Conservation Assessment for the

Oregon Slender Salamander

(*Batrachoseps wrighti*)

Version 2.0

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Disclaimer

This Conservation Assessment was prepared to compile the published and unpublished information on the Oregon slender salamander (Batrachoseps wrighti). Although the best scientific information available was used and subject experts were consulted in preparation of this document, it is expected that new information will arise and be included. If you have information that will assist in conserving this species or questions concerning this Conservation Assessment, please contact the interagency Conservation Planning Coordinator for Region 6 Forest Service, BLM OR/WA in Portland, Oregon, via the Interagency Special Status and Sensitive Species Program website.

Executive Summary

The Oregon Slender Salamander Conservation Assessment Version 1.0 was updated in January 2009 (Version 2.0) to incorporate Appendices 2, 3, and 4, and to integrate those findings into the main document.

Species: Oregon Slender Salamander (*Batrachoseps wrighti*)
Taxonomic Group: Amphibian
Other Management Status: U.S.D.A. Forest Service, Region 6 - Sensitive; U.S.D.I. Bureau of Land Management, Oregon - Sensitive; Oregon State Sensitive-undetermined status; U.S. Fish and Wildlife Service proposed for listing in 2001; The Oregon Natural Heritage Information Center ranks this species as Globally imperiled (G2G3), Oregon State imperiled (S2S3) and it is List 1 (threatened with extinction or presumed to be extinct throughout their entire range). Management of the species follows Forest Service 2670 Manual policy and BLM 6840 Manual direction.

Range: The species is currently known from the north Oregon Cascade Range and foothills, occurring west of the crest from the Columbia River to Highway 58, and occurring east of the crest from the Columbia River to the Warm Springs Indian Reservation. It occurs across a north-south range of close to 233 km (145 miles), from around 25 meters in elevation (at the northern end of its range in the Columbia gorge) to around 1,700 meters at the southern end of its range on the west side of the Cascade Range crest. There are 740 site records, which collapse to 407 sites when locations within 200 m of each other are combined.

Specific Habitat: This terrestrial salamander is highly associated with down wood in forests. In the western Cascades, four habitat characteristics have a significant positive association with Oregon slender salamanders: canopy closure, west and east aspects, decayed logs in the 50 to 75 cm (20 to 30 in) diameter class, and snags. While it may be found in all seral stages when down wood is present, studies west of the Cascade Range have shown abundances are higher in late-successional forests. Habitat associations east of the Cascades are not well known; the species uses a variety of ground cover objects ranging from sloughed bark to down logs, and occur in younger and older forests.

Threats: Land-use activities that affect substrate, ground cover including down wood, forest condition, or microhabitat and microclimate regimes may impact individuals or populations at occupied sites (site). The primary potential threat to these salamanders and their habitat is short rotation clearcut timber harvest, which removes canopy closure, disturbs substrates, and can alter microhabitat refuges and microclimates. In particular, where there is limited large down wood volume and limited down wood recruitment, negative consequences for this terrestrial salamander are likely. However, there is uncertainty about the effect on these salamanders of partial harvest, or regeneration harvest with green tree and down wood retention.

Management Considerations: Considerations for maintaining local populations include maintaining undisturbed cool, moist surface and subsurface refuges. The timing of activities to outside of the season when animals are surface active is also a consideration for this species' management: some habitat disturbing activities that could harm the species at those times when the animals are surface active (i.e., winter/spring) may be relatively benign at other times when the animals are not surface active (e.g., fall prescribed fire). The geographic distribution of both sites and distinct populations (2 discrete populations are recognized within the range of the species) are considerations for determining sites to manage. At stand scales, a mosaic of riparian reserves, upslope patch reserves and partial harvest areas may contribute to the retention of habitat for this species.

Inventory, Monitoring, and Research Opportunities: Information gaps identified by the interagency Oregon slender salamander work group as medium to high priority include:

- field validation of the habitat modeldelineation of the southern distribution of the species on both the east and west side of the Cascade Range,
- distribution on federal lands in current gaps within the range; these may reflect lack of surveys,
- the response of the species to alternative silviculture activities such as density management and fuels reduction treatments,
- the effect of fire on this species and habitat associations east of the Cascades,
- how much coarse woody debris should be recruited to retain salamanders at a site,
- distribution of the two discrete genetic populations on federal land allocations,
- movement abilities of the salamander.

Many of these gaps can be answered by using various techniques of inventory, monitoring and research. Basic inventory techniques may assist in locating new populations or to monitor known sites over the long term to determine population trends.

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I. INTRODUCTION

Goal

The primary goal of this conservation assessment is to provide the most up to date information known about this species including life history, habitat, and potential threats, and to describe habitat and site conditions that may be desirable to maintain if management of a particular site or locality for the species is proposed. This species is an endemic vertebrate with a known range restricted to the foothills of the Oregon Cascade Range in northern Oregon. It is recognized as a potentially vulnerable species by various Federal and State agencies because it is potentially susceptible to land management activities that occur within its range. The goals and management considerations of this assessment are specific to BLM and Forest Service lands in Oregon. The information presented here is compiled to help manage the species in accordance with Forest Service Region 6 Sensitive Species (SS) policy and Oregon/Washington Bureau of Land Management Special Status Species (SSS) policy. Additional information for Region 6 SS and Oregon BLM SSS is available on the Interagency Special Status Species website: http://www.fs.fed.us/r6/sfpnw/issssp/.

For lands administered by the Oregon/Washington Bureau of Land Management (OR/WA BLM), SSS policy (6840 manual and IM OR-91-57) details the need to manage for species conservation. For Region 6 of the Forest Service, SS policy requires the agency to maintain viable populations of all native and desired non-native wildlife, fish, and plant species in habitats distributed throughout their geographic range on National Forest System lands. Management "must not result in a loss of species viability or create significant trends toward federal listing" (FSM 2670.32) for any identified SS.

Scope

We synthesize biological and ecological information for the species range-wide, relying on published accounts, reports, locality data from individuals and databases, and expert opinion, each noted as appropriate. Although we did not restrict our information compilation to that coming from federal sources, our site data are largely compiled from federal lands and the scope of the management considerations of this assessment are specific to BLM and Forest Service lands in Oregon. Known sites are located on the Salem and Eugene BLM Districts, and the Mount Hood and Willamette National Forests.

Management Status

State and federal agencies classify the Oregon slender salamander as a potentially vulnerable species due to its restricted distribution and vulnerability to a variety of anthropogenic disturbances. It is listed under U.S.D.A. Forest Service, Region 6 – Sensitive; U.S.D.I. Bureau of Land Management, Oregon - Sensitive; Oregon State Sensitive-undetermined status. The Oregon Natural Heritage Information Center ranks this species as Globally imperiled (G2G3), Oregon State imperiled (S2S3) and it is List 1 (threatened with extinction or presumed to be extinct throughout their entire range). Management of the species follows Forest Service 2670 Manual policy and BLM 6840 Manual direction.

II. CLASSIFICATION AND DESCRIPTION

Systematics

First described as *Plethopsis wrighti* (Bishop 1937), the Oregon slender salamander, *Batrachoseps wrighti* (also *B. writorum*), is one of 15 currently recognized species in the genus *Batrachoseps* (Jockusch et al. 1998). It is also one of two currently recognized species in the genus within the state of Oregon; the second species is the California slender salamander *(Batrachoseps attenuatus). Batrachoseps* is one of roughly 30 genera in a diverse family of salamanders, the Plethodontidae or lungless salamanders, which contain over half of all living salamander species. The family takes it name from the fact that most of its derived members lack lungs. Externally, the very slender shape and relatively small (often diminutive) limbs of individuals can distinguish *Batrachoseps* from most other plethodontid salamanders; this body morphology is the basis for the common name of the genus: slender salamander.

Wagner (2000) and Miller et al. (2005) demonstrated high levels of genetic divergence within this species. Mitochondrial DNA analysis showed that there is evidence of two major lineages, a northern and southern population, and random amplified polymorphic DNA (RAPD) analysis showed a pattern of isolation by distance. The northern population appears to include sites east of the crest and western sites from the Columbia River south to near Estacada, Oregon, in Multnomah, Clackamas, Hood River, and Wasco Counties. The southern population appears to include sites west of the Cascade crest, north to near Silver Creek Falls, in Marion and Linn Counties. Sampling was not conducted between Silver Creek Falls and Estacada to refine delineation of the boundary (Figure 1). These divergence patterns may be a result of limited gene flow between populations which could be reflective of limited dispersal capabilities, low reproductive rates, habitat requirements, and fragmented habitat. Miller et al. (2005) speculated that the boundary between these lineages may be coincident with the Pliocene-to-Pleistocene location of the Columbia River, which was deflected south during that time period. They suggested that there may have been a relatively recent northward range expansion, or the northern population may have been isolated during that time and diverged. Miller et al. (2005) also state that the genetic pattern may have resulted from a life history where males disperse and females do not.

Species Description

Batrachoseps wrighti is relatively uniform in external morphology (Brame 1964). Dorsal ground color varies from deep brown to black, and rarely is lighter in color (Bishop 1937, Stebbins 1951). Except for an occasional black individual, a brick, chestnut, or reddish brown mottled and uneven-edged stripe extends over most of the back from head to tip of tail (Bishop 1937, Stebbins 1951, Leonard et al. 1993, Corkran and Thoms 1996). The lower sides and undersurfaces of the belly and tail are black with clusters of pale spots that are described as bluish white or silvery in color. Although a number of salamanders possess a fine flecking on lower surfaces, none have spots as large or as prominent as the Oregon slender salamander, which makes this among the best characters to distinguish the species (Stebbins 1985, Leonard et al. 1993, Corkran and Thoms 1996). Adults are known to reach 64 mm (2.5 in) in snout-vent length and 118 mm (4.6 in) in total length, and when unbroken, the tail can be 1.0 to 1.75 times the body length (Jameson and Storm 1956, Leonard et al. 1993, Nussbaum et al. 1983, Stebbins 1985, Storm 2005). They have long bodies with 16-17 costal grooves, short legs (4.5-7.5 intercostal folds between adpressed limbs) and there are only four toes on the back feet (Storm 2005). Juveniles display adult coloration except that the dorsal stripe is less prominent and the flecking is more metal-flake in appearance. Hatchlings may be as small as 19 mm, total length, and have relatively longer legs and shorter tails than older animals (Storm 2005).

III. BIOLOGY AND ECOLOGY

Life History

The Oregon slender salamander is among the least known salamanders in the Pacific Northwest. No focused life history studies have addressed this species. West of the Cascade crest, surface activity of these salamanders has been noted to occur at cool temperatures, 10-14°C (Nussbaum et al. 1983), and a high number have been found at 18°C (S. Dowlan, pers. commun.). Two or more individuals have been found under one cover object on the forest floor surface. When disturbed, this salamander may exhibit a flipping behavior, where it coils and uncoils its body. This is likely an antipredator response. Another potential antipredator adaptation is its propensity to lose its tail. One population was reported with a 13% incidence of tail loss, suggesting a high predation pressure (Blaustein et al. 1995).

Movements

Although mark-recapture studies of salamander movement have not been conducted with this species, its relative movement capability is indicated from genetic analyses. Wagner (2000) and Miller et al. (2005) found divergence patterns suggestive of two discrete populations, which could be retained through time only as a result of limited gene flow between populations, which could be reflective of limited dispersal capabilities, low reproductive rates, habitat requirements, and fragmented habitat. Their genetic data are consistent with the hypothesis that males disperse and females do not, however, this has not been documented by field studies. A mark-recapture study of a close relative to the south, the California slender salamander (*B. attenuatus*), found most animals remained in close proximity to the cover item at which they were initially found, having a cruising radius of only 1.5 m (Hendrickson 1954). The home range of the Oregon slender salamander could well be on the order of only tens of square-meters, but this is largely speculation. They have been detected recently in stands that were clearcut in the 1950's and 1960's, suggesting that they either persisted through the disturbance or dispersed into the area from nearby stands.

Breeding Biology

As with other plethodontid salamanders in this region, breeding likely occurs with mating via spermatophore transfer to females in the fall or spring. Gravid females have been found in the spring, with clutch sizes ranging from 3-11 eggs. Spring oviposition is likely. Nests have been found in subsurface retreats, such as under bark and within crevices in logs. Eggs hatch in 4-5 months (Storm 2005).

Range, Distribution, and Abundance

The known range of the species is 1,289,840 ha (3,187,264 acres), which spans the northwest Oregon Cascade Range and its foothills, from the Columbia River Gorge to the southeast corner of Lane County, and the northeast Oregon Cascade Range foothills from the Gorge to the Warm Springs Indian Reservation (Figures 1 and 2). It occurs west of the crest across a north-south range of close to 233 km (145 miles), from around 25 meters (85 feet) in elevation (at the northern end of its range in the Columbia gorge) to around 1,700 meters (5,440 feet) at the southern end of its range. East of the crest, it occurs along a north-south span of 65 km (40 mi) and occurs to about 1,250 m (~4,000 ft) elevation. This range includes Clackamas, Linn, Lane, Marion, Multnomah, Hood River, and Wasco Counties in Oregon.

Table 1. Amount of acres within the range of Oregon slender salamander, by land allocation, and the proportion of range that represents. LSR = late-successional reserve; AMA = adaptive management area; CR = congressional reserve; AW = administratively withdrawn; AMR = adaptive management reserve; Unclassified = unknown classification; NA = not applicable.

Land Use Allocation (LUA)	Range (ha) [ac]	% LUA of Total Range	% LUA of Federal range
Matrix	316,166 [781,264]	24.5	39
LSR	225,511 [557,250]	17.5	28
AMA	63,656 [157,297]	5	8
CR	126,350 [312,218]	10	16
AW	43,407 [107,262]	3	5
AMR	3,692 [9,123]	0.3	1
Unclassified	23,178 [57,274]	2	3
(Nonfederal)	487,879 [1,205,574]	38	N/A

Table 2. Observations of Oregon slender salamander and percent distribution by land allocation.

Land Use Allocation	Number of Observations	% of federal observations within this LUA
Matrix	519	76
LSR	120	17.5
AMA	23	3
CR	11	2
AW	10	1
AMR	0	0
Unclassified	4	0.5
(Nonfederal)	53	N/A

Defining what is a "site", or what is the scale of an area that defines a group of interacting individuals is not a uniform, agreed-upon process. Sites can either be points on a map, or a collection of points that are in a certain proximity of one another. Often scientific research has not been done on the particular species to accurately define what this proximity may be; therefore biologists and managers often have to utilize what information may be known about that species, and complement it with information about other, similar species, drawing reasonable inferences. . For the Oregon slender salamander there are 740 or 407 sites of this species, depending upon how one defines a "site". At present, there are 740 observations (data records) of this animal across its range (Figure 2). These observations represent three types of data. First, these data include point sightings of individuals. In some cases, multiple individuals within a proposed project area or forest stand were reported independently as different site records. Second, some of these records are a single point representative of a larger area, study site, forest stand or habitat polygon in which this species was detected. Third, some data records are polygons. For analysis purposes in this Conservation Assessment, in order to consolidate records of individuals found in relatively close proximity to each other, site records of all three source data types were buffered by 200 m and those within this distance of another site record were combined into a single locality. A 200 m distance was chosen arbitrarily, but represents a distance other Plethodontid salamanders are known to disperse. Also, the area of a circle with a 200 m radius is 12.56 ha (31 acres) and may be of sufficient size to maintain a subpopulation (although there are currently no data available to estimate the spatial extent of stable populations for this species). Using this 200 m criterion, the 740 observations collapsed to 407 sites. Of 740 site records, 687 (93%) are on federal lands, occurring entirely within several land allocations of the Northwest Forest Plan, with most on Matrix (Table 1). Known sites are located on the Salem and Eugene BLM Districts, and the Mount Hood and Willamette National Forests.

Gaps in both distribution and knowledge may be apparent by inspecting the distribution map (Figure 2). Lack of observations on this map likely reflects both a lack of surveys in addition to a patchy occurrence of this animal across its range. At this time, surveys without detections of this species have not been compiled or mapped. In particular, the southern extent of the species' range is not well delineated on either the east or west sides of the Cascade Range crest. The northwestern distribution is not well known, and the distribution in federal reserve land allocations is unclear. Also, the upper elevational extent of this species is not well known across its range.

Tables 1 and 2 show the distribution of sites and range by federal land use allocation of the Northwest Forest Plan. Matrix has most sites and the largest proportion of the federal range.

Only a few studies have reported occupancy rates at surveyed sites west of the Cascade crest. Larson and England (1994) found a 71% occupancy rate in mature stands (N=52). Vesely et al. (1999) reported this species to have the highest capture rate of salamanders he sampled, at 1 capture per person hour of sampling. Vesely et al. also (1999) found a 75% (9 of 12 sites) occupancy rate in old-growth stands. Salamanders were undetectable in recently harvested stands in Vesely's study.

This salamander may occur in younger forest stands, especially those in which legacy down wood has been retained. Stands on the Cascades Resource Area that were clearcut prior to about

1960 may have tended to leave a fair amount of large down wood on the forest floor, typically high-grading the best-quality logs (S. Dowlan, pers. commun.). Dowlan reviewed aerial photos from the 1950s and 60s and noticed current salamander presence in stands where much log retention occurred. Leaving this substrate likely either allowed for the salamanders to persist through harvest, or to pioneer into the stands more easily. In contrast, clearcuts since about 1960 have not left large down wood, with perhaps a negative effect on the occurrence or abundance of this species. Occupancy rates among younger stands are not well known, although much of the species' distribution overlaps this forest type. Vesely et al. (1999) found no salamanders in young (2-7 years) plantations.

Figure 1. Range map of the Oregon slender salamander, showing the two genetic populations that have been distinguished (estimated boundaries are shown by the darkest shading to the north and lightest shading to the south, with the intervening area [medium shading] where population status is not known).

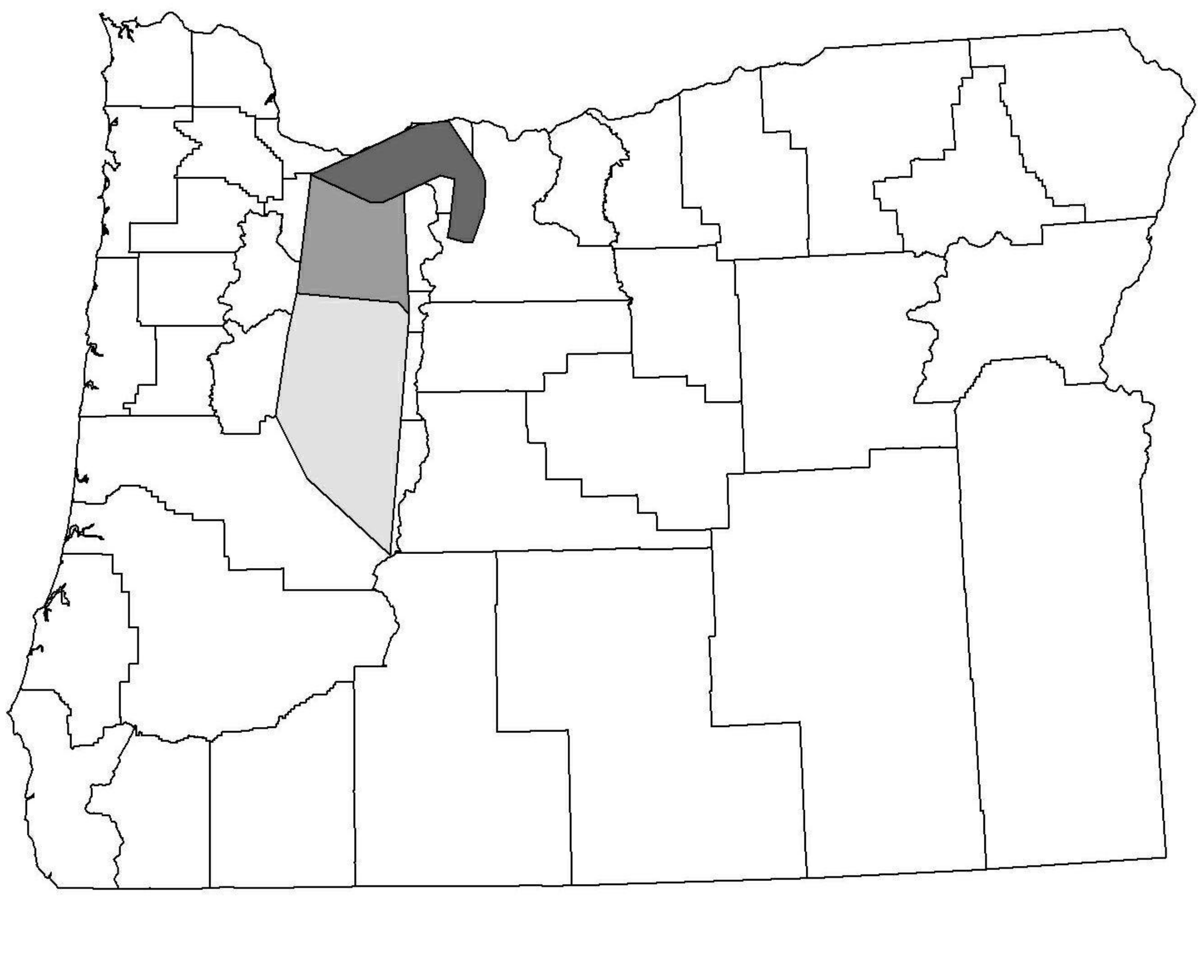
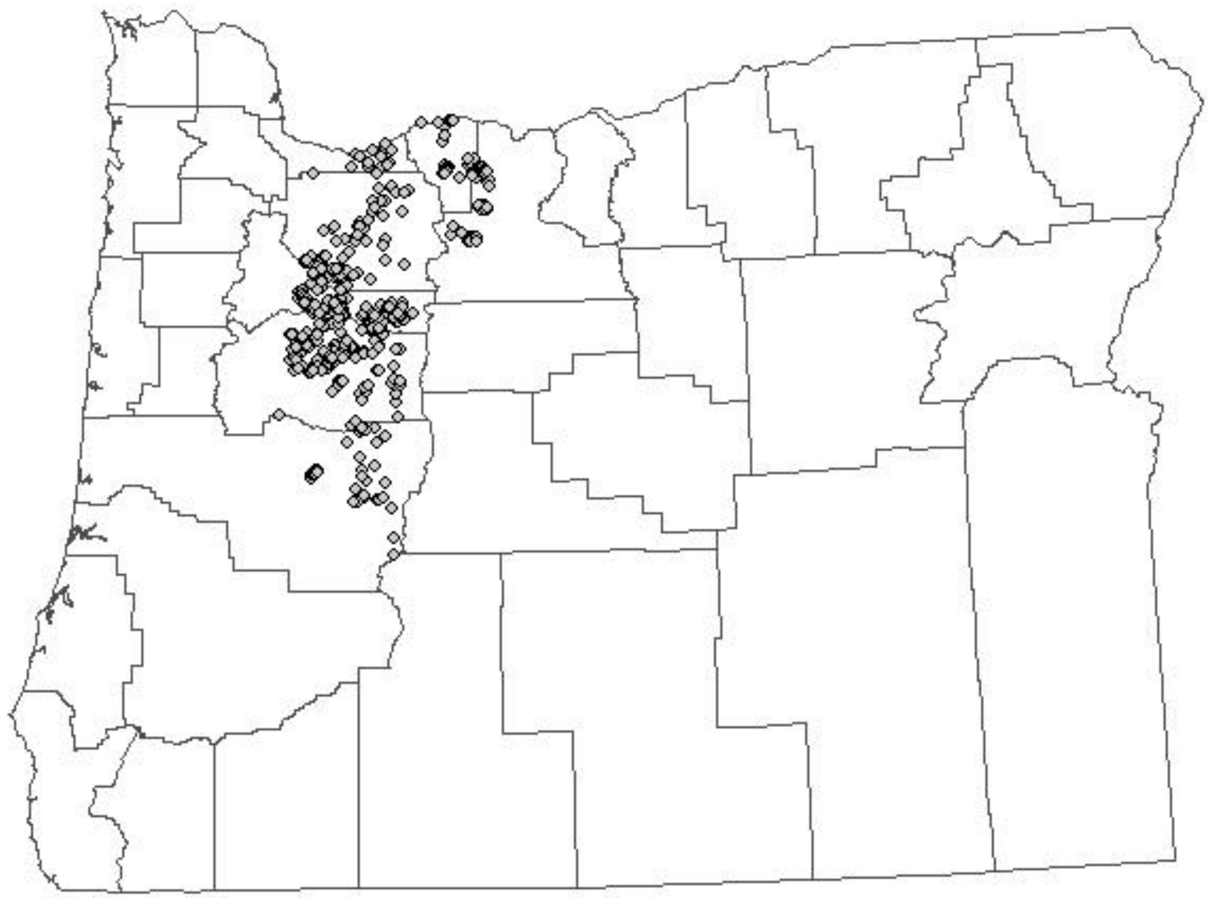


Figure 2. Sites (N = 740 observations) of the Oregon slender salamander. These observations collapse to 407 sites when observations within 200 m of each other are combined.



