket, and mount the camera.
- To facilitate centering the camera field of view, as well as maintaining the same field of view through the season, place a small piece of bright flagging or tape material on a branch of the shrub that is near the desired bullseye/center of the camera field of view.
- Set the focus.
- To verify correct camera positioning, run a temporary program with a series of images (e.g., 3 images, 30 second interval), review the images in playback (or by removing the SD card and viewing in digital camera, zoom as necessary to see detail). Reposition the camera and/or flagging on shrub as necessary based on playback image review.
- Set the final camera program (setup mode). See table below for programming guidelines:

Item	**Setting**
DATE & TIME	(Use AK standard time)
PHOTO OR VIDEO?	PHOTO
TIME LAPSE INTERVAL	1 HOUR
TIME LAPSE PROGRAMS PER DAY	2
T.L. PROGRAM #1 START TIME	MIDNIGHT
T.L. PROGRAM #1 STOP TIME	4am (4 images acquired between midnight-3am)
T.L. PROGRAM #2 START TIME*	NOON *(or best time relative to non-glare sun angle*)
T.L. PROGRAM #2 STOP TIME*	7pm (*or best time; need total of 4-6 daytime images*)
UPGRADE FIRMWARE	NO
PROGRAM SECURITY CODE	00000 (default)
TEMPERATURE UNIT	CELSIUS
AC CONNECTED?	NO
WI-FI SD CARD?	NO
CAMERA NAME	Abbreviate camera #, site, species (e.g., CAM2, AFEB) (AFEB=abbv. for Afognak elderberry)
IMPRINT INFO?	YES
VIDEO LENGTH	(leave as is; no video taken)
VIDEO QUALITY	(leave as is; no video taken)
PHOTO QUALITY	ENHANCED (20 MP)
MANAGED MEMORY	DO NOT OVERWRITE
ERASE ALL IMAGES?	NO
RESET TO FACTORY DEFAULTS?	NO

*This daytime period works best for cameras positioned south of targeted shrub. Customize daytime period as needed for cameras with east, south, or west of targeted shrub. For example, best time period for fully lit shrub during summer where camera position west of targeted shrub may be 1500-2100.

- After programming is finished, switch the camera from SETUP to ON and close the camera case.
- With a GPS unit, record camera site coordinates (waypoint)
- With a standard digital camera, photograph the camera on the T-post with the target shrub in the background (Figure A-4)

4. Maintenance. Guidelines for follow-up checks to ensure continued continuous functioning of camera and consistency of field of view.

- In office, prepare equipment and supplies needed for the field
- A camera should function continuously for at least 4-6 months if you started with fresh batteries, a 32 GB SD card, and programming described above.
- After initial installation, follow-up checks should occur at 2-3 week intervals between May and mid-July (main period of active vegetation growth) to: (1) ensure proper functioning of the camera and (2) remove foreground vegetation that is blocking, or will probably grow to block, some of the camera view of the target shrub. The latter process is facilitated by reviewing images before and after vegetation removal.
- Adjust the camera program as needed. For example, if the objective is to continue recording during the dormant season (October-March generally) then adjust the camera program to record fewer photos

(minimum 2 per day and night). The same also holds for remote installations where access is limited during the fall-spring period (e.g., October-May).

- Special Note: Most monitored species (salmonberry, blueberry, elderberry) will occasionally experience mass stem-death—topkill—resulting from harsh winter conditions or girdling of the stems by deer (elderberry). Regardless, monitoring should be continued of the affected target plant (blueberry, elderberry) or patch (salmonberry) unless continued monitoring reveals that the plant was killed, in which case, a new site (preferably near the old site) should be selected. In response to topkill, each of these species should generate new shoots and stems from the root crown. To monitor the growth of these new shoots camera field of view may need adjustment at the beginning of the growing season to document initial growth. When this occurs, periodically reposition the camera (i.e., field of view moved up) as the stems grow during the season. Also, with salmonberry, some extra effort needs to be dedicated to clear away non-target new and old herbaceous and shrub growth between the target and camera so the targeted low-growing shoots can be observed (Figure A-5).

Figure A-1. Wingscapes® TimelapseCam Pro.

Figure A-2. View of Wingscapes TimelapseCam Pro with front door open. Note desiccant pack taped to inside of camera front door.

Figure A-3. Example of timelapse camera fastened to bracket mounted on steel T-post at monitoring site.

Figure A-4. Example of photograph documentation of monitoring site including both timelapse camera and shrub targeted by timelapse camera (leafless elderberry, center right of photo).

Figure A-5. Example of monitoring of (winter) top-killed salmonberry. Note new shoots emerging from base of plant, down-pointed camera, and extensive clearing of surrounding non-target vegetation.

Appendix B. Guidelines for interpretation of trail camera images in classification of phenology of selected berry-producing shrub species in the Kodiak Archipelago, Alaska.

1. Camera operation & image interpretation

- Conduct a general review of the image file. Classification is based on the period when the first breaking of buds is observed and ending when the last leaves fell.
- Select a subset of images at 3-day intervals starting when the first breaking of buds is observed and ending when the last leaves fell. Selected images, one or two with best resolution per day (e.g., day, night) should be copied and pasted to the folder PhenoClassSubset/XXXX (year).
- Having one daytime image and one nighttime image (standard white flash) is best for image interpretation because the flash at night provides excellent contrast for determining abundance (i.e., intensity) levels, and the high lighting during the day produces higher quality images which allow for better zooming in on individual structures. It is acceptable to base the classification on 2 images in a given 24-hour period (e.g., 0000-2400 July 5).
- To facilitate image interpretation and phenology classification, use basic image-processing software to improve quality of apparently marginal daytime images by adjusting exposure and/or contrast issues resulting from uneven lighting or partial lens fogging.
- In each record set for species-site-year, select and edit one photo to delineate the area evaluated for classification. Save and label the edited image as "AreaEvaluated".
- Download the species-specific phenology classification datasheet and interpretation protocol from the National Phenology Network (NPN) https://www.usanpn.org/nn/species_search
- Print copies of the datasheets and a copy of the interpretation protocol
- Scan completed data sheets, re-label the filename consistent with conventions "speciesabbreviation_sitename_year_agency" (e.g., OPHO_Afognak_2016_ADFG) and place in the appropriate folder (e.g., ScannedDataSheet)

