Conservation Assessment for the Cope's Giant Salamander

(*Dicamptodon copei*)

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Cover Photograph by Chris Roberts from the Queets River Basin

Alex D. Foster and Deanna H. Olson

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

Authors

ALEX D. FOSTER is a wildlife biologist, USDA Forest Service, Pacific Northwest Research Station, Olympia, WA 98512

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

Disclaimer

This Conservation Assessment was prepared to compile the published and unpublished information on the Cope's Giant Salamander (Dicamptodon copei). *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/*

Executive Summary

Species: Cope's Giant Salamander (*Dicamptodon copei*)
Taxonomic Group: Amphibian
Other Management Status: U.S.D.A. Forest Service, Region 6, Oregon - Sensitive; U.S.D.I. Bureau of Land Management, Oregon - Sensitive; State of Washington, State Monitored Species; State of Oregon – species facing one or more threats to their populations and/or habitats (V); NatureServe - Globally vulnerable and apparently secure (G3G4); Oregon Biodiversity Information Center - List S2 - Imperiled because of rarity or because other factors demonstrably make it very vulnerable to extinction, taxa that are threatened with extirpation or presumed to be extirpated from the state of Oregon; Washington Natural Heritage Program state vulnerable and apparently secure (S3S4). Management of the species follows Forest Service 2670 Manual policy and BLM 6840 Manual direction.

Range: The species occurs from the northwestern corner of the Olympic Peninsula, Washington, southward to the Nehalem River watershed, Oregon, and in the Cascade Range from the Nisqually River at Mount Rainier National Park, Washington, southward to the upper White River watershed in Wasco County, Oregon. The species is absent in the northeastern portion of the Olympic Peninsula and Puget Sound lowlands, Washington, and the Willamette Valley and its foothills, Oregon. Sporadic sites between the Coast and Cascade Ranges occur in Clark and Cowlitz counties, Washington. There are 581 discrete site records, which occur in 72 5^{th}-field watersheds (164 6^{th}-field watersheds), across ~3.2 million ha (~7.9 million ac).

Specific Habitat: This is a stream-dwelling amphibian reliant on cool, perennial streams with coarse substrates, often occurring in small streams with high gradients in forested uplands. The species is often found in its larval or paedomorphic adult forms (sexually mature adult with juvenile characteristics); both forms have gills and are restricted to aquatic environments. However Cope's Giant Salamanders are known to transform into terrestrial adults, and have been found in riparian areas close to surface waters.

Threats: Land-use activities that alter stream and riparian temperatures, substrates, and stream-flow patterns may affect Cope's Giant Salamanders. Forest management and stream-road culverts are the greatest concerns, primarily due to habitat alterations that impede dispersal, increase stream siltation from erosion, and increase in-stream temperatures after canopy removal. Climate change is likely to become an increasing threat due to reduced summer stream flow and elevated water temperature. These amphibians

are likely to be adversely affected by chemicals, such as herbicides, pesticides, fertilizers, and possibly fire retardants. Stand replacement fire, floods, disease, introduced species, and population fragmentation are concerns.

Management Considerations: Considerations for maintaining local populations include maintaining the integrity of microclimates, substrates, and stream-flow conditions at occupied sites. Reducing the impacts of forest management and road work on these three factors are key considerations. Riparian buffers would benefit this species.

Inventory, Monitoring, and Research Opportunities: Information gaps include the distribution of the species, reliance on riparian habitats, life history, habitat associations, threats to the species, and efficacy of alternative riparian buffer widths in maintaining animals and habitat conditions.

Table of Contents

I. INTRODUCTION 7

Goal 7

Scope 8

Management Status 8

II. CLASSIFICATION AND DESCRIPTION 8

Systematics 8

Species Description 9

III. BIOLOGY AND ECOLOGY 15

Life History 15

Activity Patterns and Movements 16

Food Habits 18

Range, Distribution, and Abundance 19

Demography and Population Trends 26

Habitat 27

Ecological Considerations 29

IV. CONSERVATION 30

Land Use Allocations 30

Threats 30

Culverts and Roads 31

Timber Harvest 32

Fine Sediment 33

Water Temperature 34

Climate Change 35

Forest Fires 36

Habitat Fragmentation 36
Chemical Applications 37
Disease 37
Introduced Species 38
Livestock Grazing 39
Conservation Status 39
Known Management Approaches 39
Management Considerations 40
Specific Objectives 40
Specific Considerations 41
V. INVENTORY, MONITORING, AND RESEARCH OPPORTUNITIES 43
Data and Information Gaps 43
Inventory 43
Monitoring 45
Research 45
VI. ACKNOWLEDGMENTS 46
VII. DEFINITIONS 46
VIII. REFERENCES 47

I. INTRODUCTION

Goal

The primary goal of this conservation assessment is to provide the most up-to-date information known about the Cope's Giant Salamander (*Dicamptodon copei*), 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 a vertebrate endemic to and occurring primarily in a narrow band of latitude and longitude in western Oregon and Washington. The salamander's life cycle is primarily aquatic making it vulnerable to many of the same threats that affect other aquatic organisms such as fish that commonly co-occupy habitats. In Oregon, it is recognized as a potentially vulnerable species by various federal agencies and by the state of Oregon because of its restricted range and its potential susceptibility to land management activities. In Washington, the species is more common, but is recognized as a state-monitored species due to one or more of these factors: it was previously classified as sensitive; it requires habitat that is of limited availability; and it is an indicator of environmental quality. The goals and management considerations of this assessment are specific to Bureau of Land Management (BLM) and Forest Service lands in Oregon and 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 Oregon/Washington Bureau of Land Management Special Status Species (SSS) policy. 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 lands administered by the Oregon/Washington Bureau of Land Management (OR/WA BLM), SSS policy (6840 manual and IM OR-2009-039) details the need to manage for species conservation. Specifically, "BLM shall further the conservation of SSS and shall not contribute to the need to list any SSS under provisions of the Endangered Species Act (ESA)."

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

While the synthesis focuses on biological and ecological information for the Cope's Giant Salamander, information for other *Dicamptodon* 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 BLM and Forest Service lands in Oregon and Washington. The known range of the Cope's Giant Salamander on federal lands in Oregon and Washington includes the Columbia River Gorge National Scenic Area, the Olympic, Gifford Pinchot, and Mt. Hood National Forests, BLM's Salem and Prineville Districts, both Mount Rainier and Olympic National Parks, and the Willapa National Wildlife Refuge.

Management Status

The Cope's Giant Salamander has status of concern in Oregon and Washington due to its restricted distribution and potential vulnerability to disturbances. It is listed as: U.S.D.A. Forest Service, Region 6, Oregon - Sensitive; U.S.D.I. Bureau of Land Management, Oregon - Sensitive; State of Oregon –species facing one or more threats to their populations and/or habitats (V); Oregon Biodiversity Information Center - List S2 – Imperiled because of rarity or because other factors demonstrably make it very vulnerable to extinction taxa that are threatened with extirpation or presumed to be extirpated from the state of Oregon; State of Washington, State Monitored Species; Washington Natural Heritage Program state vulnerable and apparently secure (S3S4); NatureServe - Globally vulnerable and apparently secure (G3G4); International Union for the Conservation of Nature, red list, least concern. Management of the species follows Forest Service 2670 Manual policy and BLM 6840 Manual direction.

II. CLASSIFICATION AND DESCRIPTION

Systematics

The Pacific Giant Salamanders are members of the genus *Dicamptodon.* The genus contains four species; all of which are endemic to the Pacific Northwest. The genus has been variously classified within amphibian families Ambystomatidae and Dicamptodontidae, both of which have relatively robust body forms and complex life histories. For example, the Cope's Giant Salamander (*Dicamptodon copei*) is

almost exclusively aquatic throughout its life, but terrestrial forms have been occasionally observed near streams. In general, along with some *Ambystoma* salamanders, the Pacific giant salamanders include the largest terrestrial-occurring salamanders on Earth. The Coastal Giant Salamander (*D. tenebrosus*) may reach 330 mm (13 inches) in total length as a terrestrial adult, and 355 mm (14 inches) as an aquatic paedomorph—a sexually mature adult with juvenile characteristics (Jones et al. 2005). *Dicamptodon* salamanders have characteristic anatomical traits such as the presence of the lacrimal bone in the skull and vomerine teeth that have a distinct "M" shape.

Initially, there was a single species recognized, the Pacific Giant Salamander (*D. ensatus*), with a broad range across the Pacific Northwest U.S. and Canada, from northwestern California to British Columbia and east to Idaho. The Cope's Giant Salamander was described by Nussbaum (1970). Nussbaum (1976) suggested that the Pacific Giant Salamander had three geographic populations occurring in northern California through western Oregon and Washington and in Idaho, whereas the Cope's Giant Salamander was geographically isolated in western Washington and extreme northwest Oregon. Nussbaum went on to speculate that ancestral *Dicamptodon* salamanders may have been found throughout much of the Pacific Northwest as far back as early the Miocene (20 million years ago), with the Pleistocene glaciation being a factor in the present range of the Cope's Giant Salamander, confining it largely to western Washington.

Genetic studies have since shown that the Pacific giant salamanders consist of four distinct species. The Coastal Giant Salamander (*D. tenebrosus*) has the broadest range along the Pacific coast and overlaps the ranges of both the California Giant Salamander (*D. ensatus*) and the Cope's Giant Salamander (*D. copei*); the Idaho Giant Salamander (*D. aterrimus*) is geographically separated from the other three species and is suggested to be of an independent lineage (Good 1989; Daugherty et al. 1983). Comparison between the Cope's and Coastal Giant Salamanders shows that their DNA sequences have evolved independently (Brinkman et al. 2000; Daugherty et al. 1983). The Cope's Giant Salamander also displays a high degree of population-level genetic structure, most likely from a combination of climatic events such as glaciation as Nussbaum suggested, orogenic (mountain building) activities of the Coast and Cascade Ranges, and because the Cope's Giant Salamander does not readily transform into a terrestrial adult, which affects overland dispersal and gene flow (Steele et al. 2009; Steele et al. 2005).

Species Description

The Cope's Giant Salamander is the smallest of the four *Dicamptodon* species, with a total length reaching 200 mm and snout-to-vent length reaching 120 mm in both its paedomorphic and terrestrial adult forms

(Jones et al. 2005). The Coastal Giant Salamander is the only *Dicamptodon* to live sympatrically with the Cope's Giant Salamander, where their ranges overlap in southwestern Washington, northwestern Oregon, and the Cascade Range. Coastal Giant Salamanders do not co-occur in the Olympic Peninsula however, and recent genetic studies suggest the Willapa River as the species boundary (Spear et al. 2011). The two *Dicamptodon* species are difficult to differentiate (Table 1, Figures 1 and 2), especially in their larval forms. The Cope's Giant Salamander differs from the Coastal Giant in that it rarely transforms to a terrestrial adult and is found commonly as a sexually mature paedomorph with gills. Four field guides provide excellent descriptions of the Cope's Giant Salamander (Corkran and Thoms 2006; Jones et al. 2005; Leonard et al. 1993; Nussbaum et al. 1983).

Nussbaum (1970) distinguished the Cope's Giant Salamander from the broad-ranging Pacific Giant Salamander (then known as *D. ensatus*; inclusive of *D. tenebrosus*) as having a smaller larval size at sexual maturity, shorter limbs with toe tips that do not touch when adpressed front to back, a reduced number of maxillary and vomerine teeth, reduced sensitivity to induce metamorphosis through thyroid treatment, a darker venter in individuals > 50 mm in length, a shorter and narrower tail, and gill filaments somewhat shorter than gill stalks. The Cope's Giant has lighter mottling on the tail, plus the tail fin always starts posterior to the vent whereas on the Coastal Giant the fin starts opposite to or anterior of the vent (Figure 1). Cope's Giant Salamander larvae and paedomorphs are not unlike the Coastal Giant Salamander, being dark brown, but the Cope's Giant Salamander most always have distinctive yellowish tan spots or patches (xanthophores) both dorsally and laterally (Figure 1; cover photograph). The head of the Cope's is more slender (not much wider than the body) than the Coastal Giant, and the profile of the Cope's from the top of the head to the nose is more angular than the Coastal Giant, which is short and blunt (Figure 1).

