Amphibians Scoping Proposal

Independent Research and Science Team

Institute for Natural Resources – Oregon State University

Scoping Proposal

Submitted to

The Oregon Department of Forestry

Adaptive Management Program Committee

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The Independent Research and Science Team

Prepared by

The Institute for Natural Resources

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Disclaimer

This scoping proposal is submitted to the Adaptive Management Program Committee as a requirement of the Oregon Department of Forestry Adaptive Management Program rules (Chapter 629, Division 603).

The contents of this report reflect the views of the Independent Research and Science Team (IRST), which is solely responsible for the facts and accuracy of the material presented. This scoping proposal does not constitute a standard, specification, or regulation.

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Abbreviations and Acronyms

AMPC	Adaptive Management Program Committee
ARMI	Amphibian Research and Monitoring Initiative
BGO	Biological Goals and Objectives
eDNA	Environmental DNA
FPA	Forest Practices Act
GIS	Geographic Information Systems
HCP	Habitat Conservation Plan
HUC	Hydrologic Unit Code
INR	Institute for Natural Resources
IRST	Independent Research and Science Team
OAR	Oregon Administrative Rules
ODF	Oregon Department of Forestry
ORBIC	Oregon Biodiversity Information Center
OSU	Oregon State University
PFA	Private Forest Accord
PSU	Portland State University
QA/QC	Quality Assurance/Quality Control
RFP	Request for Proposals
USGS	United States Geological Survey

Executive Summary

The 2022 Private Forest Accord Report recognized that uncertainty around stream-associated amphibian population characteristics, distribution, productivity, survival, and abundance warrants prioritizing research under the adaptive management process to ensure that the efficacy of protection strategies can be evaluated and adjusted as needed (Private Forest Accord Report 2022). The Report recommended $1.5 million for an initial study through the first adaptive management funding cycle, with the expectation that ongoing research over appropriate time intervals would be necessary to understand outcomes over the long term. The Independent Research and Science Team (IRST) oversees the research projects that the Adaptive Management Program Committee (AMPC) prioritizes and delineates. This Scoping Proposal covers two research questions approved by the AMPC pertaining to amphibian species covered under the Oregon Private Forest Accord (PFA) Habitat Conservation Plan (HCP) currently in development. The research options presented in this proposal are developed in response to that commitment and in direct response to the two AMPC research questions approved for amphibian species covered under the PFA HCP. The questions are:

> Question 1: *For each of the covered amphibian species, what is the distribution (including population diversity) within Oregon, and what factors (e.g., stream gradient, stream size, fish presence/absence, slope, aspect, temperature, seasonality, micro-habitat conditions) determine this distribution at a smaller spatial scale (e.g., watershed)?*
>
> Question 2: *What is the population trend of the Columbia and Southern torrent salamanders over time on lands subject to the Forest Practices Act (FPA) rules? This question is informed by the following overarching biological goal as stated in the draft PFA HCP: "Forest practices that support the survival and recovery of the covered species by providing clean, cool, connected, and complex habitats."*

The five covered amphibian species are: Cope's giant salamander (*Dicamptodon copei*), coastal giant salamander (*D. tenebrosus*), Columbia torrent salamander (*Rhyacotriton kezeri*), southern torrent salamander (*R. variegatus*), and coastal tailed frog (*Ascaphus truei*). A third question (Question 3), focused on the effects of specific forest practice rules on covered amphibian species, is not yet finalized and will be addressed in a separate scoping proposal. The IRST reviewed the literature on these five stream-associated amphibians in Oregon, emphasizing distribution, habitat associations, and population trends relevant to the research questions. The literature review is not exhaustive but is a foundation for evaluating research options and informing the development of solicitations for further research through a request for proposals (RFP) process. Key findings from the review are:

1. Broad geographic range boundaries are reasonably well established for all five covered species across western Oregon and the Pacific Northwest.
2. General habitat associations are consistently documented: all five species are strongly associated with cold, perennial headwater streams with coarse substrates and forested riparian environments.
3. Watershed-scale distribution is incompletely characterized for all five species in Oregon. Available occurrence records are geographically uneven and derived largely from opportunistic, non-

standardized surveys, constraining inference about fine-scale occupancy patterns and continuity among adjacent watersheds.

4. Most existing surveys did not account for imperfect detection. Because detection probability varies among species, life stages, habitats, and sampling conditions, uncorrected occurrence data may yield biased estimates of species-habitat relationships and distributions.
5. Population diversity, including genetic connectivity, demographic rates, and range-wide abundance, is poorly quantified across Oregon for all five species. Existing demographic information is biased toward larval stages, with limited data on survival, recruitment, or adult population dynamics.
6. No standardized long-term time-series data sufficient to evaluate population trajectories exist for Columbia or southern torrent salamanders on lands subject to Oregon Forest Practices Act (FPA) rules.

We provide seven research options to address the research questions. Five options address Question 1 and apply to all five covered species, and two options address Question 2 and focus on Columbia and southern torrent salamanders. Full descriptions of each option, including additional potential costs, tradeoffs, and integration considerations, are provided in Section 3. Table Ex-1 provides a summary.

Table Ex-1. Summary of research options addressing AMPC Questions 1 and 2, including timeframe, general cost estimates, and knowledge contributions.

Option	Timeframe	Cost	Knowledge Contribution
Option 1	None	$0	**No Action**: Maintains current understanding from existing data; does not generate new information on watershed-scale distribution, habitat associations, population diversity, or population trends.
Q1-Option 2	1-2 years	$130k–$400k ($130k–$200k/year)	**Targeted Range & Distribution Refinement**: Limited new presence/absence records to refine range boundaries and reduce distributional uncertainty. Provides foundation for designing future field studies.
Q1 Option 3	2-3 years	$700k–$1.7m ($350k–$575k/year)	**Watershed-Scale Habitat Associations -- Broad Sampling**: Systematic, range-wide characterization of watershed-scale species presence/absence data and landscape- and watershed-scale habitat associations. Does not support reach-scale inference; apparent absences species carry uncertainty.
Q1 Option 4	3-5 years	$1.1m–$2.5m ($375k–$500k/year)	**Reach-Scale Habitat Associations -- Intensive Sampling**: Accommodates detection-corrected occupancy methods for species presence/absence at the stream-reach scale within a smaller number of watersheds, supporting more reliable habitat association inference at reach-scales within sampled watersheds. Most informative alongside Q1-3.
Q1 Option 5	3-5+ years	$625k–$1.7m ($200k–$275k/year)	**Population Diversity — Genetic and Demographic Approaches**: Population connectivity, genetic structure, and demographic rates. Most valuable as an add-on to Q1-3 or Q1-4. Each approach provides only a partial view independently.
Q2 Option 1	5-10 years	$2.3m–$7.4m ($450k–$700k/year)	**Broad-Scale Torrent Salamander Monitoring Network:** Detection-corrected occupancy trends for Columbia and southern torrent salamanders across a broad geographic extent on FPA lands. Trend detection is the primary objective. Does not explain demographic mechanisms driving observed trends.
Q2 Option 2	7-10+ years	$3.4m–$7.1m ($475k–$700k/year)	**Intensive Torrent Salamander Monitoring Network with Demographic Components**: Detection-corrected occupancy trends for Columbia and southern torrent salamanders within intensively monitored watersheds on FPA lands; abundance estimation, demographic data collection, and habitat characterization are optional enhancements; most informative when implemented alongside Q2, Option 1.

1. Introduction

1.1 Background and Project Purpose

The Independent Research and Science Team (IRST) was established via Senate Bill 1501 as part of the Oregon Department of Forestry's Adaptive Management Program. The IRST supports the work of the Adaptive Management Program Committee (AMPC) by responding to AMPC-developed research question packages. Per rule, and in consultation with the AMPC, the IRST refines preliminary research questions into final research questions, then develops scoping proposal(s) to address those questions. The scoping proposal(s) must include:

- A literature review that specifies the need for, or the type of, monitoring, research, commissioned studies, or other means of scientific inquiry necessary to answer the finalized research questions;
- A preliminary estimate of the budget for each year of the research, and a timeline to complete the research project with specific deliverables; and,
- A preliminary description of research project requirements, scope of work including an estimate of the timeline and key milestones, and an estimate of the degree to which knowledge may be improved if the research proposal is implemented.

As per OAR 629-603-0200, the IRST develops each request for proposals (RFP) in an open, competitive process after the AMPC and Board of Forestry approve an AMPC research agenda that is based on the IRST scoping proposal. See Figure 1.

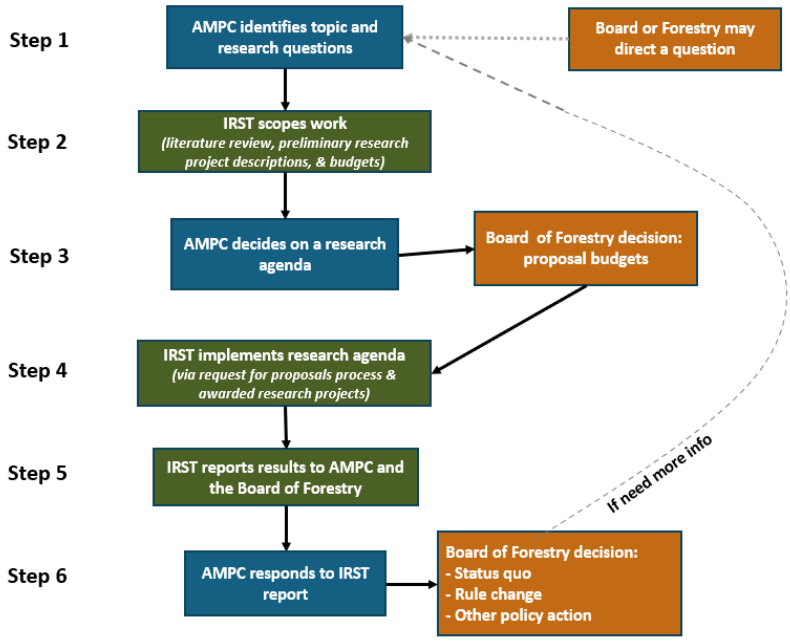

Figure 1. Adaptive Management Process.

With these requirements, the purposes of this scoping proposal are to (1) characterize existing knowledge relevant to the AMPC amphibian research questions (Section 1.2), (2) identify key uncertainties and data gaps, and (3) present research options that range in scope, cost, and inferential value to inform AMPC and Board of Forestry decisions about the utility of soliciting further research through the RFP process.

1.2 Research questions

The AMPC approved the research questions package (Appendix A) pertaining to covered amphibian species under the Oregon Private Forest Accord at their April 18, 2025 meeting.

> Question 1: *For each of the covered amphibian species, what is the distribution (including population diversity) within Oregon, and what factors (e.g., stream gradient, stream size, fish presence/absence, slope, aspect, temperature, seasonality, micro-habitat conditions) determine this distribution at a smaller spatial scale (e.g., watershed)?*

Question 1 applies to all five covered amphibian species. The AMPC's original framing of Question 1 did not envision field data collection for the geographic range component. However, several field-based options described in this scoping proposal contribute to understanding distribution at finer spatial scales and addressing habitat associations and population trends.

> Question 2: *What is the population trend of the Columbia and Southern torrent salamanders over time on lands subject to the Forest Practices Act (FPA) rules? This question is informed by the following overarching biological goal as stated in the draft PFA HCP: "Forest practices that support the survival and recovery of the covered species by providing clean, cool, connected, and complex habitats."*

Question 2 is specific to Columbia and southern torrent salamanders and focuses on temporal population change on lands subject to Oregon Forest Practices Act rules.

A third question (Question 3), focused on the effects of specific forest practice rules on covered amphibian species, was included in the AMPC question package but will be addressed separately. The AMPC requested that Question 3 be developed later. Research conducted under Questions 1 and 2 will provide distributional, habitat, and population baseline data that may inform that future work.

The Private Forest Accord Report (2022), which underpinned Senate Bill 1501 and the Adaptive Management Program, provided the following background on this request:

> *"Uncertainty exists around amphibian population characteristics, distribution, productivity, survival, and abundance. A robust effectiveness monitoring plan as part of an adaptive management program will be used to better understand the relationship between forest management and covered amphibian species. To support this program, it is recommended that $1.5 million be initially applied to research through the first funding cycle of the adaptive management program to better understand how riparian and unstable slope protections of at least the current and proposed rules for private forestland impact persistence of populations. The Authors agree that the $1.5 million will be used to fund an initial study and that ongoing research over appropriate intervals of time beyond this initial study will be necessary to*

understand research outcomes over long periods of time. The priority species for monitoring will be the Columbia and Southern torrent salamanders. With consideration to funding constraints and other priorities, this research could also include other species covered by the HCP. Additionally, it could include Cascade torrent salamanders, which are not covered by the HCP."

1.3. Covered Species

The five amphibian species covered under the Private Forest Accord HCP relevant to AMPC Questions 1 and 2 are:

- Cope's giant salamander (*Dicamptodon copei*)
- Coastal giant salamander (*Dicamptodon tenebrosus*)
- Columbia torrent salamander (*Rhyacotriton kezeri*)
- Southern torrent salamander (*Rhyacotriton variegatus*)
- Coastal tailed frog (*Ascaphus truei*)

All five species share some life-history characteristics relevant to interpreting their distribution, habitat associations, and population structure. All are stream-associated amphibians with aquatic or semi-aquatic life stages; reproductive activity is tied to cold, perennial streams or stream-adjacent habitats; larval development occurs over extended periods in flowing water; and adults exhibit limited movement relative to many terrestrial amphibians. These traits produce strong associations with local hydrologic conditions, stream temperature, and fine-scale habitat structure, and they provide important context for evaluating patterns of occurrence and population connectivity across landscapes.

1.4 Knowledge Gaps and Research Options

To address the knowledge gaps identified in the literature review (Appendix B), the IRST developed seven research options that vary in scope, cost, and inferential value. Five options address Question 1 and apply to all five covered species; two options address Question 2 and focus on Columbia and southern torrent salamanders. The options range in complexity and effort required from no additional data collection to long-term intensive field monitoring.

The knowledge contributions of each option map directly onto the components of AMPC Questions 1 and 2. Question 1 encompasses three distinct knowledge dimensions: *distribution* (including geographic range and watershed-scale occurrence patterns), *habitat associations* (at landscape, watershed, and reach scales), and *population diversity* (including genetic connectivity and demographic rates). Q1, Options 2 through 4 contribute primarily to the distribution and habitat association dimensions, with the spatial scale of inference varying substantially across options; Q1, Option 5 addresses the population diversity dimension that field surveys alone cannot resolve. Question 2 is addressed only by Q2, Options 1 and 2, which are designed specifically to generate the temporal replication needed to detect population trends for Columbia and southern torrent salamanders on FPA lands. The knowledge contribution topic areas summarized in Table 3.1 and evaluated for each option in Section 3 are organized around these dimensions to facilitate direct comparison across options.

A key methodological distinction among the field-based options is the difference between *occurrence*-based and *occupancy-based* approaches to assess species presence/absence. Occurrence data describe

where a species was detected but do not account for the probability that a species went undetected at a given site. Occupancy-based approaches incorporate repeated visits to explicitly estimate detection probability, producing improved understanding of species distribution and habitat relationships. No single option addresses all knowledge gaps identified in Section 2, and the strongest inference across both questions is likely to result from implementing complementary options. Full descriptions of each option, including approach, timeframe, preliminary cost estimates, and knowledge contributions, are provided in Section 3, along with a discussion of tradeoffs among options and integration considerations.