Population Trends

There is no information about population trends in this species.

Habitat

This species occurs in forested habitat. Three primary habitat conditions appear most important for this species west of the Cascade crest: moisture, dead wood, and older forests. First, *B. wrighti* occurs in stands with moist microhabitat conditions (Bury and Corn 1988, Gilbert and Allwine 1991). Second, there are numerous reports of associations of this species with large down wood, and some of the first publications on this species exemplify these cover associations. Jameson and Storm (1956) described an individual found under the moss of a decayed Douglas fir log and four *B. wrighti* were found under moss and bark of rotting stumps and logs of Douglas fir. Storm (1953) collected four individuals from beneath the bark of decaying Douglas fir logs.

Storm also described the collection of two *B. wrighti* from "well within" decaying fir logs and one from beneath the bark of an alder *(Alnus* sp.). Third, several more recent studies support an association of this species with large down wood and older forest stand conditions.

Bury and Corn (1988) reported that *B. wrighti* was significantly more abundant in old growth, than in 30 to 76 years old stands. Similarly, Gilbert and Allwine (1991) found these animals to be twice as abundant in mature and old-growth stands than in younger 30 to 80 year old stands. Vesely et al. (1999) further support an old-growth stand association of this species; of 56 stands of 13 forest types surveyed, *B. wrighti* was significantly more abundant in old growth (OG) than in second growth (SG) and no animals were found in clearcuts. The abundance of most classes of woody debris also was significantly lower in SG stands than in OG stands. Four habitat characteristics (canopy closure, aspect, logs in the 50 to 75 cm (20 to 30 in) diameter class, and snags) were found to have a significant positive association with Oregon slender salamanders. Canopy closure and aspect were best predictors of relative density among logged and unlogged stands. In this study, median canopy closures were 93% for old-growth stands (range = 24) and 92% for second growth stands (range = 34), precluding the development of a minimum or threshold value associated with species occupancy or abundance. However, salamander abundance was higher on west- and east-facing slopes, compared to north and south-facing areas. Vesely et al. (1999) suggested that south-facing slopes may become overly xeric in summer for persistence of this species, while north-facing slopes may be colder, retaining snow into the summer months, restricting the time interval for surface activity. Oregon slender salamander density was also positively correlated with large diameter (50 to 75 cm, 20 to 30 in) logs and snags, and negatively correlated with small (10 to 25 cm, 4 to 10 in) logs and logs in intermediate levels of decay (classes 2 and 3). This pattern is believed to reflect the Oregon slender salamander selection of microhabitats that have a greater abundance of snags and large down logs in advanced decay stages. The absence of Oregon slender salamanders in recent clearcuts was attributed to the combined effects of canopy removal and the low abundance of woody debris. Because large woody debris such as used by the salamander for nesting is rare in many recent clearcuts and plantations, Vesely et al. (1999) believed that forests intensively managed on short harvest rotations were likely population “sinks” in which mortality exceeds reproduction.

Older clearcuts on the Cascades Resource Area (prior to ~1960) with higher down wood volumes may have contributed to the persistence of this species at harvested sites. For example, many recent surveys of stands ages 40-70 yrs, that were previously clearcut or burned, and some also subsequently thinned, have detected this species (S. Dowlan, pers. commun.). Legacy large, decayed down wood volumes are relatively high in some of these stands (Olson et al. 2006). Two case studies have looked at the effect of thinning these old clearcuts on salamander abundances. Both found no difference in Oregon slender salamander abundance between the thinned and unthinned treatments (one site: Rundio and Olson 2007; two sites: Wessell et al. 2007). Again, the legacy down wood component may ameliorate the disturbance effects on the species. In contrast, more recent (i.e., 1960 to 1990) clearcut practices that retained little down wood may be associated with reduced occupancy and abundances of these salamanders, and is perhaps captured by some of the studies cited above. There has been no study of the effects to or the short or long term persistence of this species from Northwest Forest Plan regeneration harvest practices, including green tree and down wood retention and reserve land use allocations (e.g., riparian reserves). Relative to previous clearcut conditions on federal lands, 1960-1990, it is expected that the increased shading and down wood cover of Northwest Forest Plan procedures would have some benefit for the species.

A habitat suitability model developed with landscape-scale attributes available in Geographic Information Systems (GIS) corroborates some of these field studies for the western portion of the species range (Suzuki 2008; Appendix 2). At this landscape scale, analyses of individual habitat attributes indicated that Oregon slender salamanders were more likely to occur in areas with lower elevations, warmer temperatures, moderately lower precipitation, and taller, older forest stands with larger tree diameters and basal areas. Increasing hardwood canopy cover and basal area, particularly big leaf maples, also appeared to be an important factor for the distribution of this salamander. The best multivariate model to explain occurrence of salamander sites included the following factors: precipitation, minimum daily temperature, forest stand height, and basal area of Pacific silver fir (negative association with this factor; this tree is generally associated with higher elevations). This model correctly classified 64% of salamander sites as suitable (sensitivity) and 62% of random sites as unsuitable (specificity) with the total correct classification of 63%. Based on this model, odds ratios were calculated as values of habitat suitability and mapped across the landscape to facilitate practical use of this habitat suitability map for conservation planning process (Appendix 2, Figure A2.4a). Overall, this modeling exercise found that Oregon slender salamanders tended to occur in warmer, moderately dry habitats of the western Oregon Cascade Range. Their occurrence increased and peaked around 2100 mm in precipitation followed by a slight decrease along the gradient of decreasing precipitation. Temperature appeared to affect the distribution of this salamander more than precipitation. Also, Oregon slender salamanders tended to occur on southwest slopes, which receive the highest solar radiation inputs among all aspects; however their association with aspect is not strong. Appendix 4 provides information on the distribution of modeled suitable habitat for this species with federal land use allocations west of the Cascade crest.

Recent observations of this salamander east of the Cascade Range crest suggest habitat may differ geographically (R. Thurman, pers. commun.). Most observations to the east were in the dry grand fir zone, however some individuals have been found in pine/oak and the wet grand fir zone. Stand characteristics of these eastern sites include tree diameters ranging from 25-50 cm dbh (10-20 in), down wood diameters of 10-50 cm (4-20 in), with decay classes including class 1 and 2 logs (i.e., logs used by salamanders), and canopy closures ranging 40-80%. These stands have been thinned or underburned. Available down wood may be in earlier decay classes, compared to west-side forests, although this has not been well quantified.

Ecological Considerations

Plethodontid salamanders are thought to have important roles in forest ecosystems, including being a significant trophic link between small ground-dwelling invertebrates and larger vertebrate predators. The diet of Oregon slender salamanders consists of a variety of invertebrates, such as springtails, mites, flies, spiders, snails, beetles, centipedes and earthworms (Storm 2005), but their predators are not well-known. Plethodontid salamanders also comprise a considerable portion of the forest vertebrate biomass in some areas (e.g., Burton and Likens 1975a, 1975b), but the specific role of Oregon slender salamanders in local communities or ecosystem processes has not been addressed. Their general ecology and life history traits suggest they are ideal indicators of forest ecosystem integrity (Welsh and Droege 2001).

IV. CONSERVATION

Threats

Habitat loss and degradation are the primary potential threats to the persistence of Oregon slender salamander populations. Activities that may pose threats are those that disturb the surface microhabitats and microclimate conditions, compact soil, and include clearcut timber harvest and habitat loss from development such as urbanization or large recreation sites. Disturbance of surface microhabitats is of primary concern because alteration of the microhabitat can negatively impact these salamanders. Additionally, loss of connectivity among habitat patches is a concern due to the likely limited mobility of these animals and consequent population isolation.

A multivariate risk assessment conducted at the landscape scale west of the Cascade crest using potential threat factors available in GIS showed associations of modeled salamander habitat with cumulative risk (Suzuki 2008, Appendix 3). The central-western portion of the species' range in the region has many federal lands with high habitat suitability occurring in small parcels, and has a high potential cumulative risk mainly due to the high concentrations of actively managed federal timber (matrix and adaptive management areas) and private lands, as well as roads. The southwestern portion of the species' range has high potential cumulative risk mainly due to high risk of fire; furthermore, large blocks of contiguous federal lands with high habitat suitability occur in this region. The northwestern corner of the species' range appears to have the highest potential risk due to the high concentrations of actively managed federal timber lands, private lands, and roads, along with the presence of the wildland urban interface; however, the habitat suitability of this area is relatively low. The rationale for considering these various factors as potential threats to salamanders or their habitats is discussed further below.

Timber Harvest

Timber harvest is a primary land management practice in forested ecosystems in this geographic region and is estimated to have had the most impact on the species and its habitat. Numerous retrospective studies with this salamander support the negative effects of timber harvest activities on salamander abundances (see habitat above). Several disturbances can result from timber harvest practices. Removal of overstory changes the local microclimatic regime and may cause desiccation of substrates and ground cover. Tree-felling and ground-based logging systems mechanically disturb the substrate and ground cover which can result in both substrate compaction and loss of the integrity of existing down wood. These actions can result in loss of interstices used by salamanders as refuges and for their movements, and a drying out of the ground surface if cover is lost. Loss of standing green trees reduces the future potential for down wood recruitment, and as new trees regenerate in harvested stands, their smaller sizes likely do not provide the same functions for salamanders for several decades to centuries.

In addition to the retrospective studies of timber harvest effects reported above (habitat section), many other studies have reported effects to plethodontid salamanders from timber harvest, in particular regeneration harvest practices (Ash 1997, Dupuis et al. 1995, deMaynadier and Hunter 1995, Herbeck and Larsen 1999, Grialou et al. 2000). DeMaynadier and Hunter (1995) reviewed 18 studies of salamander abundance after timber harvest and found median abundance of amphibians was 3.5 times greater on controls over clearcuts. Petranka et al. (1993) found that *Plethodon* abundance and richness in mature forest were five times higher than those in recent clear cuts and they estimated that it would take as much as 50-70 years for clearcut populations to return to pre-clearcut levels. A comparison of recent (<5 years) clearcuts and mature (120 years) forests also suggested salamanders are eliminated or reduced to very low numbers when mature forests are clearcut (Petranka et al. 1993). In a paired plot study, H.H. Welsh, Jr. and others (unpubl. data) found that *P. elongatus* salamanders were greatly reduced for as long as twelve years after clear cutting when compared with an adjacent control plot. The proportion of juveniles/subadults was dissimilar between the two plots ($t = 2.49$, $p = 0.0282$, $df = 12$, power = 0.6255;). Juveniles and subadults comprised a significantly larger proportion of captures in the clear-cut compared to the late-seral stand. These data are best explained by a "source-sink" model (Pulliam 1988) wherein the clear-cut is the "sink" and the surrounding late-seral forest is the "source" of the juveniles and subadults found in the clear-cut. These two early life stages appear to be the "dispersers" (see Marsh et al. 2004). Adult territoriality likely results in the movement of subadults and juveniles out of currently occupied habitat into edges (Ovaska and Gregory 1989; Fraser 1976a, Fraser 1976b). In contrast, Messere and Ducey (1998) found no significant differences in abundance of red-backed salamanders in forest canopy gaps in stands that had been selectively logged, indicating that limited logging may have little effect on that species.

Studies in the Pacific Northwest documented greater salamander abundance in old-growth compared to clearcuts or early seral forest (e.g., Bury and Corn 1988, Raphael 1988, Welsh and Lind 1988 and 1991, Welsh 1990, Corn and Bury 1991, Dupuis et al. 1995). Alternatively, Diller and Wallace (1994) found *P. elongatus* in managed young stands in northwestern California and found no relationship of salamander presence to forest age. However, they sampled stands that were from zero to 90 years old. The areas surveyed were also in the coastal redwoods that have a milder, wetter climate than interior sites sampled by others (Welsh and Lind 1991).

The Bureau of Land Management (BLM) conducted searches for Oregon slender salamanders at paired sites: mature forest stands paired with adjacent clearcuts (Larson and England 1994). No *B. wrighti* were found in older clearcuts, even when 20 to 30 years old with Douglas-fir regeneration, but *B. wrighti* was present in 1 to 2 year old cuts where logs apparently were still wet enough for the species to be present. It is possible that *B. wrighti* might persist 3 to 5 years after regeneration harvest, a time span that may match the lifespan of *B. wrighti*. The lack of persistence in old clearcuts parallels data from the Vesely et al. (1999) study and poses questions regarding this species ability to persist on a landscape scale in light of current and proposed timber harvest within the range of the species.

While it warrants further study, it bears acknowledgement at this time to recognize that not all timber harvest practices are equal. Some harvest practices may have a reduced impact on Oregon slender salamanders. Salamanders may persist at sites, or recolonization may be accelerated, with retention of down wood and retention of standing trees that reduces ground disturbance, ameliorates microclimate alteration, and offers recruitment of future down wood. Standing trees may be dispersed (i.e., via thinning) and/or aggregated (i.e., leave islands, patch reserves or riparian reserves). Green tree retention may retain connectivity among suitable habitat patches, either via providing continuous habitat or by providing "stepping stones" of habitat patches through which animals may traverse to larger habitat blocks. In contrast, private industrial timberlands within the species range may pose a greater risk to these animals. Current clearcut rotations on some industrial lands are short, about 40 yrs, and likely do not leave sufficient down wood or standing trees to provide habitat for this species and may pose a significant barrier to recolonization of nearby federal lands in large parts of the species range (e.g., Eugene and Salem BLM lands).

Within the range of the Oregon slender salamander, the landscape is fragmented by past timber harvest practices, and is a patchwork of stands of different seral stages, from early seral to mature forests, with differing timber harvest practices. Sites with Oregon slender salamanders are nested within this patchy forested regime. There are no real estimates of how much potential suitable habitat has been impacted by timber harvest activities, but 595 of 740 (80%) salamander localities occur on land allocations in which timber harvest activities may occur (nonfederal lands, federal Matrix and Adaptive Management Area; Table 1). Looking at federal lands only, 542 of 687 sites (79 percent) occur on land with programmed timber harvest (Table 1a). However, these numbers likely reflect a bias in where survey efforts have occurred for this species because surveys have most often been associated with federal timber sale planning, resulting in fewer locations on nonfederal lands and in federal reserved lands. Inspection of land use allocations within the species' known range (minimum convex polygon of known sites, partitioned by three areas as in Figure 1) may give a better estimate of potential occurrence across the landscape: 67.5% of the species range occurs in land allocations with timber harvest activities (38% of the range on nonfederal lands, 24.5% on federal Matrix, 5% on federal AMA). Conversely, 31% of the range is in federal reserves, not including Riparian Reserves (In assessing just the range on federal lands, about 49% of federal lands are in reserves allocations, not including Riparian Reserves). The value of Riparian Reserves or owl set-asides for this species' persistence is not known, however trans-riparian transect surveys conducted by Rundio and Olson (2007) at one case study site generally resulted in more Oregon slender salamander captures > 100 m from headwater streams, suggesting narrower riparian buffers may have limited conservation value.

Thus, while historic timber harvest activities such as clearcut regeneration harvest were likely detrimental to Oregon slender salamander persistence, it is not clear if alternative silviculture practices would have the same effects. If down wood microhabitats and forest microclimates are retained with selective harvest activities, salamanders may persist or recolonize the site.

Fire

The effects of fire on Oregon slender salamanders are poorly understood. Prescribed fire for fuels reduction treatments may have different effects than natural fire that can differ significantly in intensity. Low intensity fires that retain large down wood and occur during the seasons when these salamanders are not surface active may not have adverse effects. One recent study surveyed for this species following a midsummer fire (Clark Fire, July 2003), and numerous detections were reported. However, it is unknown how detections were distributed relative to fire severity or how the fire will affect long term persistence of the population in the area. Also, this species is now known east of the Cascade Range in an area susceptible to more frequent natural fire events. The historical fire regime in the area was likely one of high frequency and low intensity fire, which consisted of very frequent underburning of the forest in the summer and fall and few stand replacement events. The effects of a more intense level of fire disturbance due to fire suppression and fuel loading is of concern in that stand replacement fire represents a more catastrophic disturbance to flora and fauna. In particular, relative to salamander habitat, it removes overstory canopy that serves to moderate surface microclimates from extremes (e.g., high temperatures and low moisture) and can reduce decayed down wood.

Chemical Applications

Chemicals such as herbicides, pesticides, fungicides, fertilizers and fire retardants may have a direct impact on all woodland salamanders. These animals breathe through their skin, which must be moist and permeable for gas exchange. However, it is not known to what extent these substances affect Oregon slender salamanders. However, due to the scale of this action across the range of this species, this action is not considered to be a primary threat.

Global Climate Change

The range of the Oregon slender salamander includes habitats that are particularly vulnerable to predicted patterns of global climate change. In particular, a change in storm patterns that alters the snow cover, either annual accumulation or seasonal pattern, would affect this species. West of the Cascade crest, warming trends could increase the elevational extent of the species range and increase occupancy of north-facing slopes, and also restrict its distribution at lower elevations or south-southwest aspects. A smaller band of habitat might result if the current foothills become less suitable for the species. East of the crest, warming trends could alter fire regimes and vegetation conditions, further restricting habitats. Indirect effects from changes of prey or predator communities are likely, but are difficult to predict. Interactions of warming trends with reduced cover from timber harvest are likely. Amelioration of climate changes may be possible by retaining canopy cover and large down wood, which moderate temperature extremes in their forested habitats.

Disease

Current research on global amphibian declines is focusing on the effects of disease agents. While disease has not been implicated for this salamander, chytrid fungus has recently been detected in a plethodontid salamander (Cummer et al. 2005). This disease is thought to be the cause of local extirpations of montane frogs in the Washington Cascade Range and the California Sierra Nevada Range.

Roads

Many roads have been constructed for various reasons within the range of the slender salamander. Road construction in suitable habitat directly removes overstory, affects down woody material, and compacts the substrate. The intensity of impacts is more intense and longer lasting than timber harvest. Road construction likely causes direct mortality to individuals and some amount of habitat loss; however due to the scale of impact and the linear nature of the action, the impacts to the species may be significantly less than timber harvest or stand replacement fire. Roads are not generally known to be barriers to plethodontid salamanders. Road kill is not well-documented for this species. However, roads are conduits for human use of forested areas, and may be indicators of impacts on habitats from recreation, forest management, and generally factors contributing to fragmentation.

Developed Recreation/Dispersed Camping

Construction of camping areas, access roads, boat ramps, and other developed recreation sites have likely impacted Oregon slender salamanders by the direct alteration of substrate as well as canopy loss due to overstory vegetation removal. Dispersed campsites also may have had an impact from soil compaction and vegetation alteration, although it is expected to be somewhat limited.

Conservation Status

This species is of concern due to its limited distribution to the northern Oregon Cascade Range and its associations with older forest habitat conditions, the extent of which have been dwindling over the last several decades. Given the hundreds of sites that are now compiled, and with our knowledge of its range being extended east of the Cascade crest, this species no longer appears to be extremely rare; it is not on the brink of extinction. However, when the animal is found, numerous individuals are rarely seen; there are often single to a few animals found with considerable survey effort. While its cryptic nature and use of subsurface habitats likely reduce its detectability and cloud our understanding of abundance patterns, this animal does not seem to occur in high numbers within suitable habitat and optimal habitat may be patchy across the landscape.

Currently, this species is considered a sensitive species by both Region 6 Forest Service and Oregon BLM, as well as the state of Oregon. The Oregon Natural Heritage Information Center ranks this species as Globally imperiled (G2G3), Oregon State imperiled (S2S3) and it is List 1 (threatened with extinction or presumed to be extinct throughout their entire range). Given that this species has low reproductive rate, vagility, and genetic diversity, and is a habitat specialist, there are concerns as to the potential effects on populations from anthropogenic events.

Known Management Approaches

The federal Northwest Forest Plan is the only management plan that has specifically addressed this species. This species was assessed on federal lands by an expert panel during development of the Northwest Forest Plan (USDA and USDI 1993, 1994) and down wood mitigations in addition to other Plan provisions such as land use allocations resulted in its rating of having no risk of extirpation. The panel determined that implementing the Northwest Forest Plan would result in a 70% likelihood that the species would persist in a well-distributed manner, a 24% chance it would persist with some gaps, and a 6% likelihood it would persist solely in reserves.

Thirty-one percent of the range is within reserve lands (late-successional reserves, administratively withdrawn areas and congressional reserves) in Region 6 and OR BLM, some of which are at higher elevations and likely function as potentially marginal or suboptimal habitat for the species. The species potential range as we currently understand it includes about 400,000 ha (~980,000 ac) of federal reserved lands. The areas of reserved lands within the ranges of the three areas delineated in Figure 1 are: northern population, ~105,000 ha (40% of the total area of this population, 31 of 199 sites); intermediate zone, ~82,000 ha (26%, 20 of 152 sites); southern population, ~208,000 ha (29%, 90 of 389 sites).

In addition to these federally reserved land use allocations, retention of spotted owl cores or riparian reserves in matrix may add a significant amount of protected land within the range of the species. However, the roles of owl cores, riparian reserves or other reserved land use allocations are unstudied relative to this species. Whether smaller patches such as owl cores or linear areas such as riparian reserves can contribute significantly to the retention of subpopulations in a managed landscape is a critical issue; there is concern that such fragmented areas may not serve the long term conservation goal of this relatively non-vagile organism. Forest habitat fragmentation is more pronounced in the foothills and lower elevation Cascade Range within this species range, where federal lands are interspersed with private industrial forestlands, which may coincide with the species' optimal habitat.