The Cope's paedomorph can be distinguished from its larvae by the paedomporph's somewhat granular-looking skin and protruding eyes. The paedomorphs of the Cope's Giant Salamander can show a marbling pattern on the skin, whereas Coastal Giant paedomorphs rarely have patterning (Jones et al. 2005; L.L.C. Jones and M.G. Raphael, unpublished). The tail on larvae of the Coastal Giant Salamander may sometimes have a black tip, but the Cope's never exhibits this marking. Coastal Giants possess an eye stripe—in the Cope's Giant, the eye stripe is faint or missing (Nussbaum et al. 1983).

A key feature that distinguishes between Cope's and Coastal Giant Salamander terrestrial adults is the massive, more robust appearance of the Coastal Giant. In addition, the rarely occurring Cope's terrestrial adult almost always has a marbled pattern, whereas the Coastal Giant can have a "plain phase" lacking any

pattern at all (Figure 2; Jones et al. 2005; L.L.C. Jones and M.G. Raphael, unpublished).

Regional trends in color-pattern variation have been observed in Cope's Giant Salamanders (L.L.C. Jones and M.G. Raphael, unpublished). For example, populations on the Olympic Peninsula have the classic pattern and color shown in Figures 1, 2 and the cover photograph, whereas Cascade and Columbia River populations are more variable, with some individuals having few patches, and are overall darker in color than those in the Olympic Peninsula. Populations in the Willapa Hills area have intermediate characteristics between those of the Olympics and Cascades, suggesting the variations are related to hybridization with the Coastal Giant Salamander in this area (Spear et al. 2011; M. Hayes, pers. commun.).

Table 1. Comparison of morphological features of larvae and paedomorph Cope's and Coastal Giant Salamanders, *Dicamptodon copei* and *D. tenebrosus* (see Figure 1).

Cope's Giant Salamander	**Coastal Giant Salamander**
Head shape long and slender, about the same width as body (Figure 1, A)	Head shape short and wider than body (Figure 1, F)
Dark brown with distinctive yellowish/tan patches, in both larvae and paedomorph (Figure 1, A,B,C,D)	Dark brown with no yellowish patches, light streaking sometimes in larvae (Figure 1, F,G,H,I)
Gill filaments usually shorter than stalks (Figure 1, A)	Gill filaments usually longer than stalks appearing more "bushy" (Figure 1, F)
No black tail tip in larvae, tail is not much higher than body (Figure 1, E). Tail fin always starts posterior to the vent	Black tail tip (not always) in larvae, tail higher than body (Figure 1, I). Tail fin starts opposite to or anterior of the vent
Toe tips do not or barely touch when adpressed against body front to back	Toe tips touch and often overlap
Dark gray ventral pigmentation in larvae/ paedomorph >50 mm in length	Lighter whitish ventral area, less pigmentation

Figure 1. Comparison between Cope's (left A-E) and Coastal (right F-J) Giant Salamander larvae and paedomorphs (see Table 1; from L.L.C. Jones and M.G. Raphael, unpublished). Note: pattern and texture is accentuated under laboratory lighting and color is somewhat distorted.

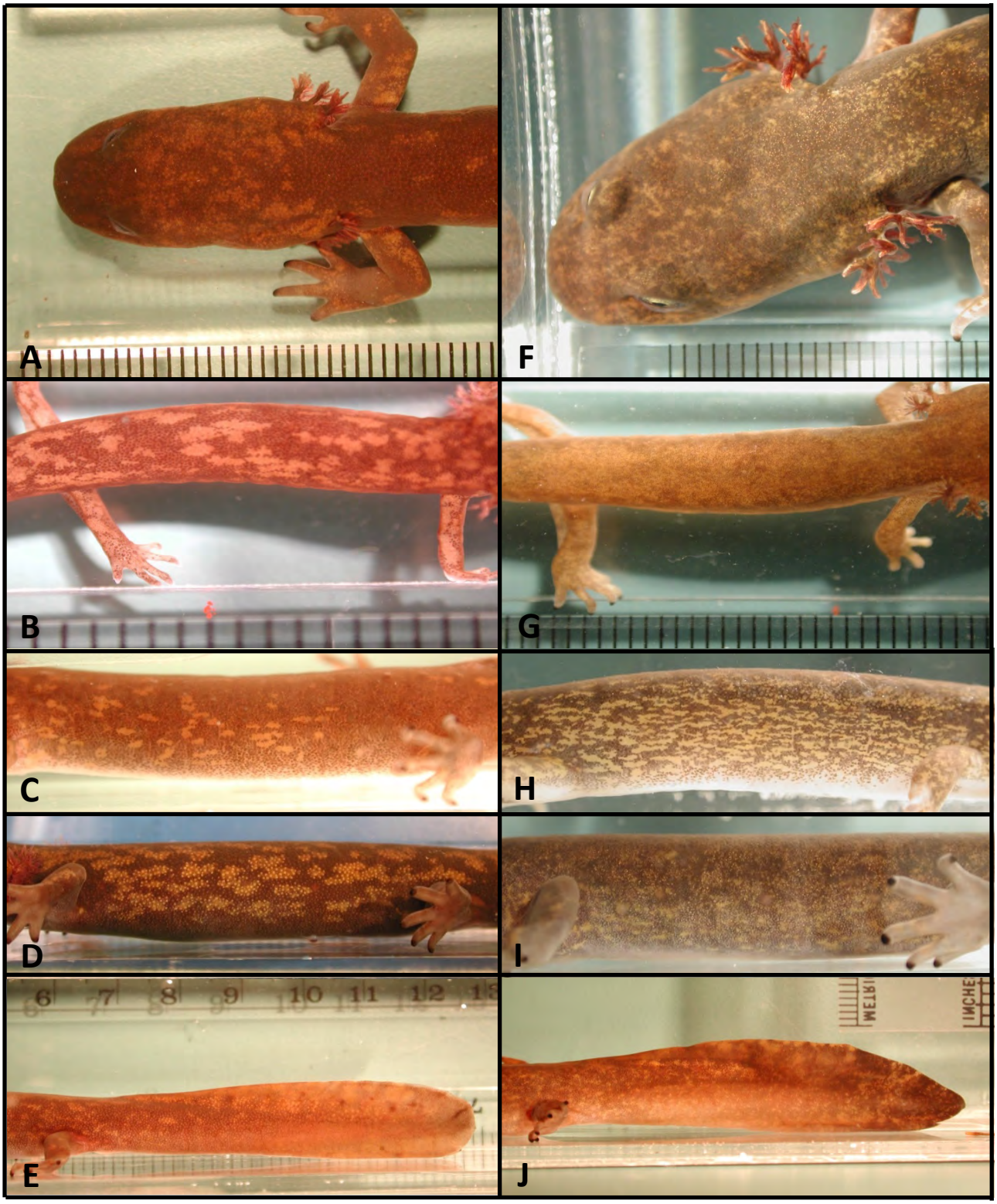
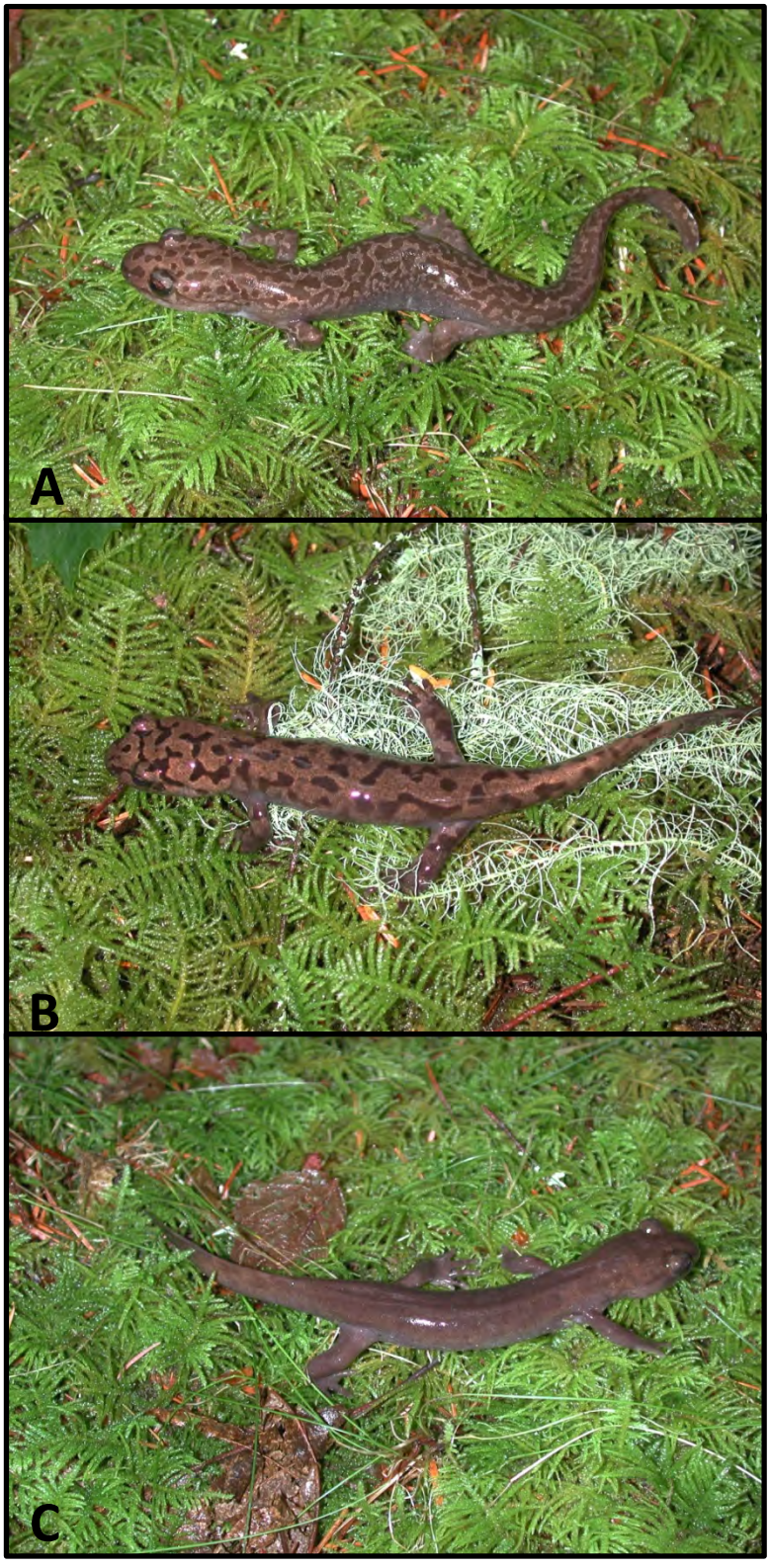


Figure 2. Adult Cope's Giant Salamander (top A); small size, marbling pattern always present but can be restricted to the head in Cascade populations. Adult Coastal Giant Salamander (middle B; bottom C). Massive size (several times larger than the Cope's); marbling present but can be faded or absent entirely. Photographs by L.L.C. Jones.