2. Scoping Literature Review

2.1 Introduction

The IRST reviewed and synthesized available scientific information regarding the five stream-associated amphibians in Oregon covered by the Private Forest Accord HCP: Cope's giant salamander *(Dicamptodon copei)*, coastal giant salamander *(D. tenebrosus)*, Columbia torrent salamander *(Rhyacotriton kezeri)*, southern torrent salamander *(R. variegatus)*, and coastal tailed frog *(Ascaphus truei)*. The review emphasized distribution, population diversity and trends, and habitat associations relevant to AMPC Research Questions 1 and 2 (Appendix A). The full review (Appendix B) is organized into four sections: Distribution, Population Diversity, Habitat Associations, and Torrent Salamander Population Status and Trends.

This chapter summarizes the key findings and insights from that review that are most relevant to evaluating the research options presented in Section 3. Takeaways are organized around four aspects that cut across AMPC Questions 1 and 2: (1) distribution and watershed-scale occurrence, (2) habitat associations, (3) population diversity, and (4) population trends. These dimensions correspond directly to the knowledge gaps that motivated the research options and to the evaluation criteria used to compare them in Table 3.1.

Interpreting the available information for these species is subject to recurring limitations that bear directly on the research options presented in Section 3. Most population diversity and habitat studies have relied on short-term, reach-scale surveys that use occurrence or relative-abundance data without correcting for detection probability, which varies among species, life stages, habitats, and sampling conditions. When detection probability is not estimated, this may lead to unreliable inference about habitat associations or population trends (Kroll 2009). Accordingly, findings from the literature are best interpreted as describing relative patterns of occurrence and habitat association, with substantial uncertainty remaining around demographic rates, population size, and trends.

2.2 Methods

The literature review drew on peer-reviewed journal articles, agency technical reports, dissertations and theses, and gray literature identified through keyword searches across Web of Science, BioOne, ScienceDirect, ProQuest, Google Scholar, the Oregon State University Scholars Archive, and the Portland State University Library catalog. Search terms combined scientific and common names for the five covered species with topic-specific terms related to distribution, habitat associations, population genetics and diversity, and population status and trends, paired with geographic terms covering Oregon, Washington, and northern California. Forward and backward citation searches were conducted for a set of foundational papers identified during initial screening, and additional sources were identified through citation mining and solicitation from IRST members, and review of unpublished sensitive species status assessments prepared by Institute for Natural Resources for the Oregon Department of Fish and Wildlife.

Distribution summaries drew on verified species occurrence records from the Oregon Biodiversity Information Center (ORBIC) Sensitive Species database, the USGS Amphibian Research and Monitoring Initiative (ARMI) National Amphibian Atlas, and published locality reports. Literature relevant to each of

the four topical areas was organized by species, following a consistent structure to facilitate comparison across taxa. Areas where available information is limited or key uncertainties remain are identified throughout. A glossary of select biological terms is provided in Appendix B.

2.3 Findings

Key findings from each of the four topical areas in Appendix B are summarized below, with emphasis on patterns most relevant to the research options in Section 3.

2.3.1 Distribution

Broad geographic range boundaries are reasonably well established for all five covered species across western Oregon and the Pacific Northwest, based on county-level records, museum specimens, and agency datasets. All five species occur primarily west of the Cascade crest. Three species (coastal giant salamander, Cope's giant salamander, and coastal tailed frog) have documented occurrences east of the Cascade crest in north-central Oregon, though these are geographically limited. Both torrent salamander species are restricted to western Oregon.

The five species span a gradient of geographic range size and ecological specialization within western Oregon. Coastal giant salamander and coastal tailed frog are the most broadly distributed, occurring across multiple ecoregions and elevational zones. Cope's giant salamander is confined primarily to portions of the northern Coast and Cascade ranges, with limited distribution in Oregon. Columbia torrent salamander is restricted to the northern Oregon Coast Range and adjacent Washington Coast Range. Southern Torrent Salamander has a broader range extending through western Oregon into northern California, including a geographically disjunct population in the western Cascades.

At watershed scales, occurrence patterns are incompletely characterized for all five species. Available records are geographically uneven and derived largely from opportunistic, non-standardized surveys, with limited systematic sampling at 5th-field HUC or finer scales. Fine-scale survey data sufficient to evaluate continuity among adjacent watersheds are lacking across much of the range of each species. Table 2 in Appendix B summarizes the degree to which geographic range boundaries and watershed-scale distributions are resolved for each species, along with the primary limitations affecting inference at watershed scales.

2.3.2 Population Diversity

As used here, population diversity encompasses local abundance, demographic and life-history characteristics, age and life-stage structure, and genetic differentiation. Across all five species, population diversity is incompletely characterized at scales relevant to Questions 1 and 2. Table 3 in Appendix B summarizes available evidence and limitations by species.

Local abundance varies widely within and among watersheds for all five species, but rangewide abundance estimates do not exist for any taxon. Most available information is derived from site-scale surveys rather than standardized, long-term monitoring, limiting inference about population stability or persistence. Demographic rates, particularly survival, recruitment, and life-stage transitions beyond larval stages, are poorly quantified for all species. Available demographic information is biased toward larval stages, and adult abundance and survival are rarely measured.

Genetic studies consistently document strong population structure and limited connectivity across all five species, reflecting the largely aquatic life histories and limited overland dispersal capacity typical of headwater stream-associated amphibians. Major rivers and other landscape features function as barriers to gene flow across all five species (Good and Wake 1992; Nielson et al. 2001; Steele et al. 2005; Emel et al. 2019). For all species, Oregon-specific genetic sampling is spatially limited, leaving population structure and connectivity across much of Oregon uncharacterized.

2.3.3 Habitat Associations

Across all five species, occurrence and density are consistently associated with cold, perennial headwater streams with coarse substrates and forested riparian environments. Table 4 in Appendix B summarizes habitat associations across three dimensions (stream characteristics, microhabitat associations, and riparian forest context) for each species.

Torrent salamanders (*R. kezeri* and *R. variegatus*) represent the most microhabitat-restricted taxa, occupying seeps, splash zones, and low-order headwater channels where stable moisture and cold temperatures are maintained. Both species exhibit notably low thermal tolerances relative to most amphibians and are consistently associated with the coldest headwater environments. *Dicamptodon copei* shows similarly strong associations with cool, steep-gradient headwaters, while *D. tenebrosus* exhibits greater ecological flexibility across stream orders and aquatic habitat types. *Ascaphus truei* is obligately associated with fast-flowing, high-gradient, permanently flowing channels with coarse cobble or bedrock substrates.

Quantitative thresholds for key habitat variables, including channel gradient, canopy cover, thermal tolerance under field conditions, and flow permanence, are not well described for these taxa. Most habitat associations are derived from site- or reach-scale studies within a limited number of watersheds; relationships observed at local scales may not generalize across headwater networks or management-relevant spatial extents. Many studies did not account for imperfect detection, limiting inference about the strength and consistency of reported habitat relationships.

Riparian forest context influences habitat suitability primarily through effects on stream temperature, moisture, and sediment dynamics rather than through direct effects of stand age alone. Experimental evidence indicates that population-level effects of timber harvest on coastal tailed frog may not manifest until years later and may not be fully prevented by riparian buffers (McIntyre et al. 2025), underscoring the need for sustained monitoring to detect management effects on these species. More broadly, forest management effects on habitat suitability for these species appear to operate primarily through hydrology, thermal regime, and substrate condition rather than stand age per se (Russell et al. 2004; Welsh and Lind 1996; Kroll et al. 2008; Neal et al. 2024; Olson and Ares 2022).

2.3.4 Torrent Salamander Population Status and Trends

Direct information on population size, demographic rates, or long-term trends is lacking for both Columbia and southern torrent salamanders. Available evidence is derived from occurrence and relative abundance studies at stream-reach or watershed scales, providing insight into localized patterns of occurrence but not supporting quantitative assessment of population trajectories.

No time-series datasets exist to evaluate population trends, extinction risk, or recolonization dynamics for either species at watershed, regional, or rangewide scales. For *R. kezeri*, recent rangewide habitat-

suitability modeling provides a spatially consistent framework for comparing relative occurrence across its restricted geographic range (Thurman et al. 2025), representing an important advance for spatial inference; however, this work does not explicitly account for imperfect detection and cannot support trend analysis without temporal replication. For *R. variegatus*, watershed-scale surveys in intensively managed Oregon and Washington forests reported near-ubiquitous occupancy of *Rhyacotriton* spp. in third-order watersheds when detection was explicitly accounted for (Kroll et al. 2010), providing a potential baseline for future comparisons but not a trend estimate.

Historical landscape modeling has estimated substantial reduction in suitable habitat since Euro-American settlement, attributed primarily to riparian canopy loss and forest fragmentation (Kagan et al. 1999). Field studies generally report reduced occurrence or abundance in recently harvested or hydrologically altered headwaters and higher persistence where perennial flow and riparian shading are retained, though effects are not uniform across studies or landscapes (Bury and Corn 1988, Corn and Bury 1989, Welsh and Lind 1996, Kroll et al. 2008, and Olson and Ares 2022). However, these patterns describe variation in occurrence and habitat association rather than direct evidence of population decline. For both species, the absence of standardized, repeat-visit monitoring frameworks means that AMPC Question 2 cannot be addressed with existing data.

2.4 Key Takeaways

Below are the key takeaways from the literature review most relevant to the research options described in Section 3. Takeaways are organized around the three principal aspects of research option design: distribution and watershed-scale occurrence, habitat associations, and population diversity and trends.

2.4.1 Distribution and Watershed-Scale Occurrence

- Broad geographic range boundaries are reasonably well established for all five covered species based on existing occurrence records and published literature.
- Targeted range refinement surveys would reduce distributional uncertainty at range margins and in data-sparse watersheds for all five species, providing a stronger empirical foundation for designing complementary field studies. Species-specific data gaps are described in Table B2 of Appendix B.
- Watershed-scale distribution is incompletely characterized for all five species. Available records are geographically uneven and largely opportunistic, meaning that fine-scale occurrence patterns and continuity among adjacent watersheds cannot be reliably inferred from existing data alone (see Distribution, Appendix B; Table B2).
- Detection probability has rarely been estimated in existing surveys. Because detection probability may vary among species, life stages, habitats, and environmental conditions, apparent absences in occurrence data cannot be distinguished from true absences without repeat-visit designs, introducing bias into inferences about distribution and habitat relationships.
- Probabilistic, watershed-scale occurrence sampling would substantially advance existing knowledge by providing systematic characterization of occurrence patterns across the geographic ranges of all five covered species, supporting landscape- and watershed-scale habitat association analyses that current opportunistic data cannot support.

2.4.2 Habitat Associations

- Core habitat associations are consistently documented across species: all five species are strongly associated with cold, perennial headwater streams with coarse substrates and forested riparian environments. These associations are robust across studies and geographic regions and provide a foundation for habitat-informed survey design.
- Quantitative thresholds for key habitat variables remain poorly constrained for most taxa. Variables including channel gradient, stream temperature, flow permanence, substrate composition, and riparian canopy cover have been linked to occurrence and relative abundance in individual studies, but the strength, scale-dependence, and generality of these relationships across Oregon's managed forest landscapes have not been evaluated systematically.
- Torrent salamanders are the most thermally and hydrologically sensitive taxa, strongly associated with the cold and steep headwater environments. The importance of riparian shading and cold-water refugia as habitat requirements is well supported across studies for both species.
- Habitat associations are predominantly derived from reach-scale, single-visit studies that did not account for imperfect detection. Repeat-visit approaches that incorporate detection probability estimation would support more reliable inference about species-habitat relationships and reduce the risk of bias from undetected absences.
- Riparian forest effects on habitat suitability are mediated primarily through stream temperature, moisture, and sediment dynamics rather than stand age alone. For example, limited but long-term experimental evidence indicates that management effects on coastal tailed frog may not manifest until 7 to 8 years post-harvest across all riparian buffer treatments, including continuous buffers (Mcintyre et al. 2025), suggesting that the ecological relationships between forest practices and amphibian habitat require sustained monitoring to detect.
- Scale-dependent habitat effects are important for study design. Landscape-level patterns in occurrence reflect broad landform and hydrologic constraints, while reach-scale occurrence is more variable and can be missed by surveys confined to short or randomly selected reaches. Combining broad spatial sampling with finer-scale sampling at watershed, subbasin, and reach scales provides the most complete characterization of habitat associations.

2.4.3 Population Diversity and Trends

- Rangewide population size and long-term trends are unknown for all five covered amphibian species. Available demographic information is primarily derived from site-scale, short-term surveys rather than standardized long-term monitoring, and is strongly biased toward larval life stages. Demographic rates for later life stages, including adult survival, recruitment, and population turnover, are largely unquantified.
- Strong population genetic structure and limited connectivity are documented across all five species, with major rivers and landscape barriers functioning as significant limits to gene flow. Effective dispersal distances are typically short, varying by species and landscape context. Oregon-specific genetic sampling is spatially limited for all species, leaving population structure and connectivity across most of the state poorly characterized (see Population Diversity, Appendix B; Table B3).

- No standardized, long-term time-series data exist for Columbia or southern torrent salamanders on lands subject to the Oregon Forest Practices Act. Available occurrence and relative abundance data from managed forests provide descriptive snapshots but do not support inference about population trajectories.
- Occupancy-based approaches are recommended over mark-recapture or relative abundance estimates for trend detection given the cryptic behavior, small population sizes, and logistical challenges for these species. However, where the goal is to characterize whether population change reflects changes in population size rather than detection probability, abundance and demographic data would substantially strengthen inference beyond occupancy alone. More complex occupancy models can be used to estimate trends in occupancy and abundance through time.

3. Scoping Proposal Options

3.1 Introduction

This section outlines research options to address AMPC Questions 1 and 2, which are closely related but address different aspects of stream-associated amphibian ecology and different sets of species. Question 1 applies to all five amphibian species covered under the Private Forest Accord HCP: coastal giant salamander, Cope's giant salamander, southern torrent salamander, Columbia torrent salamander, and coastal tailed frog. For each species, Question 1 focuses on understanding distribution, including population diversity, within Oregon, and the factors determining distribution at finer spatial scales such as the watershed, including stream gradient, stream size, fish presence or absence, slope, aspect, temperature, seasonality, and microhabitat conditions. The AMPC's original framing of Question 1 did not envision field data collection to estimate geographic ranges, however, several field-based options described below contribute to understanding distribution at finer spatial scales as part of addressing habitat associations and population trends. Nevertheless, watershed-scale distribution data gaps remain for all five species, and addressing the full scope of Question 1, including watershed-scale distribution patterns, habitat associations, and population diversity, requires field survey work that cannot be adequately substituted with existing data. Research options therefore range from no additional data collection to intensive field-based approaches, and individual proposals may address all species or a subset based on study objectives, target species ecology, and logistical feasibility.

Question 2 is specific to Columbia and southern torrent salamanders and asks what population trends exist over time on lands subject to Oregon Forest Practices Act rules. This question is informed by the overarching biological goal stated in the draft Private Forest Accord HCP: forest practices that support the survival and recovery of covered species by providing clean, cool, connected, and complex habitats.

Together, Questions 1 and 2 link spatial patterns of distribution and habitat relationships with temporal changes in populations. Research options vary in spatial and temporal scope, sampling design, and the type of scientific inference they support. Several options are designed to complement one another and may be implemented in combination; integration opportunities are noted within individual option descriptions and summarized in Section 3.3. To facilitate comparison across options, each research option is evaluated against a consistent set of knowledge contribution topic areas relevant to AMPC Questions 1 and 2 (Table 3.1).

The research options described below were developed in response to key findings and data gaps identified in the accompanying literature review (Section 2; Appendix B). Broad geographic range boundaries are reasonably well established for all five covered species, and general habitat associations with cold, perennial headwater streams are consistently documented across studies; however, watershed-scale distribution remains incompletely characterized for all five species, most available information is derived from surveys that did not account for imperfect detection, and range-wide information on population size, demographic rates, genetic connectivity, and long-term trends is limited (see Distribution, Population Diversity, and Habitat Associations, Appendix B; Tables B2, B3). For Columbia and southern torrent salamanders specifically, no standardized long-term time-series data exist on lands

subject to Oregon Forest Practices Act rules, leaving the direction and magnitude of population trends unknown. These gaps motivate the range of options described below.

