

The Past, Present, and Diminishing Future
of the Northern Spotted Owl (*Strix
occidentalis caurina*)



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Declaration

I declare that this thesis was composed by myself and that the work contained herein is my own except where explicitly stated in the text. The work has not been submitted for any degree or professional qualification except as specified.

Ami Pekrul, 2026

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Abstract

The northern spotted owl (*Strix occidentalis caurina*; hereafter referred to as northern spotted owl, spotted owl, owl, or NSO) is strongly associated with old-growth forest in the Pacific Northwest of North America. It has faced many challenges to its survival over the past century, as its fate is linked with the fate of old-growth forest. Hence, the owl has become an icon for the conservation of old-growth forest in a long-running conflict between loggers and environmentalists. This thesis reviews those aspects of the biology and ethno-ornithology, which help or hinder the owl's conservation. Habitat loss and an increase in the population of its competitor, the barred owl (*Strix varia*), are the leading causes of population decline of the NSO. Chapter 3 studies corticosterone levels in NSOs suggesting that they were more stressed when exposed to acute rather than chronic human activity.

Chapter 2 is a comprehensive study of newspaper articles showing how the owl has become an icon for environmentalists seeking to conserve the forest against the timber industry. Since deforestation is a major contributor to climate change, interest in the fate of the NSO has increased as a broader concern over deforestation, climate change and biodiversity loss have grown in the public consciousness over the past half century.

Changes in perceptions of the owl reflecting changing societal values were clearly reflected in the press, but differed between local, national and international publications. These changes mirror changes in the protection and management afforded the owls. Although federal protection underwrites its conservation, each state, tribe, and private landowner is responsible for the owl's direct management, outside of federally-managed areas. A review of the differences in management policies clarifies why, despite the array of protections, they continue to decline. Concerted management will determine if the owl has a future.

Keywords: northern spotted owl, corticosterone, public perception, management

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Introduction

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Figure 1.1: The structure and major themes of the thesis: chapter two is the newspaper analysis of the past perception, chapter three is the corticosterone analysis of present conditions, and chapter four is an examination of current and future management practices.

Figure 1.2 Northern spotted owl (Sullivan 2021).

Figure 1.3. Current U.S. range map of the northern spotted owl

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Table 1.1: Summary of references to northern spotted owls, or owls in general, across 85 tribal websites and news reports.

1.1 Thesis Objectives and Structure

This thesis was initially planned to be very different. It was originally intended to focus on causes and consequences of stress in the NSO. However, the Covid-19 pandemic prevented the author from leaving the U.K. to conduct fieldwork and thus the focus had to shift to more literature and internet-based research. Chapters 2 and 4 were added after the pandemic began, as they could be conducted from Oxford. Chapter 3 was intended to be the core chapter with in-person interviews in the field and the author collecting the samples rather than using collaborators. The focus was going to be on the captive bred owls vs wild, but the Canadian government rescinded permission right before collections. Tribal collaborations could only be done in person and thus had to be excluded from this thesis, though it is recognized that they play a significant role in this issue.

The aims of this thesis are therefore to: 1) explore how human perceptions and shifts in language around the northern spotted owl (*Strix occidentalis caurina*) have changed since 1988; 2) examine corticosterone levels and what factors may influence them, and; 3) understand the different management layers and how those might affect the rates of declining populations.

This thesis was conducted in multiple parts: literature review, experiments, socio-historic analysis, and assessment of current management. Chapter 1 is the introduction to the thesis, laying out the objectives, aims, and structure that will follow. A

basic overview of the owl's ecology and biology, then a history of the conservation conflict leading to specific iconic and symbolic species in indigenous culture in the Pacific Northwest immediately follows. Chapter 2 presents a socio-historic analysis, which looked at newspaper articles from 1988 until 2020 to gauge how perceptions of the owls have changed over time based on the articles' location and policy changes. Chapter 3 presents an analysis on corticosterone levels in two locations; remote and more-urban. Chapter 4 delves into the different layers of management and oversight for the NSO, including the governing laws, tribal management, and the Canadian government's differences. Chapter 5 draws conclusions in summary and ties the data chapters together. These chapters are simplified into Figure 1.1 with the overall intention of drawing from the past, analysing the present, and comparing plans for the future.

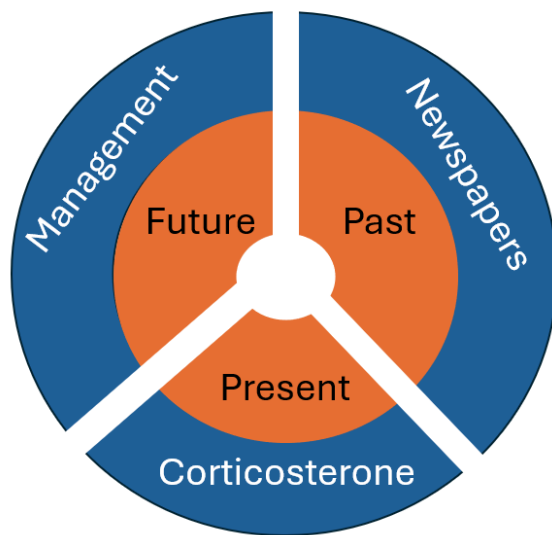


Figure 1.1: The structure and major themes of the thesis: chapter 2 is the newspaper analysis of the past perception, chapter 3 is the corticosterone analysis of present conditions, and chapter 4 is an examination of current and future management practices.

1.2 Background to Species

1.2.1 Biogeography



Figure 1.2 Northern spotted owl (Sullivan 2021).

The northern spotted owl (*Strix occidentalis caurina*) is one of three subspecies of spotted owls, along with the California spotted owl (*S.o. occidentalis*) and the Mexican spotted owl (*S.o. lucida*). It is a medium-sized raptor with mottled brown plumage and dark eyes (Figure 1.2). The NSO is an old-growth forest dweller with a specialist trophic niche in that ecosystem. The NSO is the largest of the three subspecies, and is found from southern British Columbia to Marin County, California (USFWS 2011a) (Figure

1.3). The California spotted owl ranges the length of California and into Baja California, while the Mexican spotted owl is located in Utah, Arizona, Colorado, New Mexico, Texas, and midway into western Mexico. The northern subspecies, which has become an icon for the conservation of old growth forest within a conflict between loggers and environmentalists, is the focus of this thesis, with the other two sub-species cousins providing supplemental data.



Figure 1.3. Current U.S. range map of the northern spotted owl (USFWS Service 2021).

1.2.2 Habitat

Old-growth forests with multi-layered canopies dominated by Douglas fir (*Pseudotsuga menziesii*) and a dense understory are highly desirable for northern spotted owls (Laymon et al. 1985). Franklin et al. (1981) state that there are “four key structural

components of old growth: large live trees, large snags, large logs on land, and large logs in streams”. Forests are generally considered to attain old growth status at 175–250 years after stand initiation (Franklin et al. 1981). Mid-successional forests have less than 70% canopy cover, the beginnings of a multi-layered canopy, and a shrub layer (Lesmeister et al. 2018). Early-successional forests are characterised by “small coniferous trees, shrubs and herbaceous vegetation. Trees are generally less than 2.5 cm in diameter, and less than 5 m tall, providing no greater than 30% canopy cover” (Public Utility District 1988).

While the owls have been known to forage in mid-successional (understory reinitiation phase) forests, it is rare, and most of their hunting and roosting is in late succession forest (Laymon et al. 1985). Home ranges are largest in Washington (2659-3608 ha) and smallest in California (157-2687 ha) (Buchanan et al. 2024 & California Department of Fish and Wildlife 2016). Forsman et al. (1984) found that while the owls showed a preference for unlogged forests for both foraging and nesting, they would often move locations if selective logging or clearcutting took place. Northern spotted owl nests are located primarily in forests over 200 years old and secondarily in forests 100-200 years old, with elevations ranging from 24-2040 m (Forsman et al. 1984). Loehle et al. (2015) conducted a thorough range-wide meta analysis of habitat requirements for the NSO and concluded that there was so much variance that the primary models could not predict occupancy of the owls based on vegetation. They reasoned that this was due to the influence of prey items fluctuating in the study areas, resulting in the owls occupying unexpected nesting sites.

Many other species prefer or rely on old-growth forests, highlighting the importance of preserving such areas. These include the northern goshawk (*Accipiter gentilis*), Vaux's swift (*Chaetura vauxi*), pileated woodpecker (*Dryocopus pileatus*), Hammond's flycatcher (*Empidonax hammondi*), pine grosbeak (*Pinicola enuclea*), Townsend's warbler (*Dendroica townsendi*), silver-haired bat (*Lasionycteris noctivagans*), long-eared myotis (*Myotis evotis*), long-legged myotis (*Myotis volans*), hoary bat (*Lasiurus cinereus*), red tree vole (*Arborimus longicaudus*), northern flying squirrel (*Glaucomys sabrinus*), California red-backed vole (*Clethrionomys californicus*), coast mole (*Scapanus orarius*), marten (*Martes americana*), fisher (*Martes pennanti*), and marbled murrelet (*Brachyramphus marmoratus*) (Franklin et al. 1981). Clearly then, old growth forest conservation is essential for more than just the northern spotted owl, though the NSO remains at the forefront of the conflict.

1.2.3 Biology

Life Cycle

NSOs exhibit low fecundity and while they can breed at around one year old, they typically do not until 2-7, with 1-4 eggs being typical (USFWS 2011a & Northern Spotted Owl Breeding Program 2024). These birds mate for life and the male provides food, while the female tends the eggs (Northern Spotted Owl Breeding Program 2024). Courtship begins in February or March, egg laying in March or April, eggs hatch after 32 days in April or May (Northern Spotted Owl Breeding Program 2024), fledging in May or

June, and natal dispersal in September or October, though sometimes as late as November or December (USFWS 2011a). Juvenile dispersal averages 10 miles for males and 15.5 miles for females with a juvenile mortality rate of over 70% in some areas (USFWS 2011a). Gene flow analysis shows that inbreeding is rare (USFWS 2011a).

The Northern Spotted Owl Breeding Program has done extensive work monitoring their captive owl population to gain the best understanding of how the NSO life cycle works. Much of their work validates research learned in the field, elucidating the yearly variation in breeding attempts and the (sometimes) years before an owl's first breeding attempt.

Diet

Northern spotted owls have been studied in great detail and have been known to eat at least 127 different species, including another spotted owl in one case (Allen 1987, Carey et al. 1992, Forsman et al. 2004, Graham 2012, Hindmarch & Elliott 2015, Laymon et al. 1985, Zabel et al. 1995). This diversity of prey is impressive, though the owl's primary prey by a wide margin are flying squirrels, woodrats (*Neotoma* spp.), and red tree voles, and the rest may be regarded as opportunistic (Zabel et al. 1995). Unfortunately, the first known instance of a wild Mexican spotted owl living inside a city yielded no data on prey, as no pellets were found. However, since the owl stayed for seven months, food sources were available (Martinez-Guerrero et al. 2019).

Nesting

As the NSO occupies a long latitudinal range, the nesting requirements differ from the northern parts of the range to the southern, though typically in tree cavities in old growth forests. This is reflected in the nesting season, which generally commences earlier in the south. The breeding season ranges from March 1st to August 31st in Washington, March 30th to September 30th in Oregon, and February 1st to August 31st in California. (USFWS 2011a).

1.2.4 Population Decline

The Forest Service estimated in 2022 that there were between 3,000 and 5,200 NSO left in the wild (Braun 2022). The owls have been declining at an average rate of 4% per annum since they were listed under the Endangered Species Act in 1990, though this differs between areas (ESA; Lesmeister et al. 2018). The most recent data show that of the 11 demographic zones monitored for 26 years, six have declined by 6-9% and the other five by 2-5% annually (Franklin et al. 2021). No accurate estimates exist of the owls' population from when they were listed, but at least 2,000 breeding pairs were known. This was primarily based on monitoring efforts on federally-owned and/or administrated land, as private lands had already been heavily logged (Endangered and Threatened Wildlife and Plants 1990). Genomic evidence shows that the owls did not face population declines until this last century (Fujito et al. 2021). In

1969, they were already considered a rare species, 21 years before they were listed as threatened under the Endangered Species Act (Forsman et al. 1984).

The Northwest Forest Plan of 1994 set aside land protected from logging, specifically with regard to the NSO. However, after ten years, the owls within those protected areas were still declining at a rate of 2.4% (Lesmeister et al. 2018). This should, however, be compared to the decline rates outside of the protected areas of 5.8% on non-federal lands (Lesmeister et al. 2018). Washington State has seen the highest rates of loss in the U.S., both from extensive logging and the invasive barred owl (Buchanan 2024). According to the U.S. Fish and Wildlife Service, the population is “critically imperiled”, and their status should be changed from threatened to endangered (Buchanan 2024). That status change has not yet happened.

1.2.5 Conservation Status

Two key influences of positive impact on the early protection of the NSO were the Migratory Bird Treaty Act of 1918 (MBTA) and the Endangered Species Act (ESA) of 1973. These acts were in place long before the owls were brought into conflict. The MBTA was first used in 1936 to address the need for NSOs to have extra protection in response to the species sharing a range between the U.S. and Mexico, and thus considered under the label ‘migratory birds’ as it crossed borders. (Forest History Timeline 2020). The ESA renders it “illegal for anyone to take, possess, import, export, transport, sell, purchase, barter, or offer for sale, purchase, or barter, any migratory bird,

or the parts, nests, or eggs of such a bird except under the terms of a valid permit issued pursuant to Federal regulations” (USFWS 2016a).

Oregon listed the owls as threatened in 1975, well before it was recognised nationally (Hollingsworth & Hollingsworth 2002). Washington State listed them as endangered in 1988 (Buchanan 2016). The NSO was listed in 1990 as threatened under the ESA (Endangered and Threatened Wildlife and Plants; Determination of Threatened Status for the Northern Spotted Owl 1990). In California they were listed as threatened in 2016 (DiPerna 2017). According to the IUCN Red List, the NSO is classified as Near Threatened. However, the last assessment in 2017 seems inconsistent with the current status, suggesting that a further review is urgently required (BirdLife International 2017). As of 2019, the California spotted owl subspecies is neither listed under the federal ESA nor the California ESA, which has resulted in environmental groups suing the U.S. Fish and Wildlife Service for negligence as the species is in decline (Endangered and Threatened Wildlife and Plants 2019). This highlights the prevalence of political influence on biological decisions as seen with the NSO being excluded for higher listing.

In Canada, species are managed under the Species at Risk Act of 2002, including the NSO, which is functionally extinct in Canada (Cox 2020 & Foy 2024). In 2023, the last known wild owl was living in Spuzzum Valley, British Columbia (Cox 2020). This is, however, in an area that has been, and continues to be, logged, and despite the outcry for protection, the government has not stopped deforestation (Cox

2020). The Northern Spotted Owl Breeding Program in Langley, British Columbia, was created to save the owls in 2007. Injured and non-releasable spotted owls were brought to the Centre in addition to young taken from wild nests. Since then, the Centre's captive population has increased from three to 33 owls, with more every year (Northern Spotted Owl Breeding Program 2023). These owls will eventually be released back into the wild when there are enough to sustain a population. Three were released in 2022, though two died and the third was injured (BC Gov News 2023b). It was released again in 2023 with another. Their status is currently unknown.

1.2.6 Biodiversity

The Forest Service determined that the spotted owl is an indicator species, which means that its presence in a forest indicates a healthy ecosystem (Simberloff 1998). The criteria for being an indicator species are that they reflect the health of their environment, they reflect changes in that environment, and their presence can indicate that other species are present as they have the same environmental requirements (Lawton & Gaston 2001). Inversely, their absence sparks the question of whether a forest system is missing vital elements. The owls are also an umbrella species because their habitat requirements are specific to mature and old-growth forest, which means that if protected, they invariably protect other species that rely on old growth (Simberloff 1998). Loss of biodiversity results in a weaker ecosystem. At the genetic level, the spotted owl is losing genetic variation. Fewer owls means less variation and a smaller gene pool. At the ecosystem level, the old-growth forests on which the owls rely are

shrinking and becoming more fragmented, resulting in 'islands' of habitat. This fragmentation leads to greater dispersal of the owls in order for them to find suitable habitat (Shaffer 1985). Therefore, while owls can disperse great distances, inbreeding and hybridisation with barred owls are becoming more of an issue in the conservation of NSOs, though they remain rare.

There is no denying that the spotted owl has faced intense discrimination. It is still possible to talk to people in logging communities who express strong prejudice against them, and anger from the previous decades has barely dissipated. Some restaurants claim to sell 'Spotted Owl Burgers', while some people have aged bumper stickers on their vehicles reading 'Save a Logger, Eat a Spotted Owl'. People in urban areas have partially forgotten about this ancient forest dweller, though the occasional TV reference surfaces as a reminder.

1.2.7 Urban Owls: Successes and Shortcomings

Many North American owls have adapted to live in or use urban areas. These are the barred owl (*Strix varia*), great horned owl (*Bubo virginianus*), snowy owl (*B. scandiacus*), burrowing owl (*Athene cunicularia*), barn owl (*Tyto alba*), western screech-owl (*Megascops kennicottii*), whiskered screech-owl (*M. trichopsis*), eastern screech-owl (*Megascops asio*), northern hawk owl (*Surnia ulula*), long-eared owl (*Asio otus*), short-eared owl (*A. flammeus*), northern saw-whet owl (*Aegolius acadicus*), northern pygmy-owl (*Glaucidium gnoma*), ferruginous pygmy-owl (*G. brasilianum*), and elf owl (*Micrathene whitneyi*) (Hager 2009). While some, such as the barred owl, are

more successful residents, others, such as the snowy owl, only transit through urban areas during migration. Even barred owls were once considered an old-growth forest species, and it caused great shock when they were discovered thriving deep inside cities (University of North Carolina at Charlotte 2007). Old growth trees can be found inside many cities, from cemeteries to neighborhoods to parks. Barred Owls are highly adaptable and with their generalist diet, are able to disperse into cities and find habitat in a way spotted owls could not.

Barred owls are also known to vary their diet from rural to suburban areas, showing great adaptability to changes in habitat type (University of North Carolina at Charlotte 2007). In British Columbia, barred owls were noted primarily to eat Norway rats (*Rattus norvegicus*), black rats (*Rattus rattus*), field voles (*Microtus townsendii*), and deer mice (*Peromyscus maniculatus*), among many others (Hindmarch & Elliott 2015). Bird feeders in urban areas are also a hotspot for owls to hunt, allowing birds to congregate and draw attention (Hindmarch & Elliott 2015).

1.3 Environmentalists-Logging Conflict in the Pacific Northwest

1.3.1 A Brief History of Conflict

The divergence of values between environmentalists and the logging industry is the root cause of the controversy (Bernstein 2018). There are many systems of value in

which to address the spotted owl, including its economic, intrinsic, cultural, intellectual, aesthetic, and spiritual values (Chapin et al. 2000). Each of these value systems governs how people view the owls and in what ways they think they should be preserved.

As in any conflict, many opposing viewpoints are elicited from the stakeholders involved. Besides the environmentalists and loggers, the government, wildlife managers, tribes, universities, landowners, local communities, foresters, policy makers, and many others were impacted. As the conflict progressed, more groups were brought in and, as it was very much in the public eye, many people had taken a side. In an effort to find middle ground, stakeholder groups were formed to allow all involved a voice in finding solutions. Chapter 4 of this thesis examines the influences of different stakeholders on the conservation management plans for this and other forest-dependent species. Conflicts over resources can be found throughout recorded history, especially over the past century; as human populations increase, industrialisation and habitat loss become more common issues. Food, safety, and property resources have meant the difference between life and death in some cases (Peterson et al. 2010). From competing with other predators over prey species in hunter-gatherer societies to vehicle collisions in cities, aspects of conservation conflict in the modern world range from minor inconvenience to life-threatening, and can be found everywhere. Invasive species pose a threat through damage and management, sometimes costing billions of dollars to counter (Pimentel, Zuniga, & Morrison 2005). Imperilled species management can cost equally in the billions, as well as cause other

economic impacts, as seen with the northern spotted owl and the closing of many logging communities (Freudenburg, Wilson, & O'Leary 1998).

1.3.2 Conflicts in the Pacific Northwest

The Timber Wars

The northern spotted owl was thrust into the controversy between environmentalists and the logging industry *after* tensions were already building. Poor management by timber companies allowed for the practice of over-harvest and clear-cutting to the point of diminishing timber stocks, especially in old growth forests (Kelly & Tuttle 2018). While the ESA was ratified in 1973, the spotted owl was not listed federally until 1990 despite it being recommended for listing as an endangered species the year the ESA was created (Furnish 2019). The creation of the Northwest Forest Plan (NWFP) in 1994 indicated that the situation was worsening and further protection for all old-growth forests and the species that rely on them was needed (Furnish 2019). Part of the conservation issue is that the different entities managing the owls have different and conflicting approaches to conservation. This is exemplified by the Bureau of Land Management (BLM) who argue that more logging or thinning is necessary to create and maintain future habitat (Cornwall 2016). This results in habitat with potential old growth being logged to make way for potential managed habitat 100 years from now. It is therefore helpful to review a brief history of the conflict by states in the USA and Canada.

Oregon

The timber wars began with the first tree sits, a practice in which activists climb trees scheduled for logging to prevent their felling (Bari 1993), in the Oregon forests in 1985, pitting the logging industry in opposition to the environmentalists. This occurred in Cathedral Forest in the southern part of the state, where activists also sat on dynamite, put tree spikes in trees, and blockaded roads (Bari 1993). These dangerous methods caused injuries on both sides and further fuelled the distrust between the groups (Bari 1993).

California

California was home to the Headwaters Forest Controversy. In 1985, the Pacific Lumber Company was the recipient of a hostile takeover in which Charles Hurwitz and the Maxxam Corporation took control (Bernstein 2018). The new owners began a much more aggressive plan to clear-cut forests at an accelerated rate in order to maximise profits in the shortest time (Bernstein 2018). In 1989, the President of Louisiana Pacific was quoted as saying “We don’t log to a ten-inch top, or an eight-inch top, or a six-inch top. We log to infinity. Because we need it all. It’s ours. It’s out there and we need it all. Now.” (Speece 2017). In 1996, Pacific Lumber and the Department of the Interior agreed to protect 7,500 acres of old growth forest, though the deal was not finalized until 1999 (Bernstein 2018). This added fuel to the growing fire between environmentalists and the logging industry, which was shifting from a united front to a rift

between the loggers on the ground and the management directing the fight, who were putting profit over safety (Speece 2017).

British Columbia

British Columbia also saw the use of tree spiking (putting spikes in trees so that chainsaws broke when cutting) as early as 1980 as part of a campaign to prevent old growth forests from being logged in native lands on Meares Island in the Clayoquot Sound (Bari 1993). After many years and protests, including the largest civil disobedience in Canadian history in 1993, the First Nation Tribes and white protestors had succeeded in protecting the Clayoquot Sound forests and establishing First Nation tribes as the managers of the forest and its logging (Tindall 2013). Furthermore, the Sound was designated by UNESCO as a biosphere reserve for its biodiversity (Tindall 2013).

1.4 Native American Tribes and First Nations

Ethnobiology considers the integration of human ecology, noting the illusory nature of human exceptionalism (Tidemann & Gosler 2012). The spotted owl plays an important role in indigenous cultures. In the Spuzzum First Nation of British Columbia, Canada, the spotted owl is considered sacred, and therefore part of the cultural as well as natural heritage (Cox 2020). The holistic approach of the tribes focuses more on ecosystem-based rather than species-specific management, considering all needs rather than a single, potentially damaging industry or culture (Leech 2009). This runs

counter to current management practices in the U.S. that focus on species-specific plans. The perceived relationship between humans and nature of First Nations, as with many indigenous cultures globally, might be characterised as 'People in Nature' (Ingold 2022), a view which contrasts subtly with current sensibilities in nature conservation characterised as 'People and Nature' (Mace 2014). The Leq'a:mel First Nation in British Columbia was recognized in 2020 for their good forestry practices managing "timber harvesting, road construction, reforestation and fire prevention" in the protection of the spotted owl habitat (Louis 2020).

Not all tribes feel the same about the spotted owl on the subject of managing land for conservation. In some places, it has caused friction with the U.S. government and the USFWS when they come into an area and enforce protections. This was observed in the North Fork Mono Tribe of California, where a California spotted owl was heard in a previously tribal-managed forest (Boero 2017). The forest, with some 400-year-old trees, became protected and was managed to promote ideal habitat for the owls with a dense understory that was previously removed by the tribe (Boero 2017). When a wildfire swept through the area, it caught the understory and destroyed all the trees (Boero 2017). This type of interaction between tribes and federal agencies can cause deep rifts of distrust. It also highlights the importance of ecosystem management rather than species management.

Genomic evidence suggests that the spotted owls only started to decline in the last century with exploitation of forests for lumber (Fujito et al. 2021). As shown in the

example above, protections for the spotted owl do no good if the management results in the forest burning down. Conservation management needs to balance with fire management for the protection of not only the spotted owls but for all the other forest species. Besides habitat loss, the economy of tribal lands is intensely affected by federal regulations restricting cultural and historical practices (Hoagland 2016). A balance must be found to manage not just the species but also the people and land they live on.

There are roughly 50 federally-recognised tribes/tribal communities in B.C., 30 in Washington, six in Oregon, and 44 in California within the northern spotted owl's range (Foy 2021 and Native Land Digital 2021). Tribal perception of the NSO is clearly significant for its conservation, and so a review of Traditional Ecological Knowledge (TEK) related to it would be valuable. A full ethnography of NSO TEK would be a major undertaking in itself. However, whilst not a comprehensive survey, a search of tribal websites on the internet suggests a rich connection with the bird in some areas.

This review found only a handful of NSO references that specifically mentioned the species and not owls in general. Some mentioned non-species-specific owl stories on their websites: the Hoh Tribe told of the hill named 'owl' on their land, the story of Day Owl and Night Owl and where they lived, how Night Owl's hill was avoided, and that one of the tributaries for the Hoh River was named Owl Creek in 'Owl's-house country' (Powell n.d.). There is also a story from the Table Bluff Rancheria of Wiyot Indians about how a young girl growled at Owl every night, and eventually, he visited

her and killed her. Some tribes told their word for 'owl'; 'Hatis' in Hanis (Confederated Tribes of Coos, Lower Umpqua and Siuslaw Indians), 'Haats' in Miluk (Coquille Indian Tribe), and 'pitsou'laksh' in Soulatluk (Table Bluff Rancheria of Wiyot Indians). Only the Spuzzum Nation and the Kwantlen First Nation in B.C. used a word specific to the NSO: skelúle? in Nlaka'pamux (Spuzzum) and Skalula (Kwantlen). They also told of how the spotted owl is seen as a messenger and indicator of the forests and how Owl used to be human-like and carried off children who wouldn't sleep until it turned into an owl (Labbé 2023). All of these references are shown in Table 1.1. As much of tribal culture is oral, and some Traditional Ecological Knowledge (TEK) is reserved explicitly for members of the tribe, this review was limited by what was available online and thus not representative of the full cultural significance of the spotted owl. Nevertheless, this highlights the importance of the owl through time and culture.

Table 1.1: Summary of references to northern spotted owls or owls in general across 85 tribal Websites and news reports. Text was copied verbatim from the websites.

Tribes	Word for 'Owl'	Owl Stories and References
Spuzzum First Nation	skelúle? (NSO)	bedtime stories about how spotted owls used to be human-like creatures who would carry off children who refused to go to sleep. “It took too many kids and was turned into an owl; now, it can only make the sound of a larger beast.” (Labbé 2023).
		In 1971, a Spô’zêm matriarch was called upon by our Ancestors to tell the story of our much-loved relatives, the skelúle?, otherwise known as the Northern spotted owl (as named by the settlers of Canada),” said Chief James Hobart, Spuzzum Nation. “Our messengers are extremely powerful beings: they are the messengers to our spirit world and of our physical world. They are species that are indicative of the health of an environment. Our matriarch Hrome’Tik’Inquakosen’s artistic documentation of skelúle? was instrumental in the preservation of our old growths and the work we are continuing with today for Skelúle?’s return into the wild (BC Gov News 2022).
Kwantlen First Nation	Skalula (NSO)	“sacred spotted owl” (BC Gov News 2022).
Hoh Tribe	kwokwollsdó (Night Owl)	There were apparently three Hoh-tributaries that were considered to drain their own regions: (i) Owl Creek (see # 24 below), called kwokwollsdó’ti (‘Owl’s-house country’)
		A mile above the mouth of Nolan Creek, west of Anderson Creek, was an 800 foot high hill that was called kwokwollsdó, “owl”. It was a source of irony to Herb Fisher that the Whiteman named a different place Owl Creek and Owl Mountain on

		the Upper Hoh, but the Hoh's themselves had had an owl-place all along which is now almost totally forgotten. According to Quileute and Hoh tradition, this hill was Owl's home at the Time of Beginnings.;
		Finally, Day Owl's home (hohohOsti) was there. He was a day owl because Bald Eagle, who originally had bad eyesight borrowed his eyes and ruined them, so when HohohO's got them back he couldn't see at night anymore (Bald Eagle finally borrowed YakwOkwadas the Slug's eyes and never gave them back, so Eagle has good eyes and slug and his nephew Snail had no eyes at all). The ancestors of all those birds lived on the Calawah. But Night Owl, Kwokwollsdo, who was kind of shy and had found it difficult to say no to Eagle's constant requests to borrow his eyes, moved to the Lower Hoh River, where he lived in peace (HG quoting Harold Johnson, Herb Fisher). Owl's home was atop the hill west of Anderson's Creek. Ghosts could turn into "night birds" (owls) and were known to call the name of someone who was about to die (Reagan and Walters, p.317). The hill called Kwokwollsdo was avoided by the Old People. (Powell n.d.)
Confederated Tribes of Coos, Lower Umpqua and Siuslaw Indians	Hatis - owl (Abundance StoryMap 2024)	
Coquille Indian Tribe	Haats - owl (Metcalf 2023)	
Table Bluff Rancheria of	Pitsou'laksh (Great-Horned	"In the evening you can hear the owl talking and young girl went out and growled at him every

Wiyot Indians	owl)	evening. Her mother told her not to do this. One time all the older folks went off and told young girl to pound and leach acorns. She promised that she would and began to pound. Soon she heard someone. He wore Deerskin with a belt and sat opposite of the young girl. He asked her if she was alone, and she told them where they went. He asked did she ever hear talking in the evenings. She said she heard owl and that she talked to him, but that owl never spoke to her. He then asked her if he could help pound with her. She told him not to, but he took the pestle. Soon he put down the pestle and grabbed her lags and took her apart and made her look like she was sitting there and went away. The folks came home, saw young girl and found her dead. They didn't know who did it. They never heard owl again. A long time after they found out that owl did it." (Wiyot Tribe 2023)
Skokomish Indian Tribe	wəhaw ḡaḡaʔaḡ^w (screech owl) (Drachman 2020)	
Stillaguamish Tribe of Indians		Another event was the looming prospect of a federal listing of the Northern spotted owl under the Endangered Species Act (ESA), whose range had been impacted by intensive logging of old-growth forests on state regulated and federal forests (Stillaguamish Tribe of Indians 2022).
		The Stillaguamish Tribe Wildlife Program, in partnership with U.S. Forest Service, the Sauk Suiattle Tribe, and various bird organizations, hopes to use land bird observations as an indicator of habitat complexity. This is particularly important for vulnerable species like the northern spotted owl and marbled murrelet
Confederated		Grasses, flower nectar, seeds and berries touch

Tribes of Siletz Indians		off a tangled food web, twisting through insects to rodents, birds, and bats, and finally to raptors like northern goshawks and northern spotted owls that hunt from adjacent unburned forests
		Spotted owl: are adapted to take advantage of patches of moderate-severity fire. They use standing dead snags for perches to hunt rodents from, especially if there is nesting habitat nearby. Some studies suggest that they can live in forests regrowing after mixed-severity fires with up to 70% being high-severity burn (Vesper Meadow Education Program n.d.)
Karuk Tribe		Not traditionally managed for specifically (Karuk Tribe 2009).
Hoopa Valley Tribal Reservation		This requires surveying for species protected under the Federal Endangered Species Act (ESA) such as the northern spotted owl and marbled murrelet. The Wildlife Department began with the hiring of a wildlife biologist in May 1991 shortly after the northern spotted owl was listed as a threatened species. Since that time there have been numerous seasonal technicians hired to complete the surveys for spotted owls and marbled murrelets (listed as threatened in 1992).
		The main projects that have been worked on over the years include the demographic monitoring of the reservation's northern spotted owl population, reservation wide marbled murrelet surveys, research on black bears and tree damage and fisher habitat selection and demographics.
		Every year since 1992 the wildlife crew has surveyed the entire reservation (except the South Tish Tang and Box Camp Reserves) for northern spotted owls. All spotted owls located are banded with color bands and USFWS number bands. Previously banded birds are re-sighted each year and all new territorial birds are captured and banded along with all juveniles. The banding and re-sighting data is used to estimate demographic

		parameters including 1) Apparent Survival, 2) Reproduction, 3) Recruitment and 4) Population Change. The data is used to support Threatened and Endangered species consultations with the U.S. Fish and Wildlife Service which are required because of the owl's status as a Federally Threatened species. The spotted owl surveys involve calling for owls at night and then finding their roost and nest sites during the day. We have kept track of barred owl responses received during the course of spotted owl surveys since 1991. Barred Owls (an invasive species from the east) have increased dramatically and as they have increased the spotted owl population has decreased. In 2009 we started specifically surveying for barred owls in an effort to document their increase and the apparent impact to the spotted owl population. Since the threatened spotted owl is declining on the reservation and throughout much of it's range it is important that we determine whether the decline at Hoopa is related to barred owls or timber harvest. We strongly suspect that it is primarily due to barred owls taking over the landscape (Hoopa Tribal Forestry 2012).
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1.5 Meta-analyses

Seven range-wide meta-analyses have been conducted on the NSO; Anderson & Burnham 1992, Burnham et al. 1996, Franklin et al. 1999, Anthony et al. 2006, Forsman et al. 2011, Dugger et al. 2016, and Franklin et al. 2021. These extensive studies provide the bulk of our understanding about the species in the most comprehensive way by combining efforts from government agencies, universities, tribes, and private groups into one document roughly every five years. These researchers have tracked the decline of the species and identified threats to be addressed as well as how the owls use or transition through territory.

