

Conservation Assessment for the Van Dyke's Salamander

(Plethodon vandykei)

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Photograph by Caitlin McIntyre

Deanna H. Olson and Charles M. Crisafulli

U.S.D.A. Forest Service Region 6 and U.S.D.I. Bureau of Land Management

Authors

DEANNA H. OLSON is a research ecologist, USDA Forest Service, Pacific Northwest Research Station, Corvallis, OR 97331

CHARLES M. CRISAFULLI is an Ecologist, USDA Forest Service, Pacific Northwest Research Station, Amboy, WA 98601

Disclaimer

*This Conservation Assessment was prepared to compile the published and unpublished information on the Van Dyke's Salamander (*Plethodon vandykei*). 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 at <http://www.fs.fed.us/r6/sfpnw/issssp/contactus/>*



Photograph by William P. Leonard

Dedication

Lawrence L.C. Jones has been a champion of *Plethodon vandykei* research and conservation, and has contributed significantly to development of amphibian survey and management guidance in the Pacific Northwest. With his more recent focus on reptiles in the American Southwest, his efforts have advanced herpetofaunal knowledge across much of the western United States. We dedicate this Conservation Assessment to Larry - 'Commander Salamander' - and thank him for his inspiration, as well as his contributions to an early draft of "management recommendations" for the Van Dyke's Salamander, which served as an initial template for this document.

Executive Summary

Species: Van Dyke's Salamander (*Plethodon vandykei*)

Taxonomic Group: Amphibian

Status: U.S.D.A. Forest Service, Region 6; U.S.D.I.-Bureau of Land Management, Oregon/Washington – Sensitive in Washington; federal Survey and Manage species in the Cascade Range only; NatureServe Global/National rank, G3/N3, “vulnerable;” IUCN Red List category, least concern; Washington Natural Heritage Program and Washington Department of Fish and Wildlife state rank, S3, “vulnerable,” Washington State Candidate. The species is a Forests and Fish-designated amphibian under the Washington State Habitat Conservation Plan.

Range: The species occurs in three discrete geographic areas in Washington state: the Willapa Hills; the Olympic Peninsula; and the Washington Cascade Range. Only Olympic Peninsula and Cascade Range populations occur on federal lands. The full range extent may not be known.

Specific Habitat: Van Dyke's Salamander occurs primarily in association with streambanks, seeps, and saturated rock faces. Incidental occurrences are known from woody debris or rock accumulations in upslope forests, in cave entrances, and along lake shores.

Threats: Habitat loss and degradation are the main threats to this species. Alteration of microhabitats, microclimate, hydrologic, and geomorphic regimes within surface and subsurface refuges are of highest concern. The main human-caused threats are activities related to timber harvest, which reduces canopy closure, disturbs substrates, and can alter microhabitat refuges, microclimates, and hydrologic patterns. Also of concern are road construction and culverts, mining and excavation, recreation, floods and debris flows, disease, climate change, forest fires, chemical applications, rural development, overexploitation, and volcanism.

Management Considerations: Considerations for persistence of local populations include maintaining the integrity of substrates, microclimates, hydrological, and forest conditions at occupied sites. Reducing the impacts of forest and roads management, recreation activities, rock

disturbances, and chemical applications are key considerations. Where populations occur in streamside areas, riparian buffers are a management consideration.

Inventory, Monitoring, and Research Opportunities: Information gaps include the distribution of the species, colonization capacity, threats to the species, and efficacy of alternative riparian buffer widths, and other mitigations in maintaining populations and habitat conditions.

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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 the Van Dyke's Salamander (*Plethodon vandykei*), 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 vertebrate is endemic to a narrow band of latitude and longitude in western Washington. The salamander's life cycle is terrestrial-to-semiaquatic, with affinity to moist forest microhabitats near seeps and stream banks or in association with down wood or rocky substrates. Hence, it is considered vulnerable to many of the same threats that affect the integrity of forest floor conditions and aquatic habitats. In Washington, it is recognized as a federal Survey and Manage species in the Cascade Range, a Forest Service and BLM sensitive species rangewide, and a vulnerable species range-wide by NatureServe and by the state of Washington because of its restricted distribution, low numbers of known locations, and its potential susceptibility to land management activities. The goals and management considerations of this assessment are specific to Forest Service and BLM lands in Washington, but the information can be useful for management in other ownerships. The information presented here is compiled to help manage the species in accordance with Forest Service Region 6 Sensitive Species (SS) policy, and the Survey and Manage Standards and Guidelines. Additional information for Region 6 SS and Oregon/Washington BLM SSS is available on the Interagency Special Status Species website (www.fs.fed.us/r6/sfspnw/ISSSSP).

For OR/WA BLM administered lands, SSS policy (6840) 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.

Where listed as a Survey and Manage species (Washington western Cascades), management of the species must follow the Survey and Manage Standards and Guidelines (USDA and USDI, 2001).

Scope

Whereas this synthesis focuses on biological and ecological information for the Van Dyke's Salamander, information for other closely related *Plethodon* species is also included to describe general characteristics of the genus. This Conservation Assessment relies on published accounts, reports, locality data from individuals and databases, and expert opinion, each noted as appropriate. Although information compiled here is not restricted to that coming from federal sources, the scope of the management considerations of this assessment are specific to Forest Service lands in Washington. The known range of the Van Dyke's Salamander on federal lands in Washington includes the Olympic, Gifford Pinchot, and Mount Baker-Snoqualmie National Forests. Spokane BLM considers the species "suspected", as some of their landbase falls within the general range of the species.

II. MANAGEMENT STATUS

Due to its rarity and apparent vulnerability to a variety of anthropogenic disturbances, the Van Dyke's Salamander is classified by both state and federal agencies as a species of concern. It is listed as a U.S.D.A. Forest Service, Region 6 and U.S.D.I.-Bureau of Land Management, Oregon/Washington – Sensitive species, and a Washington State Candidate species. It is managed under the federal Survey and Manage Standards and Guidelines on Forest Service lands in the Cascades Range portion of its range. As such, every known site within that portion of the species' range is managed for site-level persistence, and surveys are required before projects may be planned in suitable habitat within its range on federal lands. NatureServe has classified this species as Globally and Nationally "vulnerable" (G3/N3) and it is of least concern according to

the International Conservation Union (IUCN) Red List. Lehmkuhl and Ruggiero (1991) assessed species status, and gave this species a high-risk ranking. The risk assessment on federal lands conducted by USDA and USDI (1993) projected both the Olympic and Cascades populations to be at risk of losses, but rated the Cascades population as a higher risk, likely due to its greater rarity and likely distribution on non-reserved lands. In 1994, only 28 localities were known in the Cascade Range (Lund et al. 2004), however, more information has been accrued since then (see below). Management of the species follows BLM 6840 and Forest Service 2670 Manual policy, as well as the Survey and Manage Standards and Guidelines

III. CLASSIFICATION AND DESCRIPTION

The Van Dyke's Salamander (*Plethodon vandykei* Van Denburgh 1906) is a member of the family Plethodontidae, the lungless salamanders. These animals breathe through their skin, have nasolabial grooves, are largely terrestrial, and have a distinctive tooth pattern (Stebbins 1985). Salamanders of the genus *Plethodon*, the woodland salamanders, are slim and elongate with short legs, and generally occur on the forest floor in moist microhabitats.

Van Dyke's Salamander was described by Van Denburgh (1906) from a specimen from Paradise Valley, Mount Rainier National Park. It is named in honor of its collector, Dr. Edwin Cooper Van Dyke.

Nussbaum et al. (1983) reported three groups of northwestern *Plethodon* salamanders, with *P. vandykei* belonging to the Van Dyke's group. *Plethodon idahoensis* (Coeur d'Alene Salamander) and *P. larselli* (Larch Mountain Salamander) are its two closest known relatives in the region today (Howard et al. 1993; Wilson and Larsen 1999; Mahoney 2001).

Phylogenetics of the Van Dyke's Salamander have proven to be a rich topic of research, as techniques have developed and different questions could be addressed. Historically, *P. vandykei* was described as occurring in four isolated areas (southwestern Washington, northwestern Washington, the Washington Cascade Range, and Idaho). Morphometric variation and patterns

of polychromatism were reported as being discordant with geographic distribution across its entire historic range (Brodie 1970). Subsequently, electrophoretic data shed some light on the subject: Highton and Larson (1979) suggested that the Rocky Mountain form was a separate species, the Coeur d'Alene Salamander, *P. idahoensis*, as originally proposed by Slater and Slipp (1940). However, this view was not immediately accepted (e.g., Nussbaum et al. 1983) because of a small sample size and the lack of phenotypic concurrence. This prompted Howard et al. (1993) to investigate biochemical differences in greater detail. Their findings indicated a high degree of divergence between Rocky Mountain and western Washington populations, warranting the splitting of the two species. However, they also found the southwest Washington (Willapa Hills) and northwest Washington (Olympic Peninsula) populations to be statistically identical, but differing from Cascade Range populations. Further, they found that divergence (long-term reproductive isolation) was high between two populations in the Cascade Range (the only two they sampled). Wilson (1993) compared morphology of the *P. vandykei-idahoensis* group, and found that coastal *P. vandykei* were more slender and had shorter limbs than Cascade populations, and both were very different from *P. idahoensis*. Within-Washington genetic variation warrants additional study to this day to resolve boundaries of unique populations. In another study, Carstens et al. (2004) found that the genetic patterns of *P. vandykei* and *P. idahoensis* supported a geological or climatological isolation event and persistence through the most recent Pleistocene glaciation, which also appears to explain the similarly disjunct distributions of *Dicamptodon* and *Ascaphus* species, in contrast with the dispersal events that may explain these types of patterns in some other taxonomic groups. This explanation makes sense, given our current understanding that these animals have fairly low mobility. Of interest relative to phylogenetics, Highton (1991) reported on the similarity between *P. neomexicanus* (Jemez Mountains Salamander) in New Mexico and *P. larselli*, with both having close relationship to the phylogenetic branch with *P. vandykei* and *P. idahoensis*; however Mahoney (2001) did not concur on the close relationship of *P. neomexicanus* to northwestern *Plethodon*. It should be noted that literature reports of *P. vandykei* have not always distinguished among populations in Washington and those *P. idahoensis* in Idaho, thus information presented here may be relevant to that larger Van Dyke's complex.