III. BIOLOGY AND ECOLOGY

Life History

Due to limited information on Cope's Giant Salamanders, reliance on knowledge of its congeners is used extensively. Courtship and egg-laying in earlier-known, broad-ranging Pacific Giant Salamanders (now California Giant Salamanders) (*D. ensatus*) occurs throughout the spring, summer, and fall months, perhaps with peaks in the spring and fall (Nussbaum et al. 1983; Nussbaum 1969). There is little synchrony in breeding. Females deposit eggs in clutches in hidden chambers under stones, undercut banks, and logs. Eggs are attached singly to the roof and sides of the chamber. The female remains in the nest chamber until the eggs hatch. Guarding females will sometimes bite or snap at an intruder, often another giant salamander attempting to feed on the eggs. Other giant salamander individuals are frequently found near the egg chambers, often with eggs in their stomachs and bite marks on their bodies. Only partial clutches have been encountered, so egg predation appears to be high. Clutch size ranges from 25 to 115 eggs, averaging about 50 eggs. Deposited ova are white, and 5.5 mm in diameter. In a laboratory setting at 8.0°C, 240 days were required for hatching. The hatchlings begin feeding at 34 mm in length. Larvae of both sexes mature at about the same size, ~65 to 77 mm total length.

Nussbaum (1969) observed eggs of the Pacific Giant Salamander (*D. ensatus*) attached to the underside of in-stream large down wood in Benton County, Oregon. The female was in attendance on the egg mass and poised to protect the eggs from cannibalism by males. The first 2 weeks in May was described as the egg-laying period for *Dicamptodon* in coastal areas. Young of the year were not found until December and January, suggesting that the incubation period for *Dicamptodon* was about 275 days, the longest duration reported for any salamander.

In mid-July, 1984, Jones et al. (1990) observed a clutch of Coastal Giant Salamander eggs in Douglas County, Oregon. 1989. The clutch was 23 cm long and 13 cm wide, containing 129 eggs. When the authors returned to the site three months later, they counted 72 larvae with yolk sacs that had an average total length of 40 mm. This late-summer hatching suggested a shorter incubation period than reported by Nussbaum (1969); however neither paper reported water temperature during incubation as a possible correlate. As of this writing, courting, mating, habitat comparison, hematological parameters, and response to stress are being studied in both the Coastal and Cope's Giant Salamanders which should provide further insight into the life histories and persistence of both species (Lisa Wagner, Oregon State University, pers. commun.).

Larval Cope's Giant Salamanders are entirely aquatic, with hatchlings being 20 mm in total length, living off their yolk to 35 mm, and larvae becoming paedomorphic adults at 65-75 mm snout-to-vent length (Jones et al. 2005; L.L.C. Jones and M.G. Raphael, unpublished). In addition, observations of transformed terrestrial adults have been made in southwestern Washington (Jones et al. 2005; Jones and Corn 1989; L.L.C. Jones and M.G. Raphael, unpublished).

In comparison, sexual maturity of the former broad-ranging Pacific Giant Salamander (*D. ensatus*) usually occurs at sizes greater than 115 mm snout-to-vent length (Nussbaum and Clothier 1973), but can occur earlier in some populations (e.g., 85-107 mm; Nussbaum 1976). Metamorphosis in the Coastal Giant Salamander is very complex. At some localities, all Coastal Giant larvae transform to terrestrial adults, whereas at other localities a high percentage of the population remains as sexually mature paedomorphs. In small streams, metamorphosis occurs in the second year, whereas paedomorphs appear to make up a large portion of the breeding animals in larger streams. Nussbaum (1976) suggested that metamorphosis of the Coastal Giant Salamander may be related to stream flow, with intermittent streams having a higher percentage of transformed individuals. However, in contrast to other *Dicamptodon* species, almost all Cope's Giant Salamanders are sexually mature paedomorphs (Jones et al. 2005), and they commonly occur in small streams.

Activity Patterns and Movements

Very little information exists for Cope's Giant Salamander activities and movements. Both Coastal Giant and Cope's Giant Salamanders (larvae, paedomorphs, and adults) are most active at night (Johnston and Frid 2002; Johnston 1998; Parker 1994; L.L.C. Jones, unpublished).

Steel (2006) examined the genetic structure of Cope's and Coastal Giant Salamanders. He found that the genetic structure in Cope's Giant Salamanders supported a dispersal-limited species with greater population isolation, in comparison to the broader-ranging Coastal Giant Salamander. This implies that there is limited movement of Cope's Giant Salamander across landscapes, but does not contribute to our understanding of movements within streams or riparian areas.

Movements of marked larval Coastal Giant Salamanders in small streams showed they covered short distances, averaging only 3.2 m (maximum = 51 m) during the summer and 15 m in the winter (maximum = 89 m) (Sagar 2004). Movement was predominately upstream in the summer and downstream in the

winter; the annual movement of Coastal Giant larvae was 60% downstream and 40% upstream, and was not associated with larvae size (Sagar 2004). Culverts also had an effect on larval movement, with less upstream movement in pipe culverts than in open-bottom arched culverts that retained the natural stream-bed substrate and roughness (Sagar 2004). During the winter, some surveyed streams were depauperate of *Dicamptodon*, implying some subterranean overwintering (Antonelli et al. 1972). Using perforated PVC pipes to sample hyporheic zones of streams in summer to fall low-flow conditions, Feral et al. (2005) captured seven *D. tenebrosus* in traps sampling 30-60 cm below the substrate surface. This report of subsurface occurrences documents the likely vertical migration of individuals, and the three-dimensional use of the stream bed by *Dicamptodon*.

A telemetry study in British Columbia showed that adult terrestrial Coastal Giant Salamanders lead a fairly sedentary lifestyle, spending most of their time in refugia such as burrows and rotten logs, yet making occasional long-distance forays over a short time-frame (Johnston 1998; Johnston and Frid 2002). They moved a maximum distance of 67 m and cumulative distance of 310 m in 48 hours, and they also generally stayed relatively close to streams (e.g., three animals ventured 19, 22, and 66 m away from streams during radio-tracking: Johnston 1998; Johnston and Frid 2002). Johnston and Frid (2002) found *D. tenebrosus* closer to streams in clear-cuts as compared to forested stands, which may have been related to microclimates of those areas. Also, they estimated the home range of a single animal to be 935 m^2, suggesting that a relatively large area could be traversed by a single individual. Observations of *D. tenebrosus* farther from streams are also documented by pitfall trap studies in western Oregon (to 135 m: McComb et al. 1993a; to 200 m: Gomez and Anthony 1996; to 400 m: McComb et al. 1993b).

Genetic studies similarly support larger-scale movements of *Dicamptodon*, and influences of climate and landscape factors on dispersal. Dudaniec et al. (2012) examined northern “peripheral” populations of *D. tenebrosus* in British Columbia, Canada, in comparison to population “core” regions in Washington State, and found genetic support consistent with a post-glacial northward range expansion of the species. Their data suggest that the northernmost populations are more isolated, hence with a naturally fragmented population structure; consequently, they posit that these populations may be more sensitive to additional changes in habitat conditions. In their analyses of landscape correlates of population genetic structure, Dudaniec et al. (2012) found that slope and elevation had the greatest influence on genetic structure in the northernmost peripheral sites examined, whereas among core populations in Washington, genetic structure was best explained by flat topographies and the length of the growing season. These results suggest that both landscape and climate features affect dispersal, and may affect populations differently across their range.

Food Habits

The bulk of the Cope's Giant Salamander diet consists of immature aquatic insects, with additional components including fish eggs, small fish, Coastal Tailed Frog (*Ascaphus truei*) tadpoles, and small larvae and eggs of their own species and of the Coastal Giant Salamander (Nussbaum et al. 1983).

Both the Cope's and the Coastal Giant Salamander frequently occur in streams inhabited by fish. Dicamptodontids (both species) and Rainbow Trout (*Onchorynchus mykiss*) were both found to be opportunistic feeders on aquatic insects (Antonelli et al. 1972), whereas Slender Sculpin (*Cottus tennuis*) were more selective of their prey. Like the sculpin, Dicamptodontids were found to feed primarily from the benthos. The bulk of aquatic insects found in the gut of the Dicamptodontids were Ephemeropterans, followed by Plecopterans and Trichopterans. In addition, in the Willapa Hills of SW Washington, a Cope's paedomorph was observed with the hind limb of a terrestrial Camel Cricket (*Tropisdischa xanthostoma*) hanging from its mouth (Price et al. 2006), suggesting that in pursuit of terrestrial prey, paedomorphs may occasionally make short jaunts away from water.

In Coastal Giant Salamanders, diet appears to vary geographically. Parker (1994) found that both aquatic and terrestrial insects that fall into the water were the primary dietary components, with Ephemeroptera nymphs being the most frequently consumed prey type. A study in a 4th-order stream in the Oregon Cascade Range examined the stomach contents of 39 Coastal Giant Salamanders with a mean snout-vent length of 113 mm (Esselstyn and Wildman 1997). The mayfly *Baetis* was the most frequent item found in animals captured from an upstream reach, whereas the aquatic snail *Juga* was the most common prey type found in stomach of animals in the downstream reach; crayfish were commonly found in stomachs of animals in both reaches. Small quantities of a broad array of taxa were also found in salamander stomachs, including other Ephemeroptera, Trichoptera, Plecoptera, Coleoptera, Diptera, Hydracarina, Decapoda, Cottidae, and terrestrial insects. Graff (2006) found that food resources were not strongly partitioned between age classes in Coastal Giant Salamanders, and the most frequently consumed benthic macroinvertebrates included larval Diptera, Ephemeroptera, Plecoptera, and Trichoptera. Coastal Giant Salamander larvae and paedomorphs readily consumed tailed frog larvae when placed in holding buckets during electrofishing surveys, and terrestrial adults have been observed consuming banana slugs (D.H. Olson, pers. observ.) and small mammals (E. Forsman, pers. commun.). During an experimental study of predator-prey relationships, *D. tenebrosus* larvae readily consumed Dunn's Salamanders (*Plethodon dunni*), but rejected Southern Torrent Salamanders (*Rhyacotriton variegatus*) as apparently unpalatable

(Rundio and Olson 2003).

Range, Distribution, and Abundance

The Cope's Giant Salamander ranges across two distinct ecoregions in western Washington and Oregon, occurring predominantly in the Coast Ranges and Cascade Range (Figure 3). In the Coast Ranges, it occurs from the northwestern corner of the Olympic Peninsula in Washington southward to the Nehalem River watershed in Oregon, and in the Cascade Range it occurs from the Nisqually River at Mount Rainier National Park, Washington, southward to the upper White River watershed in Wasco County, Oregon. The species is absent in the Puget Sound lowlands and the northeastern portion of the Olympic Peninsula in Washington, and the Willamette Valley lowlands and foothills in Oregon. Sporadic sites between the Coast Ranges and Cascade Range are known through Clark and Cowlitz counties in Washington.

We compiled site records from state databases and individual researchers from a number of agencies and institutions. Most data were compiled from the Washington State Natural Heritage Program and the Oregon Biodiversity Information Center spatial databases, both of which included compilations of historical records for past state status assessments. For example, Burke Museum of Natural History and Culture (University of Washington) data records and historical records from R.A. Nussbaum were included in the Oregon Biodiversity Information Center database. Additional site records were provided by: Barbara Samora (Mt. Rainier National Park), for sites and species verification by Michael Adams (US Geological Survey, Corvallis, OR) during surveys in Olympic and Mt. Rainier National Parks and Willapa National Wildlife Refuge, WA; Andrew Storfer (Washington State University) genetic studies; David Vesely (Oregon Wildlife Institute, Corvallis, OR), inventories; Mitch Wainwright (Forest Service, Gifford Pinchot National Forest, WA); Alan Dyck (Forest Service, Mt. Hood National Forest, OR), National Forest Resource Inventory Sites; L.L.C. Jones and A.D. Foster (Forest Service, Pacific Northwest Research Station), research sites; and the Museum of Vertebrate Zoology, University of California, Berkeley. It should be noted that the site records and range documented here may not be complete or current. There has been no systematic sampling of this species across its Oregon and Washington range, and hence the known distribution is biased by an accumulation of opportunistic sampling events. Collation of such haphazardly collected data may bias the portrayal of the species distribution.