2. General guidelines for imagery-based classification of phenology

- Increasing leaf size. Accuracy greatest when evaluating backwards from point at or near maximum growth to point where leaves first unfold.
- Recent leaf drop. Same guideline as above. This will also facilitate estimation of decline in number of leaves at the end of the growing season.
- Fruit. Trend in abundance (e.g., fruit max., fruit drop) of blueberries and salmonberry can be facilitated by (1) counting fruit observed in the image; (2) listing the number observed per day in the blank area below the respective daily; and (3) classification based on the recorded record.

3. Species-specific guidelines for imagery-based classification of phenology

Blueberry, Bog (*Vaccinium uliginosum*)

- Leaves & increasing leaf size. Do not include newly emerged unfolded leaves.
- Colored leaves. A leaf is colored when leaves lose green color. In bog blueberry, leave senescence is denoted by reddening-browning.
- Flowering. Starts before leaves unfold then continues as leaves unfold.
- Open flowers. Usually requires magnification/zooming to show that the inverted bell-shaped flower has expanded in diameter and that its aperature, located at the bottom, has opened.
- Ripe fruit. A berry is completely blue.

Blueberry, Oval-leaf (*V. ovalifolium*)

- Leaves & increasing leaf size. Do not include newly emerged unfolded leaves.
- Colored leaves. A leaf is colored when any portion shows yellowing. Additionally old senescing leaves typically develop spots. Usually the spotting occurs first followed by yellowing.
- Flowering. Starts before leaves unfold then continues as leaves unfold.

- Open flowers. Usually requires magnification/zooming to show that the inverted bell-shaped flower has expanded in diameter and that its aperture, located at the bottom, has opened.
- Ripe fruit. A berry is completely blue.

Devilsclub (*Oplopanax horridus*)

- Colored leaves. Includes partial and/or wholly colored leaves. When a leaf turns completely yellow, it rapidly withers followed by dropping from plant.
- Flowering. In the flower spike/cluster, flowering proceeds from the top of the spike/cluster to the bottom of the spike and may takes 2-3 weeks to complete.
- Flowers and flower buds. Count and record total inflorescences (i.e. flower spikes composed of many individual flowers/flower buds)! For example, if there are two inflorescences with many flowers or buds each, then abundance should be recorded as <3. Include inflorescences that you can only partially observe in the foreground evaluation view.
- Open flowers. Estimate the number of individual open flowers. Flowering progresses over ~2 weeks from the top to the bottom of the inflorescence. Base the estimate on the average number of open flowers per cluster. Since devilsclub flowers indeterminately (topmost part of flower cluster flowers first, bottom last), only a fraction of total flowers will be open at any given time. To derive an estimate of open flowers, divide by the average potential for total flowering, which is estimated at about 380. Although you can only observe one side of the flowering structure, your estimate should include the entire structure based on the assumption of equivalent number of flowers on both visible and invisible surfaces.
- As with flowering, fruit development progresses over several weeks from the top to bottom of the inflorescence.
- Fruits. Estimate individual immature and/or ripe fruit per inflorescence multiplied by the number of visible inflorescences. Unless it is obvious that fruit clusters are exceptionally large or exceptionally small, base estimates on the average value of 380 (n=45 clusters sampled in 2016). Although you can only observe one side of the fruiting structure, your estimate should include the entire structure based on the assumption of equivalent number of fruit on both visible and invisible surfaces. Within the estimate include inflorescences that can only be partially observed.
- Ripe fruit. In two different classifications, estimate percentage and number of individual ripe fruit per fruit cluster multiplied by the total number of visible fruit clusters. Unless it is obvious that fruit clusters are exceptionally large or exceptionally small, base estimates on the average of 315 (n=45 clusters sampled in 2016). Although you can only observe one side of the fruiting structure, your estimate should include the entire structure based on the assumption of equivalent number of fruit on both visible and invisible surfaces. Within the estimate include inflorescences that can only be partially observed.
- When berries become discolored (blackish), they are no longer "ripe".

Red Elderberry (*Sambucus racemosa*)

- Flowers and flower buds. Count and record total inflorescences (i.e. flower cluster) as a single flowering structure! For example, if there are two inflorescences (clusters) with many flowers and/or buds each, then abundance should be recorded as <3. Include inflorescences that you can only partially observe (because remainder is concealed by leaves or branches).
- Open flowers. Estimate the number of individual open flowers. Flowering progresses over ~2 weeks from the top to the bottom of the inflorescence. Base the estimate on the the average value "300" flowers per inflorescence, which is based on 2015 sampling of potential fruit cluster yield. Although you can only observe one side of the flowering structure, your estimate should include the entire structure based on the assumption of equivalent number of flowers on both visible and invisible surfaces.
- Fruits. Estimate individual unripe (immature) and ripe fruit per fruit cluster multiplied by the total number of visible fruit clusters. Unripe immature fruit usually become apparent on inflorescences within a few days of flower petal loss. Unless it is obvious that fruit clusters are exceptionally large or exceptionally small, use "300" as the basis of estimated total (unripe and ripe) fruit per inflorescence. Although you can only observe one side of the fruiting structure, your estimate should include the entire structure based on the assumption of equivalent number of fruit on both visible and invisible surfaces. Within the estimate include inflorescences that can only be partially observed.

