TRAILS
FOR THE THREE OF US

TRAIL DESIGN PLANNING
USING TEMPORAL AND DYNAMIC RELATIONSHIPS
BETWEEN PLANTS, ANIMALS, AND HIKERS

ERICA ANDRUS

TRAILS

FOR THE THREE OF US

TRAIL DESIGN PLANNING
USING TEMPORAL AND DYNAMIC RELATIONSHIPS
BETWEEN PLANTS, ANIMALS, AND HIKERS

ERICA ANDRUS

Approval

Project Chair: Chris Enright

Committee Member: Mark Eischeid

Submitted in partial fulfillment for the Master of Landscape Architecture

Department of Landscape Architecture
College of Design
University of Oregon 2020

ABSTRACT

Introducing trail systems into a protected natural area that has undergone habitat restoration sends alarms to ecologists and cheers from avid hikers. Habitat assessments help map which plants and animals need protection; however, it is difficult to translate this information to the trail design process. There is a need for an approach to trail design that views habitats as a dynamic relationships between species across scales, space, and time. This project introduces a framework that addresses the often-overlooked challenge of not only which species to design for, but also when specific design strategies are appropriate. Through temporal and spatial mapping this project examines sensitive times of plants' and animals' life cycles and their expected response to an introduction of trails. This mapping supported the creation of a framework that allows designers to evaluate and prioritize options for future public trails in ecologically rich landscapes. This research uses the Willamette Confluence Preserve in Springfield, Oregon, where public trails currently do not exist, as a site to test the feasibility of this framework. This new framework is transferrable to use on other sites and habitat types and is an opportunity for future research.

Acknowledgements

This project would not have been possible without many who offered their time and knowledge to share with me.

Thank you **Ed Alverson** for being continuously supportive and encouraging the past year and taking time to show me trails around Mt Pisgah.
Lori Hennings, your literature review and meeting with me in Portland provided foundational information for this project.
Thank you **Melissa Olson and Jason Nuckols** from The Nature Conservancy for listening, giving me a tour of WCP, and providing me with a tremendous amount of resources.
Thank you **Daniel Dietz, Elizabeth Goward, and staff at McKenzie River Trust** for having interest in my project and beginning dialogues about introduction of people on protected land.
I am also thankful for the many brainstorming conversations with **Jeff Kreuger, Roxi Thoren, Susan Holmes, Chris Bernhardt, Harper Keeler, Bart Johnson, and Sarah Jensen Carr**.
Thank you **Mark Eisheid**, for your ability to jump into ideas and provide incredible insight as well as good belly laughs.

And to **Chris**, thank you for being a solid rock for me the past three years. You back me up, challenge me, and make me smile every time we meet. For any MLA who has Chris as an advisor in the future, you are in the best hands.

To my family, who I would not have had this entire opportunity and experience without, and to my best friends, you have been my cheerleaders this whole time. To Will, thank you for keeping me sane taking me out on walks in the woods, and for all of your love and support. And thank you for doing your job, actually *building* the beautiful trails we all care so much for.

To my cohort, we made it without being in the spring penthouse.
I will miss you all terribly.

Table of Contents

Table of Contents

List of Figures

List of Figures

KEY TERMS

LISTED IN ORDER OF APPEARANCE

ACRONYMS

PNA
Protected Natural Area

TNC
The Nature Conservancy

WCP
Willamette Confluence Preserve

TERMS:

Disturbance

To animals: Time taken away from an animal's normal activities such as foraging and feeding their young (Rodríguez-Prieto et al. 2014). In this project, disturbance will primarily refers to hikers.

To plants: The term 'disturbance' when used to describe phenomenon that disrupts plant community structure often refers to fire, floods, droughts, storms, landslides, grazing, disease, among others. However, in this context, 'disturbance' will largely refers to trampling of vegetation on either side of trails by hikers.

The sliding scale of ecological restoration

It is important to recognize the wide use of the term 'restoration' in landscape architecture, which ranges from designs that focus on the human experience to designs whose primary focus is the health of plant and animal species. In this project, when the term 'restoration' is mentioned it refers to recovering sites that have been damaged or degraded and are aiming to emulate the structure, function, and diversity of a specific ecosystem ("Society for Ecological Restoration" n.d.). In addition, the term 'restored landscapes' refers to those that support natural systems and show signs of equilibrium between plants and animals.

Equilibrium

The term 'equilibrium' uses the definition by the Society of Ecological Restoration in the book "Assembly Rules and Restoration Ecology" which describes equilibrium as a state of an ecosystem that sustains the life of both species and communities while also allowing fluctuation compatible with that sustainability (Temperton 2004).

Stress response

The functional response to an external stressor such as seasonal changes in temperature and food availability or sudden disturbance. Animals most often have a physical, anti-predator response, which can help them avoid a threat, yet chronic stress can have negative impacts on the animal (Hing et al. 2016).

Moment

This project will uses an Oxford English dictionary definition of 'moment' as "A period of time (not necessarily brief) marked by a particular quality of experience. A cause of or motive for action; a decisive or determining influence."

Resistance

A plant's resistance is its ability to withstand immediate damage, in this project's case, damage through trampling by hikers.

Resilience

A plant's resilience is its ability to recover after trampling has ended. A perennial for example, could have low resistance and break easily if trampled, yet it has high resilience since it will likely return the following year.

Tolerance

Tolerance of a plant species describes both its resistance and resilience. In terms of trampling, a tolerant plant has characteristics that can withstand initial trampling, as well as an ability to recover following years.

Flight initiation distance (FID)

The distance from a person at which an animal first flees from perceived danger. The higher the FID, the lower the animals' tolerance to disturbance (Fernández-Juricic, Vaca, and Schroeder 2004). This is a good behavioral indicator of stress in wildlife.

Alert distance (AD)

The distance between an animal and an approaching human at which point the animal begins to exhibit alert behaviors to the human (Fernández-Juricic, Jimenez, and Lucas 2001).

FORWARD

As soon as I could keep up hiking with my parents and older sister I've enjoyed being on a trail. Growing up in Vermont, I was taught to respect the landscape around me, to not walk off-trail at higher elevations where the vegetation is fragile, and to practice LNT (leave-no-trace). In general, I thought of snowmobiles, four wheelers, and other loud, churning, all-terrain vehicles to be the recreation we should be most concerned about disrupting our landscapes. It wasn't until recently that I learned the uncomfortable fact that "leaving only footsteps" (which us hikers like to take pride in), comes with more disturbance than we think, and it takes more than LNT to sustain healthy populations of threatened plant and animal species around trails.

Hikers have effects on habitats that are broader than the width of a trail, especially as interest and access to wilderness areas increases across the country. "A century ago, nature had elbow room." Expresses Christopher Solomon, writer for the New York Times. "Now there's a lot less of it". This project seeks out the conflicts between us and plant and animal species, and explores if there are gaps in trail design that can be filled by addressing these relationships.

A studio project during my first year at University of Oregon explored the restoration and trail design of Suzanne Arlie Park, a recent 500 acre restoration project in Eugene, Oregon. I also helped the McKenzie River Trust two summers ago imagine what Green Island, a recently restored riparian landscape, could look like with the introduction of public access through a river trail checkpoint. These experiences opened my eyes to the complex tension between habitat restoration efforts and opening protected natural areas to public use.

I originally imagined ecologists always advocating for the protection of ecosystems by restricting public access, and landscape architects encouraging human spaces in the landscape whenever possible. Throughout this project, I learned that these two fields do work together, and have the ability to collaborate even more to understand the relationships between created human spaces and plant and animal habitats.

Specifically, I am interested in the opportunities to potentially introduce public hiking access to protected natural areas that have recently undergone restoration. I am interested in the process of habitats that had been degraded because of human influences, restored because of the help of human influence, and now perhaps re-introducing humans in a different way. How can trail designers and planners do this to best support the recent restoration of habitat?

This project scratches the surface of this question, creating a framework that studies how and when plants and animals are sensitive to hikers and proposing strategies to make decisions on how and when to introduce trails. Initially I was determined to make general rules-of-thumb for trail design, or a decision tree to guide design guidelines. One of the most valuable lessons learned during this project was that it is very difficult, and often does not make sense, to make generalizations for a framework whose intent is to be used in different locations. Instead, this project provides a way to approach trail design and planning, in the most fundamental form of the word *frame*work.

Chapter 1

Introduction

Gap in Knowledge

Current Restoration Efforts

Objectives

GAP IN KNOWLEDGE

Currently, hiking trail management in Protected Natural Areas (hereafter referred to as PNAs) often focuses habitat protection efforts on the rehabilitation and creation of re-routes to avoid sensitive plant and animal species. These efforts are most often facilitated after trails have been established and degraded over time. There is extended research on hiking and biking trail management of solutions to minimize degradation of trails as increased foot traffic is predicted, as well as studies on effects of trail use on certain animal populations (Tomczyk et al. 2017; Pickering et al. 2010; Hennings 2017; Ballantyne and Pickering 2015). The field of recreation ecology has also addressed monitoring tactics to determine levels of existing trail degradation and impact. Studies such as Tomczyk et al. (2017) measure tradeoffs between conservation and recreation by measuring recreational impacts and modeling a monitoring approach for four levels of trail degradation. These levels are:

1) An appropriate level of degradation
2) Threatened trails, functioning properly though at-risk during an extreme event
3) Damaged trails, requiring immediate response for restoration
4) Heavily damaged trails, degraded to the extent of required trail closure

(Tomczyk et al. 2017).

These studies are often conducted after a site is open for recreation and disturbance has already affected plant and wildlife communities. Figure 1.1 outlines the typical progression of ecological restortion with the introduction of trail design. This project focuses on the period of time highlighted in yellow, after restoration and before building trails. Rather than a reactionary response to impactful degradation, is there a process by which designers can use risks of human disturbance on plant and animal species to prioritize future trail design plans in a PNA? The term 'disturbance' in this context will largely refer to hikers, who sometimes trample vegetation on either side of trails and whose presence can cause stress to animals resulting in time taken away from an animal's normal activities.

In PNAs where there is an interest in public access, hiking trail designs are predominately led by human-centered desires of destinations and by the constraints of the form and geology of the landscape. People are drawn to good views, trails with a variety of difficulty levels, watching wildflowers bloom in the spring, and having space to themselves (Kornze, International Mountain Bicycling Association, and

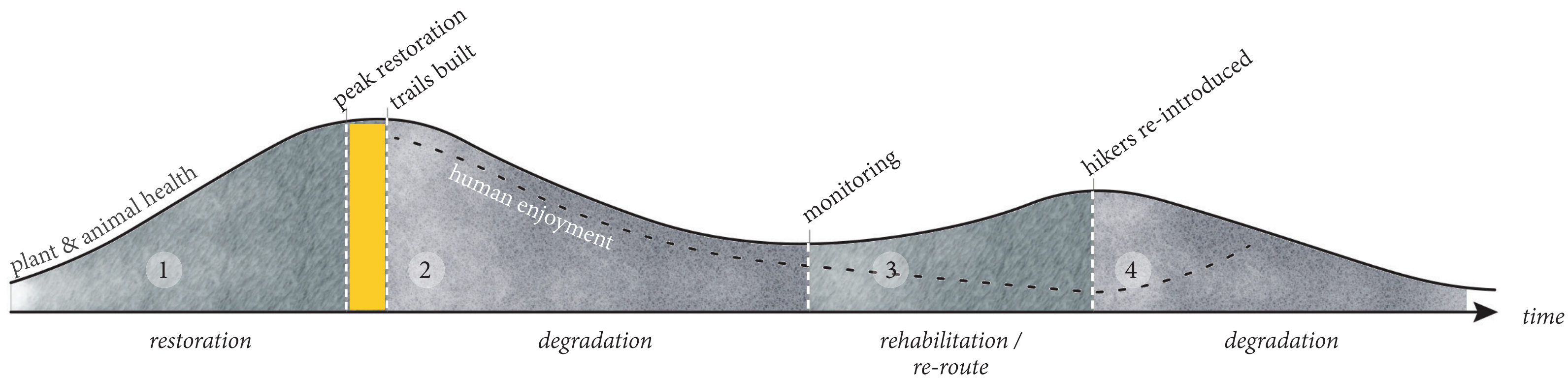


Figure 1.1

Typical cycle of progression of ecological restoration with trail introduction. This project focuses on the period of time highlighted in yellow, after restoration and before building trails.

1. Protected natural areas that undergo restoration efforts improve the health of native plant and animals to that ecosystem. There is an ideal "peak restoration", at which point desired future conditions are obtained, which often reflect historic native vegetation and few invasive species.

2. Once trails are introduced onto these restored sites, the health of plant and animal habitat decreases in certain areas due to trampling, introduced species, and disruption to animals. As trails are degraded, the human experience also declines as trails become eroded, muddy, or trails become crowded.

3. In some cases, monitoring occurs on trail systems to track impacts on the landscape. This can be done by counting visitors or measuring soil degradation from overuse. When there is a concerning level of degradation to the trail, stewards may conduct rehabilitation of the land and create re-routes for hikers to use temporarily, or permanently if they choose to not re-open the original trail. During the time of rehabilitation, plant and animal health may increase, but typically not to the level at which it was prior to public access. At the same time, human enjoyment continues to decrease as the new re-routes may not have the same qualities such as views along the original trails.

4. Once rehabilitation of a trail is complete and re-opens, or when a re-route is complete, the process begins again.

This project focuses the time period highlighted in yellow, and asks the question: Can designers and planners better plan to minimize the initial degradation process, and prevent the decline of human experience when trails begin to degrade?

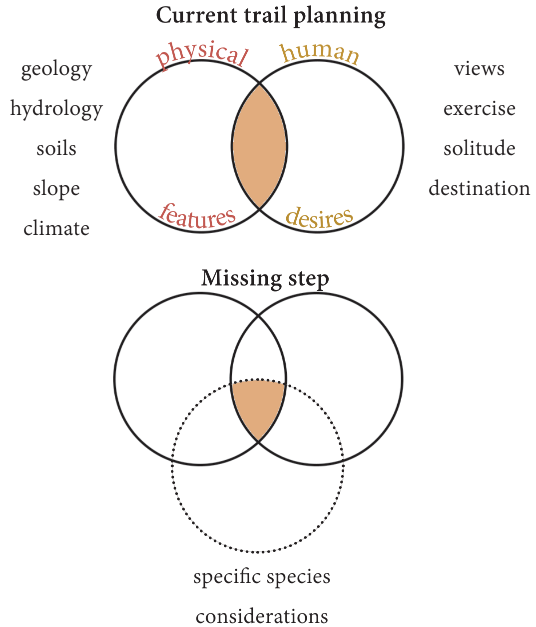


FIGURE 1.2

MISSING STEP

Current design planning primarily focuses on physical landscape features of a site and human desires. This project addresses a missing step in the process that considers individual plant and animal needs to thrive.

Department of the Interior Bureau of Land Management 2018). Slope, aspect, soil types, terrain, and weather also influence the placement and form of trails. Existing condition evaluations of a future hiking trail often include some level of habitat assessment before the implementation of trails by wildlife biologists or ecologists. These assessments often record the evidence of exisiting animal habitat, and occasionally, how much space those animals species require to live (Bernhardt 2020). There is already well-established discourse on negative impacts new trail systems can have on natural areas, including degradation of vegetation along trail edges and disturbance of certain animal habitats (Thompson and Henderson 1998; Bennett et al. 2009; Knight and Gutzwiller 1995). An intermediary step, however, between initial assessment mapping of conditions and trail design is important and often-overlooked. This project focuses on a framework that considers specific animal and plant species' moments of sensitivities and possible reactions to help determine prioritizations for trails in a publicly accessible PNA (Figure 1.2).

A framework is a tool that identifies necessary information and organizes it in a way that accelerates the process of analysis and encourages effective communication.

(Adapted from Marshall Wallace's 'Principles to Practice').

I am proposing a framework which identifies necessary relationships between plants, animals, and humans that reveal temporal patterns of sensitivity throughout the year. This project aims to communicate how to better analyze a protected natural area by using this framework as a common language before introducing trail systems (Figure 1.3).

CURRENT RESTORATION EFFORTS

PNAs, especially those that have undergone restoration efforts, have qualities of relationships between plants and animals which fundamentally change when humans are introduced. Restoration projects such as those led by The Nature Conservancy (TNC) have clear goals to conserve and restore ecological function to specific landscape types and improve habitat conditions for target plant and animal species. Desired future conditions of a site often aim to preserve ecological functions between plants and animals to the highest degree (The Nature Conservancy 2012).

In the study "Planning, implementing, and monitoring multiple-species habitat conservation plans" by Franklin et al., there is a strong emphasis on spatially prioritizing the distribution of strategy species in the design of nature reserves (Franklin et al. 2011). Ed Alverson, Natural Area Coordinator for Lane County Parks, emphasizes this importance in his article on preserving prairie and savanna habitats.

"The aim {...}", Ed writes, "[is] to identify sites where the greatest number of high-quality habitats and rare species occur together and so should be the highest priority sites on which to focus conservation efforts." (Alverson 2005).

In addition, desired future conditions of a site often aim to preserve ecological functions between plants and animals to the highest degree, which may exclude public access. Yet simply to exclude recreation in a PNA prevents accessibility to captivating landscapes that provide beauty, improved health, and appreciation for conservation efforts from the public. Having access to outdoors and nature are repeatedly cited as being important for mental wellbeing, and studies have shown that spending time in green spaces can substantially lower stress, blood pressure and heart rate, especially while engaging in physical activity (Yuen and Jenkins 2019; Alcock et al. 2019). In addition, studies such as one performed in England linked residential neighborhoods with access to public parks with higher rates of nature appreciation and pro-environmental behavior than those neighborhoods with less access to a public green space (Alcock et al. 2019). The contrasting goals between restoration efforts and public recreation often lead to difficult decisions for designers and planners in determining tradeoffs for the future outcome of a site.

"This project asks the question, how should habitats be prioritized in trail design?"

PROJECT OBJECTIVES

The tension between the goals of restoration sites and desire for recreation access is not a new dilemma, yet there is a gap in knowledge in the trail planning process that allows designers to hold the impact of the human footprint to the same high standard as ecologists do for restoration projects in a PNA. This project asks the question, how should habitats be prioritized in trail design? Animal species, plant species, and the human experience are all aspects of trail design that need attention, and it is often difficult to measure who needs the highest level of consideration in order for trail

"Not only do species' sensitivities matter, the temporal components of season and time of day are dynamic...

*...This project introduces the importance of the often overlooked challenge of not only who to design **for**, but also **when** specific design approaches are appropriate.*

systems to reach a level of equilibrium[1] where all three species can thrive. This project explores the importance of specific characteristics and relationships of plant and animal inhabitants that help inform trail design, as they play fundamental roles in the ecological health of a given area. For example, for beavers to successfully aid in the restoration of wetlands they must be in good health. Barriers that cause stress during periods of breeding and foraging could lower their health and affect the construction of wetlands. These characteristics of stress are caused by species' sensitivities and their potential reactions to human disturbance. Furthermore, not only do species' sensitivities matter, the temporal components of season and time of day are dynamic. In current trail planning, the inclusion of how plants and animals react to foot traffic seasonally are considered secondary, if considered at all. This project introduces the importance of the often overlooked challenge of not only who to design for, but also when specific design strategies are appropriate. There is a need for an approach to trail design that analyzes trail systems as dynamic relationships between species in space and time on a large scale across habitats, as well as fine grained design implementations.

In Chapter 2, this project offers an original synthesis of identifying sensitivities among plant and animal species. This includes defining types of human disturbance on trails, and potential species' reactions to those disturbances during different times of the year. In Chapter 3 this project uses the process of documentation, diagramming, and mapping to create a framework as a way to prioritize the continued protection of species as trails are introduced into a PNA. This framework uses methods of mapping plant and animal species' sensitivities temporally and spatially on a site map. By doing this, the framework reveals patterns of sensitivity among plant and animal species in different types of habitats. Chapter 4 tests the framework at a specific site, the Willamette Confluence Preserve in Springfield, OR. This chapter presents possible design implementation strategies across multiple scales from site-wide planning to the use of materiality. By doing this, the process explores the application of the framework across different landscapes (Figure 1.3).

[1] In this project, the term 'equilibrium' is consistent with the definition provided by The Society of Ecological Restoration in the book "Assembly Rules and Restoration Ecology" which describes equilibrium as a state of an ecosystem that sustains the life of both species and communities while also allowing fluctuation compatible with that sustainability (Temperton 2004).

Figure 1.3

project process diagram

	GOAL	METHOD	RESULT
Part 1 (Ch 1)	**Define gap**	Literature Review Interviews with experts Site visit	Temporal and spatial relationships among species
Part 2 (Ch 2)	**Identify sensitivities**	Restored habitats A B C Target species plants animals Sensitive times/year plants animals Popular times to hike	Communication for who to do design for and when
Part 3 (Ch 3)	**Develop framework**	Map temporal plants animals hikers Map spatial plants animals hikers	Reveal patterns of sensitivy HIGH MEDIUM LOW
Part 5 (Ch 5)	**Offer solutions**	large med sm Space large med sm Time	Adaptable & flexible solutions on large, medium, and small scales across space and time

Part 4

Test on WCP

(Willamette Confluence Preserve)

(Ch 4)

Chapter 2

Background

MOMENTS OF SENSITIVITY

HUMAN DISTURBANCE

REACTIONS

TEMPORALITY

CHAPTER PREVIEW

Regardless of species or their habitat, all plants and animals have a level of sensitivity to disturbance. The first section of this chapter will review moments of sensitivities for plants and animals. Apart from predation from animals and natural ecological processes such as weather, humans are often a major cause of disturbance through the use of trails, which will be discussed in the following section. Next, reactions to disturbance will be illustrated to show why sensitivities of plants and animals are important to trail design. Lastly, temporal variation will explain how time of year and time of day can cause reactions to differ among species (Figure 2.1).

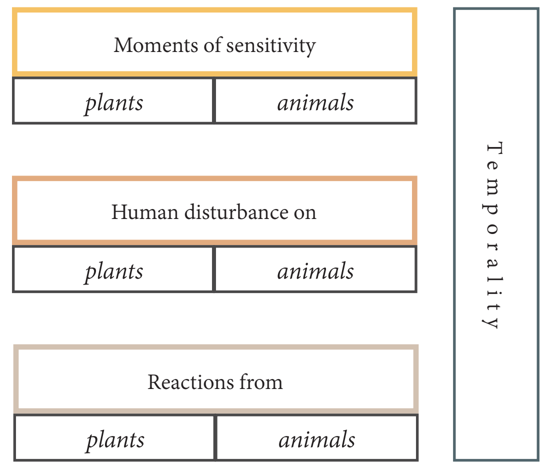


FIGURE 2.1

CHAPTER 2 PREVIEW

MOMENTS OF SENSITIVITY

A ‘moment’ in the context of this project is described as “a period of time (not necessarily brief) marked by a particular quality of experience. A cause of, or motive for action; a decisive or determining influence” (Oxford Dictionary). Moments of sensitivity among plants and animals are times at which they are vulnerable. These are moments during which disturbance may take time away from essential processes for their survival.

‘Sensitivity’ largely refers to the sensitivity to human disturbance, namely hiking. Characteristics of human disturbance vary greatly depending on the specific circumstance.

MOMENTS OF SENSITIVITY

ANIMALS

For animals, sensitive times are moments when energy towards an activity that is crucial to their own or their offspring's wellbeing is taken away by disturbance. If an animal's attention is forced to be reallocated to something other than this activity, they may risk their own health (immediately or in the future). This is most often initiated by stress from an outside influence. Animals are sensitive during breeding, rearing (tending their young), feeding, sleeping, and hibernating (Hennings 2017).

BREEDING

Across all species, breeding is an activity to which animals are especially sensitive. Extra energy is expended during breeding season, as it takes time and energy to sustain their populations. Breeding also may require a more specific type of habitat for animals than their normal foraging and sleeping territory. For example, some amphibians require standing water for breeding seasons and dry land for foraging and sleeping. Those animals who require a complex habitat are more vulnerable to degradation through disturbance (Guderyahn, Smithers, and Mims 2016).

REARING

How animals tend to young depends on the species. For avian populations, rearing begins when birds are lying on their nests before eggs hatch. For most animal species, this time continues until offspring are able to leave their nest, though they still rely on a parent for a food source and protection from predators. During rearing, parents spend a large amount of time fulfilling their own requirements as well as their offspring. A study of Brent geese found that as disturbance increased, the amount of food that parents collected remained constant, but less was delivered to the young (Houston, Prosser, and Sans 2012). For some species nesting, the importance of protecting their young may outweigh fleeing their nest when faced with predation, even though this can cause a significant amount of stress.

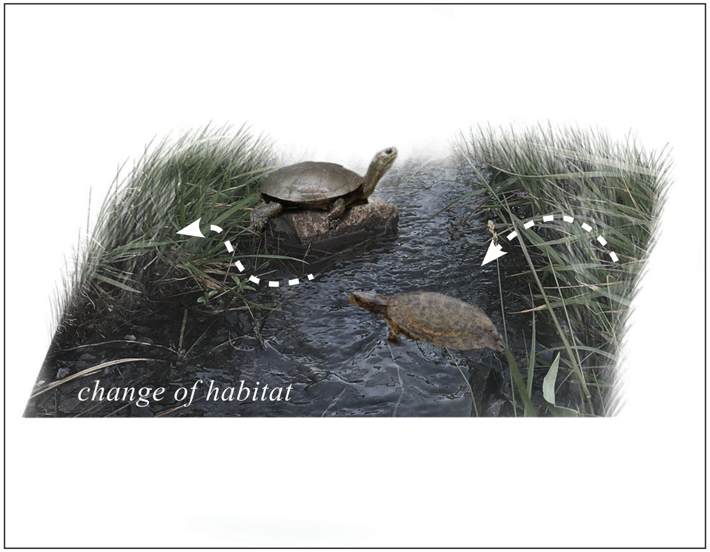
FEEDING

As animals feed, their energy is allocated more heavily on finding food, rather than being alert for predators. If an animal becomes disturbed during feeding, energy is taken away from feeding and redirected to fear caused by stress. During this time animals must make a decision based on tradeoffs, and if disturbance is high enough the tradeoff can be between starvation and predation (Houston, Prosser, and Sans 2012).