Description

Van Dyke's Salamander can be variable in both ground and stripe color (e.g., Leonard et al. 1993; Jones et al. 2005). Different color phases are described based on ground color, which can be black, yellow, or pink (Brodie and Storm 1970; Nussbaum et al. 1983). The dark phase has a black ground color and yellow or red stripe; the yellow phase is tan or yellow with an indistinct stripe; and similarly, the rose phase is pinkish with an indistinct stripe (Nussbaum et al. 1983). Leonard et al. (1993) and Jones and Crisafulli (2005) combine the yellow and rose phases into a "light phase." Dark phase individuals have white speckling on the sides and a yellow throat (Leonard et al. 1993). Nussbaum et al. (1983) report that the rose phase is common in the Willapa Hills, the yellow phase occurs in the Willapa Hills and the Olympic Peninsula, whereas most individuals in the Cascade Range are dark phase. Hatchlings are always dark phase. Jones and Crisafulli (2005) describe the dorsal stripe as having “drips of color extending from the dorsal stripe onto the sides, which is most conspicuous on juveniles or dark phase adults.”



Yellow phase *Plethodon vandykei*. Photograph by Caitlin McIntyre.



Yellow phase *Plethodon vandykei*. Photograph by Caitlin McIntyre.



Dark phase *Plethodon vandykei* with a black ground color and yellow stripe. Photograph by William P. Leonard.



Yellow phase (left) and dark phase (right) with a rose-colored stripe. Photograph by Caitlin McIntyre.

Van Dyke's is a relatively stocky plethodontid salamander with a short body (Cascade Range animal: maximum snout-vent length, SVL = 64 mm; maximum total length 122 mm; Aimee McIntyre, pers. comm.) and only 0.5-3.0 intercostal folds between adpressed limbs (Nussbaum et al. 1983). It has the smallest number of costal grooves (mode = 14), widest head relative to its size, and shortest tail of all western *Plethodon* (Nussbaum et al. 1983). It has parotoid glands and slightly webbed toes (Jones and Crisafulli 2005).

IV. BIOLOGY AND ECOLOGY

General Ecology, Life History, and Reproductive Biology

Van Dyke's Salamanders are semi-aquatic to terrestrial; they do not require standing or flowing water at any stage of their life cycle, but are most often observed in very moist conditions such as seeps and stream banks. However, as for most northwestern plethodontids, little is known about Van Dyke's Salamander reproduction. It is likely that courtship occurs in the spring and/or fall, and oviposition occurs in the spring (Nussbaum et al. 1983). Gravid females were found in April and July in western Washington, with 11 and 14 eggs (Stebbins 1951). Six egg clutches and nesting sites have been reported from the Olympic Peninsula. Noble (1925) described a clutch of eggs hanging by a single strand from beneath moss-covered stones, but it was not mentioned

whether the female was in attendance. Jones (1989) found a clutch with 7 eggs inside a rotting conifer log near a stream in May. The female was in attendance in this case, which is typical for woodland salamanders. The temperature of the nest cavity was 11°C (52°F), while the outside temperature away from the stream was 29°C (84°F), an 18°C (32°F) difference, demonstrating the thermal buffering capacity of the natal microenvironment. Blessing et al. (1999) found four nests in the Olympic Peninsula. All nests were in large, rotting, conifer logs, about 7 cm from the upper surface of the log. A female adult was in attendance at all nests. One of the nests they described was monitored for development and thermal buffering. The eggs were laid in May and did not hatch until at least 144 days, longer than the period known for any other *Plethodon*. The nest stayed moist and well-buffered against outside temperature extremes; there was very little variation in temperature inside the nest. Another study of interior log temperatures supported the thermal buffering capacity of both logs and substrates in western Oregon managed forests (Kluber et al. 2009). Females likely breed every two years, and longevity may be 12 years for this animal (Jones and Crisafulli 2005).

Much of the natural history and ecology of this species has not been studied. The juvenile period and longevity of salamanders are unknown.

Van Dyke's Salamanders are thought to have limited dispersal ability, making daily to seasonal vertical migrations in the ground surface as microclimate conditions change, but not extensive horizontal overland movements. Very few individuals have been captured in upland forest conditions. In a mark-recapture study in the Cascade Range, at two stream sites with 10 and 11 trapping occasions from June to November, most animals moved less than 2 m, 36% of recaptures were under the same cover object, and the longest distance of movement was 33 m (McIntyre 2003). Additional mark-recapture studies of movements are needed to confirm their suspected small home ranges.

Because these animals occur over a broad elevation range (4 to 1,655 m), their activity patterns vary by location (Nussbaum et al. 1983). High-elevation populations likely have a much shorter active period when snow is absent. In one Cascade Range study, surface activity continued

throughout the summer and into the freezing temperatures of autumn (A. McIntyre, pers. comm.). Closed-canopy forests may extend the freeze-free period annually (A. Wilson, pers. comm.), with a corresponding extension of salamander activity.

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, and comprising a considerable portion of the forest vertebrate biomass in some areas (e.g., Burton and Likens 1975a, 1975b). Recent work suggests that western terrestrial plethodontids are an integral component to forest-floor carbon management (Best and Welsh 2014). Their general ecology and life-history traits suggest they are ideal indicators of forest ecosystem integrity (Welsh and Droege 2001). The specific role of *P. vandykei* in local communities and ecosystem processes has not been addressed.

The diet of *P. vandykei* has never been studied, but prey might be similar to that of the closely related *P. idahoensis*, since they are ecologically similar. Wilson and Larsen (1988) and Lindeman (1993) showed that *P. idahoensis* ate a variety of small prey species, particularly insects and their larvae, from both the semi-aquatic and terrestrial environment.

Van Dyke's Salamander is sometimes microsympatric with other salamanders, including torrent salamanders (*Rhyacotriton* spp.), Dunn's, Western Red-backed and Larch Mountain salamanders (*P. dunni*, *P. vehiculum*, and *P. larselli*, respectively; Jones and Crisafulli 2005), but how they may compete for, share, or partition resources is poorly known. Ovaska and Davis (1992) showed that *P. vandykei* can recognize Western Red-backed salamander (*P. vehiculum*) feces and pheromones (but not *P. dunni*), but does not avoid them. Predators have not been documented for this species.

Range, Distribution, and Abundance

Van Dyke's Salamander is endemic to Washington state, occurring in three disjunct distributional centers: the Willapa Hills, the Olympic Peninsula, and the Cascade Range (Figure

1). The first two areas are separated by the Chehalis and Willapa Rivers. The Puget Trough forms a physical barrier between these coastal populations and those of the Cascade Range. Van Dyke's Salamander is found from 4 m to 1,655 m in elevation (~12-5,430 ft., Wilson 1993, A. Wilson, pers. comm.) into the subalpine zone (Crisafulli et al. 2005a). However, the full extent of the range may not be known. The Coeur d'Alene Salamander (*P. idahoensis*) in Idaho is a close relative of this species, and recent surveys have extended its distribution considerably. It is unknown whether *P. idahoensis* or *P. vandykei* may occur in northeastern Washington in isolated stream or seep populations between the Idaho panhandle and the Washington Cascade Range.

To date, we have compiled 418 locality records for this species, with 126 localities occurring in the Cascade Range portion of the species range. However, quality assurance is limited for some site data, reducing certainty that the species identifications were accurate at all locations. Some of these records include animals in close proximity to each other, making determination of numbers of unique "sites" difficult. Due to their aquatic affinity, watershed-scale mapping is useful to assess potentially distinct sub-populations because contiguous hydrological flow conditions and ribbons of moisture along streams likely provide some enhanced connectivity of habitats within basins. *Plethodon vandykei* site records are distributed among 42 5th-field watersheds and 81 6th-field watersheds (5th and 6th code hydrologic units; Figures 1 and 2). In contrast, the lack of direct aquatic connectivity over ridgelines would likely require salamanders to disperse via use of microhabitat cover such as coarse substrates, logs, or side-slope seeps that maintain suitable microclimate conditions, and coincide with wet periods such as winter snowmelt and spring precipitation. Over-ridge dispersal distances would require movements greater than those currently known for this species, but dispersal events for this species has not been studied. Herein, we enumerate occupied watersheds to give an index of the number of subpopulations of potentially more-frequently interacting individuals within the species range. The numbers of occupied 5th-field watersheds by regional areas are: Cascade Range, 19; Olympic Peninsula, 13; Willapa Hills, 9; 1 location at the edge of Puget Sound; and 1 location abutting the Cascade Range in a watershed of the Puget Lowlands. The numbers of occupied 6th-field watersheds by these areas are: Cascade Range, 30; Olympic Peninsula, 30; Willapa Hills, 20; Puget Sound, 1; Puget Lowlands, 1.

Using these data, we calculated range area using a Minimum Convex Polygon, excluding one outlier locality record at the edge of the Puget Sound: Cascade Range, 7,021 km²; Olympic Peninsula, 5,558 km²; Willapa Hills, 2,499 km²; sum of all three, 15,078 km². The known northern limit of the species is in the vicinity of the north side of Mt. Rainier (Poch Creek; Cataract Creek; and snout of Carbon Glacier, but populations at the latter 2 locations have not been confirmed in many years [Wilson 1993]).