- Ripe fruit. In 2 different classifications, estimate percentage and number of individual ripe fruit per inflorescence multiplied by the number of visible inflorescences. Unless it is obvious that fruit clusters are exceptionally large or exceptionally small, use "200" as the basis of estimated fruit per inflorescence. Although you can only observe one side of the fruiting structure, your estimate should include the entire structure based on the assumption of equivalent number of fruit on both visible and invisible surfaces. Within the estimate include inflorescences that can only be partially observed.
- Estimation of the number of fruit requires understanding the number of small fruit borne in typical clusters. Use the average value of 350 for estimating the number of fruit per average-sized fruit per cluster.
- You would need to see more than 28 clusters to report "6" (more than 10000 fruit).
- Number of fruit & fruit clusters visible in the camera image frame will decline as leaves continue to grow/expand after completion of flowering and before fruit ripening. This may result in a decline in the reported number of fruit, which is acceptable.

Salmonberry (*Rubus spectabilis*)

- Colored leaves. Note subtle changes in leaf color from green to yellow-brown often starting in mid to late August.
- Flower buds are present during the same time that leaf buds are swelling and breaking, making it difficult to distinguish between the two in a photograph. Therefore, the "flower or flower buds" record doesn't begin until the first pink petals appear.
- When a flower drops its petals are we then calling it an immature fruit? At this stage the ovaries are fertilized but severely underdeveloped and small. Hardly a fruit, but we need a rule to follow. We started classification of the fruit phenophase after a flower(s) completely dropped petals.
- Ripe Fruit. Per NPN protocol, ripe fruit is classified as "present" the moment it turns from green to wholly yellow, orange, or rd. Though typical color of ripe fruit varies in shades of red, ripe fruit also may occur as yellow or dark red. As red fruit ages it turns increasingly dark and, if it does not drop or is not removed, eventually shrivels and/or molds on the stem. A fruit is no long classified "ripe" when it is no longer palatable, succulent—shriveled, black, and/or moldy.

Appendix C. Red elderberry (*Sambucus racemosa*) fruit cluster data systematically collected on nearly ripe fruit to support development of field estimation of fruit abundance (percentage fruit/cluster), Kodiak Island, Alaska, 2015.

Plant ID	Fruit Missing	Fruit Present	Fruit Potential	Abundance (%)	Height (%)	Width (cm)	Width (cm)	Cluster Volume (cm^3)
1	41	408	449	91	10.0	8.5	8.0	680
2	76	456	532	86	10.0	8.5	7.5	638
3	92	164	256	64	9.5	7.0	6.5	432
4	244	221	465	48	10.5	8.5	6.5	580
5	235	197	432	46	10.5	8.0	6.5	546
7	193	233	426	55	12.5	10.5	6.5	853
8	177	19	196	10	9.0	7.0	5.0	315
9	263	73	336	22	11.0	8.0	6.5	572
10	176	67	243	28	10.5	8.0	6.0	504
11	161	52	213	24	8.0	8.5	5.0	340
12	131	48	179	27	8.5	7.0	5.0	298
13	222	186	408	46	13.0	9.0	9.5	1112
14	167	47	214	22	9.0	8.0	5.0	360
15	25	419	444	94	8.0	9.5	7.5	570
16	181	222	403	55	10.5	6.5	8.0	546
17	179	9	188	5	9.0	5.0	4.0	180
18	279	122	401	30	8.0	7.5	7.5	450
20	71	73	144	51	6.0	8.5	4.5	230
21	77	165	242	68	9.0	8.5	6.5	497
22	135	155	290	53	8.0	7.5	5.0	300
23	154	217	371	58	11.0	9.5	7.5	784
24	314	11	325	3	10.0	9.0	8.0	720
25	32	263	295	89	8.0	7.5	7.0	420
26	52	358	410	87	9.0	8.0	8.0	576
27	26	305	331	92	8.0	9.0	9.5	684
28	29	15	44	34	4.0	3.0	2.5	30
29	49	94	143	66	6.0	6.5	4.0	156
30	8	170	178	96	8.0	6.0	6.0	288
31	2	251	253	99	10.0	8.0	8.0	640
32	109	30	139	22	6.5	5.0	5.0	163
33	27	86	113	76	8.0	6.0	6.0	288
34	6	113	119	95	6.5	6.0	6.0	234
35	6	151	157	96	7.5	9.0	6.5	439
36	17	124	141	88	10.0	5.0	8.0	400
37	93	358	451	79	8.0	7.0	8.0	448

Appendix C. (continued)

Plant ID	Fruit Missing	Fruit Present	Fruit Potential	Abundance (%)	Height (%)	Width (cm)	Width (cm)	Cluster Volume (cm^3)
38	24	373	397	94	8.5	9.0	7.0	536
39	112	258	370	70	10.0	9.0	7.0	630
40	73	186	259	72	7.5	7.5	7.0	394
41	444	21	465	5	12.0	10.0	9.0	1080
42	271	35	306	11	11.0	5.5	7.5	454
43	196	29	225	13	9.0	6.0	5.0	270
44	329	40	369	11	13.5	9.0	8.5	1033
45	285	0	285	0	10.0	6.0	4.0	240
46	326	16	342	5	10.5	9.0	8.0	756
47	37	227	264	86	9.0	8.0	6.0	432
48	44	178	222	80	6.0	9.0	7.5	405
49	25	452	477	95	10.5	8.0	7.5	630
50	106	364	470	77	11.0	7.0	7.0	539
51	50	338	388	87	11.0	11.0	7.5	908

Appendix D. Red elderberry (*Sambucus racemosa*) fruit cluster data, Kodiak Island, Alaska, 2015. Data specifically collected from clusters protected with netting to evaluate potential change between immature and ripe fruit in cluster dimensions.

