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Using a Native Landscape to Integrate Undergraduate Research into Variety of Science Classes for both Majors and Non-Majors-A Framework

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We have incorporated authentic undergraduate research projects into select science courses at Lane Community College. Students examine topics of phenology and ecology through a stepwise framework that includes field sampling in our native landscape, a sustainable means for students to collect and analyze their own data against site-specific climate data and other variables. Students design and implement research projects, with outcomes that contribute to a broader knowledge of localized research in ecology and climate patterns. We offer a transferable framework for implementing the research process over a term and present summaries by course describing the scope of each project.

Keywords: undergraduate research, native landscape, phenology, ecology, environmental monitoring

Introduction

Incorporating research and writing into undergraduate curricula is recognized as a best practice in science education (AAAS, 2011; Moskovitz et. al., 2011). Engaging students in firsthand research promotes active learning and opens doors into science careers (Lopatto, 2007; Russell et. al., 2007). Providing research experiences at two year colleges is challenging. However, models are emerging that present various ways to incorporate research into undergraduate education through classes or capstone experiences. These models allow for the variety of budgets available for necessary equipment and faculty support. Here we describe the design and incorporation of authentic undergraduate research projects into several majors and non-majors biology and environmental science courses at Lane Community College (LCC).

The spectrum of undergraduate scientific research ranges from highly academic (e.g. publishable) data to citizen science data (highly accessible, large data sets, but questionable quality). Research experience can vary from precise experimental manipulations to observational monitoring, providing skills and knowledge likely to be useful in a variety of professions from the senior researcher to the lab or field technician. In our undergraduate research projects, we offer students opportunities to practice research while studying ecology and environmental science and to gain proficiency in both course materials and the culture of scientific research. The setting for this research is LCC's native plant landscape and campus watershed, which are easily accessible and a very short distance from our classrooms. Projects are implemented in a variety of ways depending on the course and time allotted. Here we present a general framework from biology classes designed for non-science majors (BIO 103H Mushroom Biology) and for science majors (BOT 213 Principles of Botany and Z 213 Principles of Zoology). We also present select environmental science courses that focus on climate data and collection methods.

Immersing students in an authentic research experience requires choosing a research project that goes beyond a class assignment and preparing a curriculum. Students then can work with what they know is meaningful data which they collect, own, and manage. LCC's physical setting lends itself well to ecological research projects. The main LCC campus sits within a larger watershed comprising the headwaters of Russel Creek, which drains into a 35 acre, LCC-owned wetland complex before entering the confluence region of the Coast Fork and Middle Fork Willamette Rivers. The Science and Math building is also surrounded by the Native Plant Landscape Project (NPLP) covering a 1.24 acre complex within the built environment of campus. The project is in its thirteenth year of growth and development and has resulted in a functioning ecosystem and valued campus learning resource. Phenology monitoring and associated research began earnestly within the NPLP in 2008. In 2013 LCC embarked on an expanded environmental monitoring program throughout the natural and landscaped sites.

A critical complement for ecological data is climate data. The expansion of the campus weather station system was established in 2013 on the NPLP using instruments and siting practices that follow protocols established by the GLOBE (Global Learning and Observations to Benefit the Environment) program. For more information about this program, visit https://www.globe.gov/. Prior to the availability of the expanded weather recording we used a combination of local and regional weather records taken from the LCC campus, local newspapers and weather reporting web sites such as National Weather Service (weather.gov). With our expanded system we now have detailed site-specific climate data that includes atmospheric temperature and humidity, wind speed and direction, precipitation, evapotranspiration, ultraviolet radiation, soil temperature, and soil moisture at multiple depths (see Materials section for details on monitoring equipment). Within the Russel Creek watershed, systematic water monitoring sites have been created in cooperation with the City of Eugene. These data are readily available to faculty members and students for incorporation into our various field-research projects.