This narrow latitudinal band of occurrence may be due to the more xeric conditions encountered in the Columbia River Gorge, as well as the width of that river being a potential dispersal barrier, and the rain shadow of Mt. Rainier (Wilson 1993). It is possible that a rain shadow effect may account for the lack of known locations on the eastern side of the Olympic Peninsula.

Due to its status of concern under the federal Survey and Manage Program, 1993-present, more knowledge has been compiled about this species in the Cascade Range than in the other population segments. In the Cascade Range, *P. vandykei* was known from only 28 locations in 1994 (Lund et al. 2004). Today, it is known from 126 locations, from west of the Cascade crest to the Cascade foothills in three clusters (Figures 1 and 2). This contrasts with 147 site records from the Olympic Peninsula, 144 site records from the Willapa Hills population segments, and 1 Puget Sound site. It is not known if the Cascade Range site clusters represent a true distributional pattern or if populations between them remain to be discovered. Mount St. Helens occurs in the middle of these three clusters. Its 1980 eruption created a severely disturbed blast area (Swanson and Major 2005), yet Crisafulli et al. (2005a) reported that Van Dyke's salamanders were present at 18 of 47 seep locations sampled, and they found juveniles at 12 of 18 occupied sites, supporting successful breeding activities. They also found the species in the riparian zone of four subalpine lakes. Based on presumed low vagility, the authors assumed that these sites represented refugia within the 518 km² (200 mile²) area denuded by the 1980 eruption, where animals had survived the volcanic eruption and persisted in the post-eruption landscape for decades.

Across the species range, 241 (58%) known locations occur on federal lands. The US Forest

Service has the dominant share of federal location records (147, 61% of 241), followed by the National Park Service (85, 35%), the Fish and Wildlife Service (6, 2.5%), and the Department of Defense (3, 1%). The remaining 177 known locations occur on other land ownerships.

The relative rarity of this species is evident from the results of survey efforts over the last ~20 years. As a caveat common to most survey efforts for this species, it is uncertain to what extent detection bias might affect results; in particular, animals occurring subsurface are less likely to be detected. Wilson's (1993) exhaustive survey effort aimed to locate all historic locations as well as to identify new ones. Wilson (1993) failed to find *P. vandykei* in 18 of 44 historic locations (all three western Washington distribution centers combined). Wilson (pers. comm.) reported that repeated visits may be necessary to reasonably assure detection (yet see below for results of McIntyre's 2003 sampling efforts at two focal sites). Even so, historic extirpation of known locations cannot be ruled out. In some areas, *P. vandykei* seemed to be locally abundant or part of a larger network of subpopulations, but this was not typically the case. Wilson located specimens at only 13 of 243 (5.3%) Cascade Range sites surveyed. Given the fact that he searched specifically for this species in moist microhabitats and at known and reported localities during the right time of year, this is indeed a low number. It could be argued that searching only such specialized sites might preclude detection of populations in other habitats. However, results of surveys conducted under the federal Survey and Manage provision do not support that conjecture.

Select terrestrial amphibians were surveyed under the federal Survey and Manage provision, including surveys specifically for the Van Dyke's Salamander (Jones 1999) and also surveys in upland terrestrial habitats for the Larch Mountain Salamander, *P. larselli* (Crisafulli 1999). Surveyors looked for both species during surveys in the Washington Cascade Range due to uncertainty in their ranges. With 700 pre-project surveys conducted within the first decade of the provision, only 3 new locations were detected for Van Dyke's Salamanders (Lund et al. 2004). Lund et al. (2004) reported findings of a Survey and Manage 'strategic survey' project in which another 8 sites with Van Dyke's Salamanders were found from among 156 riparian sites surveyed (4.2%), and opportunistic sampling targeting specific habitats was the most successful

type of survey for this species, as it yielded another 20 sites. Strategic surveys (Olson et al. 2007) conducted for Van Dyke's Salamanders under the Survey and Manage provision were valuable to assess occurrences within a watershed that was known to be occupied, compare survey approaches, assess habitat associations, and examine population ecology (McIntyre 2003; Lund et al. 2004).

There are two studies of abundance patterns at known locations. Raphael et al. (2002) examined effects of streamside forest management on vertebrates at 62 sites in the Olympic Peninsula, and due to their use of a standardized survey protocol could report Van Dyke's Salamander detections per area surveyed. They reported mean detections per 100 m² for six types of forest management treatments. In unharvested old-growth sites, Van Dyke's Salamanders detection was 0.56/100 m², and their detection was 0.09/100 m² in buffered old sites (sites with unlogged stream buffers consisting of old-growth trees, >100 yrs, with clearcut uplands). This species was not detected in any other treatment, all of which included timber harvest at stream sites without riparian buffers. Among amphibians sampled in this study, this species had the lowest overall detection rate, < 0.01/100 m².

McIntyre (2003) conducted a mark-recapture study at two high-gradient stream sites in the Cascade Range: a site lacking overstory canopy located in the Mount St. Helens blast area, and a site in an old-growth coniferous forest that received ~30 cm of cool sand to small pebble size air fall (i.e., tephra) deposits during the 1980 eruption. She found animals at the sites during every summer and fall sampling occasion, which provides a contrast to the notion that multiple site visits may be necessary to detect occurrence. Abundance differed between sites, with the blast area site having more animals and recaptures (125 individuals, 20 recaptured individuals) compared to the old forest site (37 individuals, 8 recaptures). The modeled abundance estimate for the blast area site was 458 individuals and the old-growth site was estimated to have 100 salamanders. Capture probabilities were low, less than 0.10 for both sites, with the average capture probability being 0.038. Although these results seem anomalous given our rudimentary understanding of the species' habitat associations, local site microclimate and substrate conditions might account for this pattern.

McIntyre (2003) and colleagues conducted a census of 24 known salamander sites along first- and second-order streams in the Cascade Range, in addition to 26 representative sites with matched conditions at which salamanders were not known to occur. Van Dyke's Salamanders were detected at 26 of 50 sampled streams, occurring at only 2 of 26 representative sites where they were not previously known to occur. At each site, 3,200 m² of streamside area was searched; the average number of animals detected at an occupied site was 13 (range 1-49 animals; average = 0.0041 animals/m²). These data support the rarity of the species on the landscape and at individual sites.

In headwall seeps, McIntyre et al. (2006) reported no more than 3 individual salamanders per seep. They speculated that seeps in their sample may be ephemeral relative to surface water conditions, and marginal habitat for salamanders. In the southern Washington Cascade Range, headwater stream surveys of 26 sites in which Van Dyke's were not previously known to occur yielded detections at only 2 sites (McIntyre 2003); however, surveys targeting headwall seeps detected the species at 10 of 35 seep locations in which they were not previously recorded (McIntyre et al. 2006).

Figure 1. Known locations of the Van Dyke's Salamander (*Plethodon vandykei*) in western Washington, distributed across 42 5th-field watersheds (hydrologic units, HUs).