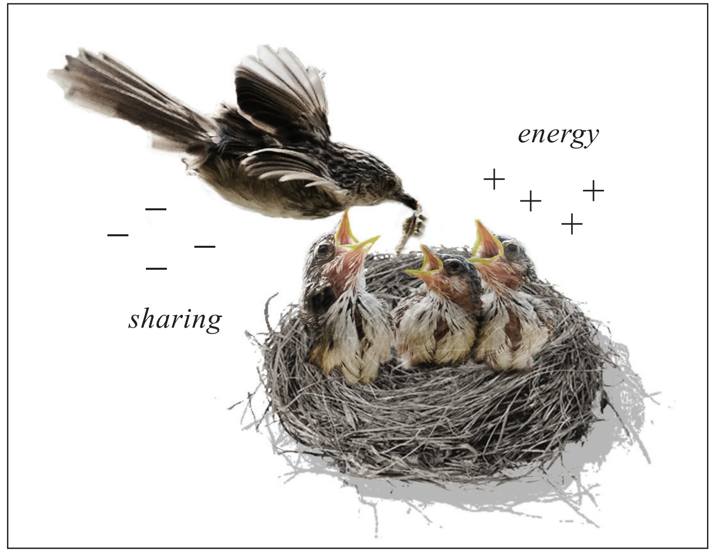
SLEEPING

During sleeping hours animals are regenerating vital energy in order to be active and efficient in foraging and being alert the following day (Hennings 2017). Several studies, including a study of elk in Rocky Mountain National Park, have shown that animals may shift their normal daytime habits to nighttime in order to avoid disturbance. Elk were found foraging during the nighttime, yet not sleeping at all during the day to gain those hours lost (Schultz and Bailey 1978). Habits such as these can wear on the health of the animal. During hibernation, animals are also in the process of storing energy which is an important process that should not be interrupted (Bennett et al. 2009, 114).

BREEDING



REARING



FEEDING

SLEEPING

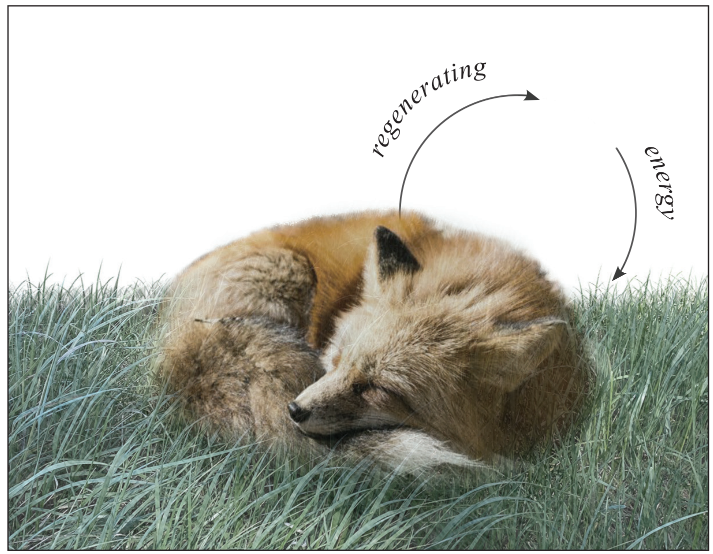


Figure 2.2

breeding, rearing, feeding, sleeping

MOMENTS OF SENSITIVITY

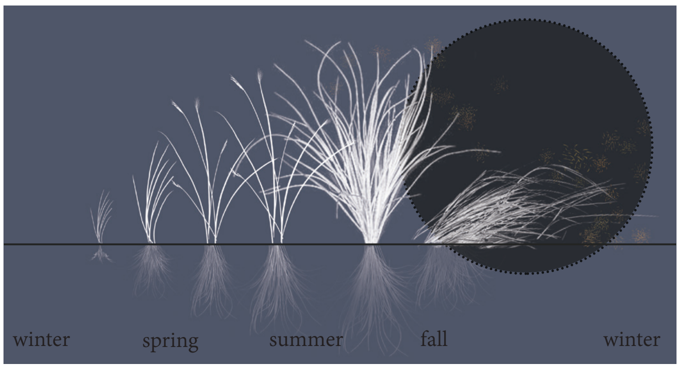


FIGURE 2.3
LIFE CYCLE OF PLANTS

Stages of growth including bloom periods and spreading their seeds are vulnerable moments for plants. Disruption during these periods can lead to decrease health of the plant and its community.

PLANTS

Moments of sensitivity for plants are less dynamic, yet equally as threatening to their health. There are two main characteristics that define plant species' sensitivities: stage of growth and physical form. There is existing knowledge that general types of vegetation communities are more sensitive to disturbance, such as a study where Charman and Pollard (1995) found that blanket bogs with broad leaves recover more slowly from disturbance than grasses in drier ground. These details of plant form have influenced design in landscape architecture such as where to site football fields and play yards (Yorks 1997). Yet for more complex situations such as introducing trails to a conservation area with several land cover types, a closer look at species' habits is important to most effectively protect them.

ANNUAL VS PERENNIAL

An annual plant is most sensitive to trampling because it will not regrow the following year if severely damaged. If a perennial which sends up only one shoot per year is severely damaged, such as a trillium, it will not regrow that same year, however, it has the ability to grow the following year. Most tolerant are those perennials which send up more than one shoot per year, such as a perennial grass. If severely damaged, the grass may re-grow shortly after in the same year.

annuals > perennials 1 shoot/year > perennials more than 1 shoot/year

Most sensitive *Least sensitive*

STAGES OF GROWTH

Susan Holmes, a plant biology instructor at Lane Community College, Eugene, Oregon, and Ed Alverson, Natural Area Coordinator for Lane County Parks, suggest considering what processes a plant species is undergoing during certain times of year to help define sensitivity (personal communications). In general, plants' most sensitive time in their life cycle is while they are growing. During this time the process of photosynthesis allows them to produce energy and grow. During bloom periods, plant species that require seeds for reproduction such as many perennial grasses are especially sensitive to disturbance, since they have not yet spread their seeds to reproduce (Figure 2.3) “For bulbs”, Alverson explains, “the current year’s photosynthesis is building the bulbs for next year’s growth. So, the earlier the trampling occurs, the more damaging it is” (Alverson 2020).

PLANT FORM CHARACTERISTICS

A significant number of studies have researched the impact of vegetation from foot and vehicle traffic (Dale and Weaver 1974; Hill and Pickering 2009; Pescott and Stewart 2014). Factors that affect the responses of vegetation include frequency of passes, distribution of passes, the season, weather, and soil type (Hennings 2017). Studies which monitored how well plants were able to recover from trampling, however, found that these outcomes were largely based on physiological plant form. Authors Prescott and Stewart, who made a formal systematic evaluation of the effects of trampling on vegetation stated “intrinsic properties of vegetation appear to be some of the most important determinants of resilience, with the magnitude of the actual disturbance explaining much less of the community response”(Pescott and Stewart 2014). These properties vary from species to species, though in general resistance ranking can be categorized as follows, by Yorks et al.:

graminoids > trees > forbs > shrubs
(Yorks 1997)

Graminoids tend to have physiological characteristics of flexibility, horizontal branching stems, narrow leaves, and grow starting from below ground, which all allow recovery. On the other side of the spectrum, Yorks explains, “shrubs, ferns, and forbs that have broad leaves, vertical or woody stems, leaves only on the ‘above ground’ parts and reproductive structures high on the plant, are likely to be more sensitive to trampling impacts” (Yorks 1997, 2). Least resilient plant form characteristics include perennials with fibrous or fleshy root form, upright plants that have rigid leaves and stalks, and plants with a single exposed perennating bud (Pescott and Stewart 2014) (Figure 2.4).

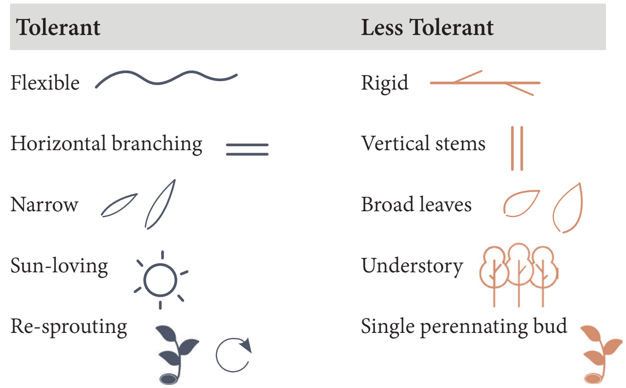


FIGURE 2.4

DIFFERENCES OF TOLERANT VS LESS TOLERANT PLANT CHARACTERISTICS

Resistance
A plant's ability to withstand immediate damage, in this project's case, damage through trampling by hikers.

Resilience
A plant's ability to recover after trampling has ended. A perennial for example, could have low resistance and break easily if trampled, yet it has high resilience since it will likely return the following year.

Tolerance
Describes both resistance and resilience. In terms of trampling, a tolerant plant has characteristics that can withstand initial trampling, as well as an ability to recover in following years.

ABILITY TO RECOVER

Before categorizing plants by these attributes, is important to highlight the difference between the definitions of resilience, resistance, and tolerance. *Resistance* is the ability of a plant to relatively immediately recover after being trampled, before damage occurs (Hill and Pickering 2009). *Resilience* is the ability of a plant to recover its health over a longer period of time, which may be the following year. Not all resistant plants are resilient. For example, a shade-loving upright shrub with thick stalks such as *Maianthemum racemosum*, False Solomon's Seal, can resist some trampling, though as soon as its stalk breaks, it will not be able to grow back until the following spring. *Tolerance* may be the most encompassing definition, describing both the resistance and resilience of a plant to trampling (Hennings 2017).

HUMAN DISTURBANCE

As humans are introduced into the landscape through the use of trails, they contribute and add to types of disturbance on both animal species and plant communities. Some types of disturbance, such as frequency of foot traffic, can affect both plants and animals. There has been extensive research on the general types of disturbance on plant and animal species, which are summarized in the following section.

HUMAN DISTURBANCE

ANIMALS

NOISE

Hikers who are talking with others create noises that are unexpected for most animal species. Even if an animal is alone, they are exceptionally in tune with surrounding sounds that may be near predators. A study in New Zealand showed that conversation with a noise of 50 decibels (equivalent to a library speaking volume) caused 35% of birds to flee the immediate area (Karp and Guevara 2011). As the size of a group of people increases, sound also likely increases, and therefore causes larger disturbance.

SPEED

Hikers use trails at different speeds. Some hike slowly, especially on a steep climb, and others trail run. Different movement speeds can cause certain animals to react in different ways, and the degree of disturbance can vary among animals. In general, faster, more abrupt movements have a greater negative effect on animals (Taylor and Knight 2003).

FREQUENCY & DURATION

The amount of time people are near an animal's habitat has an effect on the health of an animal. People who are bird watching, for example, may linger on or off a trail and seek out close proximity to a species especially if photographs are taken (Klein 1993). Additionally, Taylor and Knight identified frequency of disruption to an animal habitat as significant, as stress of animals generally increased as frequency increased (Taylor and Knight 2003).

PREDICTABILITY

On-trail visitors are less disturbing than those off-trail. In general, hikers are a recreation group that is most likely to go off-trail compared to bikers or birders (Hennings 2017). Taylor and Knight (2003) found that the probability of animals fleeing as hikers passed increased 30% when users went off-trail rather than staying on trail. In general, the highest risk for animals is disruption that is unexpected (such as going off-trail) and frequent (Hennings 2017) (Figure 2.5).

DISTANCE

The distance between a trail and an animal's habitat greatly affects the desired location of a nesting and foraging site. In general, in areas where there are trails, animals are more likely to exist further from the trail. A Boulder, Colorado study of bird counts in grasslands similar to those of the Willamette Valley found that the zone of influence of trails on animal species is up to 100 meters from the trail. The exception to this rule is some generalist species and those who like edge habitat, such as deer, American Robins, and Blue Jays which were more abundant on sites with trails (Miller, Knight, and Miller 1998).

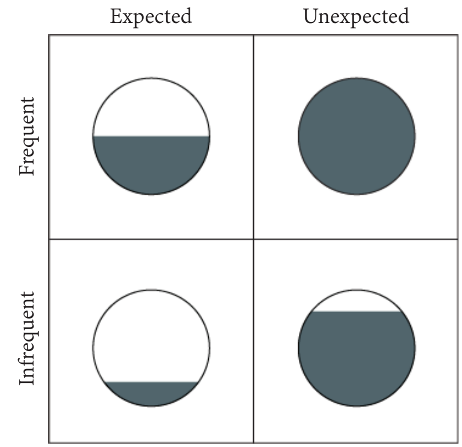


FIGURE 2.5

LEVEL OF DISTURBANCE TO ANIMALS

Expectedness describes hikers staying on trail or going off-trail. Frequency describes how often hikers use the trail. The highest disturbance occurs during frequent and unexpected trail use.

DOGS

Because of their quick movements, high speed, and interest in following scents, dogs are especially disruptive to wildlife as they cause drastically elevated stress responses. Several studies have been conducted on the negative effects of target animal species' health in areas where dogs can be off leash. These studies' results often show that there is a dramatic decrease in target species density near the trails with the presence of dogs (Lenth, Knight, and Brennan 2008). In addition, the scent of dog urine or feces can cause animals to avoid certain areas, which results in longer-lasting impacts of disturbance than a hiker or dog passing by (Kats and Dill 1998).

As Professor Rick Knight of Colorado State University emphasizes, "*There's something about the presence of humans and their pets when they go on hikes that causes a bit of a 'death zone' of 100 meteres on either side of a trail*".

HUMAN DISTURBANCE

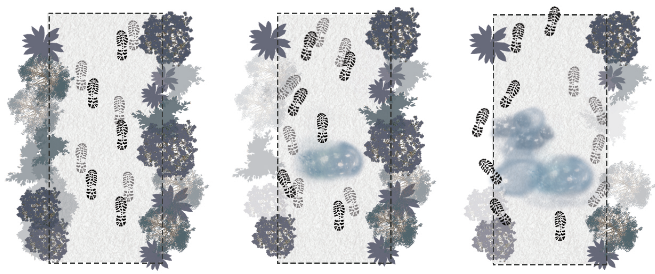


FIGURE 2.6

TRAIL WIDENING

As the frequency of hikers increases, the width of the trail often widens. This is caused by hikers avoiding muddy areas going around the edges of a trail. As trails widen, vegetation cover is reduced.

PLANTS

The term 'disturbance' when used to describe phenomenon that disrupts plant community structure often refers to fire, floods, droughts, storms, landslides, grazing, disease, disturbance by rodents, among others. However, in this projects' context, 'disturbance' will largely refer to trampling of vegetation on either side of trails by hikers.

PHYSICAL IMPACT ON VEGETATION

The construction of a trail removes vegetation and directly impacts the wildlife who rely on that vegetation for habitat and food (Hellmund 1998). As the frequency of hikers increases on a trail system, the width of the trail often widens. This can be caused by people walking side by side on a trail, or hikers avoiding muddy areas by going around the edges of a trail. As trails widen, vegetation cover is reduced which can lead to increased erosion with exposure of bare soil (Tomczyk et al. 2017). Once soil is exposed and hikers continue to use trails, erosion can quickly occur on steep terrain, during rain events, or where there are limited drainage features (Figure 2.6). A trail management study by Olive and Marion (2009) emphasizes that "Trail erosion, in particular, is a significant concern because it is irreversible without costly management actions that may further impact resources" (Olive and Marion 2009, 1483–84). Degradation of surrounding vegetation can encroach on animal habitat. For example, a study conducted on the Black Grouse found that cover of grasses and woody plants are indicators of habitat. In areas where trails were recently built, those that intersected the groundcover vegetation mosaic recorded fewer sightings of the Grouse (Immitzer, Nopp-Mayr, and Zohmann 2014).

SEASON

During wet seasons, which are often in the early growing season here in the Willamette Valley, soils tend to be soft and malleable. Vegetation may be more easily damaged in these conditions than during dry seasons when soils are more hard-packed (Hennings 2017).

REACTIONS TO HUMAN DISTURBANCE

Animals and plants have responses to hiker disturbance that vary in severity and duration, and depend largely on the specific species. In general animals either freeze, hide, or flee when under stress. Plant species may spread, resist, change composition, or die when disturbed. It is important to understand the possible responses from species to begin to see potential patterns of effects from disturbance on communities. These patterns can have implications for decisions in the planning and design of trails that interact with these dynamic communities.

REACTIONS

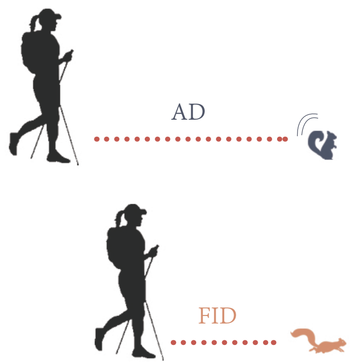


FIGURE 2.7

ALERT AND FLIGHT INITIATION DISTANCE

Alert distance (AD) is the distance between an animal and an approaching human at which point the animal begins to exhibit alert behaviors to the human.

Flight initiation distance (FID) is the distance from a person at which an animal first flees from a perceived danger.

ANIMALS

Stress causes animals to release hormones that initiate a physical reaction. A certain level of this is beneficial for animals, as it allows them to respond to nearby threats such as predators. Chronic stress, however, can cause detrimental effects to an animal's health (Cizauskas et al. 2015). There are three main reactions of animals to hikers along a trail, which can generally be defined as freezing, hiding, and fleeing. These reactions are largely dependent on whether animals are experiencing sensitive moments, described earlier such as reproduction, rearing, or foraging. All the following reactions describe levels of an animal becoming more alert under stress, which causes them to cease their routine activities, altering their normal behavioral state.

FREEZING

The reaction that requires the least amount of physical energy from animals under stress is freezing. Freezing often limits animals' resources only for a short amount of time since they are not being physically displaced. Most often, animals will freeze if they think they may not be seen by a predator, or in the case of trails, hikers (Hennings 2017). If an animal reacts by freezing, they are briefly reallocating their energy towards being vigilant rather than engaging in typical activities. A study by Ydenberg and Dill (1986) on the economics of animals fleeing from predators explains that the decision-making process is based on tradeoffs. If an animal were to instead flee to a new location, they may able to relax with less fear of a predator (Ydenberg and Dill 1986).

HIDING

An animal may choose to hide in their surrounding areas when in fear. Often this decision is based on the quantity and quality of cover nearby. In general, studies have shown that in open habitat types, such as a prairie, animals have a longer flight initiation distance (FID). FID is the distance from a person at which an animal first flees from a perceived danger (Figure 2.7). The higher the FID, the lower the animals' tolerance to disturbance (Fernández-Juricic, Vaca, and Schroeder 2004). Additionally, if an animal has become habituated to disturbance, they may freeze or hide rather than flee. Animal behavior studies have found that animals whose

Figure 2.8

freeze, hide, flee

habitats are close to trails may learn that hikers are not a threat and alter their natural behavior to adapt. Studies such as Thompson and Henderson's (1998) review of elk habituation across the Rocky Mountains suggest that "habituation is an adaptive behavior strategy for maximizing reproductive fitness". If hiding nearby rather than fleeing means animals can still protect their nest while rearing, it is more favorable for them to attempt to hide.

FLEEING

Each animal response can be defined as a different alert distance (AD) and flight initiation distance (FID) (Figure 2.7). AD is the distance between an animal and an approaching human at which point the animal begins to exhibit alert behaviors to the human (Fernández-Juricic, Jimenez, and Lucas 2001). Fleeing is a response that uses the most amount of an animal's energy, which is being reallocated from activities such as breeding, feeding, or sleeping.

Short term: Some animals will return to areas they had fled within a couple of hours (Knight and Gutzwiller 1995). This may result in a decrease in energy acquired foraging, though animals often return to their preferred foraging or nesting area.

Long term: Over repetitive periods of disruption, behavioral changes can evolve to a change of preferred foraging areas, an increase in energy expended during flight, and an unsupervised nest during breeding or rearing season. These continuous disruptions can result in overall decreased productivity of a species and may even lead to death from lack of resources (Knight and Gutzwiller 1995). Death can also result from predators who have learned to follow human scent trails to a nest site.

A NOTE ON HABITUATION AND SENSITIZATION

Some animals become more habituated (have a decreased response) to regular foot traffic through learning, whereas some experience sensitization (an increase in response as foot traffic increases). It is important to note however, that animals who show signs of habituation are *not necessarily unaffected* by disturbance. Thompson and Henderson (1998) define habituation as "when animals stop responding to repeated activities that are not accompanied by positive or negative reinforcement" (Thompson and Henderson 1998). These animals may have adjusted their habits in a way that is not necessarily most efficient for their health, and there should be continued effort to not disturb them.

As disturbance conditions heighten, animal species may either run out of time or be limited by an energetic constraint, which forces them to make decisions based on tradeoffs. In general, long term effects of disturbance by hiking on individual animal species can result in altered behavior, vigor, productivity, or death. At a larger scale, this can change the abundance, distribution, or demographics of a species population (Knight and Gutzwiller 1995, 52). Though it is difficult to gain specific information on individual species on how they may react to human disturbance, it is important to understand the possible outcomes and the long-term effects on their health. These consequences can better inform trail design when a goal is to protect sensitive animal species.

REACTIONS

SPREAD

As trampling increases adjacent to trails, the population of invasive species often increases along the edge. Invasive species have aggressive and high tolerance characteristics, such as the ability to grow in a wide range of soil types, sun exposure, and harsh conditions. The demise in some vegetation on the edge through trampling, a form of disturbance, allows opportunities for other vegetation to grow. Wimpey and Marion (2010) describe the construction of a trail as “day-lighting” which encourages altered plant composition by favoring shade-intolerant species, which are often non-native and aggressive (Figure 2.9).

The spread of invasive species along trails is an outcome that has been widely studied (Wichmann et al. 2009; Yorks 1997). Through facilitation of invasive seeds on shoes, clothing, and dogs, invasive species can be introduced in trampled areas with more available light. Most studies have found that introduced invasive species will spread on average 2-20 meters from the trail, with the exception of shade-thriving plant species (Dale and Weaver 1974). Though this may not be far, a study by Wichmann et al. found that seeds carried on shoes can often travel farther than wind carries seeds, as far as 5 km while hiking (Wichmann et al. 2009).

RESIST

A reaction to trampling between spreading and dying is resistance. The more resistant qualities a plant has (flexible, horizontal branching, narrow leaves, and below-ground growth) the more likely a plant will be able to resist a higher frequency of trampling (Hill and Pickering 2009). Experimental trampling trials by Hill and Pickering (2009) found that reduced vegetation height, species richness, and vegetation cover were all possible outcomes of trampling depending on a species’ resistance. The ability of a plant to withstand disturbance is also largely based on climate type and attributing characteristics such as aridness, soil, wind, and altitude (Hill and Pickering 2009). These characteristics dictate how well a plant ‘holds up’ when the added disturbance of trampling is introduced.

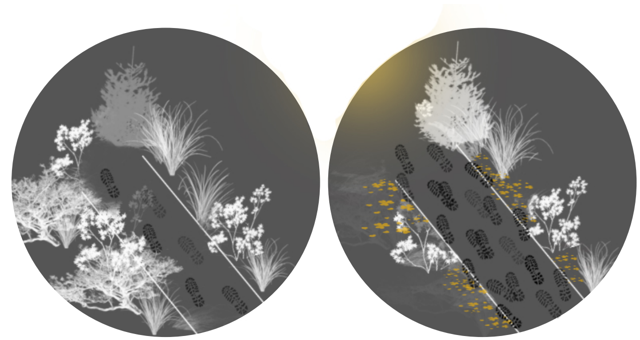


FIGURE 2.9

DAYLIGHTING

As trampling decreases edge species, the process of daylighting allows other species, often fast-growing, to thrive.

CHANGE IN SIZE AND SPECIES RICHNESS

As trampling increases, so does the stress and damage on a plant. Stress, like in animal species, can lead to a decrease in reproduction. This can occur during a process called facilitation, where one species (often called a 'nurse') can be beneficial to the health and growth of another species (a 'beneficiary') by providing it required shade or wind protection (Ballantyne and Pickering 2015). If a nurse shrub along the edge of a trail were to be trampled, the change in conditions may change the health of the beneficiaries next to those shrubs. The declining health of edge species can lead to an overall decrease in species richness of a plant community in that immediate area. A trampling study by Hill and Pickering (2009) found that communities of grasses and graminoids that cushioned and protected smaller herbs had a higher resistance to repetitive trampling. Competition from height differences between plants can also change the composition of a vegetation community. Trampling of tall grasses could allow shorter grasses which are more trampling-tolerant to persist (Kilinç, KaraviN, and Kutbay, n.d.).

DIE

Direct damage by trampling can cause mortality to a plant species. Characteristics such as vertical, woody, and brittle stems and fibrous roots are all susceptible to being easily damaged. When a plant species has fragile characteristics (low resistance) and also an inability to recover (low resilience), it may not be able to withstand trampling (Hill and Pickering 2009). This can be true especially for annuals, which are unable to have a chance to grow back the following year.