Quality, quantity, and longevity of down wood at managed sites are key issues for this species. Research supports use of decayed large logs by this salamander (> 50 cm [20 in]). The quality of habitat provided by a log in a clearcut may be reduced in comparison to a log in an intact stand (i.e., altered interior log microclimate, M. Kluber and D. Olson, unpublished data). While the Northwest Forest Plan provides minimum guidelines that recommend retention of large (20 in. diameter) down woody debris on federal lands, it is unclear if these guidelines are sufficient in quantity and quality for this species. In particular, this species does not appear to be able to use large down wood until it is in advanced state of decay. The NWFP S&Gs promote retention of this older decay class, and Standards and Guidelines in place to limit soil and ground disturbance during harvest operations also provide for retention of this resource. In addition, where there is dramatic reduction of canopy closure such as occurs with regeneration harvest, it is uncertain that the recruitment of large wood would be sufficient to provide suitable microhabitat conditions for the species at these sites over the long term, although the NWFP S&Gs promote the need for long term down wood recruitment in the stand. There are observations of this species on the Salem BLM District, Cascades Resource Area occurring in stands clearcut >30-40 years ago when downed woody material was retained (S. Dowlan, unpublished data), suggesting that these past practices retain habitat for this species. Also, the species has persisted at two case study sites where forest thinning (thinned from approximately 200 to 80 trees per acre) has been conducted, suggesting that alternative silvicultural practices to clearcutting may not negatively impact the animal (D Olson pers. obs.). Regeneration harvest is only one harvest method used on federal lands; timber harvest on many of the federal lands managed for timber production within the range of this species may be through thinnings and small group selections. How this mosaic of federal forestry practices coupled with reserve lands impact the persistence of Oregon slender salamanders is uncertain at this time. However, given that a considerable portion (38%) of its known range lies within private land, it is highly likely that further direct habitat loss and fragmentation will continue to occur over the short term at least.

Management Considerations

The conservation goal for Oregon slender salamanders is to contribute to a reasonable likelihood of long-term persistence within the range of the species, including the maintenance of well-distributed populations, and to avoid a trend toward federal listing under the Endangered Species Act.

Although considerations can be developed for the entire range of the species, the variety of site conditions, historical and ongoing site-specific impacts, and population-specific issues warrants consideration of each site with regard to the extent of both habitat protection and possible restoration measures. Methods to identify occupied sites to manage to meet agency specific policy goals may involve surveys in areas of high conservation concern or locations with limited knowledge of species distribution or abundance patterns.

Modeled habitat suitability and risk maps (Appendices 2, 3, 4) provide useful landscape-to-site scale contexts for management of this species.

General considerations

To maintain an occupied site, an understanding of the site-extent and habitat quality is needed. Occupied habitats range from small patches to entire hillsides. For large sites, species management may vary across the site such that areas of conservative protection are identified, as well as areas for restoration or for management activities that have a higher risk to salamanders or their habitat integrity. To assess site extent, surveys may be conducted or the site extent can be visually estimated. For an estimate, once the presence of Oregon slender salamander has been determined at a site, all similar habitat contiguous with the site may be included as part of the site; occupancy may be assumed for contiguous similar habitat unless information demonstrates otherwise. Spatial heterogeneity in vegetation, microclimate, and illumination (as determined by aspect and topography) may also be used to qualitatively assess habitat suitability for these ground-dwelling salamanders.

Retention and both short-term and long-term recruitment of large down wood should be considered when managing sites of Oregon slender salamanders. At this time, there are no known minimum guidelines but studies suggest sizes and decay classes preferred by the species (Vesely et al. 1999). Vesely et al. (1999) found that the Oregon slender salamander was positively associated with large (51-70 cm) logs in decay classes of 4 and 5. Restoration of young managed stands might include thinning, and to promote tree growth for future large down wood recruitment. A short-term risk in altered microclimate conditions from reduced canopies might be weighed with a longer term benefit of growing larger trees.

Management activities in areas adjacent to known sites may be evaluated with regard to their affect on habitats and populations of salamanders. Exactly how edge effects may interact to affect suitable microclimate conditions for salamanders is unknown. Also unknown are the variances that may occur with different sorts of forest edge conditions (i.e., not all edges are clearcuts). Occupied sites that abut Federal reserve land allocations (e.g., botanical reserves, owl cores, riparian reserves) with similar suitable habitat conditions for salamanders may provide larger areas for subpopulations, habitat connectivity to other sites, and reduce fragmentation of the animal subpopulations across the landscape. In contrast, the habitat value for Oregon slender salamanders of private or industrial timber lands adjacent to federal sites may be limited. Managing sites for the maintenance of well-distributed populations may require this expanded look of the position of sites and habitats across land allocation and ownership boundaries. Also, an understanding of the variety of land management activities predicted to occur at each site relative to their impacts on salamanders and their habitat needs is important.

Also, landscape design needs consideration. Based on land allocations, some portions of watersheds may promote conditions for salamander persistence, with activities having higher risk to salamanders occurring in other portions. Effects to landscape habitat conditions might be considered relative to the quality, amount, and orientation of current and future habitat for the species, while acknowledging that many stands in a landscape may not currently be occupied by the species, the species may have a limited ability to disperse, and there are likely effects due to short or long term habitat barriers, particularly within checkerboard federal and private ownerships.

Specific Considerations

The following Considerations are actions or mitigations that a deciding official can consider as a means of providing for the continued persistence of the species' site. These considerations are not required and are intended as general information that field level personnel can choose to use and apply to site-specific situations.

- Maintain the integrity of substrates (avoid soil compaction) for subsurface refugia.
- Reduce, where possible, the area traversed by large machinery or over which logs are dragged.
- Maintain and manage for current and future large down wood (51+ cm or 20 inches plus) of various decay classes, especially 4 and 5, for current cover, and decay classes 1-3 for future cover. Grow large trees (51+ cm or 20 inches plus), and if current or future decayed down wood levels are or will be sparse, fell large trees.
- Maintain or restore canopy closure to retain cool, moist microclimate conditions. In old growth stands canopy closure was a median of 93 percent, with a range of 24 percent; in second growth stands, canopy closure was a median of 92 percent, with a range of 34 percent.
- Consider the benefits of partial harvest approaches. Thinning or aggregated green tree retention areas can reduce ground disturbance, retain canopy closure, ameliorate microclimate shifts, and provide standing trees to provide future down wood.
- Manage to reduce likelihood of stand replacement fires.
- Avoid chemical applications.
- Assess the proposed activity to identify the potential hazards specific to the site. The hazards and exposure to salamanders of some activities relative to ground disturbance, microclimate shifts, and incidental mortality may be minimal. A minimal or short-term risk may be inappropriate at a small, isolated population, whereas it may be possible in part of a large occupied habitat. Restoration activities can be assessed, in addition to other disturbances. Thus, both current and predicted future conditions of the site and its habitat can be considered during risk assessment procedures. If the risk, hazards, or exposure to actions are unknown or cannot be assessed, conservative measures are recommended.

- Seasonally restrict activities to dry summer or fall conditions. For land-use practices proposed for areas within Oregon slender salamander sites (e.g., thinning, prescribed fire), take the seasonal activity patterns of this species into consideration. Disturbance of animals and their habitats during wet periods (fall/spring), when animals have increased surface activities could result in direct mortality of individuals. A seasonal restriction for any ground disturbing activity may be implemented during wet spring, fall, or winter conditions to reduce direct mortality of animals. Exact dates of a seasonal restriction can vary, based on local conditions.
- Consider the context of the site with regards to the larger scale. Assess the amount and condition of adjacent reserve lands to determine if site management is needed, and whether a more protective or less protective approach is warranted.
  - Consider benefits of riparian reserves and upslope set-asides (e.g., leave islands, owl cores).
  - Consider proximity to large reserve blocks, maintain connectivity to such areas.
  - Consider proximity to lands unlikely to serve as suitable habitat and their possible edge effects.
- Consider monitoring the effects of land management on this species.
- Consider delineating the spatial extent of the area occupied by this species.
- Report observations of ill or dead animals. Individuals or tissues collected can be analyzed at regional or national laboratories.
- To avoid the spread of disease, disinfection protocols for field personnel and field gear are under development for aquatic habitats, and include soaking boots and field gear such as nets in bleach solutions between their use in different water bodies. Use of disposable gloves when handling diseased animals has been suggested. Similar disinfection of field gear used in terrestrial habitats could be applied.

V. INVENTORY, MONITORING, AND RESEARCH OPPORTUNITIES

Data and Information Gaps

Additional data are needed to refine distribution and management effects on this species. Both monitoring and research studies may contribute to knowledge gaps. Appendix 1 lists all information gaps determined by an interagency work group assessing this species. The work group determined that in particular, information is lacking in these priority areas:

- The distribution of the species: 1) to the south, west of the crest; 2) to the south, east of the crest; 3) to the west and northwest, west of the crest; 4) on federal reserve land allocations; 5) at higher elevations, east and west of the crest; and 6) relative to the two discrete genetic populations.

- The distribution of optimal habitat across the species range relative to federal land allocation.

- Assessment of threats relative to geographic distribution. In particular, is the species persisting at historically logged sites (1960s) and/or were these sites recolonized? Do size distributions of animals provide information on source/sink populations? Are there differences in species abundances related to amounts of down wood left behind?

- The response of the species to alternative silviculture activities such as differing intensities of density management, regeneration harvest, prescribed fire, and with differing levels of down wood retention and recruitment.

- The role of riparian reserves and other set-asides for population persistence at stand-to-watershed spatial scales.

- What is the movement capability of this species (including potential dispersal and home range distances, and movements down in the substrate in dry seasons and in low canopy closure stands)?

Work is currently underway to address some of these information gaps, and the progress to date is shared below:

- *The distribution of the species to the south, west of the crest.* In FY08, field surveys were conducted to assess the species distribution along the southwest of the species range, on lands administered by Eugene BLM and Willamette National Forest. Sites were selected for surveys based on occurrence of suitable habitat, from the landscape scale habitat suitability model (model is discussed and shared in Appendix 2). Of 42 forest sites surveyed across three watersheds (Winberry, Fall Creek, and Little Fall Creek), Oregon Slender Salamanders were found at only 2 sites in Little Fall Creek watershed. The species appears to be extremely patchy in occurrence in this portion of its range.

- *The distribution of optimal habitat across the species' range relative to federal land allocation.* Using existing site data, a habitat suitability model was developed in FY07 using habitat parameters that are available spatially, in Geographic Information System (GIS) coverages (Appendix 2 and 4). Attributes assessed for the model include climate data, forest composition, and topographic attributes such as elevation and aspect.

- *Assessment of threats relative to geographic distribution*. Relative to species locations and suitable habitat, as modeled for (1) above, the spatial distribution of key threats was investigated in FY07, as threat data are available in GIS coverages (Appendix 3). For example, since this species is associated with down wood and older forest conditions, an assessment can be made of the species habitat and range relative to likely forest harvest intensities. This was estimated by using the habitat model developed in (1) above, the distribution of forest lands by ownership, and the land use allocation.

- *Movement capability.* A mark-recapture study was initiated in FY08 to examine movements of individuals within a managed forest stand. This effort includes installment of two cover-board arrays at a managed forest site, to allow repeated sampling of this artificial cover that will not destroy existing down wood at the site. Cover boards were installed n summer 2008. FY08 sampling was begun in the fall, and due to a limited time of wet but not freezing weather, only a few animals were marked in that season. Efforts are expected to be renewed in spring 2009.

- *Habitat model validation.* In FY09, surveys will be conducted to field validate the Oregon Slender Salamander habitat suitability model (Appendix 2). A minimum of 80 randomly selected sites are expected to be surveyed for salamanders west of the Cascade Range crest, with 20 sites selected from each of four habitat suitability categories.

Inventory

Survey approaches may vary with objective and available resources. Several protocols can be considered for the Oregon slender salamander to detect presence and estimate relative abundance.

First, terrestrial mollusk surveys have routinely detected this species. An advantage of this approach is the multi-taxa sampling that can be conducted, and the streamlined approach used. However, it is uncertain if the microclimate conditions used for mollusks and the relatively small sampling area per plot may result in some false negatives for salamanders. The Survey and Manage terrestrial mollusk survey protocol is available at: http://www.blm.gov/or/plans/surveyandmanage/SP/Mollusks/terrestrial/IM-OR2003-mollusks-final-v3.htm

Second, standardized survey protocols were developed for the federal Survey and Manage program to help assess terrestrial salamander presence prior to habitat disturbing activities associated with land management and these may be applicable to the Special Status Species program. The survey protocol for the Larch Mountain salamander (*P. larselli*) also is suited for this species, due to its use of extensive transect surveys across suitable habitat patches. The Larch Mountain salamander similarly occurs in the Cascade Range, and may be detected in association with down wood. This protocol outlines survey procedures and environmental conditions that optimize detection probabilities. Surveys using this protocol may assist biologists with some of the information gaps such as, microhabitat conditions required by the species as well basic answers to the potential effects of various land management activities on the species. This survey procedure requires more effort than the terrestrial mollusk protocol. It is available online at: http://www.blm.gov/or/plans/surveyandmanage/SP/Amphibians99/protoch.pdf, Other protocols that may be appropriate for this species includes survey protocols for both the Siskiyou Mountains and the Del Norte salamanders; these are also available at the website shown above.

Third, surveys designed with a random site selection can provide inference to the larger landscape in which the surveys are conducted. This approach is useful for understanding the estimated occupancy patterns on different lands, such as federal reserves vs. matrix, or older vs. younger forest stands.

Other types of inventory or research methods may be needed for studies that address such questions as species-habitat associations, long-term effects of timber harvest, and other activities, movement or occupancy patterns. This type of work will have additional inference to the sampled population if random site selection is used. Nonrandom site selection results in case studies with implications only to the sampled sites; biased samples and results may occur. Pitfall trapping and mark-recapture methods may be effective approaches for long-term site or population studies (Heyer et al.1994). The success of artificial cover boards to survey for terrestrial salamanders has been limited in xeric forest habitats of southern Oregon (K. McDade, unpublished data), but may be effective within the range of this more northerly species. Nocturnal surveys may be effective, but may be hazardous to surveyors in remote areas.

Monitoring

Knowledge of land management activities at sensitive species' sites can enable monitoring and adaptive management relative to species management objectives. If impacts to sites occur, annual accomplishment reporting could be considered, and electronic data entry in GeoBOB/NRIS provides a standard format for documentation. Complete all applicable GeoBOB/NRIS data fields (e.g., site management status, non-standard conservation action; threat type; and threat description). With later monitoring, impacts to habitats or species can be recorded into GeoBOB/NRIS or other local or regional sensitive species databases in order to facilitate persistence assessments.

In particular, monitoring is needed to better understand the species' response to:
- Prescribed fire, especially for areas east of the Cascade Range
- Large-scale or high intensity fire
- Thinning
- Regeneration harvest with Northwest Forest Plan guidelines
- Alternative levels of down wood, with various overstory treatments
- Heterogeneous stands with riparian reserves, patch reserves, thinned areas, clearcut areas.

Resurveys of historic populations are needed, in addition to both implementation and effectiveness monitoring of past management actions. Have populations changed in the last few decades? How has land-use changed in the area over the last twenty years? What population-specific threats were present in the 1970's, and how have they changed today? Do current timber practices continue to impact this species at the same level as previously perceived? What protective measures have been implemented, and what were the results of this management?

Ongoing monitoring of current-populations and the implementation and effectiveness monitoring of currently-imposed protective measures also are needed. What are the recognized hazards, exposure to hazards, and risks to animals or habitats at each locality and for each population? How is management addressing each identified scenario of hazards, exposures, and risks per site or population? How can hazards be reduced over the long term in highly sensitive areas? Rather than always focusing on site-specific management, can the results of compiled risk analysis be used to generate long-term area management goals?

Research

The data gaps discussed above each relate to needed research on this animal. In particular, there is little information on how various management practices may affect microhabitats or populations of these salamanders. It is also of particular interest to investigate gene flow capability among discrete lineages, and to determine lineage boundaries.

The use of the Federal GeoBOB/NRIS databases will allow several questions of the spatial distribution of this species to be addressed for the development of landscape-level design questions and the further assessment of habitat associations. If sites surveyed with no detections were also reported in these databases, relationships in salamander distributions relative to the spatial distribution of vegetation types, slope, aspect, topography, elevation, riparian areas, land allocation, land ownership, historical disturbances, and current disturbances could begin to be assessed. A risk assessment is currently being developed between these factors and the long-term persistence of populations to assist in answering such questions as: are there populations or areas where stronger or relaxed protective measures may be warranted, or where adaptive management might be attempted? Development of strategies to address these questions of conservation biology is a critical research need.

VI. ACKNOWLEDGMENTS

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VII. DEFINITIONS

Persistence

The likelihood that a species will continue to exist, or occur, within a geographic area of interest over a defined period of time. Includes the concept that the species is a functioning member of the ecological community of the area.

Site (Occupied)

The location where an individual or population of the target species (taxonomic entity) was located, observed, or presumed to exist and represents individual detections, reproductive sites or local populations. Specific definitions and dimensions may differ depending on the species in question and may be the area (polygon) described by connecting nearby or functionally contiguous detections in the same geographic location. This term also refers to those located in the future. (USDA, USDI 1994)

Oregon and California Natural Heritage Program Definitions

Globally Imperiled

G2 – Imperiled because of rarity or because other factors demonstrably make it very vulnerable to extinction, typically with 6-20 occurrences.

G3 – Rare, uncommon, or threatened but not immediately imperiled, typically with 21-100 occurrences.

State Imperiled

S2 –Imperiled because of rarity or because of other factors demonstrably making it very vulnerable to extinction throughout its range.

S3 – Either very rare and local throughout its range, or found locally (even abundantly at some of its locations) in a restricted range, or vulnerable to extinction throughout its range because of other factors.

List 1 -contains taxa that are threatened with extinction or presumed to be extinct throughout their entire range

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APPENDIX 1

Information and Conservation gaps identified by an interagency workgroup for the Oregon slender salamander

During the spring and summer of 2006, a group of Forest Service and BLM biologists met on 5 occasions regarding the Oregon slender salamander. The goal of the group was to identify the information and conservation gaps regarding the species, and develop a strategy to address these gaps including tasks, personnel, costs, and timelines. The following displays the results of brainstorming the team did to identify the gaps in information and conservation for this species, as it relates to management under the agencies Special Status and Sensitive Species policies.

Team personnel consisted of:
Mike Blow, Eugene District BLM
Dave Clayton, Rogue River/Siskiyou National Forest
Steve Dowlan, Salem District BLM
Rob Huff, Region 6 Regional Office, Forest Service and Oregon State Office, BLM
Dede Olson, Pacific Northwest Research Station, Corvallis
Rich Thurman, Mt. Hood National Forest
Kelli Van Norman, Region 6 Regional Office, Forest Service and Oregon State Office, BLM
Fred Wahl, Willamette National Forest

Information and Conservation Gaps

Life History

- Movements (dispersal, home range distances)
- How far down in the substrate do they go in dry season, and in low canopy closure stands?

Habitat

- How to measure habitat attributes at stand level (goal is to assess and manage stands)?
- Define microsite requirements
  - Amount, size, and decay classes of downed wood
  - Canopy closure
  - Climate
- What is the role of riparian reserves in helping provide for the persistence of the species?
- What level of landscape connectivity is needed for species persistence?
- What is the distribution of habitat across the landscape, given land management allocations/ownership, elevation, climate (coarse filter)?
  - What is the potential for young stands to provide habitat?
  - Can we look at down wood recruitment potential? Where? When?

Survey/Survey efforts

- Determine the range of the species

    - refine southern range (and potentially habitat) both on westside (Eugene BLM) and eastside (Warm Springs, Deschutes National Forest)
    - distribution gap on westside Mt. Hood and Willamette National Forests (including the western edge; what is the western edge of the range)
    - Range gap - are there sites between eastside Mount Hood and Westside Columbia River Gorge?
- Compile site and survey data; we don't have it all in one spot (FS and BLM work)
    - Mining other data efforts: Warm Springs, Deschutes National Forest, "CVS" plot work, H.J. Andrews, USGS, etc.
- Need for a consistent survey protocol, data and habitat forms
    - What is the most efficient and cost effective detection technique?
    - How many site visits do we need for presence/lack of detection?
- Delineate the genetic sub-populations to answer questions about managing and conserving sub-pops.
    - Why do we have eastside Mount Hood populations? What sort of genetic link might there be between this population and westside sites?

Site Issues/Threats

- Need to be able to assess risk of a potential project upon this species, since we may not be able to survey for it all the time (or we may survey and find it….and do the project). Could develop a "risk assessment" model, Bayesian Belief model, habitat model map.
- What is a site? How to delineate a site.
- Are we recruiting adequate coarse woody debris?
- Is the species persisting at historically logged sites (1960s) and/or was it recolonization? Differences due to amounts of coarse woody debris left behind?
    - Are there juveniles? Measure reproductive capability? Sink/source?
- Need for development of a Conservation Strategy
    - Define management objectives for the species

Population monitoring/trends

- Post treatment surveys of treated sites (fire, thins, regen) looking at the effects/effectiveness of the treatment prescription.
    - What are the responses to alternative types of harvest and fuel treatments?
    - Is catastrophic fire a threat to sites and to species persistence?

The team then determined which gaps were the most relevant to address in order to help BLM and FS management of the species. Those medium and high priority information and conservation gaps are presented in the text of the document.

APPENDIX 2

Developing Landscape Habitat Suitability Models for the Oregon slender salamander (*Batrachoseps wrighti*) in the western Oregon Cascades

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July 2008

Abstract

I developed spatially explicit habitat suitability models for the Oregon slender salamander to aid in the species conservation planning on U.S. federal lands in the western Oregon Cascade ecoregion. The habitat suitability models were developed using non-linear nonparametric regression analysis in Generalized Additive Models by comparing GIS data on climate, topographic, and forest stand structure variables between randomly selected known salamander sites and locations where no known salamander sites were previously reported. The analysis of individual habitat attributes indicated that Oregon slender salamanders are more likely to occur in areas with lower elevations, warmer temperatures, moderately lower precipitation, and taller, older forest stands with larger tree diameters and basal areas. Increasing hardwood canopy cover and basal area, particularly bigleaf maples, also appeared to be important factors for the distribution of this salamander. A Generalized Additive Model with precipitation, minimum daily temperature, forest stand height, and basal area of Pacific silver fir was selected as the final habitat suitability model with 83% likelihood of being the best model among the 8 top models. The final model correctly classified 64% of salamander sites as suitable (sensitivity) and 62% of random sites as unsuitable (specificity) with the total correct classification of 63%. Based on the final model, odds ratios were calculated as values of habitat suitability and mapped across the landscape to facilitate practical use of a habitat suitability map for forest landscape planning.

Introduction

The Oregon slender salamander (*Batrachoseps wrighti*) is endemic to Oregon, occurring in a small geographic area mostly on the west slopes of the Cascade Range but some sites are known on the east slopes near the Columbia River (Nussbaum et al. 1983, Leonard et al. 1993, Blaustein et al. 1995, Storm 2005). To date very little is known about the biology and ecology of this plethodontid salamander; however, its close association with forest stands at advanced successional stages (mature and old-growth forests) has frequently been documented (Nussbaum 1983, Leonard et al. 1993, Blaustein et al. 1995, Storm 2005). Certain structural characteristics of forest stands, such as abundance of large downed wood and high levels of canopy closure, have been hypothesized as providing key habitat components and suitable microhabitat conditions for the Oregon slender salamander (Gilbert and Allwine 1991, Vesely 1999). In addition, the occurrence of this species may be related to some topographic features, such as slope aspect, that are closely linked to microclimate (Vesely 1999). Moist microclimate is thought to play an integral role in maintaining optimal habitat conditions for plethodontid salamanders, which rely on moist skin for gas exchange (Feder 1983). To my knowledge, only one study quantitatively assessed habitat associations of the Oregon slender salamander (Vesely

1999). The presumed association of the Oregon slender salamander with late-successional forests raises concerns for loss of their potential habitat by human activities, such as timber harvesting (Blaustein 1995), and natural causes, such as catastrophic fires.