Links to More Information and History about the LCC Campus Natural Areas and NPLP:

http://www.lanecc.edu/science/biology/natural-resources (Project Overview)

http://www.lanecc.edu/sites/default/files/science/biology/backgroundhistory.pdf (NPLP History)

http://www.lanecc.edu/sites/default/files/science/biology/lccnaturetrailbrochure.pdf (Trail Brochure)

http://npsoregon.org/bulletin/2012/NPSO_1202.pdf (Phenology Matters: Phenology Research at LCC)

http://www.lanecc.edu/sites/default/files/science/biology/preventingnativehabitatlossonthelanecommunitycollegecampus.pdf (Importance of LCC's Natural Habitats)

In this paper, our focus is on an overarching theme of integrated research steps that we have implemented into the curricula of several courses. For the purposes of presenting student lab activities that take place over the course of a 10-week term into a condensed workshop format, we have outlined a transferrable framework of six generalized steps that our biology students take over the term (see Notes for the Instructor). Specific research is summarized by course in the Student Outline section of this manuscript. To illustrate how we implement the research steps, select supplemental materials are referenced in the Appendices.

Student Outline

Research Summaries by Course

BIO 103H-Mushroom Biology

Course catalog description: Through field, classroom, and laboratory work students identify and develop an understanding of mushroom evolution, structure, function and place in the ecology of the areas we study. Required Saturday or Sunday trips to the Cascades and Central Oregon Coast. 4.000 Credit hours. No Prerequisite.

<u>Fungal Phenology Research Project:</u>

There are several step-wise assignments and labs that students perform in teams and individually throughout the term that lead them through this scientific investigation. In preparation, students begin by examining research abstracts in fungal phenology provided by the instructor. This background research gives the project scientific context and helps direct appropriate research questions for students to address. Students sample forested and woodland habitats located on campus twice over the course of the fall fruiting season, early and late, to measure the effects of temperature and precipitation on the diversity and abundance of fungal species. These data are entered into a common Excel spreadsheet that is made available to students for individual analysis (See Appendix A: BIO103H Phenology Research Sample Data). The final assessment is a scientific research paper where individuals present and analyze data collected by the class. Outcomes should demonstrate knowledge of fungal ecology and growth requirements and apply logical conclusions about predictions made in their background studies.

BOT 213-Principles of Botany

Course catalog description: Designed for Life Science majors. Topics: evolutionary trends of flowering plants, diagnostic characteristics of plant families, species distribution and community ecology interactions. Skills: explain phylogenetic relationship between plant groups, describe plant associations and species interaction in a variety of ecosystems, proficient use of botanical keys; ecological research that includes data documentation and analysis. 4.000 Credit hours. Prerequisites include Math 95 and successful completion of BIO 211 & 212.

<u>Native Landscape Plant Phenology Research</u>

The steps of the framework for the BOT 213 phenology research project are similar to that of the BIO 103H, however, differences reflect outcomes for a majors-level course. Primarily, students experience greater independence throughout the research process and have more control over experimental design. For example, once students are introduced to the project in class, the majority of their data collection and work occurs outside of class time. The research project is performed by teams of two students throughout the 10-week term. While simultaneously gathering and analyzing their data students also complete a series of reports that build upon their work. Each report targets specific research steps in the project and serves as part of a rough draft for the final report in the format of a scientific paper. The results section carries the highest grade point value because it develops skills for evaluating and presenting data and makes students accountable for and trust in their results; this is the core for understanding research and the foundation for a meaningful discussion section (Moskovitz et. al., 2011, McDonald 2012).

ZOO 213-Principles of Zoology

Course catalog description: Survey of comparative vertebrate anatomy, vertebrate evolution, cladistics, and ecology. Skills: dissection, digital documentation, cladogram construction, and mathematical models in biology. Designed for Life Science Majors. College-level writing and math skills strongly encouraged. 4.000 Credit hours. Prerequisites include Math 95 and successful completion of BIO 211 & 212.