Degradation of matter that supports the life of plants, such as soil, moisture levels, and sunlight can also lead to mortality of a plant species. In many climates with muddy seasons such as spring, hikers avoid saturated ground and hike-around thereby widening the trail. This causes disturbance to the soil through compaction and movement of the top organic matter layer can lead to an unsupportive medium for plants (Hennings 2017).

CO-DEPENDENCE OF ANIMALS AND PLANT HEALTH

Analyzing the reactions of animals and plants to disturbance can begin to show patterns of dependence on each other. A study in Arkansas which explored the effects of recreational trail use on the degradation of edges of trails found that the initial loss of seed production from damage to plants affected the amount of foraging available to avian populations. When birds became physiologically stressed at the edge of their habitat, they were forced to relocate further off the trail where they may not thrive because of change in plant communities, sunlight, and temperature (Grooms and Urbanek 2018).

Figure 2.10

PLANT REACTIONS TO DISTURBANCE

In general, once plants have been trampled they will either spread if they spread by seed, resist, change composition such as size or species richness, or die. These outcomes rely on specific morphological characteristics. Plants with horizontal branching, sun-loving, and flexible leaves will be able to resist trampling more than those with opposite characteristics (Figure 2.4).

SPREAD

RESIST

CHANGE COMPOSITION

DIE

TEMPORALITY

Animal and plant sensitivities and types of human disturbance hold a different weight depending on the time of year and time of day. In the context of trail design, temporality may be one of the most overlooked aspects of protecting sensitive plant and animal communities. It is important to understand when the most crucial times are in order to be most effective when planning for future trail systems.

TEMPORALITY

ANIMALS

For animals, breeding and rearing (caring for their young) seasons are sensitive times to be disturbed and this information can be easily found for most species. The energy allocated for breeding and rearing is already energy taken away from other activities for an animal's own health, so disturbance can further shorten this time. It is important to note that these months of sensitivity and duration of breeding and rearing are species dependent. For example, the gestation period for the American Beaver, can be from February until June, while the Western Pond Turtle gestates for only a month. These differences help define the extent of seasonal sensitivities among animal species who share similar habitats. Hibernation is also an activity that is season dependent. If animals are hibernating during winter, disrupting them during this time can have especially negative consequences on their health. Bats, for example, use hibernation as a time to slow their metabolism and accumulate enough fat for a long winter. Disruption during this time can take away energy from this process and eventually lead to mortality (Kuebler 2019). Temperature during seasons may also influence responses to disturbance. During winter in many climates, animals require more energy to forage due to outside temperature and lack of available vegetation to forage. Less abundance of vegetation may require animals to travel further for food, expending more energy (Houston, Prosser, and Sans 2012).

PLANTS

For plant species, bloom time is a good indication of when they are most sensitive during the year. In most climates this occurs in spring, though species such as bulbs are often early, and grasses often late season. Disturbance of plant species before they are able to spread their seeds (if they do) restricts perennials from fully reproducing (Alverson 2020). The soil conditions may drastically differ between seasons in certain climates, which can affect the level of degradation of vegetation from trampling. In the Willamette Valley, Oregon, summer is the dry season, in which climatic conditions create more durable surfaces. During wet winters, deciduous vegetation is dormant and can withstand trampling, however, the moist and malleable soils can cause significant damage to trails and thus their edge vegetation. By contrast, Colorado's winters are cooler and dry, which result in a less sensitive time of year for vegetation and trail conditions.

HUMANS

In general, hikers have the desire to be on trails during the most comfortable times of year. This also greatly depends on location and climate; however, climate characteristics of warmth and dry air are usually most desirable. Other seasonable variables that draw hikers on trails include peak times for spring flowers blooming, access to water to cool off on a hot summer day, and longer summer days that extend daylight hours. The following methods of this project focus on tracking specific temporal information of animal, plant, and hiker behavior to begin to see where there are times of conflict and opportunity for the three to co-exist.

Chapter 3

Methods

DETERMINING SPECIES TO PROTECT

ADDRESSING SENSITIVITY & RESPONSE

QUANIFYING SENSITIVITIES

MANAGING RISK

CHAPTER PREVIEW

This chapter explains how temporal and spatial mapping of sensitive plant and animal species can be used to create a lens through which to assess trail introduction and design for a PNA. By organizing sensitivities by habitat type, designers and planners can manage the site more dynamically, addressing the differences between plant and animal communities.

These mapping methods are accessible when provided enough information about specific species, and this information is typically a priority for habitat mangament plans.

SENSITIVITIES INFORMING DESIGN

Before deciding how to design trails to protect plant and animal habitat, it is important to determine what qualities we have the ability to design for, and when those qualities matter most. This project focuses on individual plant and animal species' sensitivities to help guide design, as human disturbance can have a significant influence on sensitivities. These findings of influence are common in the field of recreation ecology, however, there is a gap in knowledge for how designers can use these sensitivities to inform how to protect species without excluding human presence entirely. Methods of this framework include determining species to protect, identifying their sensitivities and moments of sensitivity, determining their physical location on a site, and managing their risks. The use of temporal and spatial mapping help find patterns that can inform design.

DETERMINING SPECIES TO PROTECT

Gathering as much information as possible on specific species aids in a more focused habitat protection goal for the future of a protected natural area. Target species are often used in habitat management and restoration plans to serve as a basis for setting conservation goals and measuring conservation effectiveness as they help represent the biodiversity goals of a site (Lane County Parks Division 2018). Target species aimed to be protected should reflect local habitat management plans, conservation strategies, or recommendations from local ecologists on plant and animal species which are important to the native ecosystem and considered sensitive or threatened. If management plans are not available, methods such as using wildlife cameras can help reveal existing animals on site, and a glimpse of how sensitive they are to human disturbance. Bird counts can also be especially useful and are often accessible with enthusiastic volunteers willing to share sightings.

ADDRESSING SENSITIVITY & RESPONSE

Each target species has a unique time of their lifecycle at which they are most sensitive, so in order to continue to protect habitats on a landscape restoration level to the highest quality, designers should not generalize characteristics of species or prescriptions for design or planning. To understand the timeline of these sensitivities, this framework uses a temporal mapping method that records when animals are breeding and rearing, and when plants are blooming. These moments are temporal habits when animals and plants are vulnerable, and information about their timing is often accessible. Times which animals are breeding, rearing, and hibernating (if applicable) are recorded in circle diagrams by months during the year. Times which animals are foraging are recorded as AM or PM, reflecting if they are nocturnal (Figure 3.1a). During these times for animals, if stress leads them to alter daily activities, their overall health can be at risk. For plants, times when blooming occurs are recorded (Figure 3.2a). For annuals or perennials which produce one shoot per year, stress could cause death which may lead to unsuccessful growth the following year. For those plants that spread by dispersing seeds, stress can cause a decline in reproduction. By starting to map when these sensitivities occur, we can look for patterns and use these to inform trail design when we introduce humans into the landscape.

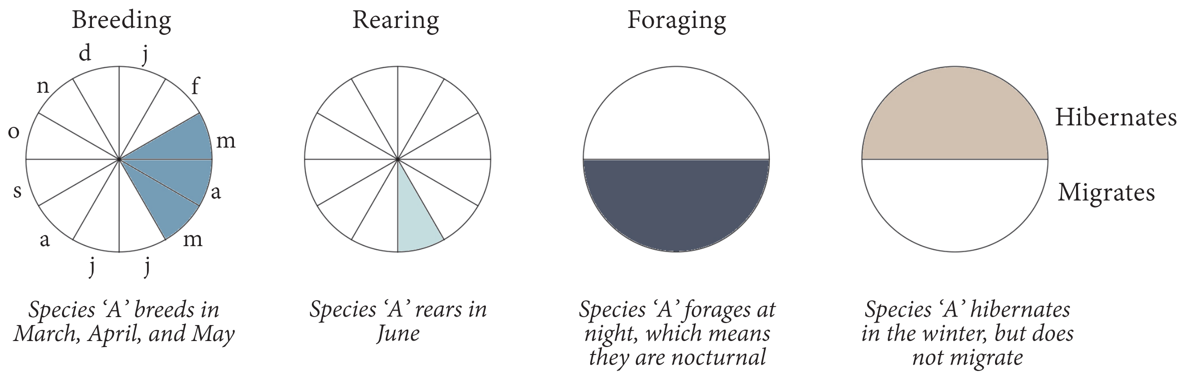
In order to understand how the timing of sensitivities and reactions begin to manifest on a site, moments of sensitivity are organized by habitat type. Habitat types can be determined by using land cover maps of the site, or desired future conditions after restoration. Then, within each habitat, temporal patterns of high or low sensitivity begin to appear after documenting all species within the same habitat type (Figure 3.1b and 3.2b). Adding times of the year which are most desirable for humans to be on the site to these diagrams begins to illustrate when and where to introduce hiking trails. Human desires on hiking trails is unique to the geographic location of the site, its weather, and types of community interest.

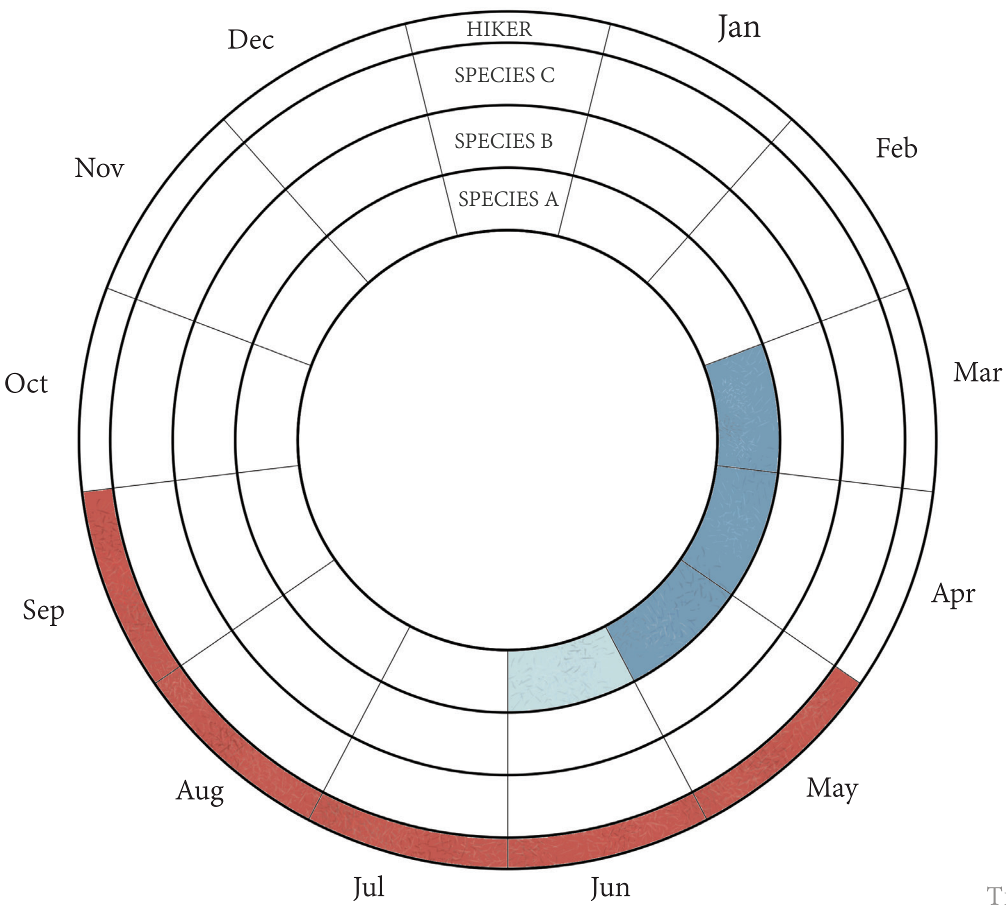
HABITAT X

ANIMALS

Figure 3.1 a

TEMPORALLY MAPPING SPECIES 'A'





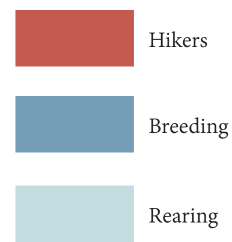


FIGURE 3.1 b

MAPPING ALL SPECIES

Each ring represents a single species. The outermost ring represents popular times to hike in a specific location. With several species together, one can start to see months during the year that are most and least sensitive. Temporal information of foraging, hibernating, and migrating is not included in the combined diagram, yet is still important data on sensitivities.

HABITAT X
PLANTS

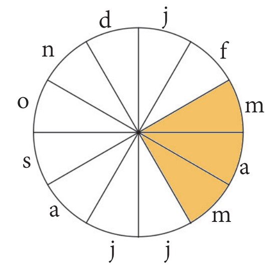
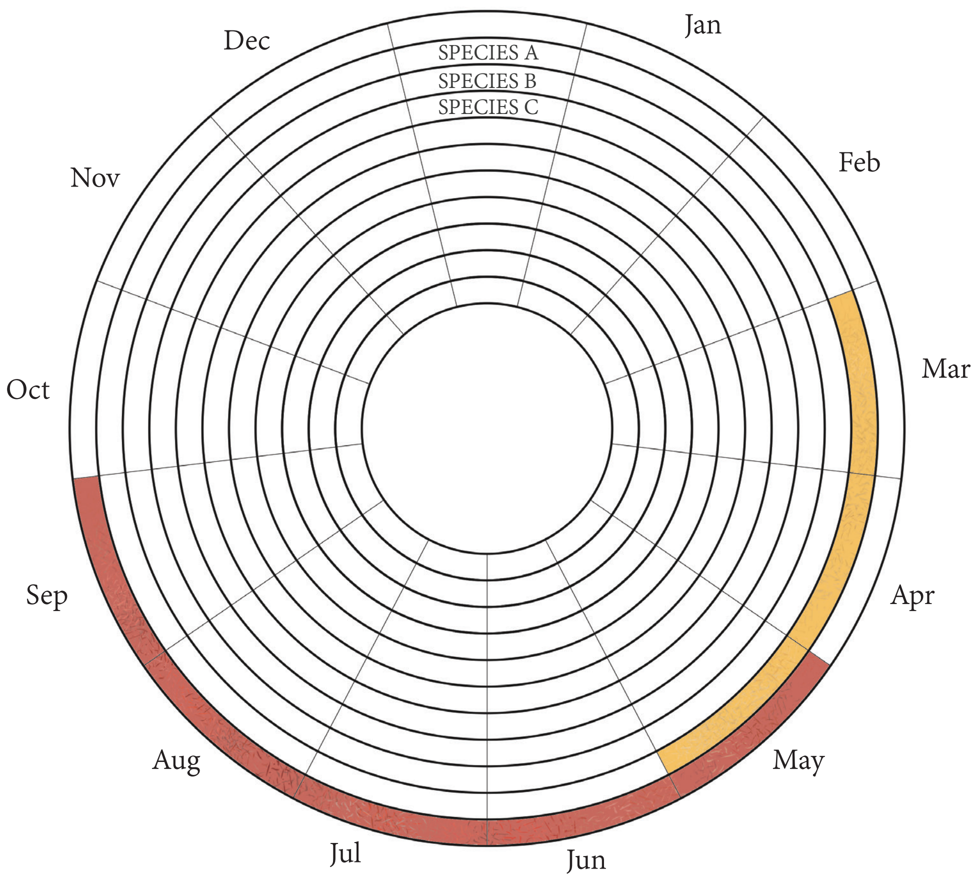


Figure 3.2 a

plant species 'A'

Species "A" blooms in March, April, and May



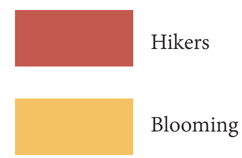


Figure 3.2 b

all species

Each ring represents a single plant species. The outermost ring represents popular times to hike in a specific location. For each habitat, having a large number of species represented helps more accurately represent a habitat community.

QUANTIFYING SENSITIVITIES

To determine overall levels of sensitivity, quantities of potential sensitive plant and animal species on a site are combined for each habitat type, categorized by season (Figure 3.3). This step begins to show a gradient from which priorities and trail restrictions can be made by transferring information onto a map.

ANIMALS

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Habitat 'A'	1	1	1	2	3	3	1				1	1

+

PLANTS

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Habitat 'A'		1	2	3	3	3	1	1				

=

TOGETHER

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Habitat 'A'		2	3	5	6	6	2					

Figure 3.3

QUANITIFYING SENSITIVITIES

The number of animals and plants that are sensitive during each month are recorded. These months are then categorized to low, medium, or high sensitivity. By adding animals and plants together, an overall sensitivity for each month per habitat emerges.

- low sensitivity, fewest sensitive species during given month
- medium sensitivity
- high sensitivity, most sensitive species during given month

SENSITIVITY DOCUMENTATION SUMMARY

Once associated species for any habitat are determined, their sensitivites can be recorded using the circle diagrams and then quantified numerically on a chart.
Target species for any associated habitat can be determined using a habitat management plan or observational data. These species can then be diagrammed for when they are sensitive throughout the year using the circle diagrams. This information can be quantified numerically using the above chart that begins to show a gradient of low to high sensitivity within each habitat. Because sensitive animals and plants are organized by habitats in these methods, this temporal data is easier to transfer onto a spatial site which will be demonstrated in Chapter 4.

CHAPTER 4

APPLICATION

WILLAMETTE CONFLUENCE PRESERVE

SELECTING SPECIES

TEMPORAL MAPPING

SPATIAL MAPPING

CHAPTER PREVIEW

This chapter applies the created framework to a site in the Willamette Valley, Oregon. Doing so tests the application of the framework to a specific protected natural area that has undergone habitat restoration and may allow public access in the future. This site has a unique set of target plant and animal species to map within four types of habitat: Oak savanna/upland prairie, oak woodland, riparian, and wetland prairie/open water.

WILLAMETTE CONFLUENCE PRESERVE

The Willamette Confluence Preserve (WCP) in Springfield, Oregon, is used to illustrate how the framework can be applied on a restored landscape that may have trails in the future. The WCP is 1,272 acres of protected land at the confluence of the Middle Fork and Coast Fork of the Willamette River, currently owned by The Nature Conservancy (TNC) (Figure 4.1). Prior to European settlement, this area was dominated by extensive prairie, oak savanna and oak woodland, and expansive floodplains of channels, sloughs, and marshes adjacent to the river. Since European settlement, native habitat has been compromised primarily due to new development and intensive agricultural practices.

During the late 1800s and early 1900s the land was primarily used for agriculture and livestock grazing. By the 1940s the Army Corps of Engineers constructed a series of dams for flood control and hydropower that have restricted the river's complex meandering movement. From 1952 to 1971 the property was used for aggregate mining operations creating several extraction pits. Some areas have been backfilled; however, vegetation is now predominately invasive species. In 2010 TNC acquired the property to restore ecological functions to the site that reflect the pre-European settlement land mosaic. The Conservancy's goal for the past ten years has been "to preserve and restore river and floodplain habitats, prairie and oak savanna, oak and Douglas-fir forests, habitat for declining wildlife species, rare native plant and animal species, and prevent future development" (The Nature Conservancy 2012). These efforts have been to restore the previous land use of mining operations to ecological function of historic landscape types. TNC is now in the process of transferring the property to new ownership, though has strong requirements for continuing to protect historically and ecologically important plant and animal communities on the site. The preserve borders Howard Buford Recreational Area (HBRA) which is Lane County's largest park, holding over 30 miles of trails that over 500,000 hikers visit annually ("Trails & Recreation | Friends of Buford Park and Mount Pisgah" n.d.). If new management of WCP leads to pressures to open the preserve for hiking, there will likely be high standards for the continued protection of sensitive species. TNC has decided to keep the property closed to the public thus far to focus on achieving its high-quality level of restoration without distraction of managing public access which requires providing public resources (The Nature Conservancy 2012).

Currently there are remnant roads from the mining operations, which would likely be used for any future public access. However, in this project the animal and plant species habitat will be the primary determinant of areas of public use rather than current infrastructure. The goal of this project is not to provide a trail map for WCP, but rather to test the framework for what could be implemented for trail planning and zoning in a PNA.

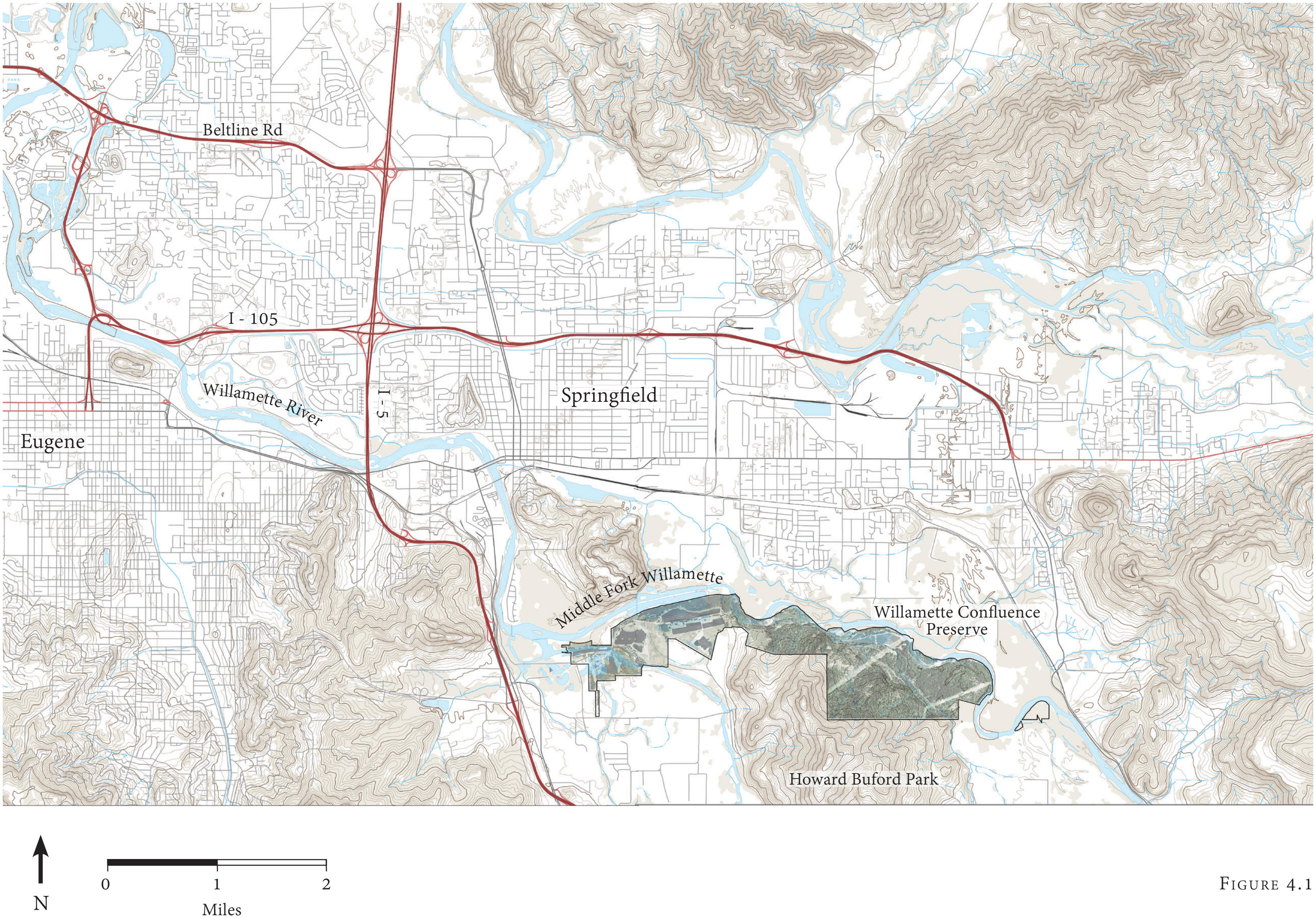


Figure 4.1

WILLAMETTE CONFLUENCE PRESERVE CONTEXT MAP

DETERMINING HABITAT AND SELECTING SPECIES

The Nature Conservancy provided land use/land cover data, including what they refer to as desired future conditions. The desired future conditions map detailed vegetation that represent the restoration goals for WCP. I used the vegetation of desired future conditions as a base for determining which animal and plant species to protect because ideally full restoration efforts would be complete before the introduction of trails. In order to determine which animal species require each habitat type, I simplified these habitats into four main types: oak woodland, oak savanna, riparian shrub, and wet prairie/standing water (Figure 4.2).