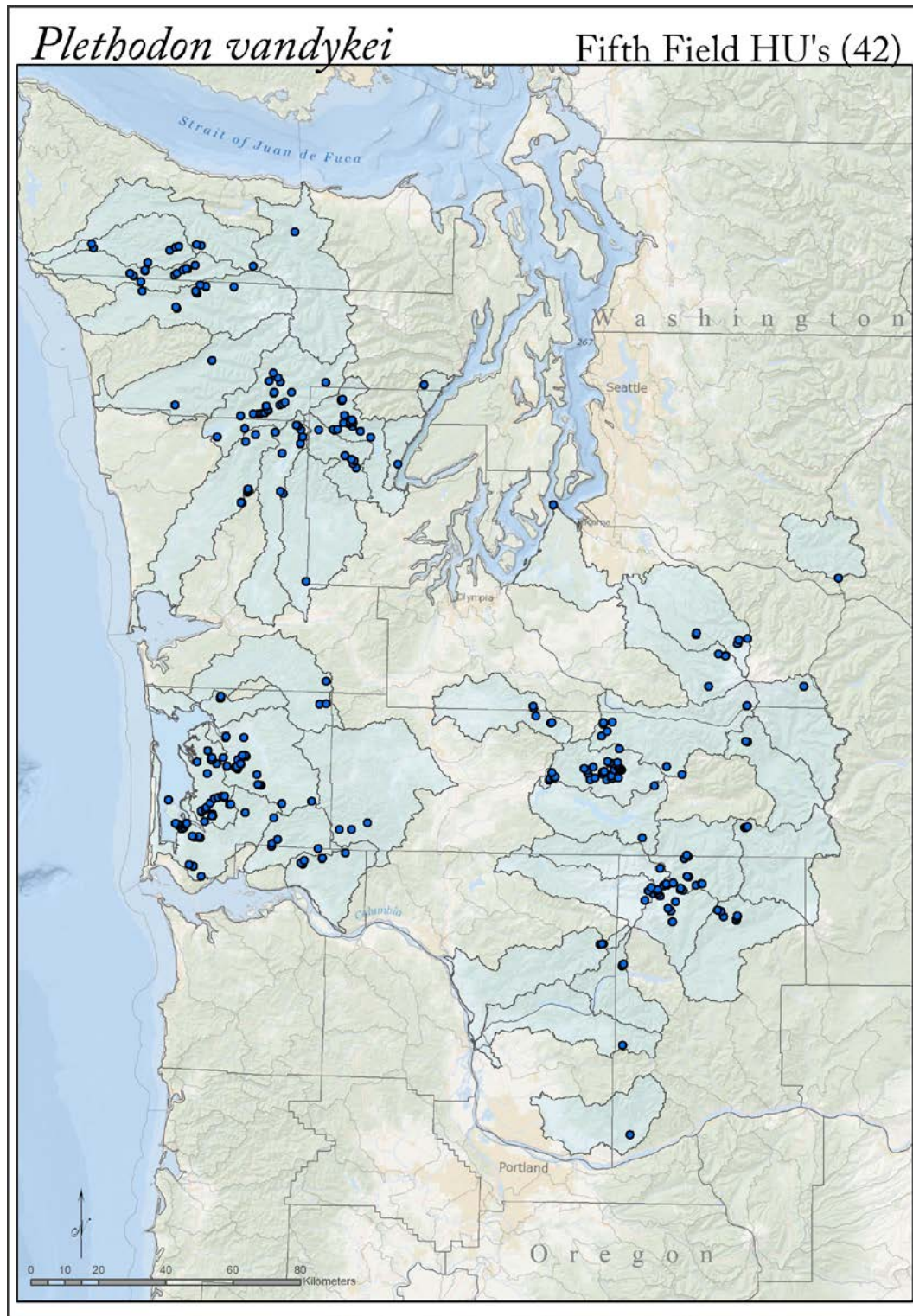
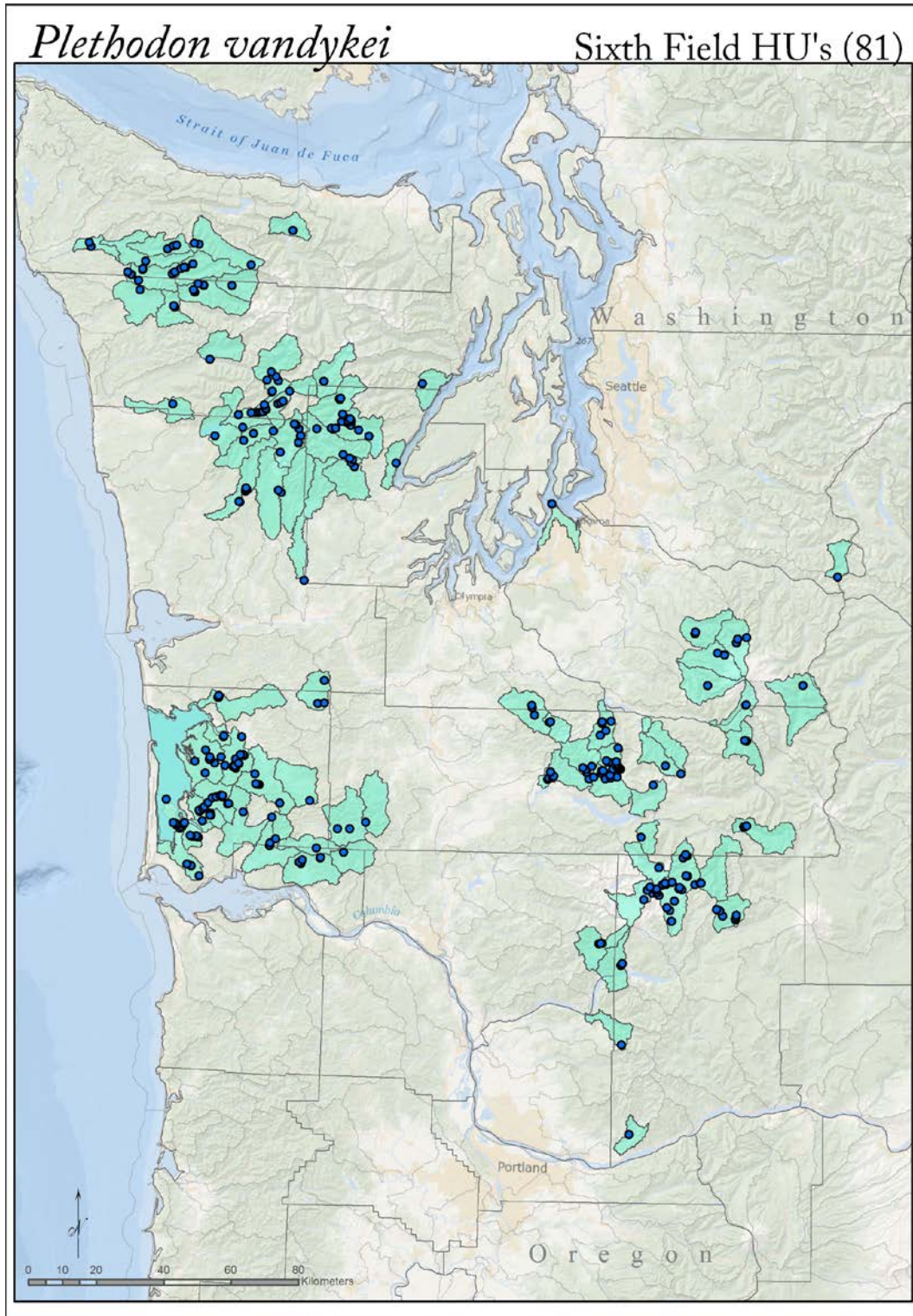


Figure 2. Known locations of the Van Dyke's Salamander (*Plethodon vandykei*) in western Washington, distributed across 81 6th-field watersheds (hydrologic units, HUs).



Demography and Population Trends

Little is known about the demography or population trends of this species. In the Cascade Range, McIntyre et al. (2006) reported that at headwater seeps, adults comprised only 9.6% of animals captured, in comparison to adults representing 33.7% of captures associated with streams. In both habitat types, juveniles dominated the captured samples. It is not known if there was a sampling bias toward juveniles. For example, it is possible that life stages partitioned the vertical habitats of the streamside zones and seeps in such a way that adults were deeper and out of reach during sampling of the topmost layers of substrates. No long-term population monitoring efforts have been conducted.

Habitat

Van Dyke's Salamanders are dependent upon cool, moist environments (Wilson et al. 1995), and are considered semi-aquatic because most locations are associated with streams or seeps (Brodie and Storm 1970; Leonard et al. 1993; Wilson et al. 1995; McIntyre 2003; McIntyre et al. 2006). Their association with streams and seeps is probably a result of the influence of moisture, temperature, and geomorphology on the local environment, rather than a direct reliance upon free-flowing water. They are not found within the flowing water of streams, but are distributed along banks, occurring in the splash zone of streams and waterfalls (Leonard et al. 1993; Wilson 1993), and in humid streamside areas outside the saturation zone—in a narrow band of suitable habitat starting from a flowing body of water and extending to the top of the valley wall or into the surrounding habitat, but typically <10 m (<30.5 ft) from water (L.L.C. Jones, pers. comm.). The species may be found where there is a thin sheet or film of water or where the habitat is moist, but not in deeper water or in more xeric upland sites. Suitable habitat appears to be based on hydrologic-geomorphic conditions. Stream and seep sites may be isolated, patchy, or continuous. Van Dyke's have also been observed in association with down wood near seeps (C. Knauf, Bureau of Land Management, pers. comm.). More detailed stream and seep habitat associations are described below.

In addition, Van Dyke's Salamanders have been found in upland forests away from surface water

(Slater 1933), in forested talus (Herrington 1988), along lake shores (Crisafulli et al. 2005a), and at cave entrances (Aubry et al. 1987). Although habitat associations of these salamanders away from streams and seeps are not well quantified, an optimal upland site has been generally characterized as being on a well-shaded, north-facing slope, with a dense carpet of mosses underlain by rock (Slater 1933; Nussbaum et al. 1983). Salamander microhabitats at these sites include surface rock or woody debris. Crisafulli et al. (2005a) reported this species along the shores of high-elevation, cirque lakes in the Mount St. Helens blast area. Animals were found under debris at the margins of the lakes. Some populations are closely tied to fissures and rocky debris from bedrock exfoliation often associated with cliffs, rock walls, streambanks, and roadcuts. Although the species may be found in woody debris (Jones 1989; Jones and Atkinson 1989; Zalisko and Sites 1989; Wilson 1993), it is usually associated with nearby or underlying rock sources. Coastal populations may have more of a tendency toward using woody debris (Jones 1989; Jones and Atkinson 1989; Wilson et al. 1995; Blessing et al. 1999) than Cascade Range populations. In the Cascade Range, they are often found in cracks and fissures of saturated rock faces and in or under rocky or woody debris from colluvial deposition. Crisafulli (pers. observ.) has also found this species on north-facing slopes within late-seral forest with talus substrates, >200 m (610 ft) from water. Aubry et al. (1987) reported Van Dyke's Salamanders in the entrance of a cave, where they were sympatric with the Larch Mountain Salamander, *Plethodon larselli*. Additional cave locations have been recently found (Crisafulli, pers. observ.). At caves, they occur under surface debris in seep-like or moist part of the cave (lava tube, sinkhole) entrance (the "twilight" zone). Within the different habitat types, Van Dyke's Salamander seek out cool and moist or wet cover. In some respects, Van Dyke's Salamander might be perceived to be a generalist because it may be found in a variety of habitats at a large range of elevations, but is the commonality of cool, wet microsites present across the range of known supports this species as highly specialized with respect to habitat.

Although the tie to a near-lotic environment is not absolute, it is probably rooted to an underlying temperature-moisture preference (see Spotila 1972; Feder 1983). However, direct evidence of temperature-moisture preferences and critical limits is lacking for the species. Nevertheless, the "guild" of stream-associated amphibian species found in the Pacific Northwest appears to be

most adapted to live in a cool, wet environment and may exhibit little tolerance for warm, dry conditions (e.g., Corn and Bury 1989). Ray (1958) demonstrated that torrent salamanders, *Rhyacotriton* species, and Dunn's Salamanders, *P. dunni*, which are microsympatric with *P. vandykei*, had the lowest tolerance for water loss of all salamanders studied. For example, the mean lethal point for *Rhyacotriton* occurred at only 19.4% water loss, whereas *Ensatina* (*Ensatina eschscholtzii*), an upland plethodontid in the same region, could tolerate up to 39.2% water loss. Similarly, on the thermal spectrum, the same two stream-associated species had some of the lowest mean voluntary body temperatures recorded by Brattstrom (1963) in his survey of about 40 species. Due to occupancy of the same types of streamside habitats, these data support the requirement of the Van Dyke's Salamander for particularly cool, moist habitats, especially in comparison to other species.