2

A Socio-historical Comparative Analysis of Language Shifts Relative to the Range of the Northern Spotted Owl

Ami Pekrul, Bastian Thomsen, & Andrew Gosler

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Abstract

The northern spotted owl (*Strix occidentalis caurina*) has been an icon representative of the conflict between conservationists and loggers in the US Pacific Northwest for 40 years owing to its use of old growth forests. Newspaper articles on the northern spotted owl since the 1980s show a shifting narrative that reflects local sentiment. The influence of national and international newspapers and the spread of awareness of the decline of the owl have contributed to that shift. This chapter compared 2,598 newspaper articles in decadal blocks since the 1980s to explore the change in narrative and major events in the conflict around the owl's protection. I tested the hypothesis that there was a documented societal shift from 'nature despite people' to 'people and nature' which was reflected in the narrative relating to the northern spotted owl. I compared the language used in articles published within its geographic range with those published outside. I also focused on articles that reached the front pages of national papers to consider the influence of national coverage on local communities. A language shift from "timber" to "forest" expressed a trend in which trees were seen less as a commodity or resource and more as an entity to be preserved. This analysis, which spanned a period in which nine presidential elections took place, also examined how sweeping changes in environmental policy impacted the owl, sometimes for decades.

Keywords: Conservation, human-wildlife conflict, language, newspaper, northern spotted owl, socio-historical, Strix occidentalis caurina

2.1 Introduction

Since the 1970s, the northern spotted owl has been a mascot, icon, and figurehead for environmental issues in the Pacific Northwest of the United States. The owl was chosen by the environmentalists to serve as a proxy because there were no laws governing the forests at that time to protect them. During the era of the ‘Timber Wars’, a period of turmoil in the 1990s Pacific Northwest that pitted economically-minded logging communities against ecologically-minded environmentalists, the owl became a rallying point that highlighted the ‘plight of nature’ in the consuming wake of human expansion. As people become more disconnected from nature, the conceptual divide between nature and humans increases, generating controversies like this one (Gelsthorpe 2017). Ethno-ornithology, or conservation social science on a larger scale, is vital to view conservation conflict issues from the standpoint that humans are a part of nature, not apart from it (Dayer et al. 2020b).

In the 1980s and ‘90s, the general societal view of nature in the United States shifted from “nature for itself” to “nature despite people” (Mace 2014). This reflected a growing awareness of the link between human activity and long-term environmental consequences (Ceballos et al. 2015), as the actualization of earlier warnings by Carson (1962), Ward (1972), and others became starker. The effects of habitat loss and pollution were being studied in greater detail at the end of the 20th century, and the public was able to witness this progression and increasingly wanted to be part of the process of stopping it. The recognition grew in significance when the spotted owl was

federally listed as threatened in 1990 and 90 percent of known owls existed on federally-owned/administered lands. This is because almost all of the old-growth had been logged on private and tribal land, which highlights the vital importance of preserving public lands for imperiled species that would be extinct without protections (Endangered and Threatened Wildlife and Plants 1989). The role of nature itself continued to develop in this dialogue so that by 2000 the importance of “nature for people” marked the priority of resource management and ecosystem services (Mace 2014).

A further shift has occurred since then, recognising the legitimacy of humans within the biosphere so that the narrative is today characterized as “people and nature”, as reflected in the eponymous title of the journal launched by the British Ecological Society (2024) in 2018. This shift also saw a greater recognition of the importance of Traditional Ecological Knowledge, or TEK (Mace 2014 & Berkes 1993). TEK is knowledge of the environment, usually indigenous, sometimes gained over thousands of years, and more recently applied to scientific understanding (Thomsen et al. 2024, Ruelas Inzunza et al. 2023, and Soares et al. 2023). This wealth of understanding, knowledge, and history of the species and its land management is invaluable to current management practices. It should, however, be recognised that the stewardship perception of indigenous peoples generally is not so much of ‘people and nature’ as ‘people in nature’, i.e., the recognition of people as part of nature.

New fields, such as ethno-ornithology, the study of humans and birds (Tidemann & Gosler 2012), is emerging as the scientific community leans more towards interdisciplinarity rather than hyper-specialization. It is becoming no longer possible to investigate a large-scale biological problem without considering the role people have in the issue, whether it is economic, management jurisdiction, researcher bias, etc. This is especially true in conservation conflicts, which are influenced by evolving data patterns, making their recognition a crucial step in understanding the narrative.

Anderson et al. (2021) used culturomics to show how ecological terms changed from the 1930s to the 2020s from fundamental to more applied ecology. Culturomics is the study of cultural and linguistic change over time through quantitative analysis of large bodies of digital work (Ladle et al. 2016). This method is being used with increasing frequency in conservation, where identifying public interest and the changing overall sentiment allows researchers to gauge which facets of conservation will be more successful (Correia et al. 2016). In China, for example, a study used culturomics to assess how the public used *Sina Weibo* (a *Twitter* equivalent 新浪微博) in 2013 in regard to keywords used around the ivory trade (Ladle et al. 2016). The researchers discovered that the majority of the public was against ivory use, which had direct conservation management implications as they realized that the evidence of the situation differed significantly from their assumptions. Culturomics can also be used for environmental monitoring and valuation, identifying conservation emblems (or icons), assessing cultural impact, and policy and issue framing (Ladle et al. 2016).

Socio-historical theory is a blanket term for a diverse set of disciplines including “historical-comparative sociology, social-science history, economic history, historical social science, social history, world-systems analysis, historical anthropology, historical geography, cultural history, and so on” (Hall 2007). One analytical method derived from socio-historical theory involves reviewing newspaper articles over a period of time to gain perspective on the overall views of society during that time, as demonstrated later in this chapter with the spotted owl. This is similar to the theory of the public sphere, which concerns how societal changes are reflected by the media’s exposition of changing public opinions (Andersen & Skouvig 2006). Newspapers have been used in many studies to show how public opinion on a certain topic changes over time (Sabatier & Huveneers 2018). One study, for example, showed how newspaper articles changed prior to, during, and after successive shark attacks in Australia from 2011-2013 (Sabatier & Huveneers 2018). The outcome of this study had important implications: the media contributed to public anxiety about rare fatal events and that scientists needed to engage with the media more to avoid misconceptions and unnecessary fear (Sabatier & Huveneers 2018).

Many examples exist of conservation conflicts that have polarized public opinion, the consequential impacts of which have ranged from life-threatening to economic (Thomsen et al. 2021, 2022). The grey wolf (*Canis lupus*) offers a well-known example of conservation controversy. The public perspective on wolves has changed over the years, but most especially between 1930 and 1970 (Williams et al. 2002), during which a shift occurred from trying to eradicate a predator to trying to save them by creating

protected areas (Smith et al. 2003). Another example of public opinion changing during a conservation conflict is that of farmed salmon (*Salmo* spp.). The negative public view has eased somewhat as standards and technology have improved the fish farm industry, as well as providing a lower-cost alternative to wild-caught salmon (Trilling 2017).

2.1.1 Northern Spotted Owls

In some timber-dependent communities, such as Longview, WA or Forks, WA, the environmentalist-logging conflict is still prevalent, though not nearly as much as it was in the 1990s. Simply speaking to residents in the area reveals the still strong emotions about the birds. For example, the raptor's name is used as 'menu items' and on bumper stickers: 'save a logger, eat an owl'. Thirty years since the appearance of the owl's prominence in the logging debates, its population is still declining as new threats challenge an already threatened species. One has only to hike into almost any old-growth forest to encounter logging operations or discarded chains and saw marks in the Pacific Northwest.

The ecological specialization of the spotted owl has led to its presence being regarded as an indicator species for healthy forest ecosystems in the region (Moore 1993). Consequently, their absence sparks the question of whether a forest system is missing vital elements. It is also an umbrella species because its specific habitat requirements are such that, through its protection, many other old-growth species are also effectively protected (Simberloff 1998). According to Buechley et al. (2019), the

spotted owl is the eighth most researched raptor in the world, having been brought back into the spotlight in 2020-21, when the Interior Secretary for the Trump Administration removed protections for 3.5 million acres of critical habitat just days before leaving office in 2020 (USFWS 2021). This was in conjunction with the USFWS findings that year that federally uplisting the spotted owl from threatened to endangered was “warranted but precluded by higher priority actions” (Endangered and Threatened Wildlife and Plants; 12-Month Finding for the Northern Spotted Owl 2020). In 2021, the Biden administration reversed this decision, keeping the owls in the news across the country.

Mounting tensions between environmentalists and the logging industry were exemplified by human-owl relations. The creation of the Northwest Forest Plan (NWFP) in 1994 helped break the stalemate between environmentalists and loggers, and the owls benefited from the large-scale protection of their habitat (Forest Ecosystem Management Assessment Team 1993). More recently, the Bureau of Land Management (BLM) shifted away from the NWFP framework and towards viewing more logging as necessary to create and maintain spotted owl habitat (Cornwall 2016). This resulted in habitat with old-growth being logged to make way for potential managed habitat 100 years from now. This is seen as justification to log regardless of the spotted owl’s decline.

When looking through a historical lens, primary sources are key to understanding the political/social views, language, and feelings of a particular time (Urbach 2012). A controversial series of events, such as those associated with the northern spotted owl,

presents a unique reflection of how different communities interpreted the same information. Articles coming from logging towns might be expected to differ significantly in the opinions expressed on the situation than would a newspaper coming from out of state. Logging communities are still being affected by the laws protecting the owls and many businesses are blaming the owl for slowing the rate of cutting and processing timber (Gutiérrez 2020). When the owl was listed, researchers agreed that one barrier to recovery was the fragmentation of habitat caused by logging old-growth and that if logging were to cease in those forests, then the owls had a chance to recover (Marcot & Thomas 1997). During the late 1980s and early '90s, when the spotted owl was listed federally, the *Los Angeles Times* and *The New York Times* took up the issue and spread awareness around the country (Egan 1988 & Stein 1990). Another important consideration when looking at newspapers for analysis is on what page the article was located. The *New York Times* article on the conflict was found on page one, a strong indicator of the issue's importance (Egan 1988). The 1990s saw an increase in articles on lawsuits and high court rulings in response to the owl's listing, highlighting the bitter contention between stakeholders.

This chapter presents a socio-historical approach tracking changes in perception toward the owl over time, both locally (i.e., within the geographic range of the owl and in neighboring states) and nationally. Using archival material, newspaper articles were examined as a surrogate of public opinion from the 1980s to 2021 from key locations in the owl's range. Both urban and rural areas were used to assess the differences in both how nature is viewed and in the level of disconnect that can appear when an industry

becomes dominant (Dayer et al. 2020a). Timber harvesting is a significant industry, especially in the Pacific Northwest, and previous research into views of nature has demonstrated that in logging communities, the cutting of trees is considered natural and ethical, while urban area residents are more likely to oppose the mass felling of trees (Williams 2002). In 1999, Bendix and Liebler conducted a study on the geographic variance in newspaper coverage on the spotted owl. They found that between 1990, when the owl was listed, and 1994, people in areas closer to the spotted owl range felt more strongly about the logging industry, and in areas further away people were more owl-friendly. The socio-historical method of analysis allowed both quantitative and qualitative analyses of the language used in this discourse to be conducted, with both inductive and bottom-up (specific articles towards general perceptions of regions) approaches to illuminate the human sociocultural and socioeconomic dynamics that influence owl-human relations and their potential effectiveness for the owls' conservation (Creswell & Creswell 2017).

2.1.2 Predictions For This Study

Based on the previous studies detailed above, shifts in the language used about the owls are expected, especially during election years and/or in the first year of a U.S. presidency and around the introduction of significant environmental legislation. Since the owl conflict had persisted since the 1970s, evidence might be expected from shifts in the language for the changed 'view of nature' trends described earlier as: 'nature for itself' (1918-1972), 'nature despite people' (1973-1989), 'nature for people' (1990-2008),

and ‘people and nature’ (2009-2021) (Mace 2014). The beginning of the owl-timber conflict showed environmentalists fighting for the owls and their habitat for their own intrinsic value rather than the economic value of their habitat. The earlier phases of this trend were already clear. The owls were federally listed during the period of ‘nature despite people’, and survived the ‘nature for people’ stage where the lumber community and timber products were taking priority. Now that they are in the ‘people and nature’ stage, it is likely that the outlook for perception will improve, even if the owl’s population density does not, although the framing still fails fully to acknowledge the indigenous stewardship understanding of ‘people in nature’.

2.1.3 1-5 Year Implications

Public perception of spotted owls is shaped by patterns in the surrounding narrative, which in turn influences the broader conservation conversation. As perceptions grow more positive, they can drive legislative change and strengthen protections. A public more invested in saving the owls is also more likely to participate in comment forums on new laws or support changes to the species’ federal or state status, such as an upgrade from threatened to endangered.

2.1.4 Hypothesis

The goal of this chapter is to explore how public perceptions changed over the course of the controversy with the owls from before the listing to after the pandemic. The hypothesis is that the Pacific Northwest with its prolific logging culture would have a less

sympathetic view towards the owls, while the regions outside the owl's range and therefore beyond the affective repercussions of protections would be more sympathetic.

2.2 Methods

The conflict around the owl and its listing saw a significant increase in the use of media to tell the story, including newspapers, books, and references in movies. The Google NGram viewer (Michel et al. 2011) was used to examine the frequency of northern spotted owl occurrences in published books. When creating the NGram, occurrences in literature of the northern spotted owl were compared over a 100-year period with three more widely-known American species: barn owls (*Tyto alba*), great horned owls (*Bubo virginianus*), and barred owls (*Strix varia*).

2.2.1 Sourcing Newspapers

English-language newspapers were sought from databases (LEXIS-NEXIS, ProQuest, Historical New York Times, NewsBank and Newslibrary), local paper archives, and University Archives. Local, national, and international newspapers have covered events around the northern spotted owl and were all used in this study. When searching NewsBank, “northern spotted owl” and “Northern Spotted Owl” returned the same 22,968 results, indicating that the search was not case-sensitive. Nearly half of these were unrelated to the owls and merely contained the three words somewhere (e.g., *snowy owl was spotted in northern Michigan*). Over half of the relevant papers only

offered references (e.g., “such as the northern spotted owl” or “like the Spotted Owl”). To prevent duplication, and to maintain consistency across the full time range, only the print version was included in cases where the same newspaper offered text in both a web article and a print article. Web articles were not excluded if there was no print version. Page number was taken to mean the first page of the article rather than that on which the spotted owl was mentioned. Table 2.1 shows the criteria used for inclusion in the analyses.

Table 2.1. Inclusion and exclusion search criteria for newspaper articles used in the socio-historical analysis of northern spotted owls.

	Criteria	
	Inclusion	Exclusion
Database	ProQuest, NewsBank, OSU Special Archive, local newspaper websites	Journal and magazine articles
Search Terms	Northern Spotted Owl	California and Mexican Spotted Owl
Language	English	Any other
Time Period	January 1-December 31 of 1988, 1989, 1998, 1999, 2018, 2019, 2020, 2021	Years before 1988 and gaps in between established years
Articles	Print unless there is only a web article	Redundant articles or web articles that already have a print edition

2.2.2 Article Analysis

Articles were grouped by two-year sets (1988-89, 1998-99, 2018-19, and 2020-21) to compare the time around the owl’s listing to current views. Changes over time were gauged: nearly every ten years, as well as a comparison from pre- and post-listing of 1990 threatened status and pre- and during the Covid-19 pandemic (2020—2021).

Using two years in each set allowed a clearer picture to emerge of perceptions for that decade than would a single year, whilst not becoming overwhelmed by the scale of the task. Future research would benefit from analysing every year in the timeframe to assess whether other factors might influence perceptions. The scope of this paper did not allow for the significant time required to undertake such a complete survey. Nevertheless, of the nine presidential elections that occurred during this timeframe, two, in 1988 and 2020, fell within the scope of analysis. Both pandemic and presidential elections were major disturbances to environmental policy and affected newspaper coverage.

Primary factors for analysis included: date (day, month, and year); if the newspaper was local to the owl's range, national, or international; and if the narrative was overall positive or negative. Secondary factors included the author, the paper's name, the intended audience, the article's location in the paper, and the section of the article (Zamawe 2015). The main questions of this research were to assess whether and how national or international coverage influenced the reporting in local areas, how administration changes influenced opinion, and changes over time in perspective (pre- vs post-pandemic and 1980s vs 2020s). The NVivo analytical package was used to detect trends in common keywords and word frequency (Purnama 2012). Keywords were also analysed according to year-sets, how many were on the front page, and all the articles together.

NVivo was chosen as the primary analytical tool for its flexibility with both inductive and deductive coding, transparency, and alignment with context-rich research. Other methods such as machine learning and large language models would require more standardised datasets, which was not possible here with the newspaper articles coming in many different formats (pdfs, scans of originals, or text copies) (Milligan 2019). Some of the articles had to be transcribed from grainy pictures, which could only be done by a person. Topic modeling was another method that was not chosen due to its possibility of losing context in favor of word groups (Goldstone & Underwood 2014).

All articles that appeared on the front page of newspapers were collected into a set for additional analysis. The attributes for each article were categorized as: title, author, day, month, year, newspaper, location of newspaper, within or outside the spotted owl's range shown in Figure 2.1 (as well as a buffer zone of 50 miles outside the range to allow for exploration of nearby communities outside the range that may share sentiment one way or the other), the section of the paper, name of the database where it was found, overall theme, length of the article, number of times "spotted owl" was mentioned, positive or negative narrative, and the word frequency of forest vs timber. This query was run using stemmed words, rather than exact words to allow for greater reach (e.g. forest, forests, forested, etc.).



Figure 2.1. Current range map of the northern spotted owl for the U.S. though Canada is excluded as the owl is functionally extinct there with only one wild owl left. (USFWS 2021).

Word clouds were generated from the 50 most common words using NVivo software. Common words such as and, like, and as were excluded as well as words with fewer than three letters. These word clouds were used to demonstrate pictorially the frequency of common words throughout the articles, which were shown as a whole and separated into those within the owl's range versus outside. The larger a word appears in the cloud, the higher its relative frequency of use in the articles. A chi-square test of independence was carried out on the results from these clouds to explore the significance of associations between "timber" and "forest", and local and national. Frequency counts for each term were organized into a table with local and national

columns. The test assessed whether observed frequency deviated from those expected between the terms by location.

We then created a table using Nvivo to summarize the 50 most used words for front page articles and separated them by those within/buffering the NSO range and those outside. To simplify the process, we used stemmed words and listed the singular terms in the table. The word counts and weighted average percentages were listed for each word.

2.3 Results

The Google NGram carried out an occurrence of owls of four species in literature since 1919 (as this was as far back as it went) demonstrating the explosion of information published in books about the northern spotted owl during the conflict (see Figure 2.2). This corresponded particularly with its being federally listed. In 2013 it dropped in importance below barn owl and great horned owl and 2016-2018 briefly below barred owl (Google NGram Viewer 2022). While many of the books published are technical reports and recovery plans, etc., there is also travel literature, textbooks, nature guides, and fiction (Google NGram Viewer 2022). This analysis demonstrates how the northern spotted owl far outpaces the other owl species, justifying the use of other media to assess the species' importance in the context of conservation conflict.

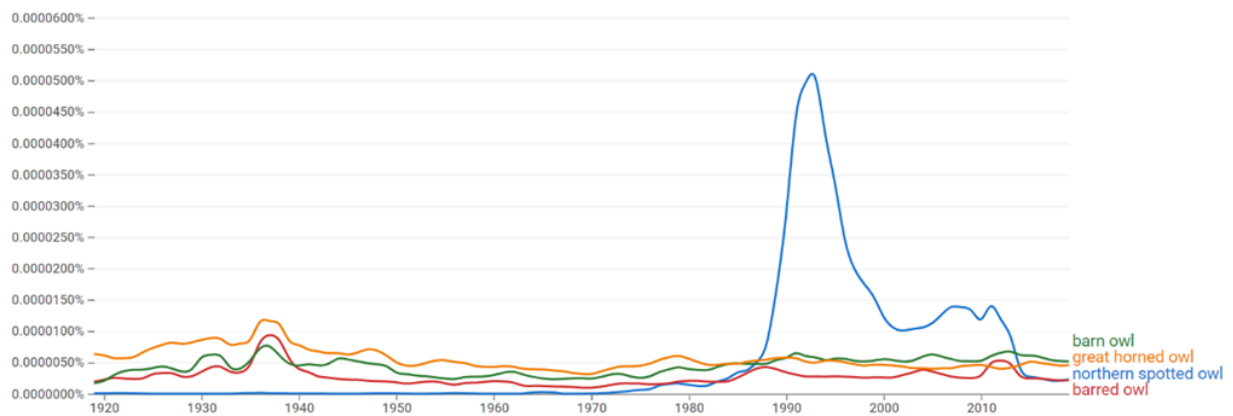


Figure 2.2. A Google NGram (2022) graph comparing the ‘northern spotted owl’, ‘barn owl’, ‘great horned owl’, and ‘barred owl’ occurrences in books published in the United States from 1919-2019.

For newspaper media, NewsBank was found to be the most useful archive, yielding far more newspaper articles across a broader range than any other source. It did not include international articles, however, which were found elsewhere. In total, 2,598 articles were used in this study. The totals per year were as follows: 1988: 107; 1989: 585; 1998: 266; 1999: 328; 2018: 247; 2019: 359; 2020: 248; and in 2021: 459. As an example of how archive material was selected, in 2018, when searching for ‘northern spotted owl’, NewsBank returned 601 articles. Many of these were not about the owls or mentioned them only as a reference to another topic. Of that 601, only 246 were selected for further analysis as they either contained more than one mention of the owls or the article focused on, or was relevant to, the owl story. Finally, of the 246 articles, 132 were published within the owl’s historical range, and 114 were in nationals. Seven articles from 1989 and one article from 2021 were missing the location and title

of the newspaper. These eight articles were included in the analysis for relevance and listed as unknown in Figure 2.3, which gives the decadal breakdown of articles by newspaper region.

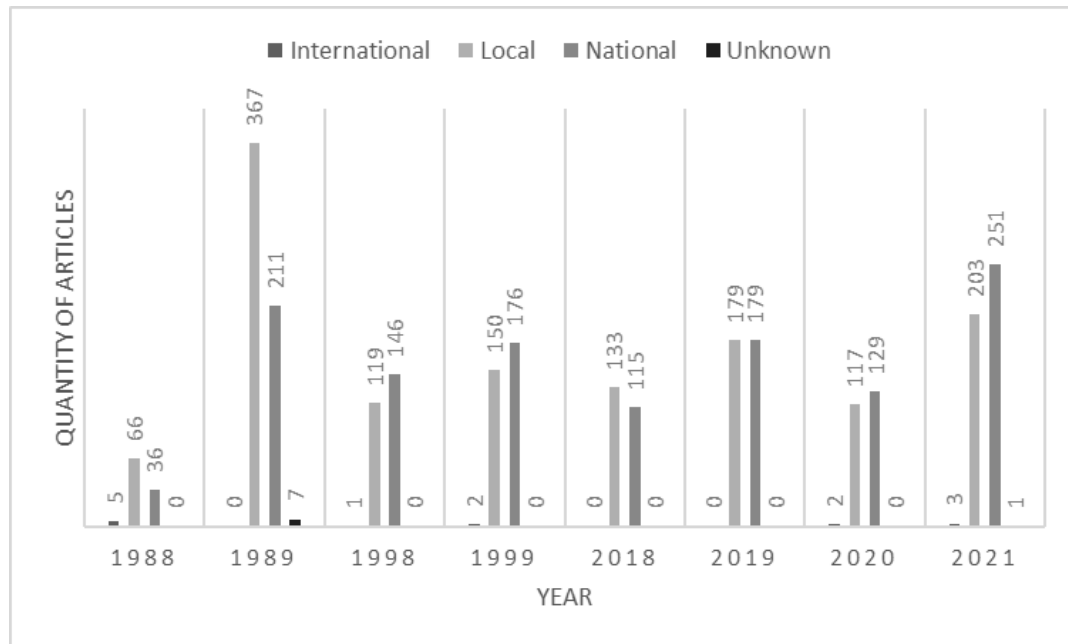


Figure 2.3. Breakdown of articles surveyed for references to the northern spotted owl in each year in international, local, national, and unknown (locations for unknown were unavailable in the NewsBank database) newspapers of the USA.

2.3.1 Word Use

The NVivo analysis of word frequency by year-set across all articles, both within and outside of the owl's range, found the word "forest" to be more frequent than "timber" in every set although they matched closely in 1988-89. In that set, the term "forests" was mentioned 5,202 times throughout all the articles, while "timber" was mentioned 4,102

times. This year-set immediately pre-dated the federal listing of the owls as threatened in 1990. “Timber” was 2nd in the 1988-1989 and 1998-1999 year sets. The 2018-19 set showed a further fall of “timber” to 10th place before climbing back to 7th in the 2020-21 set. These terms are highlighted in Table 2.2 and Table 2.3. Interestingly, the term “forest” went from 1st to 2nd and 1st again. As the goal of this analysis was to see what words the public would be exposed to the most, the exclusion terms were not an issue.

Table 2.2. Top ten word frequency of newspaper articles by year-set focusing on the frequency of forest and timber. Exclusion terms (in bold) refer to words as part of an organizational name, and that column shows the quantity of term used without those exclusions included (e.g., Forest Service or Jones Timber Company). Generated from NVivo software.

Rank	1988-89	Quantity	Without Exclusion Terms	1998-99	Quantity	Without Exclusion Terms
1	Forest	5202	3726	Forest	4327	3278
2	Timber	4102	4035	Species	2092	
3	Owls	4062		Year	1960	
4	Old	2530		Log	1958	
5	Service	2515		Plan	1854	
6	Growth	2302		Timber	1846	1776
7	Log	2197		Federation	1715	
8	Spotted	2157		State	1715	
9	Year	1789		protect	1659	
10	Oregon	1537		Land	1604	

Table 2.2. Continued...

Rank	2018-19	Quantity	Without Exclusion Terms	2020-21	Quantity	Without Exclusion Terms
1	Owl	3271		Forest	3953	3410
2	Forest	2609	2324	Owl	2578	
3	Species	1521		State	1777	
4	Spotted	1401		Spotting	1648	
5	State	1373		Protect	1641	
6	Year	1244		Habitat	1613	
7	Fire	1072		Timber	1574	1508
8	Barring	1050		Oregon	1572	
9	California	999		Fire	1551	
10	Timber	985	955	Species	1511	

Table 2.3: A breakdown of the exclusion terms by year-set.

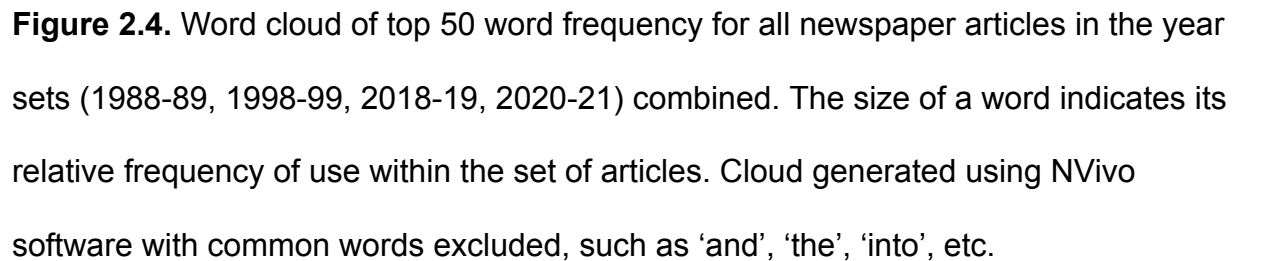
Years	Forest Service	Forest protection association	Forest association	Totals	Timber Co.	Timber association	Timber company	Totals
1988- 89	1468	6	2	1476	14	32	21	67
1998- 99	1037	10	2	1049	18	2	50	70
2018- 19	285	0	0	285	4	0	26	30
2020- 21	543	0	0	543	5	0	61	66

Table 2.4: Top ten word frequency of all newspaper articles by year-set in order of which words appear in all four year-sets, only three year-sets, only two year-sets, and only one year-set. Shaded boxes are words that do not appear in that year-set's top ten. Terms that appear as part of an organizational name were excluded (e.g., Forest Service or Jones Timber Company).

	Words	88-89	98-99	18-19	20-21	Sum totals
All 4 Year-sets	Forest	3726	3278	2324	3410	12738
	Timber	4035	1776	955	1508	8274
3 Year-sets	Owl	4062	1384	3271	2578	11295
	Year	1789	1960	1244	1506	6499
	Spotted	2157	1080	1401	1648	6286
	Species	1148	2092	1521	1511	6272
	State	1192	1715	1373	1777	6057
2 Year-sets	Log	2197	1958	701	1246	6102
	Protect	1254	1659	909	1641	5463
	Oregon	1537	957	756	1572	4822
	Fire	195	200	1072	1551	3018
1 Year-set	Service	2515	1556	779	1148	5998
	Land	1399	1604	961	1444	5408
	Federal	1429	1715	793	967	4904
	Old	2530	710	454	689	4383
	Plan	1134	1854	658	689	4335
	Habitat	748	829	836	1613	4026
	Growth	2302	580	336	504	3722
	California	511	611	999	812	2933
	Bar	75	102	1050	417	1644

The term “job loss” was mentioned 22 times (six on the front page), but only in 1988, 89, 98, and 99, while “unemployment” was mentioned 76 times (17 on the front page) across all the years. This highlights the ongoing conflict by correlating the NSO protection with people losing their jobs. The term “unemployment” has less direct implication. “Habitat loss” was mentioned 80 times (four on the front page) across all the years except 1998 and 1999. “Biodiversity” was referenced 161 times (14 on the front page), but only 28 (17.4%) of those were before 2018. The words “destroy” and “kill” were used 354 (59 on the front page) and 969 times (106 on the front page) respectively, and in every year. These shifts in language use demonstrate the changing perspectives in the public arena.

The top ten words by frequency in the 1988 and 1989 set were forests, timbers, owls, old, service, growth, logs, spotted, years, and Oregon. The term “service” almost entirely referred to Forest Service, USFWS, Park Service, and Weather Service. The top 50 words for all the years are shown as a word cloud in Figure 2.4. Figure 2.5 shows the prevalence of certain words, comparing articles within the owl’s range versus those outside the range. Some words stayed dominant by abundance of references, such as the number one in both: “forests” with no significant difference between areas ($\chi^2 = 0.60$, $p = 0.44$), while some differed considerably and significantly between clouds, as seen with the word “timber” and “owl” from those inside to those outside the range (see below).



2018-2019 and 2020-21 year sets (Table 2.3). The term “owls” is ranked 3rd in 1988-89, not at all in 1998-99, 1st in 2018-19, and 2nd in 2020-21.

2.3.2 National vs Local

Across all 2,598 articles, 1243 were in national papers (outside of the owl’s range), 13 international, 1334 were local (within the owl’s range), and eight were unknown. Local papers made up 63% of the total for 1988-89, 45% for 1998-99, 51% for 2018-19, and 45% for 2020-21 (Fig. 2.3), reflecting its transition from a local to a national and even international interest.

	1988	1989	1998	2018	1999	2019	2020	2021	Totals
International	5	0	1	0	2	0	2	3	13
Local	66	367	119	133	150	179	117	203	1334
National	36	211	146	115	176	179	129	251	1243
Unknown	0	7	0	0	0	0	0	1	8
Totals	107	585	266	248	328	358	248	458	2598

Table 2.5: Number of newspaper articles by year separated by inside or outside of the NSO range.

The relative size differences of ‘timber’ ($\chi^2 = 71.56$, $p < 0.0001$) and ‘owl’ ($\chi^2 = 68.01$, $p < 0.0001$) in articles published within vs outside the owl’s range, shown in Figure 2.5 and 2.6, was statistically highly significant, highlighting the importance of how the stories’ reporting shifted further from the conflict.



Figure 2.5. Top-50 word clouds for front page articles published outside (Left) and inside/buffering the range of the northern spotted owl (Right) across all year-sets. The size of a word indicates its relative frequency of use within the set of articles. Word clouds were generated using NVivo software.

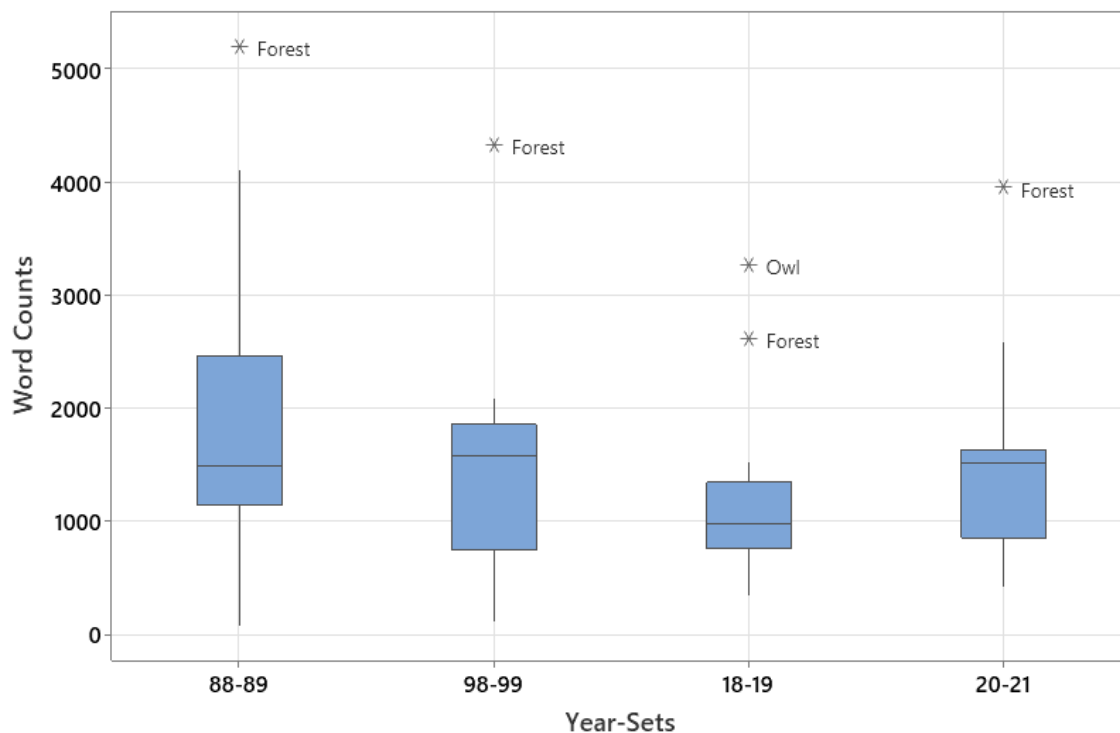


Figure 2.6: Boxplot showing the outliers and the weighted averages of the top 50 words on front page newspaper articles of the NSO, including 'exclusion' words. The outlier words are labeled.