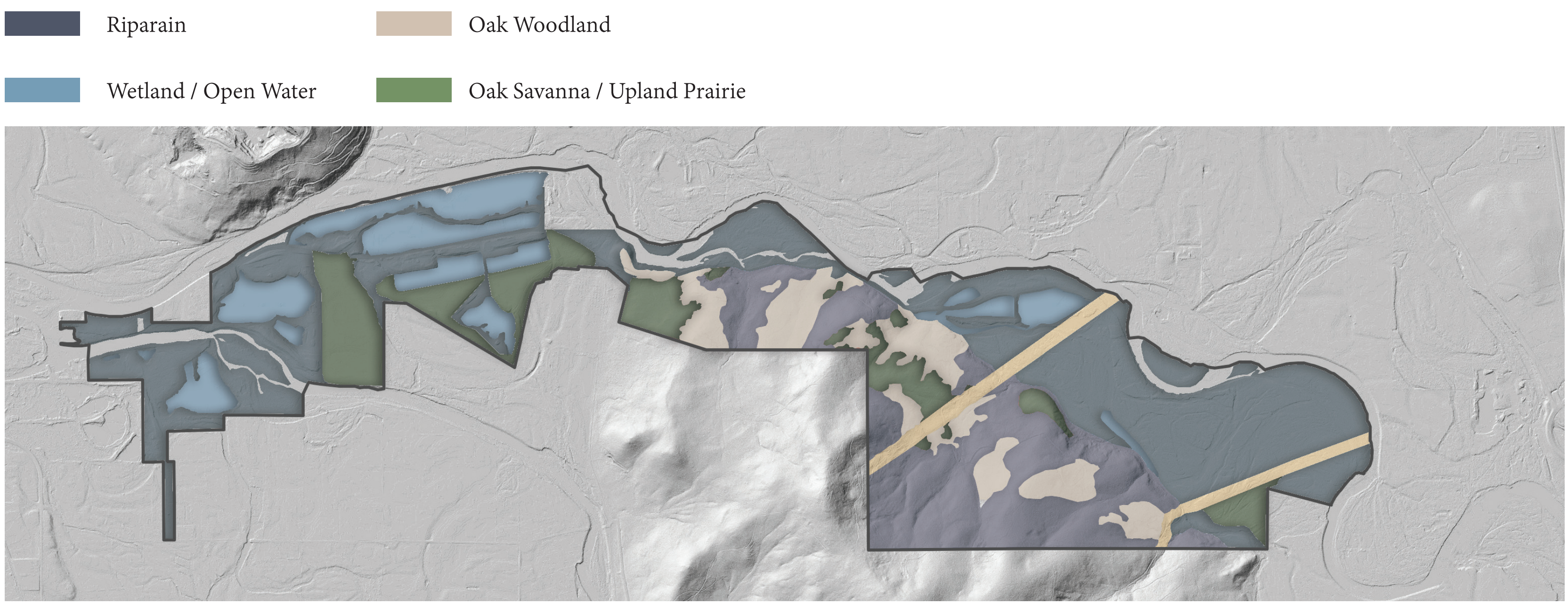


Figure 4.2

deseired future conditions map

Habitat management plans in the Willamette Valley often list strategy species to protect based on these four habitat types. Target plant and animal species were derived from some of these management plans that reflect similar landscape types. In addition, the Oregon Conservation Strategy and native plant lists from local botanist Bruce Newhouse were used to select a suite of focused plant and animal species. For plant species, herbaceous forbs and grasses were primarily chosen due to characteristics that make them vulnerable to trampling. Sensitive animal species were narrowed by selecting species from a variety of different families including amphibians, fish, birds, rodents, and bats in order to include a range of habits (Figure 4.3).

Figure 4.3

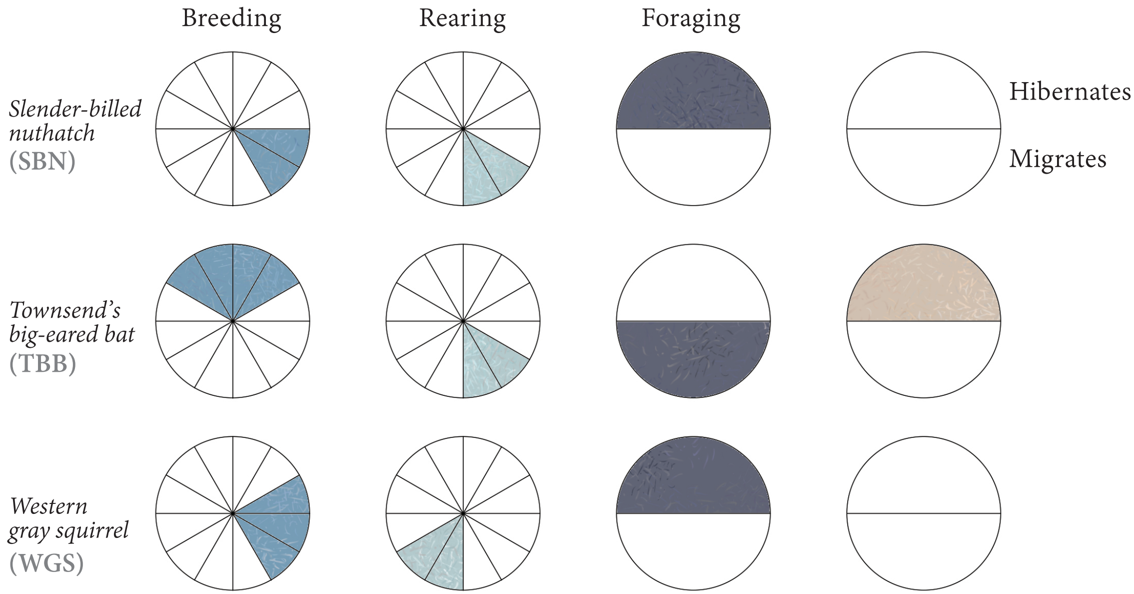
STRATEGY ANIMAL AND PLANT SPECIES SELECTED FOR THE WILLAMETTE CONFLUENCE PRESERVE

Oak Woodland		
Western gray Squirrel	Yellow & Red Columbine	Oregon Geranium
Slender-billed Nuthatch	Wayside Aster	Western Waterleaf
Townsend's big Eared Bat	Willamette Daisy	Howell's Bentgrass
	Willamette Valley Larkspur	Thin-leaved Peavine
	Pacific Houndstongue	California Fescue
Oak Savanna / Upland Prairie		
Camus Pocket Gopher	June Grass	Shaddy Horelia
Oregon Vesper Sparrow	Roemer's Fescue	Kincaid's Lupine
Grasshopper Sparrow	California Oatgrass	White-topped Aster
Western Meadowlark	Balsamroot	Racemed Goldenweed
	Grass Widows	Upland Yellowviolet
Riparian		
Bald Eagle	Tall Bugbane	Tall Western Groundsel
Yellow-brested Chat	Celery Leaved Lovage	Siberian Candyflower
Willow Flycatcher	Alaska Oniongrass	Tall Western Meadowrue
American Beaver	Henderson's Sedge	Smooth Woodland Violet
Western Pond Turtle	Western Trillium	Spring Beauty
Wetland / Open Water		
Red-legged Frog	Meadow Checkermallow	Willamette Daisy
Pacific Lamprey	Hitchcock's Blue-eyed Grass	Meadow Sidalcea
Oregon Chub	Bradshaw's Desert Parsley	Rosy Plectritis
	Peacock Larkspur	Howellia
	Timwort	Soft Rush

TEMPORAL MAPPING

To determine sensitive areas of the WCP, target plant and animal species are studied by using the diagrams previewed earlier (Figure 3.1a - 3.2b). First, each individual animal species' breeding, rearing, foraging, and hibernating or migrating time are documented for when they are engaged in each activity during the month or time of day (Figures 4.4 - 4.7). For plant species, bloom time is tracked (Figures 4.8 - 4.11). In order to begin to determine spatiality of these qualities on a site, temporal mapping is divided into four separate habitat types of oak woodland, oak savanna/ upland prairie, riparian/forest, and wetland/open water. Each animal and plant species has a desirable habitat type and falls into one of these categories. After each individual species is tracked, a temporal diagram is made to represent all species together within a habitat type. This begins to highlight which times of the year are more sensitive than others. For animal species, these diagrams are simplified to show moments of breeding and rearing. In general, rearing occurs directly after breeding. However, for some animals, there is a longer gestation period which is evident by gaps between breeding and rearing. For plant species, the entire average bloom cycle is recorded. Viewing all temporal mapping of habitats together begins to reveal times of opportunity for public access of a site, where there is an interest in trail use by hikers, and low risk for sensitive target plants and animals (Figure 4.15 - 4.16).

OAK WOODLAND
ANIMALS



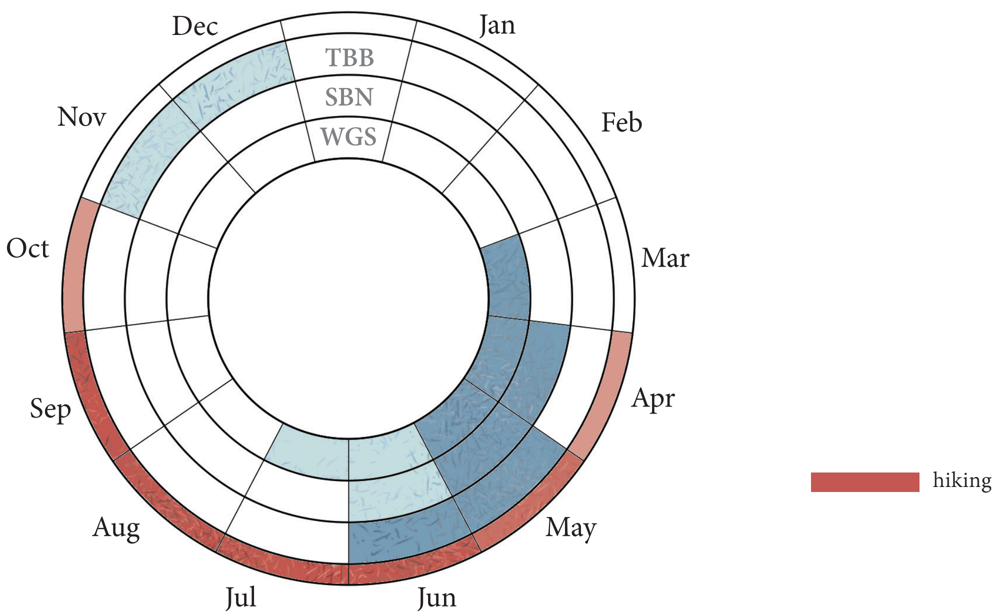
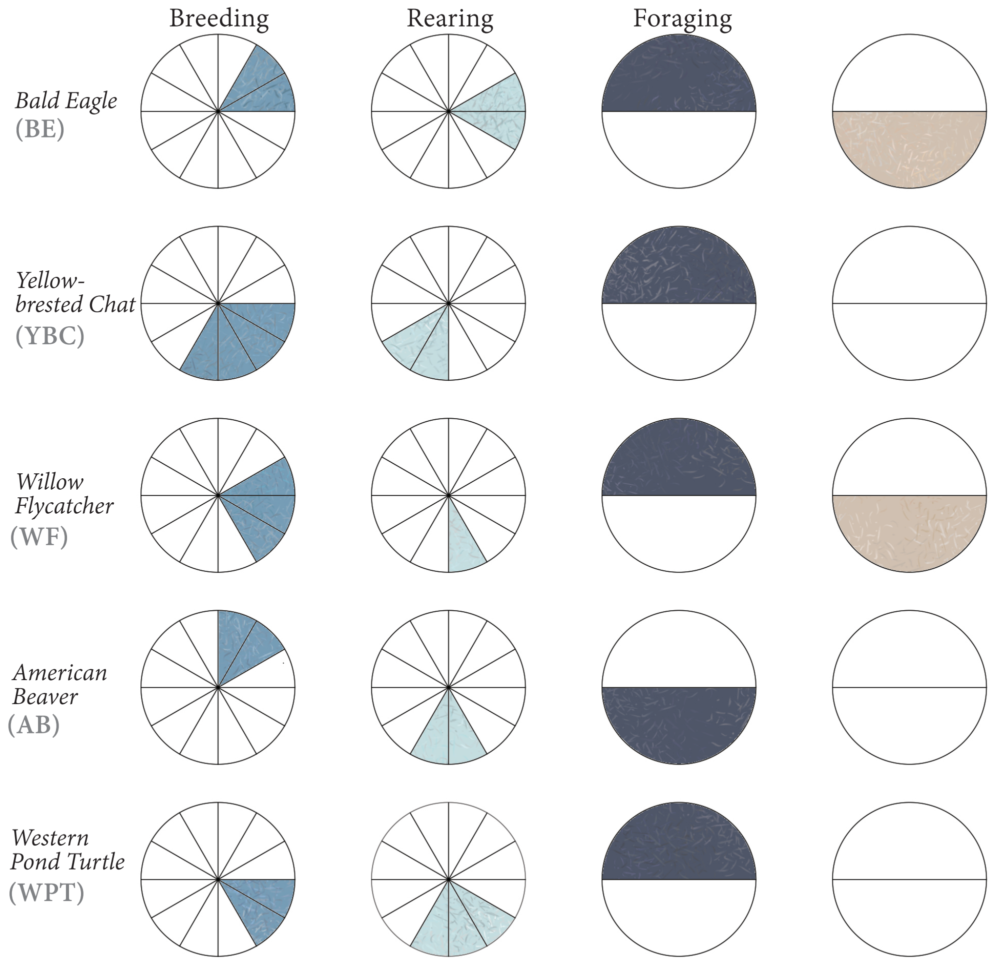


Figure 4.4

OAK WOODLAND: ANIMALS

Sensitive species were chosen based on existing strategy species in habitat management plans in the Willamette Valley. Diagram on left combines moments of sensitivity for all three chosen species who use oak woodland as habitat.

RIPARIAN
ANIMALS



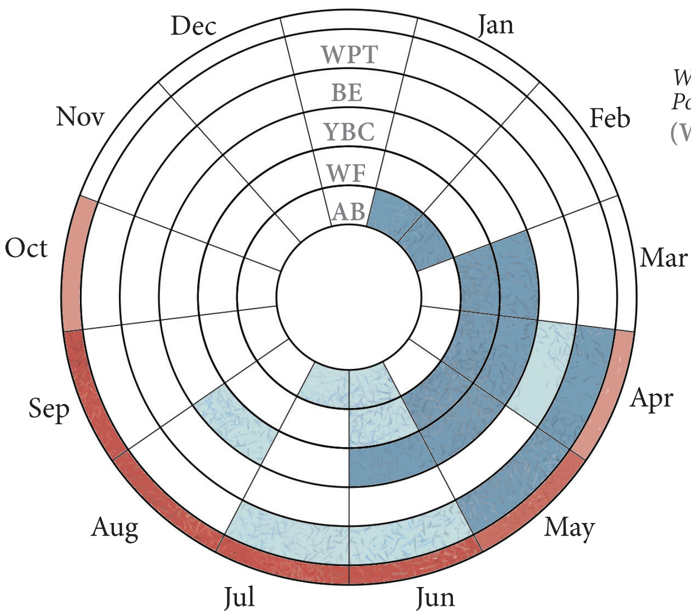


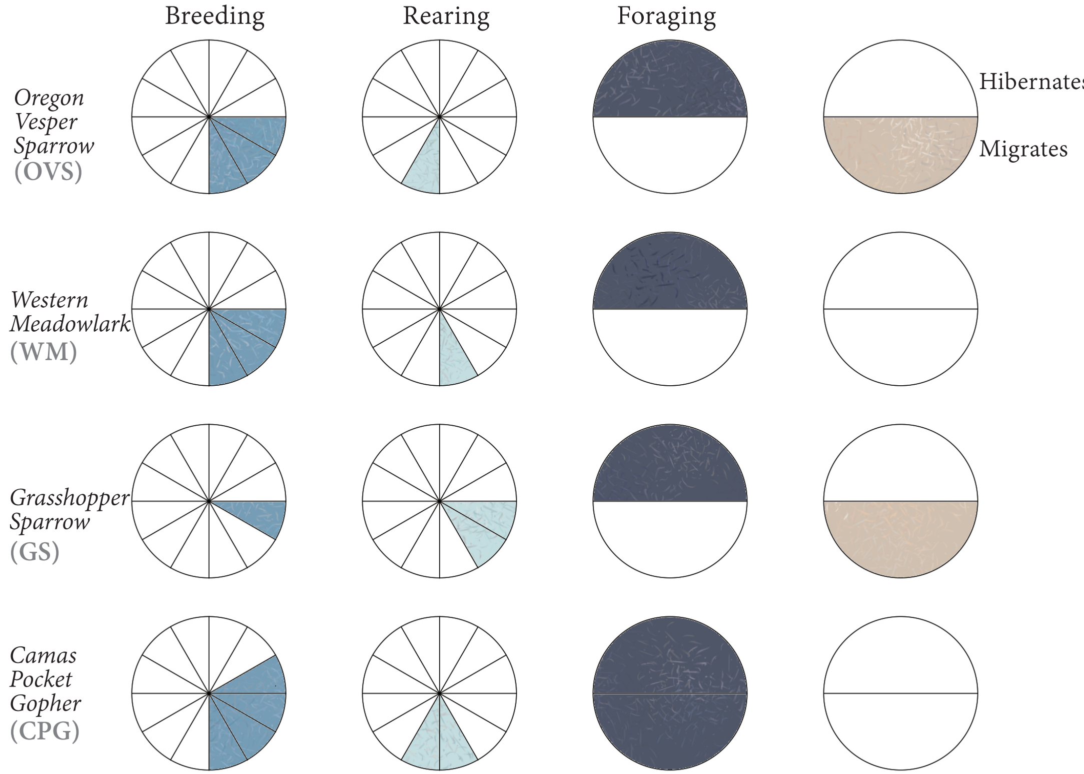
FIGURE 4.5

RIPARIAN: ANIMALS

Sensitive species were chosen based on existing strategy species in habitat management plans in the Willamette Valley. Diagram on left combines moments of sensitivity for all five chosen species who use riparian forests as habitat.

OAK SAVANNA & UPLAND PRAIRIE

ANIMALS



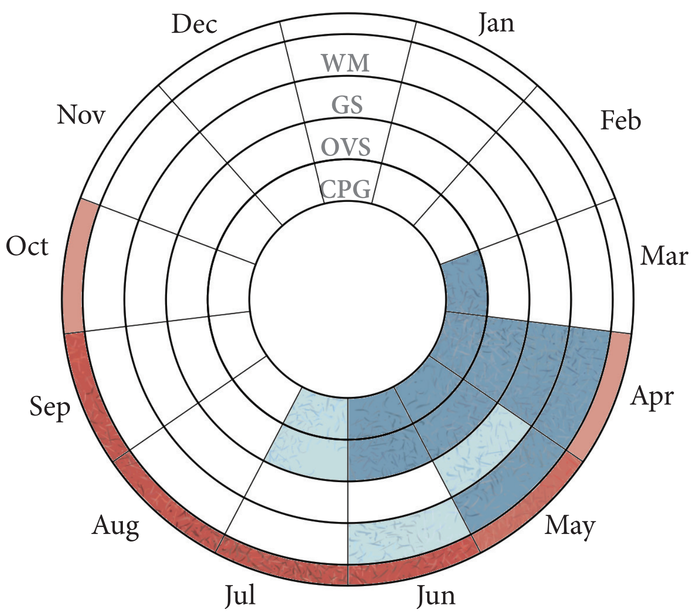
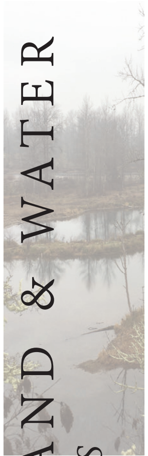


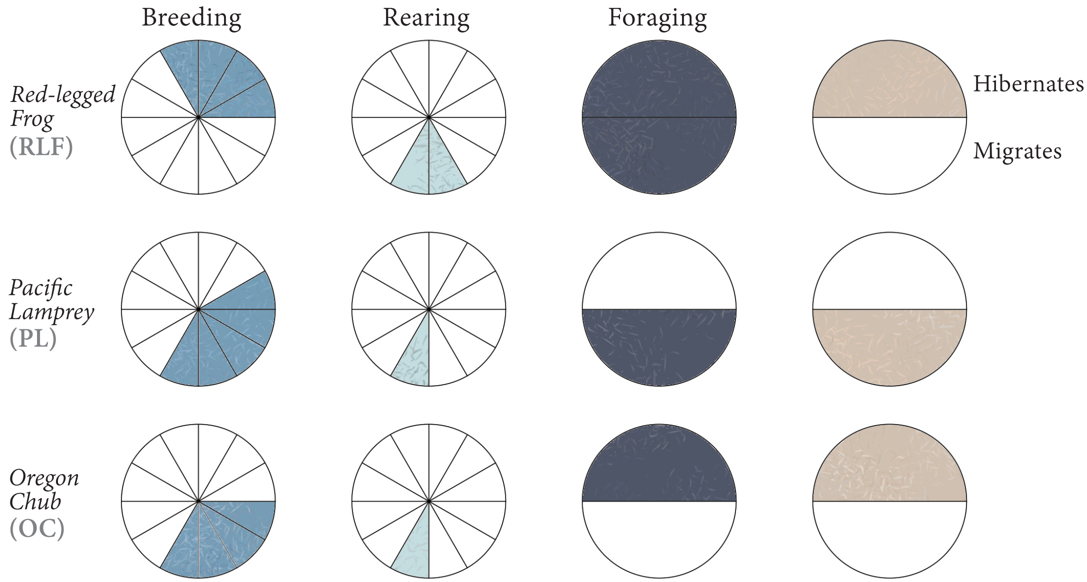
Figure 4.6

OAK SAVANNA & UPLAND PRAIRIE: ANIMALS

Sensitive species were chosen based on existing strategy species in habitat management plans in the Willamette Valley. Diagram on left combines moments of sensitivity for all four chosen species who use oak savanna and upland prairie as habitat

WETLAND & WATER
ANIMALS





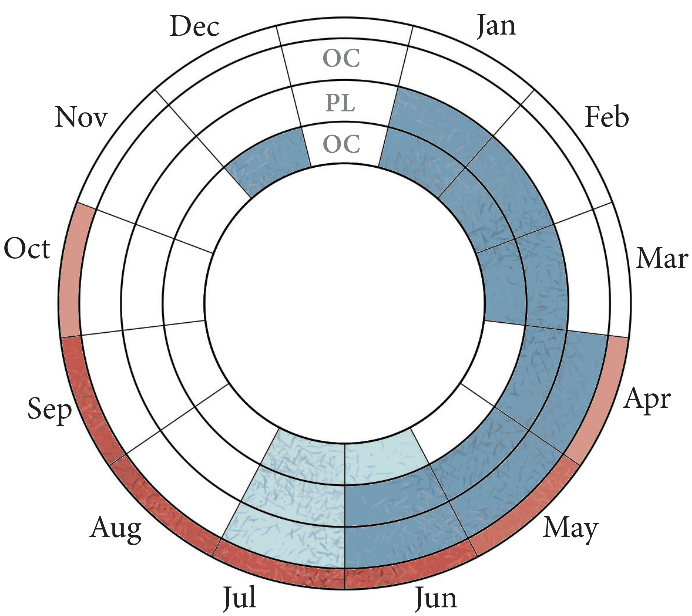


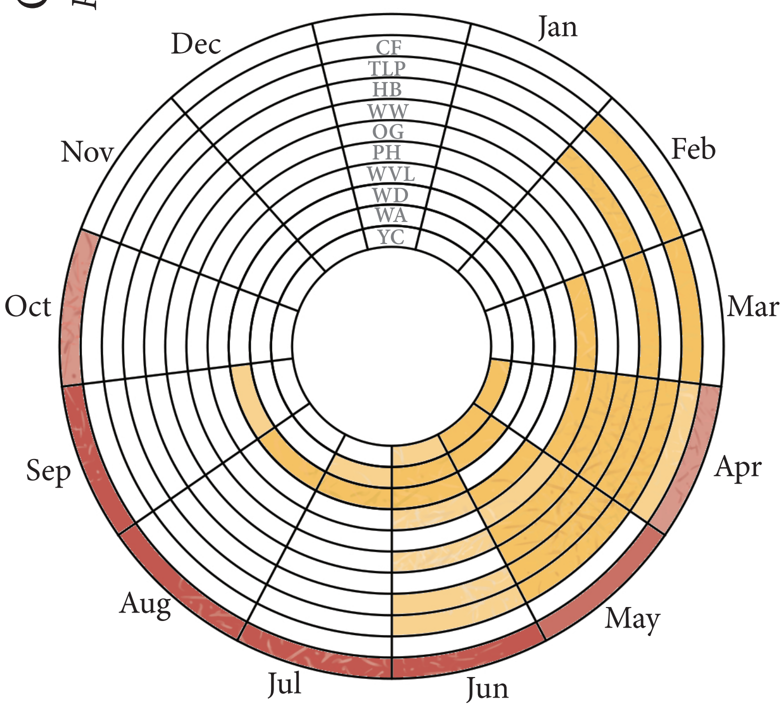
Figure 4.7

WETLAND & OPEN WATER: ANIMALS

Sensitive species were chosen based on existing strategy species in habitat management plans in the Willamette Valley. Diagram on left combines moments of sensitivity for all three chosen species who use wetlands or water bodies as habitat.