We compiled a total of 985 site records in Oregon and Washington (Figure 3). Many site records were duplicates from identical locations, representing either re-visits to the same site over time, duplicate entries of the same data among collated databases, or many individual animals detected from the same location

during a single visit, with a single record entered into the database per animal. We consolidated site records from the same exact coordinates, and the number of sites collapsed to 581. Some of these 581sites were in close proximity to each other along the same stream reach or within the same small drainage basin.

Here, we do not define "site" beyond a discrete coordinate, and we do not address the spatial scale that might relate to a sub-population. Status assessments often distinguish occurrences into two types, data records and consolidation of records into "discrete" areas (e.g., NatureServe assessments: https://connect.natureserve.org/sites/default/files/documents/NatureServeConservationStatusMethodology_Jun12.pdf). For such compilations of data records into meaningful discrete areas relative to population biology, the movement abilities of animals may be considered, as well as habitat contiguity. Unfortunately we have little knowledge of either of these factors for the Cope's Giant Salamander. Movements may occur in-stream, along the aquatic network, or overland, but little is known about the extent of such daily to lifetime dispersal. Similarly, the extent of occupancy of Cope's Giant Salamanders along stream reaches and networks is not well understood. Hence we did not conduct a nearest-neighbor consolidation of site records by a distance factor, as has been done for other species. Nevertheless, watershed boundaries may be useful to consider for occupancy patterns of highly aquatic species such as *D. copei*. To account for known occupancy across the species' range, we counted the number of drainage basins that had at least one site record. There were 72 occupied 5th-field watersheds (hydrologic unit code 10, HUC10) and 164 occupied 6th-field watersheds (HUC12; Figures 5 and 6). Sites ranged in elevation from 5 m (15 ft) in the Puget Sound (Western) Lowlands physiographic province of Washington to 1593 m (5,226 ft) in the Cascades East province. The average elevation was 475 m (1558 ft) across the entire range with higher elevation sites tending to occur more in the Cascades provinces (Figure 4). The Oregon and Washington combined total range is about 3,198,367 ha (7,903,337 ac), derived using the calculation of three minimum convex polygons of site records, excluding the unoccupied Puget Sound lowlands and Willamette Valley from the calculation, as indicated in Figure 3. Dividing this range into three subunits: coastal sites, 407 site records, range = 1,885,704 ha (4,659,676 ac); Cascades, 164 site records, range = 1,172,498 ha (2,897,306 ac); and in between these two ranges, 10 site records, range = 140,165 ha (346,355 ac).

In Washington, the Cope's Giant Salamander is known from 11 counties (Clallam, Jefferson, Grays Harbor, Mason, Pacific, Wahkiakum, Cowlitz, Lewis, Clark, Skamania and Pierce), and in Oregon, it occurs in seven counties (Hood River, Wasco, Clackamas, Multnomah, Clatsop, Washington and Tillamook). Most sites that we compiled occurred on federal lands (372 of 581 [64 %] site records, Table 2), likely reflecting a bias of both survey locations and information that we were able to compile. Of those

372 sites on federal lands, the majority (46%) were located on Olympic National Park (N = 171), while on National Forest lands, Olympic National Forest had 20% (N = 74), Gifford Pinchot National Forest had 16% (N = 61), and Mount Hood National Forest had 13% (N = 50).

Table 2. Distribution of Cope's Giant Salamander, *Dicamptodon copei*, site records among federal land allocations in Washington and Oregon, before and after duplicate records were identified.

Land Ownership	Land Allocation	Number of site records	
		With duplicates	Duplicates removed
Federal			
	Columbia River Gorge National Scenic Area	8	8
	Gifford Pinchot National Forest	265	61
	Mount Hood National Forest	52	50
	Mount Rainier National Park	1	1
	Mount Saint Helens National Volcanic Monument	82	6
	Nap of the Earth Army Helicopter Training Area	1	1
	Olympic National Forest	96	74
	Olympic National Park	219	171
Nonfederal	State, private, tribal, other	261	209
Total		***985***	***581***

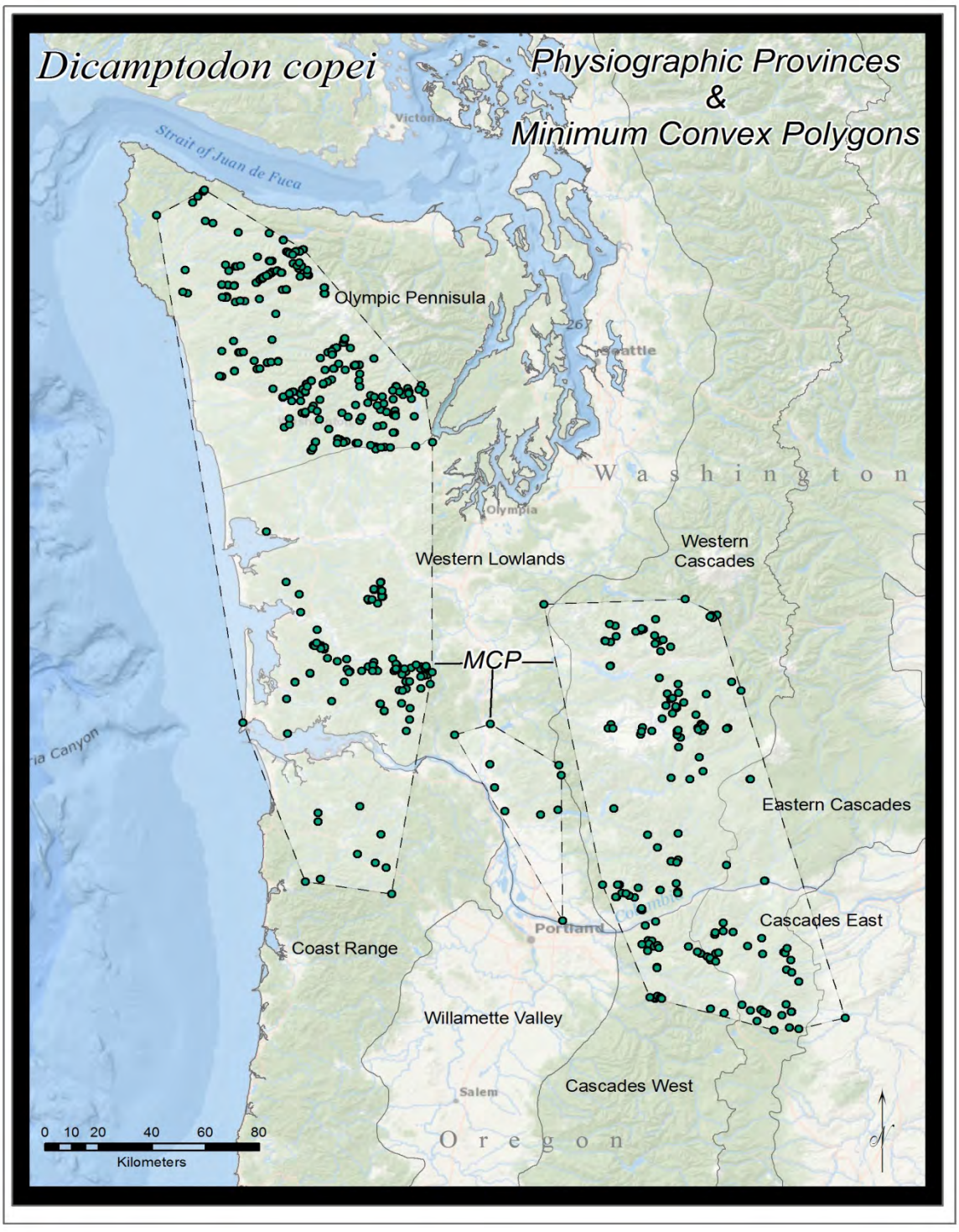


Figure 3. Known site records depicting the range of the Cope's Giant Salamander, *Dicamptodon copei*. Minimum convex polygons (MCP) of three areas of the range are indicated, with 407 records in the coastal area, 164 records in the Cascade Range area, and 10 records in between.

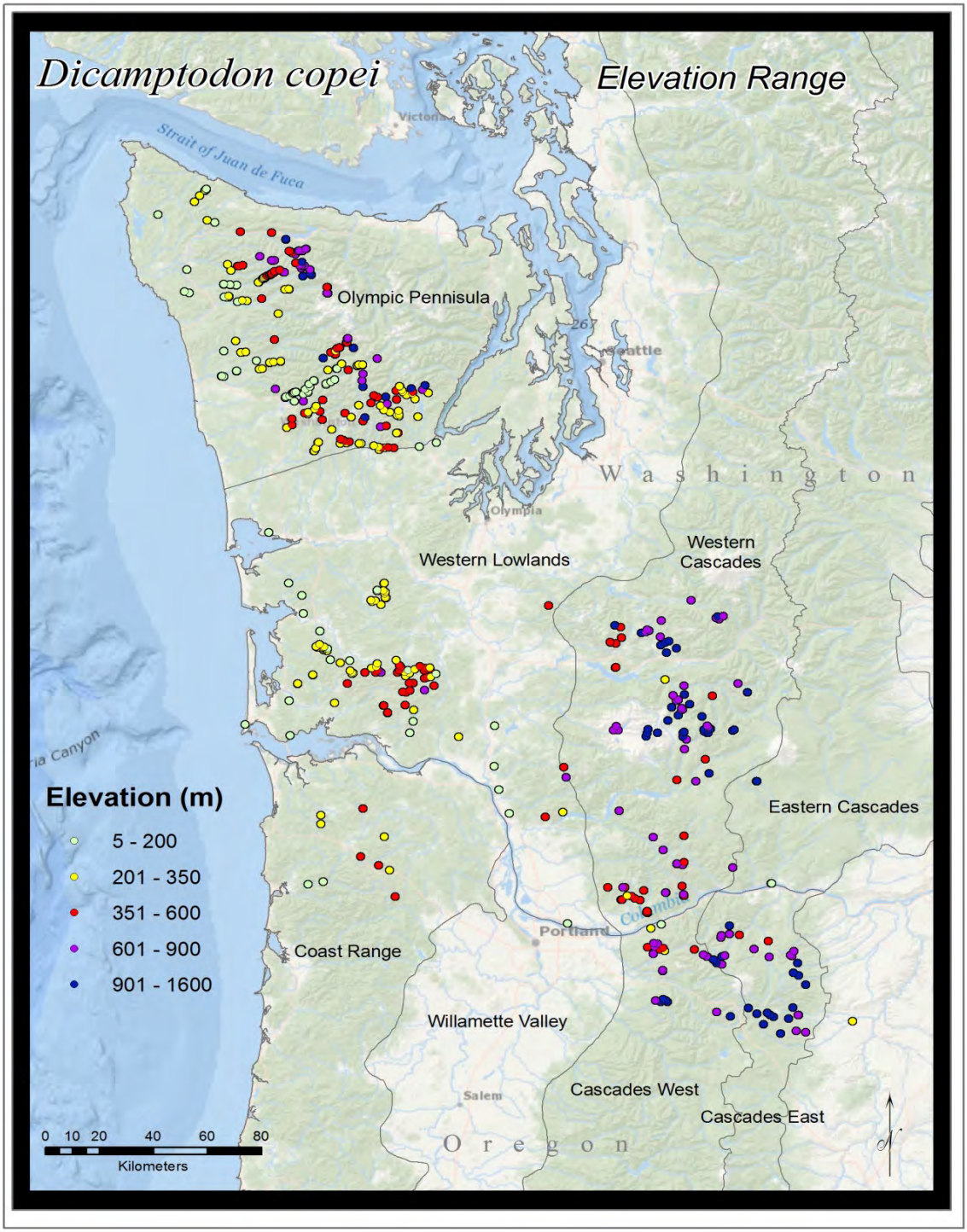


Figure 4. Elevation range of known site records of the Cope's Giant Salamander, *Dicamptodon copei.* Sites ranged in elevation from 5 m (15 ft) to 1593 m (5,226 ft). The average elevation was 475 m (1558 ft) across all provinces.