The research options span a range of approaches depending on the specific question and spatial scale. Whether occurrence-based or occupancy-based sampling approaches are used to assess species presence/absence can influence the inferential strength and cost of several of the options. Occurrence data describe where a species was detected based on presence or absence observations, but do not account for the probability that a species present at a site went undetected during a survey. Occupancy-based approaches typically incorporate repeated visits to the same locations, which increases costs, but support explicit estimates of detection probability, producing detection-corrected occupancy estimates of species presence/absence that more reliably distinguish true absences from non-detection and support stronger inference about species-habitat relationships. Repeated visits to the same locations over time also enable detection of population trends, a design feature central to the Question 2 monitoring options. Where repeated visits are feasible, detection-corrected occupancy estimation is the preferred analytical approach; however, single-visit designs with appropriate covariates may also support meaningful habitat association inference depending on the specific study objectives and field conditions.

Occurrence- and occupancy-based approaches are likely to be more feasible than traditional estimation for these species at broader spatial scales. Physical capture and marking methods required for mark-recapture approaches are logistically intensive and have more complex permitting requirements; however, abundance can also be estimated from repeated samples of unmarked individuals using hierarchical N-mixture models that explicitly account for imperfect detection (Royle 2018). Low and variable detection rates, life-stage-specific differences in detectability, and small patchy populations can result in abundance estimates with high uncertainty (see Distribution and Habitat Associations, Appendix B). Occurrence- and occupancy-based approaches avoid many of these limitations while still supporting meaningful inference about distribution patterns and habitat associations across landscape, watershed, and reach scales. For monitoring options where the goal extends beyond occupancy, such as trend detection or characterizing population status, hierarchical occupancy and N-mixture models can also provide estimates of abundance and population change over time without requiring individually marked animals. Where applicants seek to estimate individual-level metrics such as movement rates, growth, or survival, mark-recapture methods would be required. Moreover, demographic data on life-stage structure, survival, and movement can provide insight into the processes driving observed population trends and understanding variation in these metrics through space and time.

The estimated knowledge contributions of each option are evaluated against the topic areas described in Table 3.1, both within individual option descriptions and in the consolidated summary tables in Section 3.3. These evaluations are to aid comparisons among research options. No single option addresses all knowledge contribution topic areas, and the strongest inference across both questions is likely to come from implementing complementary options in an integrated research framework.

Table 3.1. Knowledge contribution topic areas used to evaluate research options.

Knowledge Contribution Topic Area	Description	Relevant AMPC Question
Geographic range refinement	Reduces uncertainty in species' spatial extent and broad range boundaries across Oregon	Q1
Watershed-scale distribution	Supports inference about occurrence patterns among watersheds at a spatial scale smaller than the geographic range	Q1
Landscape-scale habitat associations	Evaluates relationships between species presence/absence and environmental variables across watersheds and regions (broad-scale)	Q1
Watershed-scale habitat associations	Evaluates relationships between species presence/absence and environmental variables among watersheds	Q1
Stream reach-scale habitat associations	Evaluates relationships between species presence/absence and local stream, microhabitat, and riparian forest conditions at a fine spatial scale	Q1
Population connectivity and genetic structure	Evaluates genetic variation, population structure, and/or connectivity	Q1
Population demography	Provides insight into population processes through evaluation of life-stage structure, movement, and/or reproductive condition	Q1
Population trends (torrents)	Evaluates change in occupancy or abundance over time for Columbia and southern torrent salamanders	Q2
Abundance estimates (torrents)	Supports estimation of population abundance or density beyond presence/absence or occupancy	Q2

3.2 Research Options

Seven research options are described below, ranging from no additional data collection to long-term intensive monitoring. Option 1 is the No Action baseline and applies to both AMPC Questions 1 and 2. Q1, Options 2 through 5 address AMPC Question 1 and apply to all five covered species. Q2, Options 1 and 2 address AMPC Question 2 and focus specifically on Columbia and southern torrent salamanders. Each option includes the relevant AMPC research question with the components addressed by that option in bold, followed by a summary of the addressed question components.

For all field-based options, sampling locations, watersheds, or study areas would be selected through a structured design process documented within individual research proposals. Selection criteria should ensure representation across relevant geographic regions and environmental gradients, tailored to the specific objectives and spatial scale of each option. Survey methods for field-based options may include visual encounter surveys of stream and riparian habitats. Environmental DNA (eDNA) sampling may also be used for detecting species presence, though the extent to which eDNA protocols have been validated for each of the five covered species should be evaluated prior to implementation. Where applicable, environmental variables would be collected alongside biological sampling and may include landscape-scale factors such as forest cover, geology, and slope; watershed-scale factors such as drainage area and

stream network structure; and reach-scale factors such as stream gradient, water temperature, substrate composition, flow permanence, fish or crayfish presence, and riparian forest conditions. Specific environmental variables collected would be defined within individual proposals.

Cost estimates are presented as order-of-magnitude ranges including a 26% indirect rate applied to direct costs, and exclude administrative startup and closeout. eDNA laboratory processing costs are included in high-end estimates where noted, and genetics laboratory costs for options that include tissue sampling are incorporated into the high-end project totals and are also shown as separate line items to indicate their contribution to overall cost. The indirect rate reflects the approximate Oregon state-funded university contract rate; proposals with different negotiated indirect rates should adjust accordingly. Estimated sampling scope for each option is expressed as a proportion of the approximately 1,288 HUC12 subwatersheds intersecting the coastal tailed frog range in Oregon, which represents the broadest range of the five covered species, and approximately 716 HUC12 subwatersheds intersecting the Columbia and southern torrent salamander ranges.

Where ranges include an optional eDNA component, the low end assumes visual encounter surveys only and the high end assumes eDNA sampling is included. Both eDNA and genetics laboratory costs are significant drivers of high-end estimates. Long-term trend monitoring options will require ongoing investment across multiple funding cycles. Annual costs for Q2 monitoring options substantially exceed the $1.5 million initial study funding recommendation in the 2022 Private Forest Accord Report.

Table 3.2. Summary of research options addressing AMPC Questions 1 and 2, with timeframe, costs (+ 26% indirect; eDNA costs included in high-end estimates; genetics lab costs incorporated into high-end project totals and shown separately as one-time project costs), and knowledge contributions. All estimated costs rounded to nearest $25,000.

Question - Option	Timeframe	Cost	Knowledge Contribution
Option 1 No Action	None	$0	• Maintains current understanding of species geographic ranges, distributions, and habitat associations based on existing literature and occurrence data • Does not generate new information on watershed-scale distribution, habitat associations, population diversity, or population trends
Q1, Option 2 Targeted Geographic Range and Distribution Refinement	1-2 years	$130,000–$400,000 ($130,000–$200,000/year)	• Generates new presence/absence records at targeted locations to refine species range boundaries and reduce distributional uncertainty; builds foundation for future studies • Does not support statistical inference about occurrence patterns, habitat associations, population diversity, or population trends
Q1, Option 3 Watershed-Scale Habitat Associations - Broad Sampling	2-3 years	$700,000–$1,700,000 ($350,000–$575,000/year)	• Provides systematic, range-wide characterization of watershed-scale presence/absence and supports landscape- and watershed-scale habitat association analyses across approximately 80--120 HUC12 subwatersheds • Does not support reach-scale inference; apparent absences could carry uncertainty due to lack of repeat visits; does not address population diversity, demographic rates, or population trends
Q1, Option 4 Reach-Scale Habitat Associations – Intensive Sampling	3-5 years	$1,100,000–$2,500,000 ($375,000–$500,000/year)	• Feasibly accommodates detection-corrected occupancy estimation within a smaller number of watersheds (~20--35 HUC12 subwatersheds), supporting more reliable habitat association inference at reach scales; most informative when implemented alongside Q1, Option 3 • Supports narrower spatial inference than Q1 Option 3; does not address population diversity, demographic rates, or population trends
Q1, Option 5 Population Diversity - Genetic and Demographic Approaches	3-5+ years	standalone: $625,000–$1,675,000 ($200k–$275k/yr) added to Op. 3 or 4: ($100,000–$150,000/year) Pop genetics: ~ $248,000	• Provides insight into population connectivity, genetic structure, and demographic rates; most valuable when implemented as an add-on to Q1, Options 3 or 4 • Each approach (genetic, demographic) provides only a partial view independently; does not address watershed-scale distribution, habitat associations, or population trends
Q2, Option 1 Broad-Scale Torrent Salamander Monitoring Network	5-10 years	$2,225,000–$7,375,000 ($450k–$700k/yr) Pop. genetics: ~ $414,000 one-time cost	• Generates systematic, detection-corrected estimates of occupancy trends for torrent salamander populations across a broad geographic extent (~50--100 HUC12 subwatersheds) on FPA lands • Does not explain the demographic mechanisms driving observed trends
Q2, Option 2 Intensive Torrent Salamander Monitoring Network with Demographic Components	7-10+ years	$3,350,000–$7,075,000 ($475k–$700k/yr) Pop. genetics: ~ $62,000 one-time cost	• Generates detection-corrected occupancy trends within intensively monitored watersheds (~5--15 HUC12 subwatersheds) on FPA lands; abundance estimation, demographic data collection, and habitat characterization are optional enhancements; most informative when implemented alongside Q2, Option 1 • Does not support range-wide spatial inference

Option 1: No Action

Approach

Rely on existing geographic range and distribution maps, species occurrence records, habitat information, and population trends derived from published literature, agency datasets, museum collections, and biodiversity data systems summarized in the accompanying literature review (Appendix B). No additional data synthesis or field sampling would be conducted.

Timeline

0 months

Cost

$0

Knowledge Contribution

Maintains the current understanding of the five HCP-covered amphibian species' geographic ranges, occurrence, and habitat associations in Oregon, drawing on the existing literature and occurrence data summarized in the accompanying literature review. Broad geographic range boundaries are reasonably well established for all five species, and general habitat associations with cold, perennial headwater streams, coarse substrates, and forested riparian environments are consistently documented across studies (see Distribution and Population Diversity, Appendix B).

However, this option does not resolve the key uncertainties that may limit the ability to address AMPC Questions 1 and 2. Watershed-scale distribution remains incompletely characterized for all five species due to historically uneven and largely opportunistic survey effort, meaning that fine-scale occupancy patterns cannot be reliably inferred from existing data alone (see Distribution, Appendix B; Table B2). Available occurrence records are predominantly based on surveys that did not account for imperfect detection, which introduces bias into inferences about habitat relationships and species distributions. Population diversity, genetic connectivity, and demographic rates remain poorly quantified across Oregon for all species (see Population Diversity, Appendix B; Table B3). For torrent salamanders specifically, no standardized long-term time-series data sufficient to evaluate population trajectories exist for either species on lands subject to Oregon Forest Practices Act rules, leaving AMPC Question 2 unaddressed under this option (see Torrent Salamander Population Status and Trends, Appendix B).

Q1, Option 2: Targeted Geographic Range and Distribution Refinement

> **Question 1**
>
> *For each of the covered amphibian species, what is the **distribution** (including population diversity) within Oregon, and what factors (e.g., stream gradient, stream size, fish presence/absence, slope, aspect, temperature, seasonality, micro-habitat conditions) determine this distribution at a smaller spatial scale (e.g., watershed)?*

Approach

Conduct targeted, non-probabilistic field surveys to document species occurrence and refine geographic range boundaries across Oregon. For example, range boundaries near the Cascade crest remain somewhat incompletely characterized for some species, and watershed-scale occurrence records are sparse or absent across portions of the ranges of all five species (see Distribution, Appendix B; Table B2). Surveys would focus on filling spatial gaps in existing occurrence data across both the geographic range and its margins where records are sparse, uncertain, or absent.

All five covered species have occurrence data gaps sufficient to warrant targeted survey work, though the nature and location of those gaps vary by species and region. Target locations and geographic areas would be identified drawing on existing occurrence records and habitat suitability information. The accompanying literature review documents data gaps for each species that should inform this prioritization (see Distribution, Appendix B; Table B2).

Specific focal species, target locations, and sampling intensity would be defined within individual proposals. Proposals would target 20–40 locations depending on the distribution of data gaps and available resources. Upper headwater drainages provide opportunities to survey all five covered species simultaneously, depending on range overlap. Survey design should account for differences among species in microhabitat use, life stage, and detectability (see Population Diversity and Habitat Associations, Appendix B). Resulting data would be used to document new occurrences, refine species range boundaries, and improve confidence in distribution maps across Oregon, providing an updated foundation for future field studies under Q1, Options 3 through 5 and Q2.

Timeline

Short- to medium-term (1-2 years)

Cost

$130,000–$400,000 total ($130,000–$200,000/year). Includes 26% indirect.

Knowledge Contribution

Generates new presence/absence observations at targeted locations to refine species range boundaries and reduce uncertainty in geographic extent across Oregon. Improves confidence in statewide distribution maps by filling key spatial data gaps, particularly at range margins and in watersheds where existing occurrence records are sparse or absent (see Distribution, Appendix B; Table B2). Results provide a stronger empirical foundation for designing future field studies by identifying where species are present or absent and prioritizing areas for more intensive sampling.

However, because this option uses targeted, non-probabilistic sampling, results cannot support statistical inference about occurrence patterns across the broader landscape. Surveys are unlikely to be designed with repeated visits to estimate detection probability, meaning that apparent absences cannot be distinguished from non-detection with confidence (see Distribution data gaps, Appendix B). This option does not address habitat associations, demographic responses, population diversity, or population trends.

Knowledge Contribution Topic Area	Q1, Option 2
Geographic range refinement	✓
Watershed-scale distribution	
Landscape-scale habitat associations	
Watershed-scale habitat associations	
Reach-scale habitat associations	
Population connectivity & genetic structure	
Population demography	
Population trends (torrents, Q2)	
Abundance estimates (torrents, Q2)	

Q1, Option 3: Watershed-Scale Habitat Associations -- Broad Sampling

Question 1

For each of the covered amphibian species, what is the distribution (including population diversity) within Oregon, and ***what factors (e.g., stream gradient, stream size, fish presence/absence, slope, aspect, temperature, seasonality, micro-habitat conditions) determine this distribution at a smaller spatial scale (e.g., watershed)?***

Approach

Conduct probabilistic sampling of amphibian presence/absence across a large number of watersheds or sub-watersheds within the known geographic ranges of the covered species. This option uses a probabilistic sampling design intended to support inference across the geographic range. Sampling would prioritize broad spatial coverage with fewer sampling locations within each watershed than Q1 Option 4 to increase the number of sampled watersheds and incorporate both landscape- and watershed-scale variables alongside species data.

All five covered species have data gaps at this scale. Watersheds and sub-watersheds would be selected using a structured design to ensure representation across geographic regions, environmental gradients, and management conditions. Upper headwater drainages provide opportunities to survey up to all five covered species simultaneously. Survey design should account for differences among species in microhabitat use, life stage, and detectability (see Population Diversity and Habitat Associations, Appendix B). Specific focal species, selection criteria, and sampling intensity would be defined within individual proposals. Proposals would typically target 80–120 HUC12 subwatersheds (~6–9% of the approximately 1,288 HUC12 subwatersheds intersecting the tailed frog range in Oregon), though the appropriate scope will depend on study objectives, species of interest, and available resources.

Individual proposals would describe how reach-scale environmental variables are collected alongside species presence/absence data, as described in Section 3.2, and analyzed across sampled reaches. This approach supports characterization of relationships among reaches range-wide, but reach-scale data

would need to be aggregated within a sufficient number of reaches per watershed to support inference within a stream-network context.

Resulting data would be used to evaluate relationships among amphibian presence/absence and environmental variables across landscape and watershed scales, supporting inference about habitat associations and drivers of distribution patterns across Oregon.