<u>Vertebrate Inventory Project</u>

Spring 2014 is the second year of the vertebrate monitoring project, paralleling the BOT 213 phenology project. In spring 2013 students piloted monitoring projects for herps (amphibians and reptiles), birds, small mammals, and large mammals. Each monitoring project applies protocols established by various local agencies and organizations. Students are encouraged to develop their own experimental design based on recommended protocols. We consulted with the research committee from the Mt. Pisgah Arboretum, which is nearby, to emulate their herpetological monitoring methods (this trains our students to volunteer in the future to collect data for the Arboretum and potentially merge databases for a wider regional data set). Outcomes are to provide a report where students present and defend their results to a relevant audience of land management groups for handling their particular research taxa within a site-specific context. To increase ownership of the research, students generated a list of people and agencies to which the final report could be sent (examples include campus management groups, government agencies, and stewardship organizations).

ENVS 182- Atmospheric Environment and Human Population

Course catalog description: A lab course that stresses the interactions between humans and the atmosphere. Students study weather, climate, sustainability of plant and animal biomes, population, and human influences on climate change. Topics also include air pollution, ozone depletion, global warming, and ice and glacier loss. Students study how to improve shared and personal effects on atmospheric systems that help sustain life.

Environmental Monitoring:

In this class students participate in taking daily solar noon weather observations from a traditional weather station, including observations of clouds, contrails and sky cover as well as standard meteorological observations. They are also provided access to the real-time automated rooftop weather station as well as the local airport observations. All students must become proficient at interpreting all of their weather observations and participate in group and individual sky monitoring throughout the term. Since this course is primarily a winter term course, the most common observation is "grey" so we work on cloud types quite a lot! Students who take this class and then take ENVS 183 (Aquatic Environment) are particularly ready to embrace the research project developed for that class (see below).

ENVS 183- Aquatic Environment

Course catalog description: Students learn about freshwater and marine systems including their biology, geology, chemistry, circulation, climate and interactions with humans. Topics include aquatic biodiversity, streams, water pollution, ocean currents, fisheries, sustaining aquatic systems and water resources.

Russel Creek Monitoring Project

A small ephemeral stream (Russel Creek) is being monitored on the upper and lower campus to examine the effect of campus on water quality measures including turbidity, temperature, dissolved oxygen, nutrient load, pH, alkalinity, and conductivity. In the near future we also are working to develop ongoing monitoring in the lower wetlands region, also on campus property across the main highway within an oak savannah habitat. Students in the new Watershed Science Technician career and technical degree program (http://www.lanecc.edu/science/watershed) participate in this project, which follows GLOBE hydrology protocols.

Materials

Materials lists are provided below and arranged by course/research project.

BIO 103H-Mushroom Biology

Fungal Phenology Research Project

Equipment includes clipboards, cameras, local mushroom flora or field guide, mushroom collection equipment, map of study area, and access to Excel software.

BOT 213-Principles of Botany

Native Landscape Plant Phenology Research

Equipment includes clipboards, rulers, camera, map of study area, access to Excel software, and phenophase data sheets based on data tables developed by the citizen science phenology monitoring network Project Budburst (http://budburst.org/). Another source for a data sheet framework is the USA National Phenology Network's Nature's Notebook (http://www.usanpn.org/#). Our BOT 213 data sheet template is available in Appendix B: Sample Data from BOT 213 Native Plant Phenology Research.

Z 213-Principles of Zoology

Vertebrate Inventory Projects

Equipment needs vary based on research organism, however all projects utilize summaries of recent weather data (see introduction), map of study area, and access to Excel software.

Herp monitoring:
  Various cover board materials: 2'x2' pieces of wood, metal, carpet and black plastic, one of each per station, local herp guides, cameras, temperature probes

Bird monitoring:
  Bird guides (iPad versions with vocalizations are especially helpful), binoculars

Small Mammals:
  Sherman traps, local mammal guides

Large Mammals:
  Game camera

ENVS 183 - Aquatic Environment

Russel Creek Monitoring Project

- dissolved oxygen/temperature meter
- conductivity meter
- GLOBE Transparency Tube (in lieu of turbidity); data being compared to Vernier Turbidity Probe
- pH probe
- Alkalinity test kit and standard test kits for nutrients (Phosphorus, Nitrate/Nitrite)
- Streamflow sensor
- GLOBE Data Sheets (Hydrology)
- Handheld GPS (12 channel field grade)
- Digital camera
- iPad or Field book

Notes for the Instructor

Implementing the steps of a research project over a 10-week term has been challenging and informative. We suggest the scaffold approach where scientific investigation is deconstructed and presented to the students in manageable sections (Moskovitz et. al., 2011). Although each project's circumstances are unique and will vary accordingly, general support tactics that we have found useful across all projects include the allotment of time in class for structured and guided group work that lends itself to refining independent work that can be accomplished outside of class. As students turn in pieces of their projects as "works in progress" we offer mentoring to improve each component along the way.