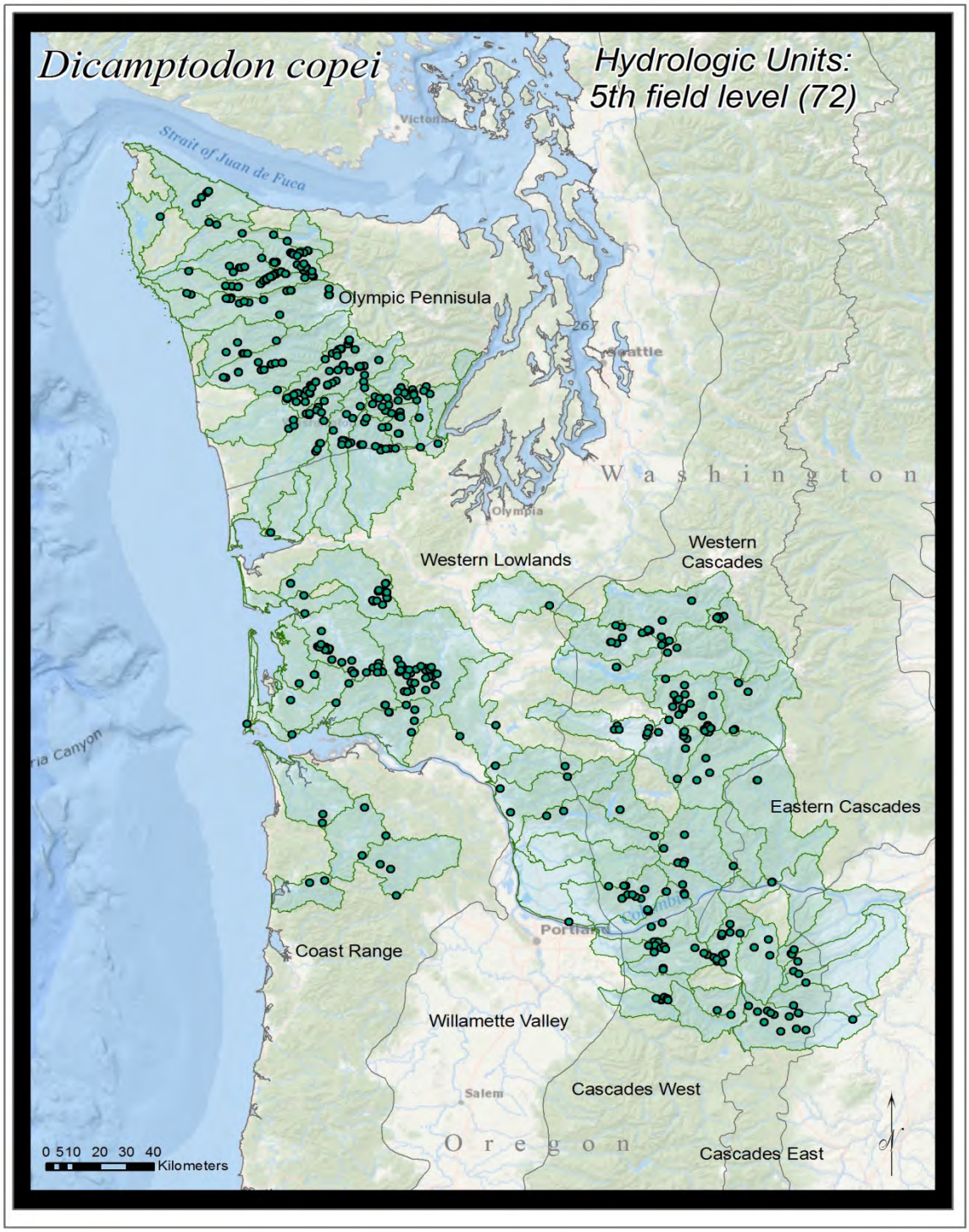


Figure 5. Fifth-field watersheds (N = 72) with known site records of the Cope's Giant Salamander, *Dicamptodon copei*.

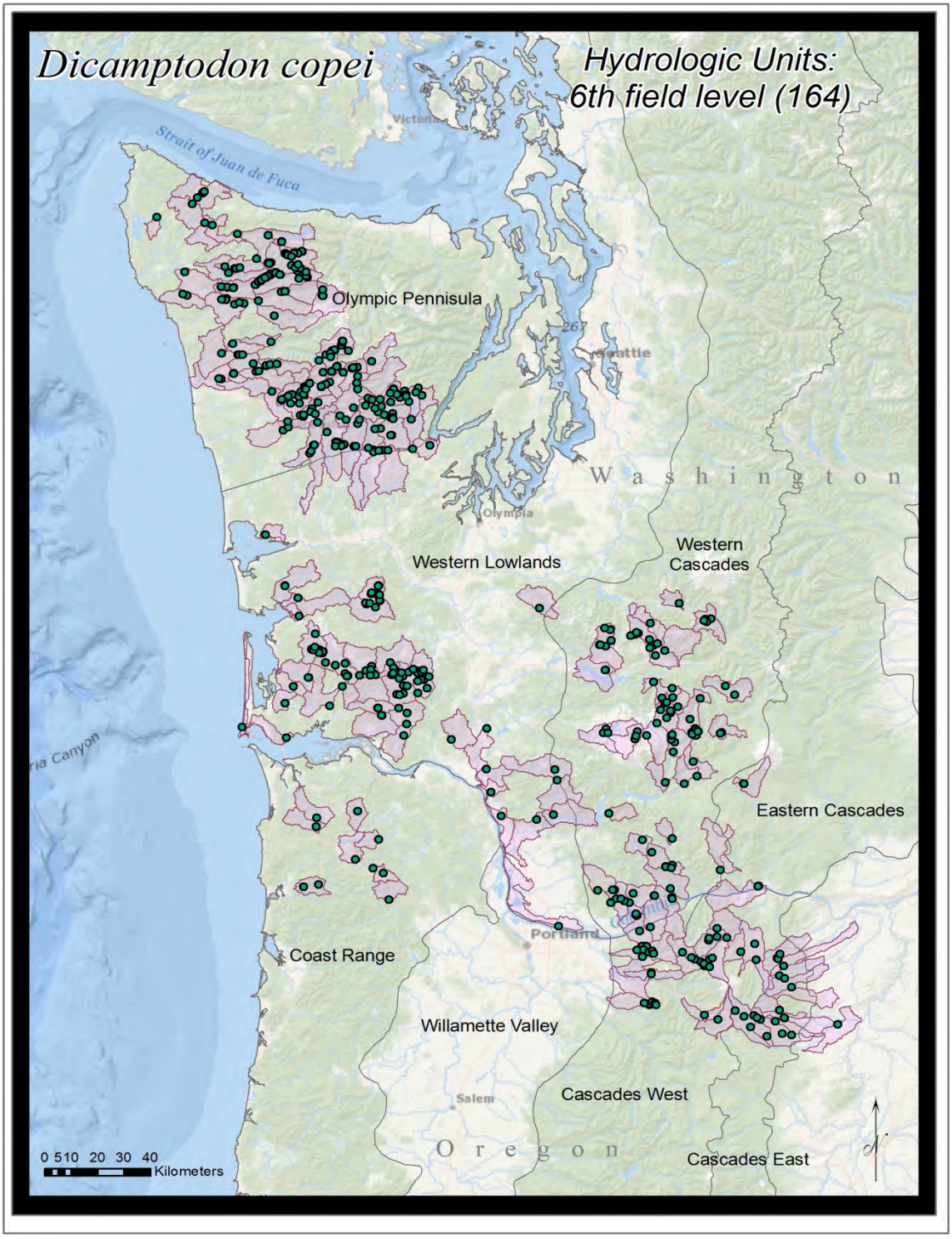


Figure 6. Sixth-field watersheds (N = 164) with known site records of the Cope's Giant Salamander, *Dicamptodon copei*.

Demography and Population Trends

In general, aside from some unpublished data, very little information exists about the age-size structure of Cope's Giant Salamander populations. From earlier knowledge of the single broad-ranging species, the Pacific Giant Salamander (*D. ensatus*); the structure of larval populations was known to vary greatly across its range (Nussbaum and Clothier 1973). More recent surveys in the Olympic Peninsula specific to *D. copei* suggest some age-size segregation. For example, on twenty-eight small- to intermediate-sized streams (~2 to 6 m wetted width) surveyed during the summer (June through August) 1996 through 1999, larval and paedomorphic Cope's Giant Salamanders had a distinct bi-modal distribution showing two size-classes (age categories), with average total lengths of 53 mm and 143 mm respectively (A.D. Foster, unpublished data). Surveys have assessed *D. tenebrosus* population size distributions in Oregon, and there appear to be differences in age-size structures of populations with location, habitat type, animal growth rate, and the time of year of metamorphosis. In some locations, two size-classes of Pacific Giant Salamanders were present during the spring and early summer. For example, the size-class structure of Coastal Giants in small streams (< 3 m wide at low flow) of the Oregon Coast Range showed that populations were made up mostly of first-year larvae, with very few older larvae or paedomorphs (snout-vent length range: ~30-100 mm; Sagar et al. 2007; Sagar 2004). In addition, summer survival for first-year larvae was lower than for 2nd- and 3rd-year larvae. These studies suggested that older larvae may be better able to secure refugia, and thus evade detection and predators. *Dicamptodon tenebrosus* were the dominant vertebrate in another study of headwater streams in western Oregon (Olson et al. 2013; Olson and Weaver 2007), and the total lengths of individuals in those streams (1-4 m wide) ranged from 25 to 285 mm (snout-vent lengths ranged 12-180 mm), without clear delineation of age classes (D.H. Olson, unpublished data). Downstream of one of those headwater study sites, in a larger reach (~10 m wide during low flow) of Schooner Creek in the Oregon Coast Range, in-stream *D. tenebrosus* ranged from ~32 to 265 mm in total length, again without distinct age classes present (D.H. Olson, unpublished data).

Recent genetic studies have confirmed obligate neoteny (paedomorphism) as a factor in the Cope's Giant Salamander distribution. Phylogenetic patterns of population structure between sympatric populations of the Coastal Giant and Cope's Giant Salamanders indicated that the metamorphosing Coastal Giant displayed a lack of population structure, whereas the non-metamorphosing Cope's exhibited a larger degree of population structure (Steele 2006). These results help explain the large post-glacial distribution of the Coastal Giant, facilitated by its higher dispersal ability, as compared to the apparently more fragmented occurrences and smaller range of Cope's Giant Salamanders. It was further shown that stream and overland distance were correlated with genetic distance for the Cope's Giant Salamander but not so

for the Coastal Giant (Steele et al. 2009), suggesting that the Coastal Giant is dispersing among localities regardless of physical or topographic features, and is doing so to a degree sufficient to cause genetic mixing, but the Cope's Giant Salamander is not, thus its populations have heightened genetic isolation, although some long distance (13 km) dispersal has been noted in the Olympics (Spear et al. 2011). Interestingly, Cope's Giant Salamanders reach their highest population size in the Willapa Hills and South Cascades and the lowest in the Olympics where populations are exclusively Cope's Giants (Spear et al. 2011). The deepest phylogenetic divergence among Cope's Giant Salamander populations was the separation of several populations found along the Columbia River from the remainder of the other populations. These divergent populations are geographically restricted to several short tributaries that drain directly into the Columbia River and are not joined to the large interconnected network of headwater streams that run throughout the Coast and Cascade Ranges (Steele and Storfer 2007).