Plant ID	Cluster ID	Cluster Volume (cm^3) 7/24/15	Cluster Volume (cm^3) 8/13/15	Volume Difference (%)	Fruit Missing (no.)	Fruit Present (no.)	Fruit Potential (no.)	Abundance (%)[1]	Wet Weight (g)[2]
1	1	315	366	16	26	301	327	92	0.05
1	2	439	248	-44	18	297	315	94	0.04
1	3	608	414	-32	33	358	391	92	0.04
2	1	1050	924	-12	64	198	262	76	0.08
2	2	765	803	5	60	132	192	69	0.08
3	1	420	420	0	52	145	197	74	0.05
3	2	510	392	-23	30	214	244	88	0.06
3	3	300	374	25	12	190	202	94	0.07
4	1	504	446	-11	41	273	314	87	0.07
4	2	332	332	0	63	267	330	81	0.08
4	3	760	608	-20	17	360	377	95	0.08
5	1	551	506	-8	8	334	342	98	0.05
5	2	506	446	-12	7	339	346	98	0.06
5	3	600	570	-5	24	293	317	92	0.06
6	1	351	264	-25	6	85	91	93	0.10
6	2	545	655	20	4	190	194	98	0.12
6	3	488	488	0	6	141	147	96	0.09
7	1	315	340	8	32	177	209	85	0.10
7	2	528	546	3	31	244	275	89	0.08
$\bar{x}$		520	481	-6	28	239	267	89	0.07
SD		187	174	18	20	83	83	9	0.02

[1]Fruit/fruit cluster
[2]Mean weight of 10 berries/cluster.

Appendix E. Devilclub (*Oplopanax horridus*) fruit cluster data, Kodiak Island, Alaska, 2016.

Plant ID	Cluster ID	Fruit Missing	Fruit Present	Fruit Potential	Abundance (%)	Height (cm)	Diameter (cm)	Cluster Volume (cm^3)
1	1	42	391	433	90	25	13	1106
2	1	42	162	204	79	8.5	6.5	94
3	1	25	58	83	70	10	6	94
3	2	28	152	180	84	13	10	340
3	3	14	150	164	91	13	8.5	246
3	4	150	166	316	53	14	8	235
4	1	43	342	385	89	18.5	10	484
4	2	85	507	592	86	21	13	929
5	1	6	503	509	99	13	10	340
5	2	1	336	337	100	18	8.5	340
5	3	82	539	621	87	14.5	10	380
6	1	19	329	348	95	16	10	419
7	1	37	413	450	92	13	7	167
8	1	59	294	353	83	22	10	576
9	1	27	201	228	88	14	7	180
9	2	12	96	108	89	14	6	132
9	3	59	279	338	83	19	9	403
10	1	45	291	336	87	17	10	445
11	1	7	403	410	98	15	9	318
12	1	16	263	279	94	15	9	318
13	1	88	46	134	34	8.5	4	36
13	2	137	232	369	63	17	8	285
14	1	153	130	283	46	20	6.5	221
15	1	39	647	686	94	19	10	497
16	1	40	268	308	87	19	10	497
17	1	6	590	596	99	19.5	13	863
18	1	36	418	454	92	14	10	367
19	1	12	626	638	98	27	13	1195
20	1	43	494	537	92	19	10	497
20	2	83	467	550	85	20	12	754
20	3	17	416	433	96	19	9	403
21	1	52	318	370	86	16	7.5	236
22	1	16	198	214	93	16	9	339
22	2	6	27	33	82	8	4	34
23	1	19	462	481	96	18	10	471
24	1	50	446	496	90	20.5	12.5	839
25	1	21	406	427	95	18.5	11	586
26	1	105	485	590	82	21	14	1078

Appendix E. (continued)

Plant ID	Cluster ID	Fruit Missing	Fruit Present	Fruit Potential	Abundance (%)	Height (cm)	Diameter (cm)	Cluster Volume (cm^3)
27	1	85	370	455	81	19.5	12	735
27	2	32	79	111	71	6.5	6	61
28	1	71	315	386	82	18	12	679
29	1	6	156	162	96	12	7	154
30	1	47	495	542	91	22	13	973
		85	58	143	41	12	8.5	227
		119	160	279	57	13.5	11	428
		173	90	263	34	14	8.5	265
		49	118	167	71	12	8	201
		158	448	606	74	23	13.5	1097
		105	195	300	65	16.5	10.5	476
		127	560	687	82	18	11	570
		80	235	315	75	17.5	9	371
		123	201	324	62	19.5	13.5	930
		112	733	845	87	25	16.5	1782
		78	577	655	88	22	11	697
		80	401	481	83	22	11	697
		96	292	388	75	20	15	1178
		118	161	279	58	13.5	9.5	319
		74	172	246	70	13	8	218
	$\bar{x}$	61	317	378	81	17	10	497
	SD	45	174	177	16	4	3	352
	max	173	733	845	100	27	17	1782
	min	1	27	33	34	7	4	34

Appendix F. Devilclub (*Oplopanax horridus*) structural data, Kodiak Island, Alaska, 2016. Plants were systematically selected to represent a wide range of size, age, and fruit abundance.