Framework for Implementing Research Steps over Term

Step 1) Background Research and Hypothesis Development

For non-science majors this is a group lab activity and for majors it is a team report. In both cases, students do a guided "literature search" to provide background information on the research organism(s) they are investigating. Faculty provide a broad research question and students work to streamline it to include measurable dependent and independent variables of research that can be accomplished within the term and with available resources. The question is then stated as a hypothesis, setting the stage for making predictions. As instructors, this is an exciting process because we are interacting as scientists with our students and making sure we let the students be in the "driver's seat". If the research has been done in past classes and a research base is established students are provided with examples of previous research at some point is this process and can refer to and cite these reports. Cloud storage venues are perfect places to store and make previous students work available. From the start students are required to use electronic storage and know that their reports will became part of an ongoing data base to be viewed by future students.

Step 2) Group Field Sampling / Data Gathering

For non-majors, sampling occurs during class time and for majors, students work independently in teams outside of class (see all Appendices for sample data sheets and templates). The completion of Step 1, especially the identification of dependent and independent variables, is the basis for data sheet construction. Phenology monitoring has pretty standard datasheets but it is critical to guide students in properly recording the variables they are measuring. For majors, a group data-collection exercise is done where students ask questions about accurate measurements, timing, sample size and much more. They are becoming scientists! For non-majors, students are assigned data gathering methods. Students work collaboratively in this process to provide a realistic research experience and their group discussions establish the importance of accurate and ethical data collection. This is quite challenging and faculty generally step back and let students wrestle with solutions.

Step 3) Development of Written Introduction and Methods

For non-majors this is an individual assignment and for majors it is a team report. With completion of Steps 1 and 2, students are well positioned to draft a simple introduction stating their hypothesis and how it might expand on what is known about their organism or research interest. This is where students learn about citations. The practice data gathering session and the data sheet provide them with what is needed to write a methods section outline that can be fleshed out as the students hone their skills. By now each student or team should have a clear idea of the scope of the project; this is an important time for more feedback to focus and direct their research.

Step 4) Group Management and Submission of Data

It is important to remind students to analyze data during its collection and not wait until the end. As data is gathered, students must keep it organized, start graphing or entering into tables to make it available to others for review and for class discussion. This also allows students to compare data and perhaps work collaboratively on similarities and differences of their data sets. A class presentation of interim data sets is a rich learning experience, important for feedback, and results in more clarification of how to present data. For non-majors, this is a group lab activity. For majors, teams of students submit a report with the rough draft of their results which includes raw data summaries in table and figure formats. Cloud storage venues are perfect places for students to store and share their data while also allowing for faculty access.

Step 5) Data Analysis and Visualization

This step can be simultaneous with Step 4. With the non-science majors, we work as a class to sort and identify trends in the data. The majors students are responsible for this step in independent research groups and present their draft results in a class discussion. In both cases, students are encouraged to refer to past student examples of how their data can be visualized (we make notebooks available of previous student work, see Appendix C: BOT 213 Phenology Research Sample Data) and determine if it was done effectively, how they might improve and add to the growing data base.

Step 6) Writing of Results and Meaningful Conclusions

For non-science majors this is an individual report; for majors the results and conclusions sections are now integrated into the drafts of their previous reports. In both levels, the final report is a culmination of the term project in the format of a scientific paper where each student has had several opportunities for feedback throughout the process. Students are expected to present results that include appropriate comparisons of data consistent with the hypothesis and predictions addressed in their introduction.