The objective of this project was to develop spatially explicit habitat suitability models for Oregon slender salamanders across the western Oregon Cascade ecoregion.

Methods

I assessed the habitat suitability of Oregon slender salamanders across the landscape by comparing Geographic Information Service (GIS) data on climate, topographic, and forest stand structure variables between randomly selected known salamander sites and locations where no known salamander sites were previously reported. I developed habitat suitability models using the nonlinear semi-parametric regression analysis in Generalized Additive Models (GAM).

Selection of salamander sites and random points for analysis

I compiled 1006 known sites of the Oregon slender salamander from the Geographic Biotic Observation (GeoBOB) database, Natural Resource Information System (NRIS) database, and Natural Heritage database. GeoBOB and NRIS are maintained by USDI BLM and USDA Forest Service, respectively (Pers. Comm. Kelli Van Norman, BLM Oregon State Office, Portland) and Natural Heritage database is maintained by Oregon Natural Heritage Information Center at Oregon State University. Among these databases, 878 known sites were identified between 1993, at the initiation of federal Northwest Forest Plan process, and 2006, at the initiation of this study. Only 147 known sites were identified prior to 1993.

From the 878 known sites identified since 1993, I randomly selected 211 known sites of Oregon slender salamanders on federal lands in the western Oregon Cascade Range. Randomly selected salamander sites were at least 1 mile apart from each other to distribute the random selection throughout the study area and to reduce the amount of spatial autocorrelation. For selection of random points for habitat comparisons, I overlaid 12 40-km x 40 km grid cells over the map of the study site (6 rows and 2 columns = 12 grid cells from north to south). For each grid cell, I selected a number of random points equal to the number of randomly selected salamander sites for that grid cell as well as for each land use allocation type within the grid. A total of 211 random points were selected across the landscape to match the 211 randomly selected salamander sites. I selected no known record of salamander sites within 1 mile of randomly selected points and the distance between random points was greater than 1 mile.

GIS Data

The selection of habitat parameters from GIS data was based on the hypotheses that Oregon slender salamanders are associated with: 1) a certain range of microclimate conditions; and 2) a set of stand structural characteristics typically found in late-successional forests. To test these hypotheses and develop habitat suitability models, I selected climate and topographic parameters that directly affect microclimate conditions and forest stand characteristics that indicate successional stages or tree species compositions that indicate microclimate conditions.

Climate. I obtained climate data (1971-2000) from the PRISM (Parameter-elevation Regressions on Independent Slopes Model) climate mapping system (available at http://prism.oregonstate.edu/). I used 800 m GIS grid data of annual precipitation, daily minimum temperature (averaged over 365 days), and daily maximum temperature (averaged over 365 days).

Topography. I used a 30 m digital elevation model (DEM) to estimate elevations at selected points and to create GIS layers of flow accumulation, hill shade, slope, aspect, and curvature of the land surface in Arc GIS spatial analysis tools. The SW aspect index, also known as the heat load index, was based on the equation: index value = (1-cos (ϴ-45))/2, where ϴ-45 degrees is expressed in radians. This SW aspect index is 1 at the southwest aspect (225^o), which absorbs the greatest amount of solar radiation during the day, and is 0 at the northeast, which absorbs the least amount of solar radiation. The EW aspect index = |sin ϴ| gives a maximum value of 1 for either east (90^o) or west (270^o) and a minimum value of 0 for either north (0^o) or south (180^o). This index was intended to characterize aspects of moderate solar radiation input. The NS aspect index gives a maximum value of 1 for south and a minimum value of 0 for north [NS aspect index = (1-cos ϴ)/2]. The spatial scale of all topographic variables was 30 m to characterize conditions in immediate vicinity of known salamander sites.

Stand structure and tree species. Forest stand structure and basal area of tree species were based on 30 m GIS grid layers from GNN (Gradient Nearest Neighbor imputation) vegetation mapping projects for the western Oregon Cascade ecoregion by the Landscape Ecology, Modeling, Mapping & Analysis (LEMMA) team (data available at http://www.fsl.orst.edu/lemma/common/mr.php?model_region=6). The GNN method of mapping forest composition and structure was explained in Ohmann and Gregory (2002). Among the information available in the original GNN grid layers, I selected 14 stand structural attributes and 6 tree species attributes for analysis of habitat association and development of a habitat suitability model (Tables A2.1). I used focal statistics to calculate average values of each attribute over 210 m x 210 m areas (10.90 acres/ 4.41 ha) and 810 m x 810 m areas (162.13 acres or 65.61 ha). The smaller scale (210 m) approximates a typical size of area (10 acres) used to survey plethodontid salamanders in the region and the larger scale (810 m) approximately corresponds to the spatial scale of climate data.

Data Analysis and Mapping

Values from each habitat-attribute GIS layer were extracted for randomly selected salamander sites (n = 211) and randomly selected points (n = 211) in a point shape file. Association of salamanders with each variable was tested using univariate logistic Generalized Additive Model (GAM) as well as using a Wilcoxon rank-sum test.

To develop habitat suitability models, I formulated 46 combinations of habitat attributes as *a priori* models and selected the best model using an information theoretic approach (Burnham and Anderson 2002). Each variable in these 46 *a priori* models also was tested for its model fit in linear, loess (lo), and spline (s) functions, and the best function was determined based on the lowest Akaike Information Criteria (AIC) value. To avoid multicollinearity, correlations between variables were screened with Pearson's correlation coefficient using all selected sites (*n*

= 422; PROC CORR; SAS Institute 1999). Variables with a strong correlation ($r > 0.7$) were not included in the same GAM model.

The best model was validated using the 10-fold cross-validation procedure (Stone 1974, Efron and Tibshirani 1993). In this procedure, data were randomly selected and divided into 10 mutually exclusive subsets, each representing an equal number of known sites and randomly selected points; 9 of the 10 subsets were used to develop the model and 1 remaining subset was used to validate the model. This process was repeated 10 times using different subsets to validate the model each time. Average classification results from validations of 10 subsets were used as the overall model performance. The best model was used to map odds ratios of salamander occurrence as habitat suitability values across the landscape. I examined the GAM function of each habitat variable in the best model to identify the range of values with high levels of uncertainty in producing reliable habitat suitability values. These ranges of values in the best model were used to map areas of uncertainty associated with habitat suitability values across the landscape.

Results

Univariate Analysis

Climate. Daily minimum and maximum temperatures were greater at salamander sites than at random sites (Figure A2.1 and Table A2.1, also see Figure A2.2a and A2.2g). Furthermore, annual precipitation was less at salamander sites than random sites. Oregon slender salamanders tended to occur in warm, moderately dry habitats of the western Oregon Cascade Range. Their occurrence increased with decreasing precipitation and peaked around 2100 mm annual precipitation. The lower AIC values of temperature attributes relative to that of precipitation indicated that temperature appeared to affect the distribution of this salamander more than precipitation (Figure A2.1).

Topography. Oregon slender salamanders were more likely to be found at lower elevations (Table A2.1 and Figure A2.1). It also appears that they tended to occur on south west slopes, which receive the highest solar radiation inputs among all aspects; however, this habitat association is inconclusive due to inconsistency in p-values from different analyses (GAM and Wilcoxon test, Table A2.1 and Figure A2.1). They were not associated with either east or west slopes, or with either north or south slopes. They also were not associated with hill shade (or solar illumination), a GIS index of amount of solar radiation, which accounts for elevation, slope, topographic shade in calculation. The potential associations of this species with flow accumulation and land curvature were inconclusive.

Stand Structure. Forest stand height was the best predictor of the salamander occurrence based on the lowest AIC values among 14 stand structure attributes (Figure A2.1). Forest stands were taller, older in age, greater in tree diameter and basal areas at salamander sites than at random sites (Table A2.1). Hardwood canopy cover and hardwood basal area were also consistently positively associated with the salamander occurrence. None of the 3 attributes of down wood volume were significantly associated with salamander occurrence. This lack of association may indicate difficulties of predicting down wood volume from the currently available landscape down wood model at the special scale relevant to the habitat association of the Oregon slender salamander.

Tree Species. Oregon slender salamanders were less likely to occur in areas with increasing abundance of Pacific silver fir, which is generally associated with higher elevation (Figure A2.1 and Table A2.1). They were more likely to occur in areas with increasing basal areas of hard wood species, particularly big-leaf maple.

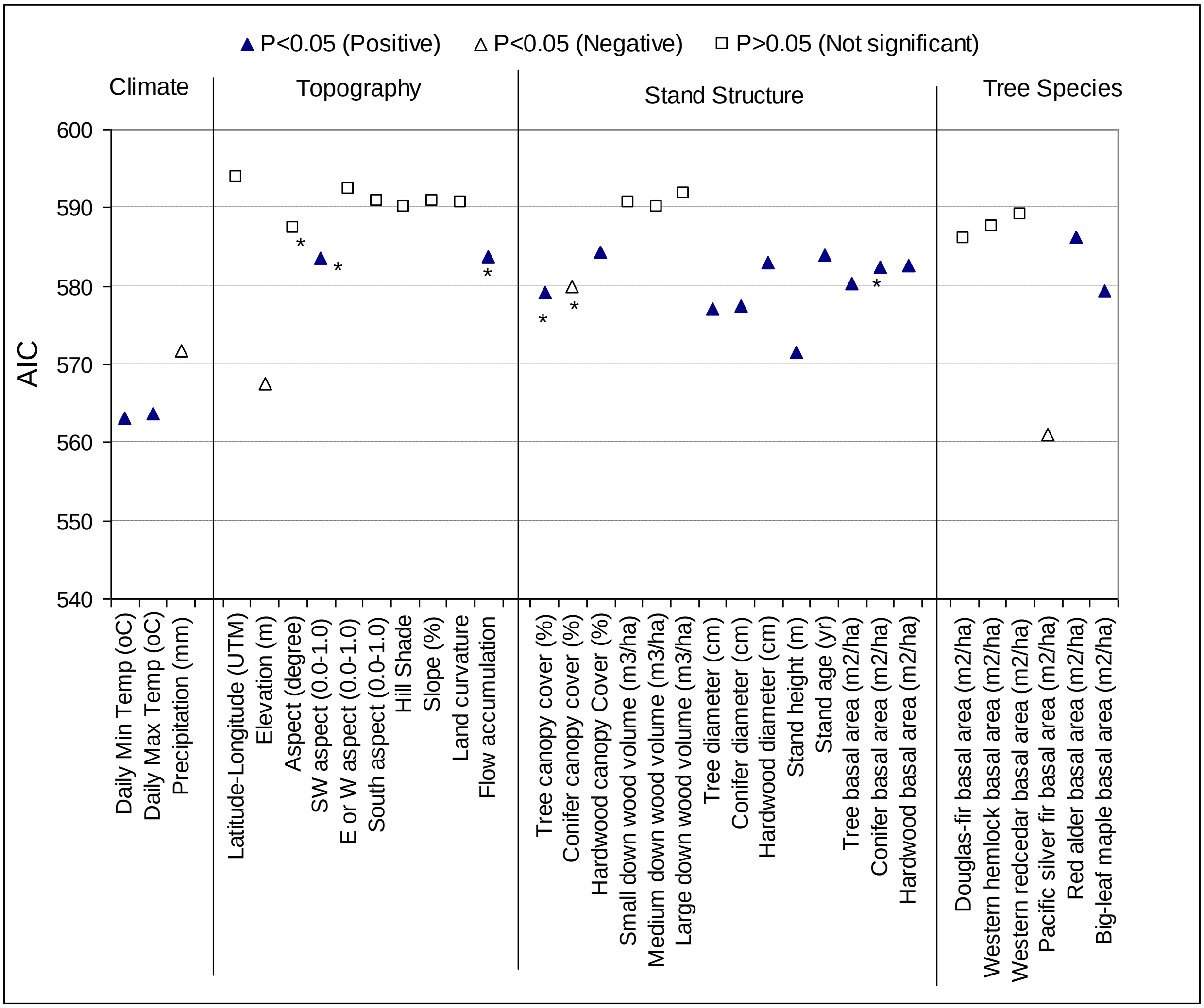

Figure A2.1. Effects of ecological attributes on presence of Oregon slender salamanders in the western Oregon Cascade Ecoregion based on univariate logistic regression analysis in a Generalized Additive Model (GAM). Solid triangles and empty triangles indicate significant positive and significant negative associations, respectively, of ecological attributes with salamander presence. The AIC value of each attribute indicates strength of association, which allows comparisons of association strengths among attributes. A lower AIC value indicates a stronger association. * indicates there is an inconsistency in P-values between univariate GAM and Wilcoxon rank-sum test, suggesting that interpretations of these variables are inconclusive.

Table A2.1. Effects of habitat attributes on presence of Oregon slender salamanders in the western Oregon Cascade Ecoregion based on comparisons between 211 known salamander sites (Salamander) and 211 random sites (Random) in Wilcoxon rank-sum tests and univariate logistic Generalized Additive Models (GAM). Variables in bold letters indicate consistently low *P*-values (*P*<0.05) for both Wilcoxon tests (*P*-WRS) and GAM (*P*-GAM). The ranking (RK) of Akaike Information Criterion values (AIC) from GAM provides evidence of support for each variable relative to other variables (lower the RK value, higher the level of support).

	Salamander		Random					
Variable	Mean	SE	Mean	SE	*P*-WRS	*P*-GAM	AIC	RK
Climate								
Min Temp (oC)	**3.45**	**0.09**	**2.92**	**0.10**	**<.0001**	**<0.0001**	**563.13**	**2**
Max Temp (oC)	**14.22**	**0.10**	**13.60**	**0.11**	**<.0001**	**<0.0001**	**563.75**	**3**
Precipitation (mm)	**2097.44**	**23.60**	**2186.74**	**27.21**	**0.0084**	**0.0001**	**571.76**	**6**
Topography								
Latitude-Longitude (UTM)	N/A	N/A	N/A	N/A	N/A	0.2911	593.84	33
Elevation (m)	**733.25**	**20.23**	**871.78**	**22.87**	**<.0001**	**<0.0001**	**567.60**	**4**
Aspect (degree)	195.47	7.15	175.53	7.12	0.046	0.1079	587.43	22
SW aspect (0.0-1.0)	0.54	0.02	0.51	0.03	0.3199	0.0214	583.51	16
E or W aspect (0.0-1.0)	0.63	0.02	0.60	0.02	0.3582	0.6317	592.44	32
South aspect (0.0-1.0)	0.50	0.02	0.51	0.03	0.5831	0.3909	590.90	30
Hill Shade	222.06	1.96	222.61	1.98	0.6669	0.2829	589.98	25
Slope (%)	31.94	1.54	33.67	1.52	0.3001	0.3826	590.84	29
Land curvature	0.00	0.06	0.09	0.06	0.0557	0.3495	590.57	27
Flow accumulation	37.70	12.66	62.97	36.17	0.2828	0.0239	583.77	17
Stand Structure								
Tree canopy (%)	73.73	0.55	72.30	0.82	0.7052	0.0034	579.26	9
Conifer canopy (%)	69.93	0.70	69.31	0.94	0.6286	0.0046	579.95	11
Hardwood canopy (%)	**9.83**	**0.68**	**7.86**	**0.64**	**0.0044**	**0.0297**	**584.28**	**19**
Small down wood (m3/ha)	213.89	6.15	213.60	7.23	0.9803	0.3437	590.68	28
Medium down wood (m3/ha)	196.21	6.04	195.51	7.13	0.9491	0.2873	590.02	26
Large down wood (m3/ha)	138.24	5.32	136.48	6.15	0.7135	0.5021	591.86	31
Tree diameter (cm)	**47.79**	**0.93**	**43.26**	**1.06**	**0.0035**	**0.0013**	**577.12**	**7**
Conifer diameter (cm)	**49.44**	**0.93**	**44.52**	**1.05**	**0.0012**	**0.0015**	**577.46**	**8**
Hardwood diameter (cm)	**9.20**	**0.60**	**6.79**	**0.53**	**0.0027**	**0.0173**	**583.02**	**15**
Stand height (m)	**26.89**	**0.45**	**24.12**	**0.52**	**0.0003**	**0.0001**	**571.57**	**5**
Stand age (yr)	**84.17**	**3.25**	**73.91**	**2.67**	**0.0294**	**0.0262**	**584.01**	**18**
Tree basal area (m2/ha)	44.21	0.85	41.45	1.02	0.076	0.0055	580.41	12
Conifer basal area (m2/ha)	41.97	0.91	39.82	1.07	0.2087	0.0133	582.40	13
Hardwood basal area (m2/ha)	**2.24**	**0.18**	**1.62**	**0.15**	**0.0012**	**0.0151**	**582.70**	**14**
Tree Species Basal Area								
Douglas-fir (m2/ha)	27.30	0.92	24.98	1.01	0.0434	0.0606	586.00	20
Western hemlock (m2/ha)	7.32	0.48	8.52	0.56	0.0912	0.1182	587.62	23
Western redcedar (m2/ha)	2.57	0.31	2.45	0.26	0.4848	0.0947	589.02	24
Pacific silver fir (m2/ha)	**1.27**	**0.40**	**2.77**	**0.45**	**<.0001**	**<0.0001**	**561.11**	**1**
Red alder (m2/ha)	**1.06**	**0.15**	**1.01**	**0.17**	**0.0435**	**0.0389**	**586.31**	**21**
Big-leaf maple (m2/ha)	**1.06**	**0.19**	**0.56**	**0.08**	**0.0051**	**0.0031**	**579.33**	**10**

Habitat Suitability Model and Model Validation

There was strong evidence (Δ AIC < 2) to suggest that the model with precipitation, minimum daily temperature, forest stand height, and basal area of Pacific silver fir was the best model (Table A2.2, first row). The cumulative value of w*i* also suggested that there was an 83% likelihood that this model was the best model among the 8 top models in Table A2.2. The functional shape of 4 variables in the best model is presented in Figure A2.2a – A2.2d. The range of values with high prediction uncertainty, thus likely to produce unreliable habitat suitability values, was identified from each variable function at points where upper confidence and lower confidence trend lines started to show inconsistencies and where coefficient of variation (CV) exceeded 100%. Adjusted functions for 3 of the 4 variables in the best model (precipitation, minimum daily temperature, and basal area of Pacific silver fir) were developed by extending constant values from the point of last reliable values (Figure A2.3). No adjustment was necessary for the forest stand height variable due to its low variability and to its consistent upward trends between upper and lower confidence predictions.

The best model with adjusted functions correctly classified 64% of salamander sites as suitable (sensitivity) and 62% of random sites as unsuitable (specificity) with the total correct classification of 63% based on the 10-fold cross-validation procedure. Based on the best model, odds ratios were calculated as values of habitat suitability and mapped across the landscape (Figure A2.4a and A2.4b).

Table A2.2. Habitat models of Oregon slender salamanders. Models with Δ AIC < 10 are shown. All models were based on logistic Generalized Additive Models (GAM). "s" indicates a spline function used to create a nonlinear fit of a variable.

Top models	K	AIC	Δ AIC	w*i*	∑(w1-w*i*)
Presence ~ s(precip) + s(min temp) + stand height + s(P. silver fir)	**5**	**536.86**	**0**	**0.829**	**0.829**
Presence ~ s(precip) + s(min temp) + stand height + s(SW aspect)	5	541.69	4.83	0.074	0.903
Presence ~ s(precip) + s(min temp) + stand height + s(flow accumulation)	5	542.64	5.78	0.046	0.949
Presence ~ s(precip) + s(min temp) + stand height	4	544.54	7.68	0.018	0.966
Presence ~ s(precip) + s(min temp) + s(DBH)	4	545.58	8.72	0.011	0.977
Presence ~ s(precip) + s(min temp) + s(P. silver fir)	4	545.99	9.13	0.009	0.986
Presence ~ s(precip) + s(min temp) + s(P. silver fir)	4	545.99	9.13	0.009	0.994
Presence ~ s(precip) + s(min temp) + stand height)+ s(Big-leaf Maple)	5	546.81	9.95	0.006	1.000

Note: Precip = annual precipitation (mm), min temp = minimum daily temperature averaged over 365 days.

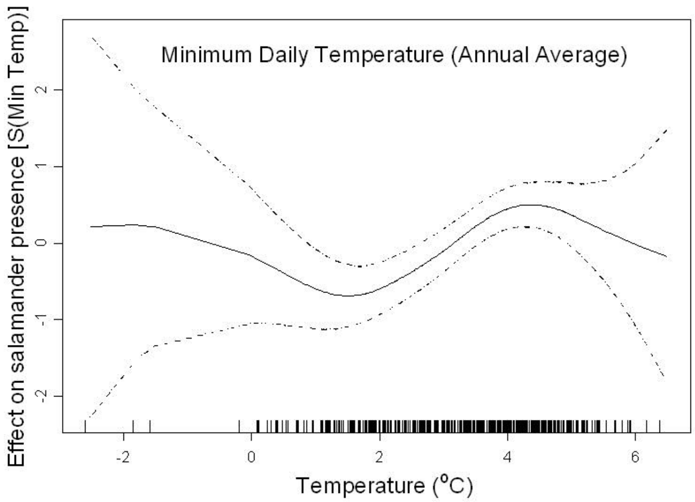

Figure A2.2a Spline function of minimum daily temperature in a Generalized Additive Model showing positive effects of increasing temperature on salamander presence.

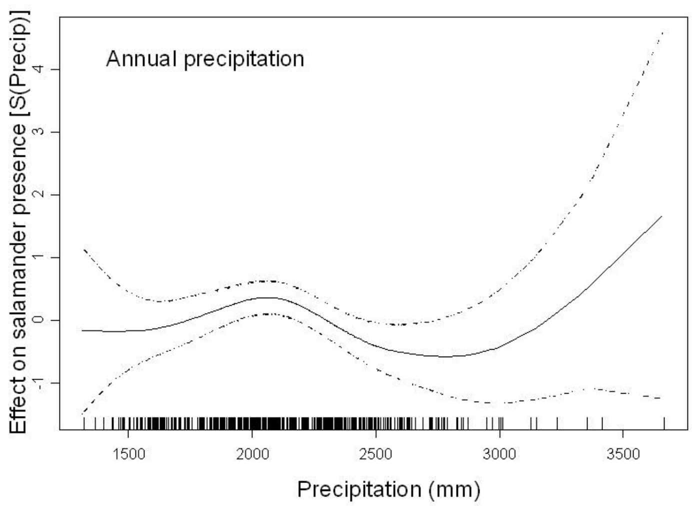

Figure A2.2b Spline function of precipitation in a Generalized Additive Model showing a peak in the positive effect of increasing annual precipitation on salamander distribution followed by a negative effect of increasing precipitation.