The increase in national interest is represented in Figure 2.7, which shows the number of newspapers running stories both nationally and locally. The NSO are mentioned across the country before their listing, with an increase in state coverage over the years. Every state except Hawaii had at least one agency running stories by 2021.

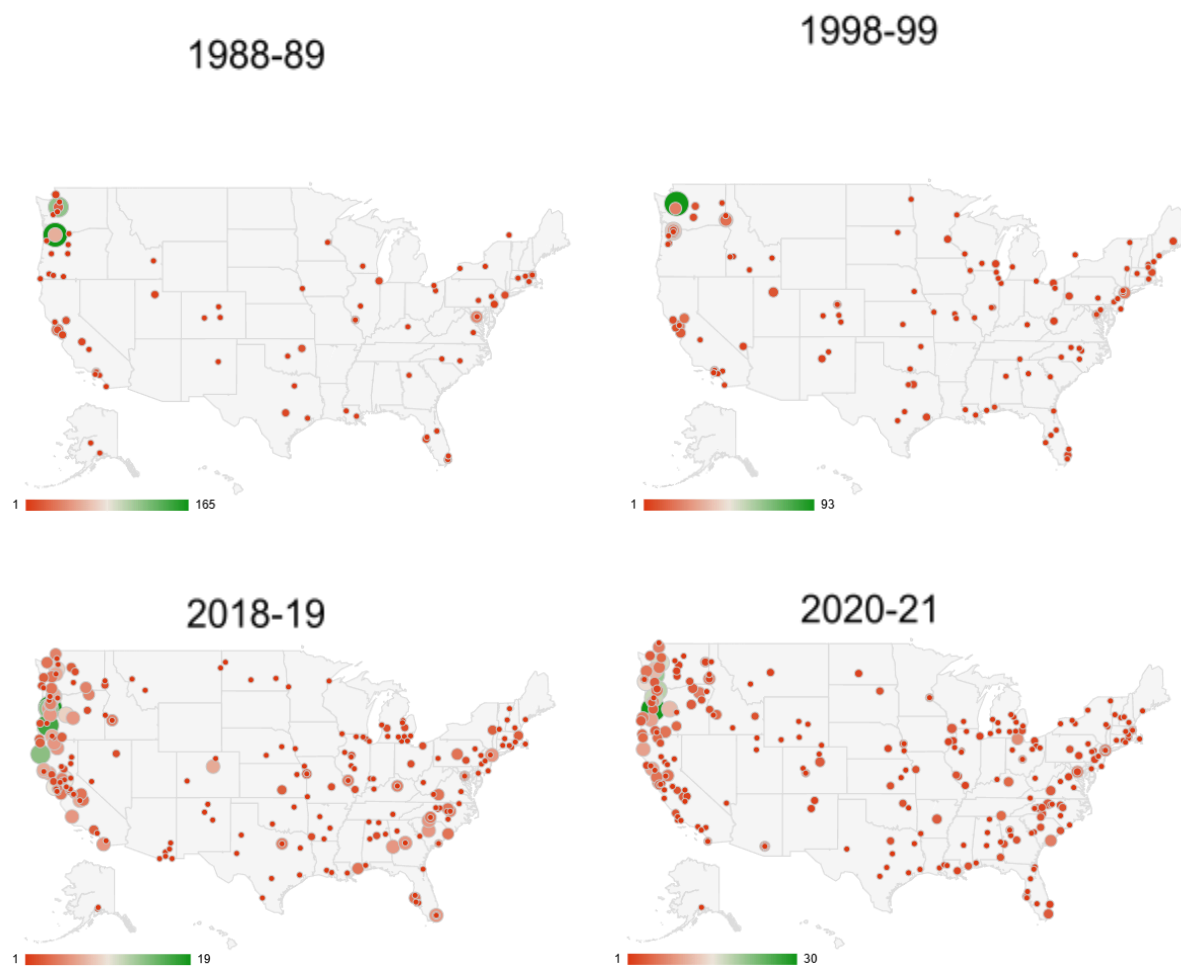


Figure 2.7: Heatmaps of the number of different newspaper agencies running stories inside the United States on northern spotted owls by year-set.

2.3.3 Front Page

The NSO appeared with increasing frequency on the front page in newspapers throughout the years, as the controversy gained national and then international coverage. In 1988, seven articles about the owls appeared on the front pages. Four of

these had three or more mentions of the owls. The longest article (3826 words), was “Owl Upsets Logging Plan for Ancient Forests” from the *New York Times*. Spotted owls were mentioned 34 times on the front page in 1998. Nineteen of those were outside the owl’s range. They were mentioned 50 times on the front page in 1999. Sixteen of those were outside of the owl’s range. There were two international mentions in 1999 (Ontario, Canada) and only one in 1998 (London, U.K.).

Of the 182 front-page articles discussing the spotted owl, 37 mentioned the owls twice, and 80 mentioned the owls once. 62 articles have three or more mentions of the owls. Five articles have ten or more mentions, with the highest having 37 mentions in one article. That article was published in 2020 in *The Bulletin* from Bend, OR, a location designated in the buffer zone (within 50 miles of the spotted owl’s range). Of the 182 articles that appeared on the front pages, 30 (16%) articles were from buffer cities to the spotted owl’s range, 48 (26%) were outside the range, and 104 (57%) were within the range. Excluding the articles with only one or two references to the spotted owls, the rest of the front-page articles had a Word Frequency Query run on them. This revealed that the top ten most frequently used words were, in order: forests, owl, timber, service, spotted, years, logs, old, growth, and species.

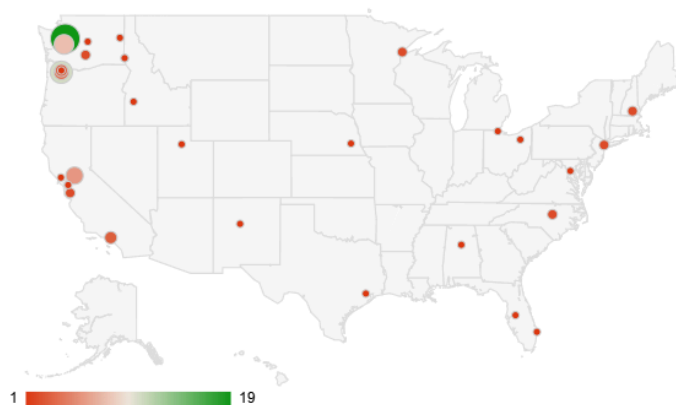


Figure 2.8: Heatmap of front page newspaper articles on northern spotted owls in all year-sets.

The word clouds in Figure 2.5 show a prominence of the word “owl” for the articles within and buffering the owl’s range, while in the articles outside the range, the term is relatively small. The word “forest” is significant in both, and the words “service”, “protect”, and “years” are nearly the same, but “timber” makes a stronger showing for those within the range, being significantly less frequent in articles outside the range. A contingency test of association of “timber” versus “forest” inside versus outside the owl’s range showed a highly significant tendency to report timber as well as, or rather than, forest inside the range; a tendency that was absent outside the range ($\text{Chi-sq}_2 = 54.93$, $P < 0.00001$). Another example of word differences between the clouds was that “salmon” and “fishing” appear in the articles within, while only “fishing” appears in the articles outside, both terms being small in size on the word cloud. Again, this demonstrates how word choice within the range is more specific than those outside.

Using Minitab Statistical Software, we found that of the top 50 words used in front page newspaper articles mentioning the NSO, eight words were only found inside the range of the NSO and eight words outside. The inside only words were Oregon, salmon, growth, manage, Washington, river, sale, and water (these are all stemmed words. i.e.: manage also includes manageable, managed, management, managers, managing, and manages). The outside only words were park, new, caribou, law, official, last, act, and school. The top 50 words are listed in Appendix A, Table 2.6 showing the weighted averages and word counts. A Grubbs' Test showed that the term "timber" was an outlier (Mean 0.386, SD 0.171, P 0.01) inside/buffering the NSO range.

2.3.4 Sum of All Articles

In total, 399 separate newspaper agencies published 2,598 articles within all the year-sets mentioning the spotted owl. Of these, 27 carried at least ten articles across the studied year-sets (Table 2.7 below). The *Oregonian* was the most consistent over all of the year-sets, publishing more than 300 articles in all across year-sets. The *Contra Costa Times* changed to *East Bay Times* halfway through the period of this short analysis and so was counted as the same paper. Ten newspaper agencies had more than ten articles in 1988-89. There were 11 with more than 10 in 1998-99, nine in 2018-19 and 11 in 2020-21. These papers were the prime drivers of the issue and in keeping the owl in the public view.

Table 2.7: List of newspapers either inside or outside the northern spotted owl's range in alphabetical order with at least ten occurrences (highlighted) of articles mentioning the owls in at least one year-set across all of the articles.

Inside or Outside Range	Newspaper Name	1998-1989	1998-1999	2018-2019	2020-2021	Totals
In	Albany Democrat Herald	0	2	19	7	28
In	Capital Press	0	0	11	18	29
Out	Contra Costa Times (East Bay Times)	0	20	4	3	27
In	Corvallis Gazette Times	0	2	20	8	30
Out	Los Angeles Times	6	10	3	1	20
In	Marin Independent Journal	0	0	10	7	17
In	San Francisco Chronicle	37	7	2	3	49
In	Seattle Post Intelligencer	49	42	2	1	94
Out	St. Louis Post Dispatch	11	2	0	3	16
In	The Astorian	0	0	1	15	16
In	The Bulletin	0	0	10	13	23
In	The Chronicle	0	0	0	21	21
In	The Columbian	0	73	7	2	82
Out	The Lewiston Tribune	0	49	2	8	59
Out	The Mercury News	20	10	4	1	35
Out	The Miami Herald	12	1	9	4	26
In	The News Review	0	0	17	10	27
In	The Olympian	1	0	4	12	17
In	The Oregonian	222	53	18	25	318
In	The Register Guard	0	0	6	34	40
Out	The Sacramento Bee	19	15	11	6	51
In	The Seattle Times	86	51	7	15	159
In	Times Standard	0	0	11	10	21
Out	Tulsa World	12	2	1	3	18

In	Ukiah Daily Journal	0	0	7	10	17
Out	USA Today	43	8	0	0	51
Out	Wall Street Journal	0	11	2	4	17

2.4 Discussion

2.4.1 Word Use

This analysis aimed to assess the degree to which the northern spotted owl had become an icon for the conservation of old-growth forests and whether and how this may have changed over time and differ between regions, inside and outside the bird's range. An icon is defined by Merriam-Webster (2022) as “a person or thing widely admired, especially for having great influence or significance in a particular sphere”, as an emblem or symbol. The owls fit this definition well with their national coverage and even restaurants named after them far from the region of conflict (e.g., The Spotted Owl Tavern, New York). Through the use of Google NGram, Figure 2.2 clearly demonstrates the impact the conflict had on the owl's perceived importance. The highly significant differences between the spotted owl and other well-known American owls over a hundred-year period justify use of the title icon in respect of this conflict (Figure 2.2). Public perception of the owls has become more positive since the owl-timber conflict started in the 1970s, and this is vital to reversing their population decline.

The quantity of articles in 1988-89 and 2020-2021 was comparable at the higher levels, while 1998-99 and 2018-2019 numbers were much lower (Fig. 2.3). This

highlights the importance of the issue near to when the owls were listed as threatened. There is also a more recent re-emergence in the news due to the demand to up-list the owls to endangered in light of a continuing decline towards extinction. As environmental and climate issues grow in importance, controversies, such as this one with the owls, are being studied more deeply to separate sentiment and politics from scientific evidence.

The dominant newspapers covering stories on the owls were *The Oregonian* (Portland, OR) and *The Seattle Times* (Seattle, WA), having 318 and 159 articles respectively across all of the year-sets, as seen in Table 2.7. Every other newspaper had fewer than 100 articles. These two cities are the largest in their respective states and the Pacific NW region, so explaining their considerable coverage. A greater surprise, however, was the extensive coverage of the issue in newspapers, not only from outside the region, but also on the other side of the country. These newspapers included *The Miami Herald* (Miami, FL), *USA Today* (Arlington, VA), and *The Wall Street Journal* (New York, NY), with 26, 51, and 17 articles respectively across all year-sets.

The analysis of word-use gave important insights into differing and changing concerns. The more dominant use of the word “forest” in articles outside the owl’s range contrasts sharply with the more dominant use of the word “timber” in areas within the owl’s range. This difference reflects the prominence of interest in the timber industry within the range of the northern spotted owl. This shift might be considered to mirror Mace’s (2014) four ‘stages’ of conservation narrative, with areas outside the owl’s range

shifting towards ‘people and nature’, while areas in which readers were dependent on the timber industry for livelihoods adopted a ‘nature for people’ stance.

The significance of the term ‘job loss’ being used only in the first four years of this analysis, and “unemployment” being used more frequently across all of the years, is that job loss refers to an event while unemployment refers to a state of economic disruption (Brand 2015). This in itself provides context behind the long-term effects of the spotted owl’s federal listing. ‘Habitat loss’ was mentioned evenly across all of the years, but ‘biodiversity’ grew in frequency after 2018 as climate change and biodiversity losses became more of a public debate, even though it was coined and gained prominence in 1988, and was in widespread use by 2000 (Magurran 2005).

2.4.2 National vs Local

The ratio of national to local papers remained fairly even for three of the year-sets, as shown in the heat maps (Figs. 2.7 and 2.8), but the first one (1988-89) is understandably showing a higher percentage of local papers, as this was a year before the owls were listed as threatened. Locals were worried about the impacts this would have on economies and communities reliant upon the timber industry that was being limited. This study confirms that of Bendix & Leibler (1999), which considered the geographic variation in public perception of the owls. Figure 2.3 shows the dominance of local papers in the first two years, but nearly every year after has a higher percentage of national papers. This is partly due to syndication: the running of the same story in

multiple papers across the country, and partly because of the increasing importance of the issues around the over-exploitation of common-pool resources. Articles Inside/buffering the spotted owl range were on average longer than those outside, which were often reruns of the same story with details removed. Figure 2.7 above shows how fast this conflict became a national story with every single state except Hawaii running at least one story on the owls in the 2020-2021 year set.

2.4.3 Front Page

Since articles from local papers were often syndicated across a broader region and to national papers, a further test of reader sympathies, at least as perceived by newspaper editors, is to ask whether the language used changed at syndication. Some evidence of this was found. On August 8 and 9, 2020, *The Astorian* and *The Oregonian* (two Oregon papers from inside the owl's range) both ran the same article, but while *The Oregonian* ran the story on the front page, *The Astorian* ran it on the second page with substantially less information about the owl. While the reasons for these differences can't be known for sure, the occurrence of slight differences suggests the author's bias (and by extension, that of their likely readership).

2.4.4 Sum of all Articles

Studies like this one are key to recognizing patterns in data that change and influence the narrative in a conservation conflict. It is important to see how new legislation can change how the public views and engages with a topic in conservation.

This better informs lawmakers how the public will react. This was demonstrated in 2019 with an experiment to kill barred owls (see Section 2.3. and 3.2.2) in order to reduce pressure on northern spotted owls, and the national coverage and input from the public that ensued. One clear implication of this study is that the logging industry has been fighting the uplisting of the owls to endangered status for many years with continued success, as seen again in the 2020 rejection to uplist the owls even though the Forest Service said it was warranted (Endangered and Threatened Wildlife and Plants; 12-Month Finding for the Northern Spotted Owl 2020). Despite this, public opinion is shifting from timber-focused to forest-focused and the theme of this decade is more clearly framed as 'people and nature', as seen in Table 2.8, rather than 'nature for people'.

Table 2.8: Timeline of significant events in the northern spotted owl's history compared to the conservation views prevalent for the four major time spans and the ratio of forest vs timber word usage (Diller et al. 2016, Mace 2014, Marcot & Thomas 1997, Meslow 1993, & USFWS 1989).

Conservation Views	Year	Northern Spotted Owl Event	Newspaper Analysis: Ratio of the "Forest" to "Timber" Use
Nature for Itself	1918	Migratory Bird Treaty Act (MBTA) created	
	1936	Northern spotted owl (NSO) added to MBTA	
	1970s		
Nature Despite People	1973	Endangered Species Act (ESA) & Oregon Endangered Species Task Force formed and began to develop guidelines for NSO management	
	1976	National Forest Management Act created	
	1988	FWS decision not to up-list was appealed in court & Record of Decision on the Supplemental Environmental Impact Statement (SEIS) for Spotted Owls for WA and OR	56::44
	1989	FWS proposed to list the spotted owl as threatened & Interagency Spotted Owl Scientific Committee (ISC) created	
Nature for People	1990	NSO listed under ESA as threatened (only 12% of former habitat remaining) & A Conservation Strategy for the Northern Spotted Owl created by ISC	
	1992	U.S. Fish and Wildlife Service (FWS) released Draft Recovery Plan for the Spotted Owl	
	1994	Northwest Forest Plan went into effect	
	1998		70::30
	1999	3rd spotted owl Meta-analysis released	
	2004	FWS released first 5-year review for the NSO	
	2006	4th spotted owl Meta-analysis released	
	2007	FWS released 2nd Draft Recovery Plan	
	2008	FWS released Final Recovery Plan	
	2009	Experimental Barred Owl removals began	
People and Nature	2011	FWS released Final Revised Recovery Plan & 2nd 5-Year Review & 5th spotted owl Meta-analysis released	
	2012	U.S. Fish and Wildlife Service Endangered and Threatened Wildlife and Plants; Designation of Revised Critical Habitat for the Northern Spotted Owl" - Federal Ruling in 2012 - Fed Reg. 77, No. 46	

	2016	6th spotted owl Meta-analysis released	
	2018		73::27
	2019		
	2020	FWS released 3rd 5-Year Review and published 12-month Finding stating that the owl needs to be uplisted to endangered, but that they do not have the resources to do so as yet	72::28
	2021	7th spotted owl Meta-analysis released & Revised Designation of Critical Habitat for the Northern Spotted Owl & U.S. Fish and Wildlife Service Endangered and Threatened Wildlife and Plants; Revised Designation of Critical Habitat for the Northern Spotted Owl	

The rise of social media and the way in which people receive news and comment on it needs further research in regard to conservation issues and perceptions. With the ease of access to a multitude of news sources and polarized platforms, people are able to limit what they see, or can view everything, both options that can distort a conservation issue. Further culturomic analysis on northern spotted owls through the lens of social media would be valuable to gain a better understanding of public perceptions. As newspapers are replaced by social media as a principal source of news, such a study would explore how new provision in smaller bites impacts people's perceptions of a conflict.

As seen in the shark bite example in the introduction, the media can sometimes stoke public opinion to strong negative or positive feelings in which misinformation exacerbates the divide. This type of bias can easily be identified through sentiment analysis where the slant of the article shows which way the author is trying to sway readers. The present study examines a large number of articles from many sources to

avoid biased outcomes, and provides insight into how popular media narratives can shape people's opinions or perspectives on conservation issues.

Finally, the necessary breaking of these analyses into four two-year time sets will inevitably create some bias as major stories and fluctuations in public opinion in the intervening years will be missed. Future research would greatly benefit from analysing more years. Especially significant events warranting focus might include years in which range-wide demographic analyses were completed (2006, 2011, 2016, 2021), or the listing of critical habitat (2012), or the USFWS status reviews of the species (2004, 2020) (USFWS 2021), or a detailed analysis of the influence of presidential election campaigns on conservation policy. This would allow for a more complete story of how perceptions around the owls have changed over time.

2.5 Conclusion

As the public's perceptions of spotted owls and the environment shift over time to more positive views of coexistence, the chance of species survival increases. The transition from 'nature despite people' before the conflict to 'people and nature' today is clear over the 40-year period, though it is still distinct from the indigenous perspective of the tribes, of 'people in nature'. The spotted owl's continued presence in the news shows just how persistent and embedded this issue is in the country while also speaking to a changing social landscape. Just as perceptions about the barred owl removal experiment were assuaged through consideration of all stakeholders, future work needs to engage

conflicting parties to make real and lasting progress. Newspapers and social media will be key in the present and future to understanding how the public will support conservation efforts, though careful scrutiny need to be applied to eliminate bias and misinformation.

3

An Analysis of Stressors on Northern Spotted Owls

Ami Pekrul, Kathleen M. O'Reilly, Daniel A. Villar, & Andrew Gosler

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Abbreviations

CORT	Corticosterone
HPA	Hypothalamic–pituitary–adrenal
NSO	Northern Spotted Owl
RIA	Radioimmunoassay

Abstract

The northern spotted owl faces many factors contributing to its declining population. Chief among these is habitat loss and fragmentation from logging, barred owl encroachment, and the direct and indirect impact of wildfires. These factors cause stress reflected in the levels of glucocorticoid corticosterone found in the birds. To understand how stressors impact the owls in relation to their proximity to humans through roads and urban areas, faecal samples were collected and assayed for corticosterone. This revealed the surprising finding that the owls in more remote locations had higher acute corticosterone levels than those found near people. This suggested that the birds could habituate to human presence over time, Although further study is needed to determine the cause of the differing levels between more urban and rural owls.

Keywords: Northern spotted owl, glucocorticoid, corticosterone, barred owl

3.1 Introduction

3.1.1 Avian Endocrinology

When exposed to stress, the hypothalamic–pituitary–adrenal (HPA) axis allows for the secretion of glucocorticoid hormones into a bird's body, resulting in increased functions that contribute to the survival of the bird while limiting secondary functions (Freeman & Newman 2018). Glucocorticoid hormone secretion can make the difference between life and death, but if the bird is exposed to continued stress, the hormones take a toll on the body's immune system and can lead to death (Freeman & Newman 2018). Since these hormones change seasonally, with reproductive status, dietary effects, species-species responses, daily patterns, sex, and age of the birds (Keay et al. 2006 and Millsbaugh & Washburn 2004), the relationship between measured blood glucocorticoid and environmental stressors is not a simple one. One cannot, for example, simply conclude that higher levels of glucocorticoid necessarily indicate that the birds are suffering greater levels of stress.

Corticosterone (CORT) is the main glucocorticoid in birds. It has been studied and analysed using different methods ranging from highly invasive to non-invasive (Tempel & Gutiérrez 2003). Taking blood samples increases the birds' stress levels due to the extent of handling required. Analysing faeces and feathers, however, are non-invasive methods that do not require the bird to be captured (unless the feathers are physically extracted rather than being collected after moult). Both faeces and

feathers can be collected without causing increased stress to the bird, making them ideal for measuring environmental stressors.

However, it is important to make the distinction between corticosterone and 'stress', which are not entirely synonymous. Glucocorticoids deal with energy balance and, when under stress, shift that balance to increase energy and allow an animal to deal with its stressor, typically through either flight or fight (MacDougall-Shackleton et al. 2019). For simplicity's sake, the word 'stress' is used in this paper, but with clear understanding that CORT has many other functions in a bird's body and cannot be an exact measure of how much stress a bird experiences (MacDougall-Shackleton et al. 2019).

3.1.2 Anthropogenic Stress

The different categories of stressors include food availability, predator presence, population density, and captivity (Dickens & Romero 2013). Dickens and Romero (2013) ranked these stressors by their likelihood of occurring naturally in wild animals and the glucocorticoid response to each stressor. It was found that anthropogenic stressors, rather than predation effects, resulted in an increase in glucocorticoids, but less than social stressors (Dickens & Romero 2013). Anthropogenic proximity is well known to increase stress in animals and reduce survival probability (Dickens & Romero 2013). Continued human presence leads to continued glucocorticoid release, which creates energy for countering the stress by taking it from other bodily functions, resulting over time in reduced fitness of the bird (Dickens & Romero 2013). However, the chronic

effects of these stressors have not been studied sufficiently to shed light on which might cause the greatest increase in the release of CORT.

Measuring anthropogenic stress is frequently examined through its effect on breeding success, because it affects population dynamics (Tarlow & Blumstein 2007). Other factors affected directly by human presence are mate choice, flush distance from human disturbance, immunocompetence (where sexual characteristics are diminished due to the body's increased need for glucocorticoid production), and heart rate (Tarlow & Blumstein 2007). Since relying on only one method to measure stress caused by humans would lead to too narrow a focus, all need to be considered to obtain a complete picture (Tarlow & Blumstein 2007).

3.2 Spotted Owl Research

Wasser (1997) demonstrated how stress levels of the northern spotted owl could be studied by using faecal hormone measures specific to the spotted owl. This study showed that the birds' stress increased with disturbance (Wasser 1997). Hayward et al. (2010) expanded on this to eliminate artificial effects during the process of faecal collection. The impacts of vehicles on stress levels in the owls, specifically faecal glucocorticoid metabolites (fGCs), address disturbance rather than nutrition (Hayward et al. 2011). The owls were less successful in terms of survival, stress levels, and fecundity the closer they were to road noise, indicating that human proximity had a negative effect on them (Hayward et al. 2011). In contrast, a study of the California spotted owl found

that low-intensity chainsaw noise had no significant impact on the owl's stress levels, but these owls lived near roads and were likely habituated to humans (Tempel & Gutiérrez 2003). This type of study directly influences spotted owl management guidelines by establishing at what distance from disturbance the owls are affected; male NSOs were found to have increased stress levels within 400 m of logging roads, but male California spotted owls exposed to chainsaw noise within 100 m did not (Tempel & Gutiérrez 2003 and Wasser et al. 1997).

3.2.1 Allostatic Load and Chronic Stress

This chapter builds on previous research by comparing near-urban populations with remote ones with the question of whether chronic and acute stress are being experienced. The purpose of this study aimed to assess CORT levels in northern spotted owls and relate them to differences in the context of stress. The scope of different habitat types and distances to humans creates a better picture of how the owls adapt to humans over their lifetime of proximity vs. rare exposure. CORT levels can be increased naturally through the concept of the allostatic load, wherein the owls can handle a certain amount of stress before it begins to compromise their survival (Hayward et al. 2011). It could therefore be hypothesised that urban owls have a higher allostatic load in regard to human stressors than have their more rural counterparts as this developed over time and possibly generations. As human development encroaches on remote areas, owls adapting to higher stress levels have a higher chance of surviving than those that cannot adapt. For example, owls can slowly adapt closer to

people through epigenetic adjustment. However, it is important to remember that no one factor rules them all; rather, the cumulative effects of all-natural and human stressors lead to allostatic overload (Hayward et al. 2011).

Chronic stress has been researched extensively, showing that it can cause animals to have impaired cognitive function, reproductive inhibition, reproductive failure, immune system repression, neural death, and premature death (Tarlow & Blumstein 2007). There are two types of chronic stress; intermittent and continuous of either homotypic (exposure to the same stressor) or heterotypic (exposure to different stressors) (Dickens & Romero 2013). Chronic stress can be caused by a failure to habituate to a stressor (Tarlow & Blumstein 2007). Birds suffering chronic stress would likely not survive long, resulting in a selected population in terms of those that can adapt. The main purpose of this study was to explore whether there was one particular environmental stressor affecting the spotted owls or if the naturally occurring CORT hormones fluctuate predictably.

3.2.2 Threats and Stressors

Habitat Loss

The biggest impact on spotted owl populations is the loss of habitat. This is discussed in more detail in 1.1.2. and 2.1.1.

Barred Owls

The barred owl is another member of the genus *Strix* but is slightly larger, more aggressive, and much more adaptable than its western congener (Gutierrez et al. 2007). Having recently extended their range, barred owls are thought to have originated in the eastern United States, coming through Canada and, since the 1990s, down the west coast (Kelly & Forsman 2004). They were first discovered in Washington state around 1965-1973, Oregon around 1974-1979, and California in 1981, reaching the full extent of the spotted owl range by 2003 (Kelly & Forsman 2004 and Kelly et al. 2003).

However, the barred owls found in the West differ from those in the East. Their plumage is darker, has more spotting, and it is smaller than the eastern barred owls (Hanna et al. 2018). Genetic evidence suggests that the eastern and western barred owls split thousands of years ago rather than the assumed low hundreds, further indicating that barred owls have been present on the western half of the U.S. much longer than they have been observed (Fujito et al. 2021). Many species are typically known to be darker in the Pacific Northwest than populations in other parts of the continent.

A barred owl removal scheme was introduced in 2009, which has continued and expanded to different areas. This benefited the spotted owl and allowed it to recover, albeit slowly and with frequent monitoring for additional barred owls (Long & Wolfe 2019). Multiple studies using many different model types, such as two-species occupancy models (Long & Wolfe 2019), individual-based (Dunk et al 2019), and

two-species individual-based (Perlman 2017), predict that the two species cannot coexist. Gause's Law of competitive exclusion states that two competitors cannot exist in the same space as one will always overcome the other (Hardin 1960). As the barred owl is more successful, it is likely to replace the spotted owl eventually unless management continues to remove the barred owls (Long & Wolfe 2019). At an estimated \$150-\$2,800 per barred owl, this is unlikely to be sustainable in the long term (Long & Wolfe 2019). It has also been noted that spotted owls select areas that are steeper and at a higher elevation than barred owls, which could result in pockets of refugia (Long & Wolfe 2019). Slight differences in habitat preferences between the two species can lead to habitat partitioning, with NSOs showing more inclination for denser understory and less canopy cover, while barred owls tended more towards less understory and more canopy cover (Long & Wolfe 2019). Different models of how these two species' ranges will interact have given conflicting results, with some positing that the barred owl will eventually infiltrate every part of the NSO range and push the NSO to extinction, while others suggest that the NSO will find safe pockets through prey or habitat partitioning (Long & Wolfe 2019).

Barred Owls are not being actively surveyed in the Pacific Northwest but rather are encountered in conjunction with spotted owl surveys, and more are reported each year in the spotted owl historical range (Dugger et al. 2016 and Franklin et al. 2021). Experimental removal of the barred owls has met with some backlash from the public, driven by newspaper headlines such as "Killing one owl to save another" (Nijhuis 2024), but overall has proven successful in aiding spotted owl recovery, though only if

consistently continued (Diller et al. 2016). The *Draft Barred Owl Management Strategy* was created in 2023 and is currently in the public comment period. This plan would allow the removal of barred owls through lethal measures for at least five years (USFWS 2023). Barred Owls are generally considered to be the leading cause of the decline in spotted owls, but more research is required to confirm this hypothesis. There is a risk that the increasing amounts of money and effort going into barred owl removal (discussed in more detail in chapter 4) will prove useless so long as protected habitat is being redesignated and opened to logging deemed not “destructive or adverse” to the spotted owls (Endangered and Threatened Wildlife and Plants 2021).

Hybridisation

Barred Owls are thought to differ genetically from the spotted owl by only 0.7% (Fujito et al. 2020), and the two species have been known to interbreed. Pairs typically consist of a female barred owl and a male spotted owl and are most often in areas dominated by spotted owls (Kelly & Forsman 2004). The successful relationship dynamic is thought to be due to the size proportions of males to females being similar in the two species (Kelly & Forsman 2004). As is typical of owls, the male is smaller than the female in both species, though both barred owl sexes are slightly larger than the spotted owl counterparts. If the relationship were reversed with a male barred owl and a female spotted owl, the two sexes would be very similar in size. One study found that hybrids that crossbred back with barred owls were more successful and produced more young than those that crossbred back with spotted owls (Kelly & Forsman 2004). Hybridisation

is not common enough to be considered a major threat to spotted owls. However, its frequency will have a bearing on the availability of territory and prey for full spotted owls and on genetic dilution (Kelly & Forsman 2004).

There is some evidence for the subspecies of spotted owl to have mixed; California spotted owl haplotypes were found in the northern spotted owl range, though interestingly, only California spotted owls were found in the northern range and not the other way around (Courtney et al. 2004). Genetic tests have found that the Mexican and California spotted owls are more closely related, and the NSOs are more genetically distant (Courtney et al. 2004).

Wildfires

Wildfires have a significant impact on NSO populations, especially as climate change increases fire frequency and intensity in the Pacific Northwest (Glenn 2009 and Franklin et al. 2000). Besides loss of habitat from the fires, loss of prey species and long term effects from smoke can affect wildlife. The smoke from wildfires can travel immense distances and inhalation can result in smaller clutch size, lower hatch success, cardiovascular-neurological-respiratory distress, and weaker immune response (Sanderfoot et al. 2021). Wildfires also impact behaviour and vocalization for months after, making it more difficult to locate birds for study (Sanderfoot & Gardner 2021). The effects of wildfires on spotted owls have only been studied since the early 2000s (Lee 2018). Owls were found to use low to mixed-severity burned forests for roosting and foraging because prey biomass was greater than in unburned forests (Lee 2018).

Fire refugia are areas, generally with large conifers, that can survive wildfires (Krawchuck et al. 2020). Wildfires are less severe in habitats suitable for spotted owl nesting (Lesmeister 2021). Spotted owls prefer areas with steep ravines on the shaded side near water, all of which contribute to lower wildfire risk (Wiens et al. 2014). These areas are vital to the survival of the spotted owl.

Climate Change

The frequency and severity of wildfires have been increasing in recent years, primarily due to anthropogenic climate change (NOAA 2023). One study examined how temperatures exceeding 31°C resulted in heat stress in the owls, as they are not efficient at dissipating heat from their bodies (Barrows 1981). This leads the owls to select dense roosting spots that provide shade. Owls were observed moving if they were in direct sunlight during higher temperatures (Barrows 1981). As annual temperatures increase, the owls may become more restricted in the availability of their preferred habitat (Glenn 2009 and Franklin et al. 2000).

Disease/ Insect Outbreaks

Habitat loss is one of the major factors for spotted owl population decline, but 8-9% of the effect of habitat loss is considered due to synergistic effects of disease and insect outbreaks (Gutiérrez et al. 1995 and Davis et al. 2022). Spirochetosis, avian malaria, parasites, and avian trichomonosis have all been documented in spotted owls, with concerns growing more recently about West Nile Virus (Thomas et al. 2002 and

Courtney et al. 2004). West Nile often kills quickly during a first outbreak, after which birds gain resistance to it, but the fragmented nature of spotted owl populations means that each subpopulation remains unexposed to it, preventing the developing of metapopulation-wide herd immunity (Courtney et al. 2004 and Wan et al. 2018).