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The authors wish to acknowledge Lane Community College's early biology instructors whose visionary teaching and concern for creative student learning laid the groundwork for the diverse, field based courses LCC offers today. These instructors included Freeman Rowe, Jay Marston, Rhoda Love and Tom Wayne. Gail Baker, our recently retired co-author, deserves immense gratitude for her instrumental work in establishing and maintaining the NPLP, her development of the botanical phenology research project that informs our framework, and for otherwise inspiring students to think like scientists!

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About the Authors

Susan Holmes teaches plant science courses at Lane Community College (LCC), co-coordinates stewardship of the Native Plant Landscape Plan, and is curator of LCC's Rowe-Love Herbarium. After receiving a degree in botany with an emphasis in mycology from Oregon State University, she spent a decade doing fieldwork in ecology before earning a master's degree in landscape architecture with a focus in applied ecology from the University of Oregon in 2007. Susie began teaching at LCC in 2009 with research interests that include phenology, plant invasions, and ecological restoration.

Gail Baker taught and coordinated the plant science courses at Lane Community College for almost two decades, instituted a permanent space for the college herbarium and co-led the establishment of the Native Plant Landscape Project surrounding the Science & Math Building. During her undergraduate education at UC Irvine she developed a love of plant ecology and an understanding that field work and research was integral to the biology learning environment. After earning her master's degree at San Diego State University and spending a decade doing field research she began full-time teaching in 1994. Gail is now retired and working with non-profit organizations on ecological restoration projects.

Stacey Kiser majored in zoology with an emphasis in marine biology at Oregon State University. She earned a master's degree in ecology at University of Oregon (UO). While at UO she worked for the Workshop Biology research project, which started her interest in biology education. Stacey teaches at Lane Community College and has been a faculty member since 1996. Over the years, she joined several professional development communities, including PKAL's F21 program, the BioQUEST Curriculum Consortium, ABLE, and NABT. She was president of NABT in 2014.

Paul Ruscher is Coordinator for the Watershed Science program, and lead faculty member in the Earth & Environmental Sciences group, having joined Lane Community College in 2012. He is a Fellow of the American Meteorological Society and has served as a member of the Bioscopes and GLOBE project team at Florida State University, where he previously taught meteorology and climatology. He received his master's degree and doctoral degree at Oregon State University in atmospheric sciences and has had a longstanding interest in field research studies and geoscience education.

Appendix A
BIO 103H Phenology Research Sample Data

Group	Species	Functional	10/9/2013# Sporocarps	10/30/2013# Sporocarps	Substrate	Habitat
2	Ascocorene sp.	S		5	dead wood	I
1, 5	Aurascalpium vulgare	S		3	Douglas-fir cone	I, II
2	black cup sp.	S	1		dead ash or oak	I
3, 2	Calocera cornea	S	60-100	100+	dead oak twig	I
3	Chantherellus cibarius	M		1	duff	I
2,3,4, 1	Collybia dryophila	M		19	duff	I, II
4, 5	Coniophora puteana	P	many "patches"		dead hardwood	II
1	Coprinus lagopus	S		100+	duff, branch	I
1	Coprinus micaceus	S		100+	dead branch	I
4	Crepidotus herbarium	S		12	dead wood	I, II
1	Crepidotus variabilis	S		3	dead branch	I
2,5	Crucibulum laeve =C. neblae	S	7		dead oak twig	I, II
1	Daedalea quercina	S		1	dead oak stump	I
5	Dasyscyphus bicolor	S	75		dead Rubus cane	II
3, 2	Fomitopsis pinicola	P	1	1	dead conifer	I
2	Galerina autumnalis	S	1		dead wood	I
3, 4	Ganoderma applanatum	P		2	dead wood	I, II
2	Gasteromycetes sp.	?	1		dead hard wood	I
3	Hypocrea sp.	P	1		F. pinicola	I
4	Hypoxylon sp.	S	5		dead hardwood	II
5	leaf spot on hazelnut	P	2		hazelnut leaf	II
4	Lycoperdon pyriforme	S		15	dead and live maple	I, II
2	Mycena capillaris	S		3	dead hardwood	I
5	Mycena cavipes	S		4	duff	II
2, 3	Mycena clavularis	S		50+	dead hardwood	I
4	Mycena haematopus	S		7+	dead wood	II
4	Mycena murina	S		50+	dead maple wood	I, II
3	Mycena pupureofusca	S		20+	hardwood	I
3	Nidula candida	S		20	dead wood	I