Research on long-term population trends for the Cope's Giant Salamander is lacking. However, in-stream reach densities have been documented by several studies. For example, in ten streams on the Olympic Peninsula, the average density was about 0.16 m^{-2} during the months of June through August (Adams and Bury 2002). Additionally, in four streams in the Willapa Hills of southwest Washington surveyed by electrofishing twice per year for three years (2004-2006), the densities across years averaged about 0.30 m^{-2} in July and 0.17 m^{-2} in September. The decline during the summer was probably due to a combination of larval mortality, emigration from the surveyed areas, or both (A.D. Foster, unpublished). In addition, densities for both Cope's and Coastal Giant Salamanders were between 0.06 - l .43 m^{-2} and 0.06 - 2.5 m^{-2}, respectively, in headwater streams in the Cascade Range of southern Skamania County, Washington surveyed in the months of June through August (Steele et al. 2002).

Habitat

Cope's Giant Salamanders are found in small, rocky, and usually steep-gradient streams in conifer or mixed forests (Corkran and Thoms 2006; Jones et al. 2005). They can be found under stones, slabs of bark, or other cover in streams, and are often found in pool habitat units with still water rather than faster-flowing riffles. In high-moisture conditions, they can be found crawling among rocks and vegetation along stream banks at night (Nussbaum et al. 1983). Down wood is associated with observations of this species. For example, in the Olympic National Park, Cope's Giant Salamander abundance peaked when there was about 10% in-stream down wood cover (Adams and Bury 2002). The same study also found that abundance decreased with increasing canopy cover, started decreasing at elevations above 500 m, was negatively associated with increasing stream width, and observed animals only on unconsolidated surface

geologies.

In another study on the Olympic Peninsula, landscape-level factors had a greater influence on the presence of Cope's Giant Salamanders than in-stream habitat conditions (Bisson et al. 2002). No relationship was found between the density of Cope's Giant Salamanders and forest age in the riparian zone or the entire sub-watershed where it occurred. There was reduced overall abundance in sub-watersheds with high road and drainage densities, implying a potential sensitivity to chronic fine sediment input, yet density was the same in sub-watersheds with episodic coarse sediment introductions from recent landslides, as compared to watersheds with little landslide activity, suggesting that the species may be resilient to these types of disturbances. Adaptation to mass wasting and associated coarse sediment influx was also suggested by Sepulveda and Lowe (2009) for the Idaho Giant Salamander.

Several studies have reported on habitat associations of Coastal Giant Salamanders, which may provide further insights to the Cope's Giant Salamander. Habitat associations of the Coastal Giant Salamander in British Columbia showed that abundance was positively associated with stream elevation, forest age, and the percentage of boulders within streams (Dudaniec and Richardson 2012). Presence was also predicted by older forest ages surrounding streams and higher site elevation. A higher stream gradient was the best predictor of Coastal Giant Salamander occurrence within a given stream reach. High stream gradient was also a predictor for the Cope's Giant Salamander on the Olympic Peninsula (Raphael et al. 2002). Additionally, pools with coarser substrates tended to have higher densities of Coastal Giant Salamanders (Parker 1991). Sagar (2004) also found large substrates showed a positive correlation to Coastal Giant Salamander larval density and movement. Similarly, densities of Pacific giant salamanders were previously correlated with substrate composition and were found only at high-gradient sites with coarse substrates (Hawkins et al. 1983). The need for coarse substrates in stream channels should not be understated; cobble and larger rocks play a role in the reproductive activities of both species of giant salamanders as well as for clutch and ovipositioning (Lisa Wagner, pers. commun.). Negative correlations to stream temperature, high stream flow, sand and large rock substrates; and positive correlations to down wood, riparian vegetation, cobble, gravel and woody debris substrate were found for California and Coastal Giant Salamanders (Welsh and Hodgson 2008; Welsh and Ollivier 1998). Streams traversing basalt lithology had almost twice the Coastal Giant Salamander abundance than those in areas of marine sediments (Wilkins and Peterson 2000). Coastal Giant Salamander abundance was positively associated with increasing pool frequencies in combination with increasing down wood accumulations in adjacent riparian areas, and decreased with increasing accumulations of large (>60 cm diameter) down wood in the channel, which tended to trap sediment. Also, the abundance of Coastal Giant Salamanders increased with

the percent canopy cover of Douglas-fir (*Pseudotsuga menziesii*) over the wetted width of the stream; Douglas-fir cover, elevation, amount of down wood cover and lithology type variables explained 96% of the variability of Coastal Giant Salamander presence (Graff 2006). In Oregon headwater streams, Coastal Giant Salamanders were associated with perennial stream reaches, down wood, and stream gradient (Olson and Weaver 2007), and in unmanaged forest stands near Coos Bay, Oregon, the species occurred in areas associated with fluvial and/or hillslope disturbance (Sheridan and Olson 2003). These studies suggest that down wood, coarse substrates, cover adjacent to the stream channel and geology may influence the abundance of giant salamanders in the channel, and in the case of Coastal Giant Salamanders, terrestrial adults in the adjacent riparian areas. For comparison, Idaho Giant Salamander occurrence was highest in roadless drainages and lowest in spatially isolated streams and in drainages with high old-growth forest density (Sepulveda and Lowe 2009), but curiously, in contrast to other studies of *Dicamptodon* habitats, densities of Idaho Giant Salamanders were greatest in streams with a high proportion of embedded substrate and fine sediment. This may reflect an adaptation to natural disturbances such as landslides or unstudied relationships between local landscape and habitat factors.

Ecological Considerations

Interspecific interactions between Cope's Giant Salamanders and other species are not well studied. Relative to potential competition for food, there is considerable overlap in the diets of co-occurring Rainbow Trout, Slender Sculpin and Pacific Giant Salamanders (Antonelli et al. 1972). Trout are able to feed throughout the water column, but sculpin and the giant salamanders are primarily benthic feeders. Interspecific interactions between Cutthroat Trout (*Oncorhynchus clarkii*) and Cope's Giant Salamanders may affect the salamander's population structure. For example, electrofishing surveys were conducted on four streams with Cope's Giant Salamanders for three consecutive years in the Willapa Hills of southwest Washington. When averaged across years, Cope's Giant Salamander population density, tended to be lower (0.15 m^{-2}) on two of the streams where Cutthroat Trout were present compared to streams with no fish (0.32 m^{-2}) (A.D. Foster, unpublished). In Oregon, Cutthroat Trout and Coastal Giant Salamander interactions were described as a complex combination of predation, competition and facilitation, where trophic cascades subsequently exert potential top-down predator effects on several other taxa (Rundio 2002). Coastal Giant Salamander larvae are palatable to Cutthroat Trout, and the salamander has behavioral defenses rather than chemical defenses against this predator. When cutthroat chemical cues were present, Coastal Giant larvae took cover in refugia provided by down wood and coarse substrates (Rundio and Olson 2003). Dietary overlap at certain times of the year is high between Cope's and Coastal Giant Salamanders where they live in sympatry, however more recent results have suggested that in

response to the presence of its congener, a shift in diet by either one or both species may occur to reduce competition for food resources (Steele and Brammer 2006).

Larval Cope's Giant Salamanders may be preyed upon by non-native Eastern Brook Trout (*Salvelinus fontinalis*) and possibly native Bull Trout (*Salvelinus confluentus*). Both species of fish live in sympatry with the Cope's Giant Salamander at particular locations across the salamander's range, plus both fish are opportunistic benthic feeders that may also compete with the salamanders for food resources. Further research is needed concerning the effects of these fish on Cope's Giant Salamander populations and trophic structure. Cope's Giant Salamanders also are preyed upon by garter snakes (*Thamnophis* spp.), adults and large larvae of the Coastal Giant Salamander, and Water Shrews (*Sorex palustris*) (Nussbaum et al. 1983). Cope's Giant Salamanders are probably preyed upon by Raccoon (*Procyon lotor*), Long-tailed Weasel (*Mustela frenata*), American Mink (*Neovison vison*), and opportunistic birds. Antagonistic behavior between a large Coastal Giant Salamander and a garter snake has been recorded (Silvestri and Douglas 2006); however because of the Cope's Giant Salamander's much smaller size compared to the Coastal Giant, it may be unable to fend off a snake attack. Proof of snake predation has been observed in a garter snake that regurgitated a metamorphosed Cope's Giant Salamander (Loafman and Jones 1996).

IV. CONSERVATION

Land Use Allocations

Relationship of the species' distribution to lands administered by the US Forest Service is a key consideration for conservation in Oregon and Washington. A considerable portion of the Cope's Giant Salamander's range and ~31% of its site records in Washington and Oregon are within the Olympic, Gifford Pinchot, and Mt. Hood 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/USDI 1994). Furthermore, the species was not designated as a Survey and Manage species under the Northwest Forest Plan largely due to the protections offered to riparian areas by the Aquatic Conservation Strategy and riparian reserve allocations—for details of these protections, please see the Known Management Approaches section.

Threats

Although threats to the Cope's Giant Salamander are not well studied, 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 road construction, timber harvest, and introduced species. In particular, factors that alter microhabitats or create barriers to dispersal and gene flow likely affect this species. Microhabitat alterations of specific concern are decreased down wood recruitment, increased erosion and fine sediment deposition in streams, and increased water or soil temperatures. Additional concerns include disease, climate change, forest fire events, and chemical applications.

Culverts and Roads

Culverts and roads may affect microhabitat and both aquatic and terrestrial dispersal for this salamander. The chief concerns with roads transecting aquatic habitats occupied by the Cope's Giant Salamander is the potential for erosion and stream sedimentation filling interstitial spaces used as refugia by the animals and dispersal. The inability to disperse puts populations at risk because it limits gene flow and the ability to recolonize after disturbance (Jackson 2004). Additionally, studies support theoretical predictions that small, isolated populations similar to those of the Cope's Giant Salamander are quite vulnerable to genetic change and population loss due to dispersal barriers (Jackson 2004). 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 2000). Within the range of the Cope's Giant Salamander, culverts have been identified as a potential threat to the Olympic Torrent Salamander (*Rhyacotriton olympicus*), a similar aquatic species often living sympatrically with the Cope's Giant Salamander (Howell and Roberts 2008). Culverts may present barriers at the pipe outflow, where they may be "perched" with significant drops from the pipe edge to the stream surface. Salamanders are not known to "jump" like some fish can do in order to move upstream across these small waterfalls. Culverts also may result in increased water velocity, which affects salamander movement because they are not capable of pushing upstream against strong currents. Furthermore, culverts may have a surface that does not present any 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. Whereas culvert and dispersal relationships specific to the Cope's Giant Salamander are unknown, culverts have been documented to affect dispersal patterns of larval Coastal Giant Salamanders. For example, culvert presence was associated with fewer long distance movements (Sagar 2004). The culvert type also affected larval

salamanders; density in arch (flat-bottom) culverts was no different from reference streams, but density was between 3.1 and 18.6 times greater in arch culverts than in pipe culverts. Although concerns about terrestrial connectivity for amphibians at road-stream crossings has been extensively documented (Andrews et al. 2008), it is unknown if Cope's Giant Salamanders can disperse out of the stream and cross the road prism, either at upland roads or at culverts.