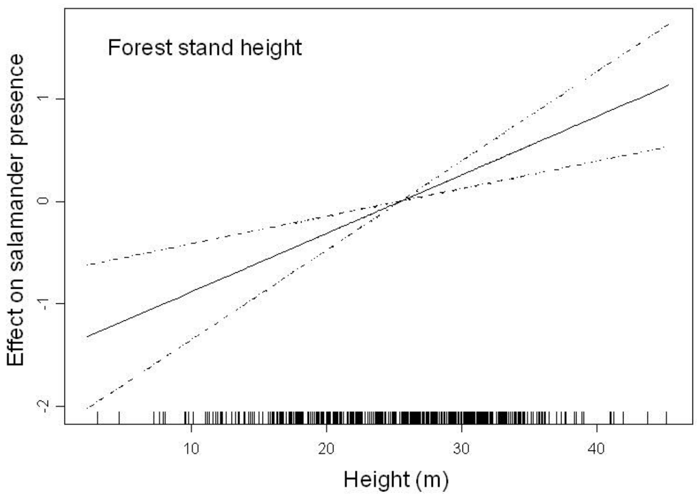

Figure A2.2c Linear function of forest stand height in a Generalized Additive Model showing the positive effect of increasing stand height on salamander distribution.

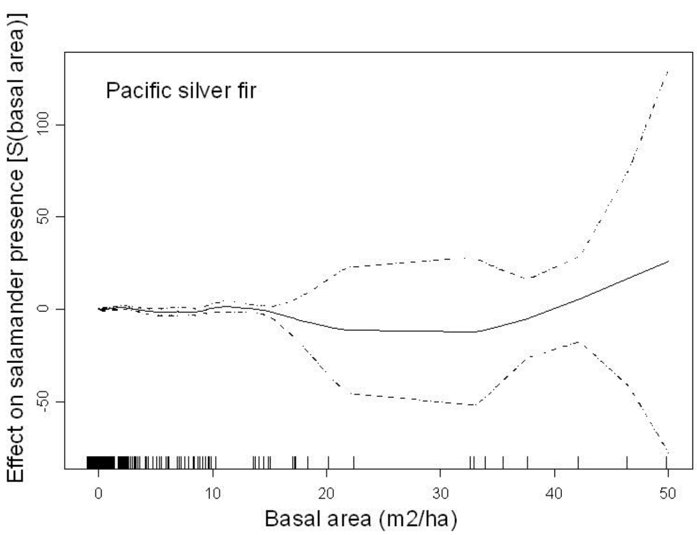

Figure A2.2d. Spline function of Pacific silver fir basal area showing the negative effect of increasing Pacific silver fir up to around 15 m2/ha and a sudden increase in uncertainty of prediction.

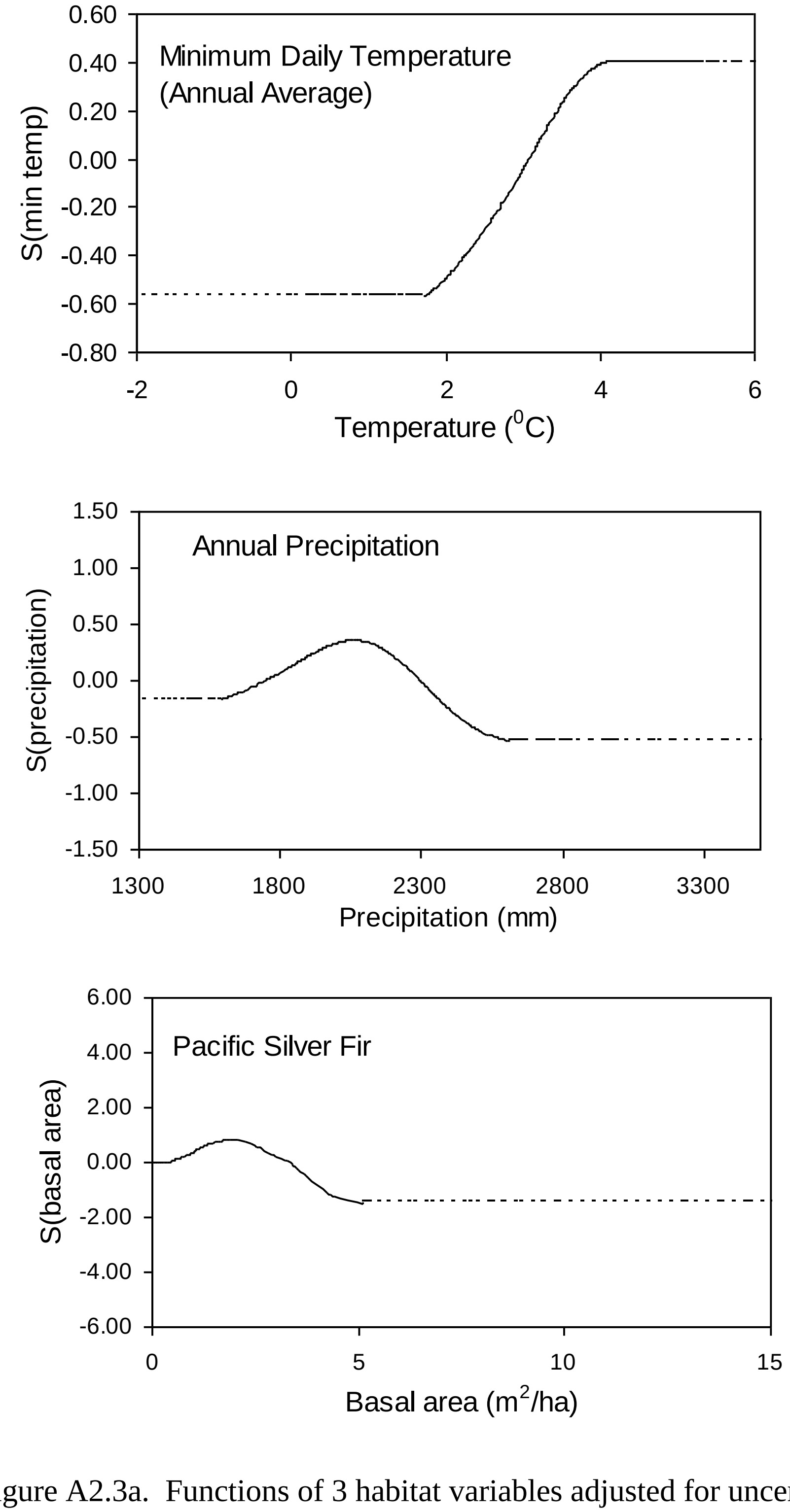

Figure A2.3a. Functions of 3 habitat variables adjusted for uncertainty. These adjusted functions of minimum daily temperature, annual precipitation, and Pacific silver fir basal area were used along with the unadjusted function of forest stand height (Figure A2.3b) in the final GAM model to estimate habitat suitability of Oregon slender salamanders in the western Oregon Cascade ecoregion.

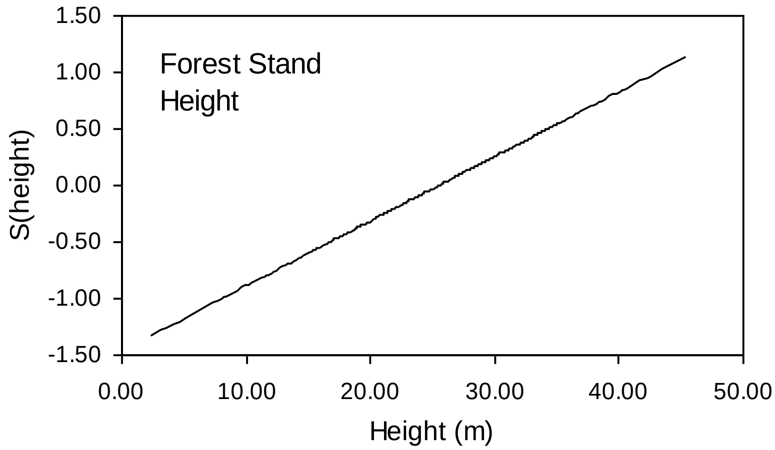

Figure A2.3b. The function of forest stand height used in the final GAM model to predict habitat suitability of Oregon slender salamanders in the western Oregon Cascade ecoregion. No adjustment was necessary for the forest stand height variable due to its low variability.

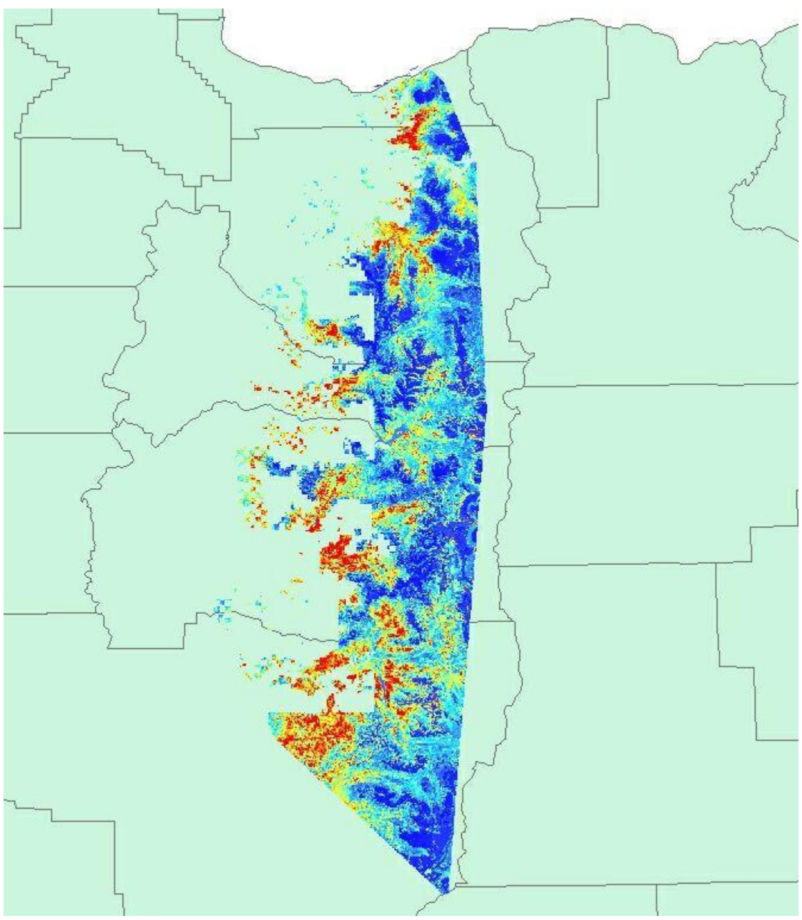

Figure A2.4a. Habitat suitability map for Oregon slender salamanders in the western Cascades ecoregion on federal lands based on the best model with minimum daily temperature, annual precipitation, forest stand height, and Pacific silver fir basal area. Highly suitable habitats are in red and unsuitable habitats are in blue.

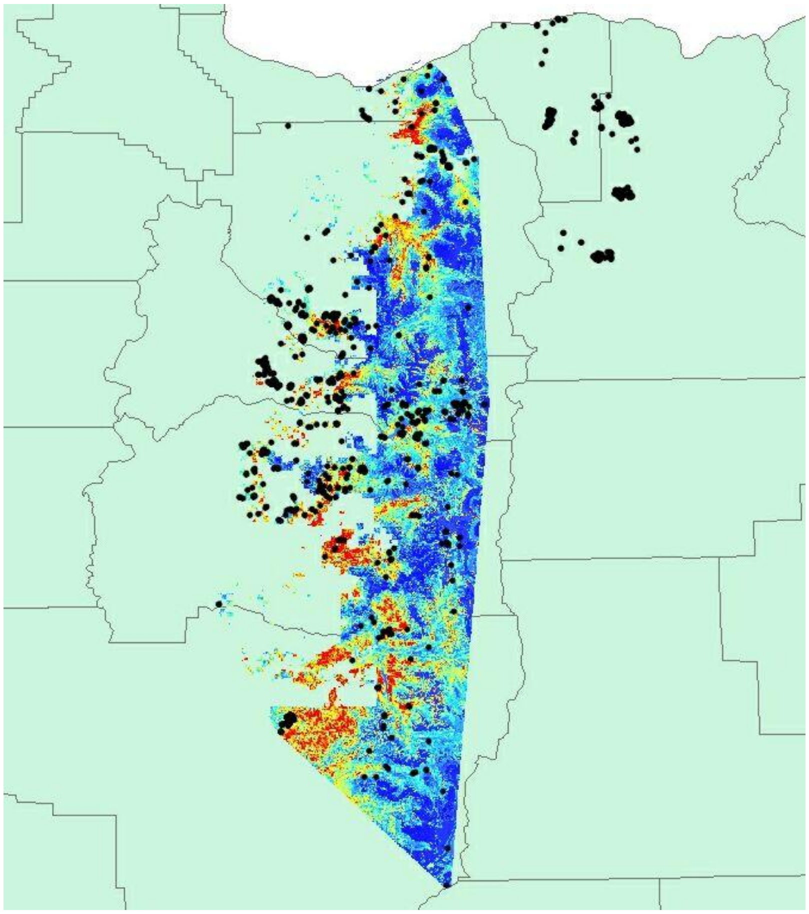

Figure A2.4b. Habitat suitability map for Oregon slender salamanders with currently known slender salamander sites.

Findings

The analysis of individual habitat attributes indicated that Oregon slender salamanders are more likely to occur in areas with lower elevation, warmer temperatures, moderately lower precipitation, taller, older forest stands with large tree diameters and basal areas. Increasing hardwood canopy cover and basal area, particularly bigleaf maples, also appear to be important factors for the distribution of this salamander.

Daily minimum and maximum temperatures were greater but annual precipitation was less at salamander sites than at random sites. Therefore, Oregon slender salamanders tended to occur in warm, moderately dry habitats of the western Oregon Cascade Range. Their occurrence increased and peaked around 2100 mm in precipitation followed by a slightly decrease along the gradient of decreasing precipitation. The lower AIC values of temperature attributes relative to that of precipitation indicated that temperature appeared to affect the distribution of this salamander more than precipitation.

Oregon slender salamanders tended to occur on south west slopes, which receive the highest solar radiation inputs among all aspects. However their association with aspect is not strong. I also did not find a strong evidence for the association of this species with hill shade index, flow accumulation, and land curvature.

Among the 14 attributes of stand structure, forest stand height was the best predictor of salamander occurrence. Forest stands were taller, older in age, greater in tree diameter and basal areas at salamander sites than at random sites. This finding is consistent with previous descriptions of this species' frequent association with late successional forests (e.g., Nussbaum 1983, Leonard et al. 1993, Blaustein et al. 1995, Storm 2005). Hardwood canopy cover and hardwood basal area were also consistently positively associated with salamander occurrence. None of the 3 attributes of down wood volume were significantly associated with salamander occurrence. This lack of the species' association with down wood may be related to the difficulty of estimating down wood distribution across the landscape using the available GIS coverages, especially when a much finer spatial scale is likely more meaningful for the Oregon slender salamander (i.e., microhabitat-scale availability of down wood). Further research efforts are needed to improve predictions of down wood spatial distribution that could be better incorporated into a habitat suitability model of the Oregon slender salamander or other down wood associated species.

Oregon slender salamanders were less likely to occur in areas with increasing abundance of Pacific silver fir, which is generally associated with higher elevation. In contrast, they were more likely to occur in areas with increasing basal area of hard wood species, particularly bigleaf maple.

A Generalized Additive Model (GAM) with precipitation, minimum daily temperature, forest stand height, and basal area of Pacific silver fir was selected as the final habitat suitability model with 83% likelihood of being the best model among the 8 top models. The final model correctly classified 64% of salamander sites as suitable (sensitivity) and 62% of random sites as unsuitable (specificity) with the total correct classification of 63%. Based on the final model, odds ratios were calculated as values of habitat suitability and mapped across the landscape to facilitate practical use of this habitat suitability map for conservation planning process.

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APPENDIX 3

Assessment of risk to conservation of the Oregon slender salamander (*Batrachoseps wrighti*) in the western Oregon Cascade Range

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July 2008

Abstract

A wide variety of human induced and natural disturbances occur throughout the range of the Oregon slender salamander. I assessed levels of potential risk associated with land use allocations, distribution of wildland urban interface, fire, and distribution of roads in relation to the estimated habitat suitability of the Oregon slender salamander on federal lands in the western Cascade ecoregion. Among the 49 5th-field watersheds I examined, 11 were identified as potentially having both high risk and high habitat suitability. All the watersheds with top quartile habitat suitability had relatively high cumulative risk (risk levels > median), indicating that there are high degrees of potential conflicts between conservation of habitat and human activities or fire. Potentially high cumulative risk to the species' habitat occurs in the western portion of the Oregon slender salamander's range in the western Oregon Cascades. The central-western portion of the species' range in the region has many federal lands with high habitat suitability occurring in small parcels, and with a high potential cumulative risk mainly due to the high concentrations of actively managed federal timber lands (matrix and adaptive management areas) and private lands, as well as roads. The southwestern portion of the species' range has high potential cumulative risk mainly due to high risk of fire; furthermore, large blocks of contiguous federal lands with high habitat suitability occur in this region. The northwestern corner of the species' range appears to have the highest potential risk due to the high concentrations of actively managed federal timber lands, private lands, and roads, along with the presence of wildland unban interface; however, the habitat suitability of this area is relatively low. These illustrations of the risk analysis in relation to habitat suitability across the landscape will provide valuable strategic information for conservation of the Oregon slender salamander and other species that occupy similar habitats in the same ecoregion.

Introduction

The Oregon slender salamander (*Batrachoseps wrighti*) occurs in forested habitats, mainly on the west slopes of the Oregon Cascade Range. A wide variety of human activities occur in the geographic range of this species. Among these, logging, road building, and urban development potentially alter current habitat conditions and may adversely affect populations of Oregon slender salamanders. In addition to direct human activities, forest stand replacement fires may significantly alter current habitat conditions. Although fires occur naturally, the expansion of densely stocked young forests, decades of fire suppression, and increased human presence in forested landscapes may further exacerbate conditions for severe fire events. No studies to date have examined the effects of these human activities or fire on habitats or populations of the Oregon slender salamander.

My objective was to assess distributions of potential risk factors relative to predicted habitat suitability of this species across the landscape. It should be noted that studies still are necessary to demonstrate whether a potential risk factor in fact is linked to conditions of species' habitats and populations. A risk factor in this report is defined as a factor that potentially alters current conditions of species' habitat. Specifically, I assessed levels of potential risk associated with land use allocations (LUA), distribution of wildland urban interface (WUI), fire, and distribution of roads in relation to the estimated habitat suitability of the Oregon slender salamander on the federal lands in the western Cascade ecoregion.

Methods

I developed Geographic Information Systems (GIS) layers of 4 potential risk factors (fire, LUA, WUI, road density) and a cumulative risk from existing GIS layers related to these factors. Risk scores were stored in grid cells (30 m initial cell size) for each GIS grid layer of potential risk. By using the spatial distributions of these risk factors along with the habitat suitability layer (Appendix 1), I assessed 5^{th}-field watershed for levels of potential risk for each factor and all factors combined in relation to habitat suitability for the Oregon slender salamander.

Developing GIS Layers of Potential Risk

Fire Risk

There was no single GIS layer that provided comprehensive scores of potential fire risk for the purpose of this project. Consequently, I developed GIS layers of potential fire risk for the western Oregon Cascade ecoregion by synthesizing existing GIS layers of various individual fire risk factors. Existing GIS layers were based on a wide variety of individual aspects of fire risk, such as fire behavior and specific stand characteristics. I obtained GIS layers of individual fire risk factors developed by the Landscape Fire and Resource Management Planning Tools Project (LANDFIRE), a project cooperatively administered by the U.S. Department of Agriculture Forest Service and U.S. Department of the Interior (data available upon request at http://www.landfire.gov/). These GIS layers of fire risk factors included: 1) 4 canopy fuel characteristics (canopy bulk density, canopy cover, canopy height, and canopy base height); 2) Fire Behavior Fuel Models; and 3) fire regimes layers (percent low-severity fire, percent mixed-severity fire, percent replacement-severity fire). In addition, I used daily maximum temperature and annual precipitation from PRISM climate data (Daly et al. 1994; current data available at http://www.prism.oregonstate.edu/), elevations from Digital Elevation Model (DEM, 30m), slope, and the SW aspect index (Appendix 2) to generate climatic and topographic attributes associated with fire risk.

I identified the following 4 categories of fire risk factors based on: forest canopy fuel conditions (CF), topography (TO), climate (CL), and fire fuel behavior fuel model category (FB). For each of the 4 categories, I determined conditions of greater than median risk across the landscape based on attributes considered in each risk category. CF is risk based on the following forest canopy fuel conditions: 1) greater than median canopy bulk density and 2) greater than median canopy cover, with either 3) greater than median canopy height or 4) less than median canopy base height. I considered fire risk for CF would be high when canopy bulk density and canopy height were high and canopy base height were low. TO is risk based on the following 2 topographic conditions: 1) greater than median value of heat load index and 2) greater than median value of slope. TO would be considered high fire risk when heat load index were high (south-west aspect) and slope were steep, which might accelerate the spread of fire into upslope areas. CL is fire risk based on the following climate conditions: 1) less than median value of precipitation and 2) greater than median value of annual daily maximum temperature. Fire risk for CL would be considered high when the amount of precipitation were low and temperature were high. FB is fire risk based on fire behavior fuel model category: classification of vegetation types based on fire behavior (rate of spread and fuel length of fire) according to Scott & Burgan (2005) Fire Behavior Fuel Models.

For example, for the CF category, I identified areas across the landscape where canopy cover and canopy bulk density were both greater than the median value of the study area (the range of the Oregon slender salamander within federal lands in the western Oregon Cascades). These areas with high canopy cover and with high canopy bulk density were further narrowed by areas with either greater than median canopy height or lower than median canopy base height. For the FB category, I identified areas where fire behavior classification ranking was above median in terms of rate of fire spread. Each of the GIS layers created for these 4 risk categories served as a single fire risk factor model (Table A3.1). Five versions of multiple fire risk factor GIS models were created by selecting areas of union and/or intersection of 2 or more layers of single factor models. The final model of potential fire risk (Table A3.1, model 9; Figure A3.1) was based on union of model 4 (fire behavior), model 5 (canopy fuel-topography intersection), and model 6 (canopy fuel-climate intersection). Grid cells (30 m) that meet the risk condition were assigned the value 1 and non-risk cells were assigned value 0.

Table A3.1. Fifteen GIS models of fire risk factors and mapping conditions that define spatial distribution of risk areas for each model. Union of GIS layers was indicated by (U) and intersections were indicated by (∩).