Timeline

Medium-term (2-3 years)

The 2–3-year timeframe reflects the field effort required to achieve adequate spatial coverage across 80–120 HUC12 subwatersheds rather than a requirement for temporal replication; this option is not designed to detect population trends through time.

Cost

$700,000–$1,700,000 total ($350,000–$575,000/year). Estimates are based on probabilistic sampling across 80–120 HUC12 subwatersheds (~6–9% of 1,288) and include a 26% indirect rate. The high end assumes inclusion of eDNA sampling (~$40,000/year); the low end assumes visual encounter surveys only.

Knowledge Contribution

Generates presence/absence data across a statistically valid sample of watersheds, providing systematic, range-wide characterization of watershed-scale patterns and substantially advancing on existing data, which are derived largely from opportunistic, non-standardized surveys with uneven spatial coverage (see Distribution, Appendix B; Table B2). While not a comprehensive census of watershed-scale distribution, any additional watersheds sampled incrementally improve distributional knowledge as a byproduct of the primary sampling objective. Results can support landscape-scale and watershed-scale habitat association analyses relating occurrence to environmental variables such as forest cover, geology, stream gradient, and temperature across watersheds, and allow greater understanding of variation among-watersheds.

Because surveys conducted under this option are unlikely to include repeat visits, detection probabilities would likely not be be estimated, meaning that apparent absences carry uncertainty and habitat association models based on these data should be interpreted cautiously (see Distribution and Habitat Associations, Appendix B). This option does not support reach-scale inference about how species use stream networks within individual watersheds, and does not address population diversity, demographic rates, or population trends.

Knowledge Contribution Topic Area	Q1, Option 3
Geographic range refinement	
Watershed-scale distribution	✓
Landscape-scale habitat associations	✓
Watershed-scale habitat associations	✓
Reach-scale habitat associations	
Population connectivity and genetic structure	
Population demography	
Population trends (torrents, Q2)	
Abundance estimates (torrents, Q2)	

Q1, Option 4: Reach-Scale Habitat Associations -- Intensive Sampling

Question 1

For each of the covered amphibian species, what is the distribution (including population diversity) within Oregon, and ***what factors (e.g., stream gradient, stream size, fish presence/absence, slope, aspect, temperature, seasonality, micro-habitat conditions) determine this distribution at a smaller spatial scale (e.g., watershed)?***

Approach

Conduct presence/absence surveys across more complete coverage of stream networks within a smaller number of watersheds selected to capture variation in geography, environmental conditions, and management history. Where Option 3 emphasizes breadth across many watersheds, this option concentrates effort within fewer watersheds, making it more feasible to conduct repeat visits to the same locations, explicitly estimate detection probability, and produce detection-corrected occupancy estimates for presence/absence. This design supports inference about habitat associations within sampled watersheds, particularly at reach scales, and enables more complete characterization of stream networks within selected watersheds than broad occurrence sampling can deliver.

Sampling design would include:

- Higher density of sampling locations within each watershed, providing more complete coverage of stream networks
- Detailed characterization of stream networks and habitat conditions at watershed and reach scales including riparian forest conditions

All five covered species have data gaps warranting survey work at this scale. Watersheds would likely be selected through a structured prioritization process to support evaluation of ecological processes influencing species occurrence within stream networks. Proposals may address all five covered species or a subset depending on study objectives and feasibility, accounting for variation among species in microhabitat use, life stage, and detectability (see Population Diversity and Habitat Associations, Appendix B). Specific selection criteria, number of watersheds, and sampling intensity would be defined within individual proposals. Proposals would typically target 20–35 HUC12 subwatersheds (~2–3% of the approximately 1,288 HUC12 subwatersheds intersecting the tailed frog range in Oregon), though the appropriate scope will depend on study objectives, species of interest, and available resources.

Environmental variables would be collected at watershed and reach scales as described in Section 3.2, with higher resolution and repeated measurements compared to Q1, Option 3.

Results from occupancy models could be used to evaluate statistical relationships between detection-corrected occupancy estimates and environmental variables at reach scales within sampled watersheds, supporting more reliable inference about habitat associations and ecological processes influencing species occurrence than occurrence-based approaches. This option could be implemented alongside Q1, Option 3, which provides the broad spatial coverage and stronger inference among watershed that intensive watershed sampling cannot deliver alone.

Timeline

Medium- to long-term (3-5 years)

The 3–5 year timeframe reflects the effort required to survey 20–35 HUC12 subwatersheds, which could include repeated within-season visits to estimate detection probability, not temporal replication to detect trends through time.

Cost

$1,100,000–$2,500,000 total ($375,000–$500,000/year). Estimates are based on intensive repeated-visit sampling across 20–35 HUC12 subwatersheds (~2–3% of 1,288) and include a 26% indirect rate. The high end assumes inclusion of eDNA sampling (~$18,000/year); the low end assumes visual encounter surveys only. Returning to established sites reduces travel and logistics costs relative to new-site surveys.

Knowledge Contribution

Using occupancy-based methods, this option could generate detection-corrected species occupancy estimates within a smaller number of watersheds, supporting greater precision in estimates about species-habitat relationships at reach scales within sampled watersheds than single-visit occurrence data would provide. Incorporating repeated visits to estimate detection probability reduces the risk of bias from undetected absences and supports evaluation of how local conditions, including stream gradient, substrate, water temperature, flow permanence, and riparian forest conditions, influence occupancy at fine spatial scales that broad occurrence sampling cannot resolve (see Habitat Associations, Appendix B). The inferential strength of this option is greatest at the reach scale within selected watersheds. If watersheds are selected using a probabilistic design, consistent with the approach described for Q2, Option 1, this option could support range-wide habitat association inference; however, confidence, statistical power, and precision would likely be lower than under Q1, Option 3 given the smaller number of watersheds sampled.

This option gains strength when implemented alongside Q1, Option 3, which provides the broad spatial coverage that intensive watershed sampling lacks. Together, Q1 Options 3 and 4 can link reach-scale ecological processes with range-wide distribution patterns, supporting stronger inference than either approach alone. This option does not directly address population diversity, demographic rates, or population trends.

Knowledge Contribution Topic Area	Q1, Option 4
Geographic range refinement	
Watershed-scale distribution	✓
Landscape-scale habitat associations	
Watershed-scale habitat associations	
Reach-scale habitat associations	✓
Population connectivity & genetic structure	
Population demography	
Population trends (torrents, Q2)	
Abundance estimates (torrents, Q2)	

Q1, Option 5: Population Diversity -- Genetic and Demographic Approaches

Question 1

*For each of the covered amphibian species, what is the distribution (**including population diversity**) within Oregon, and what factors (e.g., stream gradient, stream size, fish presence/absence, slope, aspect, temperature, seasonality, micro-habitat conditions) determine this distribution at a smaller spatial scale (e.g., watershed)?*

Approach

Evaluate population diversity using genetic and demographic approaches to improve understanding of population structure, connectivity, and processes influencing persistence of covered species across Oregon watersheds.

Approaches may include:

- **Genetic diversity and structure:** Use tissue sampling to evaluate genetic variation, population structure, and connectivity of covered species among watersheds. Tissue sampling approaches are well established for these species and support inference about gene flow, population isolation, and long-term connectivity patterns (see Population Diversity, Appendix B).
- **Demographic and life-history studies:** Collect data on life-stage structure, survival, movement, and/or reproductive condition through repeated sampling of individuals in selected populations. Given the cryptic behavior and largely aquatic life stages of these species, mark-recapture methods are the most feasible approach for estimating many individual-based demographic parameters. Appropriate marking methods vary by species and life stage and may include visible implant elastomer (VIE) or passive integrated transponder (PIT) tags for larger species and individuals. Because direct age estimation is challenging for these species without destructive sampling, demographic analyses likely will be structured around life stages (egg, larvae, juvenile, and adult) rather than age classes (see Population Diversity, Appendix B).

Q1, Option 5 may be implemented as a standalone research effort or as an add-on to occurrence or occupancy sampling under Q1, Options 3 or 4. To adequately address Question 1, genetic and demographic sampling should be distributed across multiple sites rather than concentrated at a single locality, ensuring that population structure and diversity are characterized across meaningful geographic and environmental gradients for all five covered species. When implemented alongside Q1, Options 3 or 4, sampling locations established under those options can provide a structured framework for Q1, Option 5 site selection. Sampling would target 30–60 HUC12 subwatersheds (~2–5% of the approximately 1,288 HUC12 subwatersheds intersecting the tailed frog range in Oregon) distributed across the geographic range to characterize population structure across meaningful environmental and geographic gradients; demographic mark-recapture sampling would typically be feasible at a smaller subset of 3–8 locations.

Data could be analyzed to estimate population genetic structure and connectivity among watersheds and to quantify demographic parameters such as life-stage-specific survival, movement rates, and life-stage or sex ratios. These analyses would support inference about population processes and factors influencing persistence across watershed and reach scales.

Timeline

Medium- to long-term (3-5+ years)

The 3–5+ year timeframe reflects the effort required to collect tissue and demographic data across a sufficient number of sites; the plus sign acknowledges that mark-recapture demographic work may warrant longer-term investment at a subset of locations.

Cost

$625,000–$1,675,000 ($200k–$275k/yr) when implemented as a standalone effort; approximately $300,000–$700,000 total ($100,000–$150,000/year) as an add-on to Q1, Option 3 or 4, where shared travel and field logistics substantially reduce costs. All figures include a 26% indirect rate. The high-end standalone total includes approximately $248,000 in one-time genetics laboratory costs, based on approximately 60 HUC12 subwatersheds at 15 individuals per subwatershed at approximately $200–$400 per sample; the low end reflects field costs only.

Knowledge Contribution

Provides insight into population persistence by evaluating connectivity and diversity across watersheds. These are dimensions that remain poorly characterized at range-wide scales across Oregon for all five covered species and that are not addressable through occurrence or occupancy sampling alone (see Population Diversity, Appendix B; Table B3). Because population growth rates and dispersal are difficult to measure directly for these species, genetic and demographic data serve as complementary approaches to evaluating these processes.

Genetic data, collected through tissue sampling, describe population connectivity and structure among watersheds but do not provide direct estimates of survival or reproduction (see Population Diversity, Appendix B). Demographic data, collected through repeated sampling of individuals to evaluate life-stage structure, survival, and movement, provide more direct insight into population processes but are typically feasible only at a limited number of locations. Together, these approaches may substantially advance understanding of both connectivity and the processes influencing persistence, which is currently lacking across Oregon for all five covered species (see Population Diversity, Appendix B; Table B3). Each approach provides only a partial view independently, and their value is greatest when implemented together or as an add-on to Q1, Options 3 or 4, where established sampling sites provide geographic structure for population-level work.

Knowledge Contribution Topic Area	Q1, Option 5
Geographic range refinement	
Watershed-scale distribution	
Landscape-scale habitat associations	
Watershed-scale habitat associations	
Reach-scale habitat associations	
Population connectivity & genetic structure	✓
Population demography	✓
Population trends (torrents, Q2)	
Abundance estimates (torrents, Q2)	

Q2, Option 1: Broad-Scale Torrent Salamander Monitoring Network for Trend Detection

Question 2

What is the population trend of the Columbia and Southern torrent salamanders over time on lands subject to the Forest Practices Act (FPA) rules? *This question is informed by the following overarching biological goal as stated in the draft PFA HCP: "Forest practices that support the survival and recovery of the covered species by providing clean, cool, connected, and complex habitats."*

Approach

Establish a broad-scale monitoring network to evaluate population trends for Columbia and southern torrent salamanders through repeated occupancy surveys at sites distributed across watersheds on lands subject to Oregon Forest Practices Act rules. This option emphasizes broad spatial coverage and efficient trend detection across the landscape, using a sampling design that balances temporal replication with geographic representation.

Monitoring would be based on repeated surveys at the same sites over time using methods that explicitly account for imperfect detection, supporting detection-corrected occupancy estimation and trend analysis. A nested or rotating panel design may be appropriate to balance trend detection with spatial coverage across watersheds. For example:

- Core monitoring sites sampled annually across the network to support detection of range-wide population trends over time
- Rotating sites sampled every 3-5 years to efficiently extend spatial coverage across a greater number of watersheds without proportionally increasing annual sampling effort

The repeated detection-corrected occupancy monitoring network is the core design element addressing the AMPC question. Environmental variable collection and tissue sampling for population genetic analyses are optional enhancements that extend beyond the strict scope of trend detection; proposals need not include them. This option prioritizes spatial coverage across watersheds over sampling intensity within individual watersheds. Watersheds and monitoring sites would be selected using a probabilistic or spatially balanced design on Oregon Forest Practices Act lands to ensure representation across geographic regions, environmental gradients, and management conditions. Proposals would typically target 50–100 HUC12 subwatersheds (~7–14% of the approximately 716 HUC12 subwatersheds intersecting the Columbia and southern torrent salamander ranges in Oregon), with the specific number informed by power analyses for trend detection given species-specific occupancy and detection probabilities.

Environmental variables could be collected alongside occupancy data at landscape and watershed scales as described in Section 3.2 under Q1, Option 3. Where feasible, tissue sampling may be incorporated at monitoring sites to evaluate population connectivity and genetic structure among monitored watersheds, consistent with approaches described under Q1, Option 5.

Resulting data would be analyzed using occupancy modeling approaches that account for imperfect detection to estimate trends. Analyses could evaluate temporal changes in occupancy across the monitoring network and assess variability in trends among watersheds, regions, and environmental conditions. This option is most informative when implemented alongside Q2, Option 2, which provides the within-watershed process understanding needed to interpret observed trends.

Timeline

Minimum 5 years (recommended 5-10 years)

The 5–10 year timeframe reflects the temporal replication required to detect meaningful population trends, not the effort required to establish the monitoring network. Trend detection requires repeated sampling at the same sites across multiple years; a minimum of 5 years of data is generally needed to detect moderate changes in occupancy, with longer time series providing greater statistical power and the ability to distinguish real trends from interannual variation.

Cost

$2,225,000–$7,375,000 ($450,000–$700,000/year). Estimates are based on repeated-visit occupancy monitoring across 50–100 HUC12 subwatersheds on Oregon Forest Practices Act lands (~7–14% of 716) and include a 26% indirect rate. The high end assumes eDNA sampling (~$50,000/year); the low end assumes visual encounter surveys only. The high-end total includes approximately $414,000 in one-time genetics laboratory costs where optional tissue sampling for population connectivity is incorporated. Annual costs substantially exceed the $1.5 million initial study funding recommendation in the 2022 Private Forest Accord Report; long-term implementation will require investment across multiple funding cycles. See Section 3.3 for cost efficiencies achievable when Q2 monitoring is implemented alongside Q1 sampling.

Knowledge Contribution

Generates systematic, detection-corrected estimates of population trends for Columbia and southern torrent salamanders across a broad geographic extent on lands subject to Oregon Forest Practices Act rules, substantially advancing on available information which lacks standardized, long-term time-series data sufficient to evaluate population trajectories for either species at watershed or range-wide scales (see Torrent Salamander Population Status and Trends, Appendix B). Trend detection is the primary objective of this option; depending on analytical approach, estimates may include occupancy trends alone or, where hierarchical count-based models are applied, changes in abundance over time. By repeatedly sampling the same sites across multiple years and explicitly accounting for imperfect detection, this option supports inference about whether torrent salamander populations are increasing, decreasing, or stable at the landscape scale, and allows assessment of variability in trends among watersheds, regions, and environmental conditions.

Because this option prioritizes broad spatial coverage over sampling intensity within individual watersheds, it is designed to detect the regional signal of population change rather than explain the demographic mechanisms driving it. Q2, Option 2 is designed to address those questions through intensive within-watershed sampling and is most informative when implemented alongside this option, linking the landscape-level trend signal with within-watershed process understanding (see Torrent Salamander Population Status and Trends, Appendix B).