Plant ID	Basal Diameter (mm)	Diameter Breast Height (m)[1]	Plant Height (m)	Plant Width 1 (m)	Plant Width 2 (m)	Lowest Foliage (m)	Canopy Volume (m^3)	Fruit Clusters (#)	Annual Growth Rings (#)
1	26	n/a	0.32	1.95	1.15	0	0.72	1	13
2	30.4	12.8	1.46	2.15	1.35	0.16	3.77	1	16
3	40.1	22.2	2.15	2.8	2.6	0.85	9.46	4	13
4	42.5	n/a	1.53	1.4	1.65	0.9	1.46	2	
5	29.5	17	1.73	1.71	1.17	0.6	2.26	3	13
6	22	21	1.95	1.71	1.22	0.99	2.00	1	12
7	22	15	1.55	1.77	1.05	0.65	1.67	1	8
8	18.6	n/a	1.08	1.4	1.1	0.22	1.32	1	6
9	40	n/a	1.35	1.95	1.7	0.2	3.81	3	21
10	17	n/a	1.4	1.13	0.33	0.57	0.31	1	7
11	34	n/a	0.5	1.35	1.2	0	0.81	1	10
12	24.3	n/a	0.69	1.31	1.3	0.18	0.87	1	13
13	27.7	11.2	1.49	2.65	1.5	0.35	4.53	2	15
14	22	n/a	1.1	1.16	1.26	0.55	0.80	1	17
15	19.4	14.2	1.66	1.16	1.26	1.3	0.53	1	6
16	29	n/a	0.78	1.41	1.28	0.1	1.23	1	15
17	28.9	16.1	1.65	1.75	1.2	0.93	1.51	1	10
18	27.5	14	1.83	2.4	1.7	0.71	4.57	1	14
19	24.2	n/a	0.88	1.48	1.54	0.42	1.05	1	11
20	45.2	13.9	1.6	3	1.8	0.3	7.02	3	23
21	22.7	n/a	1.15	2.3	0.91	0.6	1.15	1	12
22	23.9	n/a	0.97	1.35	1.15	0.25	1.12	2	12
23	16.2	n/a	0.45	1.21	0.83	0.35	0.10	1	6
24	25.1	n/a	1.02	1.31	1.18	0.25	1.19	1	8
25	21.9	n/a	1.03	1.18	1.18	0.4	0.88	1	12
26	23	n/a	0.72	1.1	1.15	0.22	0.63	1	10
27	25.5	n/a	0.6	1.75	1.05	0.17	0.79	2	13
28	24.5	n/a	0.68	0.9	0.81	0.35	0.24	1	16
29	21.3	n/a	0.35	0.87	0.71	0	0.22	1	4
30	17.6	n/a	0.75	1.15	1.25	0.2	0.79	1	9
$\bar{x}$	26.4	15.7	1.15	1.63	1.25	0.43	1.89	1.4	11.7
SD	7.5	3.5	0.50	0.56	0.40	0.33	2.13	0.8	4.4
max	45.2	22.2	2.15	3.00	2.60	1.30	9.46	4	23
min	16.2	11.2	0.32	0.87	0.33	0.00	0.10	1	4

[1]"n/a" denotes no measurement taken because plant of insufficient height.

Appendix G. Salmonberry (*Rubus spectabilis*) data systematically collected on nearly ripe and ripe fruit to support development of field estimation of fruit quality.

Fruit ID	Length (mm)	Width (mm)	Radius (mm)	Volume (mm^3)	Drupelet Count (no.)	Wet Weight (g)	Dry Weight (g)
1	25.6	33.9	17.0	454	73	7.30	1.01
2	26.8	26.5	13.3	372	68	5.12	0.73
3	21.8	25.6	12.8	292	54	4.00	0.59
4	18.6	19.6	9.8	191	49	2.35	0.41
5	27.1	24.1	12.1	342	70	4.43	0.63
6	27.1	28.1	14.1	399	81	6.23	0.92
7	22.3	21	10.5	245	45	3.11	0.49
8	20.9	22.9	11.5	251	35	3.11	0.52
9	20.5	24.7	12.4	265	34	3.69	0.50
10	19.8	19	9.5	197	33	2.04	0.32
11	16.5	16.6	8.3	143	9	0.92	0.11
12	24	27.1	13.6	341	41	4.55	0.70
13	18	18.5	9.3	174	41	2.02	0.33
14	14.6	18	9.0	138	19	1.55	0.22
15	27.1	25.9	13.0	368	67	4.00	0.46
16	25.2	24.1	12.1	318	59	4.82	0.72
17	18.6	19.6	9.8	191	15	1.58	0.25
18	25.6	26.4	13.2	354	60	5.00	0.76
19	19.4	17	8.5	173	33	1.66	0.28
20	21.6	18.2	9.1	206	44	2.73	0.43
21	28.7	30.8	15.4	463	75	6.88	0.85
22	15	16.2	8.1	127	34	1.38	0.23
23	15.4	15.1	7.6	122	23	1.33	0.23
24	19	19.2	9.6	191	26	1.61	0.28
25	12.9	14.6	7.3	99	7	0.78	0.12
26	20.4	21.9	11.0	234	35	3.28	0.49
27	19.9	24.2	12.1	252	24	2.74	0.46
28	23.1	24.4	12.2	295	54	4.19	0.56
29	23.8	20.3	10.2	253	79	3.35	0.50
30	22.2	21.7	10.9	252	39	3.38	0.53
31	18.1	19.7	9.9	187	30	3.26	0.36
32	24.3	21.8	10.9	277	31	2.68	0.31
33	28	22.4	11.2	328	67	3.82	0.53
34	24.6	23.2	11.6	299	65	4.55	0.68
35	24.7	20.9	10.5	270	31	2.99	0.32
36	17.4	15.9	8.0	145	22	1.98	0.34

Appendix G. (continued)