Models	Mapping Conditions
Single Risk Factor GIS Models	
1. Canopy fuel condition (CF)	CF (see text)
2. Topography: Slope and Aspect (TO)	TO (see text)
3. Climate: Precipitation and Max Daily Temperature (CL)	CL (see text)
4. Fire behavior fuel model category (FB)	FB (see text)
Multiple Risk Factor GIS Models	
5. Canopy fuel and Topography	CF∩TO
6. Canopy fuel and Climate	CF∩CL
7. Canopy fuel, Topography, and Climate	CF∩TO∩CL
8. Canopy fuel and Topography /Canopy fuel and Climate	(CF∩TO)U(CF∩CL)
9. (Canopy fuel and Topography /Canopy fuel and Climate) and Fire behavior fuel model	[(CF∩TO)U(CF∩CL)]U(FB)

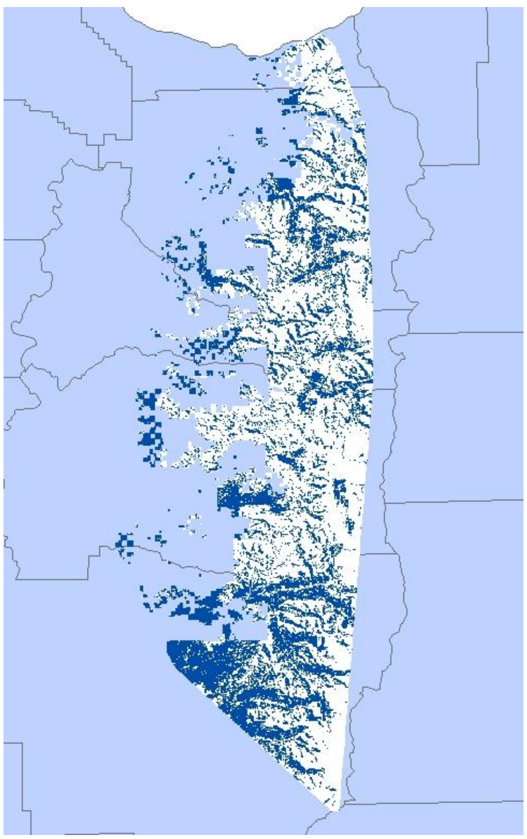


Figure A3.1. Fire Risk Factor Model No. 9 (Table A3.1) accounts for the intersection of risky canopy fuel conditions and risky topography as well as the intersection of risky canopy fuel conditions and risky climate along with areas classified as high fire risk based on fire behavior fuel model.

Land Use Allocation Risk

Because it is difficult to determine levels of risk among various federal land use allocations, I simplified and reclassified the initial types of federal land allocation into the following 3 categories based on similarity in their sizes and management schemes: 1) federal managed timber lands, 2) small reserves < 100 ha, 3) large reserves > 100 ha. In addition, private lands adjacent to or surrounding parcels of federal lands were considered as the fourth category in the analysis. Federally managed timber lands included federal matrix lands and Adaptive Management Areas. Large reserves were any federally reserved lands (Late-successional Reserves, Adaptive Management Reserves, Administratively Withdrawn Lands, and Congressional Reserves) that were > 100 ha. Small reserves were any federally reserved lands that were < 100 ha and federal riparian reserves. There was no single comprehensive GIS layer of federal riparian reserves for the entire range of Oregon slender salamander; therefore, I used a 150-foot riparian buffer on each side of all streams within a GIS stream coverage (USGS map with 1:24000) as an estimate of federal riparian reserves.

A GIS shape file of land use allocation was converted to a GIS grid layer (30 m cell size) to store risk scores among various land use categories across the landscape. The lowest mean risk score was given to the land category with the lowest relative likelihood of negative habitat change and successively higher mean risk scores were given to land allocations with higher relative likelihoods of negative habitat change. I defined large reserves as the lowest risk category and gave it a mean risk level = 0 by assigning their grid cells with random numbers, with standard normal distribution of mean = 0 and standard deviation (SD) = 1. Small reserves were defined as the next lowest risk category and I raised its mean risk level to 1 by assigning random numbers with normal distribution of mean = 1 and SD =1. For the presence of active land-management activities, mean risk levels of federally managed timber lands and private lands were raised to 3 and 4, respectively, by assigning random normal numbers with mean = 3 and SD = 1 for federal managed timber lands and with mean = 4 and SD = 1 for private lands. This risk assignment assumes timber harvest activities on private lands have a greater effect on salamander habitats than those on federal lands, which may be supported by increased harvest intensity (less green tree or down wood retention) and frequency (minimum of ~30-yr rotations on private lands, ~80-yr rotations on federal lands). Based on these assignment schemes of normally distributed random risk scores to the land use categories, mean risk scores were determined to be 1 SD apart between a land-use category in one risk level to another land use category in the next risk level. Two SD apart would mean that random scores were drawn from 2 completely different populations of numbers.

Wildland Urban Interface Risk

Assignments of risk scores to wildland urban interface (WUI) were similar to those assigned to land use allocations, but these assignments were conducted independently. After the polygon shape file of WUI was converted to a 30 m GIS grid layer, I assigned normally distributed random numbers with mean = 0 and standard deviation = 1 for grid cells outside WUI, and with mean =1 and SD =1 for cells inside of WUI, assuming the habitats inside the boundary were more likely to be altered by management activities than the habitat outside.

Road Risk

Although effects of roads on the Oregon slender salamander are unknown, we included roads as a potential risk factor to examine how road networks were distributed in relation to known salamander sites and potentially suitable habitats. A GIS layer of the Oregon road map based on the USGS 1:24000 topographic map was used to assess potential risk associated with the road network within the species range. The shape file of road network layer was converted to a grid layer of 30 m cell size. These grid cells were assigned a value =1 where roads were present.

The GIS road layer represented the general pattern of road distributions across the landscapes, which was sufficient for the purpose of this project. However, road densities on the ground may be ~10% higher than those estimated from the GIS layer (M. Blow, BLM, personal communication, Feb. 15, 2008).

Calculating risk scores for landscapes

I used focal statistics to calculate either the mean or sum of risk factors in a 810 m x 810 m square neighborhood (162.13 acres or 65.61 ha) of each 30-m grid cell across the landscape. For the road risk raster and the fire risk raster whose cells were coded as 1 = potential risk present and 0 = potential risk absent, the sum of 30-m grid cells with potential risk present was calculated. For risk factors of land use allocation and wildland urban interface, mean risk scores of 30 m grid cells were calculated for the square neighborhood around each cell. For each risk factor, neighborhood risk values stored in grid cells across the landscape were rescaled to values 1 (lowest risk) to 100 (highest risk) based on 1-100 percentiles of the original neighborhood risk values (Figures A3.2 and A3.3). Cumulative risk was calculated by summing percentile risk values of 4 factors and rescaling these summed values to 1-100 percentile scores (Figures A3.2 and A3.3).

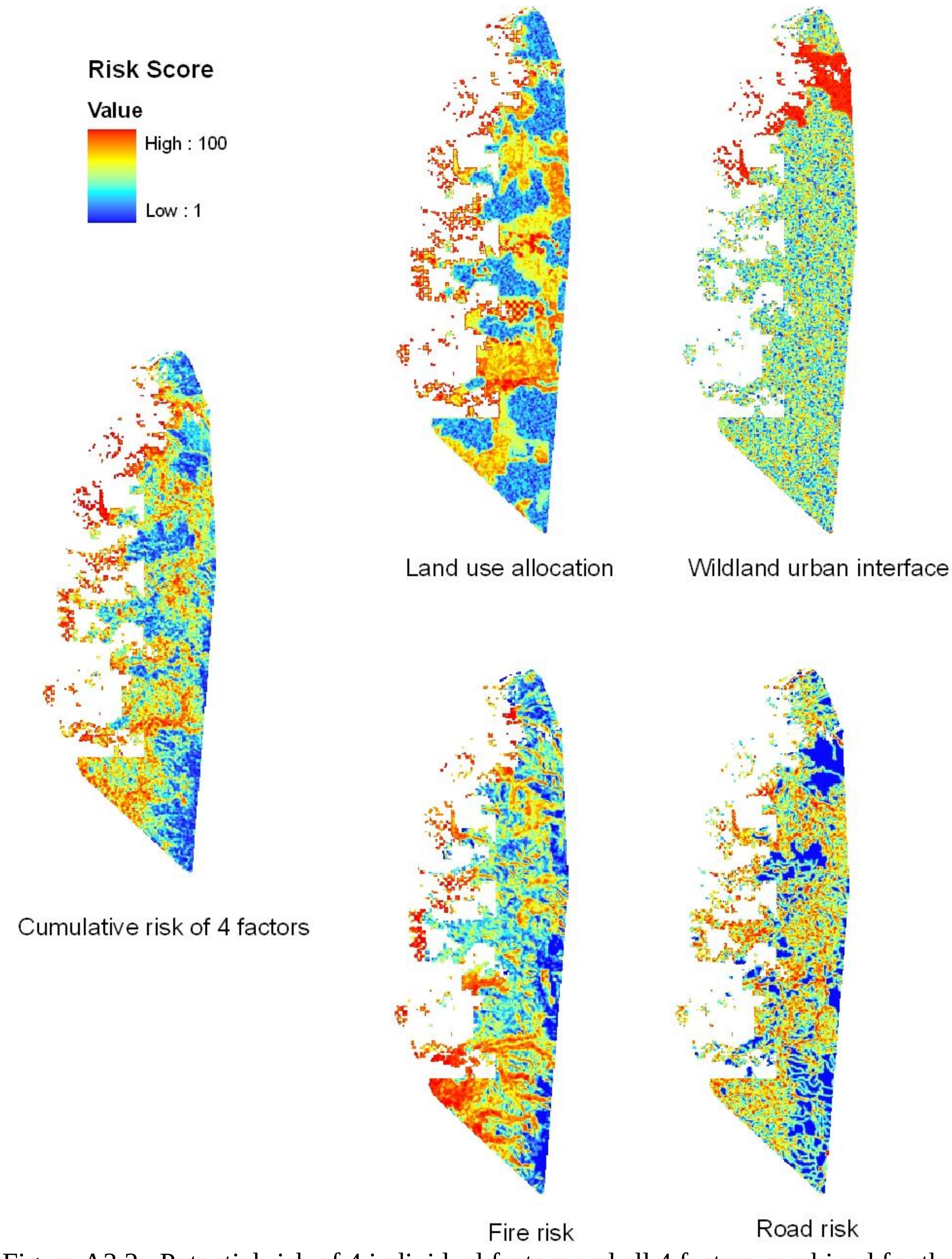


Figure A3.2. Potential risk of 4 individual factors and all 4 factors combined for the federal lands within the range of the Oregon slender salamander in the western Oregon Cascade ecoregion. Scores were calculated for an 810 m x 810 m neighborhood around each 30-m grid cell and re-scaled to the scores of 1 to 100 percentiles.

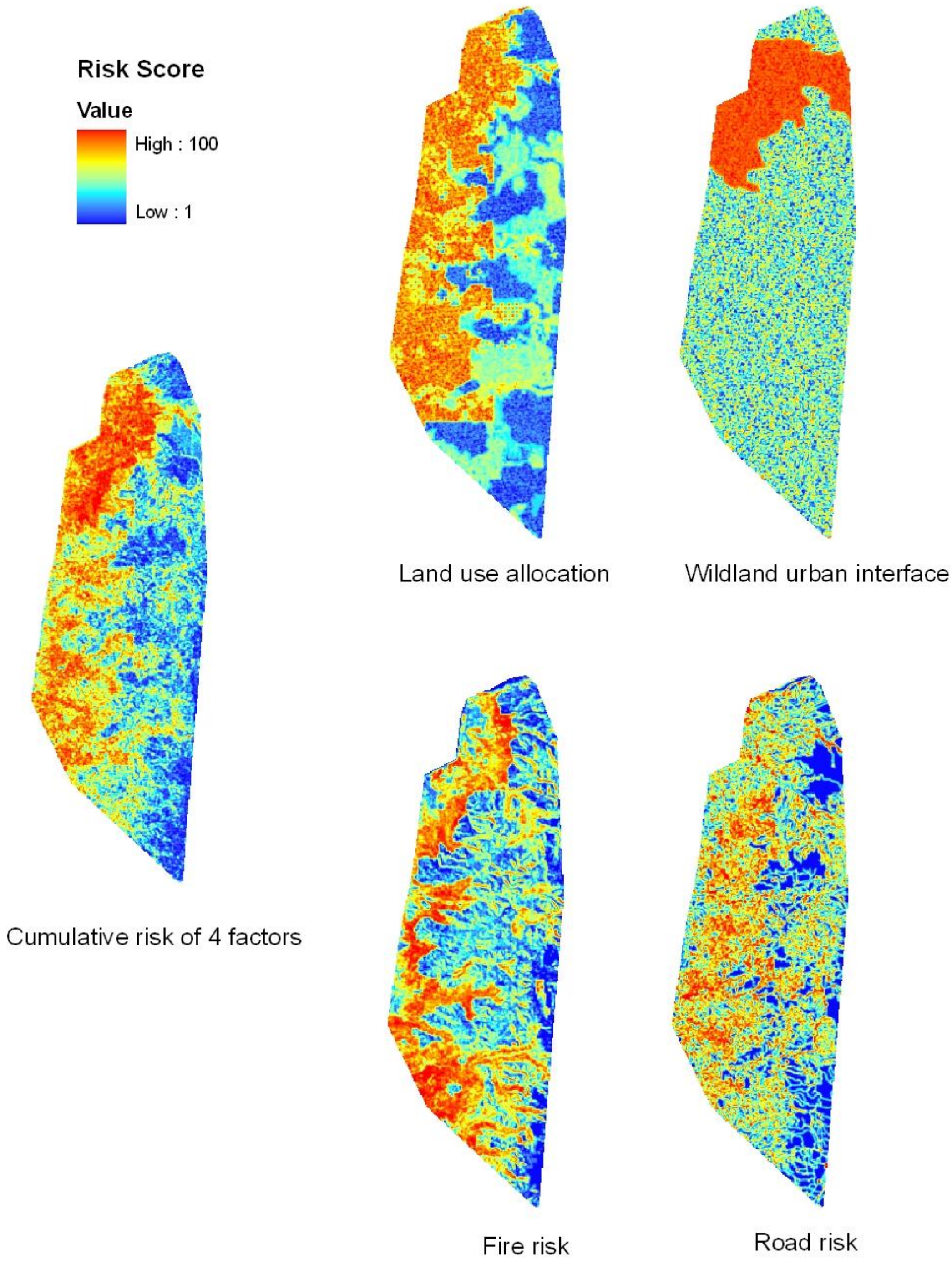


Figure A3.3. Potential risk of 4 individual factors and all 4 factors combined for the range of the Oregon slender salamander in the western Oregon Cascade ecoregion; both federal and non-federal lands were included in the analysis. Scores were calculated for an 810 m x 810 m neighborhood around each 30m grid cell and re-scaled to the scores of 1 to 100 percentiles.

Analysis of risk at the watershed scale

I assessed risk patterns at an intermediate scale using 5th-field watersheds (hydrologic unit code, HUC) to partition the larger landscape. There were 49 5th-field watersheds within the area of this analysis, the range of Oregon slender salamander in western Oregon Cascade ecoregion (Figure A3.4). Cumulative risk scores as well as risk scores of individual risk factors were averaged for each 5th-field watershed (Figures A3.5a and A3.6) and for the federal lands within each 5th-field watershed (Figures A3.5b and A3.7). Similarly, habitat suitability scores were averaged over the federal lands within the 5th-field watershed (Figure A3.8). Using an X-Y plot, I ordered 5th-field watersheds along x-axis with increasing habitat suitability from left to right as well as noting the position of each watershed relative to median and 75 percentiles of habitat suitability scores for the 49 watersheds (Figure A3.9a-A3.9f). Along the y-axis, an average risk score of each watershed was plotted in a 1-100 percentile scale, which was used to determine whether a watershed had a high risk (> 75 percentile), moderate risk (> median), or low risk (< median) for a particular risk factor or combination of all factors. A series of these X-Y plots (Figure A3.9a-A3.9f) were used to identify watersheds that potentially support high habitat suitability (suitability > 75 percentile) while being threatened by high risk levels (>75 percentile) of at least one factor (Table A3.2).

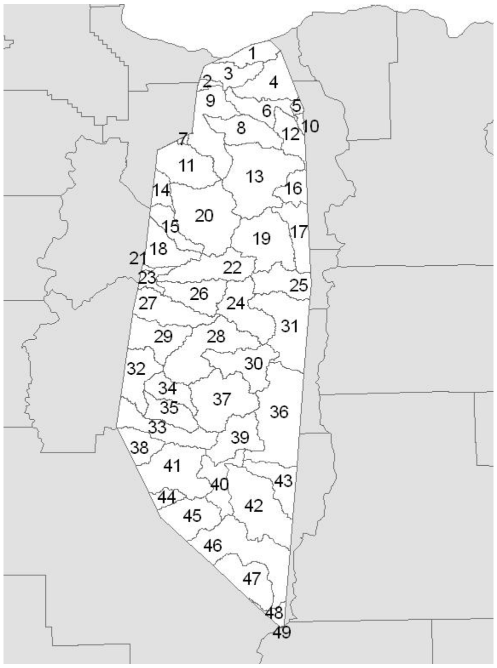


Figure A3.4. Identification numbers (ID) and names of 5th-field watersheds within the range of Oregon slender salamanders in the western Oregon Cascade ecoregion.

ID	5th Field Watershed Name
1	Columbia Gorge Tributary
2	Johnson Creek
3	Lower Sandy River
4	Bull Run River
5	Upper Sandy River
6	Middle Sandy River
7	Abernethy Creek
8	Eagle Creek
9	Lower Clackamas River
10	Zigzag River
11	Lower Molalla River
12	Salmon River
13	Middle Clackamas River
14	Rock Creek-Pudding River
15	Butte Creek-Pudding River
16	Oak Grove Fork Clackamas River
17	Upper Clackamas River
18	Abiqua Creek-Pudding River
19	Collawash River
20	Upper Molalla River
21	Mill Creek-Willamette River
22	Little North Santiam River
23	Lower North Santiam River
24	Detroit Reservoir-Blow Out Divide Creek
25	North Fork Breitenbush River
26	Middle North Santiam River
27	Thomas Creek
28	Quartzville Creek
29	Crabtree Creek
30	Middle Santiam River
31	Upper North Santiam River
32	South Santiam River-Hamilton Creek
33	Calapooia River
34	South Santiam River-Foster Reservoir
35	Wiley Creek
36	Upper McKenzie River
37	South Santiam River
38	Mohawk River
39	Blue River
40	McKenzie River-Quartz Creek
41	Lower McKenzie River
42	South Fork McKenzie River
43	Horse Creek
44	Little Fall Creek
45	Fall Creek
46	North Fork of Middle Fork Willamette River
47	Salmon Creek
48	Salt Creek-Willamette River
49	Deschutes River-Browns Creek

Results

Distribution of potential risk at the landscape scale

There were generally high concentrations of risk in the western portion of the Oregon slender salamander's range at the landscape scale (Figures A3.2 and A3.3). The distinction in risk scores between western and eastern portions of the range examined is more pronounced in Figure A3.3 than Figure A3.2 due to the inclusion of private lands, which are highly concentrated in the western portion, in the analysis. Potential risk of fire is high at the western fringe of the species range, particularly at the southwestern corner. Wildland-Urban Interface only occurs at the northern section of the species range.

Distribution of potential risk and suitable habitats at the 5th-field watershed scale

Potential cumulative risk is higher in the western half of the species range than the rest (Figure A3.5). High risk associated with land use allocation and roads coincide in the western portion (Figures A3.6a, 6d, 7a, and 7d). These risk maps indicate juxtapositions of federal managed and private lands as well as high concentrations of roads potentially contributing to the relatively high cumulative risk in the western portion of the species range. Potential risk of fire is mainly concentrated on the southwest corner of the species range (Figure A3.6c).

The highest potential cumulative risk occurs in the northwest portion of the species range due to the designation of the northwest portion as Wildland-Urban Interface (WUI) in a landscape that is already dominated by actively managed federal matrix and private lands (Figures A3.5, A3.6b, A3.7b). In the northwestern portion of the range, lands with moderate to high potential suitability of salamander habitat occur in an area around Bull Run River (ID = 4) and Lower Sandy River (ID =3).

More Lands with potentially high habitat suitability at the 5th-field watershed scale occur from the central-west portion to south-west corner of the species range (Figure A3.8). The largest area of contiguous federal lands within one of the potentially most-suitable habitat blocks occurs in the Fall Creek watershed (See Figure 3, ID = 45), followed by the lower McKenzie River basin (ID = 41). Federal lands with high suitability also occur in small parcels at west-central locations (e.g., Mill Creek-Willamette River (ID=21), Abiqua Creek-Pudding River (ID = 18), Lower North Santiam River (ID = 23), South Santiam River-Foster Reservoir (ID = 32)).

Assessment of risk in relation to habitat suitability

Eleven 5th-field watersheds were classified as potentially having both high habitat suitability and high levels of risk in at least 1 factor (Table A3.2, Figures A3.9, A3.10, and A3.11). Among these 11, 6 had potentially high cumulative risk, 8 had potentially high risk associated with land use allocation, 5 had risk associated with fire, and 2 had potentially high road risk, and only 1 had potentially high risk associated with Wildland Urban Interface.

When levels of potential risk were lowered and moderate risk (risk levels > median) was considered (Table A3.3), Butte Creek-Pudding River (ID =15) appears to be vulnerable to all the

4 risk factors as well as cumulative risk of these factors. Lower North Santiam River had high risk (>75 percentile) associated with land use allocation, roads, and moderate risk (> median) associated with fire.

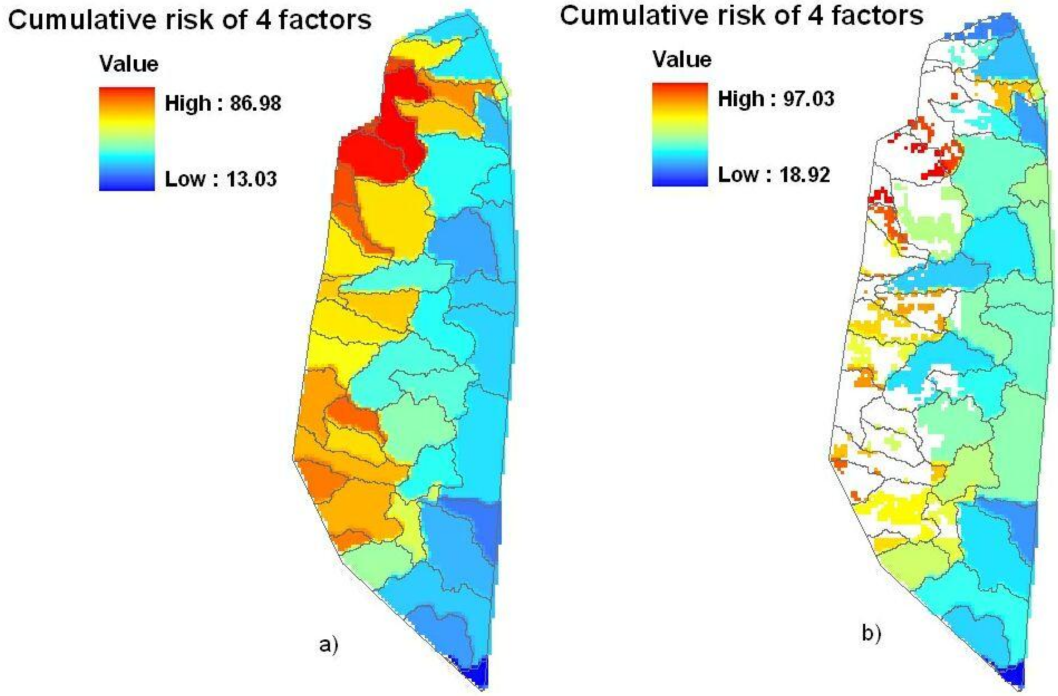


Figure A3.5. Cumulative risk scores of 4 risk factors (land use allocation, wildland urban interface, fire, and road) of Oregon slender salamanders, within the species range in the western Oregon Cascade ecoregion, averaged over: a) 49 5^{th}-field watersheds; and b) federal lands within 49 5^{th}-field watersheds.