In terms of potential natural vegetation zones, *Plethodon vandykei* occurs in conifer-dominated forests of Sitka Spruce (*Picea sitchensis*), Western Redcedar (*Thuja plicata*), Western Hemlock (*Tsuga heterophylla*), Douglas-fir (*Pseudotsuga menziesii*), and Mountain Hemlock (*Tsuga mertensiana*). It is largely absent from areas that receive less than 150 cm (59 in) annual precipitation and from lowlands of unconsolidated quaternary deposits (Wilson et al. 1995).

Wilson (1993) reported aspect and overhead cover of the sites he surveyed. Although canopy closure was typically high at most sites, many lacked tree cover; some were in the Mount St. Helens blast area and others in timber harvest areas. However, the canopy cover reported did not separate vegetation from topographic overhead cover. Also, Wilson often reported evidence of logging, but subsequent knowledge of some of these sites (L.L.C. Jones, pers. comm.) indicated that this included everything from clearcuts to late-successional sites with a few select trees removed for timber or road construction. Hence, it is difficult to obtain a clear impression of the management practices at given sites. Not surprisingly, many known sites are at roadcuts (Brodie 1970; Wilson 1993), which are more easily surveyed and expose rocky substrates that may have suitable microclimates for these animals.

Two quantitative studies have addressed habitat associations of the Van Dyke's Salamander.

First, Raphael et al. (2002) conducted a retrospective study of the effects of timber harvest on the distribution and relative abundance of stream and riparian vertebrates on the Olympic Peninsula. They assessed animal abundances at 62 forested stream-riparian sites with 1st-to 3rd-order streams, with site histories ranging from clearcuts to old-growth forest. They found Van Dyke's Salamanders only in old-growth forest sites and buffered forest sites (sites with unlogged old-forest (> 100 yrs) streamside buffers that were 10-30 m wide, with clearcuts upland of these buffers). These salamanders were not found in mature sites (second-growth, 35 to 100 yrs after clearcut; no stream buffers), thinned mature stands (commercial thinning; no stream buffers during first or second entry), buffered mature sites (originally clearcut with no buffers, then the second-growth along streams was retained in a buffer when the upland was clearcut again; buffer stand age was 35 to 100 yrs), or young sites (< 35 yrs). Although this work supports the salamander as having associations with old-growth forest conditions, a complicating factor was that old-growth sites were at higher elevations and in steeper terrain - so that definitively teasing apart significant components of habitat suitability was not possible. They also noted that Van Dyke's Salamanders were primarily found inside the valley wall of streams (L.L.C. Jones, pers. comm.).

Second, McIntyre (2003) and McIntyre et al. (2006) reported species associations in the Washington Cascade Range at streams and seeps. Among 50 small (1st- and 2nd-order) stream sites occurring at 140 to 1480 m elevation, McIntyre (2003) found Van Dyke's Salamanders were associated with the proportion of stream valley walls with canopy cover <5%, and stream substrates dominated by boulder, bedrock, and soils. Adjacent to streams, salamanders increased in numbers with increasing non-forested areas, bedrock, and vertical or V-shaped channel wall morphology. At the stream microhabitat scale, animal occurrence increased where trees were absent, seeps were present, and cobble-sized substrates were present. Among 40 seeps at 450 to 1550 m elevation, McIntyre et al. (2006) found the probability of Van Dyke's Salamander occurrence "increased with increasing proportions of seep face having both dry and sheeting hydrology, and increasing proportions of seep face >5 m high." Within seeps, salamander occurrence decreased where total overhead cover was >25%. At microhabitat scales, animals were associated with small cobble, small gravel, and bedrock substrates. These findings are

consistent with an animal that is especially sensitive to desiccation (McIntyre et al. 2006), and that vegetation is likely of secondary importance compared to hydrology and substrate.

V. CONSERVATION

Land Ownerships and Habitat Management

The relationship of the species' distribution to lands administered by the federal government and the US Forest Service, in particular, is a key consideration for conservation of the Van Dyke's Salamander in Washington. Most (65%) of known locations are on federal lands and 58% of federal locations of this species are on Forest Service lands. When considering the three distribution centers of this species in western Washington, only the Willapa Hills locations fall outside of significant federal land holdings. Hence, two of the three areas of known locations have landscapes dominated by federal lands, where most Forest Service sites occur on the Olympic and Gifford Pinchot National Forests. Due to the species' stream associations and the coverage of the Northwest Forest Plan across the species' range in these national forests, riparian reserves play a significant role in the protection of this species (USDA and USDI 1994).

Furthermore, the species was designated as a Survey and Manage species under the Northwest Forest Plan largely due to its rarity and habitat associations. Many riparian-associated amphibian species were assumed to be protected by the Plan's riparian reserve provision. Due to known upland sites in 1993, this species was likely not considered restricted to riparian areas, and its risk rating likely reflected both its uncertain upland habitat affinities and the low numbers of sites at that time, especially in the Cascade Range (Olson, pers. observ.). Given the extensive efforts to survey for this species in the Cascade Range since then, its relative rarity has been confirmed, and whereas both aquatic- and upland-associated sites are known, the vast majority of all known sites are associated with aquatic habitat.

Threats

Threats to the Van Dyke's Salamander are not well studied, but the primary suspected threats

across the species' entire range include activities that may change habitat, microhabitat, and microclimate conditions. The main anthropogenic activities that may alter the species' habitat conditions include timber harvest, road construction and culverts, mining and excavation, and recreation. In particular, factors which alter the surface and subsurface microhabitats and microclimates used by this animal or create barriers to dispersal and gene flow likely affect this species. Microhabitat alterations of specific concern are increased microhabitat temperatures, decreased moisture conditions, altered hydrological patterns, direct ground disturbances to streamside areas, seeps, and moist rocky areas. Additional potential threats include floods and debris flows, disease, climate change, forest fire events, chemical applications, rural development, overexploitation (repeated disturbances from collectors or surveyors), and volcanism.

Timber Harvest

One retrospective study addressed timber harvest effects on this species in streamside habitats. Raphael et al. (2002) found that Van Dyke's Salamanders were only found along streams in old-growth forest sites, or sites with old-growth forest buffers that were 10-30 m wide—but the species occurred in much lower densities in those old buffers. The species was not detected at sites that had been initially clearcut then regrown to current mature stand ages spanning 35 to 100 yrs. Nor were animals found in other treatments with greater levels of harvest. The implication was that this species is old-growth forest associated, and is highly sensitive to habitat disturbances associated with clearcutting along streams. Assuming Van Dyke's Salamanders were present at these sites before harvesting, clearcutting the riparian zone likely negatively affected the salamanders, and populations had not recolonized or recovered in the next 30 to 100 yrs. In addition, Van Dyke's Salamander abundances were much lower along streams with old-growth buffers, 10-30 m wide, and upland clearcutting, suggesting that this treatment also had negative effects on the animals, yet the animals persisted likely due to the ribbon of intact streamside habitat.

Broad distributional patterns of this salamander also suggest the effects of past timber

management disturbances. This salamander has never been found in the area between the Willapa Hills and the Olympic Peninsula, in the Capitol Forest, or on the Kitsap Peninsula, or between distributional centers in the Cascade Range (Wilson 1993). All of these areas were heavily logged in past decades and some are going through a third commercial rotation of timber harvest. However, we cannot prove that this broad spatial pattern of their occurrence is an outcome of logging or other processes, and we may lack knowledge of their occurrence in these areas. Crisafulli (pers. observ.) has not found Van Dyke's Salamanders in a streamside haunt where he regularly used to see them, but more recently the stream valley had been sluiced out by catastrophic floods. This is an example of a natural disturbance that may affect this species.

Many studies have reported effects on North American plethodontid salamanders from timber harvest, in particular regeneration or clearcut harvest practices (e.g., deMaynadier and Hunter 1995; Ash 1997; Herbeck and Larsen 1999; Grialou et al. 2000). A review of 18 studies that looked at salamander abundance after timber harvest (deMaynadier and Hunter 1995), 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 in recent clearcuts, 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-year-old) forests also suggested that salamanders are eliminated or reduced to very low numbers when mature forests are clearcut (Petranka et al. 1994). In secondary forest that was thinned in western Oregon, Rundio and Olson (2007) found reduced abundance of plethodontid salamanders in stream to upland transects at one of two sites examined within two years post-harvest. Also at secondary forest sites, Olson et al. (2014) found lower abundances of stream bank amphibians in narrow streamside buffer zones compared to wider buffers with upland forest thinning, 10 years post-harvest. Several other 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, 1991; Welsh 1990; Corn and Bury 1991; Dupuis et al. 1995).

In contrast, Kluber et al. (2008) and Hawkes and Gregory (2012) found no effects on upland

plethodontids after upland thinning with stream buffers in Pacific Northwest forests, in Oregon after ~5 years of harvest and in Washington after 10 years, respectively. Also, Messere and Ducey (1997) found no significant differences in abundance of plethodontid salamanders in forest canopy gaps in stands that had been selectively logged, suggesting that limited logging may have little effect on their study species. It appears to be important not to cast all logging practices in the same light, as clearcuts and thinning activities may have differential effects on ground-dwelling plethodontids, and riparian buffers may offer some protection to terrestrial-breeding species (e.g., Kluber et al. 2008; Olson et al. 2014). Important interacting factors that may affect the representation of these site-specific studies with limited direct inference to forests elsewhere include subsurface habitat conditions and microclimates, and timber harvest effects on these facets (Welsh 1990).