Avian trichomonosis has been found in spotted owls, likely from a spillover from outbreaks among pigeons and doves (Rogers et al. 2016). Barred Owls are believed to have brought some diseases to the spotted owl range, including nematodes and avian malaria, commonly found in barred owls but not yet seen in spotted owls (Rogers et al. 2016). In 1989, Gutiérrez showed that all of the spotted owls surveyed had at least one blood parasite, either *Leucocytozoon* or *Haemoproteus* spp, while for barred owls, only 67% of birds were infected (Ishak et al. 2008). A *Plasmodium* infection was also detected in spotted owls for the first time (Ishak et al. 2008). Blood parasite prevalence for the spotted owls was 52%, while barred owls in the same areas only had 15%, suggesting that barred owls have better immune health (Ishak et al. 2008). Periocular nematodes in barred owls within the spotted owl range pose a serious threat, as 49% of sampled barred owls were infected, and the severity of conjunctivitis increased in infected birds (Niedringhaus et al. 2023). One study concluded that the main cause of death in spotted owls in their project was avian predation, while for barred owls, it was parasitic worms (Wiens et al. 2014).

Mountain pine beetles (*Dendroctonus ponderosae*) have increased in population as the climate has warmed in the Pacific Northwest (Littell et al. 2009). These beetles

lay their eggs under the bark of pine trees and, in so doing, spread blue-stain fungi that are found on the adults (Leatherman et al. 2007). The fungus kills trees from the inside, and when the beetle larvae hatch, they spread to other trees and spread the fungus further and faster (Leatherman et al. 2007). Sudden Oak Death is caused by a fungus which paradoxically infects Douglas fir (Courtney et al. 2004). Spruce budworms were responsible for an outbreak that started in 1998, and fir-engraver beetles and western pine beetles all contribute to further habitat loss (Courtney et al. 2004).

3.2.3 Hypothesis

The goal of this chapter is to examine the differences between two different populations of NSOs to assess the existence of clear variables influencing corticosterone levels between owls exposed to more human activity and those in more remote areas. The hypothesis tested is that more remote owls would have lower chronic and higher acute stress than owls exposed to more anthropogenic disturbance.

3.3 Methods

The goal of this study was to collect faecal samples from near-urban spotted owl populations in California and from more remote ones in Oregon. These samples were assayed in the laboratory to explore the differences in corticosterone levels in reference to their geographic location, ecological context, and potential stressors in the

environment. The myriad factors affecting each population were explored for impact and compared.

3.3.1 Collaborators

Due to the limitations imposed by the Covid-19 pandemic, collaborators were sought across the spotted owl range. This was done through direct contact with biologists, both private and governmental. Social media provided a platform to reach out to some, and networking with those contacts resulted in further collaborator contacts. Additional participants were sought throughout the entire project. All collaborators are listed in the acknowledgments of this paper. It was necessary for the collaborators to collect samples only opportunistically as they were volunteering their time and it could not interfere with their other activities. We acknowledge that this makes the samples included a 'convenience sample' rather than a random sample.

3.3.2 Study Area

Wild Populations: The sites selected for sampling were based on permissions granted by the environmental consultancies collecting the faecal samples in the field or from the National Park Service after obtaining a permit (Appendix B). The more remote sites centred in southern Oregon, and the more urban sites in Marin County, California (Figure 3.1 & 3.2). The Oregon sites are hereon referred to as 'OR' and the California sites as 'CA'. It is vital to keep in mind that these terms do not mean that the samples

were representative of each state. The two areas can be thought roughly as remote (OR) and near-urban (CA). These sites were volunteered by collaborators.



Figure 3.1: Northern spotted owl range and the OR and CA faecal sample collection areas shown in black circles.

Captive Owl: WildCare, a wildlife rehabilitation centre in California, provided faecal samples and detailed records of observations for their captive owl. Although this bird was 19 years old, and as such unlikely to be representative of captive populations, the values are of interest in their own right and provide valuable insight into the physiological state of an owl that has lived around people the entirety of its life.

3.3.3 Collection Protocol

Samples were collected non-invasively and assayed to understand NSO stress levels in relation to urban proximity. The following protocol is adapted from the protocol developed by Hayward et al. (2011).

Site location: Owls were located using audio surveys, visual surveys, and information from previous field seasons. Once located, a habitat metrics form was filled out. The collaborating field biologists located the owls. The breeding centre in California provided samples throughout both years based on their own set schedule and using similar collection methods.

Collection: All crews were provided with the same Fisherbrand™ 7mL Borosilicate Glass Scintillation Screw-top Vials (although in a few circumstances, larger plastic screw-top vials were used) and a copy of the collection protocol (Appendix C). Owls in the wild had samples collected opportunistically or near known activity centres (areas where the owls are more active in their territory) or nests as long as the ID was confirmed to be from a spotted owl. Ideally, these samples would be collected based on previous protocols where a sheet is placed under the nest tree and samples are collected free of debris. This was not possible for the collaborators, who were volunteering time to collect when and where they could. Once samples were collected, typically by using a stick to scrape or push the faecal sample into the collection vial, the time, date, GPS coordinates, age and sex of the owl, the band ID (if seen), and the collector's initials were recorded on the vial. These were then placed into a cooler as

soon as possible and transferred to a standard freezer at the end of the day. Samples were stored long-term until their transfer to the laboratory at the University of Portland, where they were stored in a -20°C freezer until ready for assay. It was not always possible for collaborators to do this immediately and some samples sat in coolers with ice packs for the entire day before transfer to the freezer. This unfortunately impacted the level of CORT recorded.

Captive Owl: The only variables collected were month, time, and if the sample was collected after an educational display. The samples were collected, stored, and transported the same way as those from wild owls.

3.3.4 Laboratory Methods

Once all of the samples arrived at the lab in the University of Portland, OR, they were lyophilised using a Benchtop 3.3 Vacu-Freeze and organised by faecal-to-urate ratio. The samples with only urates were set aside. Faecal samples were poured into plastic weighing boats, put under a dissecting microscope, and cleaned of urates and debris and faecals were returned to the original vials. The cleaned faecal samples were then weighed and put into clean and labelled tubes. A parallelism test was then run using one captive owl and one wild owl sample (Wasser et al. 2000). An additional parallelism test was run on urate-only samples to determine if corticosterone was detectable. The faecal test came back validated. Some of the samples were very small, but based on the parallelism test, it was determined that 0.8 g should be the standard minimum.

The faecal samples were organised into three racks by location of collection and had 8 ml of 90% methanol added. They were vortexed for 30 minutes on a Glas-Col Multi-pulse Vortexer and spun for five minutes on a Beckman GS-6R Centrifuge. The samples went through the first extraction, had another 8 ml methanol added, vortexed and spun again, and went through the second extraction. Of the then 16ml of extract, 2 ml of each was put in a clean labelled tube and set in a hot water bath using an Iso-Temp210 air evaporator overnight.

The dry tubes then had 500ul of assay buffer added and were put on a Thermolyne Maxi-Mix III for 45 minutes. The supernatant was poured off, and the tubes were ready for the MP Biomedical's Corticosterone Double Antibody Radioimmunoassay (RIA) kit protocol, which was undertaken exclusively by KO'R due to the limitation of radiation handling permits.

3.3.5 Mapping

An ArcGIS map was created using the GPS coordinates for each faecal sample collection. Distances were measured in Km from each point to roadways (logging/trail, public, and highway) and urban areas (<2,500 people, 2,500-19,999 people, and >20,000 people). Public roads were defined as the nearest paved road with open access. Urban area density was categorized by population size; small: fewer than 2,500 people, medium: between 2,500 and 19,000, and large: more than 20,000. Terrain and elevation details were taken from the map.

3.3.6 Statistics

Analysis was undertaken using R version 4.4.3 (R Core Team 2024), using the *car*, *lme4*, and *MuMIn* packages (Bárton 2013; Bates et al. 2015; and Fox & Weisberg 2019). We used a generalised linear model (GLM) with a Gaussian family and an identity link function to study the drivers of corticosterone in owls. The potential explanatory factors included were proximity to roads and urban areas (measured in km), age (juvenile or adult), sex (male or female), elevation (measured in feet), mean monthly temperature (measured in F°), mean monthly precipitation (measured in inches), month, time of day, number of owls seen together, canopy cover (0-25%, 26-50%, 51-75%, 76-100%), activity centre or nest collection, distance to wildfire in both current and prior year (measured in km), land management type, and tree prevalence (**CN** – Conifer / **BL** – Broadleaf / **MX** – Mixed / **LS** – Late Successional (old-growth) / **MS** – Mid Successional (mature)/ **ES** – Early Successional (young)). These variables were chosen based on available data from both the collaborators and online sources, since it had not been possible for all requested variables to be recorded by all collaborators.

Before constructing the GLM, multicollinearity was tested for using variance inflation factor (VIF), checking that VIF was less than 10 (Akinwande et al. 2015). Removal of aliased variables and variables which had a VIF of over 10 led to a new global model which included wildfire same year, wildfire prior year, owls seen, elevation above or below 300m, temp mean, precipitation, road distance, month, nest or AC,

terrain type, PM2.5 daily average (a type of air pollution made up of fine particulate matter in the air), and year. An information theoretic approach was used in selecting the most parsimonious models which would be the basis of our interpretations of the data (Burnham & Anderson 2010). The global model was 'dredged' through all possible sub-sets, and selected the best model based on the Akaike's information criterion corrected for small sample sizes (AICc) (Sugiura 1978). This gave a model with an AICc 8.648, which included Elevation above or below 300m, wildfire same year, and year as potentially explanatory variables. We tested for the regularity of the residuals of our model using the Shapiro-Wilk Test for Normality (Shapiro & Wilk 1965). One-way ANOVA tests were run through Minitab Statistical Software on each of the variables against Log₁₀ CORT.

3.4 Results

3.4.1 Corticosterone Levels

Of the 165 total samples collected for this study, only 59 contained faecal material that could be analysed for CORT; 40 wild and 19 captive samples. The 108 other samples contained only urates. A parallelism test was run using urate-only samples to see if the RIA kit for corticosterone could be validated. The results showed no detection of corticosterone. The urate-only samples were set aside for possible future work (either further corticosterone or other hormone studies). The samples are shown in Figure 3.2 below on a blank map to preserve anonymity of the locations. Some sites were

surveyed in both years, suggesting that it was the same owl/owls, and some sites were near enough to a previous site to be within the same territory. However, without complete band number or GPS data, it is impossible to say which were the same owls and which were different from each site/ year.

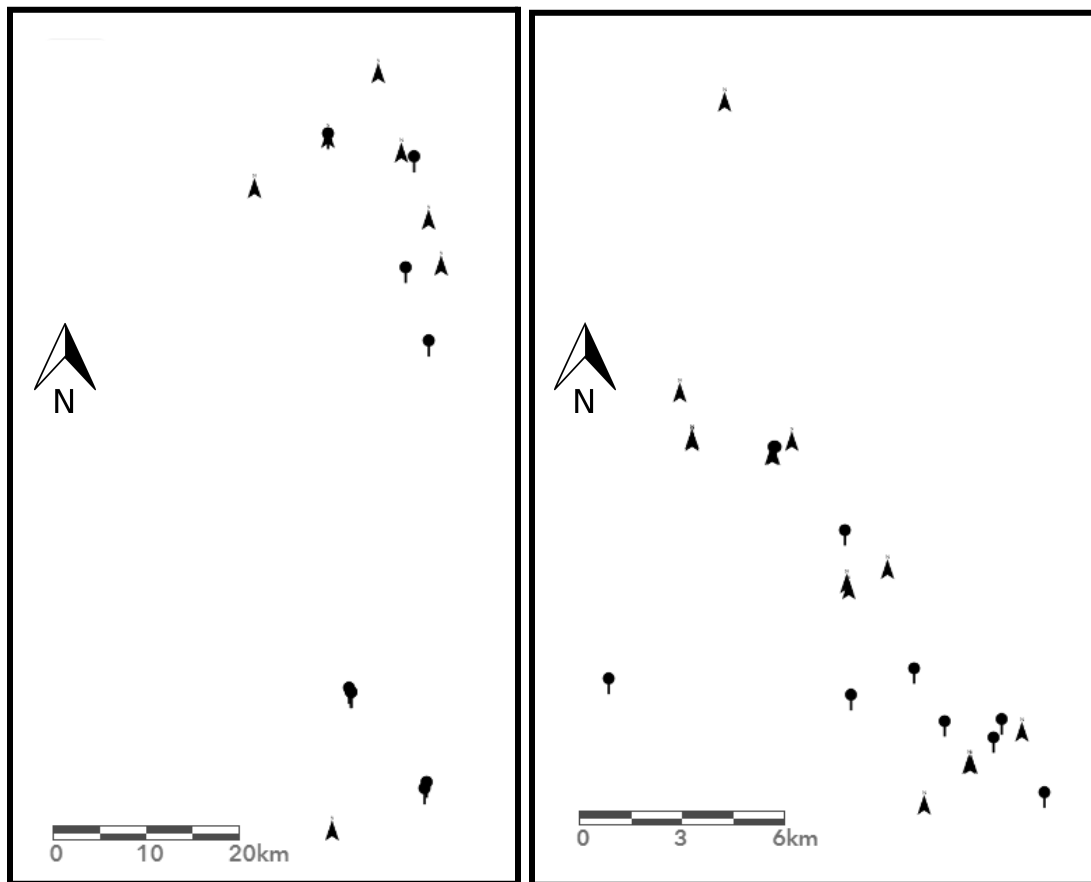


Figure 3.2: OR collection sites are on the left, and CA collection sites are on the right, with ▲ for the 2021 collections and ● for the 2022 collections. This map is blank to preserve anonymity of spotted owl locations, but is presented to indicate the general lack of overlap and potential pseudoreplication.

The faecal samples were divided into the two main locations (OR and CA) over the 2021 and 2022 breeding seasons. For the Oregon (OR) samples, 12 samples were submitted for 2021, of which seven were viable and assayed. Ten samples were submitted for 2022, of which nine were viable and assayed. For the Californian (CA) samples, 53 samples were submitted for 2021, 15 of which contained faecal material and were assayed for the study. In 2022, 64 samples were submitted, of which nine were viable and assayed. The sum total of all CORT is summarized in Table 3.1.

Although definitive conclusions are difficult or impossible to draw from such sample sizes due to the number of variables involved, some trends can be discerned which may be indicative of the birds' stress levels.

Table 3.1: Mean corticosterone levels in ng/g across years and sampling locations.

Sample sizes are OR 7 and 9, CA 15 and 9 for 2021 and 2022 respectively, 40 in all.

OR		CA		Total mean
2021	2022	2021	2022	
64.14	85.56	74.57	33.5	65.0

There were four main outliers (using box plot data visualization); two CA sites with CORT levels of 325 and 138 and two OR sites with CORT levels of 233 and 123 (Table 3.2). All other samples were below 100 CORT. The 325 CORT sample was collected in May 200m from a logging road/trail, less than 1km from a small urban area. The sample was taken from an adult with a juvenile nearby at a nest site. The canopy cover was 76-100% in a mixed mid-successional forest. The 138 CORT sample was

collected in the same area a week later. One adult and 2 juveniles were seen and the sample was collected from a juvenile.

The 233 CORT sample was taken in July, 300m from a logging road/trail and 16km from the nearest urban area. Four owls were seen together at an activity centre: an adult female with three juveniles. The sample was taken from the adult. The canopy cover was 76-100% in a conifer mid-successional forest. Finally, the 123 CORT sample was taken in July 380m from a logging road/trail and 10km from an urban area. It was from a lone adult female in an activity centre with a canopy cover of 76-100% in a conifer late-successional forest.

By contrast, the lowest three CORT samples were 9, 12, and 25 and all in CA sites. The 9 CORT sample was taken in June 50 m from a public road and within a medium urban area. Two adults and a juvenile were seen together and it is unknown which the sample came from. It was a nest site with 76-100% canopy cover in a mixed mid-successional forest. The 12 CORT sample was collected in May 290 m from a logging road/trail and less than 1 km from a small urban area. Two adults were seen together, but it is unknown which sex the sample is from. It was at an activity centre with 51-75% canopy cover in a mixed mid-successional forest. The 25 CORT sample was from the same area as the 12 CORT sample, but collected in April 280m from a logging road/trail and within 1km of a small urban area. It was taken from a male with an unknown companion at an activity centre in a 51-75% canopy cover mixed mid-successional forest.

The high outliers and the lowest CORT samples had many things in common, including distances to roads and urban areas, number of owls seen together, and whether the sample was collected at a nest or activity centre. The differences were seen in canopy cover, tree prevalence, and land management type. The highest CORT samples were more likely to have come from federal sites, from conifer-dominant forest, and high canopy cover. The lower CORT samples came from mixed forests, more open canopy, and from non-federal sites.

Table 3.2: The lowest three (shaded) and the four high outlier CORT samples for comparison with the primary sampling factors.

Site	CORT ng/g	Road Proximity	Urban Proximity	Elevation (feet)	Month	Time	# Owls Seen	Age	Sample From	Nest or AC	Canopy cover	Trees	Land Mng. Type
CA	9	.05km	0km	200	June	1129	3	2 Adults/ 1 Juvenile	Unknown	Nest	76-100%	MX-MS	Marin County Parks
CA	12	.29km	<1km	600	May	955	2	Adult	Unknown	Activity Centre	51-75%	MX-MS	Private
CA	25	.28km	<1km	600	April	1700	2	Adult	Male	Activity Centre	51-75%	MX-MS	Private
OR	123	.38km	10-11km	5400	July	2030	1	Adult	Adult Female	Activity Centre	76-100	CN-LS	Federal
CA	138	.02km	<1km	450	June	1203	3	1 Adult/ 2 Juveniles	Juvenile	Nest	76-100%	MX-MS	Marin County Parks
OR	233	.03km	16-17km	3650	July	1930	4	1 Adult/ 3 Juveniles	Adult Female	Activity Centre	76-100	CN-MS	Federal
CA	325	.02km	<1km	450	May	1122	2	1 Adult/ 1 Juvenile	Adult	Nest	76-100%	MX-MS	Marin County Parks

Separating the samples by year rather than location (Figure 3.3) suggests the possibility of seasonal fluctuation. The years differed in their peaks, with 2021 peaking in May and 2022 in July. However, if the outliers are removed, the trends become more similar, indicating that those are the normal seasonal trends, while the outliers are most likely responses to acute stressors. This observation supports the contention that, despite the small sample size, the analytical results were reliable.

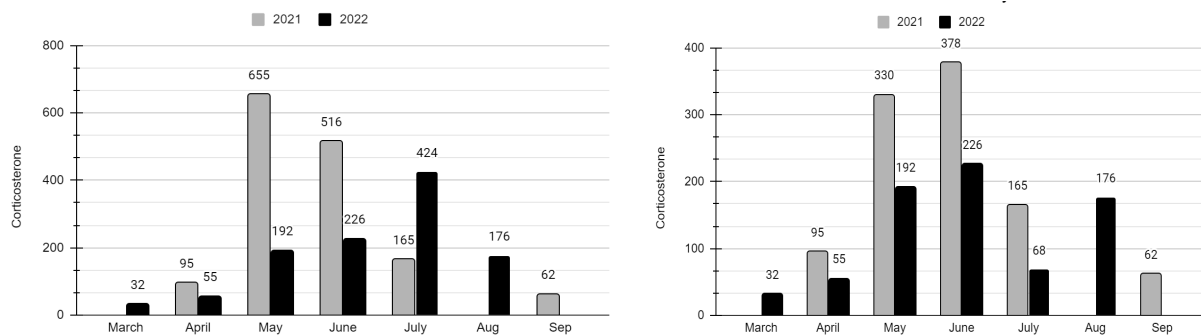


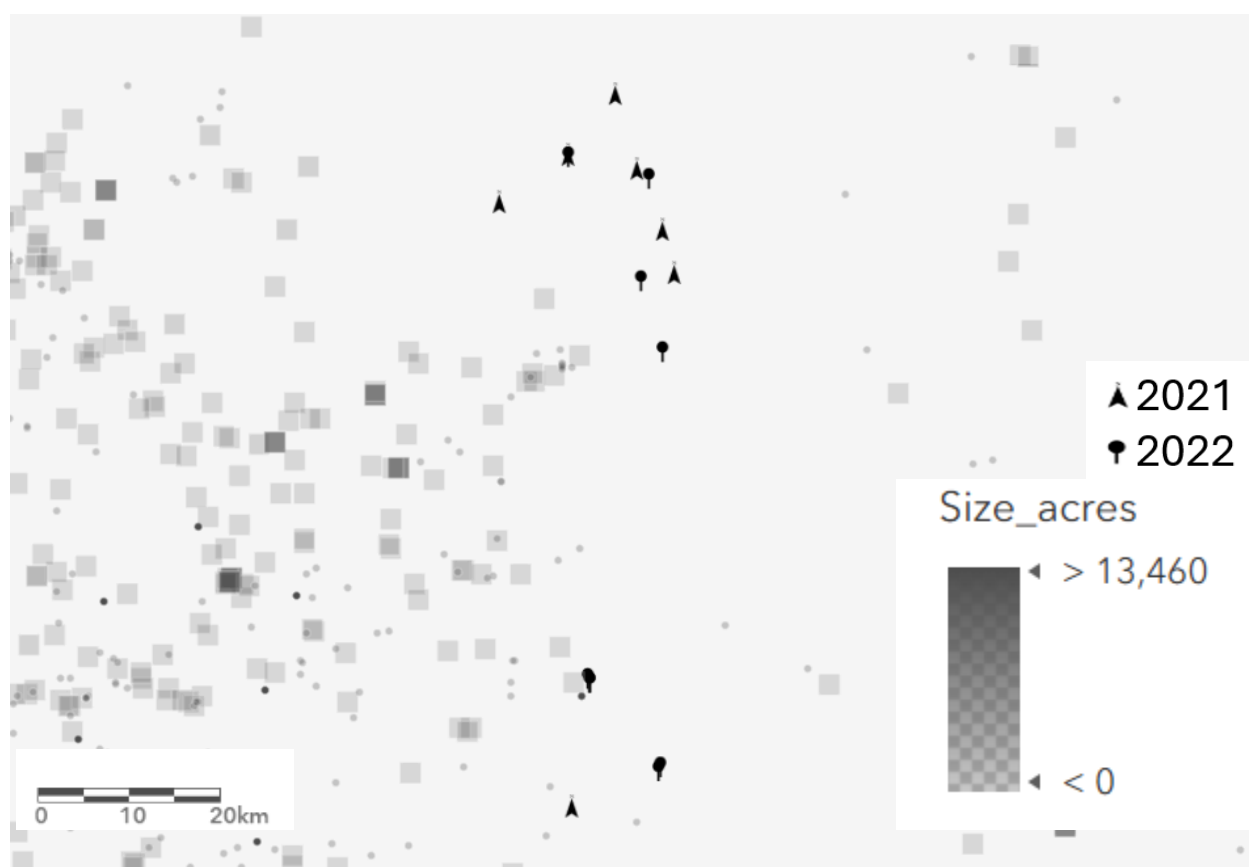
Figure 3.3: Sums of corticosterone levels in the northern spotted owl by month and year for both locations (left) and with the four outliers removed (right).

Wildfires

Table 3.3 suggests that in CA the high mean for 2021 (75) vs the low mean for 2022 (34) could be due to the area of wildfire (km²) burned in each year (9039 and 1252, respectively). The effect contrasts with results from the OR sites, suggesting the presence of another stressor/s causing the fluctuation.

Table 3.3: The CORT means by location and year in reference to wildfire km² burned.

	OR 2021 CORT ng/g Mean	OR 2022 CORT ng/g Mean	CA 2021 CORT ng/g Mean	CA 2022 CORT ng/g Mean
	64	86	75	34
Wildfire km² Burned	3354	1846	9039	1252

**Figure 3.4:** Oregon wildfire proximity and size in relation to NSO collection sites.

Squares represent 2021 wildfires and circles represent 2022 wildfires. Color density shows severity.

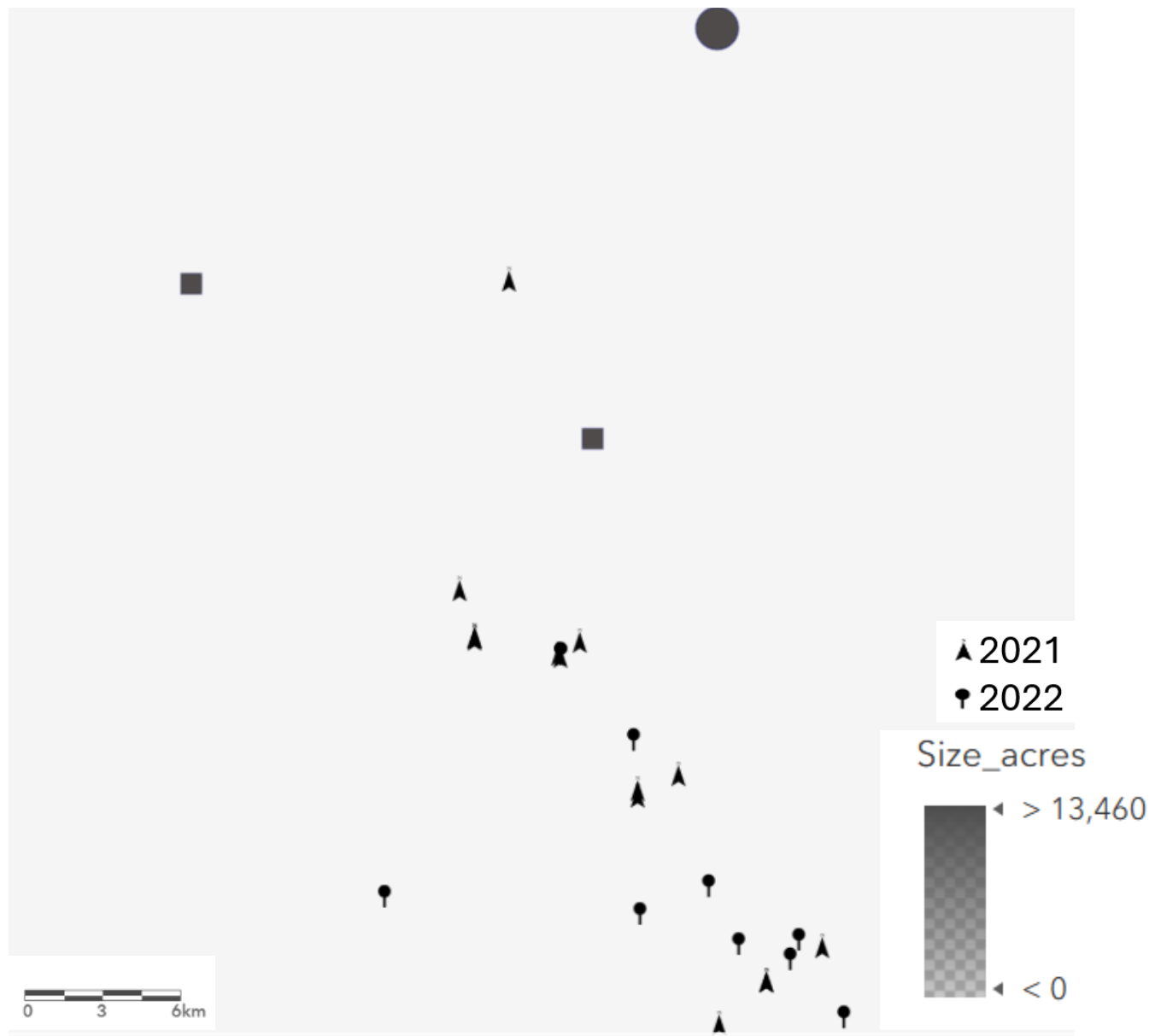


Figure 3.5c: California wildfire proximity and size in relation to NSO collection sites. Squares represent 2021 wildfires and circles represent 2022 wildfires. Color density shows severity.

3.4.2 Statistics

In a series of one-way ANOVA tests (Table 3.4, Appendix D), the only variables found to affect CORT levels significantly were Wildfire Distance Same Year, Area (OR and CA, which correlates to elevation) and Land Management Type (Federal, Private, Marin County Water District, and Marin County Parks). Combining all variables in a single GLM (Table 3.5) to avoid the risk of a Type I error resulting from pseudoreplication and the inflation of tests, essentially found the same results. The dredge results for the model selection using AIC is shown in Table 3.6 (Appendix E), with delta AIC values and weights. However, as the results were over 4000 rows long, it was impractical to include it in its entirety and how been compressed to the top ten rows. The top model had the non-significant variable “year”, but because it was the best supported model, it was used in the final GLM. Area effects (i.e., OR or CA) captured by elevation (lower elevation CA sites versus higher elevation OR sites) and a significant negative effect of wildfire distance in the same year are summarized in Table 3.6.

These results suggest that anthropogenic stressors may have been more important in 2021-2022 than non-anthropogenic environmental stressors, since previous reports of the significant effects of precipitation and temperature (Mikkelsen 2021) were not replicated. However, these results reflect the shortcomings of a study conducted over a short time period. A longitudinal study conducted over many years would be required to identify background environmental effects on the birds’ stress physiology.

Table 3.5: General Linear Model output.

Coefficients:				
	Estimate	Std. Error	t value	Pr(> t)
(Intercept)	263.73082	163.25618	1.615	0.11495
Elevation_above.below_1000ft	0.23861	0.08045	2.966	0.00533 **
Wildfire_Dist._Same._in.out_10km	-0.20434	0.08259	-2.474	0.01820 *
Year	-0.12962	0.08078	-1.605	0.11733

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1				
(Dispersion parameter for gaussian family taken to be 0.06017907)				
Null deviance: 3.1414 on 39 degrees of freedom				
Residual deviance: 2.1664 on 36 degrees of freedom				
AIC: 6.8834				
Number of Fisher Scoring iterations: 2				

The Land Management Type variable is similarly explained by an area effect in that the OR sites were all on Federal land while the CA sites only had one Federal site (Table 3.7). The habitat differences between OR and CA sites are stark, but elicited no significant differences to the CORT levels other than the Land Management Type. This prompts the question of what stressors were causing the variations between areas and years if not habitat-based. However, as barred owls were not surveyed, it is hard to eliminate this as a potential source of stress.

Table 3.7: The habitat characteristic quantities of all 59 samples from both sites and both years combined.

		OR	CA
Land Management Type	Water District	0	5
	Private	0	8
	Parks	0	10
	Federal	16	1
Tree Prevalence	CN-LS	13	0
	MX-MS	0	21
	CN-ES	0	1
	CN-MS	3	2
Terrain Type	Spur	10	5
	Ridge	4	1
	Draw	1	13
	Valley	0	1
	Saddle	0	1
	Hill	1	0
Canopy Cover	0-25%	1	0
	26-50%	0	0
	51-75%	2	11
	76-100%	12	13
Sample Location	Nest	4	20
	Activity Centre	12	4

Captive Owl

For the captive owl, the only variables collected were month, time, and if the sample was collected after an educational display. Samples were collected every fortnight apart from June and August. The educational displays were followed by

sample collection, which each showed an increase above the mean CORT (Figure 3.6). The displays were in February, April, May, and October. The mean CORT level after displays was 90.6 (SD=19.1), and the mean for non-display times was 57.2 (SD=32.54). This shows a significant impact of the displays on CORT level ($F = 4.59$, $DF = 1$, $P = 0.047$). The mean and total CORT levels are shown in Figure 3.6. This owl was brought to WildCare in 2005 and is now 19 years old, having lived her whole life at the facility. From the One-Way ANOVA tests of CORT, there was no significant difference between time of day ($F = 0.46$, $DF = 12$, $P = 0.881$) or month ($F = 2.82$, $DF=9$, $P = 0.069$). The only significant difference was between display and non-display times.

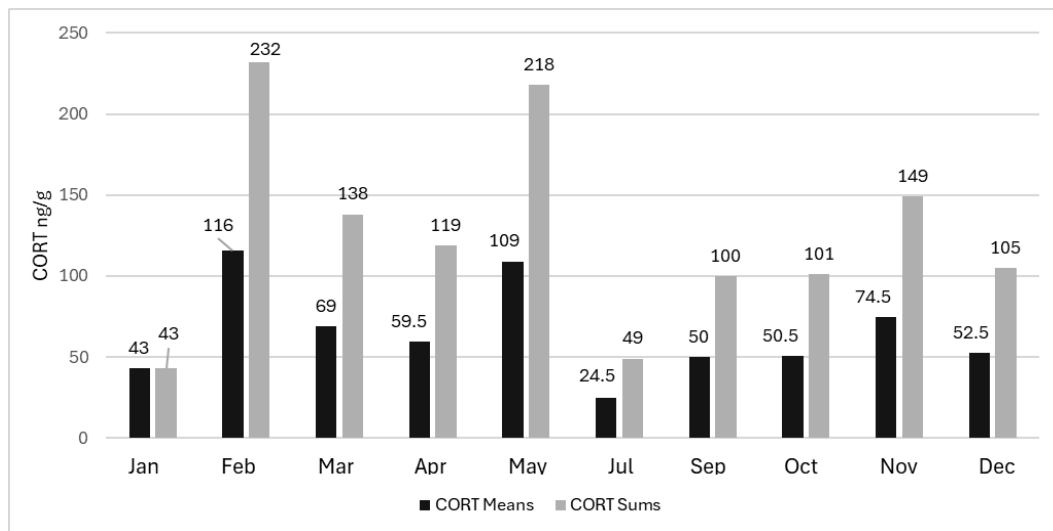


Figure 3.6: Means and sums of CORT levels in the captive owl by month.

3.5 Discussion

3.5.1 Corticosterone Levels

Unfortunately, fewer than half of the samples submitted to this study contained faecal material that could be assayed for corticosterone. This greatly diminished the ability to achieve an adequate sample size for strong conclusions. As the urate-only samples could not detect corticosterone, they were of no further use at this time. Nevertheless, even this small sample of 40 reliable tests yielded valuable information.