BIO 103H Phenology Research Sample Data (continued)

Group	Species	Functional	10/9/2013# Sporocarps	10/30/2013# Sporocarps	Substrate	Habitat
1	Nidula niveotamentosa	S		9	branch	I
3	Phaeolus schweinitzii	P		1	duff	I
1, 2, 3	Phellinus pini	P	44		live Douglas-fir	I, II
2	Phellinus sp.	P	1		dead branch	I
2, 3	Pluteus atromargihatus	S		2	duff	I
3, 1	Polyporus badius	S		23	dead wood	I
2	Polyporus elegans	S		3	dead wood	I
3, 1	Polyporus varius	S		6	dead wood	I
3	Postiaspa sp.	?		1	dead wood	I
1	Psathyrella gracillus cf.	S		3	soil	I
2, 3, 5	Psathyrella sp.	S		23	dead wood	I, II
2,4, 1, 5	Pseudohydnum gelatinosum	S		53	dead branch	I, II
4, 5	Rhytisma punctatum	P	numerous		maple leaf	II
5	Simocybe centiculus	S		4	dead wood	II
1, 3, 5, 2	Stereum hirsutum	S	112	20+, 10	dead wood	I, II
3	Stereum sp.	S		15	dead wood	I
2, 3,4	Strobillurus trullisatus	S		260	doug fir pinecones	I, II
4,1	Trametes hirsuta	S		100+	dead maple twig	I, II
4, 3	Tremella mesenterica	S	25	50	dead hardwood	I, II
1, 2, 4	Trichaptum abietinus	S	190+		dead hard wood	I, II
3	Tyromyces caesius	S		1	dead wood	I
3	unknown black velvet resupinate	S	1		dead oak branch	I
4, 5	unknown mold on Lonicera sp.	S	2		hairy honeysuckle	II
3	unknown resupinate Phellinus sp.	S	1		dead oak branch	I
5	unknown slime mold #1 w/pink tips	S	50		dead hardwood	II
4	unknown slime mold #2 w/black tips	S	1 cluster		dead hardwood	II
3, 1, 5	Xeromphalina cauticinalis cf.	S		12	dead wood	I, II
2	Xeromphalina sp.	S		10+	dead wood	I
2,4	Xylaria hypoxylon	S		20+	dead hardwood	I, II

Appendix B
BOT 213 Phenology Data Template

Bot 213 Phenology Research Project

Table 1: Phenophase and Climate Summary for ______________________ **Research Team:** ______________________