Several types of disturbances can result from timber harvest practices. Removal of overstory may cause desiccation of rocky substrates and loss of the moss ground cover. Microclimate edge effects from a clearcut into an intact stand can permeate hundreds of meters (Chen et al. 1995). Tree-felling and ground-based logging systems disturb the substrate, resulting in shifting and compaction of substrate, which reduces subsurface interstices used by salamanders as refuges and for their movements. Site preparation practices such as broadcast burning remove the moss covering that helps to stabilize rocky substrates. Site hydrological patterns may also be affected by forest harvesting (e.g., Moore and Wondzell 2005). Alteration of surface flows is a key concern for Van Dyke's Salamanders. The dynamics of ephemeral flow regimes are little known at this time, especially how they may relate to anthropogenic disturbances such timber harvest.

Forest microclimate patterns, critical for these salamanders, can be affected by timber harvest activities (e.g., Anderson et al. 2007; Janisch et al. 2012). With upland forest thinning, riparian buffers along small streams retained microclimate conditions at the stream center when the buffer was at least 15 m wide (Anderson et al. 2007). Rykken et al. (2007) reported that a riparian buffer of 30 m retained streamside microclimates with upland clearcutting. They discussed the counterbalancing of an upland edge effect along buffers with the cool, moist "stream effect" prevailing from streams into uplands. Wessell (2005) found that interior forest microclimates

were retained at the center of a 0.4-ha (1-acre) 'leave island' of secondary forest, with thinning outside that circular island of green-tree retention.

The landscape with the range of the Van Dyke's Salamander is somewhat fragmented by past timber harvest practices and is a patchwork of stands of different seral stages, from early-seral to mature forests. Sites recover from these various disturbances on different timelines. Sites with Van Dyke's Salamanders are nested within this patchy forested regime. There are no real estimates of how much potential suitable habitat for the species has been affected by timber harvest activities, nor do we have specific information on whether or how these various practices may affect these animals. As with other salamanders, the impact of timber harvest on a given population will depend on the effect the harvest method has on the microclimate and microhabitat structure (Welsh 1990). Streamside Van Dyke's Salamander populations may be at risk from timber harvest along streams, even if buffer strips are retained (Raphael et al. 2002), suggesting that upland disturbance can affect downslope animals or their habitats. This finding was echoed in principle by Olson et al. (2014), who reported reduced abundances of streambank plethodontids in narrow versus wider buffers with upland thinning in Oregon. However, the fact that populations are sometimes found in naturally or artificially deforested areas suggests that either the critical habitats occupied by these animals were not affected or that Van Dyke's Salamanders have resiliency to habitat modification from some of the various harvest-related activities. This would be expected to vary on a site-by-site basis. Areas most at risk are probably those that cannot maintain an acceptable temperature-moisture regime when trees are removed, or those that might experience hydrological damage. An example of this would be a small stream receiving little snowmelt, in which exposure from timber harvest would mean increases in water and air temperatures, evaporation, and excessive transport of colluvial materials. Upland sites and possibly isolated headwall seep sites also may lose moisture during the summer with timber harvest. Areas in which less impact would be expected include rock faces where the primary refuge is deep within cracks in bedrock and a year-round cool water flow is expected. However, surface activities might be limited by unsuitable conditions in these cases, and potentially affect life-history functions such as foraging or breeding. Also, deep stream valleys or canyons may provide overhead cover and hill-shading even in the absence of trees. Near-coastal sites may

benefit from maritime weather patterns, reducing xeric conditions.

Roads and Culverts

Road construction or stream-crossings of roads may have negative effects on these animals, although no studies have been conducted to quantitatively assess impacts. When roads are constructed in rocky areas, explosives, heavy machinery, and petroleum products are used. Physical damage to the salamanders could occur from crushing, entrapment, shock waves, and exposure to chemicals. Road construction exposes subsurface rock which could have either deleterious or beneficial effects on this species, depending on the circumstances; currently, no studies address these issues. Exposure could conceivably cause mortality due to increased warming and drying, or could adversely affect individuals due to the erosion and sedimentation filling interstitial spaces of microhabitats. Road building also may change existing hydrological patterns, altering potentially critical habitat for these salamanders. Also, roads lead to secondary interactions from humans for recreation, timber production, mining, fertilizing, development, and other activities. These secondary activities could adversely affect salamanders and are discussed separately.

At road-stream crossings, culvert installation is a ground-disturbing activity that may affect resident salamanders. Maintenance of aquatic organism passage is a priority management concern, especially on federal lands (Hoffman et al. 2012; GAO 2001). Culverts at road-stream crossings have a long history as barriers to fish migration (Hoffman and Dunham 2007), and can be barriers to amphibian movement in forested landscapes as well (Andrews et al. 2008; Marsh et al. 2005; Sagar 2004; deMaynadier and Hunter 1995). Culverts may present barriers at the pipe outflow, where they may be “perched” with significant drops from the pipe edge to the stream surface. Culverts also may result in increased water velocity, which may inhibit movements of instream salamander species because they are not capable of pushing upstream against strong currents, and streambank-associated salamanders like the Van Dyke’s Salamander where increased flows more readily achieve bankfull widths. Furthermore, culverts may have a surface that lacks natural roughness characteristics like those of the natural streambed, which may be a

significant factor for an animal that crawls for dispersal—the culvert bottom may be too smooth for the salamanders to maintain a grip even against relatively slow water velocities. General maintenance to the road prism, culvert or ditch cleaning, waterbars, or other such work, may affect salamanders, but effects may be reduced if seasonal restrictions are considered. Culverts that become blocked and eventually result in a failure can release a sudden pulse of impounded water (flood surge) and debris, adversely affecting salamanders and their habitat integrity.

Road decommissioning and culvert removal may have long-term benefits for Van Dyke's Salamanders. If it is known where the animals occur along streams, then the road crew can take steps to protect the salamanders and habitat from short-term adverse effects. For example, culverts can be removed in a way that disturbs the ground and water flow as little as possible; substrate shifting can be avoided; the active channel can be maintained; ground stabilizing vegetation and non-intrusive devices can be used to control ground movement; sediment transport can be controlled.

In many ways, trail building may have effects similar to roads on these animals, although likely with smaller scope and impacts. Alignment of trails to avoid occupied habitats may be possible to reduce the effects of habitat disturbance and subsequent trampling of salamanders and their habitats.

Mining and Excavation

Mining and rock excavation may have similar negative effects to those of road construction, yet may have more concentrated areal impacts rather than being a linear disturbance across the landscape. Such ground disturbance would significantly alter the habitat and potentially harm animals directly or indirectly via disruption of hydrological processes and microclimates. Also, rock fields can be deliberately intersected to supply the raw materials for the construction of roads, and this may affect rock-associated amphibians (Herrington 1988).

Recreation

Spelunking might cause an impact on a population if cover objects are disturbed or the microclimate is altered for cave-entrance populations. Foot travel over rock rubble, which the animals use for cover, is the greatest threat to the cave populations; substrates at cave entrances tend to shift when walked on.

Human and horse trails probably have an effect on the immediate surroundings by causing soil compaction or physical trauma, although increased access to sites might cause other problems (pollution, fire, firewood collection).

Campgrounds may affect populations nearby. For example, areas around campgrounds tend to have compacted soil and lack large woody debris. A campground near a known locality also may result in increased collecting.

Floods and Debris Flow

The stream channel structure and water flow patterns are of critical importance to this species, and geomorphic/hydrologic changes are potentially deleterious. In particular, alteration of water flow can influence surface and subsurface microhabitats. It is possible that sluicing events, especially catastrophic slope failure from logging, road building, extreme storm events, or culvert activities, could extirpate populations. Natural rainfall patterns are so variable that a site may seem stable for many years; however, long-interval floods are normal, and these confound anthropogenic activities and structures. Any activity that increases evaporation and temperature could be detrimental. Wilson (1993) viewed hydrologic disturbance as a potential threat to the species.

Disease

The amphibian chytrid fungus (*Batrachochytrium dendrobatidis*) (*Bd*) is known from Washington (<http://www.bd-maps.net/>). This disease is particularly notable relative to Van Dyke's Salamander because of both the salamander's and fungus' aquatic life history. *Bd* is an

aquatic fungus that thrives best at cool temperatures, and has been found more frequently in aquatic than in terrestrial amphibians. Some amphibian species can be carriers of *Bd*, and do not show symptoms of the disease. Although the mechanisms of resistance are not fully understood, carriers may be resistant to the disease, or the intensity of infection *Bd* or strain virulence may be low. As far as we have been able to determine, no studies have tested for *Bd* in Van Dyke's Salamanders. In general, *Bd* prevalence appears to be low among Northwest amphibians associated with small streams, but only one study, Hossack et al. (2010), has targeted amphibians in those habitats. The disease deserves mention here to alert biologists to be aware of and report observations of ailing or dead animals. *Bd* is a skin disease that acts on keratin in amphibian skin. Skin has vital functions in amphibians, including important roles in the exchange of oxygen, water, and electrolytes with the environment. Lungless salamanders breathe entirely through their skin; however, salamanders have keratin only in the skin of their feet. Symptoms of chytridiomycosis, the disease associated with *Bd* infection, include excessive sloughing of the skin; lethargy; unresponsive animals, including loss of their "righting reflex" (they do not right themselves if turned upside down); and anorexia. Salamanders may exhibit lesions on their feet, where their skin has the most keratin. Field gear such as boots or nets, and translocated animals or water (e.g., during fire management or water diversions) can spread *Bd* to uninfected areas. Disease disinfection protocols for gear and water are available at (http://www.fs.fed.us/r4/resources/aquatic/guidelines/aq_invasives_interim_fire_guidance08_final.pdf).