Fruit ID	Length (mm)	Width (mm)	Radius (mm)	Volume (mm^3)	Drupelet Count (no.)	Wet Weight (g)	Dry Weight (g)
37	10.3	12.4	6.2	67	4	0.42	0.04
38	22.1	21.5	10.8	249	39	2.92	0.44
39	12.2	12.1	6.1	77	5	0.35	0.05
40	15.7	17	8.5	140	13	1.35	0.18
41	28.5	26.9	13.5	401	54	6.70	0.77
42	14.6	16.3	8.2	125	25	1.43	0.23
43	28	21.9	11.0	321	59	4.44	0.67
44	5.7	5.7	2.9	17	1	0.11	
45	21.1	21.4	10.7	236	49	3.31	0.47
47	26.3	21.3	10.7	293	71	4.29	0.41
48	20	24	12.0	251	57	4.11	0.60
49	16.1	13.5	6.8	114	11	1.23	0.22
50	15.5	19.3	9.7	157	25	2.35	0.40
51	27.8	22.6	11.3	329	92	4.82	0.77
52	22.1	23	11.5	266	57	4.04	0.74
53	20.9	21.3	10.7	233	69	2.90	0.60
54	22.9	21	10.5	252	49	4.05	0.64
55	24.5	22	11.0	282	64	4.67	0.65
56	12.1	16.9	8.5	107	8	0.84	0.12
57	14.5	15.3	7.7	116	21	1.39	0.26
58	28.3	23.3	11.7	345	63	6.55	0.85
59	13.9	19.4	9.7	141	14	1.33	0.19
60	20.9	22.3	11.2	244	40	3.17	0.51
61	25.3	21.4	10.7	283	66	4.25	0.67
62	19.7	18.6	9.3	192	27	2.35	0.29
63	23.1	16.3	8.2	197	58	4.49	0.64
64	22.8	20.5	10.3	245	48	3.37	0.45
65	27.1	23.3	11.7	331	60	4.35	0.54
66	20.4	21.5	10.8	230	23	2.62	0.46
67	24.1	24.6	12.3	310	45	4.47	0.67
68	24.9	22.1	11.1	288	41	3.30	0.48
69	19.6	19.5	9.8	200	57	2.58	0.44
70	18.9	20.5	10.3	203	38	2.70	0.46
71	21.2	25.4	12.7	282	31	4.67	0.77
72	22.7	23.2	11.6	276	52	4.48	0.71
73	24.2	25.8	12.9	327	51	4.90	0.73

Appendix G. (continued)

Fruit ID	Length (mm)	Width (mm)	Radius (mm)	Volume (mm^3)	Drupelet Count (no.)	Wet Weight (g)	Dry Weight (g)
74	15.6	19.3	9.7	158	24	2.29	0.35
75	13.9	15.4	7.7	112	15	1.21	0.19
76	19.4	17.4	8.7	177	30	2.11	0.33
77	16.5	17.7	8.9	153	14	1.37	0.21
78	24.2	26.1	13.1	331	47	5.24	0.84
79	23.7	28.6	14.3	355	70	5.72	0.61
80	15.3	15.7	7.9	126	19	1.26	0.22

Appendix H. Results of Wilcoxin paired-sample test of difference between years in selected characteristics of berry-producing species, 2015-2016, expressed as probability-value (sample size[1]). Bold-faced values denote significant between-year difference ($p \leq 0.10$).

Species & characteristic	Road System	Uganik Lake	Karluk Lake	Red Lake
Red Elderberry				
Basal Diameter	**0.0281** (29)	**0.0734** (30)	**0.0000** (30)	**0.0100** (10)
Diameter Breast Height[2]	0.6672 (25)	0.3740 (27)	0.0069 (26)	0.6200 (10)
Total Height	**0.0738** (28)	0.1035 (28)	**0.0836 (29)**	0.3200 (10)
Canopy Volume	0.1132 (30)	**0.0012** (30)	0.5237 (30)	**0.0100** (10)
Fruit Clusters/Plant	**0.0460** (27)	0.9362 (26)	**0.0027 (29)**	0.4400
Fruit/Cluster	--[3]	**0.0400** (15)	**0.0100 (18)**	--[3]
Cluster Volume	0.7566 (25)	**0.0100** (22)	0.5029 (26)	--[3]
Salmonberry				
Total Height	0.6963 (84)		**0.0000** (75)	**0.0000** (85)
Foliar Cover	**0.0552** (31)		**0.0001** (53)	**0.0000** (47)
Fruit No.	0.5548 (71)		**0.0000** (71)	**0.0000** (88)
Oval-leaf Blueberry				
Total Height	**0.0015** (96)			
Foliar Cover	**0.0019** (114)			
Fruit No.	**0.0968** (100)			
Devilsclub				
Basal Diameter	**0.0200** (20)			
Total Height	0.5400 (17)			
Canopy Volume	0.4200 (19)			
Fruit Clusters/Plant	0.6400 (8)			
Cluster Volume	0.4200 (16)			

[1]Total matched pairs tested excluding pairs with zero differences.
[2]Some additional pairs excluded from testing where data missing in cased of short, young plants.
[3]Small sample size precluded testing.

Appendix I. Mean monthly air temperature (°C) and soil temperature (°C) at red elderberry (*Sambucus racemosa*) study plots, Kodiak Island, Alaska, 2015 – 2016.