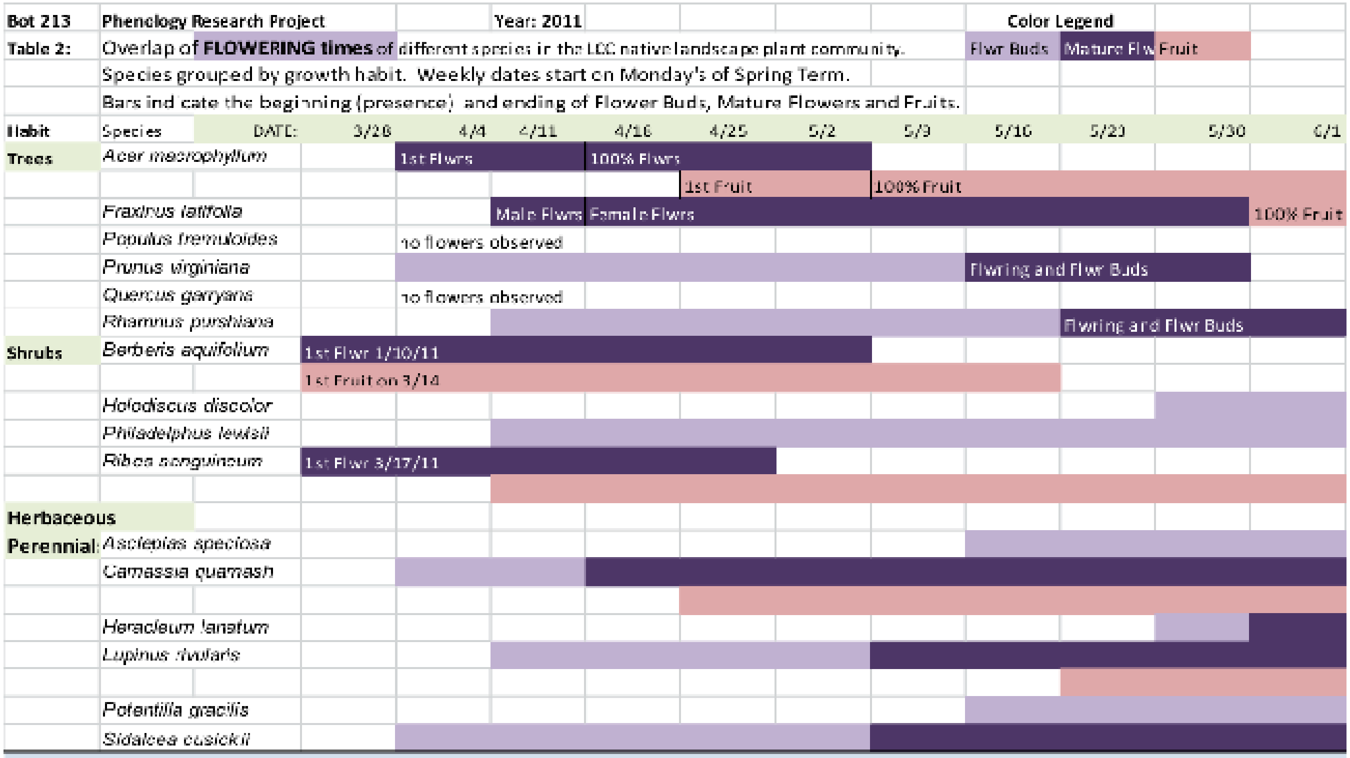
Total number of plants monitored, N= ___

Weekly dates start on Monday's of spring Quarter

Bars indicate the beginning (presence) and ending of phenophase for all palnts monitored.

	Year: 2013		**Date: week**		4/1	4/8	4/15	4/22	4/29	5/6	5/13	5/20	5/27	6/3
Climate Data														
Weekly	Total Rain (cm)													
Cumulative Rain (cm)														
Weekly	Temperature Range: max/min (°C)													
Day Length (hrs/min/sec)														
Reproductive Development														
Flower Buds: 1st buds														
90%														
50%														
Mature Flowers														
1st Flwr														
>75%														
Fruit	1st Fruit													
50%														
Full Fruit														
Seed or Fruit Dispersal														
Vegetative Development														
Leaf buds														
Breaking lv buds														
New lvs														
Increasing lf size														
mature lvs														
mature lvs >50%														
Branch elongation														

Appendix C
BOT 213 Phenology Research Sample Data



Year: 2011		Date: week	3/28	4/4	4/11	4/18	4/25	5/2	5/9	5/16	5/23	5/30	6/1
Weekly	Total Rain (cm)		3.3	5.5	1.3	10.4	6.8	7.9	2.4	2.60	3.00	1.50	3.00
Cumulative Rain (cm)			3.3	8.8	10.1	20.5	27.3	35.2	37.6	40.2	43.2	44.7	47.7
Weekly	Temp (°C)	Mean		6.8	9.7	8	7.8	8	9.90	10.40	11.70	10.90	15.30
	Temp Range	max	20.2	16.7	13.6	18.1	17.5	19.6	19.8	15.7	23.8	12.0	20.8
		min	0.4	-0.6	0.1	-1.1	- 0.1	3.5	3.3	5.1	9.7	4.8	5.1
Eugene OR Day Length (hrs/min,			12/39/11	13/00/18	13/21/03.	13/41/16	14/00/16	14/19/14	14/36/23	14/51/49	15/5/09	15/18/30	

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