The observation of a seasonal effect in 2021, which, after removal of outliers, repeated in 2022, gives credence to the assertion that these tests yielded reliable results. This was also supported by the apparent stressing effect of public displays on the physiology of a long-habituated captive bird. The means for CA and OR sites showed an inverted comparison by year. OR was low the first year and high the second year, while CA was high the first year and very low the second. A pattern has previously been noted that spotted owls show a cycle of low fecundity followed by high fecundity every other year called the “odd even year effect”, which could explain the difference observed between the two years in this study (Burnham et al. 1996 and Dugger et al. 2016). However, it has been noted that, while broadly true, the odd-even year effect is not entirely reliable and the owls do not adhere to it (Dugger et al. 2016). The owls in Marin County are also noted by biologists to lack an alternating year effect, though they do show annual variation (R. Cormier, personal communication, 26 February 2025). The

difference between the years may have resulted from the effect of wildfires, which fluctuated between the two years.

As noted above, without the outliers, the trends become more similar, with peaks in May and June for 2021 and June for 2022. This agrees with previous research which shows May having the highest CORT, especially in males as they are protecting territory at the beginning of the breeding season, and later in the season with females protecting the nest and young (Hayward et al. 2010 and Wasser et al. 1997). In previous research, females were noted to have higher CORT later in the season, while males exhibited more CORT in the early season (Wasser & Hunt 2005). The few data available from birds of known sex in the present study also supported previous findings. The only male with higher than mean CORT was in May, while the rest of the above mean CORT were either female, juvenile, or unknown.

The corticosterone means in Table 3.1 suggest that the more remote owls were more stressed than the near-urban ones. The captive owl sample had higher means than the wild urban owls. However, since age is known to affect CORT levels (Millsbaugh & Washburn 2004), this could be due to the bird being 19 years old. Each of the areas had two main outliers for corticosterone levels, but the results still show lower overall stress levels in owls that more regularly encounter people. This suggests that the CA owls have habituated to anthropogenic disturbance and thus have a higher allostatic load, while the OR owls experience more chronic and acute stress in the presence of humans. Although we could not assess this directly, the presence of barred

owls may also be a factor, since this species occurs at higher densities in the northern part of the range and conflict with the NSOs more frequently.

The four high outliers prompt an interesting question about acute and chronic stress. It is likely that most owls sampled were expressing the baseline or chronic stress, while the outliers were expressing acute stress due to an experience specific to the time of collection. However, without knowing all the circumstances around the sample collection and events in the area, it is impossible to say with any certainty which factor was the prime influencer.

Urban Proximity

Overall, there was no statistically significant finding that proximity to either roads or urban areas increased the corticosterone levels of the owls. The OR sites were closer to logging roads, while the CA sites were closer to recreation trails. These two types were grouped together because they were approximately the same distance from the sample collection sites. As the first point of contact for the owls to anthropogenic proximity, they were likely to reflect in the corticosterone levels. The OR sites in 2021 were closer to logging roads than in 2022 and showed lower levels of corticosterone. However, the higher CORT sites were closer to public roads. As logging roads are not guaranteed to be in use or at least frequent use, the public roads would be the most likely to generate noise disturbance. The CA sites had significantly higher CORT in 2021 than in 2022, and the trails were much closer. The public road distances were approximately the

same in the two years. Collection sites were much closer to highways in 2022, suggesting that road noise levels were so consistent that the owls were not as affected.

Studies relating owl CORT levels to the distance from roads have reported lower CORT levels in birds further from roads than those nearby (Tempel & Gutierrez 2003). However, Hayward et al. (2011) found that, although they had fewer young, owls living near roads were less stressed if they had good nutrition. That seems to indicate a clear distinction between higher stress closer to the first point of contact with humans and less further away. The distance to highways might be sufficient to limit stress. The very high outliers were not always the closest to roads. For logging roads, they were third and fourth place for CA sites and 2nd and 13th for OR. For Public roads, they were 10th and 11th, and 3rd for OR sites. For highways, they were 22nd and 23rd, and for OR sites 11th and 13th.

Previous research by Wasser et al. (1997) concluded that male owls within 400 m of logging roads had higher CORT levels than those further away. A study by Tempel and Gutierrez (2003) concluded that California spotted owl males within 300 m of a road did not have an increase in CORT when exposed to chainsaw noise and may therefore be more habituated to roads and human noise, although they describe potentially confounding variables. For this study, the CA sites coincide with the previous study as the three above-mean CORT levels were all within 400 m. However, for the OR sites, only two samples were collected within the 400 m, and both were above the mean. There were also six above-mean samples further than 400 m from a road, with one

being a very high outlier. When looking at public roads, the CA sites had one higher-than-mean CORT within 400 m and four further, including the two highest concentration samples. The OR sites were all over 400 m, and all but one were above-mean CORT. For highways, there was only one sample (CA) within 400 m, and it was a below-mean CORT level.

Urban Areas

The mean CORT levels in the OR sites for 2021 were lower than in 2022 and were closer to small urban areas. Individually, the CA sites showed more CORT, and the OR sites showed less CORT closer to small urban areas. For medium urban areas, CA showed far less CORT and OR showed more the closer they were to those areas. For large urban areas, CA sites showed less CORT and OR sites showed more CORT closer. These results suggest, by their randomness, that there is no correlation between CORT and urban areas.

The captive owl presents an interesting avenue for future research. The bird had lived her whole 19 years (since she was found as a chick) so far at the centre and had been habituated to humans and urban environments, including sights and sounds and travel. The owl showed significant increases in CORT levels after an educational display (mean= 90.6 CORT ng/g, SD 19.1, P-Value 0.047), which suggests that there are more stressors to the bird during these times, despite habituation. The total mean was 66 CORT ng/g and the mean for times other than after displays was 57.2 CORT ng/g. She is described as being very calm and well gloved trained, comfortable sitting in front of a

group of people (WildCare 2020). Previous research shows that CORT levels reasonably correlate with physiological stressors, which seems to apply to this captive owl (Wasser et al. 2000 and Wasser et al. 1997).

Wildfires

The wildfires in the OR sites were much closer than the ones in the CA sites (National Interagency Fire Center 2021 & 2022). As the CA sites were more urban, the response time to control the fires was much faster than the more remote OR sites. In September of 2020, massive wildfires raged across the Pacific Northwest (Reilly et al. 2021), which could have a long-term effect on the owls the next year, including effects of PM 2.5, an airborne particulate that can be inhaled (World Air Quality Historical Database 2024 and The California Air Resources Board 2005). The wildfire season in California was exceptionally bad in 2021 and seven times less in 2022 (CA.gov. 2021 & 2022). This could have contributed to higher stress levels during the first year. One OR site had fires within 2km in both years. One site had a higher-than-mean stress level, while the other had the highest of all the OR sites. As these sites were within 1km of each other and four owls were seen at each, it is very likely these are the same owls. They were recorded a month apart, with the higher stress near the end of the season where a female was identified with the juveniles. The rest of the OR fires were over 10km away from the sites. The CA sites had eight fires within 10 km in 2021 and one in 2022. The site closest to wildfires had a higher-than-mean corticosterone level.

3.5.2 Possible Reasons for non-significant Results

As with many research projects, variables are outside the control of the researchers. Covid-19 made it necessary to change the project from the lead author visiting sites and collecting samples to recruiting collaborators already in the field collecting samples. While the inclusion of multiple agencies and organizations enlarged the project, it allowed for variations in collection techniques and storage. Samples were shipped to the lab in different ways and could not always be collected promptly, resulting in samples sitting in coolers in high temperatures. KO'R and AMP conducted the lab work using a reference protocol, but learned the process as they went and used trial-and-error in some situations, such as the lead author (AMP) separating urate and faecal material in the samples. According to previous research shown in Table 3.8, any of these missteps in handling or extraction could influence the CORT levels. Previous research is equivocal on the suitability of CORT as a measure of stress in owls. While some research presents it as an excellent and verified way to measure stressors (Wasser et al. 1997), others demonstrate that CORT levels fluctuate naturally (Keay et al. 2006, Dickens & Romero 2013, and Millspaugh & Washburn 2004) and that consequently, while being the best available, may not always be a good indicator of stress in the owls (MacDougall-Shackleton et al. 2019). Dickens & Romero (2013) assert that the assumption that higher CORT equates to more stress is false and based on theory rather than data. More research on all factors would help answer this question.

This study only ran for two years of sample collection and this is known to be too short a time to gain an accurate understanding of CORT levels in these owls. With the lack of seasonal CORT fluctuation data (but note Fig 3.3) and baseline CORT, it is impossible to say with certainty that an owl was under 'stress' (Millspaugh & Washburn 2004). Collecting samples from all parts of the owl's range over a ten-year period would have been ideal, but outside the scope of this project.

Table 3.8: A summary of the major shortcomings in the project and solutions to improve them for future research.

	Sample size	Collection	Data	Shipping	Extraction	Statistics
Problems	Too small	Variation between collectors	Gathered second-hand	Variation in methods	Trial-and-error	Little experience conducting
	Only two locations		Missing data = many unknowns	All samples assayed at the end of the project		
Improvement	Collect more samples over more years	Have one person or a small team do all the collections after group training to ensure consistency	Expand the environmental metrics in the data form to include barred owls, air traffic, nearby disturbances, pollution levels, precipitation, temperature, and time from the start of exposure to people until the time of collection.	Samples are stored and transported according to the protocol	Have someone with expertise assist	Have someone with expertise assist
	Form partnerships with more agencies/ organizations and tribes	Have permits/ professionals to handle capturing the owls for attaching GPS and taking measurements, thus obtaining all required body metrics from each owl	All Information on the collection forms is mandatory to prevent gaps from missing data	Conduct assays at the end of each season	Conduct multiple tests with the same samples	Take more opportunities to learn
	Get access to owls from all parts of their range	Only collect fresh samples and separate urates out in the field				

Previous research is summarized in Appendix F, Table 3.9 with variables that correlate with corticosterone levels, findings of no impact, and information on the difficulties and shortfalls of this type of research. Most interesting from this study are the

other findings of no impact; chainsaw noise within 100m (the true part of the experiment), time of day, low-intensity anthropogenic disturbance, observer presence, and seasonal impacts on males. The present study supports some of these findings.

Previous research had reported relationships between NSO CORT and the following variables; season (Wasser et al 1997, Millspaugh & Washburn 2004, and Mikkelsen 2021), quantity of food (Hayward et al 2010, Mikkelsen 2021, and Dickens & Romero 2013), rate of defecation and metabolism (Hayward et al 2010 and Millspaugh & Washburn 2004), disturbance (Wasser et al. 1997, Tarlow & Blumstein 2007, Hayward et al 2010, and Dickens & Romero 2013), temperature (Hayward et al. 2010 and Mikkelsen 2021), diet (Millspaugh & Washburn 2004 and Hayward et al. 2010), breeding success (Tarlow & Blumstein 2007, Mikkelsen 2021, and Millspaugh & Washburn 2004), fluctuating asymmetry (Tarlow & Blumstein 2007), flight initiation distance (Tarlow & Blumstein 2007), mate choice and energy allocation (Tarlow & Blumstein 2007), immunocompetence (Tarlow & Blumstein 2007), cardiac response (Tarlow & Blumstein 2007), forest stand age (Mikkelsen 2021), urbanization (Mikkelsen 2021), territory quality (Mikkelsen 2021), quality and investment of parents (Mikkelsen 2021), age of parents (Mikkelsen 2021), forest structure (Mikkelsen 2021), annual variation in temperature and precipitation (Mikkelsen 2021), weather events (Mikkelsen 2021), genetics (Mikkelsen 2021), presence of high CORT in others nearby (Mikkelsen 2021), body weight (Millspaugh & Washburn 2004; Dickens & Romero 2013), sex (Wasser et al. 1997 and Millspaugh & Washburn 2004), chronic and acute stressors (Wasser et al. 2000, Tempel & Gutierrez 2003, Tarlow & Blumstein 2007, and Dickens & Romero

2013), proximity to forest management activity (Wasser et al. 1997), proximity to logging roads (Wasser et al. 1997), home range disturbance (Wasser et al. 1997), and offspring survival factors (Wasser et al. 1997 and Mikkelsen 2021). As many of these variables interact, all should be surveyed to gain the most complete picture, not only of the levels of glucocorticoids, but also how those levels fluctuate.

For the reasons outlined already, the present study could not survey for all of the above variables, but those measured showed no relationship to CORT levels. However, there is strong evidence for a seasonal fluctuation as seen in Figure 3.3. As spotted owls are known to breed every other year, this study was able to discern the alternating pattern between the two locations with each having a high and low year, though interestingly not in synchrony.

3.5.3 Areas for Future Research

Future research should focus on collecting more data in the field and where possible work with marked populations. Banding and measuring body metrics of individual owls together with attachment of transmitters to obtain GPS data would all greatly improve the understanding of CORT levels. Other hormones should be tested at the same time to give a more complete picture of each individual owl. Monitoring of barred owls, nearby disturbances, weather, air traffic patterns near airports or military bases, insect and disease outbreaks, and other land use would all contribute to better understanding of NSO stress. More research is needed to differentiate between natural

seasonal cycles of CORT and external stressors. This would require sampling all year long from both sexes and juveniles.

While faecal sampling can provide a non-invasive assessment of a bird's stress, it is important that sampling is of defecated rather than excreted (urate only) material. Samples would need to be taken from chicks in the nest from hatch until fledging. Data also need to be collected from dead radio-tagged owls to understand which stressors linked to cause of death are the most impactful. GPS data would allow researchers to understand if some areas are avoided and why, home territory ranges and included habitat data, dispersal of juveniles, and energy expenditure during the year. Nest cameras would greatly aid in understanding nest stressors affecting the female and chicks. These suggestions would all be susceptible to the constraints of manpower, funding, and maintenance issues, but provide an idea of the needs to conduct a complete inventory of stressors.

3.6 Conclusion

The results of this study suggest that previous research on the distance from roads is correct, but perhaps not the whole picture. As the CORT levels for the owls did generally coincide with previous research, we found examples of high CORT further away as well. This suggests that other factors, especially wildfires, contribute.

Considerably more research will be required to distinguish major and minor factors, both anthropogenic and non-anthropogenic, influencing CORT and stress in the owls.

Concurrent studies on barred owls would greatly contribute to understanding their impacts on spotted owls. Other research (Crozier et al. 2006, Endangered and Threatened Wildlife and Plants 2023, California Department of Fish and Wildlife 2016, Buchanan & Kohler 2024, Gutierrez et al. 2007, Forsman et al. 2011, Dugger et al. 2016, and Franklin et al. 2021) places the barred owl as a main contributing factor in spotted owl decline, and this needs to be explored further. Without a full survey on all of the factors during each sample collection, and without collecting from the same owl throughout the season in all years, it is impossible to say which factors have the most impact on stress levels.

4

Management Exploration and Analysis

Ami Pekrul & Andrew Gosler

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Abbreviations

AFWA	Association of Fish and Wildlife Agencies
BLM	Bureau of Land Management
EIS	Environmental Impact Statement
ESA	Endangered Species Act
FLPMA	Federal Land Policy and Management Act
FMP	Forest Management Plan
FS	Forest Service
NEPA	National Environmental Policy Act
NFMA	National Forest Management Act
NSO	Northern Spotted Owl
NWFP	Northwest Forest Plan
SWAP	State Wildlife Action Plan
USFWS	United States Fish and Wildlife Service

Abstract

From the first state listing of 'threatened' in 1975 to the federal listing in 1990, the northern spotted owl has gained increasing protection in response to continuing decline. There are many federal agencies overseeing management, filtering down to state, tribal, and private levels. As one of the world's most studied birds, it is no surprise that the federal government dedicates a considerable amount of time, money, and manpower to protecting them. Despite all this, the species is still declining and the responsibility for this rests solely on the way the protections are applied or circumvented.

Keywords: northern spotted owl, management, federal, protections, decline

4.1 Introduction

The northern spotted owl is subject to many levels of conservation management. From sweeping federal documents to private stakeholders, the owl is protected at an increasing rate, despite which, they continue to decline in population. The Endangered Species Act and the National Environmental Policy Act stand as the federal baseline across the country. The Northwest Forest Plan covers the Pacific Northwest and the Revised Recovery Plan for the NSO covers the entire range of the owl. The State Wildlife Action Plans detail how each state protects all of the species within their borders. Tribes manage their own lands and have Forest Management Plans that oversee NSO protection. This paper sought to elucidate the layers of management and understand the major differences between them and how that might even contribute to increased rates of decline in some areas.

4.1.1 Federal

Endangered Species Act

The Endangered Species Act of 1973 was created to protect and provide a framework for recovery for imperilled species (U.S. Congress 1988). It is administered by the USFWS, which oversees its implementation and enforcement. The Act outlines what can and cannot be done to protected species, how they can be listed and delisted, and the repercussions of violations (U.S. Congress 1988). The criteria for listing a species

under the ESA are habitat loss, overutilisation, disease/predation, inadequacy of existing regulations, or natural or manmade factors impacting survival (USFWS 2016b).

National Environmental Policy Act (NEPA)

NEPA was created in 1970 to guide the decision-making process for actions proposed by federal agencies that may affect the environment through Environmental Impact Statements and Environmental Assessments (EPA 2023).

National Forest Management Act

The NFMA was created in 1976 as an amendment to the Forest and Rangeland Renewable Resources Planning Act of 1974 (Forest Service n.d.). Its purpose was to guide the Forest Service, assigned by Congress to be the leader and enforcer of this Act, on how best to manage renewable resources within national forests and grasslands and establish regular status reports (Forest Service n.d.).

Federal Land Policy and Management Act

The FLPMA of 1976 governs BLM land and how their resources are managed in much the same way as the NFMA does for the FS (Killian 2023). Its goal is to enable the BLM to protect resources while also balancing sustainable yields.

Northwest Forest Plan

The Northwest Forest Plan (NWFP) was authorized in 1993 by President Clinton in response to escalations in the Pacific Northwest between loggers and environmentalists

over the use of forests. Stakeholders were brought together and agreed on this plan, which merged socio-economic and environmental values to conserve parts of the forests for imperilled species while still allowing logging. The *Northern Spotted Owl Monitoring Program* was created as part of the NWFP to monitor the owl populations, restore habitat, and ensure that it was being followed.

State Wildlife Action Plans (SWAP)

In 2000, Congress created the State and Tribal Wildlife Grants program and tasked each state to complete a State Wildlife Action Plan covering their conservation strategies by 2005. Eight Required Elements from Congress guided the SWAPs, though each State was granted autonomy in selecting priorities and creating plans (Boxer 1999-2000). A comparison of Congress, the Association of Fish and Wildlife Agencies (AFWA), and each state's interpretation is found in Appendix G, Table 4.1. It required that each state also complete an update every ten years. The 2015 documents are discussed below. AFWA created many resources and documents to aid each state in creating, revising, and learning from the SWAPs. The SWAPs give an overall view of each state's priorities concerning wildlife. Washington's State Wildlife Action Plan was the longest of the three states within the spotted owl's range.

Revised Recovery Plan for the Northern Spotted Owl

In 2011, the *Revised Recovery Plan for the Northern Spotted Owl* was completed and implemented, replacing the previous plan from 2008. It is the definitive management

plan for the spotted owl in the U.S. According to the USFWS; it is one of three parts of their management framework for recovery alongside the Species Status Assessment and the Recovery Implementation Strategy.

Spotted Owl Monitoring

The 2011 *Protocol for Surveying Proposed Management Activities That May Impact Northern Spotted Owls* was revised in 2012 and is the current instruction on the best methods of conducting NSO surveys. It includes how to identify habitat, the survey period, general survey designs, procedures, follow-ups, what to do if barred owls are present, recording data, what to do if an NSO is found, and determining nesting and activity centres (USFWS 2012a). Since its inception, there has been a shift to using bioacoustic monitoring in addition to having biologists in the field searching for owls (Davis & Lesmeister 2020). NSOs respond less than they used to because of the increased presence of more aggressive barred owls (Crozier et al. 2006). Bioacoustics pick up both NSO and barred owl presence and cover a larger area than an individual person could (Davis & Lesmeister 2020).

Status Reviews

The California document was nearly six times larger than the others. It was conducted in response to a petition to list the NSO under the California Endangered Species Act (California Department of Fish and Wildlife 2016). The Washington Document was a periodic review undertaken every five years as required by the Washington Fish and

Wildlife Commission for every imperilled species in the state (Buchanan & Kohler 2024). Oregon lists the NSO as threatened, but it follows federal guidance for management and therefore does not complete a status review.

Governance Hierarchy

Untangling the intricacies of NSO management can be daunting. The Bureau of Land Management (BLM), the US Fish and Wildlife Service (USFWS), and the Forest Service (FS) are the main, but not only, entities conducting surveys for the owls. These federal agencies and their regional offices send out contracts for private consulting agencies to bid. Those private agencies train their own employees and do the majority of the surveys in the field with oversight from a state biologist. On tribal land, the surveys are done by that tribe's Natural Resources Department or contracting biologist.

4.1.2 British Columbia

Canada has the Species at Risk Act, and British Columbia has the B.C. Wildlife Act of 1996. There is one wild spotted owl left in Canada. Three males were released from the Captive Breeding Program in August 2022, but two were found dead in May, and one was hit by a train in October and returned to the Centre until he was healed and released again in July 2023 (Northern Spotted Owl Breeding Program 2023). Another male was released with him (BC Gov News 2023a). They were named by the Spuzzum First Nation 'sítist', which means "night", and 'wikcn', which means "I see you" (BC Gov

News 2023a). Females were not released as they are needed for the breeding program (BC Gov News 2023b).

4.1.3 Washington, Oregon, & California

The NSO is protected in WA under Washington State's Environmental Policy Act of 1983, the State Forest Practices Act, and the Forest Resource Plan of 1992 (Washington State Legislature 2023). The NSO is endangered in Washington state, which prompts additional protections that the other two states do not have. The owl is also protected by the California Endangered Species Act and the California Board of Forestry and Fire Protection (California Department of Fish and Wildlife 2016). The California Bird Species of Special Concern and the Fish and Game Code provide further guidance and protection. In Oregon, the NSO is protected under Oregon Administrative Rules. The owl is listed as Endangered in Washington and Threatened in Oregon, California, and federally.

4.1.4 Tribal Protection

The Tribal Forest Protection Act of 2004 allowed the Native American tribes to manage the forests on their lands and provided grants to fund projects. The federal government requires forest management plans (FMP) for all lands in the federal trust, including tribal lands. As of 2023, all tribal lands have an FMP, though not all have been updated to maintain their accuracy (Gordon 2023).

4.1.5 Exploratory Data Analysis

The goal of this chapter is to explore how different management plans influence the survival and recovery of the NSOs. Therefore, it is driven by exploratory data analysis rather than hypothesis testing.

4.2 Methods

4.2.1 Evaluation of State Wildlife Action Plans

Washington, Oregon, and California each have a conservation strategy, tribes have forest management plans, and the federal government has regulations and acts directing management planning for the northern spotted owl. States and tribes are governed primarily by the Endangered Species Act, while British Columbia has the Species At Risk Act. These documents were coded in Nvivo 12, sentence-by-sentence under the following overarching themes: Ecological, Economic, Socio-Cultural, References, Anthropogenic Impacts, Governance, and Northern Spotted Owls. The category system of analysis is based on work done in the Atlantic fisheries by Jones and Stephenson (2019). Some sentences were relevant to more than one code and were labelled for both, but these cases were few enough not to make a significant difference. To aid in eliminating bias, a list of subcategories was used for reference, and one person (AMP) did all the coding. While standard methodological requirements typically use inter-rater reliability for content analysis, this research used an interpretive,

socio-historical approach in which the coding was a theoretical and reflexive process, thus minimising objective and singular classification of themes. However, it is acknowledged that the absence of additional coders represents a limitation and the reproducibility of coding decisions cannot be verified, though the transparency of NVivo allows all codes to easily be seen and tracked. Title pages, Cover Letters, References, Tables of Contents, Lists of Figures, Lists of Tables, Acknowledgements, and Lists of Acronyms were excluded from analysis. Each plan was broken down into a summary of weighted averages of each category using Nvivo 12. The SWAPs are used in this chapter as a surrogate for each state's priorities regarding wildlife, specifically the NSO, and are compared to the population declines in each state. A chi-square analysis was performed on weighted average code frequencies for each document, rather than raw code counts, in order to avoid confounding comparisons between documents of different lengths.

Ecological: The following subcategories helped guide the coding: Habitat, Species, Trophic Structure, Biodiversity, Ecosystem Integrity, Native Species, Invasive Species (unless specific to economy or human cause), and Other Endangered Species.

Economic: The subcategories used were: Local employment, Livelihoods, Sustainability, Diversification, New Investment, Viability and Prosperity, Distribution of Access and Benefits, and Regional Economic Benefits to the Community.

Socio-Cultural: The following subcategories were used: Equal Access, Community Health, Public Perception, Sustainable Communities, Health and Well-being, Ethics, History, Urban Growth, Heritage Sites, and Indigenous Rights.

Governance: The following subcategories were used: Management Type, Implementation, Enforcement, Laws and Regulations, Outcomes, Recommendations, Stakeholders, Programs, Control Methods, Toolkits, Outreach, Websites, and document structure or outlines.

Anthropogenic Impacts: The subcategories used were: Degradation or Loss of Habitat, Livestock Grazing, Agriculture Effects, Urbanization, Logging, and Pollution. There was a fine line between this category and Economic (above), but if the sentence leaned towards what the action did rather than simply what it was, it went into this category.

Northern Spotted Owl References: This included any mentions of the spotted owl, which were used in a separate analysis from the rest. All the mentions of spotted owls in the three management plans were coded for themes separately from the rest of the analysis. However, the sentences involved were still coded in the overall analysis under whichever category applied more accurately. The themes for the spotted owl were Ecological, Anthropogenic Impacts, and Governance. In the California document, extra consideration was given to separating and excluding mentions of the California spotted owl. Word clouds were generated for each SWAP's references to spotted owls. This was done with stemmed words rather than exact words to get more varied results (e.g. Forest instead of Forest, Forests, and Forested).

4.2.2 U.S. and Canada Spotted Owl Recovery Plans

Both plans were put into NVIVO to examine word frequency and counts. Significant categories were compared: overall goals, objectives, criteria, strategy, monitoring, recovery actions, timeline, threats, NSO population decline, NSO critical habitat requirements, critical habitat area, target populations, NSO home range medians, and cost estimates. The Table of Contents for each document was added to show the differences in structure and the range-wide habitat modelling frameworks.

4.2.3 Status Review Comparison

California and Washington had status reviews for the NSO, and B.C. had a similar threat assessment. These were assessed under the following categories: date last reviewed, page length, previous review date, annual population decline, historical population decline since the 1990s, threats, decline in habitat since 1993, home range means, core range, dispersal, tree prevalence, prey, elevation, and adult survival.

4.2.4 NSO Monitoring and Oversight

A search was conducted to find all the agencies and departments monitoring the NSO. A secondary search was done to find all the groups and committees overseeing the monitoring. These were all put into a table to clarify the hierarchy structure.

4.2.5 Native American Tribes

The Bureau of Indian Affairs maintains a list of all the federally recognised tribes in the U.S. Each tribe's website on this list was searched for the keywords 'spotted owl', 'forest management', and 'land use'. If any NSOs were referenced, they were recorded. Any forest management or land use plans were searched for any mention of NSOs, and any references were recorded. Finally, newspapers were consulted for any mention of tribes and NSOs.

4.3 Results

4.3.1 Evaluation of State Wildlife Action Plans

The Washington document was 1095 pages, the Oregon one was 439 pages, and the California one was 797 pages. The three documents took roughly 270 hours to code in total. Part of this time was due to the slowness of the Nvivo program working with such large documents. The three documents revealed some interesting differences, chiefly that the main focus of Governance was the same for Oregon (54.87%) and California (56.42%), but Ecological was the central theme for Washington (63.72%) (Figure 4.1). Oregon included much more than either California or Washington in both Socio-Cultural and Economical, while Washington had barely any of either. California had the fewest spotted owl references, but that was to be expected since the NSO populations are less threatened there and only partially come into the state. Meanwhile, the NSOs range

runs through Washington and Oregon. California also focused more than the other two on Anthropogenic Impacts. Washington and Oregon were more similar to each other with respect to this.

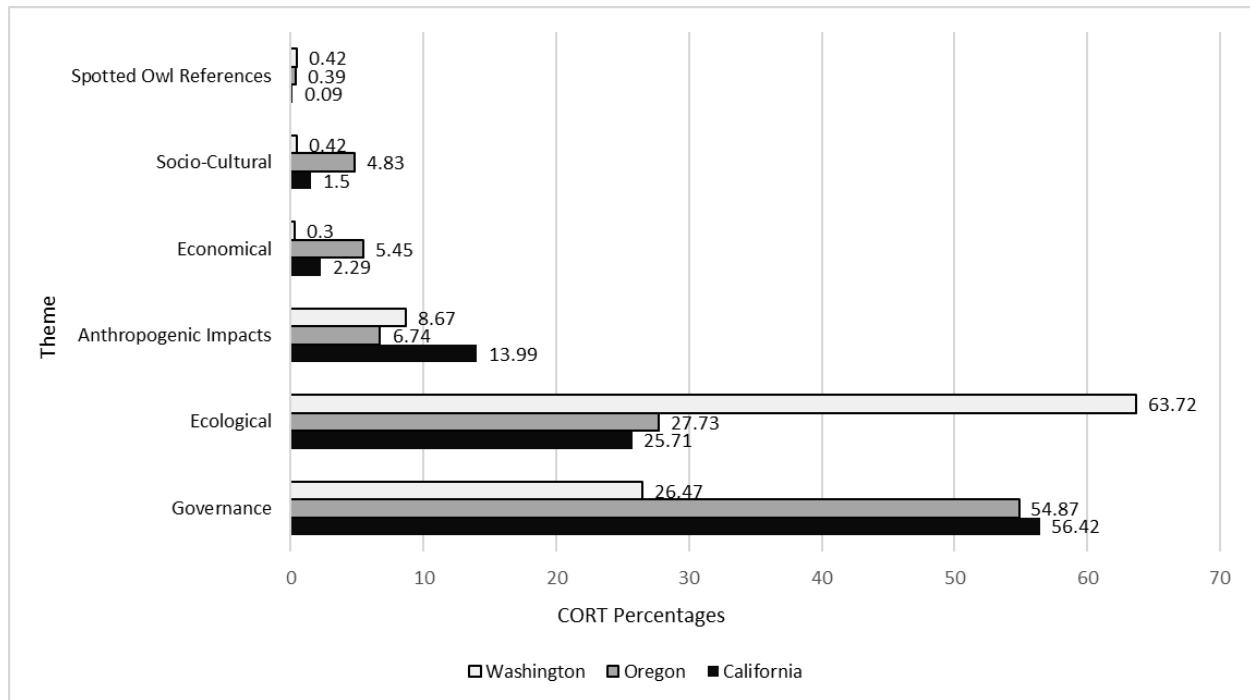
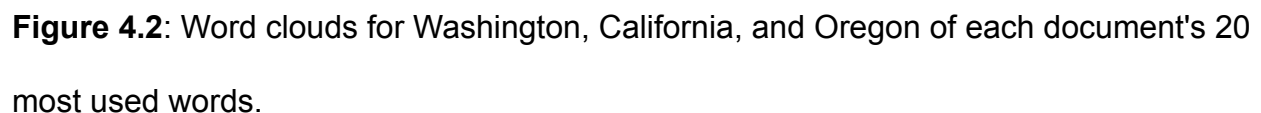


Figure 4.1: Comparison of percentages of each theme by state.

Word clouds generated for each document give an overall sense of the differences in focus, themes and priorities (Figure 4.2). Washington used more ecological words such as species, habitat, and wildlife. California used more management-oriented words such as conserving, managing, and planning. Oregon used a combination of such words e.g., conserving, habitat, and strategy. A minor point of interest is that Washington and Oregon are prominent on the word clouds, while California is less prominent, perhaps indicating a greater awareness of the broader



Another way to view these differences in focus is through the weighted averages of each theme. These are shown in Figure 4.3. As suggested by the word clouds, governance was the largest for California (56.42%) and Oregon (54.87%), and second largest for Washington (26.47%). The ecological theme was largest in Washington (63.72%) and second largest in California (25.71%) and Oregon (27.73%). Figure 4.3 reveals that California's theme for Anthropogenic Impacts was much larger than the other two states: CA 13.99%, WA 8.67%, and OR 6.74%. The economic theme in Oregon was much larger than the other two states: OR 5.45%, CA 2.29%, and WA

0.30%. Socio-cultural factors also played a more significant role in Oregon than in the other two states: OR 4.83%, CA 1.5%, and WA 0.42%.