Timber Harvest

Studies of the effects of timber harvest on Cope's and Coastal Giant Salamanders show several patterns that are likely dependent upon the context of the study and the timber harvest practices addressed, as well as the geographic location of the study. The potential effects of some timber harvest activities on microhabitat features important for the Cope's Giant Salamander include direct stream channel disturbances (e.g., historical practices of using streams as pathways to drag or float logs), sedimentation embedding coarse substrates, loss of down wood, and elevated water temperatures. Also, chemical applications may directly affect the physiology of salamanders, and fire effects may include altered chemistry of streams or stream temperatures. Historical clear-cut logging practices without riparian buffers were more likely to result in direct effects on in-stream amphibians and their habitats. Many studies do not report what mechanism or microhabitat factors that may have been involved in the effects observed (e.g., substrate alteration or temperature change), but rather report on broader-scale effects. Effects of harvest on animal occurrences versus animal abundances, diversity, and biomass are often differentiated in reports.

For example, in headwater streams draining from clearcuts harvested 26-34 years prior that ran into unharvested forested areas, there was a significant increase in the density of Pacific giant salamanders downstream of the clear-cuts (Biek et al. 2002). Comparing old growth and logged redwood forests near Redwood National Park, Pacific giant salamanders occurred on half of the old growth sites, but none were found in logged areas harvested 6-7 years prior (Bury 1983). In contrast, there was no evidence found that clear-cut timber harvest affected the density of larval Coastal giant salamanders 2 years following timber harvest in a coastal watershed in SW Oregon (Leuthold et al. 2012). Related, Bury et al. (1991) reported that there was no association of giant salamander abundance with forest type (old-growth, mature, young forest; 59 streams sampled in Oregon and California).

Corn and Bury (1989) found that Coastal Giant Salamanders in young managed forests were more numerous in higher stream gradients, but found no association with gradient in unharvested forests, suggesting that timber harvest may limit the salamanders to a narrower range of habitats than in

unharvested forests. In addition, higher-gradient reaches likely flush fine sediments from substrates, and hence maintain interstitial refugia for salamanders.

Clear-cutting also appears to have affected the behavior of metamorphosed Coastal Giant Salamanders in that they were more prone to stay close to streams, spend more time in underground refuges, and had smaller home ranges than salamanders in forested areas (Johnston and Frid 2002). Also, movement behavior was not different between riparian buffer strips and forested areas, but was different from clear-cuts.

For Coastal Giant Salamanders, genetic richness was positively correlated with the age of forest stands. Lower genetic variation and heterozygosity in recent clear-cuts suggested that clear-cut logging may be associated with local population declines (Curtis and Taylor 2003).

In contrast, both Cope's and Coastal Giant Salamander densities were greater in managed vs. unharvested second-growth forests in the Cascade ecoregion in southern Skamania County in Washington, with densities greatest in unbuffered streams (Pollet et al. 2010; Steele et al. 2002). Both authors suggested that the response was short-term, comparable to that also seen in salmonids, where canopy removal increases secondary production and quantities of macroinvertebrate prey.

Moderate thinning of young managed stands with riparian buffers appeared to have neutral or positive effects on giant salamanders in western Oregon. For example, there tended to be more Coastal Giant Salamanders detected after thinning in treatment reaches compared to unharvested reference reaches (2 years after treatment: Olson and Rugger 2007; to 10 years after treatment: Olson et al. 2013). In addition, in an upland study, there was no effect to amphibians (including giant salamanders) from thinning with riparian buffers in the Oregon Coast Range (Kluber et al. 2008).

Fine Sediment

Cope's Giant Salamanders live in areas subject to infrequent episodic mass-wasting events that introduce large pulses of both coarse and fine sediment to stream channels. However, in intensively managed sub-watersheds with high road densities, chronic fine sediment influx to stream channels coupled with increased frequency of mass wasting that is often triggered by roads or timber harvest on unstable slopes is a concern. Specific to *Dicamptodon* life histories, sedimentation may fill interstitial spaces in stream substrates, burying cobbles and boulders, and eliminating refugia and foraging habitat. Such infilling could

expose salamanders to predators, and may potentially pre-dispose salamanders to desiccation during low- or zero-flow periods, or conversely, displacement during high flows. For example, the abundance of Cope's Giant Salamanders was found to be reduced in sub-watersheds with high road and drainage densities, suggesting sensitivity to chronic fine sediment input to stream channels (Bisson et al. 2002). Also, relative abundances of lotic amphibians were significantly greater in the late-seral forest streams compared with streams transecting mid-seral forests, and while water and air temperatures were similar in both forest types, the streams in mid-seral forests had greater amounts of fine sediments compared with the streams in late-seral forests (Ashton et al. 2006). Using substrate embeddedness as a surrogate for fine sediment loading, the probability of detection of Coastal Giant Salamanders was significantly reduced when embeddedness was >75.5% (Welsh and Hodgson 2008). At the finest spatial scale (2-m sample unit), occurrence of all lotic amphibians including Coastal Giants was negatively associated with fine sediment (Stoddard and Hayes 2005).

In addition to road-related sediment sources, sediment loading in streams often corresponds to the type of timber harvest treatment prescribed (Beschta 1978). Correlations between increased sediment loads and clear-cutting were seen for one year following harvest for streams with a minimum of a 9 m (30 foot) no-entry zone along fishless streams, and a 15 m (50 foot) no-entry zone for fish-bearing stream reaches; however no significant correlation was found in areas with higher-retention treatments (Karwan et al. 2007). This tendency may contribute in part to the neutral effect on giant salamanders by variable-retention logging practices, as described previously. In contrast to chronic fine sediment sources over large areas, a large, episodic but concentrated disturbance such as a debris flow could extirpate a Cope's Giant Salamander population in a given sub-watershed for a much longer period of time than observed in the rapid recolonization by salmonids, for example, after these types of disturbances (Cover et al. 2010; Crisafulli et al. 2005; Swanson et al. 1998; A.D. Foster, unpublished).

Water Temperature

Both Cope's and Coastal Giant Salamanders often occur sympatrically with other amphibians that have at least partially aquatic life histories, including species of torrent salamanders (*Rhyacotriton* spp.) and Coastal Tailed Frogs (*Ascaphus truei*). Coastal Giant Salamanders have a slightly higher critical temperature threshhold (29.1°C) than torrent salamanders (27.9°C), and roughly the same as tailed frogs (29.6°C) (Bury 2008). Critical temperature is the temperature at which the animal would soon perish if not quickly removed to a lower temperature. Amphibians with aquatic life histories have evolved in and inhabit small- to moderate-sized streams in the Pacific Northwest. Streams with intact riparian overstory

typically have summer stream temperatures ranging from 15 to 19°C, with a mean of 16.7°C (1959 to 1982, H.J Andrews Forest, Cascade ecoregion; Johnson and Jones 2000). Timber harvest and overstory removal in riparian areas can have a large effect on stream temperatures (Beschta et al. 1987). For example, maximum temperatures after clear-cut logging along small streams in the Oregon Coast Range have often exceeded 26°C (Moore et al. 2005)—a temperature very close to the critical threshold for giant and torrent salamanders cited by Bury (2008). In contrast, while Bury et al. (1991) found a significant association between aspect and *Dicamptodon* abundance across the entire range in Oregon and Washington, in a later study specific to Cope's Giant Salamanders, the aspect association was absent and a negative association with cover was found, suggesting that Cope's Giant Salamanders may be tolerant of a broad range of stream temperatures (Adams and Bury 2002). Nevertheless, elevated or more variable stream temperatures will affect life-history characteristics such as growth rates, movement, and egg incubation, with unknown effects on Cope's Giant Salamander populations across their range. Forest Plans within the Cope's range in Oregon and Washington include measures to retain cool stream temperatures, primarily through buffer prescriptions; hence this threat may be largely addressed, at least on federal lands within the species range.

Climate Change

Climate change is adversely affecting amphibian species worldwide, and although related research for species endemic to the Pacific Northwest is deficient, climate change may be the biggest future challenge to the persistence of amphibian species (Corn 2005). 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), which may affect the Cope's Giant Salamander in unanticipated ways. In Olympic National Park, Cope's Giant Salamanders had the narrowest distribution as compared to Olympic Torrent Salamanders and Coastal Tailed Frogs, and also had the strongest relationship to climate variables of the three species, suggesting that climate could be limiting their range (Adams and Bury 2002). Also, the Cope's Giant Salamander had a strong positive association with precipitation, suggesting that an aquatic-obligate life history may increase reliance on permanent flowing streams and decrease its overland dispersal capabilities. This is problematic because 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 the Cope's Giant Salamander, and range retractions are likely in the southern

portion of the species range, particularly in the Cascade ecoregion. Conversely, range expansion is possible in the northern range boundary of the Cascade ecoregion into Mount Rainier National Park, and possibly southern coastal areas where low-mid elevation streams (generally < 800 m) are available for colonization. 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 the salamanders. This could be an issue for the Cope's Giant Salamander because we found the average site elevation across the species range was about 475 m, plus it has a quadratic association with elevation, with abundances peaking at ~500 m (Adams and Bury 2002). These elevations occur within the rain-on-snow transient zone, where periodic and complete melting usually occurs on snowpacks at elevations between approximately 300 and 900 meters during the winter, and where peak flows are often exacerbated by the extent of basin-wide clear-cutting and high road density (Harr and Coffin 1992; Harr et al. 1975).

Forest Fires

The effects from forest fires on Cope's Giant Salamanders and giant salamanders in general are relatively unstudied. Within the range of the Cope's Giant Salamander, the frequencies of large stand-replacing fires are quite different between the Coastal and Cascade ecoregions, with return intervals ranging from centuries along the Olympic coast to decades in lowland Douglas-fir forests of the Cascades ecoregion (Agee 1993). Concerning fire effects that may be relative to *Dicamptodon* salamanders, 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, likely will have little adverse effect on this species. Increased fire frequency exacerbated by climate change is a concern, especially for Cope's Giant Salamander populations in the Cascade ecoregion.

Habitat Fragmentation

As described previously, the patchy distribution of Cope's Giant Salamander suggests that landscape, climatic, and glacial factors have all contributed to natural fragmentation. The species' constrained

dispersal capability also plays a part in the degree to which adjacent populations may be connected (Steele and Storfer 2007; Steele 2006). In addition, anthropogenic disturbances such as roads and habitat fragmentation from timber management and related disturbances have likely contributed to the level of fragmentation across the species range. Long-term isolation of small populations may result in losses due to stochastic variation in population demography (i.e., random fluctuations in animal numbers that may result in extinction of small populations). Loss of current connectivity among habitat patches may be a concern for further population isolation. Trumbo et al. (2013) suggested that, within the species range, fragmentation and isolation from logging would continue, exacerbated by the effects of climate change, but that connectivity could be retained by maintaining and improving river and stream dispersal corridors, with conservation of the remaining high-quality habitats.

Chemical Applications

Chemicals such as herbicides, pesticides, fungicides, fertilizers, and fire retardants may directly affect the Cope's Giant Salamander. Exposure could result from releases of these chemicals to waterways populated by the species, as well as potential overspray effects on transformed adults within riparian areas. No data exists, however, specific to chemical effects on this species to help understand the scope of this potential threat. 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 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 Oregon and Washington is uncertain, and warrants examination. Aerial drift of agricultural chemicals onto adjacent habitats has not been investigated, and may be an additional concern.