Vulnerability of Van Dyke's Salamanders to other pathogens has not been studied. In addition to the amphibian chytrid fungus *Batrachochytrium dendrobatidis*, *Bd*, a new chytrid fungus, *Batrachochytrium salamandrivorans* (*Bs*) was described from Europe in 2013 and is causing mortality in forest-dwelling Fire Salamanders (*Salamandra salamandra*) there. An experimental study of the effects of *Bs* on a broad spectrum of the world's amphibians found that it was lethal to many salamander species (Martel et al. 2014), including Rough-skinned Newts (*Taricha granulosa*) from the Pacific Northwest. Although the response of *P. vandykei* to *Bs* has not yet been tested, during laboratory trials *Bs* was not lethal to its congener *P. glutinosus* from the eastern US. *Bs* is not known from the United States at this time, but it has been found in *Bs*-

resistant salamanders imported to Europe from Asia. Its presence in captive salamanders from Asia which may carry Bs but are resistant to its effects has emerged as a concern in the event that an infected but resistant animal or the fungus alone gets released into the wild in other places, especially areas of the US that are known salamander biodiversity hotspots, such as the Pacific Northwest.

Ranavirus is an emerging infectious disease tied to massive mortality episodes in a variety of amphibian species, including salamanders. If dead animals are found, it may be possible to test them for pathogens if the carcasses are in good condition (contact Dede Olson: dedeolson@fs.fed.us).

Climate Change

Climate change is expected to be the biggest future challenge to the persistence of amphibian species (Corn 2005; Shoo et al. 2011). Amphibians are extremely sensitive to temperature and moisture conditions, and also to hydrological regimes that may change with global circulation patterns. Summer flow regimes at seeps and small streams are important for this species. Altered climate could have severe consequences for habitat spatial distribution, and habitat fragmentation. Like other similar salamander species, Van Dyke's Salamanders have low mobility and dispersal capabilities; this suggests that local populations could be isolated or lost if temperature and moisture conditions change beyond the animal's tolerance limits. Although no empirical studies have addressed climate change and Van Dyke's Salamanders, a climate vulnerability assessment was conducted for this species, finding it quite vulnerable to changes in climate-related factors (<http://climatechangesensitivity.org/node/539>).

Regional climate models project rates of warming in the Pacific Northwest of 0.1°C to 0.6°C per decade, with precipitation trends tending toward wetter autumns and winters but drier summers (Mote and Salathe 2010), changes that may affect the Van Dyke's Salamander in unanticipated ways. Trends in annual stream flow in the Pacific Northwest show strong and significant declines at a large majority of gauging stations—in essence, the driest 25% of years (1948–2006) are

becoming substantially drier (Luce and Holden 2009). Assessing landscape and climatic factors that restrict gene flow, Trumbo et al. (2013) suggested that with the projected patterns of climate change in the Pacific Northwest, habitats will become less suitable for some aquatic-dependent species like the Cope's Giant Salamander (*Dicamptodon copei*), and range retractions are likely in the southern portion of the species range, particularly in the Cascade Range ecoregion. Cope's shares habitat and distribution with Van Dyke's Salamanders to some extent, and the Trumbo et al. (2013) predictions may be relevant to consider for the semi-aquatic Van Dyke's as well. Conversely, the same authors consider that range expansion is possible—for example in the northern range boundary of the Cascade ecoregion into Mount Rainier National Park, if climate is a limiting factor for animals in those areas. In addition, more frequent extreme precipitation events that may accompany climate change projections for the region could result in increased variability of high-flow events, which may in turn adversely affect Van Dyke's Salamanders and other species that share their habitats.

Forest Fires

The effects of forest fires on Van Dyke's Salamanders are unstudied. Within the species range, the frequencies of large stand-replacing fires are quite different between the Coastal and Cascade ecoregions, with fire return intervals ranging from decades to centuries (Agee 1993). In an interior northwest study, Pilliod et al. (2003) found that: 1) stand-replacement fire is a catastrophic disturbance to flora and fauna with subsequent changes in microclimate and stream temperatures; 2) post-fire fine sediment inputs to streams can be greatly increased; and 3) increased peak flows may result from loss of vegetation in the upland forest surrounding streams, causing channel scour. Post-fire landslides and debris flow events could sluice streams, killing salamanders within the stream prism, and may occur after stand-replacing fires or some timber management activities on unstable slopes. In contrast, low-intensity fires, including prescribed fire for fuels reduction treatments in forested uplands, could have little adverse effect on this species if local salamander microhabitats and microclimates are retained. Increased fire frequency exacerbated by climate change is a concern.

Chemical Applications

Herbicides, pesticides, fertilizers, and fire retardants may harm these animals to varying degrees, via absorption through their permeable skin or through food web processes. Similarly, oiling or lignin application on roads may adversely affect these salamanders. No data exist, however, specific to chemical effects on this salamander to help understand the scope of this potential threat. A recent study found that fire retardants compromise the immune system of frogs (Cary et al. 2014). Chemical application on state and private forest lands is a concern across the species range. However, on federal land the threat of direct chemical applications is likely generally low, and the extent of effects of downstream flow of chemicals from upstream applications on non-federal lands is unknown. The threat of fire retardants and scope of their use on lands within the species range in Washington is uncertain, and warrants examination. Aerial drift of agricultural chemicals onto adjacent habitats has not been investigated, and may be an additional concern.

Overexploitation

Known sites with easy access in close proximity to roads may be prone to oversampling by scientists, salamander enthusiasts, or for educational purposes. Due to the relative rarity of this animal, over-collecting is a potential issue of concern.

Volcanism

Cascade Range populations of the Van Dyke's salamander live exclusively in an area of volcanic activity. Most known localities occur in the vicinity of Mount St. Helens and Mount Rainier, which are both active volcanoes. Wilson (1993) suggests that the patchy distribution of the salamander seen today is in part due to previous volcanic events. Although this is not a manageable threat, it is recognized here because it may explain current distribution patterns in the Cascade Range, and have relevance for future management of landscapes subject to catastrophic natural disturbances. At least some populations of Van Dyke's Salamander survived the 1980 blast of Mount St. Helens (Zalisko and Sites 1989; Crisafulli et al. 2005a), but the number of populations that may have been extirpated is not known. Individuals likely survived

by being in subsurface refugia during the eruption, particularly in cracks in bedrock and cool, headwater systems (with a protective layer of snow). Moreover, at the time of the eruption much of the high elevation, and even lower elevation sites with north and east exposures, and areas with steep topography (cliffs) were holding deep remnant snow, which protected plants and animals from the intense eruptive forces (Crisafulli et al. 2005b). Crisafulli (unpublished data) documented several such sites where Van Dyke's Salamanders survived the eruption and have persisted in such refugia for decades. Some populations may survive or even flourish after such a disturbance event, particularly in protected sites as discussed above, yet a large disturbance event like this is likely to isolate populations and reduce connectivity. However, it would be unwise to speculate that because populations survived and have persisted in the post-eruption Mount St. Helens landscape that an equivalent response would occur following other intense large-scale forest disturbances, especially if the event occurred during the growing season when snow was not an ameliorating factor. Amphibians that inhabit streams and seeps, such as Van Dyke's Salamanders, often have low dispersal capability and are unlikely to be able to colonize even potentially suitable sites that are surrounded by large areas of hot, dry, sparsely vegetated habitats.

Known Management Approaches

Riparian protection may benefit this species. Raphael et al. (2002) found in a retrospective study that Van Dyke's Salamanders persisted along streams in old-growth forests, and in riparian buffers composed of old-growth forest with upland clearcutting. Hence, occupied streamside areas may be protected by riparian buffers. Furthermore, an expert panel convened during development of the federal Northwest Forest Plan (USDA and USDA 1994) evaluated the role of riparian protection in providing species persistence, and concluded that the Van Dyke's Salamander would benefit from riparian reserves (USDA and USDI 1997; Olson and Burnett 2013). Benefits to this species also may occur on other land ownerships through the Washington State Department of Natural Resources Forest Practices Habitat Conservation Plan (WADNR 2013), which protects stream habitat on state and private lands, and includes work to improve forest roads and culverts, and buffers along stream banks. Hydraulic permit procedures required

by Washington Department of Fish and Wildlife provide guidance for road/stream crossing construction, upgrade, and maintenance specifications for fish-bearing waters that may coincidentally be inhabited by Van Dyke's Salamanders (WDFW 2013). However, these permit procedures are only required for fish-bearing waters, and design specifications that target fish passage may not be adequate to accommodate aquatic amphibians as well.

The federal Survey and Manage provision of the Northwest Forest Plan benefits this species. Identification of localities occupied by Van Dyke's Salamanders through pre-project surveys increases our knowledge of the distribution of the animal and has confirmed its relative rarity. Subsequent management of those known sites for site-level persistence of the salamander also benefits the species by reducing the threat of anthropogenic disturbances. Strategic surveys have increased our knowledge of the salamander's occupancy patterns, habitat associations, and population metrics.

The US Forest Service 2670 and BLM 6840 sensitive species policy suggests appropriate management of this species. It is a requirement of the 2670 and 6840 policies to assess the effects of proposed activities on this species in National Environmental Policy Act (NEPA) analyses and documentation. The federal Interagency Special Status and Sensitive Species Program provide tools to address these policy requirements.

Management Considerations

The conservation goal for the Van Dyke's Salamander is to provide a reasonable assurance of species persistence within the range of the species in Washington. This includes the maintenance of well-distributed populations, and an overarching goal to avoid a trend toward listing under the federal Endangered Species Act (ESA), or a loss of viability.

Specific Objectives

Assess and prioritize areas of the species' occurrence and geographic range on federal lands,

relative to species management needs.

At sites that are managed for species persistence, maintain the integrity of microhabitat and microclimate conditions.

As a federal Survey and Manage species, all Cascade Range sites are to be managed for persistence. As knowledge of the species accrues over time and if more known sites of the species are discovered such that it is considered locally abundant and hence in an uncommon rather than rare status, a multi-agency Conservation Strategy might be considered in which priority sites for persistence are selected so as not to contribute to the need to list under the ESA. Under a Conservation Strategy, as projects are proposed on federal lands, priority sites to be managed for species persistence would be reviewed and potential or known sites within the project area would be evaluated along with any new species or area knowledge that might alter species management approaches.