OAK WOODLAND

PLANTS



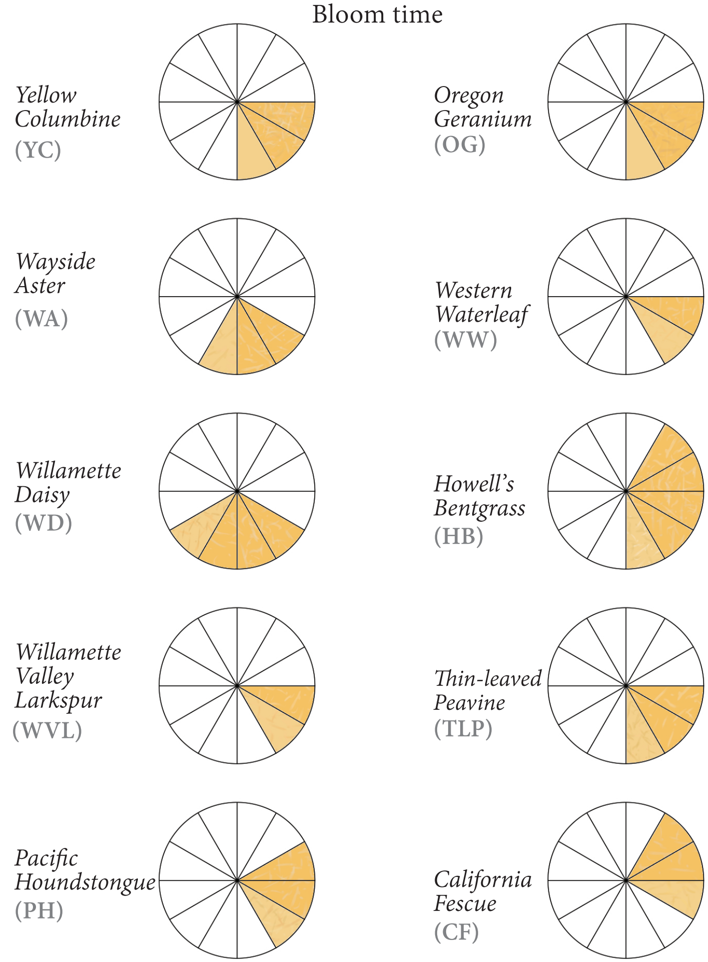
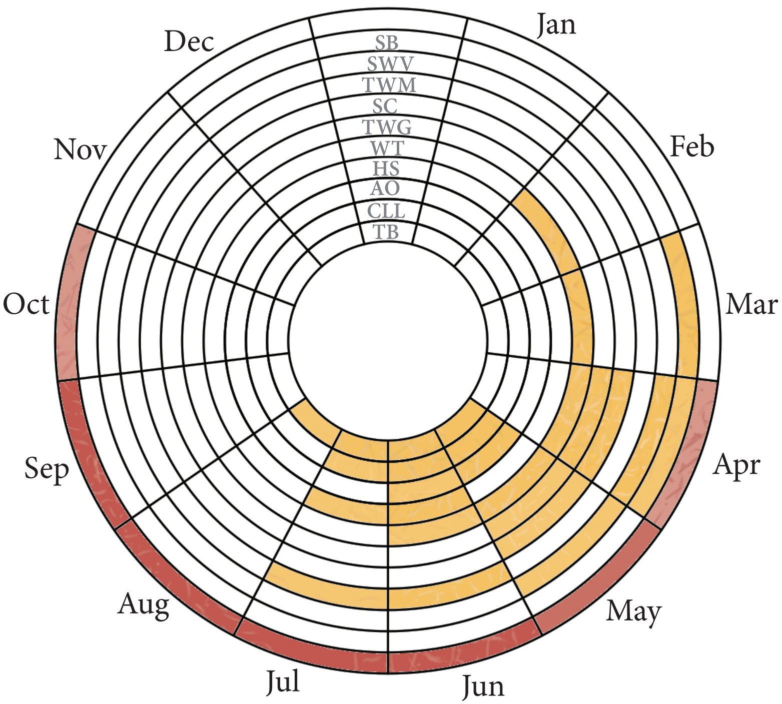


FIGURE 4.8

OAK WOODLAND: PLANTS

Sensitive species were chosen based on existing strategy species in habitat management plans in the Willamette Valley. Diagram on left combines moments of sensitivity for all ten chosen species that grow in oak woodland habitat.

RIPARIAN *PLANTS*



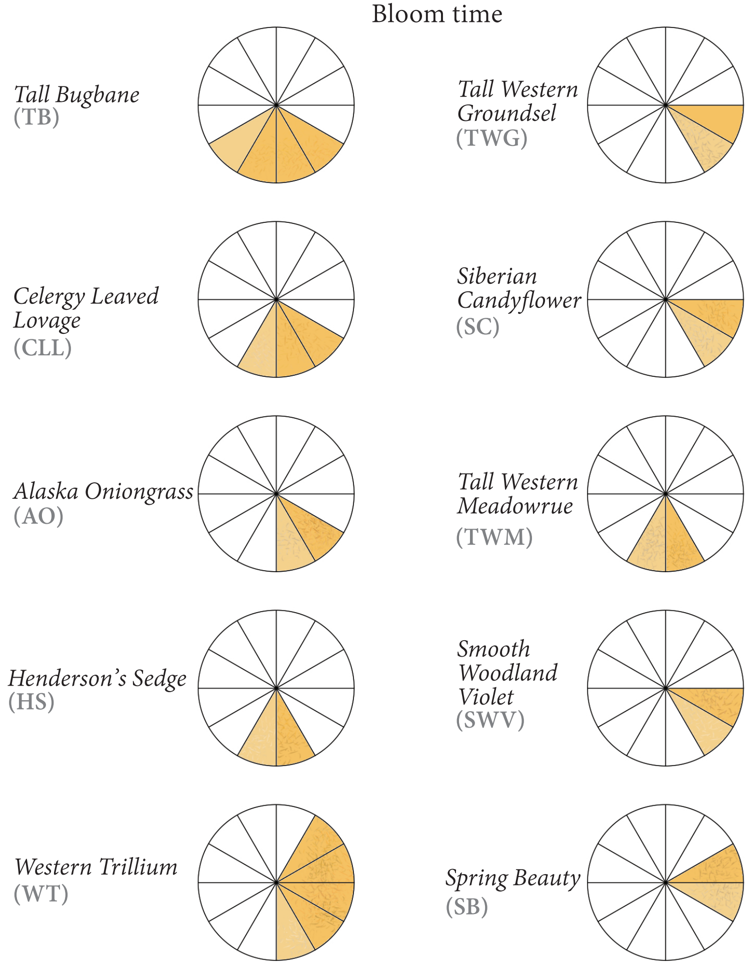
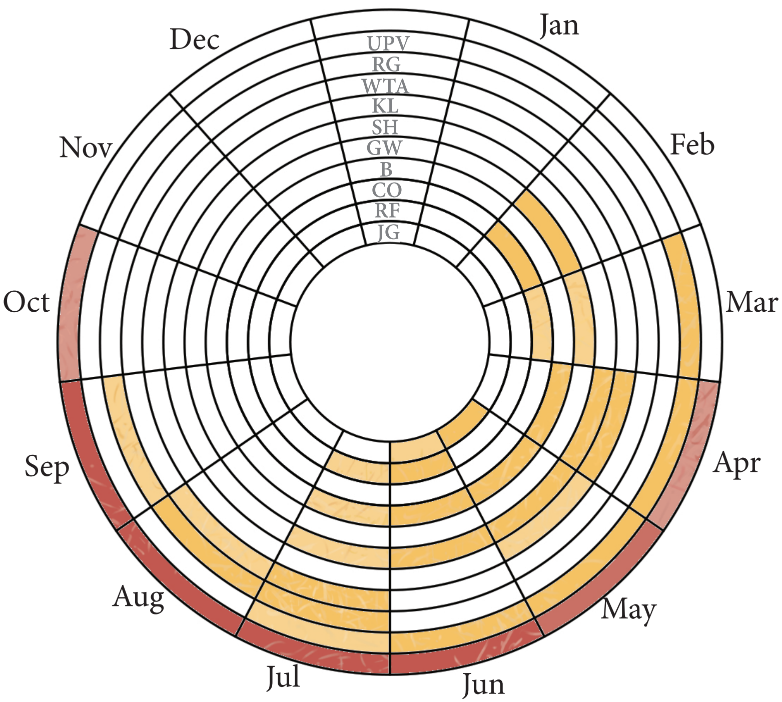


FIGURE 4.9

RIPARIAN: PLANTS

Sensitive species were chosen based on existing strategy species in habitat management plans in the Willamette Valley. Diagram on left combines moments of sensitivity for all ten chosen species that grow in riparian habitat.

OAK SAVANNA & UPLAND PRARIE *PLANTS*



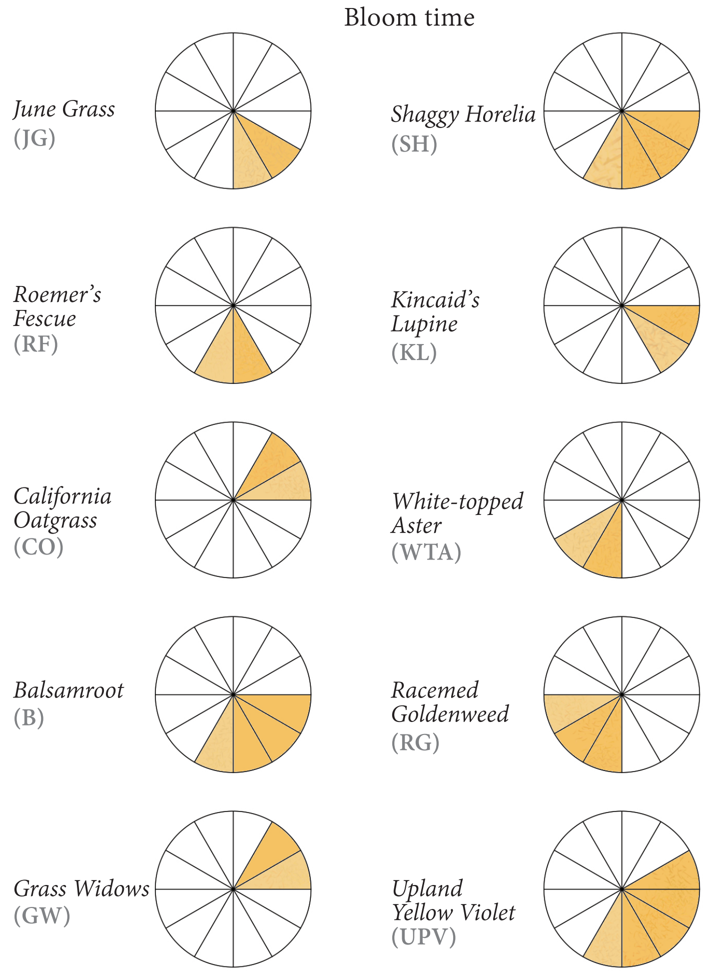


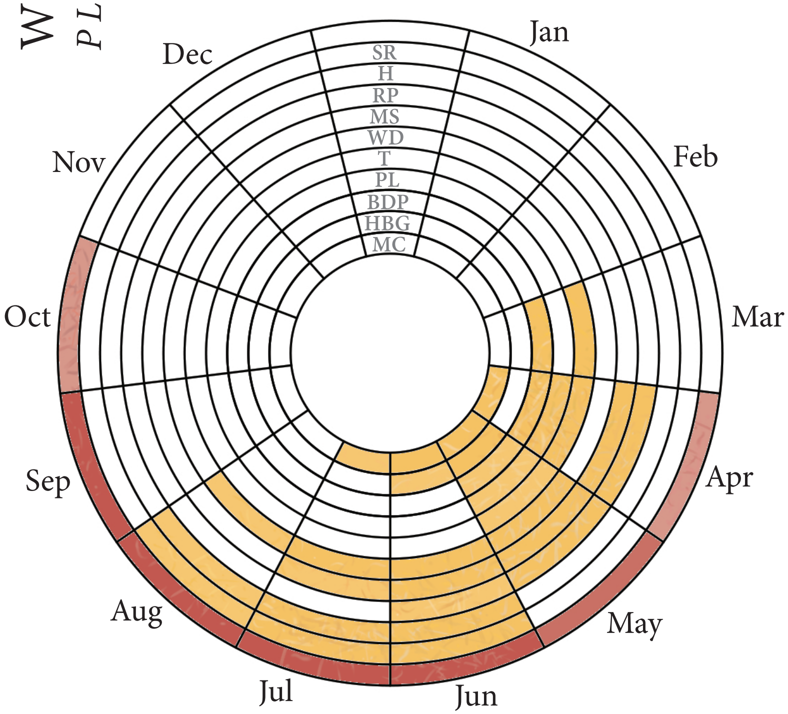
FIGURE 4.10

OAK SAVANNA & UPLAND PRAIRIE: PLANTS

Sensitive species were chosen based on existing strategy species in habitat management plans in the Willamette Valley. Diagram on left combines moments of sensitivity for all ten chosen species that grow in oak savanna or upland prairie habitat.

WETLAND & WATER
PLANTS





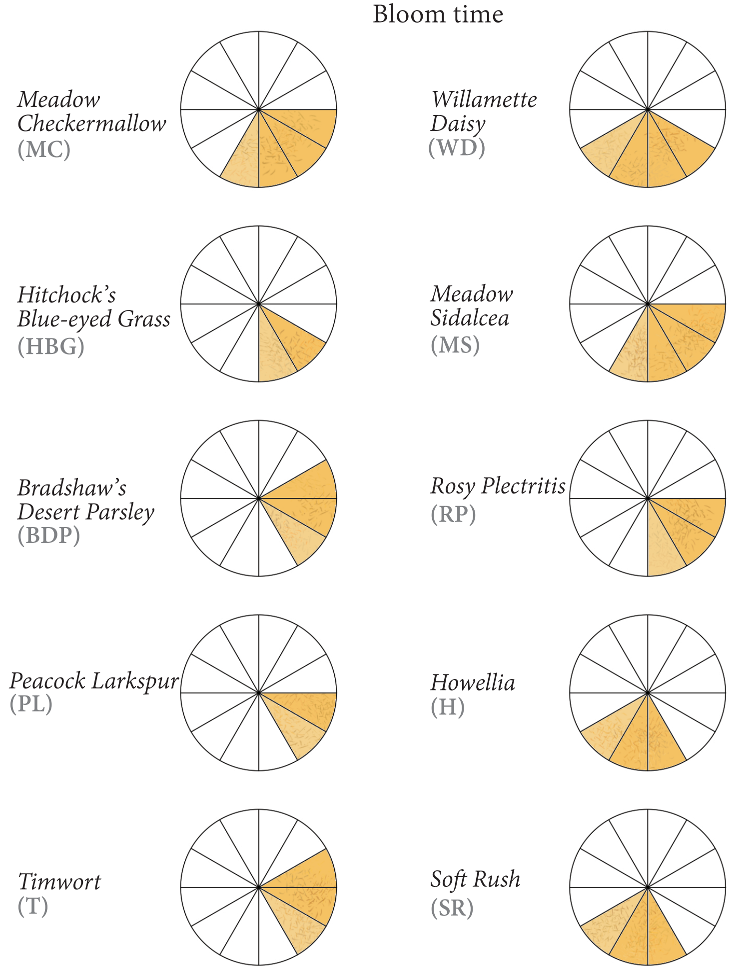


Figure 4.11

wetland & open water: plants

Sensitive species were chosen based on existing strategy species in habitat management plans in the Willamette Valley. Diagram on left combines moments of sensitivity for all ten chosen species that grow in wetland habitat.

ANIMALS

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Oak Woodland	1	1	1	2	3	3	1				1	1
Upland Prairie & Oak Savanna			1	4	4	3	2					
Riparian	1	2	2	4	3	4	3	1				
Wetland Prairie & Open Water	2	2	2	2	2	3	3					1

- low sensitivity
- medium sensitivity
- high sensitivity

+

PLANTS

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Oak Woodland		2	3	8	9	6	2	1				
Upland Prairie & Oak Savanna		2	3	4	5	5	6	2	1			
Riparian		1	2	5	7	6	4	1				
Wetland Prairie & Open Water			2	6	8	7	5	3				

=

TOGETHER

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Oak Woodland	1	3	4	10	12	9	3	1			1	1
Upland Prairie & Oak Savanna		2	4	8	9	8	8	2	1			
Riparian	1	3	4	9	10	10	7	2				
Wetland Prairie & Open Water	2	4	4	8	10	10	8	3				

FIGURE 4.12

QUANTIFYING SENSITIVITIES

The number of animals and plants that are sensitive during each month are recorded within each habitat type. These months are then categorized to low, medium, or high sensitivity. By adding animals and plants together, an overall sensitivity for each month per habitat of the Willamette Confluence Preserve emerges.

To quantify moments of sensitivities among species, the number of animals and plants which are sensitive within each habitat every month are recorded in a table (Figure 4.12). Doing this creates a hierarchy of high to low sensitive times. Months that have the highest number of animal and plant species affected are charted as “high”. Second highest chart “medium” and lowest in “low”. It is important to not only view plants and animals separately in each habitat, but to begin to create an evaluation of the site with plants and animals together. Adding sensitive species together starts to show the overall sensitivity of a habitat throughout the year.

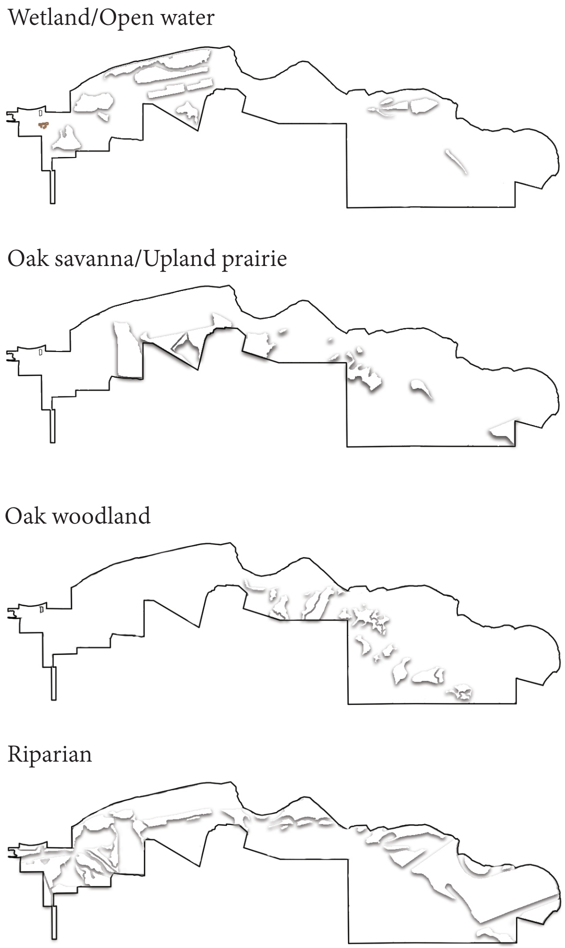


Figure 4.13

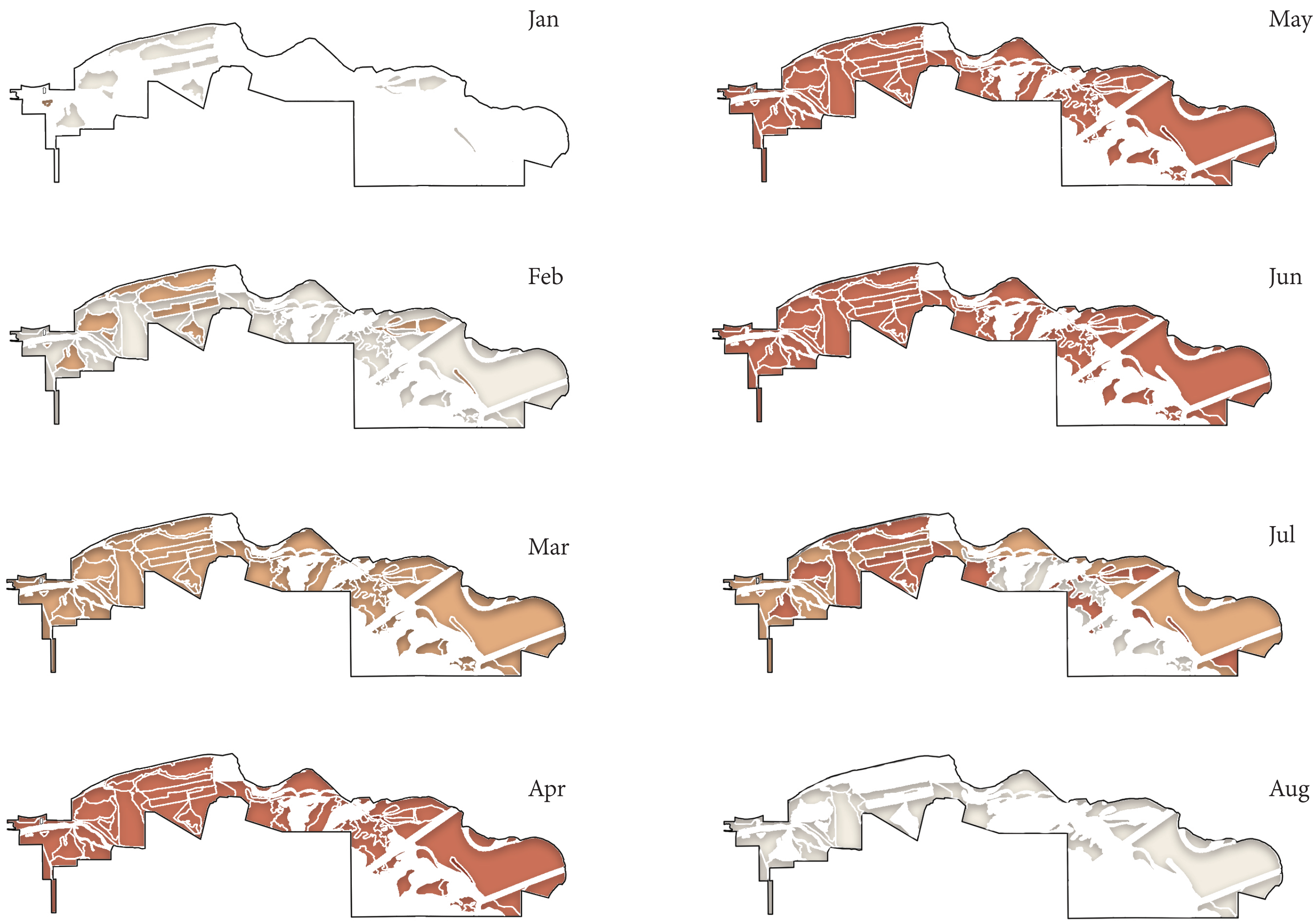
SHAPES OF HABITATS USED BEFORE ASSIGNING LEVEL OF SENSITIVTY

SPATIAL MAPPING

Levels of sensitivities determined by quantifying number of species sensitive each month and organized by month can be translated onto physical maps of the site (Figure 4.14). Habitat areas from the desired future conditions vegetation map are used to assign levels of sensitivity (Figure 4.13). For example, in figure 4.14, January shows wetland areas as low sensitivity. This habitat in February has medium sensitivity. In the month of May, wetland, oak savanna, riparian and oak woodland are all high sensitivity. The months that have the highest number of sensitive plant and animals should be a high priority for trail management when planning for future use. At a glance, the entire site looks sensitive for several months out of the year. Additionally, the most sensitive times of the year are also often the most popular times for hikers to want to be on trails. Watching flowers bloom and birds become busy in spring are some of the most enjoyable times to experience in a PNA.

To find months of opportunities for human access on the site, I diagrammed times at which plant and animal sensitivity is low on the site, and when it is a desirable time for hikers to be on trails (Figure 4.15 - 4.16). In general, October and September are ideal times to provide access for the public while keeping sensitive species protected.

The benefit of ranking habitat areas to low, medium, and high sensitivity across the year, however, is that designers and planners can implement different solutions at a range of restriction levels. For example, deciding to not build trails at all in areas of high sensitivity for several months of the year is a decision of high restriction. It is also a decision of large scale. On the other end of the spectrum, using raised boardwalks in wetland areas to decrease direct impact on habitat is low restriction as it still allows people on site. This is also a small design scale solution. Depending on access to resources, public desires, and the quality of the restored PNA, planners and designers can apply solutions across a range of level of restriction and scale (Figure 4.17). The following section will expand on planning and design strategies and recommendations for the WCP.



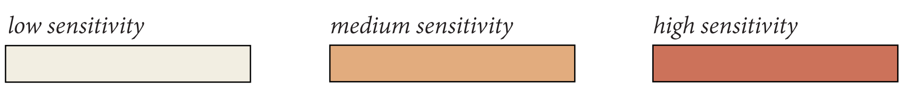
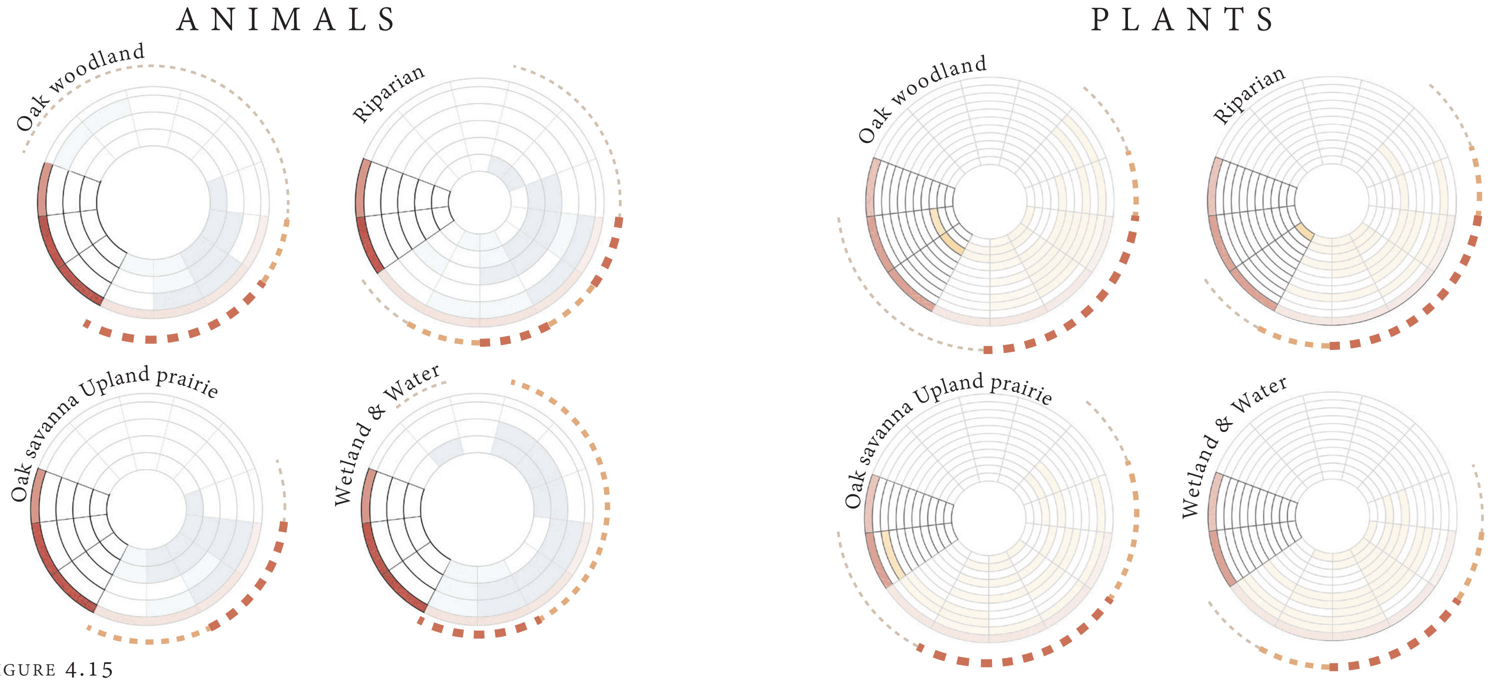


Figure 4.14

TRANSLATING TEMPORAL SENSITIVITES TO SPATIAL MAP

All months that have recorded sensitivity of any level are recorded onto the site map. For WCP, this is January - August. Shapes filled reflect the combined sensitivities of all habitats.