Knowledge Contribution Topic Area	Q2. Option 1
Geographic range refinement	
Watershed-scale distribution	✓
Landscape-scale habitat associations	✓ (*incidental to broad spatial design; not a primary objective*)
Watershed-scale habitat associations	✓ (*incidental to broad spatial design; not a primary objective*)
Reach-scale habitat associations	
Population connectivity & genetic structure	✓ (*only if optional tissue sampling is included*)
Population demography	
Population trends (torrents, Q2)	✓
Abundance estimates (torrents, Q2)	✓ (*only where hierarchical count-based models are applied*)

Q2, Option 2: Intensive Torrent Salamander Monitoring Network with Demographic Components

Question 2

What is the population trend of the Columbia and Southern torrent salamanders over time on lands subject to the Forest Practices Act (FPA) rules? *This question is informed by the following overarching biological goal as stated in the draft PFA HCP: "Forest practices that support the survival and recovery of the covered species by providing clean, cool, connected, and complex habitats."*

Approach

Establish an intensive monitoring network within a smaller number of watersheds to evaluate population trends for Columbia and southern torrent salamanders using repeated occupancy surveys, abundance estimation, and demographic data collection. In contrast to Q2, Option 1, which emphasizes broad spatial coverage across many watersheds, this option concentrates sampling effort within fewer watersheds to support stronger inference about the processes driving population change at the watershed and reach scale.

Monitoring could include:

- Repeated occupancy surveys at fixed sites throughout more complete coverage of stream networks within each watershed, with frequent revisits to improve detection probability estimates and support robust occupancy trend analysis.
- Abundance estimation at selected sites using repeated counts or mark-recapture methods to evaluate changes in population size over time, complementing occupancy-based trend detection.
- Demographic data collection at selected sites, if included, could provide insight into life-stage structure, survival, and movement through repeated sampling of individuals. Marking methods may include visible implant elastomer or visible alphanumeric tags or passive integrated transponder tags. This component extends beyond the trend detection scope of AMPC Question 2 but would substantially strengthen interpretation of observed trends, helps inform the "population diversity" objective as outlined in AMPC Question 1, and could help build a foundation for future field studies.
- Detailed characterization of environmental and habitat conditions at watershed and reach scales including riparian forest conditions, could be collected alongside biological sampling to support evaluation of factors influencing population trends

The first bullet represents the core design element directly addressing the AMPC question; the remaining components are optional enhancements that would strengthen understanding of any trends but are not required to detect trends. Tissue sampling for population genetic analyses is not a component of this option; where population connectivity and genetic structure of torrent salamanders is of interest, that work would be conducted through Q1, Option 5 at sites overlapping with Q2 monitoring locations.

Watersheds would be selected through a probabilistic or spatially balanced design on Oregon Forest Practices Act lands to support evaluation of ecological processes influencing population trends. Proposals would typically target 5–15 HUC12 subwatersheds (~1–2% of the approximately 716 HUC12 subwatersheds intersecting the Columbia and southern torrent salamander ranges in Oregon) selected to capture variation in geography, environmental conditions, and management history.

Environmental variables could be collected alongside biological sampling at reach scales as described in Section 3.2, under Q1, Option 4 with detailed characterization of stream and riparian forest conditions and repeated measurements to support evaluation of factors influencing population trends.

Resulting data would be analyzed using occupancy, abundance, and demographic modeling approaches that account for imperfect detection to estimate population trends over time within monitored watersheds. Analyses would also evaluate relationships between population trends and environmental variables at watershed and reach scales, supporting inference about the ecological processes and habitat conditions driving observed changes. This option is most informative when implemented alongside Q2, Option 1, which provides the broad spatial coverage needed to evaluate whether trends observed within intensively monitored watersheds reflect range-wide patterns.

Timeline

Long-term (minimum 5 years; recommended 7-10+ years)

As with Q2, Option 1, the 7–10+ year timeframe reflects the temporal replication required for robust trend detection and demographic parameter estimation, not the effort required to complete a single field season.

Cost

$3,350,000–$7,075,000 total ($475,000–$700,000/year). Estimates are based on intensive within-watershed monitoring across 5–15 HUC12 subwatersheds (~1–2% of 716) and include a 26% indirect rate. The high end assumes eDNA sampling (~$8,000/year); the low end assumes visual encounter surveys only. The high-end total includes approximately $62,000 in one-time genetics laboratory costs where optional tissue sampling is incorporated. Total costs substantially exceed the $1.5 million initial study funding recommendation at any realistic implementation scope.

Knowledge Contribution

Generates detection-corrected occupancy estimates and, where hierarchical count-based models such as N-mixture or dynamic occupancy models are applied, abundance estimates within a smaller number of watersheds, providing insight into whether torrent salamander populations are changing and the magnitude of those changes at the watershed scale. More complete coverage of stream networks within selected watersheds, combined with detailed habitat characterization at reach scales including riparian forest conditions, supports evaluation of how local environmental conditions are associated with population trends within monitored systems. Tissue sampling for population genetic analyses is not a

component of this option; where population connectivity and genetic structure of torrent salamanders is of interest, that work would be conducted through Q1, Option 5 at sites overlapping with Q2 monitoring locations.

While the demographic and habitat characterization components of this option extend beyond straight-up trend detection, the option does directly address the AMPC question through repeated detection-corrected occupancy surveys at fixed sites within intensively monitored watersheds. The additional components are presented here because they would substantially strengthen interpretation of observed trends and because the intensive within-watershed design naturally accommodates them; IRST was not explicitly asked to scope these elements, and proposals need not include them.

Because sampling is concentrated within fewer watersheds, results are less suited for broad inference about range-wide population trends. This option is most informative when implemented alongside Q2, Option 1, which provides the landscape-level trend signal that intensive within-watershed monitoring cannot deliver alone. Together, Q2 Options 1 and 2 address both the direction and magnitude of population change across the landscape and the habitat conditions associated with those changes within intensively monitored watersheds (see Torrent Salamander Population Status and Trends, Appendix B).

Knowledge Contribution Topic Area	Q2. Option 2
Geographic range refinement	
Watershed-scale distribution	✓
Landscape-scale habitat associations	
Watershed-scale habitat associations	
Reach-scale habitat associations	✓
Population connectivity & genetic structure	
Population demography	✓ (*if optional demographic components included*)
Population trends (torrents, Q2)	✓
Abundance estimates (torrents, Q2)	✓

3.3 Options Summary and Integration Considerations

Table 3.3 summarizes all independent research options by attributes and knowledge contribution areas. Research options span a wide range in cost, spatial scope, and inferential value, with costs increasing substantially as sampling intensity, spatial coverage, and inferential strength increase. Q2 options are inherently more expensive than Q1 options because trend detection requires temporal replication across multiple years; long-term monitoring will require ongoing investment beyond an initial funding cycle. No single option addresses all knowledge contribution topic areas: Q1, Options 3 and 4 together provide the most complete picture of habitat associations across spatial scales; Q1, Option 5 addresses population diversity and connectivity dimensions that occurrence and occupancy sampling cannot resolve; and the Q2 options address the temporal dimension of population change that Q1 options are not designed to detect. The strongest inference across both questions is likely to come from implementing complementary options in combination, as described below.

Table 3.3. Summary of research options addressing AMPC Questions 1 and 2, including timeframe, costs (including 26% indirect; eDNA laboratory costs included in high-end estimates; genetics laboratory costs incorporated into high-end project totals and shown separately as one-time project costs), and knowledge contributions.

Knowledge Contribution Topic Area	**Option 1** No Action	**Q1, Option 2** Targeted Surveys	**Q1, Option 3** Watershed-Scale Habitat Associations - Broad Sampling	**Q1, Option 4** Reach-Scale Habitat Associations - Intensive Sampling	**Q1, Option 5** Population Diversity	**Q2, Option 1** Broad Torrent Monitoring	**Q2, Option 2** Intensive Torrent Monitoring
Timeframe	None	1-2 years	2-3 years	3-5 years	3-5+ years	5-10 years	7-10+ years
Cost	$0	$130k–$400k	$700k–$1.7M	$1.1M–$2.5M	$625k–$1.68M standalone; $300k–$700k add-on; +$248k genetics one-time	$2.23M–$7.38M +$414k genetics one-time	$3.35M–$7.08M +$62k genetics one-time
Subwatersheds sampled	N/A	Targeted	~80–120 HUC12 (~6–9% of 1,288)	~20–35 HUC12 (~2–3% of 1,288)	Varies; add-on to Op. 3 or 4	~50–100 HUC12 (~7–14% of 716)	~5–15 HUC12 (~1–2% of 716)
Geographic range refinement		✓					
Watershed-scale distribution			✓			✓	✓
Landscape-scale habitat associations			✓			✓ *	
Watershed-scale habitat associations			✓			✓ *	
Reach-scale habitat associations				✓			✓
Population connectivity and genetic structure					✓	✓ †	
Population demography					✓		✓ §
Population trends (torrents, Q2)						✓	✓
Abundance estimates (torrents, Q2)						✓ ‡	✓

*****(*incidental to broad spatial design; not a primary objective*); **†** *(if optional tissue sampling included);* **‡** (*if optional hierarchical count-based models applied*); **§** *(if optional demographic components included)*

3.3.1 Tradeoffs Among Options

The seven research options differ in three primary ways: *spatial coverage*, *inferential strength*, and *cost*. These axes are not independent as options that sample more watersheds generally sacrifice depth of inference within individual watersheds, while options that concentrate effort within fewer watersheds support stronger inference at finer spatial scales but cannot support conclusions about patterns across the broader landscape. No single option addresses all knowledge contribution topic areas identified in Table 3.1, and understanding these tradeoffs is essential for evaluating which options or combinations of options best serve the information needs underlying AMPC Questions 1 and 2.

Spatial coverage varies substantially across options. Q1, Option 2 targets a small number of locations non-probabilistically to fill specific distributional gaps and does not support inference beyond the sampled sites. Q1, Option 3 samples approximately 80--120 HUC12 subwatersheds (~6--9% of the 1,288 subwatersheds intersecting the coastal tailed frog range), providing broad spatial coverage across the landscape but lacks high precision, reach scale estimates of species presence/absence and habitat associations. Q1, Option 4 concentrates repeated sampling effort within approximately 20--35 HUC12 subwatersheds (~2--3% of 1,288), trading spatial breadth for inferential depth at reach scales within sampled watersheds. Q2, Option 1 samples approximately 50--100 HUC12 subwatersheds (~7--14% of the 716 subwatersheds intersecting the torrent salamanders ranges) repeatedly over time, while Q2, Option 2 concentrates intensive monitoring within approximately 5--15 subwatersheds (~1--2% of 716). Q1, Option 5 does not define an independent watershed sample but is designed as an add-on to Q1, Options 3 or 4, with tissue collection and demographic sampling conducted at sites established under those options.

Inferential strength also varies across options in ways that do not map directly onto cost or spatial coverage. Q1, Option 2 generates presence/absence records but cannot support statistical inference about occurrence patterns or habitat relationships. Q1, Option 3 supports landscape- and watershed-scale habitat association analyses across a broad geographic extent but may not distinguish true absences from non-detection if sampling does not accommodate occupancy modeling, and will likely not support reach-scale inference. Q1, Option 4 can more easily accommodate detection-corrected occupancy estimation and support stronger inference at reach scales within sampled watersheds than Q1 Option 3. If watersheds are selected probabilistically, this option could also support range-wide inference, though with lower confidence, power, and precision than Q1, Option 3. Together, Q1, Options 3 and 4 provide the most complete picture of habitat associations across spatial scales. Q1, Option 5 addresses population connectivity and demographic rates that occurrence and occupancy sampling cannot resolve, but each sub-approach (genetic and demographic) provides only a partial view independently. For Question 2, Q2, Option 1 is designed to detect whether torrent salamander populations are changing across the landscape, while Q2, Option 2 concentrates effort to characterize the magnitude of change and the demographic processes associated with observed trends; the two options differ primarily in the tradeoff between broad spatial coverage and intensive within-watershed sampling, and are most informative when implemented together.

Cost increases substantially as inferential strength and temporal commitment increase. Q1, Option 2 is the least expensive field-based option but also the most limited in what it can support. Q1, Options 3 and 4 represent a middle range of cost with meaningful but distinct inferential value. Q2 options are inherently more costly than Q1 options because trend detection requires repeated sampling at fixed sites

across multiple years rather than a single field campaign, and both Q2 options exceed the $1.5 million initial study funding recommendation in the 2022 Private Forest Accord Report under any realistic implementation scope. Long-term monitoring will require sustained investment beyond an initial funding cycle regardless of which Q2 option is selected.

3.3.2 Integration Considerations

Several logical combinations are worth noting when considering how to implement these options. For Question 1, Q1, Option 2 can inform site selection for broader studies under Q1, Options 3 or 4 by identifying where species are present or absent before probabilistic sampling begins. Q1, Options 3 and 4 are strongest when implemented together, as Q1, Option 3 provides landscape-scale spatial coverage and Q1, Option 4 provides the reach-scale detail that broad occurrence sampling cannot deliver. Q1, Option 5 can be implemented as an add-on to Q1, Options 3 or 4, allowing population connectivity, genetic structure, and demographic data to be collected at established sampling sites without duplicating field effort.

For Question 2, Q2, Options 1 and 2 are complementary -- Q2, Option 1 is designed to detect whether torrent salamander populations are changing across the landscape, while Q2, Option 2 concentrates sampling effort within fewer watersheds to characterize the magnitude of change and the habitat conditions associated with observed trends. Where insight into the demographic processes driving observed trends is desired, Q2, Options 1 and 2 can be integrated with Q1, Option 5, which can provide data on life-stage structure, survival, and movement at sites overlapping with torrent salamander monitoring locations, linking trend detection with demographic understanding without requiring those components to be formally incorporated into the Q2 monitoring design. Both Question 2 options can also be integrated with Question 1 sampling under Q1, Options 3 or 4 in torrent salamander watersheds, which can be designed with sufficient temporal replication to simultaneously address habitat association and trend detection objectives, potentially reducing duplication of effort across questions.

Implementing Q1 and Q2 options in an integrated research program would substantially reduce total program costs relative to the independent budgets presented above. In practice, the same research team would likely address both questions simultaneously, with torrent salamander trend monitoring sites as a subset of the broader Q1 occurrence or occupancy watersheds. Shared personnel, travel, and field logistics across Q1 and Q2 could reduce combined program costs by an estimated 25-30% relative to independent implementation. Cost scenarios for three combined Q1+Q2 program configurations are provided in the accompanying cost estimate workbook and are summarized in Table 3.4.

Research conducted under AMPC Questions 1 and 2 will also provide distributional, habitat, and population baseline data that may inform future work addressing AMPC Question 3, which focuses on the effects of specific forest practice rules on covered amphibian species.

Table 3.4. Estimated costs for three integrated Q1+Q2 research program configurations. Figures include 26% indirect and reflect approximately 25–30% savings from shared personnel, travel, and field logistics relative to independent option budgets. Genetics laboratory one-time costs are incorporated into the high-end independent option totals from which integrated estimates are derived; the 25% integration savings discount is applied to the full combined total. Integrated estimates reflect 30% savings applied to the low end and 25% savings applied to the high end. All figures rounded to nearest $25,000.

Option Integration Scenario	Options Combined	Per Year — Low	Per Year — High	Total — Low	Total — High
1	Q1 Option 3 + Q2 Option 1	~$550,000	~$950,000	~$2,025,000	~$6,800,000
2	Q1 Option 4 + Q2 Option 2	~$600,000	~$900,000	~$3,125,000	~$7,175,000
3	Q1 Option 3 + Q2 Option 1 + Q2 Option 2	~$875,000	~$1,475,000	~$4,375,000	~$12,100,000

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5. Appendices

Appendix A. AMPC Research Questions Package

Appendix B. Amphibians Literature Review

Appendix A. Key Aspects of the AMPC Research Questions Package

A. Final research questions

The AMPC sent a final research question package to IRST related to covered amphibian species in April 2025. This document addresses Questions 1 and 2. Question 3, which focuses on the effects of specific forest practice rules on covered amphibian species, is not addressed here and is expected to be considered in future work. Table A1 lists all AMPC questions relevant to covered amphibian species and indicates which are addressed in this scoping proposal.