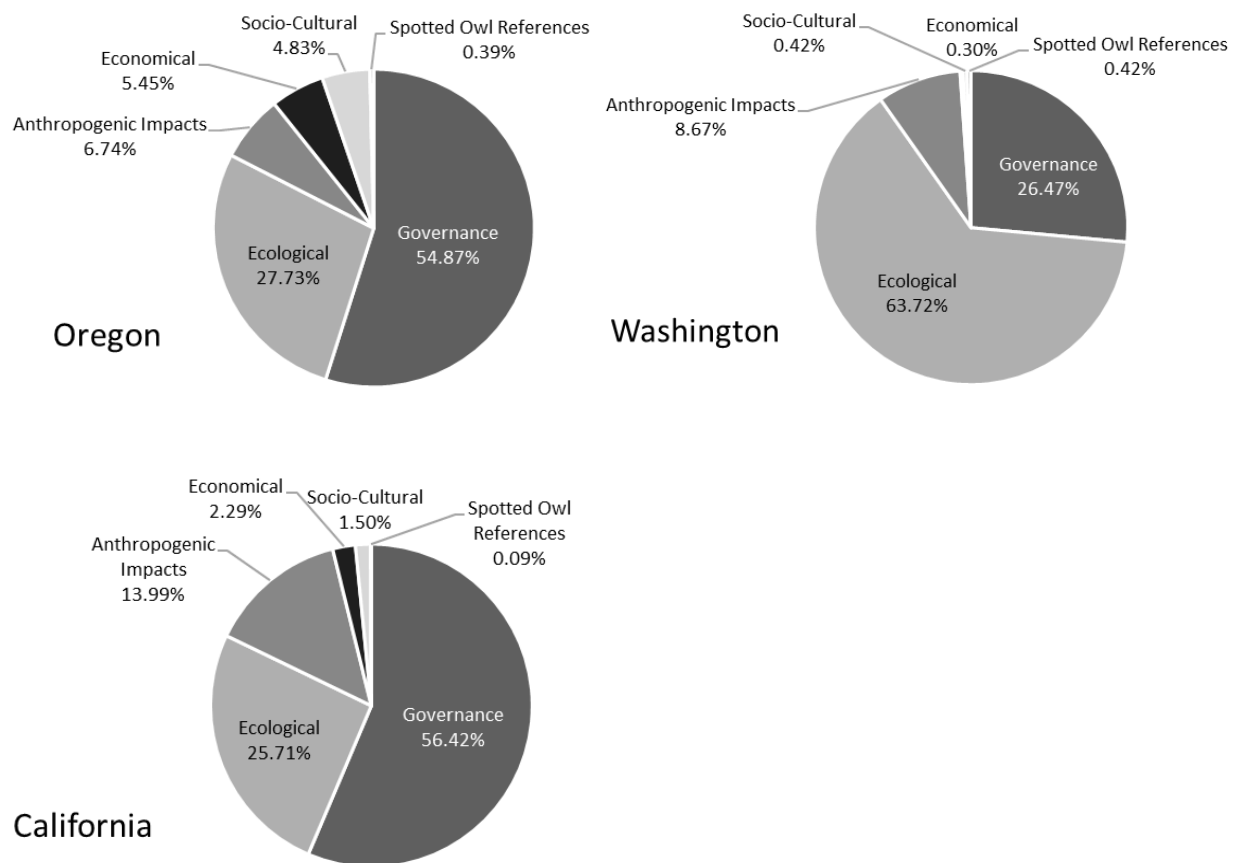


Figure 4.3: The State SWAPs breakdown by percentage of weighted averages for all themes, showing highest percentages in Governance and Ecological for all states.

Analyzing these categories in each document in Minitab Statistical Software revealed a Chi-square result of 3378.631, $p\text{-value} = 0$, with observed and expected counts of the actual coded references listed in Table 4.5. It is important to note here that Washington's document had longer codes than either Oregon or California where it was

more sentence-based. However, as the coded reference counts correlate to the percentage coverage from Figure 4.3, it is valuable to see both outputs.

Table 4.5: The Chi-square results of the categories in each state's document with observed counts on top and expected counts below.

	California	Washington	Oregon	All
Anthropogenic Impacts	439 161.1	918 1218.9	156 133.1	1513
Ecological	596 297.4	1765 2250.8	433 245.8	2794
Economical	75 25.3	20 191.7	143 20.9	238
Governance	674 1356.5	11384 10265.6	685 1120.9	12743
Socio-cultural	71 24.6	45 186.1	115 20.3	231
NSO Reference	16 6.1	27 45.9	14 5.0	57
All	1871	14159	1546	17576
<i>Cell Contents</i>				
<i>Count</i>				
<i>Expected count</i>				

The documents also differ in how they discuss the other states. CA mentions WA 9 times and OR 59 times. OR mentions WA 59 times and CA 43 times. WA mentions CA 255 times and OR 785 times. This coincides with WA focusing more on ecology as

many of these mentions are part of animal names (e.g. California Condor, *Gymnogyps californianus*).

Spotted Owl References

To determine the associations between the documents with the NSO, the SWAP documents were searched for any mention of the spotted owl, even if it was just a species on a list. These were collected and compared to each other to examine significant differences in perception and priority. Word clouds were created using the top 20 words used in all of the references of spotted owl, excluding the words northern, spotted, owl, *Strix*, *occidentalis*, and *caurina* to show more of the purpose around the reference (Figure 4.4).



Figure 4.4: Washington, California, and Oregon word clouds showing the top 20 words used in only northern spotted owl references from each state's SWAP.

The mentions of spotted owls in the SWAPs were primarily under the Ecological theme, but while California had a secondary theme category of Anthropogenic Impacts, Oregon and Washington had a secondary theme category of Governance (Appendix H, Tables 4.2, 4.3, 4.4). Washington had 23 mentions, with some being just the name of the species on a list to a whole section just about the NSO. Oregon had 13 mentions, and California had 11. As seen in Figure 4.3 above, the percentage of weighted averages of all these that made reference to the spotted owl was 0.42% for Washington, 0.39% for Oregon, and 0.09% for California.

The top five words for the NSO references for Washington were Forest, Habitat, High, Species, and Eagle (Table 4.6). California's top five were Pacific, Species, Fisher, Forest, and Include. Oregon's top five were Species, Forest, Focused, Addressed, and Habitat. These are compared to the top ten words from the overall documents for each state. Oregon had four words in common between overall top ten and NSO top ten. Washington and California had two things in common overall and NSO-specific top ten words.

Table 4.6: Top ten words from each state's documents listed by those overall and those included in the spotted owl references (any sentence pertaining to the owls).

Oregon		Washington		California	
Top 10	NSO 10	Top 10	NSO 10	Top 10	NSO 10
conserving	species	species'	forest	conserving	pacific
Oregon	forest	habitats	habitat	plans	species
habitats	focused	Washington	high	species'	fisher
strategy	address	states	species	California	forest
species'	habitat	wildlife	eagle	2015	include
wildlife	late	changing	western	managing	American
areas	needs	action	range	habitats	foraging
managers	Oregon	climatic	cascade	strategies	goshawk
using	plan	fishing	moderate	wildlife	habitat
fishing	strategy	conserving	now	waters	varied

4.3.2 U.S. and Canada Spotted Owl Recovery Plans

The U.S. encompasses most of the spotted owl range, with Canada being the northernmost tip. The U.S. Plan is 277 pages, and the Canadian Plan is 88 pages. The different recovery plans highlight the major differences between the two countries, summarised in Table 4.7 (Appendix I). The Table of Contents for each document is shown below in Figure 4.5. Though the documents varied greatly in length, it is interesting to see the differences in layout and structure. The US started with its goals and objectives, while BC had those in Section 6. BC starts with assessment information and species status. BC had threats in Section 4, while the US had threats in Appendix I.

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Figure 4.5: The Table of Contents for the Canadian NSO Document (Environment and Climate Change Canada 2023) on the left and the U.S. NSO Document (USFWS 2011a).

Top Ten Words: A comparison of the top ten words in each document showed many similarities, including Habitat, Recovery, Forest, Managing, and Areas (Table 4.8). As for the different words, the U.S. plan had Modeling, Plan, and Northern, while the Canadian plan had Within, Critical, and Species. These differences highlight the priorities through language use between the two plans. The BC one seems more focused on ecology, and the US more on governance.

Table 4.8: The top ten words by occurrence for the U.S. and Canadian federal Spotted Owl Recovery Plans, with shared words highlighted.

US 10	habitat	recovery	forests	modelling	plan	managing	northern	areas	conserving	revisions
BC 10	habitats	recovery	areas	population	within	critical	forests	species	strategy	range

A comparison of the habitat modelling frameworks mentioned in each document is shown in Figure 4.6. BC goes from habitat suitability to conservation prioritisation to population simulation. The US goes from policy to forest state time series to habitat map time series to maximum territories, connected habitat, and population models. These are oversimplified demonstrations of all the work that goes into creating population models, but they provide an interesting insight into what each federal document chose to show.

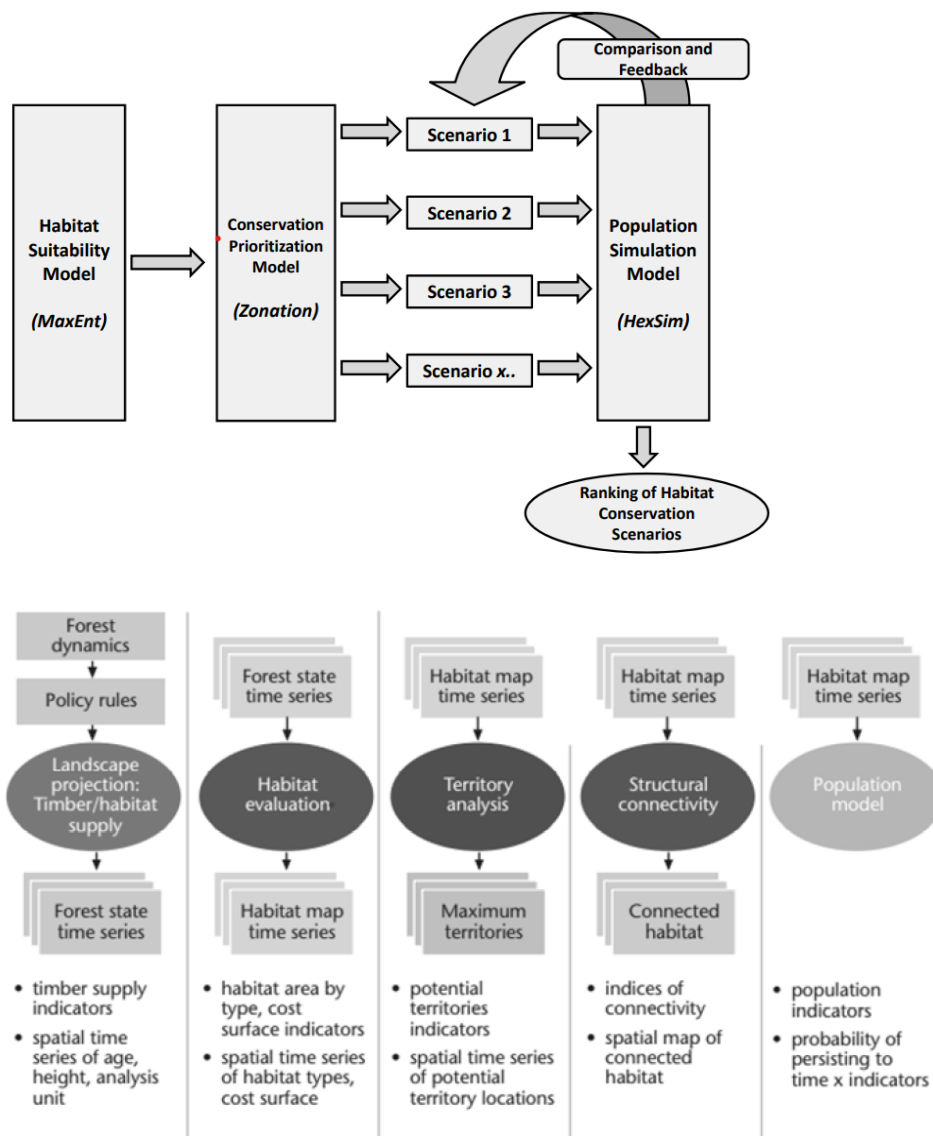


Figure 4.6: The range-wide habitat modelling frameworks for the U.S. (above) and Canada (below).

4.3.3 Status Review Comparison

An analysis of California, Washington, and British Columbia's status reviews revealed some interesting differences (Table 4.9 below). California had the most extensive document (238 pages), while Washington (34 pages) and B.C. (40 pages) were much more condensed. California's document excluded information on either when the last review was done or an estimate of the state's annual population decline. Washington's document excluded core range information. British Columbia's document excluded annual population decline, decline in habitat %, dispersal distances, elevation, or adult survival rates.

As expected, the northernmost and southernmost parts of the owl's range held many differences. California had the lowest decline rates (31-55%), while B.C. had the highest (~99%). The threats were similar, but B.C. included hunting/collecting, roads/railways, utility/service lines, housing/urban areas, commercial/industrial areas, tourism, recreation, and mining/quarrying. The home ranges were the largest in Washington (2659-3608 ha), second in B.C. (1907-3010 ha), and smallest in California (157-2687 ha). The core range was largest in California (98-1016 ha) and smallest in B.C. (within 500 m). Regarding potential prey, woodrats were more common in the southern part, and flying squirrels were more common in the northern. NSOs in California dispersed much further (0.8-150 km) than Washington's owls (13.5-24.5 km). Habitat declined more in Washington (2-68.8%) and less in California (9-16%).

Table 4.9: A summary of key differences between the Status Reviews for California and Washington and the Threat Assessment for British Columbia.

Title	California: A Status Review of the Northern Spotted Owl	Washington: Periodic Status Review for the Northern Spotted Owl in Washington	BC: Spotted owl caurina subspecies (<i>Strix occidentalis caurina</i>): Imminent Threat Assessment 2022
Date	2016	2024	2022
Pages	238	34	40
Previous Review	-	2016	2020
Annual Population Decline	-	5-9% (as of 2018)	-
Historic Population Decline since the 1990s	31-55%	80-90%	~99%
Threats	Barred owls, rapid decline in population size and demographic rates, and loss of habitat due to wildfire and timber harvest	Barred owls, fires, timber harvest, climate change, hybridisation (with barred owls), genetic variation, disease, predation, and demographic isolation	Barred owls, hunting and collecting, logging and wood harvesting, roads and railroads, utility and service lines, fire and fire suppression, housing and urban areas, commercial and industrial areas, tourism and recreation areas, mining and quarrying, and recreational activities
Decline in Habitat Since 1993	9%-16%	2-18.7% (Federal) & 40.6-68.8% (non-Federal)	-
Home Range Means	157-2687 ha	2659-3608 ha	1907-3010 ha
Core Range	98-1016 ha	-	Within ~500m of nest
Dispersal	Recapture: 0.8-150 km (males) & 1.3-141 km (females) ---- GPS: 30-156 km	13.5-14.6 km (males) and 22.9-24.5 (females)	-

Habitat	Redwood, Douglas-fir-tanoak forest, coast live oak, and tanoak series	Douglas-fir, western hemlock, grand fir, western larch, lodgepole pine, ponderosa pine, and hardwoods	Mixed coniferous forest
Prey	Primarily woodrats, but also flying squirrels, mice, voles, gophers, hares, small to medium-sized birds, bats, and insects	Primarily Humboldt's flying squirrel, but also small mammals, and small birds and invertebrates	Primarily northern flying squirrels
Elevation	300-1768 m	0-1524 m	-
Adult Survival	0.844-0.870	0.839 -0.877	-

The NSO population has been declining everywhere in its range (Table 4.10). It is higher in the north and decreases as the range extends southwards. This is primarily due to the barred owl coming from the East Coast through Canada and down the West Coast (Endangered and Threatened Wildlife and Plants 2023). There is only one wild owl left in BC, with two captive releases joining it in 2023, which makes the 99% decline unsurprising (BC Gov News 2023a). The captive breeding program aims to reverse that decline (Northern Spotted Owl Breeding Program 2023). Oregon and California's population decline continues towards an endangered status, and it is only a matter of time before their listings change. The federal government has found that the NSO needed to be uplisted to endangered status but is "warranted but precluded" by higher priorities in 2020 and again in 2023 (Endangered and Threatened Wildlife and Plants; 12-Month Finding for the Northern Spotted Owl 2020 and Endangered and Threatened Wildlife and Plants 2023).

Table 4.10: Population decline of the northern spotted owl by location and year compared to official status (Franklin et al. 2021 and Government of Canada 2022).

	Year owls were listed	Status	Population decline since 1995
BC	2002	Endangered	~99%
WA	1988	Endangered	75-80%
OR	1975	Threatened	>60%
CA	2016	Threatened	30-60%
USA	1990	Threatened	30-80%

4.3.4 NSO Monitoring and Oversight

While the U.S. Fish and Wildlife Service leads the management and monitoring of the NSO, many other federal agencies, state agencies, tribes, and private groups participate (Figure 4.7). The primary federal agencies are the National Park Service, Fish and Wildlife Service, Forest Service, Bureau of Land Management, Environmental Protection Agency, and USDA National Wildlife Research Center. The states have their departments, including California's and Washington's Fish and Wildlife Department and Oregon's Department of Forestry. There are approximately 130 tribes within the NSO historical range, each managing their own lands. BC manages the captive breeding program, and monitors released owls alongside the one remaining wild owl. The National Audubon Society funded the Washington Forest Practices Board Spotted Owl Scientific Advisory Group in 1985, which served to provide independent oversight (Dawson et al. 1987). The Northwest Forest Plan has many groups umbrellaed

beneath it, including the NSO Monitoring Program. Many of these agencies and groups share members, and there is much overlap.

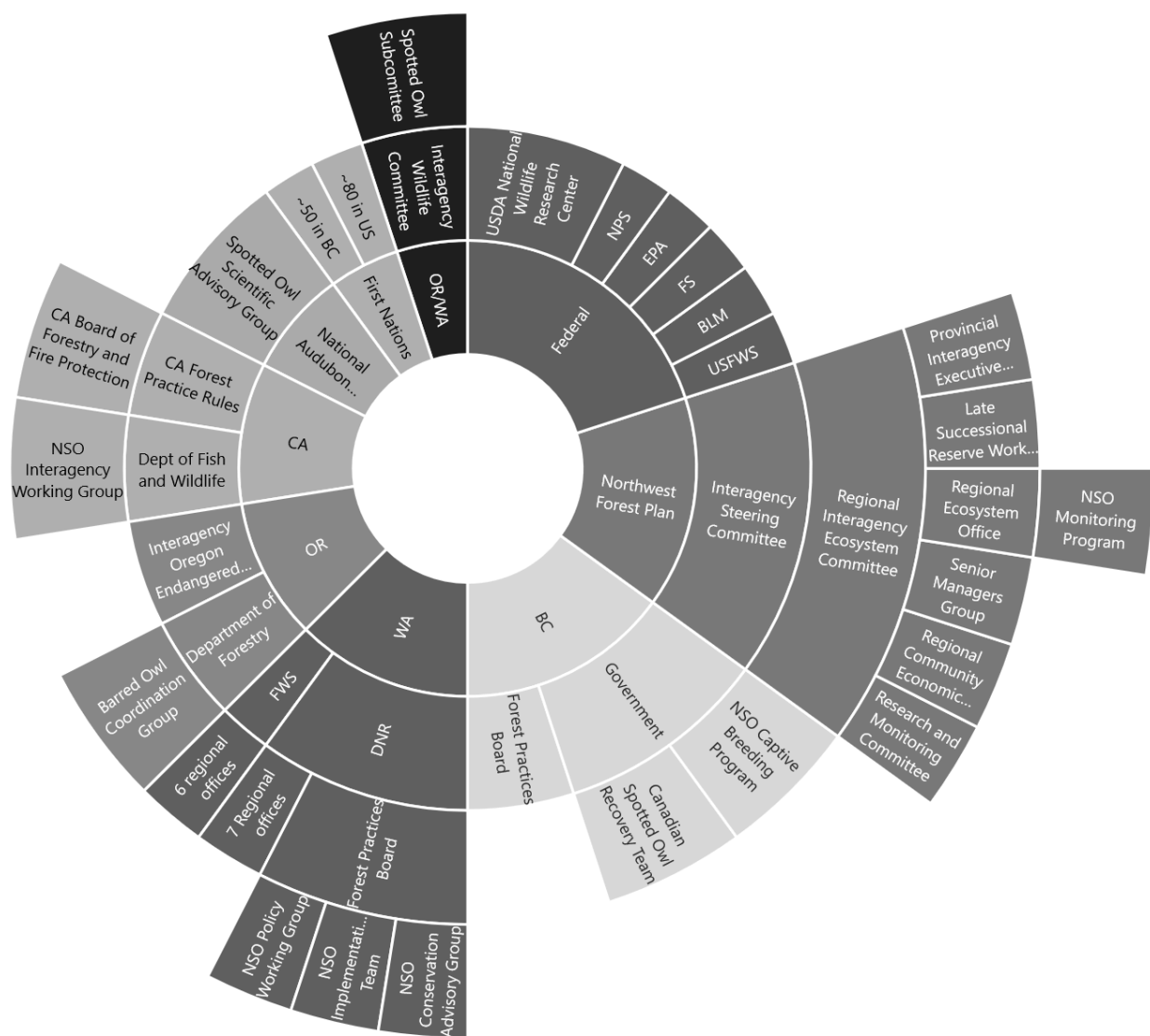


Figure 4.7: Summary breakdown of the different groups and agencies monitoring and overseeing the NSO (Table 4.11 of this information is available in Appendix J), from national or state agencies nearer the centre, to local or specialised near the periphery.

Wildfires

One study found that during an 18-year period, logging occurred in 87% of post-fire NSO sites, often encompassing the core range of an owl's territory (Bond et al. 2022). Only 12% of sites had no evidence of logging or barred owls. These areas are managed under the US Forest Service and the Bureau of Land Management, which allow for pre- and post-fire logging activities in NSO critical habitat and Late-Successional Reserves (Bond et al. 2022). Another study collected data from 38 observation years and found that 89% of the owls returned to the same territories after a fire with 57% breeding the next year, which was higher than the overall species rate (Bond et al. 2002). These large fires resulted in no short-term effects on the owls (Bond et al. 2002). The Forest Service studies, however, assert that severely-burned areas are abandoned by spotted owls and are thus available for logging after permits for "take" of NSOs are granted (Bond et al. 2022). The USFWS determined that "salvage harvests" would be allowed after one fire on 5,760 of 6,890 acres burnt (Yreka Fish and Wildlife Office 2016). The guidelines were to harvest moderate to high severity mortality for trees, which means 70% chance of dying in 3-5 years (Yreka Fish and Wildlife Office 2016). Once an area experiences a high-severity burn, the USFWS considers it non-habitat, though they also acknowledge that some owls do still use it. They even went so far as to detail the incidental take of ~103 owls deemed allowable in one area, but say that monitoring the effects of the logging is impractical (Yreka Fish and Wildlife Office 2016). Ganey et al. (2017) discuss all the conflicting data on whether and how wildfires impact the owls as research on the issue is conflicting.

Foraging habitat takes 70-150 years to develop and nesting/roosting habitat takes 150-370 years to develop, according to the FWS (Yreka Fish and Wildlife Office 2016). Habitat loss is one of the top reasons for NSO decline and this area of management is not being addressed. Not surprisingly, the Forest Service had 522 lawsuits filed against them over a ten year period (2010-2020) with the average being 47 per annum (Public Lands Sub-Committee 2023).

Budgets

One of the most significant considerations in wildlife management is funding. The federal government provides most of this, which is then distributed through the federal agencies to the states and private agencies. The summary of federal funding for the spotted owl is shown below in Tables 4.12, 4.13 and 4.14. There have been many fluctuations in funding, with a massive increase in 2018, which came primarily from the Forest Service. There was a large decrease in state funding in 2017. It was no surprise that the Forest Service and Fish and Wildlife spent the most as they lead management. An interesting note was the presence of infrequent funds from the Army, Navy, Coast Guard, and Bureau of Reclamation. The Forest Service spent a total of \$70,691,342 over the ten year period with the Fish and Wildlife Service second at \$47,787,776 (Table 4.13). BLM spent a total of \$39,408,751 over the ten years and the USDA Natural Resources Conservation Service spent \$11,207,413.

Table 4.12: Budget summary of northern spotted owl management and conservation spending from 2010-2020 (USFWS 2010-2020). The Rank each year shows how much money the NSO received compared to other imperilled species being protected.

Year	Rank	Federal Total	States Total	Species Total	Land Acquisition
2020	31	\$7,548,855	\$353,100	\$7,901,955	\$60,000
2019	13	\$6,464,993	\$914,890	\$7,379,883	\$0
2018	5	\$44,518,399	\$914,600	\$45,432,999	\$0
2017	23	\$11,852,475	\$2,200	\$11,854,675	\$0
2016	63	\$15,246,291	\$378,664	\$15,624,955	\$454,791
2015	32	\$9,764,910	\$210,500	\$9,975,410	\$1,000
2014	21	\$13,232,266	\$164,500	\$13,396,766	\$1,630,035
2013	17	\$17,505,374	\$157,000	\$17,662,374	\$3,678,200
2012	15	\$19,055,491	\$1,409,817	\$20,465,308	\$3,534,500
2011	19	\$14,368,600	\$1,132,247	\$15,500,847	\$1,732,000
2010	21	\$12,944,888	\$1,141,683	\$14,086,571	\$0

Table 4.13: Breakdown of Federal spending for northern spotted owl management and conservation from 2010-2020.

Year	USDA APHIS	USDA Forest Service	USDA Natural Resources Conservation Service	DOD Army Corp of Engineers	DOD Army	DOD Navy	DOE Western Area Power Administration	FWS Total
2020	\$400	\$1,472,921	\$0	\$38,581	\$0	\$0	\$49,679	\$2,043,885
2019	\$0	\$0	\$0	\$10,741	\$0	\$0	\$0	\$2,374,006
2018	\$0	\$36,494,350	\$92,300	\$14,111	\$0	\$0	\$0	\$4,072,138
2017	\$200	\$0	\$16,012	\$4,341	\$0	\$2,216	\$9,000	\$6,610,558
2016	\$400	\$4,962,760	\$287,000	\$14,539	\$0	\$0	\$10,000	\$4,727,716
2015	\$0	\$0	\$380,500	\$4,786	\$0	\$0	\$7,000	\$4,389,083
2014	\$0	\$3,263,492	\$1,472,000	\$5,676	\$50,000	\$0	\$5,400	\$4,896,153
2013	\$100	\$7,576,813	\$3,979,601	\$7,353	\$75,000	\$0	\$4,400	\$4,281,003
2012	\$100	\$8,337,006	\$2,633,000	\$3,592	\$0	\$0	\$900	\$4,866,236
2011	\$0	\$4,952,000	\$2,347,000	\$7,414	\$0	\$0	\$5,500	\$4,507,584
2010	\$300	\$3,632,000	\$0	\$4,980	\$0	\$0	\$1,300	\$5,019,414

Table 4.14: Continuation of the breakdown of Federal spending for northern spotted owl management and conservation from 2010-2020.

Year	DOI Bureau of Indian Affairs	DOI Bureau of Land Management	DOI National Park Service	DOI USGS	DOI Bureau of Reclamation	Federal Energy Regulatory Commission	DHS Coast Guard	DOT Federal Highway Administration
2020	\$0	\$3,146,916	\$484,653	\$311,520	\$0	\$300	\$0	\$0
2019	\$0	\$3,296,977	\$453,076	\$297,193	\$33,000	\$0	\$0	\$0
2018	\$404,000	\$2,774,148	\$409,906	\$244,191	\$3,000	\$0	\$0	\$0
2017	\$482,864	\$4,078,100	\$399,655	\$248,529	\$0	\$1,000	\$0	\$0
2016	\$0	\$4,297,000	\$402,414	\$229,379	\$0	\$3,100	\$5,000	\$306,983
2015	\$328,000	\$3,705,500	\$382,295	\$214,966	\$20,000	\$1,600	\$2,200	\$329,980
2014	\$429,000	\$3,579,710	\$318,050	\$113,299	\$0	\$2,700	\$0	\$360,786
2013	\$901,555	\$3,816,300	\$294,000	\$122,439	\$0	\$5,500	\$0	\$119,510
2012	\$259,000	\$4,548,000	\$436,500	\$154,448	\$0	\$1,409	\$0	\$186,300
2011	\$430,000	\$2,864,600	\$439,400	\$189,629	\$0	\$1,200	\$151,273	\$205,000
2010	\$420,000	\$3,301,500	\$526,065	\$38,629	\$0	\$700	\$0	\$0

The NSO Revised Recovery Plan came out in 2011 and it is worth noting that the Rank (by how much money the federal government spent on each species) of the NSOs for total federal spending increased slightly (from 19 to 15th place) before plummeting over the next four years to 63rd place (Figure 4.8). The NSO averaged a Rank of 24th for highest total spending and ranged from 5th place in 2018 to 63rd in 2016. The average spending for the NSO over the ten year period was \$15,682,049 with the high of \$44,518,399 and a low of \$6,464,993, though the low is the year following the high. Figure 4.8 highlights that the year with the highest rank (5th) paralleled the highest spending, but the lowest rank (63rd) was an average spending year. The lowest spending year corresponded to a fairly high rank (13th).

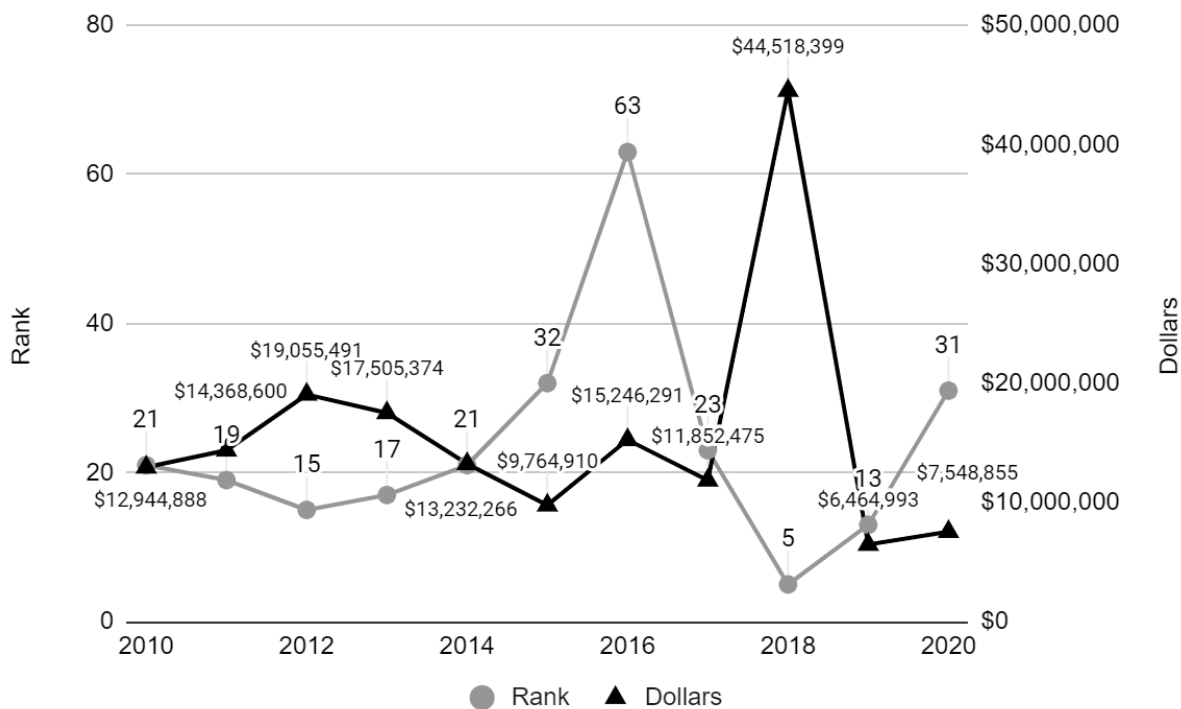


Figure 4.8: A comparison of Rank to federal spending for each of the ten years surveyed.

Barred Owl Management

The Final EIS on the Experimental Removal of Barred Owls to Benefit Threatened Northern Spotted Owls estimated the cost to be around \$2,910,000 for the preferred method, but ranged up to \$11,831,000 in 2013 (Oregon Fish and Wildlife Office 2013). This experimental removal was conducted and deemed a success with a new document written up to cover the whole range. The Draft Barred Owl Management Strategy closed for public comment in January 2024 and looks to be moving forward (USFWS 2023).

4.3.8 Native American Tribes

Tribes are not obligated to share their forest management or land use plans with the public. However, some are available on their websites. The ones that mention NSOs in their plans are summarized in Table 4.15 (Appendix K). Of the six available, some only mention the owl in a sentence as part of a list of other threatened species, and some go into much more detail. As of 2019, all of the tribes with forest land have completed a Forest Management Plan, though some go back to at least 2005 (Gordon 2023).

4.4 Discussion

4.4.1 Evaluation of State Wildlife Action Plans

Spotted Owl References

The word clouds reveal the broader focus of each management plan in regard to the spotted owl (Figure 4.4). For Washington, the other top words included Eagle. When looking at those references specifically, it can be seen that the eagle (both Bald and Golden) was always listed with the spotted owl when talking about imperilled species. This shows that the spotted owl was referred to not by itself as a focus but in a larger group. The same can be seen with California and the word Pacific, which in these cases referred to the pacific-slope flycatcher, pacific wren, Pacific giant salamander, and Pacific Fisher rather than the Ocean. Similarly, the word Fisher (as a reference to the

mustelid *Pekania pennanti*) was in the top five, though one of those four mentions included the spotted owl as the only other species, while the rest were species lists.

The word Forest appeared as the most used word in Washington's document, fourth in California's, and second in Oregon's. Oregon also used words like Focused, Address, Needs, Plans, Strategy, and Adopt. California and Washington used none of those but more species and ecology words. Interestingly, Oregon was number eight on the most common words for its spotted owl references, Washington was 11th in its own document, and California wasn't in any of its own. This hints at California taking a broader perspective.

4.4.2 U.S. and Canada Spotted Owl Recovery Plans

The first objective of each document is about population and distribution (Table 4.7, Appendix H). The US aims to remove the species from the Endangered Species Act, while Canada focuses on the habitat needed and removing human-caused threats. The second objective of the US is to see enough habitat for the NSO, and the third objective is to reduce or eliminate threats. The Canadian second objective is to re-introduce 50 captive owls, and their third objective is to find and remove all barred owls from NSO territory. The language differences highlight the priorities of each nation, though the words don't always correspond to the actions. While the Canadian document *sounds* like it put more stock in the environment, the government has sold permits and allowed for the logging of the last remaining NSO's habitat (Cecco 2023). This is ironic

considering the focus they place on maintaining critical habitat and connectivity in their plan.

4.4.3 Status Review Comparison

The purposes of the status reviews differed between California, Washington, and BC and are therefore not entirely comparable. However, the information within each is similar enough to allow for some comparisons. California's review was done in response to a petition to list the species, Washington's was a periodic review required by the state's ESA, and Canada's was a periodic review of threats. California's document was the oldest, from 2016, Canada's from 2022, and Washington's was released in 2024. While California's was significantly longer (~6 times), they shared the same main points. These three documents show the staggered decline of NSO populations from north to south, with the same main threats shared between them: barred owls and fires. Canada went into much deeper detail about the threats, which was not surprising given the intention of the document. The home ranges were similar across the range, but the core range information varied significantly. Canada defined the core as within ~500m of the nest. California said it was 98-1016ha. This could be due in part to the extreme logging practices in Canada.

Dispersal information differences between Washington and California were surprising, with CA saying 0.8-156km and WA saying 13.5-24.5km. This raises questions about habitat connectivity issues the NSOs might have, a known issue contributing to population decline. Both states mention the rate of habitat decline since

1993: CA 9-16% and WA 2-68.8%, with the highest being on non-Federal land.