OPPORTUNITIES



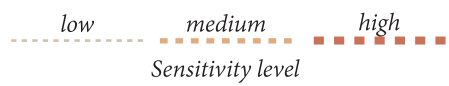


FIGURE 4.15

OPPORTUNITIES

Individual habitats highlighting windows of desired hiking months and low sensitivity.

TOGETHER

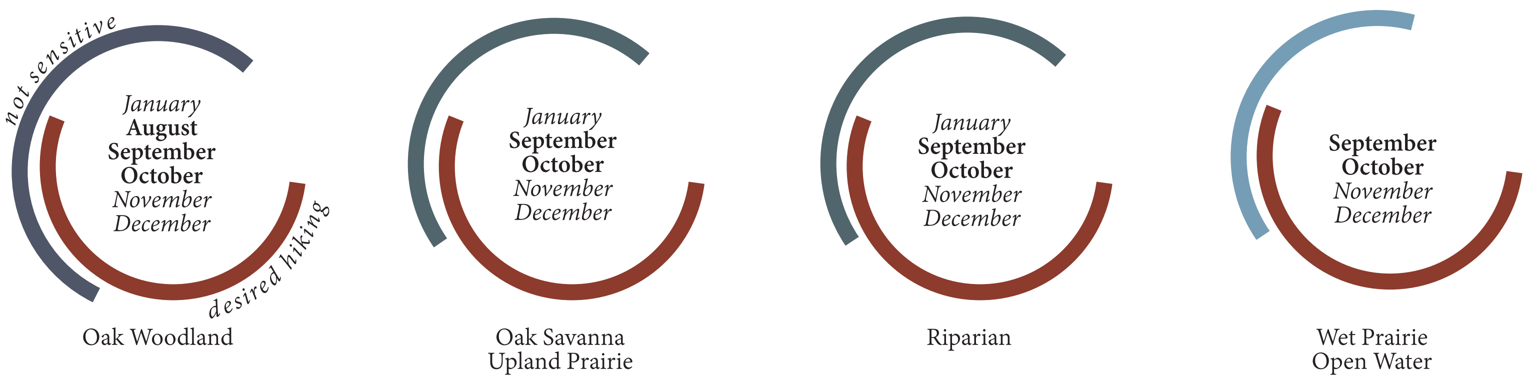


FIGURE 4.16 LESS SENSITIVE MONTHS

A synthesis of times of opportunity for public access defined by the overlap of months which are less sensitive for plants or animals, and are desirable for hikers. Months listed inside circles are when there is little to no sensitivity, and months in bold are those which overlap with desired hiking times.

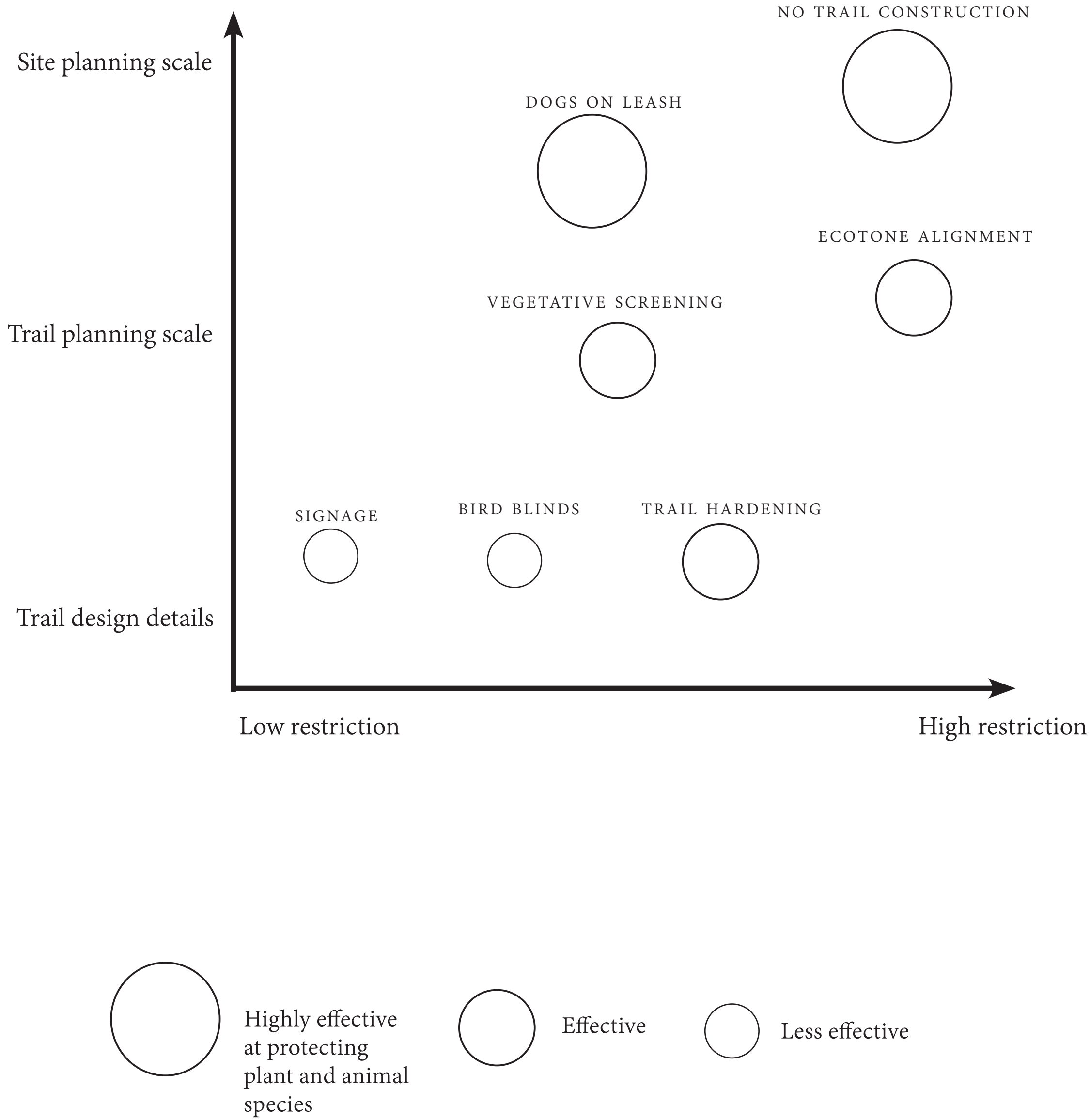


FIGURE 4.17

MANAGING RISKS BY RESTRICTIONS

Solutions to lower risk of disturbing sensitive species on a sliding scale from low to high trail use restrictions.

Chapter 5

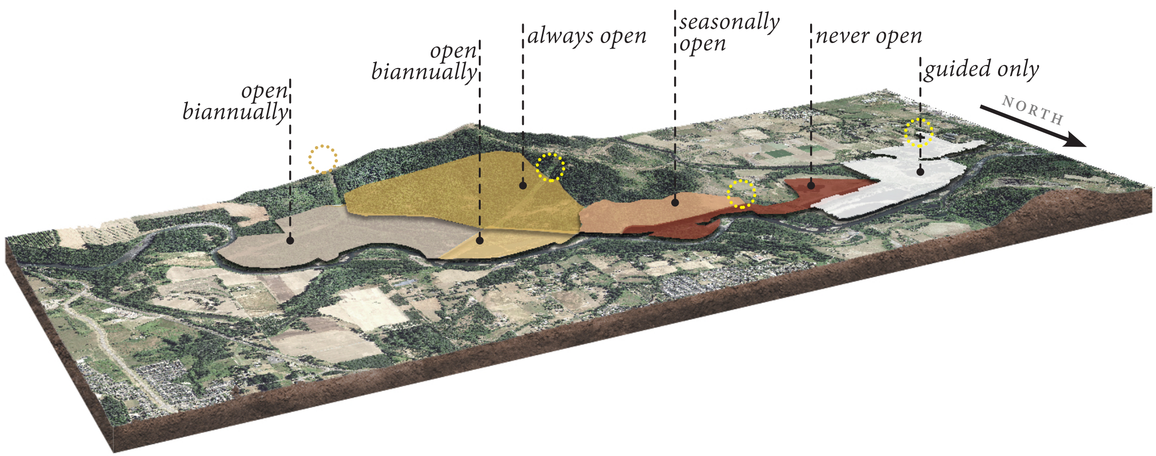
Implementation

SITE PLANNING STRATEGIES

TRAIL PLANNING STRATEGIES

TRAIL DESIGN DETAILS

In order to know when to use which type of strategy, the severity of sensitivity and the frequency of the sensitivity are considered. An area of high sensitivity for several months out of the year could lead to a strategy of no trail construction in that area. On the other hand, an area of low sensitivity for only one or two months out of the year has the potential for trail systems that implement design techniques such as trail hardening to encourage hikers to stay on trail. By adjusting considerations based on levels of seasonal sensitivities, planners and designers can look across spatial and temporal scales to plan for the introduction of public access.



This chapter will introduce possible strategies to minimize disturbance to plant and animal species on three different scales. *Site planning scale* strategies cover the entire PNA that has been restored. The *trail planning scale* presents strategies that zoom in and offer strategies of alignment and trail placement. The *trail design details* offer materiality considerations for established trail sites.

I present a set of general strategies at each of the three scales and then illustrate how a subset of these could be implemented at the Willamette Confluence Preserve (*shown in italics*). These strategies described are not an exhaustive list of all strategies and focus primarily on ones that could specifically work for the WCP.

SITE PLANNING STRATEGIES

NO-BUILD AREAS

In areas where the majority of the land cover is highly sensitive during four or more months, it is in the best interest of plant and animal habitat to avoid building trails altogether.

In the WCP, the western region of the site is largely riparian and wet prairie which is home to highly sensitive plant and animal species in several months of spring and summer. No construction of trails here may be in the best interest of the target species. However, there is an existing entrance and access road that cuts through this part of the preserve. Because wet prairie and riparian habitats can be excellent locations to witness flowering and bird activity, one option could be to leave this entrance for educational guided tours only (Figure 5.1).

SEASONAL CLOSURES

In areas of concentrated sensitivity during a few months of the year, seasonally closing these trails during peak breeding and rearing times is a good option. This largely depends on the target plant and animal habitats that the existing restoration plan is aiming to protect. In order for seasonal closures to be successful, communicating to the public the reasons and importance of protecting habitat is critical. Resources are required in order to close these trails with signage and physical barriers, as well as occasional monitoring. If a PNA does not have these resources, a better option may be to not build trails in these areas.

If the western side of WCP were to be designated for guided tours only, seasonal trails could be easily enforced by shortening tour routes and restricting them to the furthest west section (Figure 5.1).

DOGS ON LEASH

At a minimum, in areas which experience medium to high sensitivity, it is ideal to encourage owners to leash their dogs. Several studies have demonstrated that dog-owners believe that their trail use is less disturbing than other forms of trail activity. In reality, people with dogs disturb wildlife more than humans alone (Lenth, Knight, and Brennan 2008). Disturbance from dogs can reduce the opportunity for wildlife viewing and a PNA's carrying capacity for wildlife. Designing trail areas with a range of dog restrictions can offer a range of protection and enjoyment for dogs and their owners, as well as the native habitat, however, enforcing a range of levels can cause confusion. In general, if there can be a public consensus that the absence of dogs provides the best protection for sensitive habitats, the least confusing restriction is prohibiting dogs from PNAs.

In the WCP, this project suggests that dogs be on leash at all times due to the large areas of wetland habitat that are especially susceptible to harm from dogs rather than hikers. In some sensitive times of the year, dogs are prohibited.

GUIDED TOURS

Designating areas that allow public access exclusively by guided tours is a method that restricts the number of people entering a site. Doing so can decrease disturbance to plant and animal habitat by monitoring if anyone is going off-trail. Additionally, providing guided tours can teach communities members the importance of restoration and conservation efforts which may lead to hikers visiting responsibly.

The western side of WCP, where there is highly sensivity wetland habitat, can be used as guided tours only as there is already an existing entrance nearby.

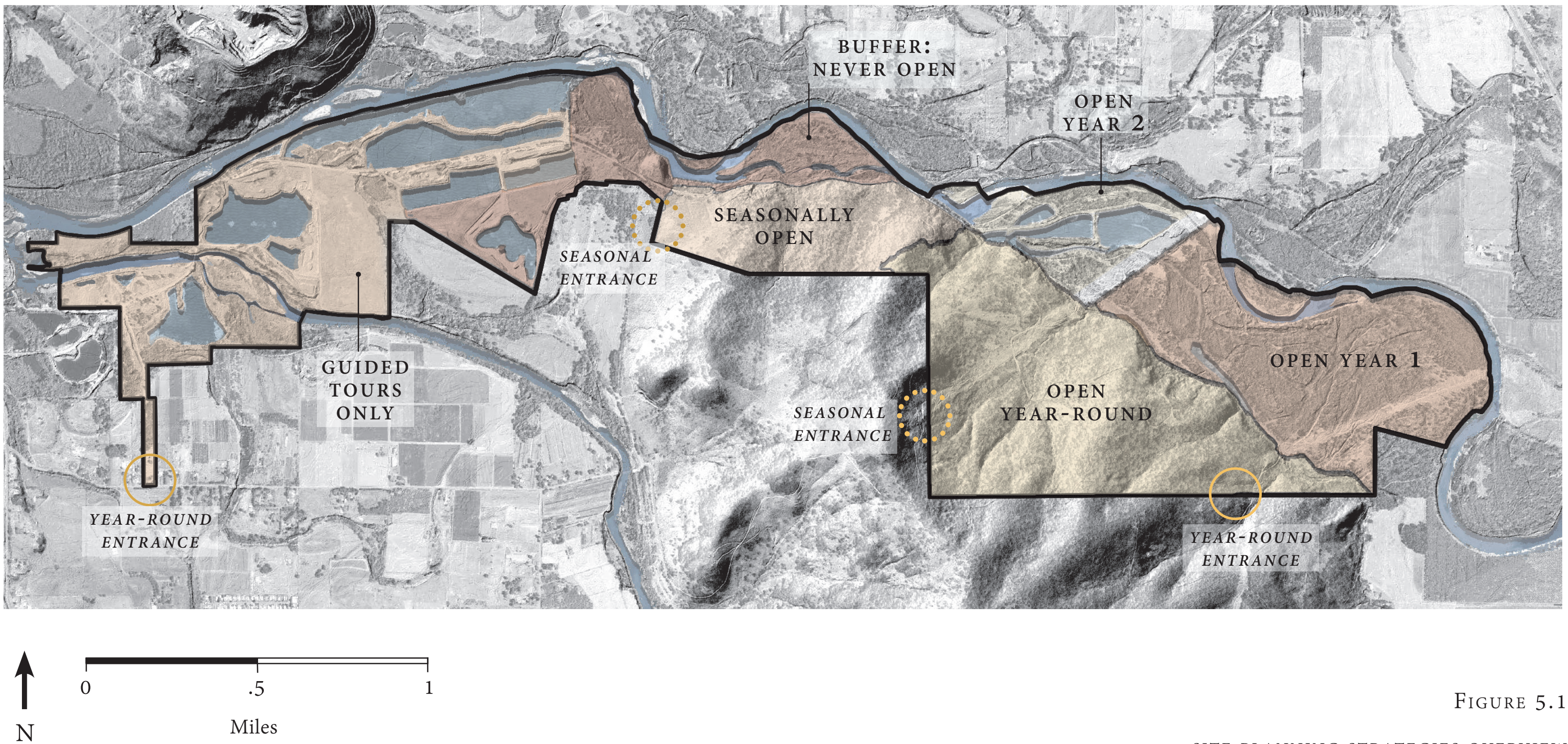


Figure 5.1

site planning strategies overview

Areas of the preserve are divided by areas that change states of restriction and access throughout the year.

WINTER

From **September - January,** the preserve is the least restrictive. Lack of sensitive animal activity such as breeding and rearing allows for hikers to be less of a disturbance. Most plants have already gone to seed, and very few are blooming during this period. Trampling on dormant vegetation will not disturb next year's growth significantly.

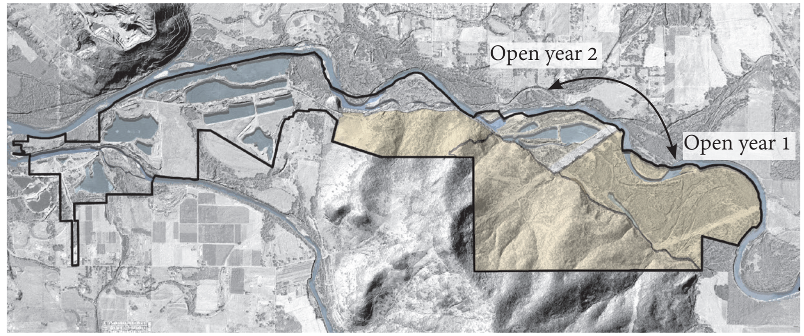
SPRING

From **Februrary - April** the preserve becomes more restrictive, as animals begin to breed and plants begin to bloom. Some areas that were open during the winter now have restricted trails with some seasonal closures. The closed area in the middle of the preserve has expanded, increasing the effect of a buffer between the guided-only area in the west and the area open year-round for all visitors.

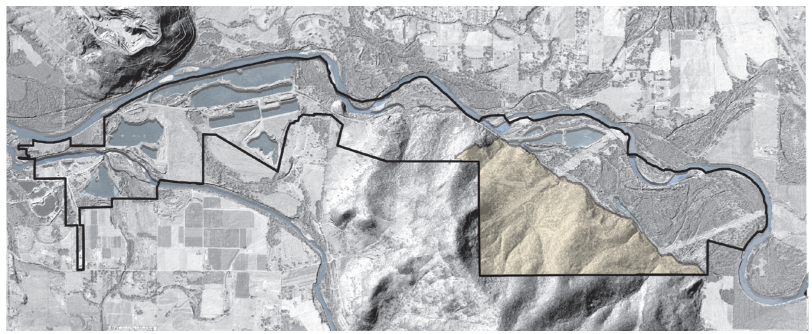
SUMMER

From **May - August** the preserve is the most restrictive to hikers. Many animals are both breeding and taking care of their young and plants are both blooming and beginning to spread their seeds. Long daylight hours are a risk for plant and animal species to be disturbed for an extended period of time. Only one entrance remains open for all hikers from Mt Pisgah trails to concentrate use.

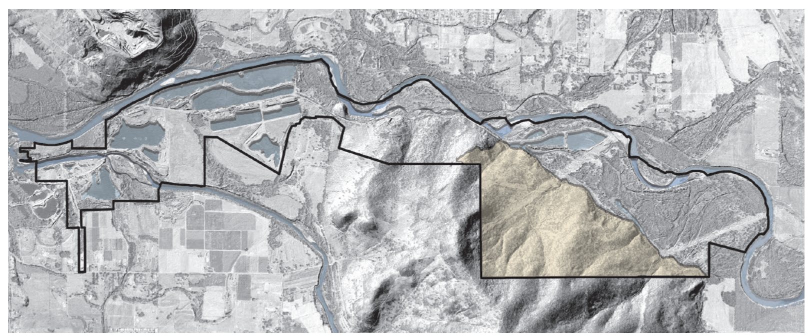
OPEN



The majority of the east side of the preserve is open. Dogs are allowed, though must be on leash. Two northeast areas are open bi-annualing, allowing habitat recovery.

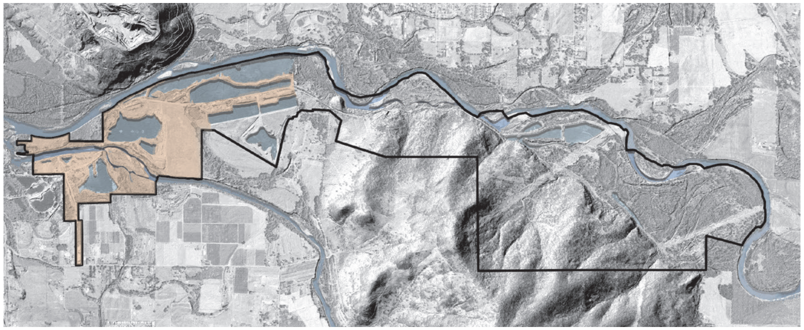


The lower east side of the preserve remains open year-round with two entrances.

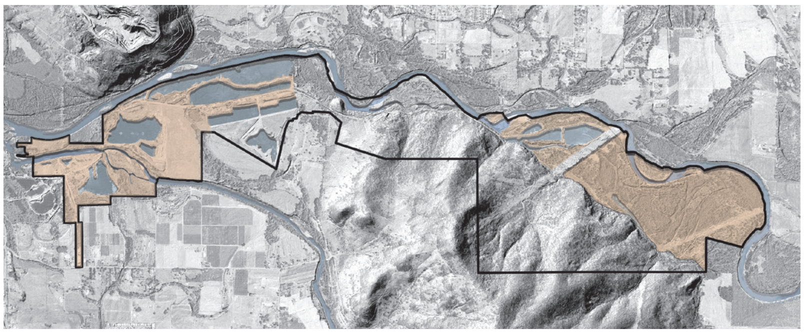


The lower east side of the preserve remains open with only one entrance.

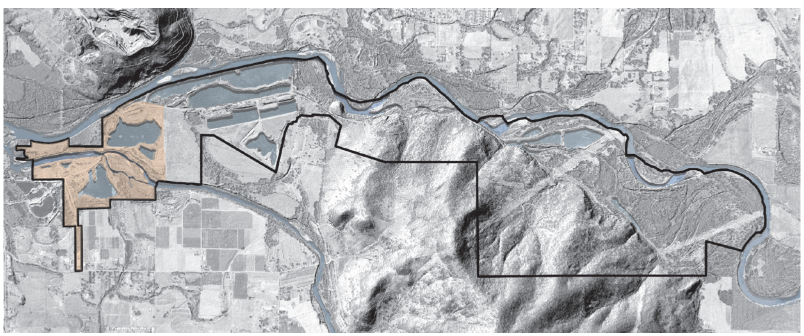
GUIDED ONLY AND RESTRICTED USE



The west side of the preserve is open due to existing road infrastructure, however because of its sensitive prairie habitat, it is only open for guided tours.

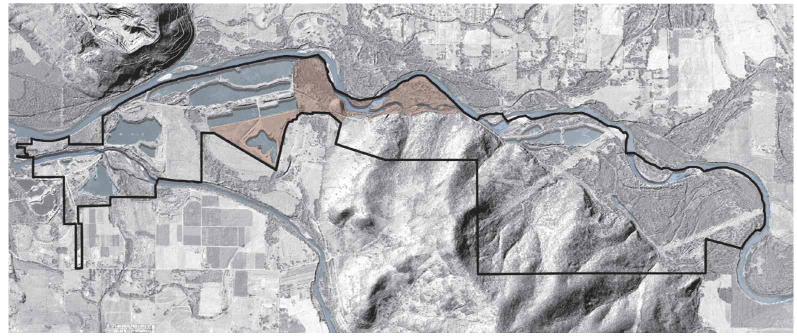


Bi-annual areas have limited use as some trails are seasonally closed to protect habitat.

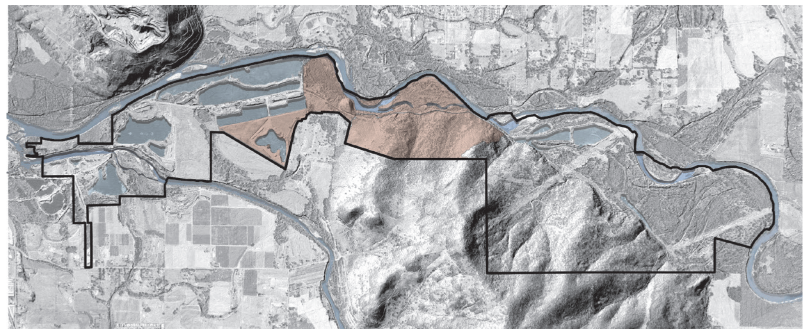


The guided-only zone remains open, however, some trails are seasonally closed.