B. Contextual information

B.1 The preliminary research questions

These research questions were approved by the AMPC and transmitted to IRST in April 2025. The AMPC directed IRST to prioritize one scoping proposal addressing Questions 1 and 2, and a separate scoping proposal for Question 3.

Question 1: *For each of the covered amphibian species, what is the distribution (including population diversity) within Oregon, and what factors (e.g., stream gradient, stream size, fish presence/absence, slope, aspect, temperature, seasonality, micro-habitat conditions) determine this distribution at a smaller spatial scale (e.g., watershed)?*

Question 2: *What is the population trend of the Columbia and southern torrent salamanders over time on lands subject to the Forest Practices Act rules?*

B.2 The rule or other issue being studied

These research questions are informed by the most recent draft of the biological goals and objectives established under the Oregon Private Forest Accord Habitat Conservation Plan for covered amphibian species. The amphibian-relevant BGOs address stream temperature, habitat connectivity, and riparian function and complex habitats. The HCP directs the applicant to prioritize a research program examining the current distribution of covered amphibian species in Oregon and the factors that influence where they occur, and quantification of population trends of covered species through time, prioritizing Columbia and southern torrent salamanders. These research questions directly address that direction and are intended to inform status and trend monitoring and targeted monitoring studies for the amphibian-relevant BGOs under the HCP adaptive management program.

B.3 The objective of the research

The objective of this research is to inform deliberations about the distribution, population diversity, and population trends of covered amphibian species on Oregon Forest Practices Act lands, thereby providing the scientific foundation needed to evaluate the effectiveness of HCP conservation measures in supporting covered amphibian species and to guide future status and trend monitoring.

B.4 A brief description of the context of the research questions

AMPC Questions 1 and 2 address foundational knowledge gaps for covered amphibian species under the Oregon Private Forest Accord HCP. Question 1 addresses species distribution and the factors controlling distribution at smaller spatial scales. Question 2 addresses population trends of Columbia and southern torrent salamanders on Oregon Forest Practices Act lands over time. Research conducted under these questions will provide baseline distributional and population data to inform future status and trend monitoring and to support evaluation of HCP conservation measure effectiveness for covered amphibian species.

The following direction is provided in the 2022 Private Forest Accord Report and provides the foundation for these research questions (Chapter 7, Section 7.3.4):

"Uncertainty exists around amphibian population characteristics, distribution, productivity, survival, and abundance. A robust effectiveness monitoring plan as part of an adaptive management program will be used to better understand the relationship between forest management and covered amphibian species. To support this program, it is recommended that $1.5 million be initially applied to research through the first funding cycle of the adaptive management program to better understand how riparian and unstable slope protections of at least the current and proposed rules for private forestland impact persistence of populations. The Authors agree that the $1.5 million will be used to fund an initial study and that ongoing research over appropriate intervals of time beyond this initial study will be necessary to understand research outcomes over long periods of time. The priority species for monitoring will be the Columbia and Southern torrent salamanders. With consideration to funding constraints and other priorities, this research could also include other species covered by the HCP."

Table A.1. Adaptive Management Program Committee (AMPC) questions relevant to amphibians and the scope of this scoping proposal. This table lists the AMPC questions developed under the Oregon Private Forest Accord and indicates which questions are addressed in the scoping proposal and literature review. The IRST focused on Questions 1 and 2 during this scoping cycle; Question 3 and its sub-questions are not addressed and are expected to be considered in future work.

AMPC Question	Question	Addressed in Scoping Proposal
Question 1	For each of the covered amphibian species, what is the distribution (including population diversity) within Oregon, and what factors (e.g., stream gradient, stream size, fish presence/absence, slope, aspect, temperature, seasonality, micro-habitat conditions) determine this distribution at a smaller spatial scale (e.g., watershed)?	Yes
Question 2	What is the population trend of the Columbia and Southern torrent salamanders over time on lands subject to the Forest Practices Act (FPA) rules? This question is informed by the following overarching biological goal as stated in the draft PFA HCP: "Forest practices that support the survival and recovery of the covered species by providing clean, cool, connected, and complex habitats."	Yes
Question 3	The following sub-questions are informed by direction from the PFA Report to "…better understand how riparian and unstable slope protections of at least the current and proposed rules for private forestland impact persistence of populations."	Not yet addressed
Question 3.1	How do rules for no-harvest RMAs affect Columbia and Southern torrent salamanders' habitat? BGO from Draft PFA HCP: Goal 2: Shade and watershed processes controlling stream temperature provide cool water compatible with the needs of the covered species. Objective 2.2 – No-harvest RMAs maintain stream shade sufficient to support desired cool water temperatures for covered amphibians. The most recent version of the BGOs is in the Dec. 2022 draft HCP. The BGOs will be finalized within the HCP due Dec. 31, 2027. Private Forest Accord Report, p. 121.	Not yet addressed
Question 3.2	How do rules for Type N streams affect Columbia and Southern torrent salamanders' habitat? BGO from Draft PFA HCP: Goal 3: Stream network connectivity satisfies freshwater habitat needs for covered species. Objective 3.3 – Timber harvest maintains stream-associated connectivity in riparian areas along non-fish streams sufficient to support covered amphibians.	Not yet addressed
Question 3.3	How do rules for steep/unstable slope protections affect Columbia and Southern torrent salamanders' habitat? BGO from Draft PFA HCP: Goal 4: Riparian areas function to support complex habitats for the covered species. Objective 4.3 – Designated Debris Flow Traversal Areas function to deliver large wood to fish-bearing streams. Objective 4.4 – Forest practices maintain stream-associated wetlands and stream-adjacent seep and spring habitat for amphibians.	Not yet addressed

Appendix B. Amphibians Literature Review

B.1. Introduction

This literature review addresses five amphibian species covered under the Oregon Private Forest Accord (PFA) Habitat Conservation Plan (HCP): Cope's giant salamander (*Dicamptodon copei*), coastal giant salamander (*D. tenebrosus*), Columbia torrent salamander (*Rhyacotriton kezeri*), southern torrent salamander (*R. variegatus*), and coastal tailed frog (*Ascaphus truei*). The review synthesizes available scientific information relevant to the amphibian research questions developed by the Adaptive Management Program Committee (AMPC) in April 2025. This review addresses AMPC Questions 1 and 2 related to amphibian distribution, population diversity, and population trends; the full set of AMPC questions and the scope of this review are provided in Appendix A.

These five species share many life-history characteristics that are relevant to interpreting their distribution, habitat associations, and population connectivity. All are stream-associated amphibians with aquatic and semi-aquatic life stages and biphasic life cycles. These species reproduce and lay eggs in cold, perennial streams or stream-adjacent habitats, and larval development typically takes place in flowing water over extended periods. Adults are closely associated with moist microhabitats within or near headwater stream networks and exhibit limited movement relative to many terrestrial amphibians. Collectively, these traits result in strong associations with local hydrologic conditions, stream temperature regimes, and fine-scale habitat structure, and they provide important context for evaluating patterns of occurrence and population structure across landscapes (Nussbaum et al. 1983; Good and Wake 1992; Hayes and Quinn 2015).

For the purposes of this review, we focus on research relevant to the following amphibian topic areas: (1) species range and watershed-scale distribution patterns; (2) population structure, genetics, and connectivity; (3) influence of local habitat factors on fine-scale distribution; (4) available information on population status and trends for Columbia and southern torrent salamanders on private forest lands in Oregon; and (5) contextual information relevant to evaluating how forest management may influence habitat conditions and, where data allow, population persistence of stream-associated amphibians on private forest lands. The review emphasizes synthesis of existing evidence within these topical areas rather than comprehensive treatment of all aspects of amphibian ecology.

Interpretation of distributional, population diversity, and habitat association patterns for headwater stream-associated amphibians is inherently constrained by recurring limitations in data coverage, study design, spatial scale, and analytical approach (Kroll 2009). Although broad geographic range boundaries for most taxa are well established, distribution at watershed and sub-watershed scales remains incompletely characterized due to uneven survey effort and limited standardized sampling, complicating inference about fine-scale occupancy patterns. In addition, most population diversity and habitat studies on these species have relied on short-term, reach-scale surveys that use relative abundance or occupancy metrics often without correcting for detection probability, which varies among species, life stages, habitats, and sampling conditions (Kroll 2009). When detection probability is not estimated, parameter estimates may be biased, leading to potentially unreliable inference about habitat associations or population trends (Kroll 2009; MacKenzie et al. 2017). Accordingly, the information synthesized in this

review is best interpreted as describing relative patterns of occurrence and habitat association, with substantial uncertainty remaining around demographic rates, population size, and persistence.

Sources considered include verified species occurrence records compiled from multiple biodiversity databases and agency data systems, peer-reviewed and gray literature relevant to Oregon and the broader Pacific Northwest, and agency-prepared summaries that synthesize existing information on species distribution, habitat associations, and management considerations. Information is organized by topical area with species-specific subsections, following a consistent structure to facilitate comparison across taxa. Throughout the review, we identify areas where available data are limited or where key questions related to distribution, connectivity, or population status have not been evaluated.

Table B.1. Glossary of select biological terms used in this review.

Term	Definition
Allelic richness	A measure of genetic diversity based on the number of different versions of a gene are present in a population that accounts for sample size.
Biphasic Life Cycle	A life-history pattern in which an organism has two distinct life stages, typically an aquatic larval stage and a terrestrial or semi-terrestrial adult stage, separated by metamorphosis.
Clade	A group of organisms that includes a common ancestor and all of its descendants, representing a single evolutionary lineage.
Congener	An organism that belongs to the same taxonomic genus as another.
Geographic Distribution	The spatial pattern of a species' occurrence within its geographic range, describing where the species is present at finer spatial scales. Distribution may be patchy and is influenced by habitat, environmental conditions.
Geographic Range	The broad spatial extent over which a species is known or inferred to occur, defined by the outer limits of confirmed or historical records. Range does not imply continuous occupancy within those boundaries.
Haplotype	A specific genetic sequence or set of genetic variants inherited together, often referring to a unique DNA sequence within a defined region of the genome.
Heterozygosity	A measure of how often individuals in a population have two different versions of the same gene, which helps indicate how much genetic variety exists within the population.
Interstitial	A term describing the small spaces between particles or structures, such as the tiny gaps between rocks or gravel in a streambed, where water, air, or small organisms can move or live.
Metamorph	An individual that has recently completed metamorphosis and transitioned from the larval stage to a terrestrial or semi-terrestrial life stage.
Mitochondrial DNA	Genetic material located in the mitochondria, inherited maternally in most animals, and widely used in population genetic and phylogeographic analyses.
Metamorphosis	A developmental process involving substantial morphological, physiological, and ecological changes that transform an aquatic larva into a terrestrial or semi-terrestrial juvenile or adult.
Neoteny	A form of paedomorphosis in which development is delayed relative to reproductive development, resulting in adults that retain juvenile or larval traits.
Oviposition	The process of laying eggs.
Paedomorph	An individual that reaches sexual maturity while retaining larval morphological traits and remaining aquatic, rather than undergoing full metamorphosis.
Paedomorphosis	A developmental phenomenon in which sexually mature individuals retain larval characteristics into adulthood; in salamanders, this may occur permanently or facultatively.

B.2. Distribution

This section summarizes the known geographic distribution of the five focal amphibian species based on documented occurrences, with emphasis on patterns relevant at watershed scales. For all five focal species, broad geographic range boundaries are reasonably well established for statewide planning purposes; however, distribution at watershed (5th-field HUC) and sub-watershed scales remains incompletely characterized, limiting inference about fine-scale occupancy patterns and management effects.

Across taxa, distributional patterns span a gradient of geographic range size and ecological specialization. *Dicamptodon tenebrosus* and *Ascaphus truei* are the most broadly distributed species, occurring across multiple ecoregions and elevational zones. *Dicamptodon copei* has a more limited and disjunct distribution, confined primarily to steep-gradient headwater streams in portions of the Coast and Cascade ranges. Torrent salamanders (*Rhyacotriton* kezeri and *R. variegatus*) are highly ecologically specialized, with occurrence records often appearing patchy and largely restricted to cold, perennial headwater environments within limited portions of western Oregon. While broad distributional patterns are well documented at county and ecoregional scales, resolution at the watershed scale remains limited for all species.

Distribution summaries draw on multiple data sources that vary in spatial resolution, temporal coverage, and survey effort. In Oregon, the primary source of vetted amphibian occurrence information is the Oregon Biodiversity Information Center (ORBIC), which maintains Sensitive Species records within the NatureServe Biotics database. These records integrate verified Element Occurrences and observation data contributed by partner agencies, researchers, and conservation programs, following standardized NatureServe and Heritage Program data quality and review procedures (Faber-Langendoen et al. 2012). ORBIC summarizes documented occurrences using Element Occurrences (EOs), which represent locations or areas of known or inferred presence and are mapped at spatial resolutions appropriate to the species and data sensitivity, rather than as point locations (Faber-Langendoen et al. 2012; ORBIC 2025).

Additional sources of distributional data include county-level summaries from the USGS Amphibian Research and Monitoring Initiative (ARMI) National Amphibian Atlas, historical museum and institutional records, agency project datasets, published locality reports, and public biodiversity aggregators (e.g., iNaturalist, GBIF, USGS BISON). Records from these sources vary in spatial precision and verification status and in many cases are already incorporated into ORBIC's database following review and quality control. No single data source provides complete or systematic coverage across all watersheds, and documented occurrence patterns reflect both true distribution and variation in survey effort. Limitations in the available distribution information, including uneven spatial coverage, variable survey effort, and data gaps at watershed scales, are noted where relevant.

Species-specific distributional information is described in detail below for each focal species. Generalized range maps from Jones et al. (2005) are included (Figures 1–5) for reference to illustrate broad geographic extent and should not be interpreted as evidence of continuous occupancy or fine-scale distribution. To aid comparison across taxa and clarify the scale and strength of available evidence, Table B.2 summarizes the degree to which geographic range boundaries and watershed-scale distributions are defined based on available occurrence data and the literature, along with the primary limitations affecting inference at watershed scales.

Table B.2. Summary of available evidence describing geographic range boundaries and watershed-scale distribution for the five focal species. The table highlights variation among taxa in the degree to which distribution is resolved at watershed (5th-field HUC) and sub-watershed scales and identifies limitations associated with uneven occurrence data and survey effort.

Species	Range Boundary Confidence	Watershed Distribution Confidence	Primary Limitation
Cope's giant salamander (*Dicamptodon copei*)	High	Low	Disjunct geographic range and uneven survey effort; limited standardized sampling constrains inference regarding continuity among adjacent watersheds.
coastal giant salamander (*Dicamptodon tenebrosus*)	High	Low	Broad geographic range but distribution documented largely through nonstandardized surveys; limited standardized sampling constrains watershed-scale inference.
Columbia torrent salamander (*Rhyacotriton kezeri*)	High	Moderate	Geographic distribution confirmed by recent rangewide standardized surveys; limited standardized sampling constrains stream-network-level inference within watersheds.
southern torrent salamander (*Rhyacotriton variegatus*)	High	Low	Broad geographic range with uneven occurrence records; limited standardized sampling constrains watershed-scale distributional inference.
coastal tailed frog (*Ascaphus truei*)	Moderate – High	Low	Large geographic range and regional survey bias, particularly east of the Cascades; limited watershed-scale standardized sampling constrains inference

Recent published studies illustrate both the potential and the limitations of existing approaches for resolving distribution at watershed scales. Rangewide survey and modeling efforts for torrent salamanders (Thurman et al. 2025) demonstrate how standardized field sampling informed by habitat associations can be implemented across multiple watersheds to evaluate occurrence patterns at spatial scales nested within 5th-field and finer HUCs. Although such efforts were not designed to exhaustively sample individual watersheds or estimate detection-corrected occupancy, they provide a transferable framework for watershed-aware survey design and highlight where distributional uncertainty remains. In contrast, unusually intensive, long-term inventories conducted at local scales (e.g., the recent Columbia County herpetological surveys; Hakim et al. 2025) show that distribution can be resolved at 5th-field HUC and finer scales when sustained, standardized sampling is applied across a defined landscape. These studies help demonstrate that while broad range boundaries are generally well established for all focal species, comprehensive characterization of watershed-scale and sub-watershed distribution remains limited, and would require targeted, systematic survey effort.