Study Site	Attribute	Plot	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Karluk Lake	Air	KLEB15	2015							11.9	12.5	8.0	5.9	1.2	0.4
			2016	1.7	1.6	2.6	4.8	11.5	14.0	13.3					
		KLEB18	2015							12.2	12.8	8.4	6.0	1.5	0.6
			2016	1.7	1.9	2.8	5.3	11.5	14.0	13.1					
		KLEB20	2015							12.2	12.7	8.1	6.1	1.1	0.4
			2016	1.7	1.8	2.9	5.9	13.6	12.8						
	Soil	KLEB15	2015							11.5	11.8	7.6			
			2016												
		KLEB18	2015							10.5	11.3	8.7	6.7	3.1	1.3
			2016	1.5	1.7	2.4	5.0	9.3	11.4	12.2					
		KLEB20	2015							10.9	11.5	8.4	6.4	1.9	0.5
			2016	1.0	1.2	2.1	5.4	--	11.4	12.2					
Red Lake	Air	RLEB01	2015								13.8	9.1	6.4	1.5	0.4
			2016	1.5	2.0	3.1	5.8	12.1	14.1	14.3					
	Soil	RLEB01	2015								12.9	9.7	7.1	2.7	1.1
			2016	1.8	2.1	3.1	5.8	10.4	12.6	13.4					
Road System	Air	RSEB02	2015								13.2	8.8	6.5	1.4	0.2
			2016	1.9	2.0	2.9	5.0	--	11.4	14.2	13.7	9.8			
		RSEB11	2015								13.6	9.1	6.9	2.1	0.9
			2016	2.4	2.7	3.5	5.6	--	11.7	14.9	13.9	10.0			
		RSEB13	2015								13.8	9.2	6.7	1.5	0.5
			2016	2.2	2.4	3.3	5.2	--	12.1	14.9	13.9	9.7			
	Soil	RSEB02	2015								11.2	8.1	6.6	1.5	0.4
			2016	1.3	1.3	2.5	5.0	--	9.9	12.2	12.4	9.7			
		RSEB11	2015								12.3	8.9	7.1	1.9	1.0
			2016	2.4	2.4	3.4	5.8	--	11.0	13.2	13.0	10.6			

Appendix I. (continued)

Study Site	Attribute	Plot	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Road System	Soil	RSEB13	2015								11.8	9.0	7.5	2.8	1.3
			2016	2.6	2.5	3.4	5.5	--	10.1	12.4	12.5	10.4			
Uganik Lake	Air	ULEB02	2015								13.6	8.8	6.3	2.0	0.5
			2016	1.8	2.1	3.3	5.7								
		ULEB04	2015								13.4	9.0	6.3	1.7	0.4
			2016	1.6	2.0	3.6	6.3	--	11.6	14.2	14.1				
		ULEB07	2015								12.5	8.4	6.1	1.5	0.4
			2016	1.5	1.8	3.1	5.3	--	11.3	13.4	13.1				
	Soil	ULEB02	2015								12.3	9.0	6.9	2.2	0.8
			2016	1.5	1.8	2.8	5.0	--	10.3	12.4	12.9				
		ULEB07	2015								11.6	8.4	6.5	1.8	0.8
			2016	1.4	1.5	2.6	4.6	--	9.9	12.2					

Appendix J. Mean monthly air temperature (°C) and soil temperature (°C) at salmonberry (*Rubus spectabilis*) study plots, Kodiak Island, Alaska, 2015 – 2016.

Study Site	Attribute	Plot	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Karluk Lake	Air	KLSB03	2015								12.9	7.9	5.9	1.1	0.2
			2016	1.5	1.6	3.1	5.3		11.2	13.5	12.8				
		KLSB07	2015										6.2	1.3	0.6
			2016	2.0	1.8	3.0	5.4		11.5	13.8	13.3				
		KLSB08	2015								12.4	7.9	6.0	1.0	0.3
			2016	1.8	1.6	2.6	4.9								
	Soil	KLSB03	2015								11.3	8.1	6.2	2.3	0.7
			2016	1.2	1.6	3.3	5.1		9.5	11.8	12.1				
		KLSB07	2015										6.6	2.7	1.4
			2016	1.7	1.8	2.9	5.4		9.5	11.4	11.9				
		KLSB08	2015												
			2016							11.2	12.1				
Red Lake	Air	RLSB02	2015												
			2016							12.9	12.7				
		RLSB04	2015								12.1	8.0	6.3	1.4	0.6
			2016	2.0	1.8	2.7	5.2		10.8	13.1	13.1				
		RLSB05	2015								12.0	7.9	6.1	1.2	0.5
			2016	1.8	1.7	2.7	5.2		10.5	12.8	12.7				
	Soil	RLSB02	2015												
			2016							12.6	13.0				
		RLSB04	2015								11.6	7.8	5.6	0.6	-0.5
			2016	0.4	0.4	1.6	5.6		9.7	11.5	12.6				
		RLSB05	2015								11.5	7.8	5.8	1.1	-0.1
			2016	0.8	0.8	2.2	5.8								
Road System	Air	RSSB01	2015								13.2	9.1	6.8	2.1	1.0
			2016	2.6	2.5	2.9	4.5		10.9	13.9	13.4	9.8			
		RSSB03	2015								13.4	9.4	7.0	2.0	0.8

Appendix J. (continued)

Study Site	Attribute	Plot	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Road System	Air	RSSB03	2016	2.5	2.5	3.2	5.0	--	11.5	14.4	14.0	10.6			
		RSSB13	2015								13.1	9.3	7.7	3.2	2.1
			2016	3.1	3.4	4.2	6.1	--	11.0	14.1	13.0	10.4			
	Soil	RSSB01	2015								11.2	8.4	7.0	2.1	1.2
			2016	2.6	2.5	3.0	4.7	--	9.3	11.7	12.2	10.3			
		RSSB03	2015								12.2	8.8	7.0	1.6	1.0
			2016	2.2	2.2	3.2	5.3	--	10.5	12.9	13.0	10.1			
		RSSB13	2015								13.1	10.0	7.9	2.7	1.8
			2016	3.0	3.1	4.2	6.9	--	11.9	13.8	13.5	11.4			

Appendix K. Mean monthly air temperature (°C) and soil temperature (°C) at oval-leaf blueberry (*Vaccinium ovalifolium*) plots, road system study site, Kodiak Island, Alaska, 2015 – 2016.