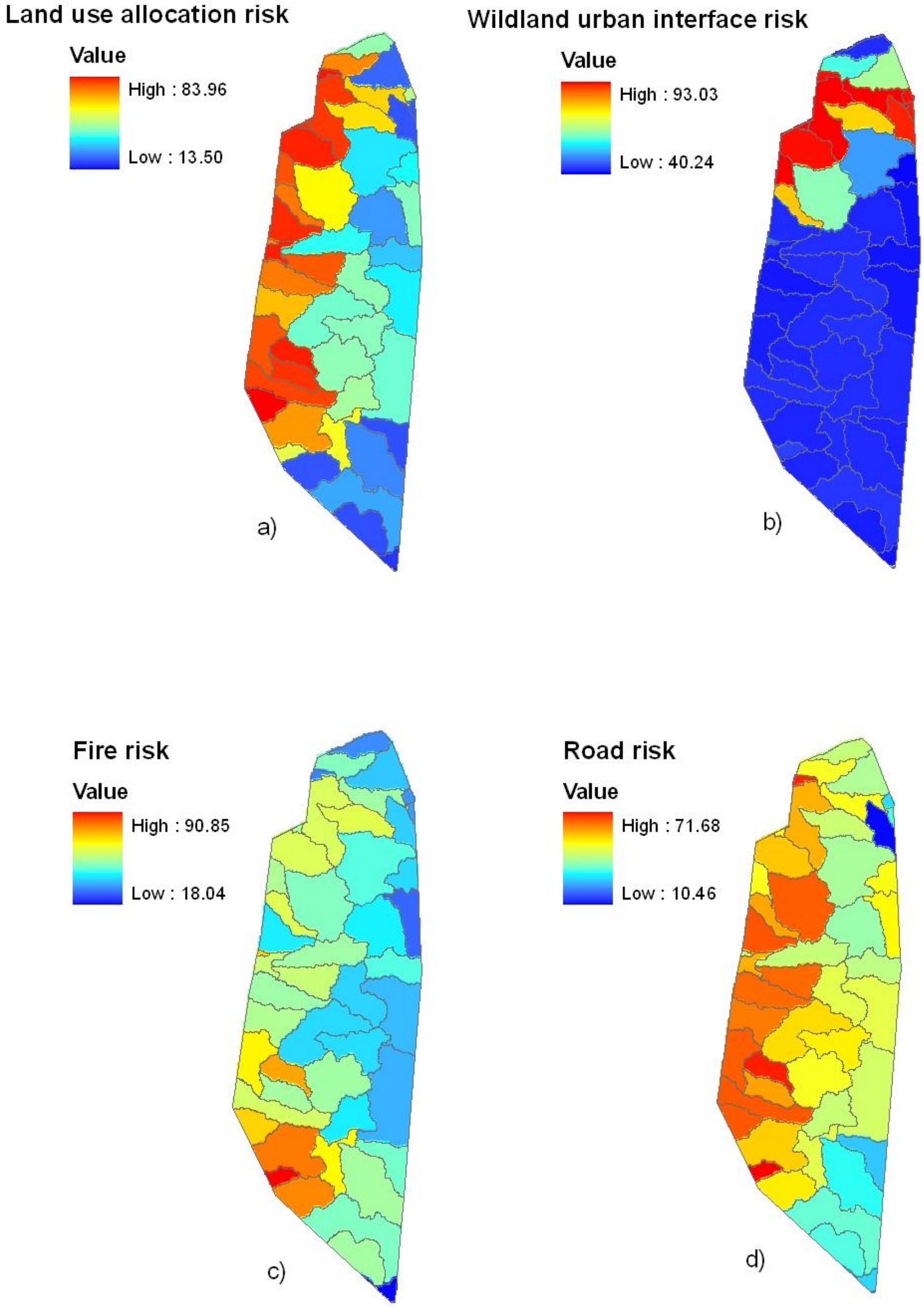


Figure A3.6. Relative risk associated with a) land use allocation, b) wildland urban interface, c) fire, and d) roads within the range of the Oregon slender salamander in the western Oregon Cascade ecoregion. Risk scores were averaged over the 5th-field watersheds.

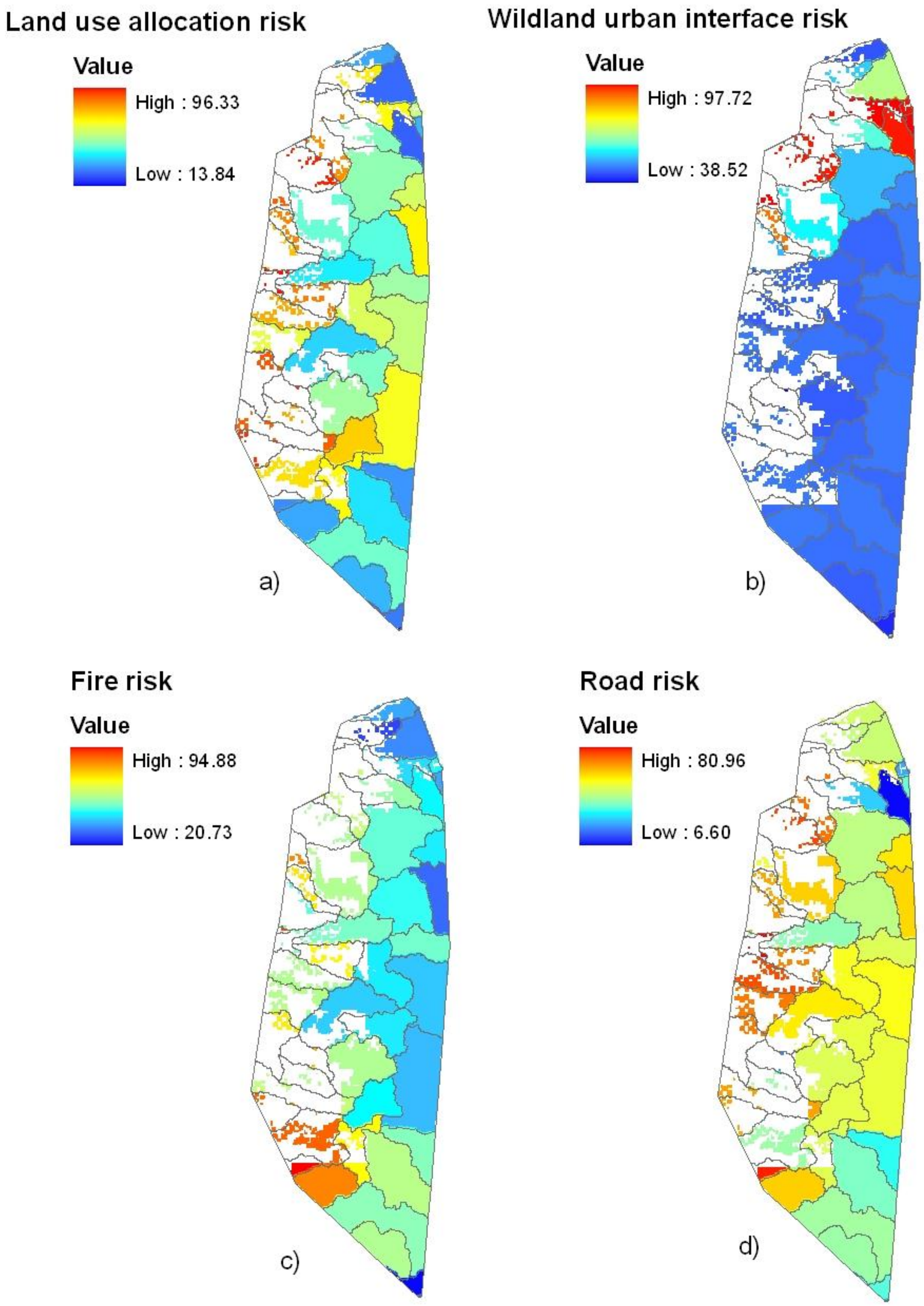


Figure A3.7. Relative risk associated with a) land use allocation, b) wildland urban interface, c) fire, and d) road within the range of the Oregon slender salamander in the western Oregon Cascade ecoregion. Risk scores were averaged over only the federal lands within the 5th-field watersheds.

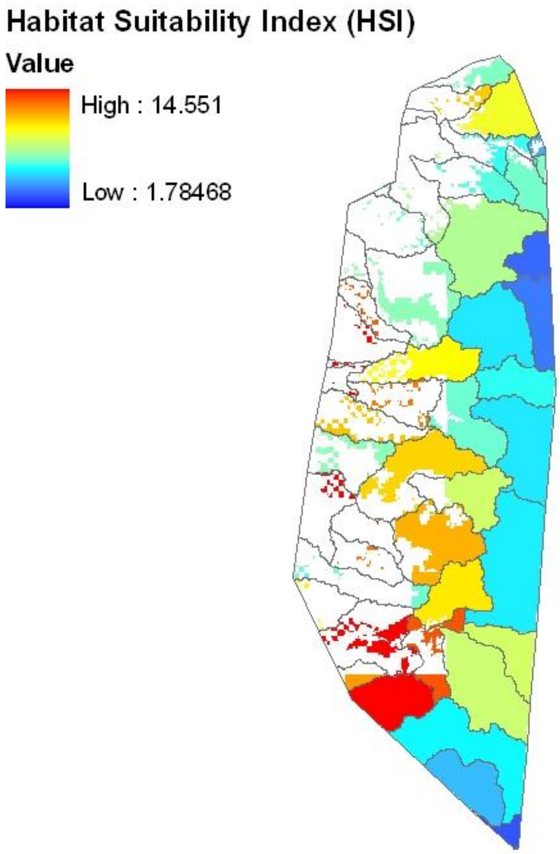
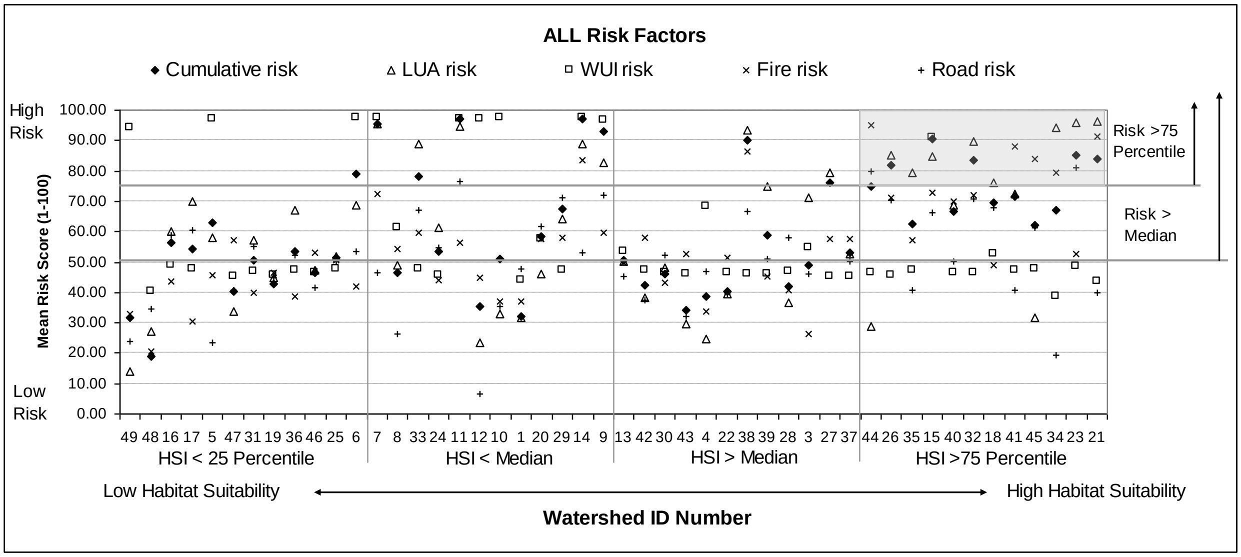


Figure A3.8. Habitat Suitability Index (HSI) scores averaged over federal lands within 5th field watersheds.

a)



b)

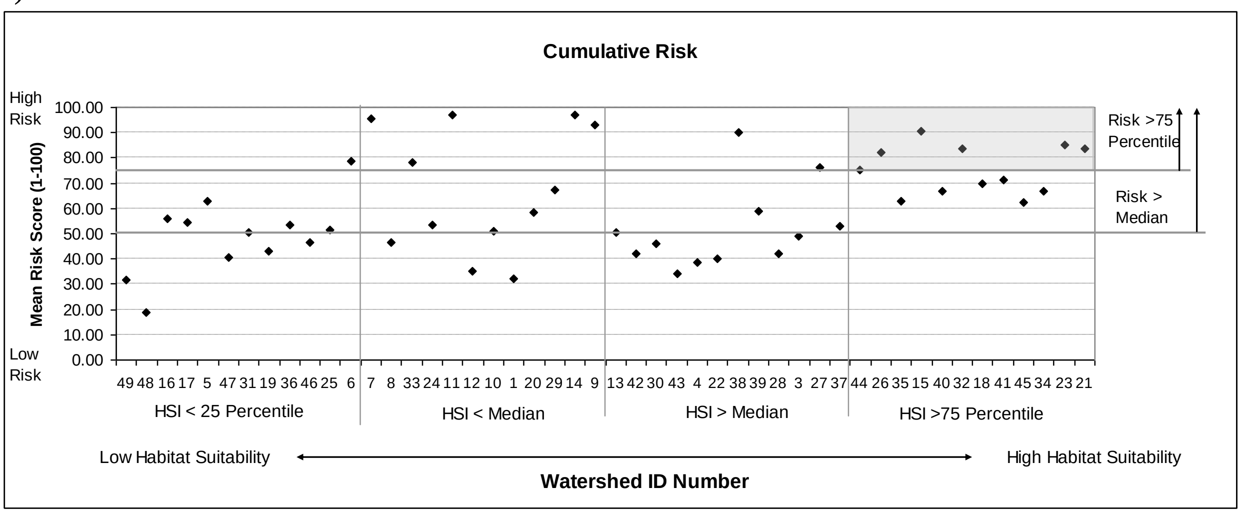
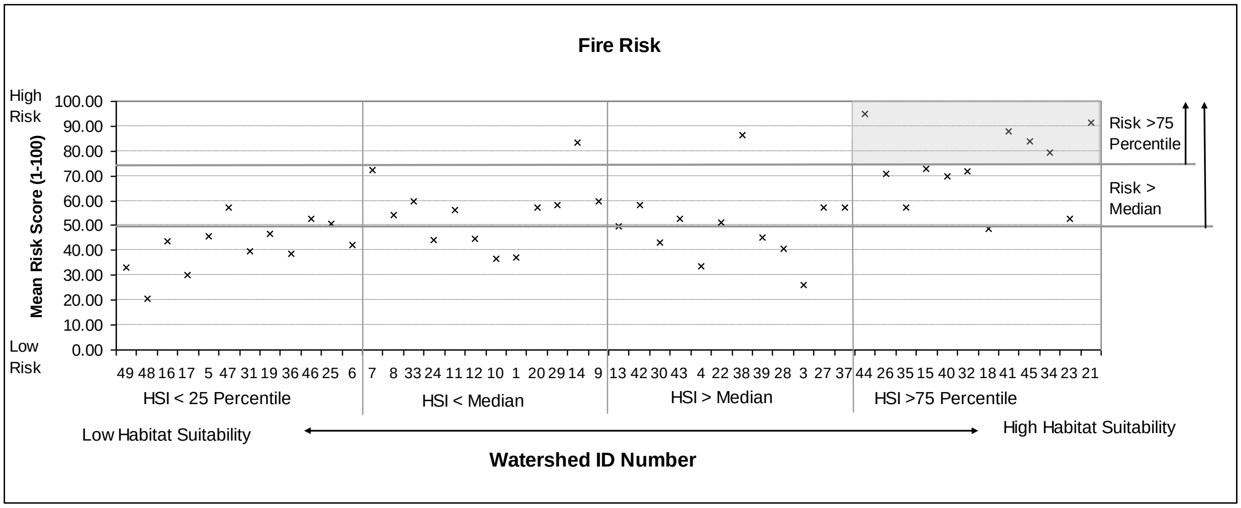


Figure A3.9 (a, b). Risk levels and habitat suitability of 5th-field watersheds were used to identify watersheds that potentially maintain good habitats for Oregon slender salamanders while being exposed to high levels of risk. Identification numbers of 5th-field watersheds (see Figure A3.4) are arranged along the x-axis in the order of increasing habitat suitability from left to right, while levels of risk are along the y-axis. Three vertical lines indicate 25 percentile, median, and 75 percentile of Habitat Suitability Index scores (HSI) of 49 watersheds. Two solid horizontal lines indicate median and 75 percentile of risk scores on federal lands. Points in the shaded area indicate high levels of risk in watersheds with high habitat suitability. Figure A3.9a shows scores among all 4 risk factors and cumulative risk and A3.9b shows cumulative risk of 4 risk factors for 49 watersheds.

c)



d)

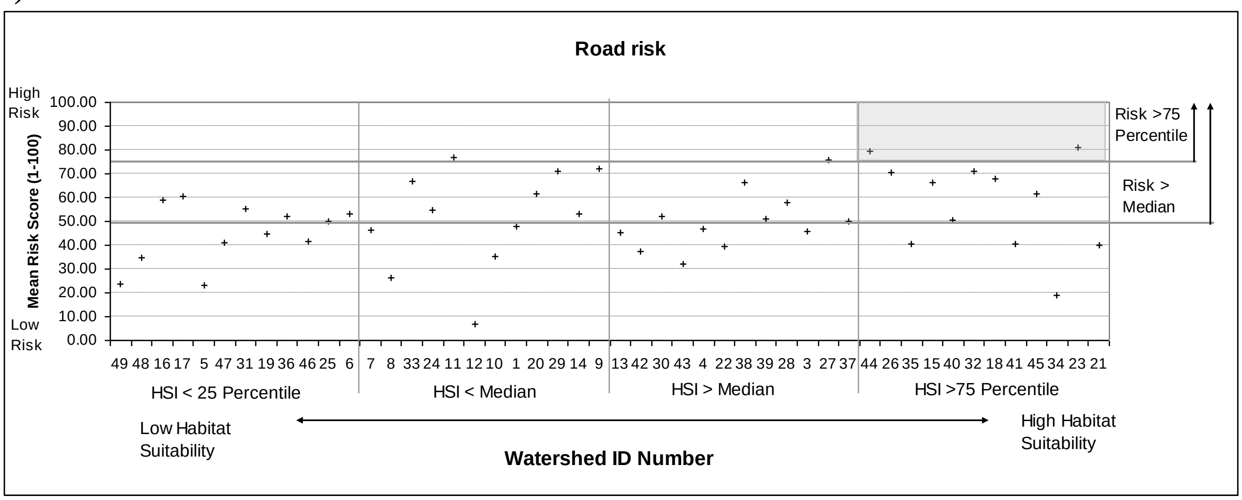
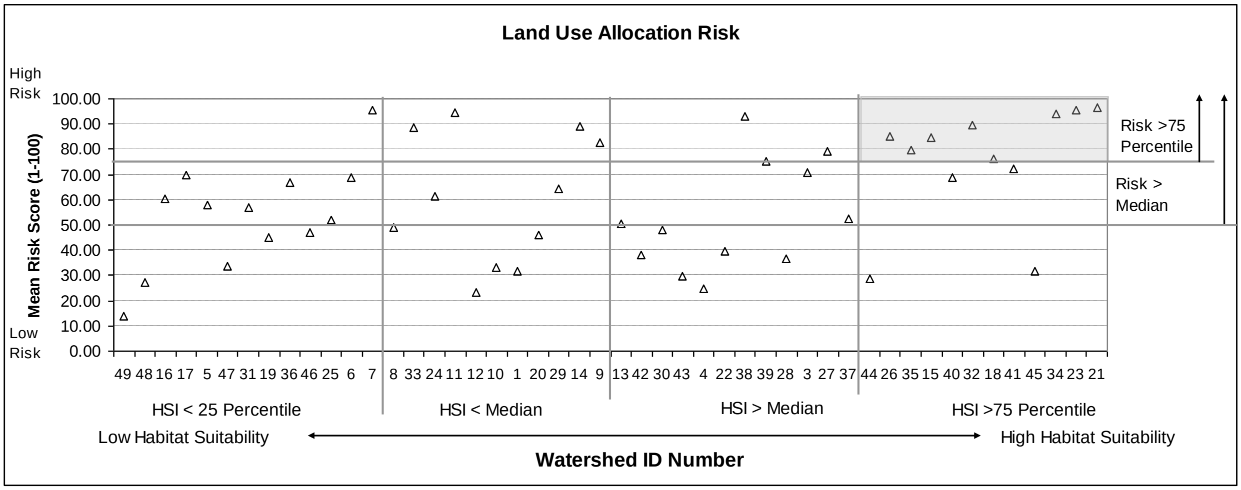


Figure A3.9 (b, c). Risk levels and habitat suitability of 5^{th}-field watersheds were used to identify watersheds that potentially maintain good habitats for Oregon slender salamanders while being exposed to high levels of risk. Identification numbers of 5^{th}-field watersheds (see Figure A3.4) are arranged along the x-axis in the order of increasing habitat suitability from left to right, while levels of risk are along the y-axis. Three vertical lines indicate 25 percentile, median, and 75 percentile of Habitat Suitability Index scores (HSI) of 49 watersheds. Two solid horizontal lines indicate median and 75 percentile of risk scores on federal lands. Points in the shaded area indicate high levels of risk in watersheds with high habitat suitability. Figure A3.9c and A3.9d show fire risk and road risk for 49 watersheds, respectively.

e)



f)

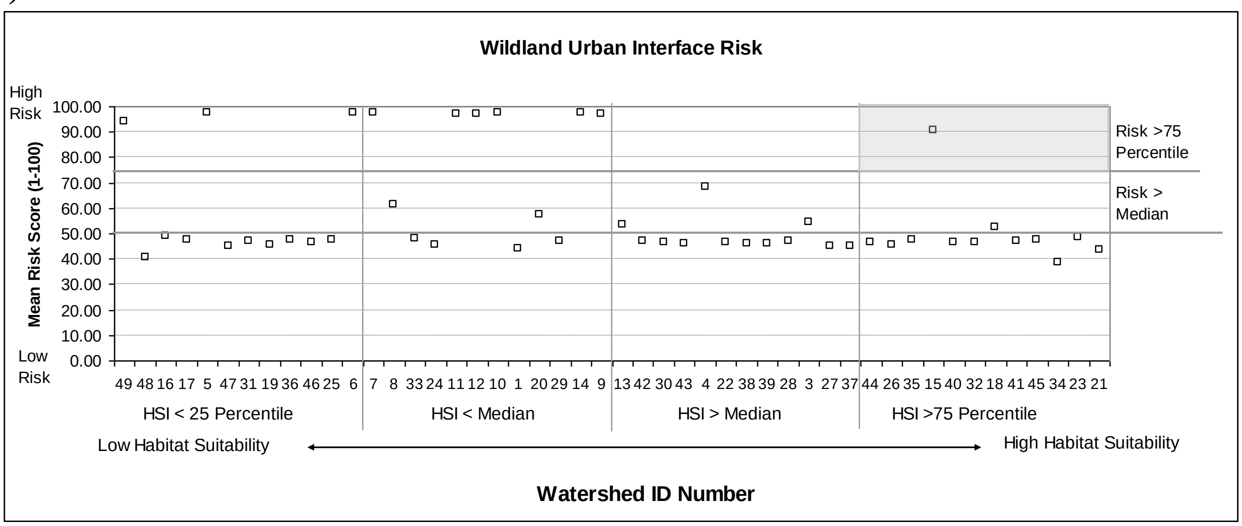


Figure A3.9 (e, f). Risk levels and habitat suitability of 5th-field watersheds were used to identify watersheds that potentially maintain good habitats for Oregon slender salamanders while being exposed to high levels of risk. Identification numbers of 5th-field watersheds (see Figure A3.4) are arranged along the x-axis in the order of increasing habitat suitability from left to right, while levels of risk are along the y-axis. Three vertical lines indicate 25 percentile, median, and 75 percentile of Habitat Suitability Index scores (HSI) of 49 watersheds. Two solid horizontal lines indicate median and 75 percentile of risk scores on federal lands. Points in the shaded area indicate high levels of risk in watersheds with high habitat suitability. Figure A3.9e and A3.9f show risk associated with land use allocation and wildland urban interface, respectively.