More recently, an ongoing, multi-year effort in Oregon's northern Coast Range (Garcia et al. 2025) illustrates how watershed-scale distribution can be resolved when standardized sampling is applied broadly and explicitly accounts for imperfect detection. This effort is cited here to illustrate current methodological advances in watershed-scale amphibian sampling, not to draw conclusions from preliminary results that are still under analysis. Garcia et al. are conducting coordinated visual encounter and environmental DNA surveys across approximately 80 HUC-12 watersheds, incorporating repeat sampling to estimate detection-corrected occupancy for torrent salamanders, giant salamanders, and

coastal tailed frogs. Preliminary results from the 2024–2025 field seasons indicate high detection probabilities for all three taxa and suggest spatial and temporal variation in occupancy associated with watershed geography (e.g., east–west drainage orientation) and stream conditions (Garcia et al. 2025). However, because these data are still under analysis and not yet publicly available, they are not currently synthesized here. When completed, this work may represent one of the most comprehensive, watershed-aware efforts underway and is likely to substantially improve inference about distribution and occupancy patterns of the species covered under the HCP within and among Oregon watersheds.

Cope's giant salamander (Dicamptodon copei)

Figure B.1. Generalized geographic range of Cope's giant salamander (Dicamptodon copei) in the Pacific Northwest, showing the species' known range within Oregon and adjacent regions. Map reproduced with permission from Jones et al. (2005).

Geographic range and distribution: *D. copei* is endemic to the Pacific Northwest and occurs in two geographically disjunct regions within the Coast and Cascade ranges of Oregon and Washington (Foster and Olson 2014). The species' range extends from the northwestern Olympic Peninsula south to the Nehalem River watershed in the Oregon Coast Range, and from the Nisqually River at Mount Rainier south through the Cascade Range to the upper White River watershed in Wasco County, Oregon (Foster and Olson 2014, Foster et al. 2015, Bury et al. 2014, 2017).
In Oregon, *D. copei* is documented from portions of the northern Coast Range and Cascades, including Clackamas, Clatsop, Columbia, Hood River, Multnomah, Tillamook, Washington, and Wasco counties (Nussbaum 1970; Foster and Olson 2014; Foster et al. 2015; Hakim et al. 2025; ORBIC 2025; USGS 2026). Occurrences east of the Cascade Crest have been confirmed in tributaries of the lower White River watershed, extending the known distribution up to approximately 50 km (~31 miles) east of the crest (Bury et al. 2014, 2017). The species overlaps with its congener *D. tenebrosus* in portions of the northern Coast Range and Cascades. Spatially, *D. copei* exhibits a patchy and discontinuous distribution, with known occurrences documented from 582 sites distributed across 165 sixth-field (HUC12) watersheds, reflecting an uneven distribution among headwater networks (Foster et al. 2015).

Elevational range: Documented occurrences of *D. copei* span elevations from sea level in Washington to about 1600 m (~5250 ft) in the East Cascades ecoregion of Oregon (Foster and Olson 2014).

Distribution data gaps: Although the broad geographic range of *D. copei* is reasonably well established, documented occurrences are unevenly distributed across watersheds and reflect variable survey effort rather than systematic coverage. Standardized sampling at the 5th-field HUC scale has been limited, constraining inference regarding fine-scale occupancy patterns and

continuity among adjacent watersheds, particularly within the Coast and Cascade ranges. In addition, the predominance of opportunistic and non-standardized records limits assessment of temporal changes in distribution. As a result, watershed-scale distribution patterns and potential gaps between known localities remain incompletely resolved.

coastal giant salamander (*Dicamptodon tenebrosus*)

Figure B.2. Generalized geographic range of coastal giant salamander (Dicamptodon tenebrosus) in the Pacific Northwest, showing the species' known range within Oregon and adjacent regions. Map reproduced with permission from Jones et al. (2005).

Geographic range and distribution: The range of *D. tenebrosus* extends from British Columbia south into California and is widely distributed in western Oregon across the Coast Range, western Cascades, and Klamath Mountains (Nussbaum 1976; Good and Wake 1992; Olson and Weaver 2007). In Oregon, the species is documented from near-coastal watersheds inland to the Cascades and into the Klamath region, with isolated records occurring east of the Cascade crest in the Deschutes River basin (Bury et al. 2017). County records include Benton, Clackamas, Clatsop, Columbia, Coos, Curry, Douglas, Hood River, Jackson, Josephine, Lane, Lincoln, Linn, Marion, Multnomah, Polk, Tillamook, Wasco, Washington, and Yamhill counties (ORBIC 2025, USGS 2026). The species overlaps with *D. copei* in portions of the northern Coast Range and western Cascades in Washington but extends substantially farther south into southwestern Oregon and northern California.

Elevational range: Documented occurrences span from near sea level to approximately 2160 m (7000 ft) elevation (AmphibiaWeb 2025).

Distribution data gaps: While the broad geographic range of *D. tenebrosus* in western Oregon is well established, documented occurrences are unevenly distributed across watersheds and reflect variable survey effort rather than systematic coverage. Standardized sampling at the 5th-field HUC scale has been limited, constraining inference regarding fine-scale occupancy patterns and continuity among adjacent watersheds. In addition, the predominance of opportunistic and non-standardized records limits assessment of temporal changes in distribution. Consequently, watershed-scale distribution patterns remain incompletely resolved.

Columbia torrent salamander (*Rhyacotriton kezeri*)

Figure B.3. Generalized geographic range of Columbia torrent salamander (Rhyacotriton kezeri) in the Pacific Northwest, showing the species' known range within Oregon and adjacent regions. Map reproduced with permission from Jones et al. (2005).

Geographic range and distribution: *R. kezeri* is restricted to coastal and near-coastal regions of northwestern Oregon and southwestern Washington, extending from the Little Nestucca River system in Tillamook County, Oregon, north to the Chehalis River in Grays Harbor County, Washington (Good and Wake 1992). In Oregon, the species is confined to the Coast Range ecoregion, with confirmed occurrences documented from Clatsop, Columbia, Tillamook, Washington, Yamhill, and Polk counties (Good and Wake 1992; ORBIC 2025, USGS 2026). Within this geographic range, distribution is non-uniform and structured across multiple spatial scales: populations are widespread but patchily distributed among watersheds (Russell et al. 2004).

Elevational range: Across its range, *R. kezeri* has been documented from near sea level to approximately 1000 m (3000 ft) elevation. The highest reported occurrences include Boisfort Peak at 948 m (3110 ft) in the Willapa Hills of southwestern Washington and Saddleback Mountain at 1001 m (3284 ft) in the Coast Range of northwestern Oregon (Good and Wake 1992; AmphibiaWeb 2025).

Distribution data gaps: The broad geographic range of *R. kezeri* is well defined and recent standardized headwater surveys confirm occurrence across much of the species' recognized range (Thurman et al. 2025), however, documented occurrences remain unevenly distributed across watersheds and do not reflect comprehensive, standardized coverage at the 5th-field HUC scale. Distribution within individual watersheds and across connected headwater stream networks remains less well characterized, constraining inference regarding fine-scale occupancy patterns and continuity among adjacent watersheds. In addition, the predominance of historical, nonstandardized records limits assessment of temporal changes in distribution.

southern torrent salamander (*Rhyacotriton variegatus*)

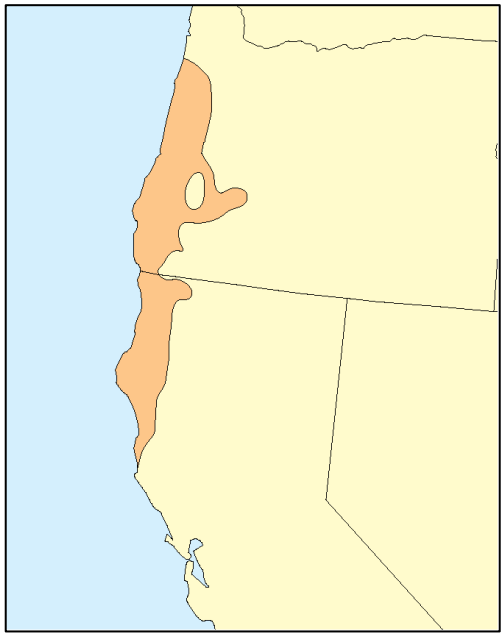

Figure B.4. Generalized geographic range of southern torrent salamander (Rhyacotriton variegatus) in the Pacific Northwest, showing the species' known range within Oregon and adjacent regions. Map reproduced with permission from Jones et al. (2005).

Geographic range and distribution: *R. variegatus* occurs in the Coast Range from approximately Mendocino County, California, north to the Little Nestucca River in Oregon (Good and Wake 1992). The species has a broad range but is patchily distributed in western Oregon across the Coast Range, Klamath Mountains, western Cascades, and marginally within portions of the Willamette Valley ecoregion (Good and Wake 1992; Wagner et al. 2006; Olson and Ares 2022). Verified occurrence records document the species in Benton, Coos, Curry, Douglas, Josephine, Lane, Lincoln, Polk, Tillamook, and Yamhill counties (ORBIC 2025, USGS 2026).

A geographically disjunct population occurs in the western Cascades of Douglas and Lane counties, Oregon, between the Willamette and Umpqua river basins (Good and Wake 1992; Wagner et al. 2006). In this region, *R. variegatus* abuts populations of *R. cascadae*; mitochondrial DNA indicate no sympatry or hybridization, and the Middle Fork Willamette River appears to function as a barrier between the species (Wagner et al. 2006).

Elevational range: Documented occurrences of *R. variegatus* span from sea level to approximately 1469 m (4820 ft) elevation, with most records associated with cool, montane headwater environments (Welsh and Lind 1996).

Distribution data gaps: Although broad range boundaries for *R. variegatus* are well established, documented occurrences are unevenly distributed across watersheds and reflect variable survey effort rather than systematic coverage. Standardized sampling at the 5th-field HUC scale has been limited, constraining inference regarding fine-scale occupancy patterns and continuity among adjacent watersheds. In addition, the predominance of opportunistic and non-standardized records limits assessment of temporal changes in distribution. As a result, watershed-scale distribution patterns remain incompletely resolved.

coastal tailed frog (*Ascaphus truei*)

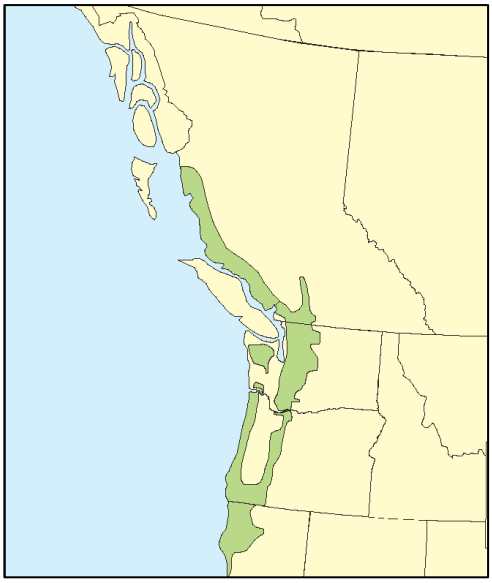

Figure B.5. Generalized geographic range of coastal tailed-frog (Ascaphus truei) in the Pacific Northwest, showing the species' known range within Oregon and adjacent regions. Map reproduced with permission from Jones et al. (2005).

Geographic range and distribution: *A. truei* ranges from southern British Columbia to northwestern California (Nussbaum et al. 1983; Hayes and Quinn 2015). In Oregon, the species occurs in the Coast Range, West Cascades, East Cascades, and Klamath Mountains ecoregions (Hayes and Quinn 2015; ORBIC 2025). Occurrence records document the species in Benton, Clackamas, Clatsop, Columbia, Coos, Curry, Deschutes, Douglas, Hood River, Jackson, Jefferson, Josephine, Klamath, Lane, Lincoln, Linn, Marion, Multnomah, Polk, Tillamook, Wasco, Washington, and Yamhill counties (ORBIC 2025, USGS 2026). Most occurrences are concentrated west of the Cascade crest. The extent of east-slope occurrence varies considerably with latitude. *A. truei* has not been recorded east of the Cascade crest from the Klamath Basin southward in Oregon despite considerable survey effort, likely reflecting the absence of mesic stream-edge habitat and low-elevation trans-Cascade passes in that region; scattered records occur east of the Cascades in the Deschutes Basin of Oregon near low-elevation passes; and many records exist on the east Cascade slope in Washington, though occurrence becomes increasingly infrequent with distance east (Hayes and Quinn 2015).

At broad spatial scales, watershed-level occupancy appears high in some regions but variable among landscapes. In surveys of randomly selected third-order watersheds in Oregon and Washington (i.e., fine-scale sub-watershed sampling units substantially smaller than 5th-field HUCs), coastal tailed frogs were detected in approximately 73% of watersheds (22 of 30) in the Oregon Coast Range and 80% of watersheds (8 of 10) in the southern Cascades, but only 30% of watersheds (8 of 27) in the Willapa Hills of southwestern Washington, indicating pronounced regional variation in distribution (Kroll et al. 2010). Repeated surveys of individual streams further demonstrate that detection probability is imperfect and that single-visit surveys substantially underestimate presence and local occupancy, particularly later in the season (Kroll et al. 2008).

Elevational range: Documented occurrences of *A. truei* span from sea level to approximately 2074 m (6804 ft) elevation (Washington Herp Atlas 2017).

Distribution data gaps: The broad geographic range of *A. truei* is well characterized across the Pacific Northwest, though the exact boundaries of its range margin east of the Cascades could be improved by additional focused surveys. While the absence of *A. truei* east of the Cascade crest in southern Oregon is relatively well characterized by extensive negative surveys, scattered east-slope records in the Deschutes Basin indicate that the latitudinal gradient of east-slope

occurrence remains incompletely described. Additional systematic surveys in this area would most substantially improve range characterization.

Documented occurrences are unevenly distributed across watersheds and reflect variable survey effort rather than systematic coverage. Standardized sampling at the 5th-field HUC scale has been limited, constraining inference regarding fine-scale occupancy patterns and continuity among adjacent watersheds. In addition, the predominance of opportunistic and non-standardized records limits assessment of temporal changes in distribution. As a result, watershed-scale distribution patterns remain incompletely resolved.

B.3. Population Diversity

Population diversity in stream-associated amphibians encompasses variation in local abundance and occupancy, demographic and life-history characteristics, age and life-stage structure, spatial distribution across stream networks, and genetic differentiation among populations. Together, these dimensions may influence population persistence in headwater stream environments. However, for many stream-associated amphibians, direct measurement of these attributes is constrained by cryptic behavior, prolonged aquatic life stages, reliance on interstitial refugia, and the logistical challenges of long-term monitoring in headwater systems.

This section synthesizes available evidence on population diversity for the five focal species, drawing from site-scale abundance and occupancy studies, demographic and life-history investigations, and population genetic analyses conducted in Oregon and elsewhere within each species' range. Rather than estimating population size or demographic exchange directly, which remains infeasible for most taxa, this section evaluates how well different components of population diversity have been characterized and identifies recurring patterns of spatial heterogeneity and uncertainty. Accordingly, the population diversity evidence summarized below primarily reflects relative patterns and qualitative differences, rather than direct estimates of population size or demographic rates.