Disease

The amphibian chytrid fungus (*Batrachochytrium dendrobatidis*) (*Bd*) has recently been detected in Oregon and Washington (http://www.bd-maps.net/). This disease is particularly notable relative to Cope's Giant Salamander because of its predominantly aquatic life history; *Bd* is an aquatic fungus and has been found in greater levels in aquatic amphibians, and more often in older larvae and metamorphosed animals due to the higher keratin content of their skin, upon which *Bd* relies. Some amphibian species can be carriers of *Bd*, and do not show symptoms of the disease. Although this is not fully understood, they may be resistant to the disease, or the intensity of infection *Bd* or strain virulence may be low. Hossack et al. (2010) reported no *Bd* on 60 Coastal Giant Salamander larvae from California, yet they found it on 3

metamorphosed Idaho Giant Salamanders from Idaho and Montana, and on 1 of 57 Idaho Giant larvae. As far as we have been able to determine, no studies have tested for *Bd* in Cope's or Coastal Giant Salamanders in Oregon or Washington (http://www.bd-maps.net/isolates/; accessed May 2013), although there is a single record of *Bd* in a Coastal Giant in California (S. Kupferberg, unpub. data). In general, prevalence appears to be low among Northwest amphibians associated with small streams, but only one study, Hossack et al. (2010), has targeted headwater amphibians—no one has so far tested any species of *Rhyacotriton*. 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. 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. 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 Cope's Giant Salamanders to other pathogens has not been studied, yet parasites such Oligochaetes have been found in the feces and spermatophores of Coastal Giant Salamanders and Trichodina has been found in blood samples of both species (Lisa Wagner, pers. commun.). In addition, Ranavirus is an emerging infectious disease tied to massive mortality episodes in a variety of amphibian species, including salamanders. In 2013, a cluster of several dead Coastal Giant Salamanders were discovered in a stream in Oregon, and were collected and tested for Ranavirus and *Bd*. Neither pathogen was detected; the cause of death remains unknown for those animals, with an unknown disease or chemicals possibly playing a role. 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).

Introduced Species

Cope's Giant Salamander larvae are likely prey for non-native Eastern Brook Trout (*Salvelinus fontinalis*). First introduced in the early 1900s, Brook Trout are widely distributed in many high mountain lakes and headwater streams and co-exist with the Cope's Giant Salamander in many areas across the salamander's range. The magnitude of this potential threat to the Cope's Giant Salamander in Oregon and Washington is not well known. The amphibian chytrid fungus and Ranavirus mentioned previously are also considered introduced species.

Livestock Grazing

Given that the Cope's Giant Salamander primarily occurs in coastal and westslope Cascade Range conifer forests, the effects of grazing are thought to be minimal. The specific effects of grazing have not been studied for this species.

Conservation Status

The Cope's Giant Salamander is listed as a species of concern in the states of Oregon and Washington and on US Forest Service lands in Oregon and Washington due to its limited distribution and potential vulnerability to several threats. It is listed as U.S.D.A. Forest Service, Region 6, Oregon - Sensitive; U.S.D.I. Bureau of Land Management, Oregon - Sensitive; State of Oregon –species facing one or more threats to their populations and/or habitats (V); State of Washington, State Monitored Species. Please refer to the Management Status section.

Known Management Approaches

There are no established management approaches that have been field-tested specifically relative to their effectiveness for the Cope's Giant Salamander and its habitat in Oregon and Washington. An expert panel convened during development of the federal Northwest Forest Plan (USDA/USDA 1994) and evaluated the role of riparian protection in providing species persistence. The panel concluded that this species would benefit from riparian reserves. The resulting Aquatic Conservation Strategy of the Plan (USDA/USDI 1994) included a riparian reserve component that was thought to mitigate threats of forest management activities for this species, especially due to its application of riparian protections to small streams. Benefits to amphibians also may occur on other land ownerships through the Washington State Department of Natural Resources Forest Practices Habitat Conservation Plan (WADNR 2013) that 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 both Washington and Oregon State Departments of Fish and Wildlife provide guidance for road/stream crossing construction, upgrade and maintenance specifications for fish-bearing waters that may coincidently be inhabited by Cope's Giant Salamanders (ODFW 2013; WDFW 2013). However, these permit procedures are only required for fish-bearing waters, plus design specifications that target fish passage may not be adequate to accommodate aquatic amphibians as well.

The US Forest Service 2670 sensitive species policy and the BLM 6840 special status species policy suggest 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 Cope's Giant Salamander is to contribute to a reasonable likelihood of long-term persistence within the range of the species in Washington and Oregon. 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).

Specific Objectives

Assess and prioritize areas of the species' occurrence and geographic range on federal lands relative to species management needs.

As projects are proposed on federal lands, identify sites to be managed for species persistence or so as not to contribute to the need to list under the ESA.

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

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 Cope's Giant Salamanders have been found:

1) Retain streamside riparian buffer zones to: A) reduce streambank erosion and intercept fine sedimentation before reaching stream channels because in-channel coarse substrates are important to the life histories of giant salamanders; B) retain stream shading to reduce alteration of stream temperatures; and C) reduce peak flow variability from runoff. Site conditions (aspect, hill-shading, vegetation condition, watershed condition, cumulative effects) warrant consideration when buffer widths are considered and whether managed buffers or no-entry buffers are needed. No studies address the efficacy of various buffer widths as protection measures for salamanders in this geographic area, hence support for a specific buffer size is lacking at this time.
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 and streams. 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 hillshading and aspect in management of source habitats; for example, such that naturally exposed areas prone to higher temperatures have vegetative buffering (canopy retention).
4) Manage road construction, repair, and maintenance to accommodate both up- and downstream passage for terrestrial and aquatic amphibians like the Cope's Giant Salamander. However, consideration of invasive species passage is also needed, so as not to inadvertently introduce non-native predators or other types of species with potential adverse effects on salamanders into upstream reaches.
5) Manage forest stands to reduce the likelihood of stand-replacement fires, including thinning of young, dense stands.
6) Closely monitor and/or restrict chemical applications near stream channels.
7) Restrict soil-compacting equipment or vehicle refueling near stream channels.
8) Reduce the likelihood of non-native predators like Brook Trout in streams.
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 to and exposure of salamanders of 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 it 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) Genetic analyses have suggested that overland movements are restricted for this species. However, we do not know the extent to which this animal may disperse overland; hence it is prudent to consider management activities to promote connectivity among stream and riparian habitats, especially 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 terrestrial and aquatic amphibians like the Cope's Giant 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.

V. INVENTORY, MONITORING, AND RESEARCH OPPORTUNITIES

Data and Information Gaps

A priority need is to gain a better understanding of the current distribution of the Cope's Giant Salamander in Oregon and Washington. Other information gaps include many aspects of the basic life history and habitat associations of the species, and effects of various disturbances including disease and climate change. With additional knowledge of habitat associations, a goal would be to create a map of optimal habitat for this species. Climate envelope modeling is also a priority for this species in order to gauge potential future threats. More information is needed on the prevalence and consequence of pathogens including the amphibian chytrid fungus, *Bd*, in this species.

Several gaps relative to site and watershed management remain. In particular, how well do riparian buffers protect this species (what riparian management options should be considered, how wide should buffers be)? Do we need to consider upland management activities to address population connectivity? What are the movement patterns of this species? To what extent are road crossings affecting dispersal across the species' range? What are some adequate culvert design criteria to insure that road crossing barriers are minimized?

With regard to life history and population ecology, how will projected reductions in stream flow and increases in water temperature, like those attributed to climate change scenarios, affect the animal's life history, movements, physiology, and metamorphosis? To what effect do non-native species like Brook Trout influence salamander populations and what are the interspecific interactions with native trout? What is the spatial extent of a stable population, or rather the range of areas for population persistence? At what abundances are these animals found in Oregon and Washington? Lastly, the ecological role of this species within the larger ecosystem is poorly understood. What is their place in the trophic structure of the ecosystem? Are they key prey (or predator) in trophic cascades? Are food webs altered by forest management practices?

Inventory

Inventories could help delineate this species' current range. While a full geographic inventory is of prime importance, if these surveys were designed carefully, then associations with habitat conditions, land management practices, population structure, and *Bd* disease occurrence could be determined

simultaneously. A habitat map would be a useful asset to federal land managers within the species' range.

Survey approaches depend on the objectives of the inventory effort. Several aspects of the survey design are relevant to consider: 1) site selection, where site is often the stream reach to be sampled; 2) sampling frequency within a site, often how many stream units or segments are sampled within a stream reach; 3) sampling method at the stream unit or segment, such as hand sampling or electrofishing described below; 4) intensity of sampling method; 5) timing of the sampling, such as which season and what time of day or night; and 6) the detection probability of the method used.

Several stream survey methods effectively detect Cope's Giant Salamander larvae and paedomorphs, including stream dipnet searches, block- or seine-netting, and electrofishing. One method is to place a dipnet (e.g., a D-frame net) flush with the stream bottom and overturn, remove, or kick substrate upstream of the net to dislodge larvae; this method is described as "rubble rousing" by Quinn et al. (2007). Similarly, another method involves placing a seine or block net across the stream and picking up, overturning, or kicking upstream substrate (rubble rousing), which will cause larvae to be dislodged, swept downstream by the current, and get caught in the net. Light-touch sampling is a variant of rubble rousing that involves turning over surface cover objects within the stream channel that are small cobble-sized (64 mm) and larger and visually searching for amphibians (Spear et al. 2011), this method can be enhanced considerably by using a Plexiglas bottomed bucket to first locate the animals before disturbing the streambed. Electrofishing will dislodge larvae and paedomorphs, which can be caught with aquarium nets or be allowed to float into a downstream block net, but may not be effective when salamanders are lodged under coarse substrates. Overnight trapping by funnel traps or by using an inverted plastic bottle baited with salmon eggs is another efficient method of capture. Lastly, night-time surveys along stream channels using a high-power spotlight is not only an effective method for juveniles, but rare transformed adults have been found this way.

For inventory objectives, several subsamples per stream reach may be needed for detection of larvae that may be clustered in space. At the stream-drainage scale, several stream reaches or segments may need to be sampled to determine occupancy in an area. In addition to simple detection of animals, the area or time of each stream unit that is searched could be standardized, as well as the number of subsamples collected per stream reach of any given length. Methods and sampling designs used in several studies cited in this report could be used as a guide.

Repeated sampling is useful for application of occupancy modeling and determination of detection

probabilities.

Monitoring

There is little to no on-going monitoring of specific sites for this species in Oregon or Washington. Most inventory and population data is either from specific research or incidental from presence/absence surveys targeting fish as a precursor to timber sale activities. Knowledge of land management activities at sensitive species' sites might be considered a prompt to consider monitoring of this species. If monitoring were initiated, standardized methods could enable future comparisons among sites. Federal sensitive species corporate data bases like GeoBOB and NRIS could provide a standard format for documentation. Also, forest practice permit applications in both Washington and Oregon require documentation of salmonid fish presence, yet could easily record *Dicamptodon* that may be observed coincidently during presence/absence surveys for fish.

Ongoing monitoring of current populations and the implementation and effectiveness monitoring of currently-imposed protective measures are needed for the Cope's Giant Salamander. 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 contemporary forest management practices such as how riparian buffers may affect microhabitats or populations of these salamanders. Stream-crossing culverts and design specifications have been little studied relative to this species. Also, the effects of climate change affecting habitats and the spread of *Bd* and other pathogens in this species are poorly known. Climate envelope modeling would allow projections of effects within Oregon and Washington, and may prioritize habitats for management or conservation. The general association of stream amphibians, including the Cope's Giant Salamander, with some of the pronounced climatic gradients on the Olympic Peninsula, for example, coupled with the overall sensitivity of amphibians to environmental change, suggest that the species may be useful in monitoring global climate change impacts (Corn 2005; Adams and Bury 2002).

The use of the federal GeoBOB and NRIS databases will allow several questions about the spatial distribution of this species to be addressed for the development of landscape-level design questions and the further assessment of habitat associations. Field units are required to enter areas surveyed with no detections 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. Development of strategies to address these questions of conservation biology is a critical research need.

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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; this 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; 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 Washington Natural Heritage Program Definitions

Globally Imperiled

G4 – Not rare and apparently secure, but with cause for long-term concern, usually with more than 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/S4 – State vulnerable and apparently secure.

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