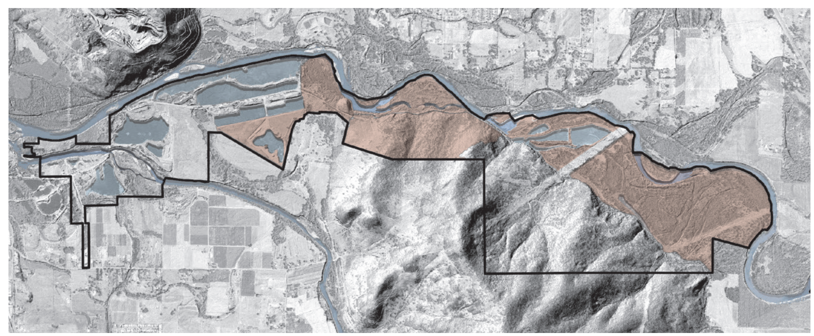
CLOSED



*The area in between the guided-only zone and the public access is a **buffer** that separates user-types, aiming to restrict wanderers into the guided zone.*



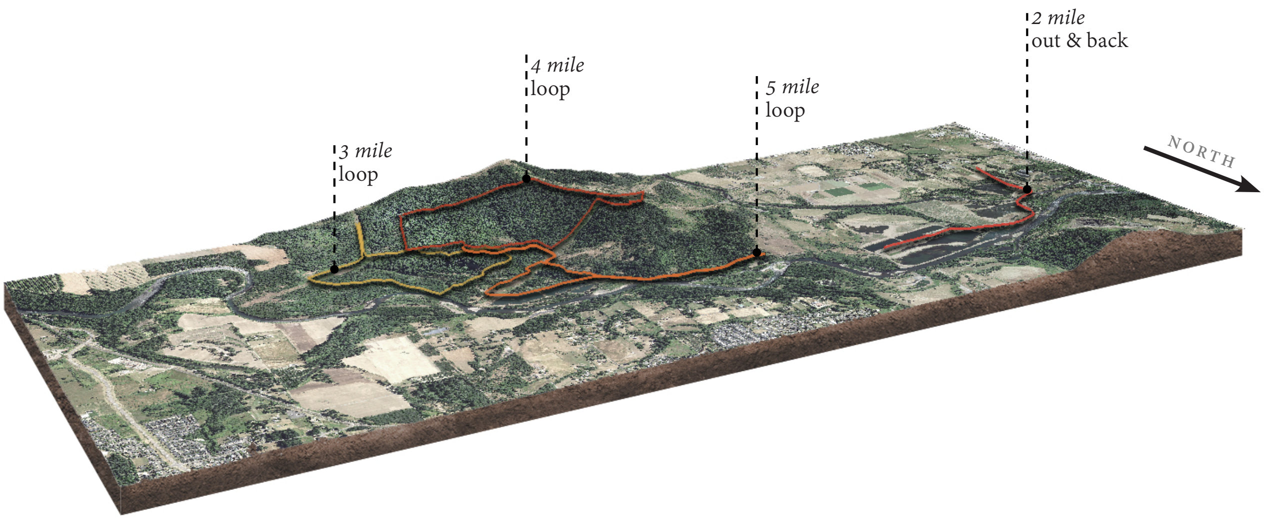
The buffer between the guided-only zone and the public access is extended in spring.



The bi-annual zone is closed, extending the restricted access for animals and plant communities to thrive undisturbed.

TRAIL PLANNING STRATEGIES

Trail planning strategies are mid-scale suggestions for maximizing sensitive plant and animal health when planning for trails. These strategies require a closer look at specific habitats on the site and consider trail placement in relation to those habitats. This stage of planning is done prior to deciding trail design details, though begins to consider how hikers may be led through the landscape. The immediate surroundings of WCP are considered as well as some, but not all, exisiting paths. This is not an exhaustive list of strategies, and in different geographic locations and climates others may be feasible.

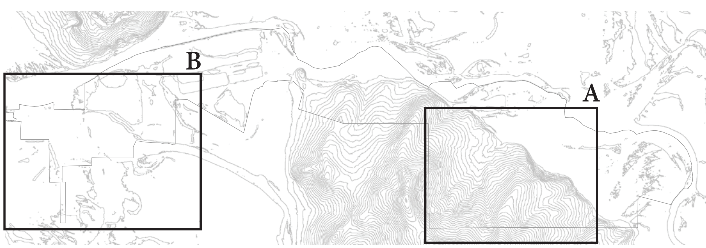


ALIGNMENT

When beginning to design hiking trail routes, designers may consider aligning trails along the ecotones (the edge between two different landscape types) of habitat types, rather than intersecting a habitat thereby causing fragmentation (Figure 5.2). For example, a trail can be aligned at the edge of an oak woodland and an upland prairie. Not only does this help protect plant and animal habitat, it has the potential of allowing the human experience to include views of a vast prairie, as well as the comfort of a forested area behind them. Some plant and animal species require edge habitat to thrive. If edge species are target species to protect in the designated PNA, trail systems could not exclusively use the edge in these habitats and would need to include sections that weave in and out of the edge, to protect targeted species (Figure 5.3).

In area 'A' on the south eastern edge of the preserve, there are patches of oak woodland that act as stepping stones for habitat. Fragmentation of these patches should be avoided.

In the WCP in area 'B' on the western side of the preserve, there are patches of oak savanna and wetland prairie side by side. In order to protect edge species between these habitats, a trail could weave in and out, leaving enough habitat for a specific species.



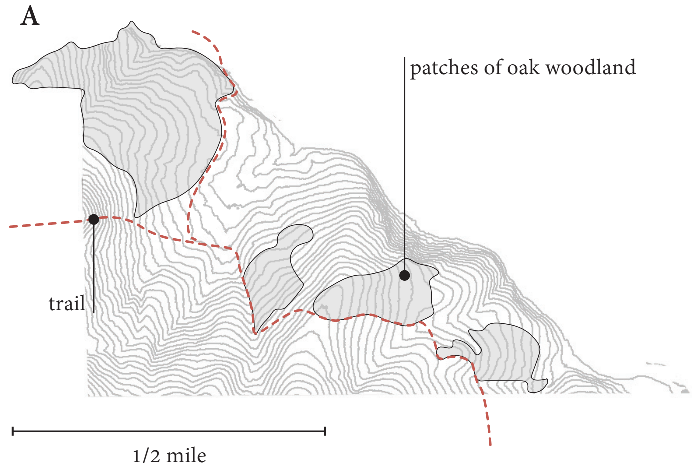


FIGURE 5.2

TRAIL DESIGNED ALONG ECOTONE TO PROTECT HABITAT PATCHES

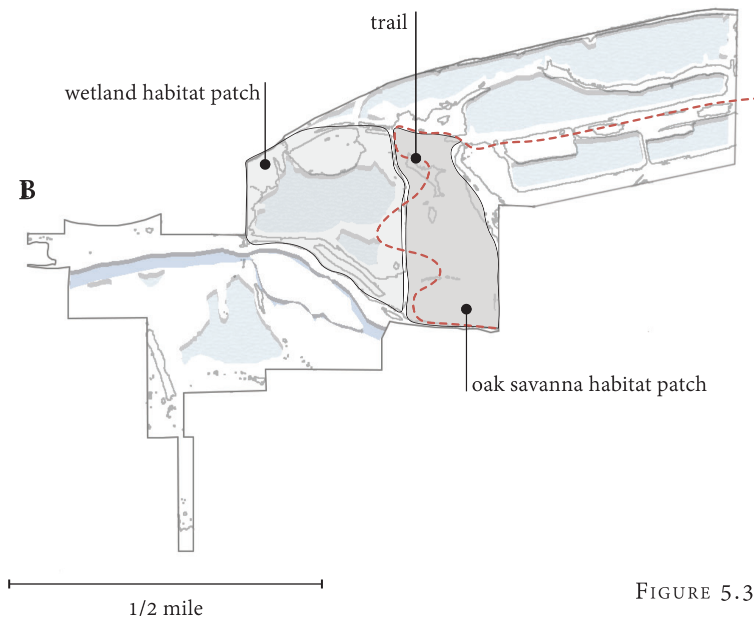
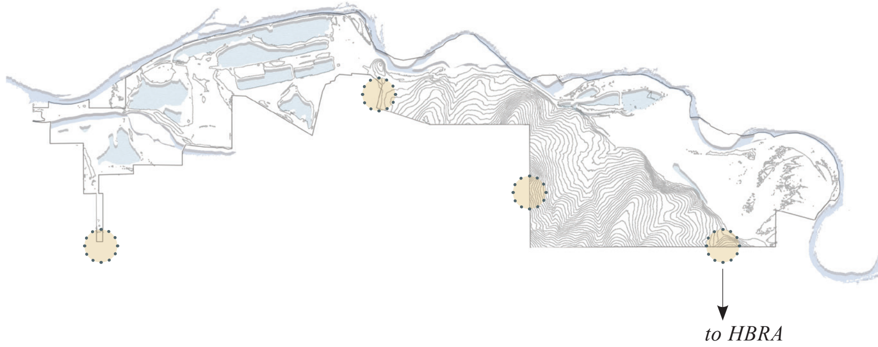


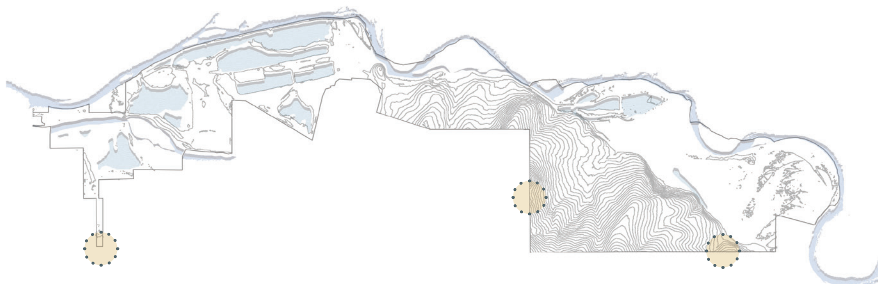
FIGURE 5.3

TRAIL DESIGNED TO PROTECT EDGE SPECIES

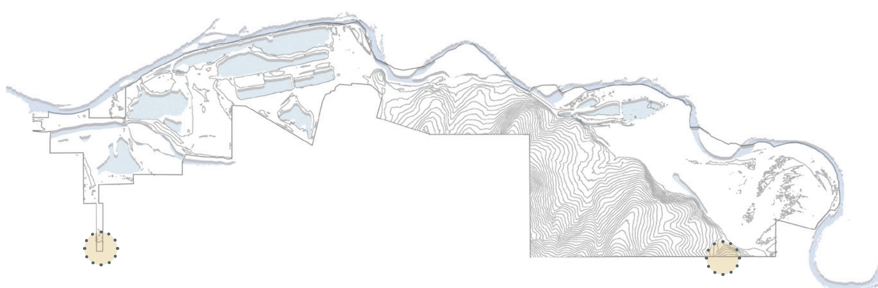
WINTER: SEP - JAN



SPRING: FEB - APR



SUMMER: MAY - AUG



ENTRANCE MANAGEMENT

To help prevent the widespread dispersal of hikers across a site in unwanted areas, establishing clear main entrances concentrates use on a public PNA. Main entrances open year-round defined by clear trail maps, designated parking, and simple facilities can help enforce this concentration of use. Areas of seasonal use may be smaller and have access to a more limited number of trails.

During winter months, the least sensitive times of year at WCP, there could be up to four possible entrances for hikers. Two of these entrances already exist (one for guided tours and another for restoration work access), and two could be a continuation of trails in Howard Buford Recreation Area (HBRA) through the transmission corridors. During early spring, the number of available entrances could be decreased to three, then in summer during high sensitivity months, restrict access to two entrances (Figure 5.4).

Figure 5.4

RESTRICTED ENTRANCES BASED ON SEASON

SEASONAL TRAIL CLOSURES

In areas of concentrated sensitivity during a few months of the year, seasonally closing these trails during peak breeding and rearing times is a good option. To more exactly choose where these seasonally closed trails could be, it is helpful to consider qualities that hikers enjoy. For example, allowing access to water for at least part of the year will provide visitors opportunitiy to enjoy a water's edge and respect its vulnerability during sensitive months in spring. Providing trails that are open year round and share an entrance (such as the intesection of the red and blue dotted trails in diagram on right) can prevent visitors from being too disappointed when one trail is seasonally closed.

In the northeastern part of WCP, trails that run along the river have a higher risk of distrupting aquatic species, especially with presence of dogs. During highly sensitive times, keeping a similar length trail open year round nearby can decrease likilhood of overuse in sensitive areas.

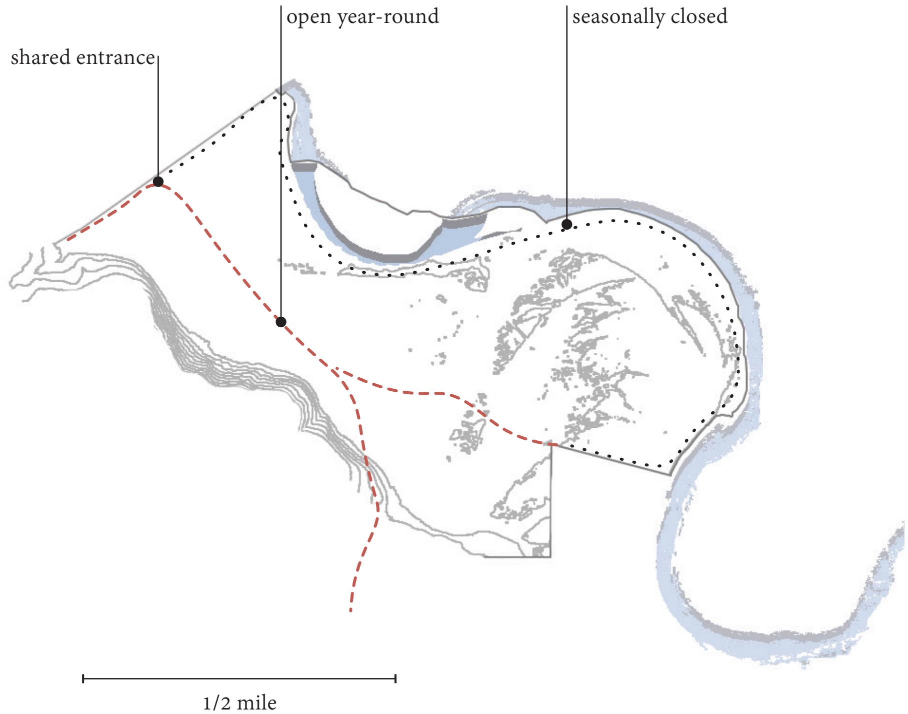


FIGURE 5.5

SEASONALLY CLOSING TRAILS TO REDUCE IMPACT

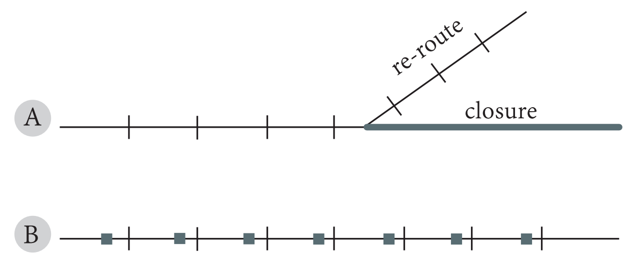
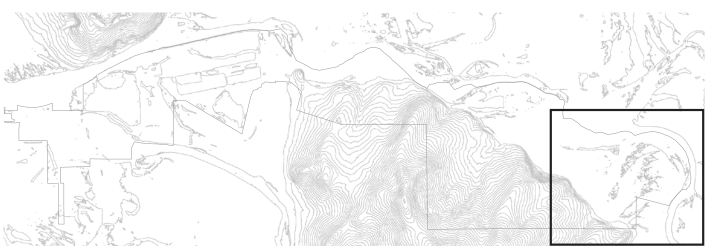


FIGURE 5.6

TEMPORAL CLOSURES CONCEPT

Rather than waiting for degradation to reach a point of required trail closure for a re-route and rehabilitation of a trail (A), seasonal trail closures could protect trail health and habitat during vulnerable times a year (B).



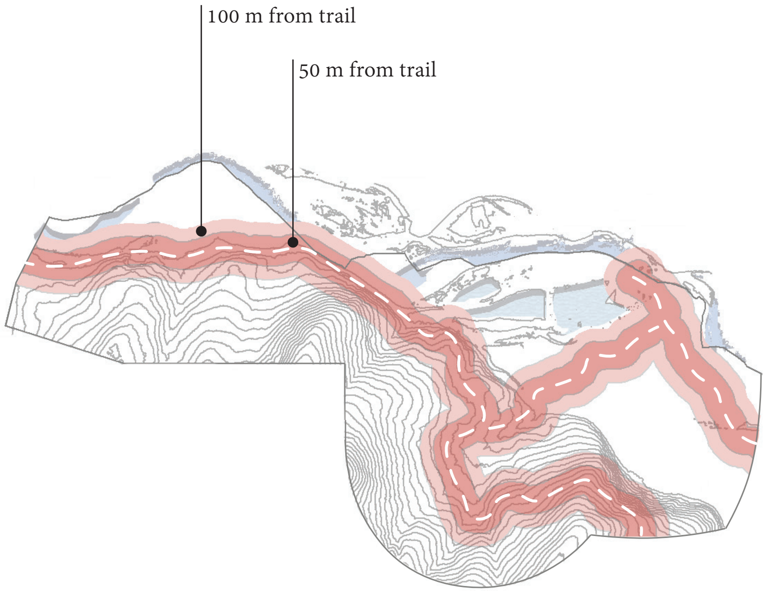


Figure 5.7

APPLYING TYPICAL FID (50M) AND AD (100M) TO BUFFER AROUND TRAIL ROUTE

HABITAT BUFFERS

If habitat assessments have been conducted for a site, existing nesting sites for animals can be mapped within a habitat. Setbacks from these locations can be implemented during the trail design process to prevent animals from needing to flush from hiker disturbance. Depending on the target species, the setback distance can be determined from the animal's FID or AD (Figure 2.7). If this information is unavailable, several studies suggest using between 50 meters and 100 meters (Miller, Knight, and Miller 1998; Rodgers and Smith 1995; Hennings 2017). Professor Bart Johnson, University of Oregon, and James Reed, Director of Stewardship for the Wildlife Land Trust translated zone of influence findings from a grasslands study conducted in Boulder, Colorado (similar to those of the Willamette Valley) to existing trails on HBRA. A 50m zone of influence buffer around the existing 30 miles of trails in HBRA covers 38% of the total acreage of the site. A 100m buffer covers nearly 65%. This impact is similar to plants, whose seeds (especially invasive) have the ability to travel up to 120m (Holmes et al. 2010).

To avoid this level of ecological footprint at WCP, designers and planners can initially recognize the impact of future trails before making trail systems too dense. In areas of WCP where there are existing trails, studying typical FID and AD distance as buffers can help highlight most sensitive edges of habitat (Figure 5.7).

CORRIDORS

For animals that tend to flee under stress from disturbance, or have short FIDs, densely vegetated trail edges can prevent them from quickly fleeing. Animals desire having both vegetation as protection as well as space to escape. Depending on the target animal species and the state of surrounding vegetation, gently modifying density of vegetation in the zone of influence may allow animals to flee without losing a significant amount of energy. Studying the landscape for existing habitat corridors can help influence placement of trails. Corridors are relatively narrow habitats that provide connectivity among similar habitat patches. Avoiding intersecting these corridors can keep the continuity of similar habitat types.

In WCP, the southeastern area is largely mixed-forest. Because of this density, creating clearings for corridors can help sensitive species flee more readily when disturbed. Alternatively, trails can be aligned with exisitng natural corridors within the habitat.

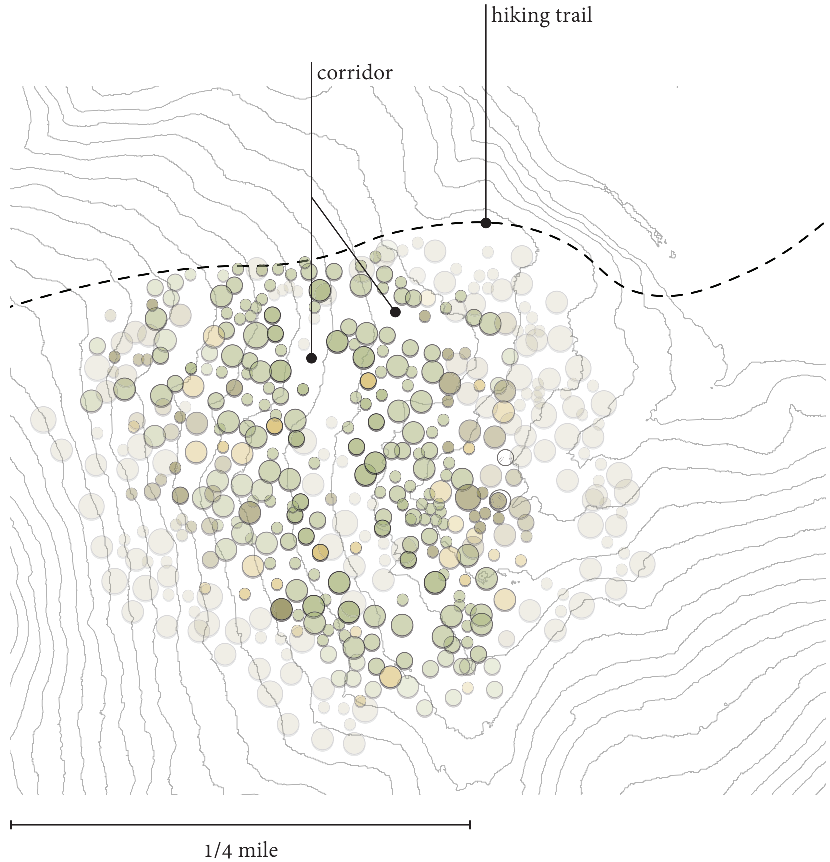
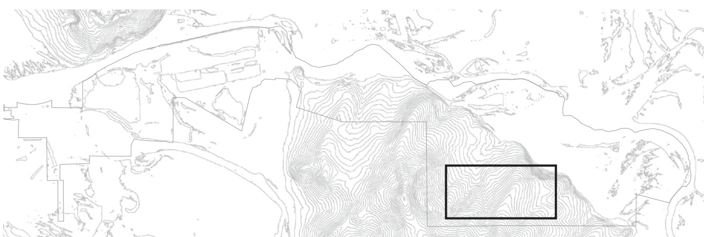


Figure 5.8

ALIGNING TRAIL PERPENDICULAR TO CORRIDORS, OR ENCOURAGING CORRIDOR CREATION



SCREENING

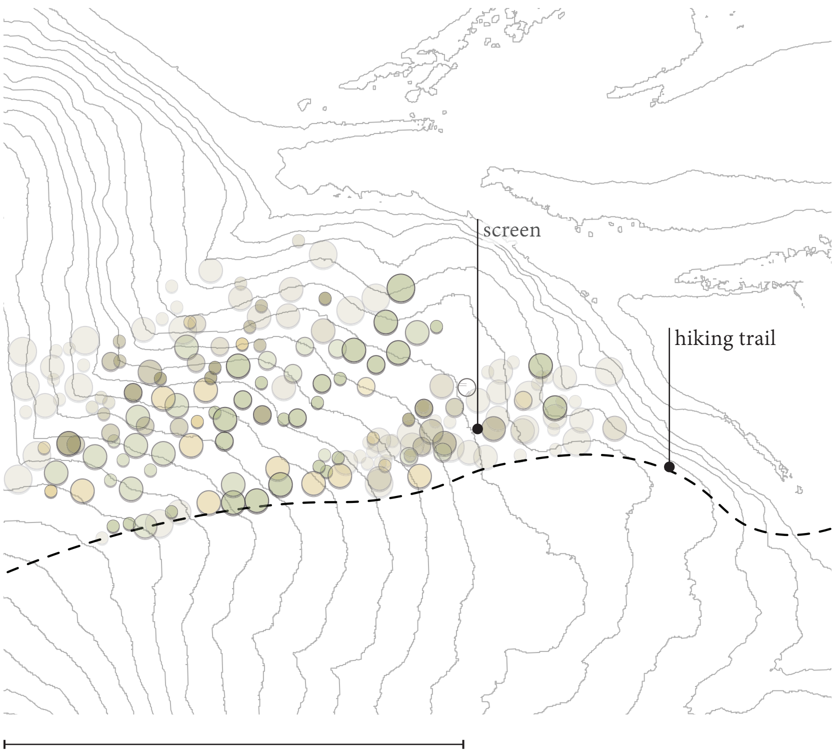


Figure 5.9

PROVIDING SCREEN FOR AUDIAL AND VISUAL BUFFER FOR SPECIES

Animals' stress levels increase when they perceive danger through their use of vision or hearing. Implementing vegetated screening around hiking trails can help decrease stress on certain animals, depending on the density, height, and extent of the screen. Studies have shown that this works best in a forest environment. (Hennings 2017; Wolf, Hagenloh, and Croft 2013). A less resource-intensive method is to plan trails along existing vegetation with high complexity and density. Vegetation borders can also discourage hikers from going off-trail, creating what are often referred to as 'social trails'. In areas such as a prairie or an oak savanna where shrub plantings do not fit the native habitat, audial animal disruption can be decreased by keeping groups small and voices low.

Prairie and riparian habitat are ideal locations for hikers interested in bird watching. Because a longer duration of time spent near bird habitat (even if quiet and motionless) results in increased stress levels of many animal species, materiality options may be more appropriate. These options are described in the follwoing section of "Trail Design Details".

ADEQUATE SPECIES HABITAT SIZE

Every animal species requires a different size landscape patch for an adequate habitat. This depends on their nesting requirements, potential for breeding, and availability of food (Kenward et al. 2018). When planning a trail system, target animal species' home ranges can be considered to avoid fragmenting habitats to the extent of causing stress to animals. In a similar way, in order for a habitat to support these target animal species, providing enough area for plant vegetation to thrive undisturbed can help its population health.