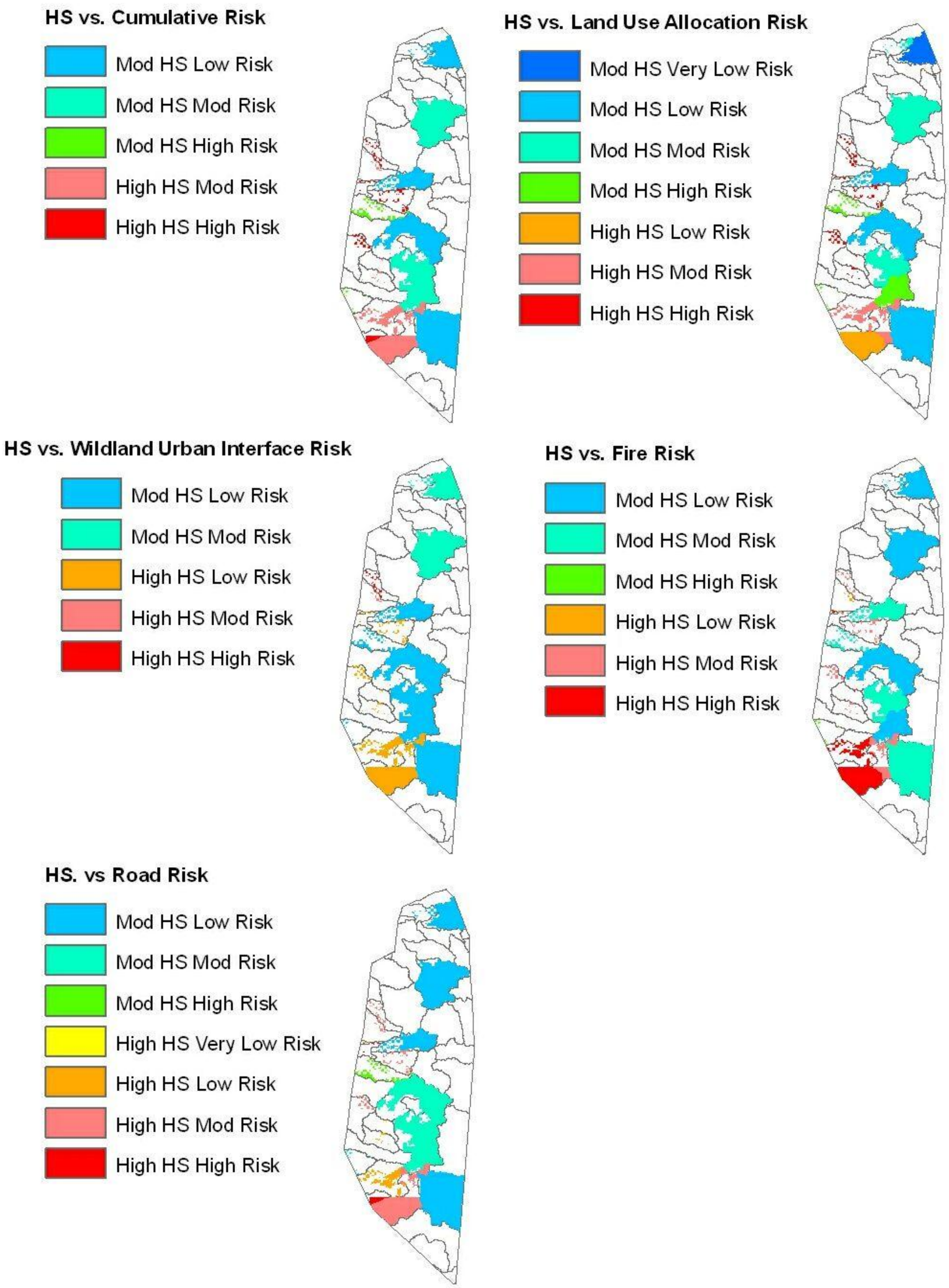
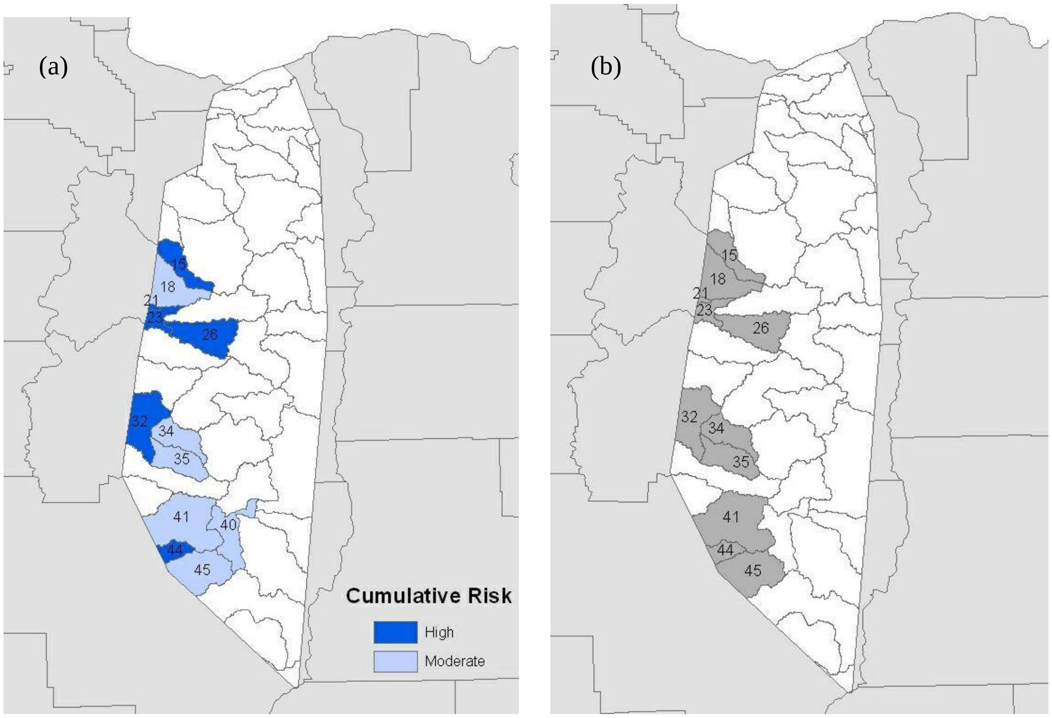


Figure A3.10. Federal lands in 5th-field watersheds of the western Oregon Cascade ecoregion classified as having moderate (Mod) and high (High) habitat suitability (HS) for the Oregon slender salamander at 4 risk levels in 5 risk factors.

Table A3.2. Eleven 5th-field watersheds with both high habitat suitability (watersheds ranked > 75 percentile of mean habitat suitability of 49 watersheds) and high levels of risk (risk levels > 75 percentile) in at least 1 risk factor.

ID	5th Field Watershed Name	Cumulative	LUA	WUI	Fire	Road
15	Butte Creek-Pudding River	x	x	x		
18	Abiqua Creek-Pudding River		x			
21	Mill Creek-Willamette River	x	x		x	
23	Lower North Santiam River	x	x			x
26	Middle North Santiam River	x	x			
32	South Santiam River-Hamilton Creek	x	x			
34	South Santiam River-Foster Reservoir		x		x	
35	Wiley Creek		x			
41	Lower McKenzie River				x	
44	Little Fall Creek	x			x	x
45	Fall Creek				x	



ID	5th Field Watershed Name
15	Butte Creek-Pudding River
18	Abiqua Creek-Pudding River
21	Mill Creek-Willamette River
23	Lower North Santiam River
26	Middle North Santiam River
32	South Santiam River-Hamilton Creek
34	South Santiam River-Foster Reservoir
35	Wiley Creek
40	McKenzie River-Quartz Creek
41	Lower McKenzie River
44	Little Fall Creek
45	Fall Creek

Figure A3.11. Fifth-field watersheds with: (a) high habitat suitability (>75 percentile habitat suitability) and with high potential cumulative risk (risk >75 percentile) or with moderate potential cumulative risk (median< risk <75 percentile risk) and (b) high habitat suitability and with high potential risk in at least one of 4 risk factors. None of the 5^{th} field watersheds with high habitat suitability was classified as having low levels of potential cumulative risk (risk < median).

Table A3.3 Twenty four 5th-field watersheds with moderate to high habitat suitability (> median) and moderate to high levels of risk (risk > median). Watersheds with high habitat suitability (> 75 percentile) were indicated in bold letters, and high levels of risk (>75 percentile) are indicated by x with underline.

ID	5th Field Watershed Name	Cumulative	LUA	WUI	Fire	Road
3	Lower Sandy River		x	x		
4	Bull Run River			x		
13	Middle Clackamas River	x	x	x		
15	**Butte Creek-Pudding River**	x̲	x̲	x̲	x	x
18	**Abiqua Creek-Pudding River**	x	x̲	x		x
21	**Mill Creek-Willamette River**	x̲	x̲		x̲	
22	Little North Santiam River				x	
23	**Lower North Santiam River**	x̲	x̲		x	x̲
26	**Middle North Santiam River**	x̲	x̲		x	x
27	Thomas Creek	x	x		x	x
28	Quartzville Creek					x
30	Middle Santiam River					x
32	**South Santiam River-Hamilton Creek**	x̲	x̲		x	x
34	**South Santiam River-Foster Reservoir**	x	x̲		x̲	
35	Wiley Creek	x	x̲		x	
37	South Santiam River	x	x		x	x
38	Mohawk River	x	x		x	x
39	Blue River	x	x			x
40	McKenzie River-Quartz Creek	x	x		x	x
41	**Lower McKenzie River**	x	x		x̲	
42	South Fork McKenzie River				x	
43	Horse Creek				x	
44	**Little Fall Creek**	x̲			x̲	x̲
45	**Fall Creek**	x			x̲	x

Findings

Eleven 5th-field watersheds were identified as potentially having both high risk and high habitat suitability. All the watersheds with top habitat suitability (HSI >75 percentile) had relatively high cumulative risk (> median risk), indicating that there are high degrees of potential conflict between conservation of habitat and human activities or fires.

Potentially high cumulative risk to species' habitat occurs in the western portion of the Oregon slender salamander's range. The northwestern corner of the species' range appears to have the highest potential risk due to the high concentrations of actively managed federal lands, private lands, and roads, along with the presence of WUI; however, the habitat suitability of this area is relatively low. The central-western portion of the species' range has high potential cumulative risk mainly due to the high concentrations of actively managed federal lands (matrix and adaptive management areas) and private lands as well as roads in the area. Habitat suitability of the area is also high. Furthermore, many federal lands with high habitat suitability occur in small parcels in this area. The southwestern portion of the species' range has high potential cumulative risk mainly due to high risk of fire. The high risk of fire probably is related to the relatively high temperatures and low precipitation in the region. In this potentially fire-prone region, relatively large blocks of contiguous federal lands with high habitat suitability occur in the Fall Creek and Lower McKenzie River basins.

Reference

Daly C, Neilson RP, and Phillips DL (1994) A statistical-topographic model for mapping climatological precipitation over mountainous terrain. J Appl Meteorol 33:140–158.

Scott, J. H., and R. E. Burgan. 2005. Standard fire behavior fuel models: a comprehensive set for use with Rothermel's surface fire spread model. US Department of Agriculture, Forest Service, Rocky Mountain Research Station. RMRS-GTR-153, Fort Collins, CO.

Acknowledgements

I thank Kelli VanNorman and Rob Huff for providing information on existing GIS data for risk analysis. I also thank Dede Olson, Rob Huff, and Kelli VanNorman for reviewing an earlier version of this report, and the Oregon slender salamander federal working group for input on this project.

APPENDIX 4

Distribution of potentially suitable habitats the Oregon slender salamander (*Batrachoseps wrighti*) in relation to federal land use allocation and to road distribution

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July 2008

This appendix provides supplemental summary statistics and visual information on the distribution of potentially suitable Oregon slender salamander habitat in relation to federal land use allocations and to road distribution. The following 2 levels of habitat suitability were used to assess land use and road distribution in relation to suitable salamander habitats: 1) lands with habitat suitability score greater than median; and 2) lands with habitat suitability score greater than 75 percentile.

Summary

Matrix lands included the largest areas of lands with greater than median habitat suitability and lands with > 75 percentile habitat suitability because they were the largest area among the 7 land use allocation types (Figures A4.1, A4.2, A4.3, and Table A4.1). However, proportions of potentially suitable habitats in late-successional reserves (52% for > median and 28% for > 75 percentile) were greater than those in matrix lands (46% for > median and 20% for >75 percentile). As a result, the land area > 75 percentile habitat suitability in late-successional reserves were only ~2,700 acres less than that of matrix lands, despite the size difference at a magnitude of ~200,000 acres between these 2 land allocations. Large proportions of Adaptive Management Areas and Adaptive Management Reserves appeared to support potentially suitable habitats. Adaptive Management Areas, in particular, appeared to support relatively large proportions of suitable habitats compared to the proportions within congressional reserves. Forty percent of federal lands with > median habitat suitability (337,724 acres) and 38% of federal lands with > 75 percentile habitat suitability (159,821 acres) have roads or were located within 100 feet of roads (Figure A4.4). Federal matrix lands appeared to currently contain the largest area of suitable habitats due to it being the largest area allocated among the federal LUAs within the area examined; however, the proportion of suitable habitat within an allocation appeared to be greater in the late-successional reserves than in matrix lands.

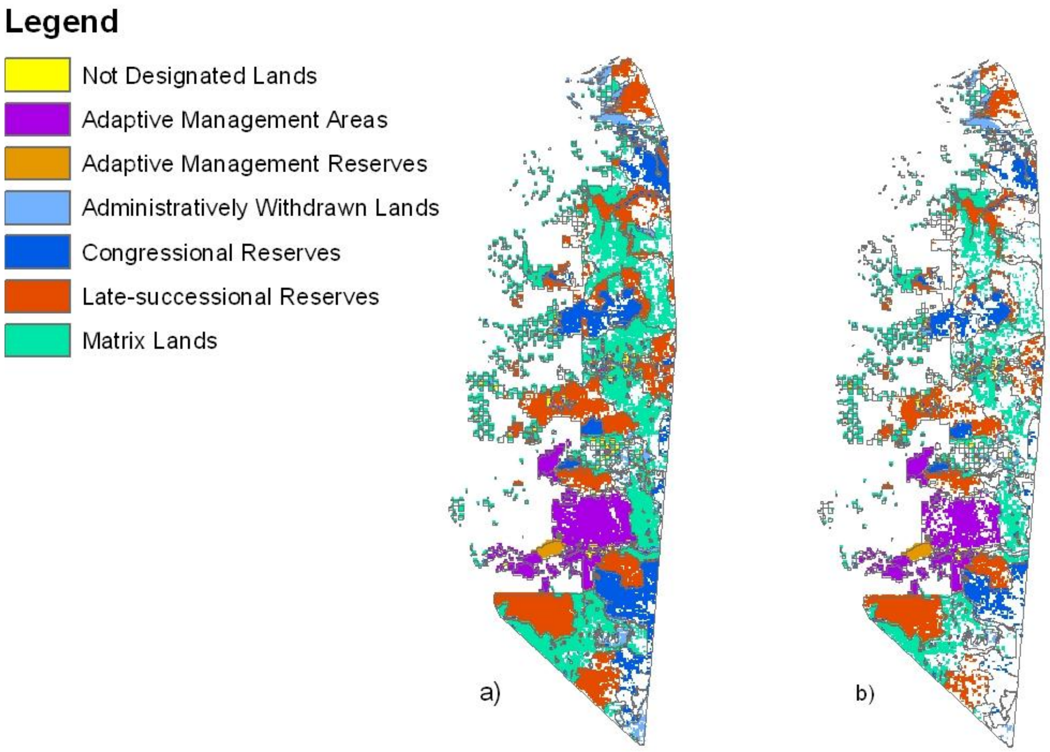

Figure A4.1. Federal lands in greater than a) the median habitat suitability index (HSI) score and b) the 75 percentile HSI score across 7 land use allocations.

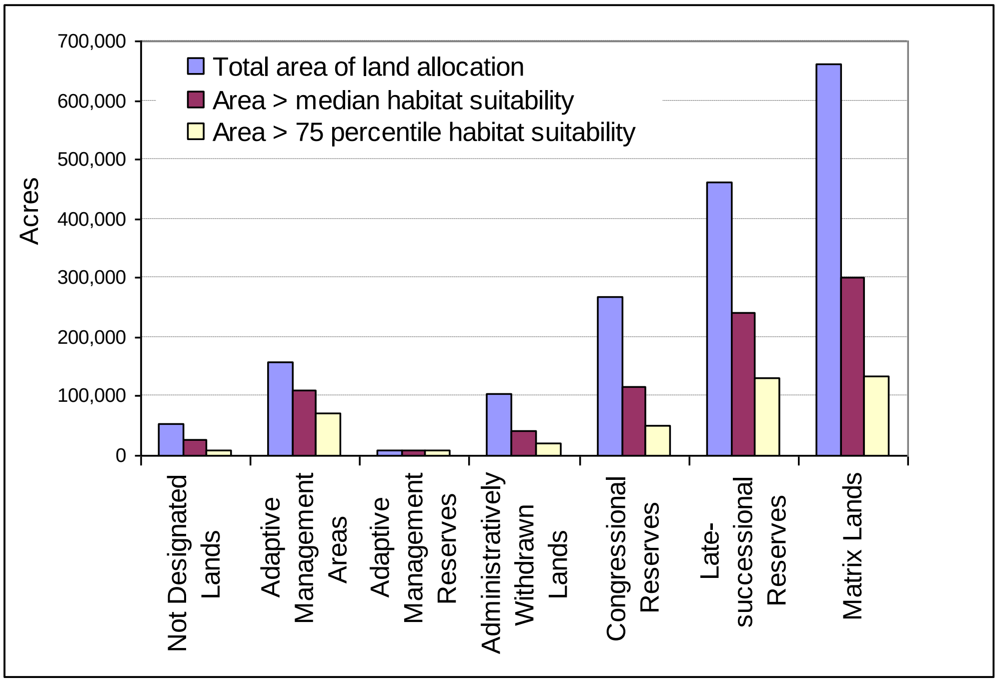

Figure A4.2. Areas of federal lands in 7 land allocations and those in > median and > 75 percentile habitat suitability scores of Oregon slender salamanders within land allocations.

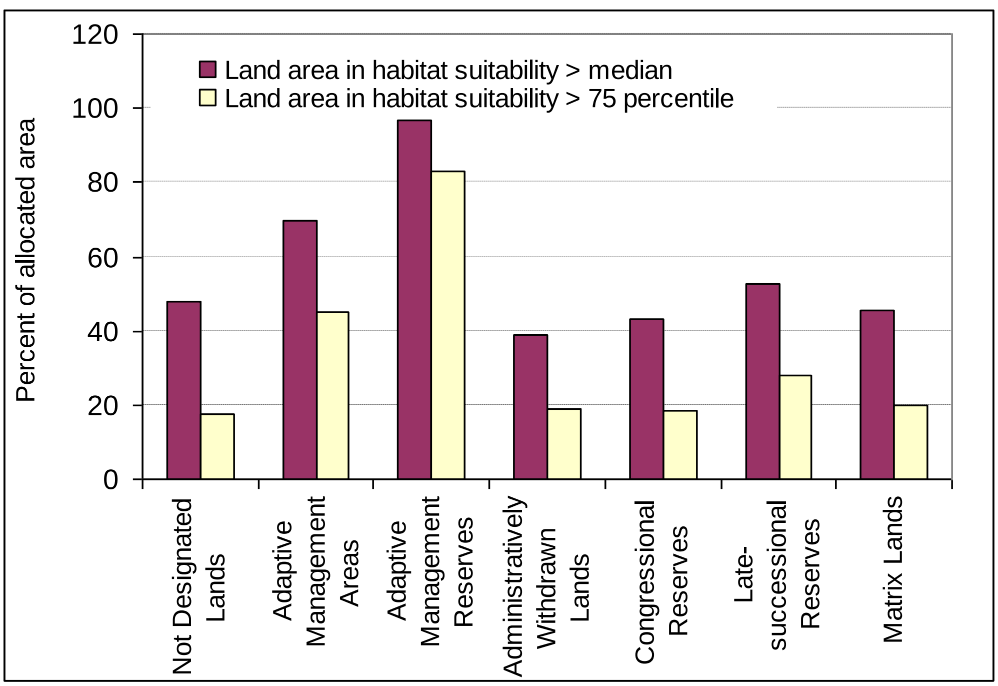

Figure A4.3. Percentages of lands in each of 7 land allocations > median and > 75 percentile habitat suitability scores of Oregon slender salamanders.

Table A4.1. Estimated areas of suitable Oregon slender salamander habitats among land use allocation types. Land areas in greater than median habitat suitability and those in greater than 75 percentile suitability were estimated for each of 7 land allocation types.

		> median habitat suitability		> 75 percentile habitat suitability	
Land use allocation type	Area of allocation (acres)	Area (acres)	% of land allocation	Area (acres)	% of land allocation
Not Designated Lands	53,850.70	25,672.15	47.67	9,550.52	17.74
Adaptive Management Areas	157,297.47	109,809.02	69.81	70,621.04	44.90
Adaptive Management Reserves	9,122.60	8,822.18	96.71	7,563.87	82.91
Administratively Withdrawn Lands	105,305.87	40,752.30	38.70	19,763.79	18.77
Congressional Reserves	269,402.02	115,923.77	43.03	49,596.50	18.41
Late-successional Reserves	462,199.04	242,583.20	52.48	130,406.79	28.21
Matrix Lands	660,931.21	300,746.57	45.50	133,077.97	20.13
Total	1718,108.91	844,309.19	49.14	420,580.48	24.48

Figure A4.4. Distribution of roads relative to federal lands in a) > median habitat suitability score and in b) > 75 percentile habitat suitability score. Colors of pixels (10 acres each) indicate at least one road is on or < 100 feet of pixel in red or the closest road is > 100 feet away from pixel in blue. Approximately 40% of lands with high habitat suitability either has roads or is located within 100 feet of a road.