Although recommendations 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 warrant consideration of each site with regard to the extent of both habitat protection and possible restoration measures. Methods to identify occupied sites for management 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. General known threats are listed above, and should be considered during development of site-level and basin-level management approaches.

Specific Considerations

At locations where Van Dyke's Salamanders have been found:

- 1) Retain streamside and seep-side riparian buffer zones to: A) reduce erosion; B) retain shading to reduce alteration of temperatures; and C) reduce peak flow variability from

runoff. Site conditions (aspect, hill shading, vegetation condition, watershed condition, cumulative effects) warrant consideration when considering buffer widths and whether managed buffers or no-entry buffers are needed. No studies address the efficacy of various buffer widths as protection measures for this species of salamander, hence direct support for a specific buffer size is lacking at this time. Raphael et al. (2002) found Van Dyke's Salamanders in 10-30 m buffers consisting of old-growth forest, with upland clearcutting. In a review, Olson et al. (2007) reported buffer recommendations for amphibians from the literature ranging from 6-76 m, in varying contexts, and buffers as wide as 300 m for retention of microclimates (Brosofske et al. 1997). However, additional more-recent research is available to apply to the retention of forest and streamside microclimates. A 1-acre (0.4-ha) circular area of forest may retain "interior" microclimate conditions with thinning (Wessell 2005), which could be applied to an isolated seep, and a riparian buffer along a small stream may retain streamside microclimates if the buffer is >15 m (~50 ft) with upland thinning (Anderson et al. 2007).

- 2) Employ variable-retention timber harvest such as commercial thinning or aggregated green-tree retention in adjacent riparian or upland forests to retain canopy closure and ameliorate microclimate shifts or erosion in the riparian zones, streams, and seeps. Restoration of riparian forests to accelerate old-forest conditions and structures such as future recruitment of large down wood may provide long-term benefits to this species and the larger community in streams and riparian areas, and should be considered on a case-by-case basis, weighing short-term costs with longer-term benefits.
- 3) Consider hill-shading and aspect in management of habitats; for example, such that naturally exposed areas prone to higher temperatures have vegetative buffering (canopy retention).
- 4) On a case-by-case basis, manage recreational use of occupied cave entrances, lake shores, and upland sites to avoid disturbances to habitats, microclimates, and animals. At occupied cave entrances, the need to initiate seasonal cave closures and the placement of elevated boardwalks or ladders to reduce risk of recreational impacts might be considered. However, at sites retaining cool, wet conditions throughout the year, animals likely have year-round surface activities.

- 5) Manage road construction, repair, and maintenance to accommodate both up- and downstream passage for semi-aquatic amphibians like the Van Dyke's Salamander.
- 6) Manage forest stands to reduce the likelihood of stand-replacement fires, including thinning of young, dense stands.
- 7) Closely monitor and/or restrict chemical applications near streams and seeps.
- 8) Restrict soil-compacting equipment or vehicle refueling near streams and seeps.
- 9) Assess the short- vs. long-term impact and the spatial scale of the impact of a proposed activity to identify the potential hazards specific to the persistence of the salamander.
- 10) The hazards of and exposure of salamanders to some activities relative to substrate disturbance, microclimate shifts, and incidental mortality should be minimized. A minimal or short-term risk may be inappropriate for a small, isolated population, whereas the activity may be possible in part of a large occupied habitat. 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.
- 11) Disinfect field gear between sites to reduce movement of pathogens. Disinfection guidelines to reduce risk of transmission of *Bd* and other aquatic invasive species are available at:
<http://www.fs.usda.gov/detail/r4/landmanagement/resourcemanagement/?cid=stelprdb5373570>
- 12) Disinfect water that is transported away from occupied stream reaches, or brought in from elsewhere (e.g., for fire management; see previous web link).
- 13) Consider delineating the spatial extent of the area occupied by this species for future monitoring. Site survey information should be compared to existing site data to document possible range extensions or retractions.
- 14) We suspect this species has low mobility, but do not know the extent to which this animal may disperse overland; hence it is prudent to consider management activities to promote connectivity among streams, seeps, and riparian habitats, especially between watersheds with no aquatic connectivity.
- 15) Minimize habitat fragmentation by retaining undisturbed areas extending from occupied

stream reaches into uplands to promote refugia or retention for salamander dispersal habitat. Upland and riparian habitat features such as seeps and/or wetlands likely benefit dispersal and persistence of semi-aquatic amphibians like the Van Dyke's Salamander across landscapes; these features should be identified (Janisch et al. 2011). Thus, buffer or riparian reserve boundaries should be extended from occupied streams to encompass and protect these features. These habitat features could also be considered for retention in linear arrays extending from streams into uplands and over ridgelines to adjacent riparian zones of neighboring drainages during timber harvest and fire management projects.

- 16) Consider proximity of sites to reserve areas, and maintain habitat connectivity to such areas.
- 17) Consider hill-shading and aspect in management of connectivity habitats; for example, such that naturally exposed areas prone to higher temperatures have vegetative buffering (canopy retention). Such considerations are especially important relative to potential future effects of climate change.
- 18) As possible, consider this species and manage impacts from mining and excavation, trail building, recreation, rural development, or overexploitation.

Inventory

Inventories could help advance knowledge of this species' current range, especially in undersampled areas of all three distribution centers. While a full geographic inventory is of prime importance, if surveys were designed carefully, then additional information about associations with habitat conditions, natural disturbance, and land management practices, population and genetic structure, and disease occurrence could be determined simultaneously.

Standardized survey protocols have been developed to assess species presence prior to habitat-disturbing activities associated with land management (Jones 1999). These protocols outline survey procedures and environmental conditions that optimize detection probabilities. Due to the cryptic nature of these animals, and their potential for patchy occurrences and low abundances, multiple site visits are recommended to detect presence at a site. Jones (1999)

survey protocol also lists management activities that are expected to affect these salamanders (survey triggers), as well as those that may be benign (survey exemptions). Although other survey approaches including timed searches, area-constrained searches, and opportunistic sampling are all potentially effective ways to detect this species, it is important to use standardized methods if survey results are intended to be compared across sites. While a species-detection at a site may be the survey goal, and accomplished readily by haphazard searches, lack of detection via haphazard search methods is difficult to interpret. Also, inventories conducted by standardized methods later can be used as baseline data for monitoring.

Survey approaches may vary for other purposes, such as research. In particular, studies addressing species-habitat associations or occupancy patterns will have 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. Methods used by McIntyre et al. (2006) and McIntyre (2003) at streams and seeps led to important habitat and population insights.

General inventory, monitoring, and research methods can be found in Heyer et al. (1994) and Graeter et al. (2013). Pitfall trapping and mark-recapture methods may be effective approaches for long-term site or population studies. Artificial cover boards may be effective for this species, but have not been well-tested. Nocturnal surveys also may be effective, but may be hazardous to surveyors in remote areas.

Monitoring

There is little to no on-going monitoring of specific sites for this species. Most inventory data are from specific research or Survey and Manage surveys. Monitoring would be useful to detect the response of populations to a variety of threats, known or suspected. Knowledge of land management activities at sensitive species' sites might be considered a prompt to consider monitoring of this species. Identification of sentinel sites for periodic tracking could be used for

detection of population abundance changes from enigmatic losses of unknown initial cause, such as disease. If monitoring were initiated, standardized methods could enable future comparisons among sites.

Research

Both monitoring and research studies may contribute to knowledge gaps. In particular information is lacking in these major areas:

1. Microclimate conditions required by the species in surface and subsurface habitat, and microclimate changes with vegetation management, including edge effects.
2. The response of the species to various land management activities that typically occur within the range of the species, including timber harvest activities (density management and regeneration harvest) and natural and prescribed fire.
3. Distribution and abundance patterns.
4. Development of habitat maps, climate niche models, and climate change effects models.
5. Reproduction, movement, dispersal, and foraging.
6. Genetic relationships between populations, geographic boundaries of discrete populations, and connectivity among populations.
7. Effects of multiple hazards or risks to species across landscapes and populations.
8. Species' role in ecological communities and ecosystem processes

The data gaps discussed above each relate to needed research on this animal. In particular, there is little information on how various contemporary forest management practices such as riparian buffers may affect microhabitats or populations of these salamanders. Stream-crossing culverts and design specifications have not been studied for this species. Also, the effects of climate change on habitats and the occurrence of *Bd* and other pathogens in this species are unknown. Climate envelope modeling would allow projections of effects of climate change in Washington, and may prioritize habitats for management or conservation. The general association of stream amphibians, with some of the pronounced climatic gradients on the Olympic Peninsula, for example, coupled with the overall sensitivity of amphibians to environmental changes, suggests

that the species may be useful in monitoring global climate change impacts (Corn 2005; Adams and Bury 2002). Lastly, due to the rarity and cryptic tendencies of this species, it would be useful to test the efficacy of the newly developed environmental DNA (eDNA) techniques (e.g., Goldberg et al. 2011) as an inventory approach. By testing filtered water samples, eDNA analyses can detect the presence of target aquatic species, and the method has proven effective for giant salamanders and tailed frogs in the US northwest. However, eDNA could be used only for stream and seep populations, and perhaps lake shores, but would not be able to detect those in rocky, cave, or down wood habitats.

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VII. DEFINITIONS

Occupied site

The location where an individual or population of the target species (taxonomic entity) was located, observed, or presumed to exist. May also be the area (polygon) described by connecting nearby detections in the same geographic location.

Persistence

The likelihood that a species will continue to exist, or occur, within a geographic area of interest over a defined period of time. Maintenance of well-distributed populations, in accordance with the viability provision of the National Forest Management Act. Includes the concept that the species is a functioning member of the ecological community of the area.

Site

Represents individual detections, reproductive sites, or local populations of a species. Specific definitions and dimensions may differ depending on the species in question. This term may also be used to represent a site that may be located in the future.

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