Washington logged 2.7 billion board feet in 2016 (Smith 2016), while California (a state much larger) logged only 1.5 billion board feet in the same year (Marcille et al. 2016).

4.4.4 NSO Monitoring and Oversight

Budgets

The Forest Service spends the most on spotted owl recovery efforts, as shown in Table 4.13, with the Fish and Wildlife Service, BLM, and the USDA Natural Resources Conservation Service following behind. The most interesting is the \$36,494,350 spent by the Forest Service in 2018, which could be in response to the \$0 amounts in the year before and after. Each federal agency submits their fiscal budget annually, but the Forest Service does not disclose where this 36 million fits or how it was dispersed through habitat management or species protection specifically (Forest Service 2017). Therefore, it is impossible to identify if the money is going to the spotted owl at all. They don't even mention the NSO on either the 2018 or 2019 budget justifications (a separate document justifying why they spent what they did and where it went), though they do refer to other species by name (Forest Service 2017 & 2018). The Kirtland's warbler (*Setophaga kirtlandii*) is mentioned three times on the FS Fiscal Budget, though they only cost the Forest Service \$228,100 on the federal Budget. The Forest Service spent more on the NSO in 2018 than all of the other species combined. The NSO also rose to the 5th most expensive species across all the federal spending. Interestingly, the NSO

and Red-cockaded Woodpecker (*Picoides borealis*) are the only species on the top 20 highest spending that are not fish for that year (USFWS 2018).

Status and Rates of Decline

Under federal management from the Northwest Forest Plan, the new phase of monitoring is being done primarily through population and habitat models. The USFS says that severely burned habitat is not suitable for NSOs and thus open to logging.

4.5 Conclusion

As the northern spotted owl is one of the most researched raptors in the world, it is no surprise that its management should be complicated and expansive as seen in Figure 4.7. Listing under the federal or state Endangered Species Acts triggers many management actions to protect a species, as well as rules under the Northwest Forest Plan and each state's Forest Practice Rules. Conservation legislation of the NSO has many layers of governance and overlapping hierarchies. Despite all of this, the spotted owl continues to decline at higher rates. The difference between states in their SWAP priorities was highlighted when we found that Washington state focused substantially more on the ecological and less on the governance in their document, reading more as a summary of current ecology and not management on how to protect species. This is telling in that the NSO has suffered the most decline in that state. The calls of the last spotted owl in Canada will soon be silenced by chainsaws and the forests in Washington are becoming quiet with the other states on the way. Perhaps the barred

owl removal strategy will be feasible on a large scale, but even if it does, the northern spotted owls still need old growth, and until critical habitats are closed to logging, this will be too little too late.

5

Conclusion

List of Figures

5.1 The structure and major themes of the thesis.

5.1 Summary

In this thesis, perceptions were explored over a forty-year period in Chapter 2, corticosterone and stressors analysed and examined in Chapter 3, and management plans were dissected and compared in Chapter 4. These three areas of the spotted owl issue rely on different methodologies and provide multiple lenses through which to view the owl's prospects for the future. The human element is intrinsically woven into the owl's decline and must be considered when deciding future management. People have a profound impact on their environment and their choices decide whether a species slips into extinction or makes a miraculous recovery. Other avian species, including the Bald Eagle (*Haliaeetus leucocephalus*), California Condor (*Gymnogyps californianus*), and Peregrine Falcon (*Falco peregrinus*) have all recovered from the brink with careful and considerate management addressing the right issues with backing from the public. However, these species were not wracked by the economic pressures the NSO faces with the timber industry, which continues to impede recovery.

5.1.1 Chapter Comparisons

It is impossible to look at only one aspect of spotted owl conservation. Figure 5.1 (also shown in Figure 1.1) reiterates the lenses through which this thesis sought to view this complex issue. Understanding the past through the stages of the conflict and perspectives shifting allows us to appreciate the complexities and difficulties in managing the owl's populations. Exploring the variables that affect corticosterone and

the impact anthropogenic disturbance can have on the owls leads to better understanding of the species and the challenges it faces. Both of these lenses influence how management will attempt to protect them in the future, and either set the stage for further decline or a remarkable recovery.

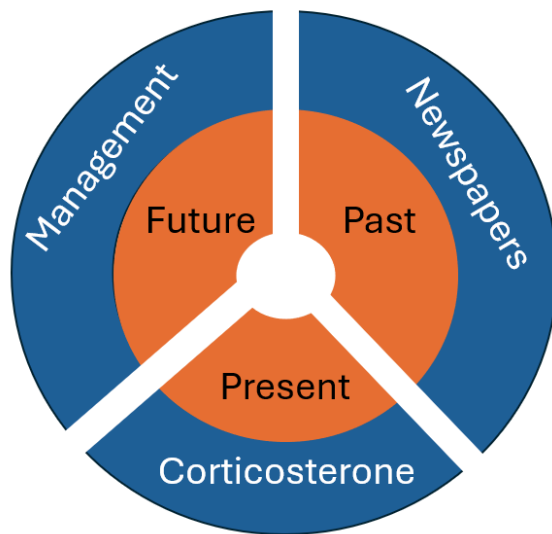


Figure 5.1: The structure and major themes of the thesis.

The shifts in perception around not only the NSO but the environment itself show how the priorities of Americans have changed since the 1980s. Management needs to reflect the public's values regarding species and the environment. Perceptions within the NSO range as reflected in newspaper coverage had greater use of the term "timber", while outside the range greater use of "forests" was noted. This reflects the power of the timber industry in the region. The 2019 Barred Owl removal experiment resulted in an increase in news articles as the public took more interest in the ethical

debate around killing some species to save another. This coincided with the 2018 Forest Service's massive increase in spending.

According to our findings in chapter 3, NSOs appear to have lower overall corticosterone levels near human activity, while more remote Owls experience higher corticosterone when exposed to stressors caused by humans. Management should reflect the need for Owls to have minimal exposure. Legal protections have too many loopholes and only look good on paper, while critical habitat is being designated that the owls cannot actually use, or logging is allowed throughout an owl's territory and called "habitat maintenance", or areas are clearcut in order to "create" future habitat. Take permits were issued, as seen in the Klamath National Forest in 2016, and it was considered acceptable for the possibility of over 100 NSO to be killed and deemed not significant to harm the entire population. Government and state spending on NSOs is not readily transparent and logging is deemed "maintenance", though habitat loss is a prime driver in the owl's decline.

Such contradictions resonate with the key finding of the analysis of conservation management plans (Chapter 4); i.e., the general lack of co-ordination between the numerous agencies and actors operating over the multi-state area of the spotted owl's geographic range. The sheer amount of money being spent on NSO conservation despite their continued decline points to internal issues in management and a need to reassess.

5.1.2 Thesis contributions

Confirmatory

In chapter two, I found that public perspectives around the owl generally followed the societal shift on nature perception (Mace 2014), although they never approached the indigenous tribal perception of “people in nature”. The dominance of the word “forest” outside the owl’s range and the word “timber” inside the owl’s range highlights that society does not all move at the same pace. The centre of the conflict area is still in the ‘nature for people’ stage while the areas outside the spotted owl range are in the ‘people and nature’ stage, on this issue at least. Every conservation conflict will have its own timeline.

In chapter three, we found Corticosterone levels (CORT) to be highest in May, and, in line with previous research, females exhibited higher CORT near the end of the season. In chapter four, we confirmed through analysis of state management plans that the rates of spotted owl population decline is higher in the northern part of the range and lowest in the southern part of the range.

Novel

Contrary to previous research we found in chapter three that roads and urban areas were not a significant indicator for CORT levels, although our sample sizes were necessarily small. Our most significant variable was wildfire presence. We also found that owls regularly disturbed by humans (recreational use of hiking, camping, ATVs, and

dog walking) did not result in higher CORT levels, suggesting that the owls habituated somewhat to people, while owls in more remote locations seemed to have higher acute CORT levels in response to anthropogenic disturbance.

In chapter four, we found that Washington's State Wildlife Action Plan was more ecologically focused while California and Oregon were more focused on management and governance. This has a profound implication that Washington does not have as many plans and protections as the others. Whole pages are summaries of current ecology rather than what the state is doing to reverse decline. These differences between the state's SWAPs is in no means synonymous with their actions, but as the document that speaks for the state's abilities to combat species decline, it should reflect more on what is actually being done.

How findings advance understanding

Public perception and understanding are vital to reversing decline of a species. The more interest that the public has in a species, the more exposure it gets, resulting in increased funding, which results in increased management. The public has in the past used societal pressure to change laws and redirect management, but first they need to be invested and care about a species. As society in general turns more towards a view of people AND nature, managers will need to find a way to navigate the needs of the economy and the desires of the people. However, the indigenous framing of the true relationship as "people IN nature" would surely be more constructive yet.

Our findings suggest that more research is needed to get the full story. Wildfire science is rapidly filling in gaps in knowledge about how the owls respond and recover during wildfire season. Barred owls are cited as the the most significant variable in spotted owl decline, but they are only being monitored in conjunction with other studies rather than in their own right. Understanding more about the variables affecting the spotted owls will help direct management better. Similarly, the lack of co-ordination between agencies and actors involved in NSO conservation needs to be addressed.

5.2 Recommendations for the future

Further research needs to be conducted on whether the management guidelines in place are the best possible to reverse the population decline of the NSO. If conflicting research arises, a review should be undertaken to discern the best course of action. For example, if the NSOs are found to have adapted to burns in such a way that they still use the habitat, understanding the effects of wildfires better might result in a decrease in land being logged post-fire. This is because the USFWS acknowledges that logging in post-fire habitat may contribute to NSO decline, but still allows for its occurrence (Yreka Fish and Wildlife Office 2016). Some research shows that barred owls avoided severely burned areas (Duchac 2021). This could be an important consideration for leaving burned habitat alone in NSO areas so providing the NSO with a refuge from barred owls.

The Barred Owl Removal plan addresses one stressor for the NSO, but diminishing habitat remains a top factor in their decline. Eliminating the current practices of logging in spotted owl habitat would be the greatest help to the species. Canada continues to log the area with their last spotted owl in it, the U.S. shouldn't follow suit by putting the financial gain from logging ahead of the species that live in them. It is estimated that forests in the U.S. will decline by 16-34 million acres (c. 6.5-13.8 million ha) by 2060 (Forest Service 2017). If the owls have nowhere to live and no way to reach each other through the fragmented forests, they will continue to decline to extinction. Management needs to focus on the species and not on treating the forests as a resource first, habitat second.

The funding for each species' management and recovery should be made more transparent. For example, it is unknown publicly whether the Forest Service considers commercial thinning to be part of NSO management and thus whether a large part of their budget includes logging. In a 2004 speech, Dale Bosworth, chief of the Forest Service, explained that a large part of their protection of species is "improving" habitat. The Forest Service considers thinning and post-fire 'salvage' to be improvements, though the evidence is clear that this would be harmful to the NSO (Thompson et al. 2007, Thompson and Spies 2010, and Lesmeister et al. 2021). More research is needed into how federal agencies spend their money allocated for imperiled species and whether the areas in which they spend it are the most beneficial to the species.

5.3 If I Could Do It Again

This thesis has changed so much from the original vision in 2019. Through the challenges imposed by the Covid-19 pandemic, it has shifted into a review-based approach as opposed to a more experiment-based one, with many aspects of hands-on fieldwork being replaced with a greater focus on literature. If I had another year to work, I would expand the newspaper analysis in Chapter 2 to include all years from 1988 to present. This would be a massive undertaking but would allow a complete picture of the changes in perception since before the owl was listed, as well as greater resolution of the regional differences in perspective. I would also expand on Chapter 4's management plans by going more in depth into the effects of wildfires and budget constraints on NSO decline and recovery. So much information remains inaccessible via the internet, and I would like to seek it out. Chapter 3 would have greatly benefited from more than two years of sample collection, though this was not possible when it first took two years to create a network of willing biologists and secure permissions before samples could even be collected. The prime intent of the chapter was to compare wild and captive samples, but the Northern Spotted Owl Breeding Program in Canada backed out two years into discussions, stating that the government "owned" the owls and had a final say in what research they could be involved with. For reasons undisclosed to me, they decided against my study. Therefore, this chapter had to turn into loosely remote versus urban for the wild samples. There was much trial and error learning how to conduct this methodology and another year of samples could have

answered some of the questions outlined in Chapter 3. Even with all the research conducted and being conducted on the NSO, there is still so much that is not known.

5.4 Final Notes

In conclusion, the northern spotted owl's decline can be reversed, but it will require an increased recognition and acknowledgement of their importance. Their status uplisting is warranted, but precluded by higher priorities of the government so even though it is acknowledged that they need more protection, it is unlikely to happen before they decrease to the point of no return. The rate of species extinction is increasing, and without putting ecological needs above economic, many more will disappear. Even with Canada's example of logging until the last owl highlighting the progression of greed, the U.S. seems poised to follow in their footsteps.

6

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7

Appendices

Appendix A

Table 2.6: Top 50 words found in front page newspaper articles mentioning the northern spotted owl separated by inside/ within the buffering zone of 50 miles of the NSO range and outside the range. These are the singular forms of stemmed words with an * for words that did not appear in each category.

Words	Outside Words Counts	Within/buffer Word Counts	Outside Weighted %	Inside/buffer Weighted %
forest	661	1664	1.47	1.55
year	334	793	0.74	0.74
species	308	515	0.68	0.48
log	303	637	0.67	0.59
service	269	710	0.6	0.66
national	239	433	0.53	0.4
federal	236	616	0.52	0.58
tree	225	395	0.5	0.37
timber	219	1047	0.49	0.98
state	214	652	0.47	0.61
owl	202	975	0.45	0.91
wildlife	196	243	0.43	0.23
endangered	189	292	0.42	0.27
one	188	388	0.42	0.36
protect	188	474	0.42	0.44
land	186	564	0.41	0.53
environmental	185	332	0.41	0.31
fishing	151	456	0.34	0.43
plans	145	466	0.32	0.44
group	136	308	0.3	0.29
cutting	134	270	0.3	0.25

time	134	259	0.3	0.24
listing	131	323	0.29	0.3
million	130	357	0.29	0.33
california	129	302	0.29	0.28
agency	125	299	0.28	0.28
government	125	278	0.28	0.26
spotted	125	567	0.28	0.53
fire	123	406	0.27	0.38
school	122	*	0.27	*
acts	121	*	0.27	*
old	120	464	0.27	0.43
last	119	*	0.26	*
official	118	*	0.26	*
work	117	287	0.26	0.27
law	113	*	0.25	*
habitat	113	309	0.25	0.29
industry	113	463	0.25	0.43
area	110	290	0.24	0.27
caribou	110	*	0.24	*
new	109	*	0.24	*
project	108	293	0.24	0.27
environmentalist	107	260	0.24	0.24
company	105	251	0.23	0.23
acres	104	313	0.23	0.29
county	104	293	0.23	0.27
northwest	101	355	0.22	0.33
people	100	257	0.22	0.24
park	99	*	0.22	*
public	95	247	0.21	0.23
Oregon	*	539	*	0.5
Salmon	*	444	*	0.41
growth	*	422	*	0.39

manage	*	342	*	0.32
Washington	*	325	*	0.3
river	*	291	*	0.27
sale	*	264	*	0.25
water	*	246	*	0.23

Appendix B

SCIENTIFIC RESEARCH AND COLLECTING PERMIT Grants permission in accordance with the attached general and special conditions United States Department of the Interior National Park Service Point Reyes	Study#: PORE-00398 Permit#: PORE-2021-SCI-0022 Start Date: Mar 01, 2021 Expiration Date: Aug 31, 2023 Coop Agreement#: Optional Park Code:
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Name of principal investigator: Name: Mrs Ami Pekrul Phone: 07415268512 Email: ami.pekrul@zoo.ox.ac.uk		
Name of institution represented: University of Oxford - UK		
Additional investigators or key field assistants: Name: David Press Phone: 415-464-5202 Email: dave.press@nps.gov		
Study Title: Stress Response of the Northern Spotted Owl (<i>Strix occidentalis caurina</i>) to Anthropogenic Proximity.		
Purpose of study: To measure the glucocorticoid levels between different populations of northern spotted owls throughout their range. The results will be studied in relation to proximity to people (roads, urban areas, etc.).		
Subject/Dis cipline: Birds/ Ornithology		

Locations authorized: Sample collection will take place near northern spotted owl nest sites and activity centers.
Transportation method to research site(s): Access will primarily be by foot to the northern spotted owl activity centers/ nests. A vehicle will be needed to reach those areas by road.
Collection of the following specimens or materials, quantities, and any limitations on collecting:
Name of repository for specimens or sample materials if applicable: Repository type: Will be destroyed through analysis or discarded after analysis Objects collected: Fecal samples from the northern spotted owls will be collected. They will be discarded/destroyed through the assay process or immediately after.

Summary of permitted field methods and activities: Fecal samples will be collected non-invasively from the northern spotted owls and sent to a lab in Portland to be assayed. There will be no handling of the birds themselves.

THIS PERMIT AND ATTACHED CONDITIONS AND RESTRICTIONS MUST BE CARRIED AT ALL TIMES WHILE CONDUCTING RESEARCH ACTIVITIES IN THE DESIGNATED PARK(S)

Appendix C

Fecal Sample Collection and Stress Hormone Analysis for the Northern Spotted Owl

Protocol

Lead Investigator: Ami Pekrul

Email: ami.pekrul@zoo.ox.ac.uk

University of Oxford, Department of Zoology

Ethno-ornithology World Atlas & Edward Grey Institute of Field Ornithology

Academic Supervisor: Professor Andrew Gosler

1. Introduction

1.1 Background

The Northern Spotted Owl is one of three subspecies of Spotted Owl in North America, along with the California Spotted Owl (*S.o. occidentalis*) and the Mexican Spotted Owl (*S.o. lucida*). Medium in size for an owl species, the Northern is the largest and darkest of the three and they are found from southern British Columbia to Marin County, California (U.S. Fish and Wildlife Service, 2011). These owls inhabit late-succession and old-growth forests with multilayered canopies dominated by Douglas-fir and a dense understory (Laymon, Salwasser, & Barrett, 1985). There are “four key structural components of old-growth: large live trees, large snags, large logs on land, and large logs in streams” (Franklin et al., 1981). Early-successional forests are characterized by “small coniferous trees, shrubs and herbaceous vegetation. Trees are generally less than 1 inch in diameter, and less than 15 feet tall, providing no greater than 30 percent canopy cover” (Public Utility District, 1988). Mid-successional forests have less than 70% canopy cover, the beginnings of a multi-layered canopy, and a shrub layer (U.S. Fish and Wildlife Service, 2014).

This project will be looking at the stress hormones of the Northern Spotted Owls through the non-invasive collection of fecal samples and assessing how a rural species adapts to human proximity. These samples will be assayed and compared throughout the extent of the owl’s range. Biologists in the field will be collecting the samples and

shipping them to the lab for processing. The information from this study will be used to examine the stress levels in owls in relation to their proximity to urban areas as well as land management type. This will aid in the understanding of how the owls are impacted by location.

Wasser (1997) demonstrated how stress levels of Northern Spotted Owl could be studied by using fecal hormone measures specific to the Spotted Owl. This study showed that the birds' stress increased with disturbance (Wasser, 1997). Hayward (2010) expanded on this to eliminate artificial effects during the process. The impacts of vehicles on stress levels in the owls, specifically faecal glucocorticoid metabolites (fGCs), addresses disturbance rather than nutrition (Hayward, 2011). The owls were less successful in terms of survival, stress levels, and fecundity the closer they were to road noise, indicating that human proximity has a negative effect on them (Hayward, 2011). In contrast, a study on the California Spotted Owl found that low-intensity chainsaw noise did not have an impact on the owl's stress levels, but these owls lived near roads and were likely habituated to humans (Tempel & Gutiérrez, 2003).

1.2 Objectives

- Creating a large dataset of samples from many different land management types.
- Map locations of samples collected.
- Assay all samples to look at stress levels by area.

2. Methodology

2.1 Materials

All materials will be provided by the Lead Investigator prior to each survey season and mid-season depending on need.

2.1.1 Fecal Sample Collection

- SKS ¼ oz Polypropylene Collection Jars with screw-top lids
- Information stickers for jars
- Latex or Nitrile gloves

2.2 Study Timeline

Wild population sample collection will begin in March and end in August in both 2021 and 2022. All samples will be shipped to the lab by the end of the season in September to be assayed.

2.3 Sample Collection

2.3.1. Wild Populations

Owls located in the wild will either have samples collected opportunistically or near known activity centers or nests as long as ID is confirmed. Samples will need to be confirmed to be from northern spotted owls and collected using the SKS collection jars. Stickers will be applied to the jars with the following information; the time, date, age and sex of the owl, GPS coordinates, initials of the person collecting the sample, and band number if possible. Samples will be transferred on the same day to a freezer. Multiple samples from the same site can be collected as long as they are fresh. There is no necessary wait time between days of collection, samples can be collected each day if found.

Step -by-Step:

1. Locate owls
2. Confirm ID for Northern Spotted Owl
3. Monitor for fresh defecation
4. Fill out information sticker on a jar
5. Collect fecal sample (if possible, separate urates from fecal)
6. Mark GPS waypoint
7. Once back at base, transfer jar to freezer
8. Fill out Habitat Metrics Form
9. Samples will either be collected by a courier or shipped to the lab, always staying in a freezer/cooler during transit.

2.4 Sample Storage

Samples need to be stored in a freezer of at least -20 degrees as soon as possible and kept there until they are transported to the lab. Depending on location, samples will be collected daily, weekly, or monthly and sent to the lab. They will be kept in a secure freezer and assayed in September.

2.5 Habitat Metrics Form

Fecal Sample Collection and Stress Hormone Analysis for the Northern Spotted Owl

Habitat Metrics Form

Collection Jar Sticker Information

Number of Owls Seen _____

Time: _____

Date: _____

Age: _____

Sex: _____

GPS: (x) _____ (y) _____

Band ID: _____

Initials: _____

Fecal Collection

Opportunistic

Nest

Activity Center

Opportunistic – collections anywhere other than nest/activity center. (i.e. along a trail)

Habitat

Canopy Cover

0-25%

26-50%

51-75%

76-100%

Tree Species Prevalence

CN

BL

MX

LS

MS

ES

CN – Conifer / **BL** – Broadleaf / **MX** – Mixed / **LS** – Late Successional (old-growth) / **MS** – Mid Successional (mature) / **ES** – Early Successional (young)

Land Management Type	State	Federal	Private	First Nation
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Name of Location: _____

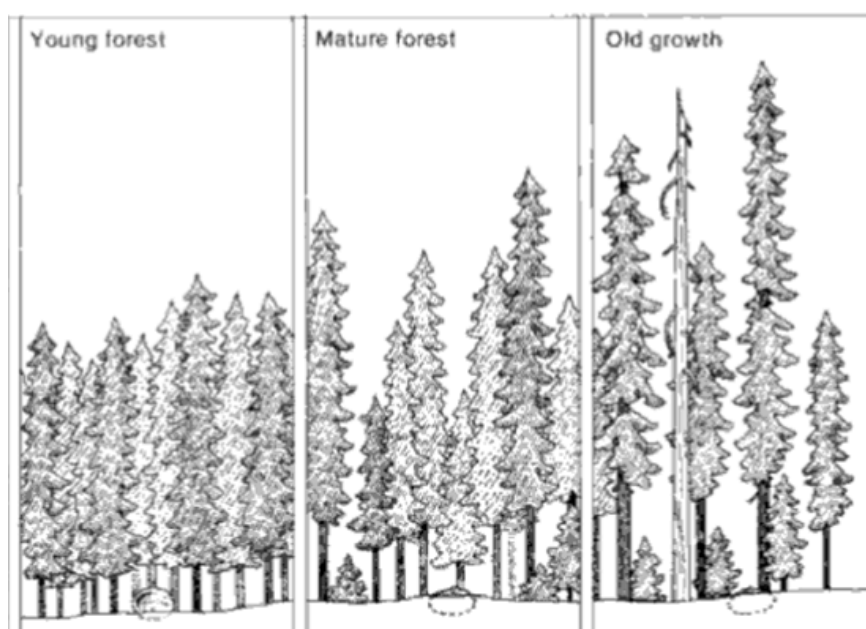


Figure 1. Visual description for stages of succession in forests (Maser, Anderson, Cromack, Williams, & Martin, 1979).

3. References

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Appendix D

Table 3.4: One-Way ANOVA test statistics for CORT levels in respect of each environmental stressor variable in order of closest to achieving the significance value of 0.05, with only Area and Land Management Type being statistically significant.

Variables	P-values	F-value	Degrees of Freedom
<u>Wildfire Distance - Same Year in/out 10km</u>	<u>0.03</u>	<u>5.08</u>	<u>1</u>
<u>Area</u>	<u>0.033</u>	<u>4.88</u>	<u>1</u>
<u>Land Management Type</u>	<u>0.038</u>	<u>3.12</u>	<u>3</u>
Year	0.16	2.05	1
Age	0.183	1.51	11
Canopy Cover	0.241	1.48	2
Owls Seen Together	0.302	1.26	3
Tree Prevalence	0.311	1.24	4
Elevation Above/Below 300m	0.041	4.49	1
Month	0.478	0.94	6
Urban Proximity	0.519	0.95	13
Nest or AC	0.620	0.25	1
Sex	0.666	0.41	2
Time	0.717	0.76	36
Wildfire Distance - Prior Year in/out 10km	0.722	0.13	1
Precipitation	0.821	0.66	26
Terrain Type	0.887	0.34	5
Road Proximity	0.915	0.54	23
PM 2.5 Daily Averages	0.92	0.51	29
Mean Temperature	0.962	0.41	31

Appendix E

Table 3.6: Model selection results based on AIC (Akaike Information Criterion), including delta AIC and weights, generated from global model selection using R.

Model #	Intercept	Elevation	Month	Nest / AC	PM 2.5	Precipitation	Road Distance	Temp	Terrain	Wildfire Distance Prior Year	Wildfire Distance Same Year	Owls	Year	df	logLik	AIC	delta	weight
2562	263.7308	0.238613	NA	NA	NA	NA	NA	NA	NA	NA	-0.20434	NA	-0.12962	5	1.558283	8.64814	0	0.047764
514	1.779658	0.216769	NA	NA	NA	NA	NA	NA	NA	NA	-0.23051	NA	NA	4	0.176806	8.789246	0.141106	0.04451
522	1.934761	0.218296	NA	NA	-0.00363	NA	NA	NA	NA	NA	-0.26976	NA	NA	5	0.896075	9.972557	1.324417	0.024632
2570	253.6553	0.239171	NA	NA	-0.00335	NA	NA	NA	NA	NA	-0.24159	NA	-0.12456	6	2.211993	10.12147	1.473328	0.022865

770	1.581854	0.233312	NA	NA	NA	NA	NA	NA	NA	0.098985	-0.23294	NA	NA	5	0.701305	10.3621	1.713957	0.020273
518	1.819463	0.251772	NA	-0.06631	NA	NA	NA	NA	NA	NA	-0.22857	NA	NA	5	0.437089	10.89053	2.242388	0.015566
1538	1.844748	0.225698	NA	NA	NA	NA	NA	NA	NA	NA	-0.24331	-0.02534	NA	5	0.412696	10.93931	2.291174	0.015191
3586	260.4848	0.24658	NA	NA	NA	NA	NA	NA	NA	NA	-0.21648	-0.02339	-0.12798	6	1.773352	10.99875	2.350612	0.014746
578	2.038945	0.218231	NA	NA	NA	NA	NA	-0.0037	NA	NA	-0.24955	NA	NA	5	0.352315	11.06008	2.411937	0.014301

Appendix F

Table 3.9: Summary of previous research discussing impacts to CORT, findings of No Impact, and additional comments to guide CORT research methodology and possible pitfalls/shortcomings to this type of work.

Authors	Sample Size	Possible Impacts to CORT	Findings of No Impact	Comments
Tempel & Gutierrez (2003)	9 non-breeding males	Owls near roads may be habituated	Chainsaw noise did not explain any variations in data	Acute stress responses must be extremely large to be detected
		4 large increases had unknown causes	No effect of time of day on CORT	
		Fluctuations occurred near same rate after treatment	SPOW can tolerate low intensity anthropogenic disturbance without response	
Hayward et al. (2010)	9 males from 2006 and 9 from 2008	Quantity of food intake, rate of defecation and metabolism and other factors may affect fecal hormone metabolite concentrations		
		Disturbance, temperature, diet, and other environmental factors should be controlled		
Wasser, et al. (2000)	1 female	Elevations in fecal glucocorticoids may reasonably be regarded as indicative of the physiological stress response		

		Fecal GC assays have been found to have predictive and explanatory value, consistently showing elevations in adrenal activity after times of presumed physiological or psychosocial stress, such as translocation to unfamiliar environments		
Tarlow & Blumstein (2007)	x	breeding success (clutch size, hatching success, and fledging success), fluctuating asymmetry—FA, flight initiation distance—FID (can change with humans feeding SPOWS), glucocorticoids (Glucocorticoids are naturally secreted to allow individuals to mobilize energy reserves in order to adaptively cope with adverse conditions), mate choice, immunocompetence, and cardiac response		A short-term stress response can suppress reproductive or territorial behavior
		Chronic environmental stressors, however, may lead to non-adaptive levels of glucocorticoid secretion, which can cause deleterious effects for the animal, which may include reproductive inhibition, immune system suppression, neuronal death, and impaired cognitive function		Chronic levels of stress, therefore, can lead to reproductive failure and premature death
		Heart rate is a measure of the stress response and may predict potential chronic stress,		Chronic stress can be caused by the inability of an animal to habituate to human disturbance

		Disturbance can affect males' ability to have enough energy to allocate to growing, colouration, and displays		steroid hormones, which aid in the development of secondary sexual characteristics, are produced at an expense of immune function
		immunocompetence is influenced by stress and some immune responses are apparently energetically costly for the animal		
Ashlee Mikkelsen (2021)	1,295 juveniles	CORT is related to forest stand age, urbanization, and territory quality		
		Quality and investment of parents affect CORT		
		Older parents are more successful at fledging young and have lower CORT		
		Differences in forest structure, annual variation in temperature and precipitation (which may affect food availability), and weather events may affect CORT		
		High temperature later in season increases CORT		
		Responses to stressors are genetically heritable		
		Those under stress can increase CORT in others around them		
MacDougall-Shackleton et al. (2019)	x			Glucocorticoids are not stress hormones, they have many other functions
				Stress cannot be measured with only one hormone

Dickens & Romero (2013)	x	Body weight is best indicator of endocrine function	Studies that show a decrease or no change in CORT to stressors are underrepresented in publication	Studies that assume that increases in stress-induced GC will indicate that a specific stimulus (such as anthropogenic disturbance in the wild) is, in fact, serving as a chronic stressor may be flawed.
		Food availability, predators, social interactions, and population density all affect CORT levels		The standard assumption that stress-induced GC will increase with chronic stress is simply not supported by the literature.
		Many studies only include males, which skews understanding of the whole species		administering exogenous GC is not a suitable surrogate for exposure to a natural chronic stressor.
		Chronic stress has been shown to specifically increase or decrease the trough or nadir of the circadian rhythm and deregulate the pulsing of the ultradian rhythm. Reported differences in baseline GC responses may, to some degree, reflect an inability to capture this effect		Two types of chronic stress: chronic continuous stress and chronic intermittent stress, presented as either homotypic (multiple exposures to the same stressor) or heterotypic (multiple exposures to different stressors)
		The strongest case for a consensus endocrine response comes from exposure to chronic social stress. Animals exposed to chronic social stress appear to consistently decrease body weight, increase baseline GC, and maintain elevated GC, even though HPA sensitivity does not appear to change		The consensus response for stress-induced GC, however, is far too variable to make any conclusions
				Too low a response might be insufficient to successfully cope with a stressor, whereas too large a response will endanger long-term health

Wasser et al. (1997)	1 captive & 18 wild	Fecal corticosterone levels were significantly higher in adult male versus female owls in the wild	No effect of observer presence on fecal corticosterone levels was found.	Fecal corticosterone levels from ACTH challenges paralleled that expected in blood
		Effects of proximity of forest management activity to the centre of the owl's home range	No effect of season on males	Rapid and significant increase in CORT within 2 hours and 12 hours and returned to normal by 26 hours from ACTH challenge
		Significant differences were found between males centred within versus beyond 0.41 km from a major logging road or recent (10 years to present) timber activity		ACTH challenge results demonstrate that the corticosterone metabolites we are measuring in feces accurately reflect the adrenal stress response
		Higher CORT in males (not females) in Wenatchee National Forest than in the Yakima Indian Reservation		Our fecal corticosterone measure provides a reliable index of physiological stress in the Northern Spotted Owl.
		Mean CORT more than doubled during the fledgling season (June-July), but went back down by August		Survey season interrupted by fires in July and August
		Significant effect of season was found for females regardless of their nesting behavior		
		Home range disturbances increased CORT in males more and offspring survival factors increased female CORT		
Millsbaugh & Washburn (2004)	x	sex, age, reproductive status, daily and seasonal rhythms, effects of captivity, diet, and excretion route		FGM measures may be affected by sampling issues and assay artifacts such as sample age, time of day the sample was obtained and short- and long-term storage techniques

		normal daily and seasonal changes in CORT, reproductive status, sex, body condition, and the animal's diet		The lack of available seasonal basal FGM values also has been inhibitive. That is, without knowledge of 'normal' values, it becomes difficult to assess whether FGM levels are elevated.
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Appendix G

Table 4.1: A comparison of the Required Elements dictated by Congress for each state to include in their State Wildlife Action Plans.