Attribute	Plot	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Air	RSBB02	2015										7.0	2.4	1.5
		2016	3.0	2.9	3.3	5.0	11.5	14.7	14.0	10.4				
	RSBB03	2015										7.3	2.8	1.9
		2016	3.2	3.0	3.4	5.0	11.4	14.4	13.9	10.9				
	RSBB05	2015										6.6	1.9	1.0
		2016	2.6	2.4	2.8	4.5	11.2	14.2	13.7	10.2				
Soil	RSBB02	2015										7.9	3.8	3.0
		2016	3.7	3.7	4.0									
	RSBB03	2015										8.0	3.7	3.1
		2016	3.9	3.9	4.1	5.6	10.1	12.3	12.7	10.8				
	RSBB05	2015										7.5	3.9	2.9
		2016	3.6	3.4	3.7	5.1	9.4	11.7	12.0	10.3				

Appendix L Mean monthly air temperature (°C) and soil temperature (°C) at devilsclub (*Oplopanax horridus*) plots, road system study site, Kodiak Island, Alaska, 2015 – 2016.

Attribute	Plot	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Air	RSDC04	2015								15.5	9.0	7.1	2.5	1.7
		2016	3.1	3.0	3.2	4.9	--	11.3	14.2	13.8	10.7			
	RSDC06	2015										7.3	2.7	1.8
		2016	3.2	3.1	3.5	5.1	--	11.5	14.5	14.0	10.8			
Soil	RSDC04	2015									9.1	7.6	3.3	2.5
		2016	3.5	3.5	3.8	5.4	--	10.5	12.8	13.0	10.8			
	RSDC06	2015										7.7	3.6	2.9
		2016	3.7	3.7	3.8	5.2	--	10.0	12.4	12.7	10.7			

Appendix M. Phenophases[1] of selected berry-producing shrubs, Kodiak Island and Afognak Island, Alaska, 2015-2016.

Species, Site, Year	Elevation (m)	Period of Record[2]	Phenophase: Breaking Leaf Buds	Canopy Fully-leaved	Open Flowers	Ripe Fruit	Maximum Ripe Fruit
Devilsclub							
Abercrombie St. Park	29						
2015		8/14 – 11/21		<8/14 – 9/7	<8/14	8/17 – 9/25	8/26 – 9/1
2016		4/10 – 10/16	4/10 – 5/10	5/25 – 9/13	no data	<8/14 – 9/22	8/20 – 8/23
Afognak Island	31						
2016		6/8 – 9/12	<6/8	6/11 – 8/31	<6/8 – 6/29	7/23 – 9/9	8/7 – 8/16
Oval-leaf blueberry							
Afognak Island	15						
2016		6/8 – 8/20	<6/8	6/8 – >8/20	<6/8	6/29 – >8/20	7/2 – 7/20
Road Area KIB[3] (site 4)	81						
2015		8/4 – 11/23	<8/4	<8/4 – 9/3	<8/4	<8/4 – 9/6	<8/4 – 8/29
2016		3/3 – 10/29	3/3 – 4/11	5/5 – 8/24	3/24 – 5/2	6/22 – 9/20	7/4 – 8/18
Road Area KIB[3] (site 5)	22						
2015		8/5 – 11/23	<8/5	<8/5 – 9/16	<8/5	<8/5 – 9/1	<8/5 – 8/29
2016		3/25 – 11/2	<3/25 – 4/19	5/21 – 8/19	3/25 – 4/27	7/8 – 9/15	7/14 – 9/6
Red Elderberry							
Afognak Island	53						
2016		6/8 – 8/20	<6/8	6/14 – >8/20	<6/8 – 6/14	7/14 – >8/20	7/20 – 8/16
Buskin River (site 3)	34						
2015		7/29-11/11	<7/29	<7/29 – 8/19	<6/20	<7/29 – 8/28	<7/29 – 8/7
2016		4/5 – 10/25	4/5 – 4/23	6/28 – 8/18	5/20 – 6/7	7/13 – 8/15	7/19 – 7/28
Buskin River (site 9)	31						
2016		3/29 – 8/5	3/29 – 4/22	6/21 – >8/5	5/19 – 6/6	7/12 – >8/5	7/15 – >8/5
Camp Island	116						
2015		5/11 – 9/11	<5/14 – 5/20	6/22 – 9/5	6/1 – 6/22	7/25 – 9/5	7/28 – 8/21
2016		5/12 – 10/21	<5/12	7/8 – 8/7	5/21 – 6/14	7/17 – 8/31	7/23 – 8/14

Appendix M. (continued)

Species, Site, Year	Elevation (m)	Period of Record[2]	Phenophase: Breaking Leaf Buds	Canopy Fully-leaved	Open Flowers	Ripe Fruit	Maximum Ripe Fruit
Salmonberry							
Afognak Island	50						
2016		6/8 – 9/12	<6/8	6/11 – 8/10	<6/8 – 6/11	6/26 – 8/16	6/29 – 7/29
Buskin River	33						
2016		3/30 – 10/14	3/30 – 5/5	6/7 – 8/18	4/26 – 6/16	6/19 – 8/6	6/19 – 7/28
Camp Island	114						
2015		6/10 – 9/10	<6/10	7/6 – 8/29	<6/15	7/6 – 8/5?	7/6 – 7/15
2016		3/31 – 10/19	3/31 – 4/24	6/11 – 8/10	4/18 – 6/14	6/26 – 8/27	6/29 – 7/20

[1] Classification derived from USA National Phenology Network https://www.usanpn.org/.
[2] Within period of record, phenology was assessed and classified at 3-day intervals.
[3]KIB=Kodiak Island Borough land.