In the WCP, the Oregon Vesper Sparrow, a target species in the Willamette Valley, requires about 10-20 acres of grassland area for its ground nests ("Oregon Conservation Strategy: A Blueprint for Conservation in Oregon" n.d.). When designing trails, maintaining patches of upland prairie 10-20 acres in size will avoid habitat fragmentation. Guiding trail users through a variety of large habitats can avoid small species rich patches. If trails are placed adjacent to small habitat patches, aligning them on the edge can decrease patch fragmentation.

ALTERNATIVE ROUTES FOR HIGHLY SENSITIVE SEASONS

During seasonal closures, alternative routes can be provided for hikers. These routes can provide similar qualities that visitors often are attracted to, such as varied terrain and views of interesting seasonal elements. Early spring in the Willamette Valley can be a sensitive time for some plants and animals and can also be a vulnerable time for the quality of trails. Wet ground that has become easily malleable over the winter months is especially susceptible to erosion by foot traffic, so an alternative route during this time should use appropriate materials and techniques that allow for drainage.

In the WCP, the northeast area could be divided to two separate areas of seasonal trail openings. These biannual openings would allow some state of recovery for large landscape habitat patches, while allowing visitors to experience a similar yet different setting of trails every other year.

DESIRABLE EXPERIENCE FOR HIKERS

Trail expert Chris Berhardt emphasizes that to a certain extent, people will go where they want to while hiking. For example, if a hiker sees that there may be good views off-trail 100m away, they will likely go off trail. For this reason, it is critical to ask the question "What is the desired experience of users?"

"In general," Chris states, "hikers seek escape, exercise, and challenge. However, those are not exclusive to one another. If the primary desired experience is escape and exercise, then you should tailor trail routes to follow those. To ask 'what is the intended purpose and how do we manage it' is the secret sauce to trail design" (Bernhardt 2020).

Trails that provide glimpses of good views occasionally may help prevent hikers from meandering off trails. If there is a patch of old growth, for example, bringing hikers to the edge of that habitat with views of the old growth may be satisfying enough. Trails that lead to occasional clearings for views of town or distant mountains are also good options to keep hikers feeling fulfilled.

There are several features in the WCP that the community may appreciate. Some examples of these are forest openings in the southeast area of the preserve, access to the river's edge, notable preserved areas such as habitat tree snags, and restoration transformations such as invasive shrubland to native prairie.

TRAIL DESIGN DETAILS

Once decisions of location and seasonal closures have been finalized and the location of trails have been determined, the use of materiality during trail building can have an influence on the health of plant and animal habitat. If resources allow, background information on target plant and animal species can be very helpful during this process, and may include installing wildlife cameras, conducting bird count studies, or detailed mapping of vthreatened species. Certain types of interventions have the potential to help physical impact, while others can help decrease sound or visual disturbance. Trail hardening, raised boardwalks, bird blinds, and fence designs are a few examples that can contribute to dampening these impacts. This is only a glimpse into the world of trail building, and there are extensive resources for trail guidelines, including a local guide by Portland Parks & Recreation (Grimwade, Horner, and Everhart 2009).

TRAIL HARDENING

PHYSICAL IMPACT: PLANTS

International trail design expert Chris Bernhardt emphasizes that if a trail is made with durable surfaces and is the obvious option as a path, hikers will more likely stay on the trail rather than creating several smaller, social trails of their own. Trail hardening is often used to describe the tactic to create durable surfaces that will last longer in the landscape. Hardened trails are less likely to be widened by hikers for several reasons. Trails that use materials that drain well and prevent erosion will be less likely to become unstable in wet months, degrade, and create pooling. This encourages hikers to stay on trail if the surface continues to be durable and there is not a more comfortable route to follow. Steps of trail hardening include removing an existing organic layer of soil, adding fist-size rocks, followed by ¾ minus crushed rock, then fines material (Bernhardt 2020).

RAISED BOARDWALKS & BRIDGES

PHYSICAL IMPACT: PLANTS & ANIMALS

In wet or seasonally wet areas, raised boardwalks can help decrease the physical impact foot traffic has on sensitive wetland plant communities which are hosts for sensitive animal species (Figure 5.10). They can also be used to provide trails for areas where grading or filling might harm tree roots. Data on FID and AD for amphibian species is difficult to find or measure. However, studies have measured distances of species' migration from aquatic breeding sites to upland habitat. Boardwalks and bridges can enhance the connectivity for these species to travel below during wet seasons (Hennings 2017). In the same respect, culverts have the potential to not only divert water from the trail into a connecting creek, but also provide a passageway for amphibians to cross (Grimwade, Horner, and Everhart 2009).

VIEWING BLINDS

SIGHT: ANIMALS

Animals that hikers enjoy watching and are most sensitive to being watched are highly vulnerable. The installation of viewing blinds can help reduce disruption to the animal species, as well as provide a means for hikers to stay and witness an animal's habits (Figure 5.10, 5.11). Blinds are most commonly use for birds, though they can be used for any animal species who would be sensitive to being observed. Blinds can help prevent hikers from wandering into sensitive habitats and be designed to give the viewer an ideal field of vision towards a specific habitat. Blinds do have disadvantages as well, such as the shock reaction from animals when hikers suddenly reappear from behind the blinds.

FENCES

PHYSICAL IMPACT: PLANTS & ANIMALS

Fences can act as a physical barrier to prevent hikers from going off trail. The cost and installation of fences can be arduous, and their aesthetic can be criticized, so they may be most successful if used sparingly where a trail cannot avoid sensitive habitat, and habitat is easily disturbed by trampling or intrusion by dogs. For areas close to trails where dogs may wander, Chris Bernhardt suggests split rail fences with woven wire along the bottom.

EFFECTIVE SIGN USAGE

There is educational value in implementing signage that communicates the importance of restoration work along trails. Studies have shown that effective signs use language that is informative, such as "This sensitive habitat area is being restored for the breeding Monarch Butterfly. Please stay on the trail". A study in Sequoia National Park focused on the differences in uses of the "ought" (injunctive) or the "is (descriptive) of behavior and the option to state these positively (prescriptively) or negatively (proscriptively) (Winter 2006). Below is a comparison of these uses. In general, the injunctive-proscriptive method was found to be most effective with keeping hikers on trail.

Option 1 (most effective) : *Injunctive – Proscriptive*
Please don't go off the established paths and trails, in order to protect the Sequoias and natural vegetation in this park.

Option 2 (less effective): *Descriptive – Proscriptive*
Many past visitors have gone off the established paths and trails, changing the natural state of the Sequoias and vegetation in this park.

Option 3 (less effective): *Injunctive – Prescriptive*
Please stay on the established paths and trails, in order to protect the Sequoias and natural vegetation in this park

Option 4 (least effective) : *Descriptive – Prescriptive*
The vast majority of past visitors have stayed on the established paths and trails, helping to preserve the natural state of the Sequoias and vegetation in this park.

(Examples by Winter 2006).

Figure 5.10

design details in winter
original photos by the nature conservancy

Winter months are low sensitivity and allow for more access to water's edge. Blinds reduce movement disturbance and boardwalks prevent physical damage to vegetation

Figure 5.11

design detail in fall
original photos by the nature conservancy

Seating placed in areas that allow hikers to witness views and wildlife from a distance.
Blinds reduce disturbance to species senstiive to movement.

Chapter 6

Conclusion

SUMMARY OF PROCESS

TRANSFERABILITY

LIMITATIONS

NEXT STEPS

SUMMARY OF PROCESS

The aim of this project was to view plants, animals, and humans all as dynamic agents in protected natural areas with public access. There are relationships between plants and animals, plants and humans, and animals and humans that are unique on trail systems, and that warrant closer investigation to see their effects. Moments of sensitivity help us understand the importance of times in plants' and animals' life cycles which are vital to their health. Studying how these species may respond to an introduction of foot traffic can help show why sensitivities matter, and reveal which attributes are worth paying attention to when planning for public access. This framework is a tool to document these moments of sensitivity in a way that reveals temporal patterns for unique habitat types on a site. These patterns can be translated onto maps that show most sensitive areas on a site during certain times of the year. Once it is determined which areas are suitable for public access, certain planning and design strategies can help balance the protection of sensitive species and the excitement of public use.

TRANSFERABILITY

I believe the ability to transfer the use of this framework to other sites is feasible with the appropriate resources available. The Willamette Confluence Preserve has a strong foundation of restoration practices that have been conducted by a leader in conservation, The Nature Conservancy. TNC has gathered useful GIS data that reflects the past, present, and future habitat conditions of the site, which is extremely helpful for developing a suite of species for the framework. The suite of species that were chosen for this project on the WCP reflected typical target species found in habitat management plans of the Willamette Valley. If this level of detail of target species is available for a protected natural area in any location, the use of this framework is accessible.

LIMITATIONS

To develop effective management plans for future trail design, it would be beneficial to have a better understanding of individual species' reactions to recreational disturbance. These studies are difficult to find and are most often conducted on large mammals in National Parks, such as elk. The tracking of smaller species is more difficult, and may require more time allocated to observational studies.

This research focused on hiking as a main recreation type. Different forms of recreation on trails, such as biking or motorized sports will have different effects on species based on their speed, frequency, and sound. Equestrian use is also a trail use that was not examined, which involves a new relationship between horses and other animal and plant species. The implications of these activities may result in different planning and design strategies.

In this project, suggestions of smaller design scale practices only begins to introduce the broad field of physical trail design. Practices of trail-building, use of specific surface materials, study of slope, water management, and monitoring are not examined in this project, though there is a tremendous amount of knowledge for specific regions of the U.S. and the world that could be useful to help decrease impact to plants and animals.

This project does not address the public process of opening trails onto a protected natural area, or the politics and questions of equity created by restricting use. Each community has different values on landscape preservation and recreation as well as public processes, and it is impractical to make blanket management suggestions for all sites. Evaluating existing opportunities in the community, providing a range of opportunities, and effectively communicating to the public are important steps that are worth investigating further.

NEXT STEPS

Some current practices of trail planning do involve habitat assessments and avoiding sensitive plant and animal species. Cities such as Boulder, CO seasonally closes trails to protect sensitive bird populations during nesting seasons. Smith Rock State Park has recently implemented a management plan for the increasing number of annual visitors that considers fragile areas of the park. In the management plan, areas of the park are marked as high priority for conservation and resource value. A next step for this project could be to take similar steps of measuring resource value to protected natural areas. In addition, creating a management plan that is presented in phases based on priority could be useful for implementation. These examples can be used as precedents and are worth exploring to understand their effectiveness.

In this framework, sensitive plant and animal species hold the same weight. For future research, it may be helpful to examine if foot traffic disturbance and its extent is greater on plant or animal species. Additionally, species could be further divided to levels of vulnerability such as threatened or endangered to create more specific prioritizations of protection. A greater suite of animal and plant species would also give a more robust view of how each habitat functions. In addition, a study of non-native, and invasive animal and plant species could be helpful to track the ability of these species to spread with the presence of hikers as facilitators. Finally, testing this framework on a site in a different location and climate could test its transferability and add new planning and design strategies that cater to different ecosystem types.

LAST REMARKS

Habitat restoration projects require a tremendous amount of information gathering, outside resources, physical labor, patience, and perseverance. Large protected natural areas are becoming fewer and far between, and the decision to introduce public trail systems has the potential to be both a celebration and a careful effort. A New York Times article by Christopher Solomon describes this sentiment well:

"Only if nature is healthy will it be able to sustain and support us in the future, when we burst through the door after a long week and hit the trail, looking to lean on its strong shoulders."

- Christopher Solomon

References

Alcock, Ian, Mathew P. White, Sabine Pahl, Raquel Duarte-Davidson, and Lora E. Fleming. 2019. "Associations between Pro-Environmental Behaviour and Neighbourhood Nature, Nature Visit Frequency and Nature Appreciation: Evidence from a Nationally Representative Survey in England." Environment International, December.

Alverson, Ed. 2005. "Preserving Prairies and Savannas in a Sea of Forest." Plant Talk, no. 40 (April): 23–27. 2020.

Alverson, Ed. 2020. Informal interview.

Ballantyne, Mark, and Catherine Marina Pickering. 2015. "Recreational Trails as a Source of Negative Impacts on the Persistence of Keystone Species and Facilitation." Journal of Environmental Management 159 (August): 48–57.

Bennett, Victoria J., Matthew Beard, Patrick A. Zollner, Esteban Fernández-Juricic, Lynne Westphal, and Cherie L. LeBlanc. 2009. "Understanding Wildlife Responses to Human Disturbance through Simulation Modelling: A Management Tool." Ecological Complexity, Special Section: Environmental micro-simulation: From data approximation to theory assessment, 6 (2): 113–34.

Bernhardt, Chris. 2020. Informal interview on trail design.

Charman, Dj, and Aj Pollard. 1995. "Long-term Vegetation Recovery After Vehicle Track Abandonment on Dartmoor, SW England, UK." Journal of Environmental Management 45 (1): 73-85.

Cizauskas, Carrie A., Wendy C. Turner, Neville Pitts, and Wayne M. Getz. 2015. "Seasonal Patterns of Hormones, Macroparasites, and Microparasites in Wild African Ungulates: The Interplay among Stress, Reproduction, and Disease." PLoS ONE 10 (4): e0120800.

Dale, D., and T. Weaver. 1974. "Trampling Effects on Vegetation of the Trail Corridors of North Rocky Mountain Forests." Journal of Applied Ecology 11 (2): 767–772

Fernández-Juricic, Esteban, María Dolores Jimenez, and Elena Lucas. 2001. "Alert Distance as an Alternative Measure of Bird Tolerance to Human Disturbance: Implications for Park Design." Environmental Conservation 28 (3): 263–69.

Fernández-Juricic, Esteban, Raul Vaca, and Natalia Schroeder. 2004. "Spatial and Temporal Responses of Forest Birds to Human Approaches in a Protected Area and Implications for Two Management Strategies." Biological Conservation 117 (4): 407–16.

Franklin, Janet, Helen M. Regan, Lauren A. Hierl, Douglas H. Deutschman, Brenda S. Johnson, and Clark S. Winchell. 2011. "Planning, Implementing, and Monitoring Multiple-Species Habitat Conservation Plans." American Journal of Botany 98 (3): 559–71.

Grimwade, Robin, Brett Horner, and Gregg Everhart. 2009. "Trail Design Guidelines for Portland's Park System." Portland Parks & Recreation.

Grooms, Bennett P., and Rachael E. Urbanek. 2018. "Exploring the Effects of Non-Consumptive Recreation, Trail Use, and Environmental Factors on State Park Avian Biodiversity." Journal of Environmental Management 227 (December): 55–61.

Guderyahn, Laura B., Ashley P. Smithers, and Meryl C. Mims. 2016. "Assessing Habitat Requirements of Pond-Breeding Amphibians in a Highly Urbanized Landscape: Implications for Management." Urban Ecosystems; Salzburg 19 (4): 1801–21.

Hellmund, Paul. 1998. Planning Trails with Wildlife in Mind. Colorado State Parks.

Hennings, Lori. 2017. "Hiking, Mountain Biking and Equestrian Use in Natural Areas: A Recreation Ecology Literature Review." September 2017.

Hill, Rachel, and Catherine Pickering. 2009. "Differences in Resistance of Three Subtropical Vegetation Types to Experimental Trampling." Journal of Environmental Management 90 (2): 1305–1312.

Hing, S., Ej Narayan, R. C. A. Thompson, and S. S. Godfrey. 2016. "The Relationship between Physiological Stress and Wildlife Disease: Consequences for Health and Conservation." Wildlife Research 43 (1): 51–60.

Holmes, Susan E., Bitty A. Roy, Jim P. Reed, and Bart R. Johnson. 2010. "Context-Dependent Pattern and Process: The Distribution and Competitive Dynamics of an Invasive Grass, Brachypodium Sylvaticum.(Report)." Biological Invasions 12 (7): 2303–18.

Houston, Alasdair I., Edward Prosser, and Eleanor Sans. 2012. "The Cost of Disturbance: A Waste of Time and Energy?" Oikos 121 (4): 597–604.

Immitzer, Markus, Ursula Nopp-Mayr, and Margit Zohmann. 2014. "Effects of Habitat Quality and Hiking Trails on the Occurrence of Black Grouse (Tetrao Tetrix L.) at the Northern Fringe of Alpine Distribution in Austria." Journal of Ornithology 155 (1): 173–81.

Karp, Daniel S., and Roger Guevara. 2011. "Conversational Noise Reduction as a Win-Win for Ecotourists and Rain Forest Birds in Peru." Biotropica 43 (1): 122–30.

Kats, Lb, and Lm Dill. 1998. "The Scent of Death: Chemosensory Assessment of Predation Risk by Prey Animals." Ecoscience 5 (3): 361–394.

Kenward, Robert E., Eduardo M. Arraut, Peter A. Robertson, Sean S. Walls, Nicholas M. Casey, and Nicholas J. Aebischer. 2018. "Resource-Area-Dependence Analysis: Inferring Animal Resource Needs from Home-Range and Mapping Data.(Research Article)(Report)." PLoS ONE 13 (10): e0206354.

Kilinç, Mahmut, Neslihan KaraviN, and Hamdi Güray Kutbay. n.d. "Classification of Some Plant Species According to Grime's Strategies in a Quercus Cerris L. Var. Cerris Woodland in Samsun, Northern Turkey," 9.

Klein, Mary L. 1993. "Waterbird Behavioral Responses to Human Disturbances." Wildlife Society Bulletin (1973-2006) 21 (1): 31–39.

Knight, Richard L., and Kevin J. Gutzwiller, eds. 1995. Wildlife and Recreationists: Coexistence through Management and Research. Washington, D.C: Island Press.

Kornze, Neil, International Mountain Bicycling Association, and Department of the Interior Bureau of Land Management. 2018. "Guidelines for a Quality Trail Experience."

Kuebler, Jeffrey. 2019. "Species Project, Big Brown Bat."

Lane County Parks Division. 2018. "Howard Buford Recreation Area Habitat Management Plan."

Lenth, Benjamin, Richard Knight, and Mark Brennan. 2008. "The Effects of Dogs on Wildlife Communities." Natural Areas Jounal 28 (3): 218–27.

Miller, Scott G., Richard L. Knight, and Clinton K. Miller. 1998. "Influence of Recreational Trails on Breeding Bird Communitie." Ecological Applications 8 (1): 162–69.

Olive, Nathaniel D., and Jeffrey L. Marion. 2009. "The Influence of Use-Related, Environmental, and Managerial Factors on Soil Loss from Recreational Trails." Journal of Environmental Management 90 (3): 1483–1493.

Pescott, Oliver L., and Gavin B. Stewart. 2014. "Assessing the Impact of Human Trampling on Vegetation: A Systematic Review and Meta-Analysis of Experimental Evidence." PeerJ 2 (May): e360.

Pickering, Catherine Marina, Wendy Hill, David Newsome, and Yu-Fai Leung. 2010. "Comparing Hiking, Mountain Biking and Horse Riding Impacts on Vegetation and Soils in Australia and the United States of America." Journal of Environmental Management 91 (3): 551–62.

Rodgers, James A., and Henry T. Smith. 1995. "Set-Back Distances to Protect Nesting Bird Colonies from Human Disturbance in Florida, Distancia de Alejamiento Para Proteger de Las Perturbaciones Humanas a Las Colonias de Aves Nidificadoras En Florida." Conservation Biology 9 (1): 89–99.

Rodríguez-Prieto, Iñaki, Victoria J. Bennett, Patrick A. Zollner, Mike Mycroft, Mike List, and Esteban Fernández-Juricic. 2014. "Simulating the Responses of Forest Bird Species to Multi-Use Recreational Trails." Landscape and Urban Planning 127 (July): 164–72.

Schultz, Richard D., and James A. Bailey. 1978. "Responses of National Park Elk to Human Activity." The Journal of Wildlife Management 42 (1): 91–100.

"Society for Ecological Restoration." n.d. Accessed May 20, 2019. https://www.ser.org/default.aspx.

Taylor, Audrey R., and Richard L. Knight. 2003. "Wildlife Responses to Recreation and Associated Visitor Perceptions." Ecological Applications 13 (4): 951–63.

Temperton, Vicky M. 2004. Assembly Rules and Restoration Ecology: Bridging the Gap between Theory and Practice. Science and Practice of Ecological Restoration. Washington, D.C.: Island Press.

The Nature Conservancy. 2012. "Willamette Confluence Preserve Management Plan."

Thompson, Mj, and Re Henderson. 1998. "Elk Habituation as a Credibility Challenge for Wildlife Professionals." Wildlife Society Bulletin 26 (3): 477–483.

Tomczyk, Aleksandra M., Marek W. Ewertowski, Piran C. L. White, and Leszek Kasprzak. 2017. "A New Framework for Prioritising Decisions on Recreational Trail Management." Landscape and Urban Planning 167 (November): 1–13.

"Trails & Recreation | Friends of Buford Park and Mount Pisgah." n.d. Accessed February 21, 2019. https://www.bufordpark.org/trails-recreation/.

Wichmann, Matthias C., Matt J. Alexander, Merel B. Soons, Stephen Galsworthy, Laura Dunne, Robert Gould, Christina Fairfax, Marc Niggemann, Rosie S. Hails, and James M. Bullock. 2009. "Human-Mediated Dispersal of Seeds over Long Distances." Proceedings: Biological Sciences 276 (1656): 523–32.

Wimpey, Jeremy F., and Jeffrey L. Marion. 2010. "The Influence of Use, Environmental and Managerial Factors on the Width of Recreational Trails." *Journal of Environmental Management* 91 (10): 2028-37.

Winter, P. L. 2006. "The Impact of Normative Message Types on Off-Trail Hiking" 11 (1): 35–52.

Wolf, Isabelle D., Gerald Hagenloh, and David B. Croft. 2013. "Vegetation Moderates Impacts of Tourism Usage on Bird Communities along Roads and Hiking Trails." Journal of Environmental Management 129: 224–234.

Ydenberg, R. C., and L. M. Dill. 1986. "The Economics of Fleeing from Predators." Elsevier Science & Technology.

Yorks, Terence Preston. 1997. "Toleration of Traffic by Vegetation: Life Form Conclusions and Summary Extracts from a Comprehensive Data Base." Environmental Management 21 (1): 121–31.

Yuen, Hon K., and Gavin R. Jenkins. 2019. "Factors Associated with Changes in Subjective Well-Being Immediately after Urban Park Visit." International Journal of Environmental Health Research, 1–12.

Appendix

Common name	*Scientific name*
Animals	
Western gray Squirrel	*Sciurus griseus*
Slender-billed Nuthatch	*Sitta carolinensis aculeata*
Townsend's big eared Bat	*Corynorhinus townsendii*
Camus Pocket Gopher	*Thomomys bulbivorus*
Oregon Vesper Sparrow	*Pooecetes gramineus affinis*
Grasshopper Sparrow	*Ammodramus savannarum perpallidus*
Western Meadowlark	*Sturnella neglecta*
Bald Eagle	*Haliaeetus leucocephalus*
Yellow-brested Chat	*Icteria virens auricollis*
Willow Flycatcher	*Empidonax traillii extimus*
American Beaver	*Castor canadensis*
Western Pond Turtle	*Actinemys marmorata*
Red-legged Frog	*Rana aurora*
Pacific Lamprey	*Lampetra tridentata*
Oregon Chub	*Oregonichthys crameri*
Plants	
Yellow & Red Columbine	*Aquilegia formosa*
Wayside Aster	*Eucephalus vialis*
Willamette Daisy	*Erigeron decumbens*
Willamette Valley Larkspur	*Delphinium trolliifolium*
Pacific Houndstongue	*Cynoglossum grande*
Oregon Geranium	*Geranium oreganum*
Western Waterleaf	*Hydrophyllum occidentale*
Howell's Bentgrass	*Viola howellii*
Thin-leaved Peavine	*Lathyrus holochlorus*
California Fescue	*Festuca californica*
June Grass	*Koeleria macrantha*
Roemer's Fescue	*Festuca roemeri*

Common name	*Scientific name*
Plants cont'd	
California Oatgrass	*Danthonia californica*
Balsamroot	*Balsamorhiza deltoidea*
Grass Widows	*Olsynium douglasii*
Shaddy Horelia	*Horkelia congesta ssp. Congesta*
Kincaid's Lupine	*Lupinus oreganus*
White-topped Aster	*Sericocarpus rigidus*
Racemed Goldenweed	*Pyrrocoma racemosa var. racemosa*
Upland Yellowviolet	*Viola praemorsa ssp. Praemorsa*
Tall Bugbane	*Cimicifuga elata var. elata*
Celery Leaved Lovage	*Ligusticum apiifolium*
Alaska Oniongrass	*Melica subulata*
Henderson's Sedge	*Carex hendersonii*
Western Trillium	*Trillium ovatum ssp. ovatum*
Tall Western Groundsel	*Senecio integerrimus var. exaltatus*
Siberian Candyflower	*Claytonia sibirica*
Tall Western Meadowrue	*Thalictrum polycarpum*
Smooth Woodland Violet	*Viola glabella*
Spring Beauty	*Cardamine nuttallii var. nuttallii*
Meadow Checkermallow	*Sidalcea campestris*
Hitchcock's Blue-eyed Grass	*Sisyrinchium hitchcokii*
Bradshaw's Desert Parsley	*Lomatium bradshawii*
Peacock Larkspur	*Delphinium pavonaceum*
Timwort	*Cicendia quandrangularis*
Willamette Daisy	*Erigeron decumbens*
Meadow Sidalcea	*Sidalcea campestris*
Rosy Plectritis	*Plectritis congesta*
Howellia	*Howellia aquatilis*
Soft Rush	*Juncus effuses*