Congress	AFWA	WA	OR	CA
Required Elements	The Eight Required Elements	8 Essential Elements	USFWS Required Eight Elements	Required SWAP Elements
(A) use such information on the distribution and abundance of species of wildlife as is indicative of the diversity and health of the wildlife of the State, including such information on species with low populations and declining numbers of individuals as the State fish and game department determines to be appropriate	(1) Information on the distribution and abundance of species of wildlife, including low and declining populations as the State fish and wildlife agency deems appropriate, that are indicative of the diversity and health of the State's wildlife	Element 1 Identify the distribution, abundance and status of species of greatest conservation need	1. Gather information on the distribution and abundance of fish and wildlife species.	Element 1: Species Distribution and Abundance. The distribution and abundance of species of wildlife, including low and declining populations, as each state fish and wildlife agency deems appropriate, that are indicative of the diversity and health of wildlife of the state. (In subsequent discussions, these species are referred to as Species of Greatest Conservation Need or SGCN.)
(B) identify the extent and condition of wildlife habitats and community types essential to conservation of the species of wildlife of the State identified using information described in subparagraph (A)	(2) Descriptions of locations and relative condition of key habitats and community types essential to conservation of species identified in (1)	Element 2 Identify condition of key habitat types essential to the conservation of SGCN	2. Describe location and relative condition of key habitats and community types essential to conservation of these species.	Element 2: Key Habitats and Community Types. The location and relative condition of key habitats and community types essential to the conservation of each state's SGCN.

(C) identify the problems that may adversely affect— “(I) the species identified using information described in subparagraph (A); and “(II) the habitats of the species identified under subparagraph (B); and “(ii) provide for high priority research and surveys to identify factors that may assist in the restoration and more effective conservation of— “(I) the species identified using information described in subparagraph (A); and “(II) the habitats of the species identified under subparagraph (B)	(3) Descriptions of problems which may adversely affect species identified in (1) or their habitats, and priority research and survey efforts needed to identify factors which may assist in restoration and improved conservation of these species and habitats	Element 3 Identify problems and threats that affect SGCN and their habitats	3. Describe problems which may adversely affect these species or their habitats. Identify information needed to improve conservation of species and habitats.	Element 3: Problems and Research/Survey Priorities. The problems that may adversely affect SGCN or their habitats, and priority research and surveys needed to identify factors that may assist in restoration and improved conservation of SGCN and their habitats.
(D) describe which actions should be taken to conserve—“(I) the species identified using information described in subparagraph (A); and“(II) the habitats of the species identified under subparagraph (B); and “(ii) establish priorities for implementing those actions	(4) Descriptions of conservation actions proposed to conserve the identified species and habitats and priorities for implementing such actions	Element 4 Determine and prioritize actions to conserve SGCN and their habitats	4. Describe necessary conservation actions for species and habitats.	Element 4: Conservation Actions and Priorities. The actions necessary to conserve SGCN and their habitats and establish priorities for implementing such conservation actions.

(E) provide for—“(i) periodic monitoring of—“(I) the species identified using information described in subparagraph (A); “(II) the habitats of the species identified under subparagraph (B); and “(III) the effectiveness of the conservation actions described under subparagraph (D); and “(ii) adaptation of conservation actions as appropriate to respond to new information or changing conditions.	(5) Proposed plans for monitoring species identified in (1) and their habitats, for monitoring the effectiveness of the conservation actions proposed in (4), and for adapting these conservation actions to respond appropriately to new information or changing conditions	Element 5 Provide for periodic monitoring and adaptive management of SGCN and their habitats	5. Propose ways to monitor the effectiveness of these conservation actions and ways to adapt actions as information or conditions change.	Element 5: Monitoring and Adaptive Management. The provisions for periodic monitoring of SGCN and their habitats, for monitoring the effectiveness of conservation actions, and for adapting conservation actions, as appropriate, to respond to new information or changing conditions.
(4) REVIEW AND REVISION.—Not less often than once every 10 years, a State shall review the wildlife conservation strategy of the State and make any appropriate revisions.	(6) Descriptions of procedures to review the plan at intervals not to exceed ten years	Element 6 Provide for review and revision of the State Wildlife Action Plan	6. Describe procedures to review the Strategy at regular intervals (not to exceed 10 years).	Element 6: SWAP Review and Update Procedures. Each state’s provisions to review its strategy at intervals not to exceed 10 years.

(5) COORDINATION. —During the development, implementation, review, and revision of the wildlife conservation strategy of the State, a State shall provide for coordination, to the maximum extent practicable, between— “(A) the State fish and game department; and Federal, State, and local agencies and Indian tribes that— “(i) manage significant areas of land or water within the State; or “(ii) administer programs that significantly affect the conservation of “(I) the species identified using information described in paragraph (2)(A); or “(II) the habitats of the species identified under paragraph (2)(B).	(7) Plans for coordinating the development, implementation, review, and revision of the plan with Federal, State, and local agencies and Indian tribes that manage significant land and water areas within the State or administer programs that significantly affect the conservation of identified species and habitats.	Element 7 Coordinate development and revision with appropriate federal, state, local agencies and tribes	7. Coordinate with federal, state, and local agencies and tribes that manage significant land and water areas or administer significant programs that affect species and habitat conservation.	Element 7: Coordination with Conservation Partners. Each state’s provisions for coordination during the development, implementation, review, and revision of its strategy with federal, state, and local agencies and Indian Tribes that manage significant areas of land or water within the state, or administer programs that significantly affect the conservation of species or their habitats.
(3) PUBLIC PARTICIPATION IN DEVELOPMENT OF STRATEGY.—A State shall provide an opportunity for public participation in the development and implementation of the wildlife conservation strategy of the State.	(8) Congress also affirmed through this legislation, that broad public participation is an essential element of developing and implementing these plans, the projects that are carried out while these plans are developed, and the Species in Greatest Need of	Element 8 Provide for necessary public involvement in the development, revision, and implementation of the SWAP	8. Engage the public in planning and implementing the Strategy.	Element 8: Public Participation Strategies. Each state’s provisions to provide the necessary public participation in the development, revision, and implementation of its strategy.

	Conservation that Congress has indicated such programs and projects are intended to emphasize.			
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Appendix H

Table 4.2: Spotted owl references from the California SWAP by theme.

California	
Ecological	Anthropogenic Impacts
Some inhabitants of coastal redwood forests include black bear, Roosevelt elk, Wilson's warbler, pacific-slope flycatcher, pacific wren, varied thrush, Northern Spotted Owl, marbled murrelet, Pacific giant salamander, rough-skinned newt, and banana slug.	The Pacific fisher and Northern Spotted Owl have been found to be impacted by rodenticide by either direct ingestion or bioaccumulation (toxins accumulate in the body from feeding on contaminated prey).

Wildlife inhabitants include such sensitive species as the Northern Spotted Owl, Northern goshawk, Humboldt marten, and Pacific fisher, as well as common species like mule deer, black bear, and red-tailed hawk.	Forest roads can introduce invasive plant and animal species (Lindenmayer and Franklin 2002), and some species, like the varied thrush, Northern Spotted Owl, Northern goshawk, and Pacific fisher can tolerate a mosaic of habitat types for foraging, but species such as the Spotted Owl, prefer nesting or resting sites that include a core area with unfragmented interior forest characteristics (Gonzales 2006).
Northern Spotted Owl* <i>Strix occidentalis caurina</i>	
The change in forest understory and increased grass cover may change small mammal assemblages and could reduce the quality of foraging habitat for sensitive species such as the Northern Spotted Owl.	
Golden eagle, prairie falcon, cascade frog, southern long-toed salamander, Northern goshawk, Northern Spotted Owl, sooty grouse, greater sandhill crane, and American white pelican nest and hunt or forage in varied habitats in the province.	
Species of Greatest Conservation Need (SGCN) include the Northern Spotted Owl, Sierra Nevada red fox, pacific fisher, American marten, American badger, and coastal tailed frog.	
Northern Spotted Owl* <i>Strix occidentalis</i>	
Northern Spotted Owl* <i>Strix occidentalis</i>	
Northern Spotted Owl* <i>Strix occidentalis</i>	

Table 4.3: Spotted owl references from the Oregon SWAP by theme.

Oregon	
Ecological	Governance
These LSRs address the habitat needs of late-successional and old-growth forest-related species, such as the Northern Spotted Owl or Marbled Murrelet.	Other NW CSC-funded research has focused on the effects of climate change on habitats of bull trout, Northern Spotted Owl, and Greater Sage-Grouse, all of which are Oregon Strategy Species.

Northern Spotted Owl (<i>Strix occidentalis caurina</i>)	Although focused on the Northern Spotted Owl, the plan was intended to address the needs of a wide array of species affected by loss and fragmentation of late-successional forests, and covers more than 1,000 species of plants, animals, and fungi
Northern Spotted Owl (<i>Strix occidentalis caurina</i>)	The focus of the Healthy Forest Reserve Program (HFRP) is to encourage landowners to manage their land for sustainable, profitable timber harvests while promoting forest conditions that improve habitat for the threatened Northern Spotted Owl. Participating landowners will receive long-term assurances that no additional regulatory restrictions under the Endangered Species Act will be imposed beyond the current, baseline conditions if they follow a plan that benefits Northern Spotted Owls
Northern Spotted Owl (<i>Strix occidentalis caurina</i>)	The intent of the NWFP is to adopt coordinated management direction for the lands administered by the USFS and the BLM, and to adopt complementary approaches by other federal agencies within the range of the Northern Spotted Owl.
Northern Spotted Owl (<i>Strix occidentalis caurina</i>)	Although focused on the Spotted Owl, the plan was intended to address the needs of a wide array of species affected by loss and fragmentation of late successional forests, and it covers over 1,000 species of plants, animals, and fungi
Northern Spotted Owl (<i>Strix occidentalis caurina</i>)	
Depending on the ecoregion, Strategy Species associated with late successional conifer forests include ringtail, fisher, American marten, red tree vole, Marbled Murrelet, Northern Spotted Owl, Oregon slender salamander, and many others.	
Northern Spotted Owl	

Table 4.4: Spotted owl references from the Washington SWAP by theme.

Washington	
Ecological	Governance

A few areas of focus have been the Mountain View project in the Blue Mountains to secure 13,000 acres of ponderosa pine and riparian habitat along the 10 miles of the Grande Ronde River that benefits high quality low-elevation riparian curl-leaf mountain mahogany, interior grasslands, talus, cliff, ponderosa pine and meadows as well as 15 aquatic species, steelhead, bull trout, elk, bighorn sheep, deer, golden eagle, northern goshawk, sagebrush lizard and interior redband trout; the Heart of the Cascades project in Kittitas County to consolidate checkerboard ponderosa pine, Douglas-fir mixed-pine conifer and riparian habitats for Spotted Owl, bull trout, wolverine, large carnivores, deer and elk; and the Methow River and Okanogan River Watersheds projects which has preserved tens of thousands of acres of riparian and low elevation shrub-steppe habitats that support salmon, sharp-tailed grouse, critical winter range for mule deer and connectivity for mule deer and large carnivores (gray wolf, grizzly bear, Canada lynx, and wolverine) through both outright purchase and conservation easements that allow for on-going continued ranching while ensuring the continued habitat value.	Federal forest lands within the range of the northern spotted owl are regulated by the Northwest Forest Plan (NWFP), adopted by the federal government in 1994 to provide for maintenance and restoration of functional, healthy and interconnected late-successional forest ecosystems, alongside sustainable and predictable supplies of timber and other forest products
Other SGCN include Steelhead, Northern Spotted Owl, and Bald Eagle.	Since the federal listing of the northern spotted owl as a Threatened species in 1990 and the passage of the Northwest Forest Plan in 1994, there have been a number of proactive efforts and agreements among public agencies, Indian tribes, conservation groups and forest landowners.
Some species have fairly large distributions; an example is the Northern Spotted Owl which is found on both slopes of the Cascade Range and the Olympic Peninsula, but which is now essentially extirpated from southwestern Washington and the Puget Trough.	NORTHERN SPOTTED OWL (<i>Strix occidentalis caurina</i>) 62
Species evaluated with moderate-high or high vulnerability (but varying levels of confidence) included: Barrow's Goldeneye, Harlequin Duck, Greater Sage Grouse, Northern Spotted Owl, Sage Thrasher, Sagebrush Sparrow, Red Knot, Spruce Grouse, Surf Scoter, Western Snowy Plover, and White-tailed Ptarmigan.	Northern Spotted Owl..... 64
25. Northern Spotted Owl	Northern Spotted Owl 44
Northern Spotted Owl, Threatened, Endangered, Yes, Low/Declining, High, Impacts from habitat loss are now exacerbated by effects of competition with Barred Owls for prey and habitat. As the population declines and becomes even smaller, other threat factors may become more relevant.	

For example, Spotted Owls are closely associated with a specific habitat within forests with complex structure (e.g. mature and old-growth forest), but are only generally associated with multiple ecological systems within their range.	
The SGCN that have an affinity for more complex conditions are Barrow's Goldeneye, Great Gray Owl, Lewis' Woodpecker, Northern Spotted Owl, Western Bluebird, Keen's Myotis, and Silver-haired Bat	
The SGCN that have an affinity for these conditions are Cascade Torrent Salamander, Bald Eagle, Barrow's Goldeneye, Great Gray Owl, Northern Spotted Owl, Keen's Myotis, and Western Gray Squirrel.	
Examples: Northern Spotted Owl nesting, roosting, and foraging habitat; Bald Eagle nesting and roosting habitat.	
Vertical structure and structure on the forest floor provide area for foraging wildlife such as woodpeckers and habitat for Northern Flying Squirrels, an important prey species for Northern Spotted Owl.	
BIRDS: Bald Eagle, Golden Eagle, Harlequin Duck, Marbled Murrelet, Northern Spotted Owl, Peregrine Falcon, Western Bluebird, Western Screech Owl	
BIRDS: Bald Eagle, Golden Eagle, Harlequin Duck, Marbled Murrelet, Northern Spotted Owl, Peregrine Falcon, Western Bluebird, Western Screech Owl	
BIRDS: Bald Eagle, Flammulated Owl*, Golden Eagle, Harlequin Duck, Lewis' Woodpecker, Mountain Quail*, Northern Spotted Owl, Peregrine Falcon, Pygmy Nuthatch*, White-headed Woodpecker*	
Species evaluated with moderate-high or high vulnerability but low or moderate confidence included Barrow's Goldeneye, Harlequin Duck, Greater Sage-grouse, Northern Spotted owl, Red Knot, Sage Thrasher, Sagebrush Sparrow, Surf Scoter, and Western Snowy Plover.	

NORTHERN SPOTTED OWL (<i>Strix occidentalis caurina</i>) Conservation Status and Concern Impacts from habitat loss of mature forest are now exacerbated by effects of competition with Barred Owls for prey and habitat. As the population declines and becomes even smaller, other threat factors may become more relevant. Federal Status State Status PHS Threatened Endangered Yes Global Ranking G3T3 State Ranking S1 Population size/trend Low/declining Climate Vulnerability High Biology and Life History The Northern Spotted Owl is relatively long-lived, has a long reproductive life span, invests significantly in parental care, and exhibits high adult survivorship. The majority of pairs do not breed every year. Courtship usually begins in February or March, and females typically lay eggs in late March or April. Northern Spotted Owls have large home ranges and in those areas use a number of prey species, chief among them the Northern Flying Squirrel, but also Bushy-tailed Woodrats, Snowshoe Hares and other small mammals. Spotted Owls are at a competitive disadvantage to the more generalist Barred Owl which has expanded its range to now include the entire distribution of the Northern Spotted Owl.	
Distribution and Abundance Formerly a widespread and uncommon resident of coniferous forests in western Washington and the east slope of the Cascade Range, the Northern Spotted Owl is now rare throughout Washington. It has been very rare in southwestern Washington for several decades and no longer breeds in the Puget Lowlands. The population of Northern Spotted Owls in Washington continues to decline, and some landscapes where long-term monitoring has been conducted now support several or fewer pairs. About 1,200 territories have been documented in Washington; trend data suggest that perhaps 25 percent or less of these remain occupied. Habitat The Northern Spotted Owl inhabits mid- and late-seral coniferous forests. Typical habitat characteristics include: generally high canopy closure; complex canopy structure involving trees of multiple age or size classes; large decaying trees and/or snags; and, in most forest areas, a high volume of downed wood. The presence of mistletoe infection is important in the eastern Cascade Range. The species occurs up to about 5,000 feet in elevation.	

Northern Spotted Owl ModerateHigh Moderate Moderate -High Westside: Moderate East-side: Moderate -High > Increased temperatures > Altered fire regimes > Increased insect outbreaks This species exhibits some sensitivity to increased temperatures both directly (i.e. physiologically) and indirectly through effects on prey availability. This species also exhibits some sensitivity to altered disturbance regimes (i.e. fire and insect outbreaks) that lead to habitat changes. For example, in the eastern Cascades in Oregon, high severity wildfire has reduced the number of Northern Spotted Owls pairs in a USFS Ranger Unit. However, it appears that dense old forests may be relatively stable on the west side of the Cascades, while more active management may help address fire risk in dry east-side forests.	
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Appendix I

Table 4.7: A comparison summary of the U.S. and Canadian Spotted Owl recovery plans.

U.S.		Canada	
Overall Goals	To improve the status of the species so it can be removed from protection under the ESA	To recover the Spotted Owl in Canada by restoring a stable population of at least 250 mature individuals distributed within a connected network of habitat representative of all three sub-regions within the species' historical Canadian range, and linked to the larger population in the U.S.A.	
Objectives	1. Spotted owl populations are sufficiently large and distributed such that the species no longer requires listing under the ESA	1. Maintain sufficient critical habitat needed to achieve the population and distribution objective and immediately cease human-caused threats where Spotted Owls are detected	
	2. Adequate habitat is available for Spotted Owls and will continue to exist to allow the species to persist without the protection of the ESA	2. Re-introduce at least 50 captive-bred Spotted Owls to the wild within 10 years (by 2033), with at least 10 released individuals surviving to become resident adults.	
	3. The effects of threats have been reduced or eliminated such that Spotted Owl populations are stable or increasing and Spotted Owls are unlikely to become threatened again in the foreseeable future.	3. Complete annual Barred Owl surveillance at sites occupied by Spotted Owl and/or where reintroductions are planned, and remove all Barred Owls that are detected.	
Criteria	1. Stable Population Trend	1. Survival characteristics: Can survival characteristics be addressed to the extent that the species is no longer at significantly greater risk of extinction or extirpation as a result of human activity?	

	2. Adequate Population Distribution	2. Independence: Is the species currently able to persist in Canada independent of deliberate human interventions, and/or will it eventually be able to achieve and maintain independence in the state where condition (1) is met, such that it is not reliant on significant, direct, ongoing human intervention?	
	3. Continued Maintenance and Recruitment of Spotted Owl Habitat	3. Improvement: Can the species' condition be improved over when it was assessed as at risk?	
	4. Post-delisting Monitoring		
Strategy	1. Completion of a rangewide habitat modelling tool	Habitat protection, enhancement and stewardship; Active population management; Research, inventory, monitoring, and population evaluation;	
	2. Habitat conservation and active forest restoration		
	3. Barred owl management		
	4. Research and monitoring		
	5. Adaptive Management		
Monitoring	Population trends through a network of demographic study areas	1990s-2008: inventories on the range, distribution, and abundance of NSO	2015: inventory/monitoring efforts became focused on revisiting previously-known Spotted Owl sites to assess re-occupancy, as well as inventory of sites identified for potential re-introduction through release of captive-bred owls
	Barred owl monitoring	1998: banding program to identify individuals and monitor their movements and habitat occupancy.	2016: a pilot program was launched to assess the utility of Autonomous Recording Units
	inventory of NSO distribution	1998-199 Three: transmitters on breeding pairs to monitor habitat use/ home range sizes.	GPS monitoring of released captive-born owls can be used to determine habitat requirements and test habitat models.

	habitat monitoring	2003-2014: juvenile owls were affixed with transmitters.	
Recovery Actions	33	Improved Spotted Owl Management Plan (SOMP2)	Removal of Barred Owls from priority habitats.
	Categories include Northern Spotted Owl Recovery Implementation Oversight, Monitoring and Inventory, Climate Change and Forest Ecosystems, Spotted Owls and Ecological Forestry, Habitat Management in Moist Forests, Habitat Management in Dry Forests, Conserving Occupied and High-Value Spotted Owl Habitat, Post-fire Logging, State and Private Lands, Diseases, Predation, Barred Owl, and Post-delisting Monitoring	Captive Breeding and Release 2303 Program,	
Timeline	30 years to delist	60 years to Identify and protect core critical habitat	
	10 years for stable or increasing populations		
Threats	Loss of amount and distribution of Spotted Owl habitat due to past activities and disturbances.	Problematic native species	fire and fire suppression
	Competition with barred owls	logging and wood harvesting	
	ongoing loss of Spotted Owl habitat as a result of timber harvest	roads and railroads	
	habitat loss or degradation from stand-replacing wildfires and other disturbances,	utility and service lines	
SPOW Population Decline	2.9% per year (1985-2006)	99% decline from historical levels	
	60-80% decline from historical levels	Three wild owls left	
NSO Critical Habitat Guidelines	1. Conserve Spotted Owl sites and high-value Spotted Owl habitats where possible in addition to Federal conservation blocks to provide additional	1. Priority for habitat protection should be based on an area's history of occupancy	6. Where practicable, maximise the amount of Type A habitat in territories

	demographic support to the Spotted Owl population		
	2. Maintain and restore the older and more structurally complex multilayered conifer forests on all lands	2. Cluster territories and maintain/enhance connectivity.	7. Consider ongoing updating, enhancing and testing of the habitat model
	Use of habitat modelling to better identify high-value habitat, including consideration of abiotic factors that influence Spotted Owl usage.	3. Consider using the existing SOMP mean territory size of 3200 ha throughout the species range in British Columbia as a minimum default standard until a new range-wide habitat management plan has been developed	
	Use of demographic monitoring and survey data to inform other measures of value, such as maintaining population distribution in underrepresented areas or reflecting the most current habitat conditions. How retention of specific areas may affect probability of persistence of the Spotted Owl population at the province scale. Use this evaluation to establish “thresholds” for recommendations of which areas to conserve or not.	4. Consider continuing to protect 67% suitable habitat within territories as the minimum default standard throughout the species’ range in British Columbia until a new range-wide habitat management plan has been developed	
	Prioritise known and historic Spotted Owl sites for conservation and/or maintenance of existing levels of habitat. The prioritisation factors to consider are reproductive status and site condition.	5. Where practicable, do not allow any further habitat removal from prescribed territories, except to assist in recruiting/restoring suitable habitat	
Critical Habitat	6.9 million acres total	310,490 of which 281,272 ha are identified by BC’s Suitable Habitat model as nesting, foraging and recruitment habitat.	
Area	1.4 million acres in California	49,257 ha of suitable and recruitment Spotted Owl habitat were established as Wildlife Habitat Areas -	

		Managed Future Habitat Areas (open to logging), but only 24,994 ha is nesting and foraging habitat.	
	3.3 million acres in Oregon		
	2.2 million acres in Washington		
Target Population	Enough to allow for stable populations in each demography area	250	
Owl Home Range Medians	1196 (Oregon)	1907 ha (Continental)	2224 ha (Sub-maritime)
	5751 (Washington) ha	3010 ha (Maritime)	
Cost Estimates	Over 30 years = 127.1 million	No mention	

Appendix J

Table 4.11: Table of the governance hierarchy that oversees and manages the northern spotted owl.

WA	DNR	7 Regional offices	
		Forest Practices Board	NSO Policy Working Group
			NSO Implementation Team
			NSO Conservation Advisory Group
	FWS	6 regional offices	
CA	CA Forest Practice Rules	CA Board of Forestry and Fire Protection	
	Dept of Fish and Wildlife	NSO Interagency Working Group	
OR	Interagency Oregon Endangered Species Task Force		
	Department of Forestry	Barred Owl Coordination Group	
OR/WA	Interagency Wildlife Committee	Spotted Owl Subcommittee	
BC	Forest Practices Board		
	Government	Canadian Spotted Owl Recovery Team	
		NSO Captive Breeding Program	
National Audubon Society	Spotted Owl Scientific Advisory Group		
Northwest Forest Plan	Interagency Steering Committee	Regional Interagency Ecosystem Committee	Research and Monitoring Committee
			Regional Community Economic Revitalization
			Senior Managers Group
			Regional Ecosystem Office
			Late Successional Reserve Work Group

			Provincial Interagency Executive Committee
Federal	USFWS		
	BLM		
	FS		
	EPA		
	NPS		
	USDA National Wildlife Research Center		

Appendix K

Table 4.15: Summary of publicly available management documents from tribal websites with specific mention of northern spotted owls.

Tribe	Plan	Spotted Owl Reference
Quinault Indian Nation	Forest Management Plan (BIA Taholah Agency 2017)	Helicopter Flight Restrictions Protections for Marbled Murrelets and northern spotted owls are limited to restricting helicopter flights below 500' over the conservation easements during the nesting season (March 1 through September 30).
		Historic data are available for marbled murrelet and northern spotted owl.
		Three species listed under the ESA: the northern spotted owl, marbled murrelet and bull trout, are known to occur within the QIR, and are protected from impact from forest management activities within the Conservation Easement, located in the North Boundary Area of the QIR.
		(ii) Northern Spotted Owls. Northern Spotted Owls were ESA listed as threatened throughout their range in 1990. Threats include loss of habitat to timber harvest and increased competition by the barred owl. Spotted owls typically occur in closed-canopy, structurally complex, unevenaged, late-successional and old-growth forest. Forest stands as young as 50 years old may contain the habitat features necessary to support nesting owls (WDFW, 2012). Spotted owls eat a variety of small forest mammals, most importantly the northern flying squirrel on the Olympic Peninsula (Forsman et al, 2001). They require cavities in large, old-growth snags or tree platforms for nest sites and typically prefer riparian areas which provide thermal regulation in the summer. Territories of

		Spotted Owls are large, particularly on the Olympic Peninsula. Home range territories on the peninsula are estimated to average 2.7 miles around the nest site or approximately 23 square miles (Hanson et al. 1993). Spotted owls typically form long-term pairs for breeding and use the same territory year after year. One Spotted Owl territory historically occurred within the boundaries of the QIR, near the headwaters of Prairie Creek in the North Boundary Area (NBA). Six other Spotted Owl home range territories overlap the boundaries of the QIR. The nest sites for these territories occur within adjacent Olympic National Forest and Olympic National Park lands. Suitable nesting habitat for Northern Spotted Owls exists in the North Boundary Conservation Easements of the QIR. This habitat is in long-term conservation status and has not been surveyed for owls recently. Tribal crews surveyed the entire NBA for Spotted Owls, from 1991 through 1997, using protocols endorsed by the USFWS. From 1993 through 1997, tribal crews surveyed adjacent Olympic National Forest lands to the north of the NBA. Additionally, the U.S. Forest Service and non-governmental agency personnel surveyed lands adjacent to the QIR for Spotted Owls. The results of these surveys are documented in the Washington Department of Fish and Wildlife (WDFW) Spotted Owl database.
		Murrelets, as with northern spotted owls, primarily depend on old-growth forests for their inland habitat
		Federally Protected Wildlife Protections for marbled murrelets and northern spotted owls are limited to restricting helicopter flights below 500' over the conservation easements during the nesting season (March 1 through September 30).
Coquille Indian Tribe	Comprehensive Land-Use Plan	According to a US Fish and Wildlife Service database, there are potentially five non-marine

	(Coquille Indian Tribe 2019).	federally listed or proposed endangered species or threatened species that may occur in the Coos Bay area. Bird species include Marbled Murrelet, Western Snowy Plover, and Northern Spotted Owl.
Confederated Tribes of the Colville Reservation	Land Management Plan (Confederated Tribes of the Colville Reservation 2013)	Consultation with the U.S. Fish & Wildlife Service may also be necessary due to the presence of bull trout in the Columbia River DPS and the potential presence of other wildlife species such as the Canada lynx, gray wolf, grizzly bear and northern spotted owl.
		LISTED Bull trout (<i>Salvelinus confluentus</i>) – Columbia River DPS Canada lynx (<i>Lynx canadensis</i>) Gray wolf (<i>Canis lupus</i>) [west of U.S. 97 and State Highway 17] Grizzly bear (<i>Ursus arctos horribilis</i>) Northern Spotted Owl (<i>Strix occidentalis caurina</i>)
		DESIGNATED Critical habitat for the bull trout Critical habitat for the Canada lynx Critical habitat for the northern spotted owl
Karuk Tribe	Resources Management Plan (Karuk Tribe 2009)	For example, instead of locating Northern Spotted Owl nesting sites and limiting managerial activity within a quarter mile radius, or 70 acre nest core, these areas need to be identified and all correlating habitats and connectivity for the owl and its food base needs to be restored. The main concerns would be to ensure the nesting and roosting trees are not disturbed during project implementation or by high intensity fire, while accounting for other species and situations
		Reduce Fuel loading in and Adjacent to Degraded Spotted Owl Habitat This CEMP is intended to supplement and enhance potential inadequacies of other fuels reduction practices in the interest of recovering local Northern Spotted Owl populations. When completed in conjunction, or in addition to, other CEMP's, this practice should help to protect,

		enhance, restore and/or maintain nesting, roosting, foraging, dispersal, and fledgling survival for the Northern Spotted Owl. In areas selected for treatment of other CEMP's that overlap or are directly adjacent to Spotted Owl activity centres or vegetation characteristics indicate high potential for dispersal (contiguous fair to good habitat characteristics within 10 to 15.5 miles from occupied nesting sites), focused attention should be placed on initial treatments benefiting the Northern Spotted Owl. In practicing other CEMP's, many benefits to this species should be indirectly applicable. However, when re-establishing the potential for restoration of natural fire regimes in individual watersheds there may be a critical need to perform interior treatments in areas not indicated as a high priority by other practices. In areas indicating potential nesting and roosting habitat, special attention should be placed on retaining 60 to 90 percent canopy closure while re-establishing or maintaining multi-layered/multi-species structural diversity, with large overstory trees (greater than 30" DBH or existing prior to effective fire suppression (1932). Some quantities of large woody debris at (varying states of decomposition when possible) should remain after treatment, but only in quantities/continuities ensuring low to moderate burn intensities in the event of wildland fire. To the greatest extent possible ladder fuels should be removed in the presence of remaining ground fuels. Occasional pockets of small vegetation thickets as well as small openings (where indications show pre-existing openings) should be retained or reestablished to promote prey escapement and/or availability (LaHaye and Gutierrez 1999). Within a ¼ mile radius of occupied nests sites, or 70 acre nest core, established limited operating periods (LOP) should be considered (February 1st to July 15th). However, with the quantity of work needed in order to restore natural fire regimes at the watershed scale and facilitate species recovery,
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		restoration activities should not to exceed ½ of a LOP in every three years for any occupied nesting site. No more than two sites or 50% (which ever is lesser) should receive treatment in a watershed/fireshed per year. The remaining time can be spent enhancing and/or restoring foraging and dispersal habitats or implementing other CEMP's outside occupied nesting sites. Human ignited fires should only occur in the evening and allowed to burn into the night during LOP's to allow escapement of this species from pile burning smoke plumes
		Air Quality – Protect species such as the Northern Spotted Owl from smoke related impacts during burning activities in LOP's
		Fire/Fuels Reduction – Restore fire adapted ecosystems and provide for a some degree of implementation in Spotted owl activity centers where there is currently no approved time period for completion when combined with other mandates and restraints.
		Forestry – Promote economic recovery or cost offsets for additional treatment needs within and adjacent to Spotted Owl activity centers while restoring historical species composition and habitat variability.
		Watershed Restoration – Restore regular natural disturbance intervals in Spotted Owl activity centers instead of having these centers trigger perpetual suppression tactics in these areas.
		Wildlife – Restore habitat infrastructure for the Northern Spotted Owl for increased reproduction success, fledgling survival, dispersal capability and occupation potential.
		Spotted Owl populations are the primary indicator for this CEMP. With the focused attention the Spotted Owl has received in recent decades, the Tribe has identified this species as being of

		special concern. Although this species was not traditionally managed for specifically, it is now an issue that needs resolution. Most management planning documents currently in effect limit integrated treatment capabilities. This CEMP is based on solving problems associated with habitat fragmentation and species survival as opposed to crippling expansive treatment capabilities in occupied nesting areas. Many of these occupied areas consist of correlating habitat qualities that severely limit the potential for successful forage, dispersal and fledgling survival which is critical to species proliferation. A success determination can be achieved by different means. First, retained use in occupied stands can be considered effective when there is a mating pair in the stand within 2 years of treatment implementation. Second, successful mating and fledgling survival is automatic grounds for success. Third, dispersal to unoccupied stands through treated areas is critical to species expansion, therefore this would also receive a success determination. This is especially true when male and female juveniles from different nesting pairs successfully disperse to occupy a treated stand. When one the above successes do not occur, an adaptation determination will most likely be needed and treatments within the occupied area should cease until limited operating periods are over. This should be immediately followed by focusing more on interconnecting habitats to suitable areas a greater distance away. New information on species requirements should be researched and applied to treatment prescriptions. Given the vast area that will be in need of treatment, and scale of time it will take to recreate and/or interconnect suitable habitats for this species, failure determinations are expected to only relate to direct harm. In the event that a nesting tree is damaged, removed, or mortality otherwise occurs as a direct effect of treatment activities, a failure determination is immediate and an alternate strategy for species restoration needs to be
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		developed for occupied stands.
Squamish Nation	Land Use Plan (Squamish Nation 2023)	Species identified as being of particular management concern by the provincial government are the Keen's Long-eared Myotis (a bat), Pacific Water Shrew, Fisher, Wolverine, Trumpeter Swan, American Bittern, Great Blue Heron, Green Heron, Northern Goshawk, Rubber Boa (a snake), Tailed Frog, Northern Spotted Owl, Marbled Murrelet, Grizzly Bear, Mule and Black tailed deer, Mountain Goat, Moose, Bald Eagle and Harlequin Duck.
Yakima Nation	Forest Management Plan (Yakima Nation & BIA 2005).	Federally-listed threatened and endangered species that may exist in or around the Yakama Forest include bald eagle, northern spotted owl, grizzly bear, lynx, and gray wolf (endangered). These species are afforded special management considerations as a result of their legal status.
		Northern Spotted Owls are permanent residents on the Yakama Forest and are generally associated with mature and old-growth stands. Forest management activities potentially affecting northern spotted owls will continue to be based on the Yakama Nation Spotted Owl Management Plan and USDI Fish and Wildlife Service guidelines.
		Northern Spotted Owls are most often found within these habitat types as are Vaux's swift and the northern goshawk.
		All Yakama Forest management operations will comply with the approved Yakama Nation Northern Spotted Owl Management Plan.
		Stands within this habitat type commonly serve as some of the most productive Spotted Owl habitats east of the Cascade Crest. Large amounts of dead and down material and multiple canopy layers (often the result of lack of natural fire) provide habitat suitable to meet the owl's requirements.