Across species, local abundance is most commonly described using relative density or occupancy metrics at individual stream or reach scales. These studies consistently document substantial spatial variation within and among watersheds but do not provide rangewide or watershed-scale abundance estimates. Demographic information is uneven and frequently biased toward early aquatic life stages, with limited direct data on survival, recruitment, or population turnover for later life stages. As a result, important gaps persist for all species in standardized abundance estimation, demographic rate quantification, and assessment of the temporal stability of local populations. Genetic studies offer valuable insight into population structure and differentiation among basins and regions, but the extent and resolution of Oregon-specific genetic information vary widely among taxa. Species-specific population diversity information is described in detail below for each focal species. To facilitate comparison across taxa and clarify the scope and strength of available evidence, Table B.3 summarizes how well different components of population diversity are characterized for each species, along with key limitations affecting inference about population diversity, including spatial variation in local abundance, demographic and life-history parameters, age or life-stage structure, and population genetic structure.

Table B.3. Summary of evidence characterizing population diversity for five focal species.

Species	Local abundance & spatial heterogeneity	Demography & life history	Life-stage structure	Genetic structure & connectivity
Cope's giant salamander (*Dicamptodon copei*)	Site-scale density estimates and patchy occupancy across headwater networks documented; substantial among-stream variation; local density may not reflect stable populations; no rangewide abundance estimates	Demographic rates remain poorly quantified. Available information is largely limited to larval abundance, size structure, and qualitative observations of developmental pathways, with little information on survival, recruitment, or life-stage transitions across habitats or regions	Early age–size structuring and possible age-class segregation inferred; populations dominated by larval and paedomorphic stages; age inference unreliable beyond early larval years	Strong structure among watersheds and major barriers (e.g., Columbia River); Oregon sampling limited and spatially uneven
coastal giant salamander (*Dicamptodon tenebrosus*)	Pronounced among-stream heterogeneity in larval density and patchy occupancy documented at reach and watershed scales; strong interannual variability; no rangewide abundance estimates	Age- and season-specific apparent larval survival quantified; life-history plasticity documented (metamorphosis vs. paedomorphosis); demographic rates for metamorphs and terrestrial adults largely unknown	Multiple larval age classes documented; populations numerically dominated by larvae in surveys; size-based age inference unreliable and adult stages underrepresented	Strong differentiation at broad geographic scales; Oregon-specific structure and within-state connectivity partially resolved
Columbia torrent salamander (*Rhyacotriton kezeri*)	Incomplete occupancy across headwater stream networks; substantial among-site variation in local abundance documented at reach and landscape scales; local density may not reflect stable populations; no rangewide abundance estimates	Life history with prolonged, multi-year larval development; demographic inference based primarily on life-stage composition and abundance patterns; survival and recruitment rates unquantified	Populations numerically dominated by larval and juvenile stages; life-stage composition inferred from captures; adult stages infrequently detected	Strong constraints on connectivity imposed by large streams, land cover, and road density; relatively low within-population diversity; Oregon sampling limited and spatially uneven
southern torrent salamander (*Rhyacotriton variegatus*)	Patchy occupancy and wide variation in local density across landscapes; abundance strongly dependent on microhabitat targeting and sampling design; local density may not reflect stable populations; no rangewide abundance estimates	Slow life history with prolonged larval development and delayed maturity; limited direct estimates of survival; demographic inference largely based on life-stage composition	Prolonged larval period and multiple juvenile age classes documented; populations numerically dominated by larval and juvenile stages; adult abundance and survival poorly characterized	Deep regional structure with strong phylogeographic breaks associated with major rivers; high genetic differentiation across range; Oregon structure partially resolved but uneven (e.g., disjunct western Cascades population).

coastal tailed frog (*Ascaphus truei*)	Strong heterogeneity in occupancy and local abundance across watersheds; locally dense larval populations documented alongside persistent low-density populations; larval abundance may not reflect adult population size or stability; no rangewide abundance estimates	Prolonged larval development and delayed recruitment documented; demographic inference largely constrained by high mortality of early life stages and limited detection of adults; adult survival and recruitment unquantified	Populations strongly dominated by larvae; metamorphs and juveniles detected less frequently; adults rare and cryptic in surveys, limiting inference about population structure	Species-level divergence from *A. montanus* well supported; fine-scale population structure within Oregon unresolved; evidence indicates potential for terrestrial connectivity in intact forests

Cope's giant salamander (*Dicamptodon copei*)

Local abundance and spatial heterogeneity: Although long-term population trends and most demographic parameters for *D. copei* remain poorly characterized, available evidence indicates limited but measurable variation in age–size structure, spatial distribution, and local abundance. Foster et al. (2015) report that, aside from some unpublished data, little information exists on age–size structure in *D. copei* populations; however, surveys on the Olympic Peninsula suggest some age–size segregation, with larval and paedomorphic individuals exhibiting a bi-modal size distribution corresponding to two apparent age classes in small to intermediate headwater streams (Foster et al. 2015; A.D. Foster, unpublished data). Age-class inference beyond the first two to three years is considered unreliable for *Dicamptodon* spp., and size-class modality should therefore be interpreted cautiously (Foster et al. 2015; Nussbaum and Clothier 1973). Regional differences in abundance have been noted, with populations reaching their highest apparent densities in the Willapa Hills and South Cascades of Washington and lowest densities in the Olympic Peninsula, where populations are exclusively *D. copei* (Spear et al. 2011; Foster et al. 2015). Although population-wide abundance estimates are lacking, several studies have quantified local in-stream densities, including mean densities of approximately 0.11 individuals/m² in Olympic Peninsula streams (Adams and Bury 2002), 0.30 individuals/m² in July and 0.17 individuals/m² in September in Willapa Hills streams surveyed over multiple years (Foster et al. 2015) and a broader range of 0.06–1.4 individuals/m² in headwater streams of southern Skamania County, Washington (Steele et al. 2002). Collectively, these data indicate that while comprehensive demographic characterization is lacking, *D. copei* populations exhibit measurable spatial heterogeneity in distribution, local abundance, and limited age–size structure at site scales, though differences in field methods among studies limit direct comparison of density and related estimates.

Demographic and life-history variation: Demographic information for *D. copei* is limited, but available evidence indicates substantial life-history variation within populations. The species was originally described as an obligate paedomorph; however, fully metamorphosed terrestrial adults have since been documented, including observations of more than 50 post-metamorphic individuals in the Willapa Hills of southwestern Washington (Wagner 2014). Although the environmental and physiological triggers for metamorphosis remain poorly understood, these observations indicate that metamorphosis occurs at non-trivial frequencies in at least some populations rather than being restricted to rare individuals (Wagner 2014). Consequently, *D. copei* is now recognized as exhibiting facultative paedomorphosis, with larvae, paedomorphic adults, and metamorphosed adults co-occurring within the species (Spear et al. 2011; Wagner 2014).

Population genetics: *Dicamptodon copei* was described as a distinct species based on morphological and life-history differences, including obligate neoteny and sympatric occurrence with *D. ensatus* (Nussbaum 1970). Subsequent genetic and phylogenetic analyses confirmed this species-level separation and indicate that *D. copei* represents an ancient lineage whose divergence predates the Pleistocene (Daugherty et al. 1983; Steele et al. 2005). Available genetic studies indicate pronounced population genetic structure and limited connectivity at multiple scales in *D. copei*. At broader spatial scales, deep genetic divergence among regions and drainage

systems reflects long-term isolation and historical separation among major lineages, with additional structure evident within species (Daugherty et al. 1983; Steele et al. 2005; Steele 2007). The Columbia River functions as a major barrier to connectivity, with no shared haplotypes (i.e., no identical genetic sequences) detected between populations north and south of the river, and represents the strongest documented discontinuity in the species' genetic structure (Steele et al. 2005; Steele 2007). At finer spatial scales, genetic differentiation is frequently partitioned among headwater catchments and stream networks, reflecting limited dispersal along streams. Genetic patterns indicate effective dispersal distances varying from approximately 5 km in the South Cascades (Steele et al. 2009), to around 10–15 km in the Willapa Hills, and up to 30 km in the Olympics among genetically homogeneous localities (Spear et al. 2011). Landscape-genetic analyses indicate that while major rivers may act as barriers, stream corridors facilitate gene flow where hydrologic connectivity is maintained, but drier conditions and more fragmented forest cover are associated with restricted gene flow and increased genetic differentiation (Trumbo et al. 2013). These patterns are consistent with the species' largely aquatic life history and limited overland dispersal capacity.

Population diversity data gaps: Rangewide population size and long-term trends for *Dicamptodon copei* remain unknown, and available information is geographically uneven and largely derived from site-scale surveys rather than standardized, long-term monitoring. While multiple studies report local densities and regional differences in apparent abundance, comparable estimates across the species' range are lacking, and it remains unclear how consistently local density metrics reflect stable breeding populations versus temporally variable occupancy. Demographic rates such as survival and life-stage transitions are poorly quantified, limiting inference about population stability and turnover. Existing evidence suggests some age–size structuring and possible age-class segregation in headwater streams; however, age inference beyond early years is unreliable in *Dicamptodon* spp., and size-class modality should be interpreted cautiously (Foster et al. 2015; Nussbaum and Clothier 1973). Genetic studies document strong population structure and major barriers to gene flow (notably the Columbia River) and indicate limited effective dispersal at local scales, but Oregon genetic sampling remains limited and concentrated in a small portion of the species' range, leaving population structure, genetic diversity, and connectivity across most of Oregon poorly characterized (Steele et al. 2005; Steele 2007, Steele et al. 2009; Spear et al. 2011; Trumbo et al. 2013).

coastal giant salamander (*Dicamptodon tenebrosus*)

Local abundance and spatial heterogeneity: *D. tenebrosus* exhibits a broader and more connected geographic distribution than its congener, *D. copei*, a pattern attributed to greater ecological flexibility, more frequent terrestrial dispersal, and reduced population genetic isolation (Foster et al. 2015). Despite this broad-scale connectivity, local populations of *D. tenebrosus* are characterized by pronounced spatial and temporal heterogeneity in occupancy and abundance across headwater stream networks. For example, at the northern range margin in British Columbia, larval densities varied widely among streams and were lower in streams affected by forest harvest than in less disturbed forest contexts, indicating substantial among-site variation in local abundance (Ferguson 1998). Detections across stream networks was patchy, with larvae detected in only a subset of apparently suitable streams within a watershed, suggesting frequent

local absence or extirpation (Ferguson 1998). Additional evidence for fine-scale population heterogeneity is provided by Steele et al. (2002), who surveyed first-order streams on managed timberlands in southern Skamania County, Washington, over two consecutive summers. Larval *D. tenebrosus* were detected in 16 of 29 streams (55%) in 1998 and in 16 of 33 streams (48%) in 1999, indicating patchy occupancy even among apparently suitable headwater channels. Where present, local larval densities varied widely, ranging from 0.05–0.79 individuals/m² in 1998 and 0.06–2.5 individuals/m² in 1999. Densities were significantly correlated between years ($r = 0.44$, $p = 0.02$) but exhibited high interannual variance, suggesting unstable local abundance and dynamic persistence at the stream scale (Steele et al. 2002). Recent reach-scale depletion surveys in 24 fish-bearing headwater streams in the Oregon Coast Range documented wide variation in population density (0.009–0.498 individuals/m²) and biomass density (0.027–2.67 g/m²), even among streams of similar size and forest condition, reinforcing pronounced local-scale heterogeneity in abundance (Neal et al. 2024).

Demographic and life history variation: Demographic information for *D. tenebrosus*, remains incomplete, but is better characterized than for more strictly headwater-restricted taxa, with evidence for strong age-structured variation during the larval stage and pronounced life-history plasticity. A two-year mark–recapture study across 14 Oregon Coast Range streams demonstrated substantially lower apparent annual survival for first-year larvae than for second- and third-year larvae, indicating strong differences in cohort persistence and recruitment success (Sagar et al. 2007). Apparent survival also varied seasonally, with higher survival during non-summer periods for both age classes, suggesting temporal variability in demographic rates within occupied streams (Sagar et al. 2007); however, because apparent survival reflects both true survival and availability for capture, these patterns may partially reflect larval movement outside sampled stream reaches or into subsurface or off-channel habitats during low-flow periods rather than mortality alone.

Background studies further indicate that *D. tenebrosus* exhibits alternative developmental pathways, with larvae either metamorphosing into terrestrial adults or remaining as paedomorphic aquatic adults following a larval period typically lasting two to three years in Oregon (Nussbaum and Clothier 1973). Larval stage length appears to vary geographically, with northern populations exhibiting slower growth and prolonged larval periods, indicating potential for regional variation in age structure and recruitment dynamics (Ferguson 1998). Population structure varies predictably with aquatic habitat type, with regularly intermittent streams unable to support persistent larval populations and permanent streams differing in the number of larval age classes present and the frequency of paedomorphosis (Nussbaum and Clothier 1973). Recent reach-scale surveys in the Oregon Coast Range confirm that stream populations are numerically dominated by small larvae, with relatively few large larvae or aquatic adults detected, reinforcing a strong life-stage bias in available demographic information (Neal et al. 2024). While aquatic adults were observed infrequently in the Sagar et al. (2007) study, their presence is consistent with this broader life-history framework. In larger permanent streams, ponds, and lakes, however, paedomorphic adults may constitute a substantial portion of the breeding population, whereas metamorphosis is more common and neoteny rare in smaller streams (Nussbaum and Clothier 1973).

Population genetics: *Dicamptodon tenebrosus* was distinguished from the historically broad *D. ensatus* species concept based on consistent morphological differentiation between northern coastal populations and the more southern California lineage of Pacific giant salamander (*D. ensatus* sensu stricto) (Nussbaum 1976). Rangewide genetic studies indicate substantial population differentiation in *D. tenebrosus* across broad geographic and ecoregional scales (Good and Wake 1992; Auteri et al. 2022). Analyses of mitochondrial DNA identify major regional lineages, broadly corresponding to coastal and interior regions and reflecting long-term historical isolation (Good and Wake 1992). Oregon populations occur near the center of the species' range and span multiple physiographic regions, including the Coast Range, Cascades, and Klamath Mountains. Although this geographic position suggests potential contact among divergent lineages, Oregon-specific phylogeographic resolution remains limited. Recent genetic analyses further indicate that watershed boundaries do not strictly delimit population structure at local scales, suggesting gene flow may occur among nearby headwater drainages (Auteri et al. 2022). Genetic evidence suggests that terrestrial movement in this species may contribute to gene flow among nearby headwater drainages where aquatic connectivity is absent (Auteri et al. 2022), a pattern consistent with broader conceptual models emphasizing the importance of terrestrial connectivity among headwater stream–riparian habitats (Olson et al. 2007).

At finer spatial scales, forest management context may influence genetic diversity and population structure in *D. tenebrosus*. In British Columbia, a small study of *D. tenebrosus* in managed forests compared to old growth forest suggested that allelic richness and heterozygosity were lower in 3–9-year-old clearcuts relative to second-growth and old-growth forests, consistent with population bottlenecks associated with harvest disturbance (Curtis and Taylor 2003). Although genetic differentiation among forested sites was modest, clearcut populations were more genetically distinct from reference old-growth sites, and recovery of genetic diversity was inferred to occur over centuries rather than decades (Curtis and Taylor 2003). However, the authors acknowledge uncertainty in the potential consequences of variation in genetic diversity and that *D. tenebrosus* has moderate dispersal ability, which can enhance gene flow among populations. These findings suggest that while local gene flow can occur among headwater populations, forest disturbance may impose long-lasting genetic effects that are not captured by short-term demographic responses.

Population diversity data gaps: Rangewide population size and long-term trends for *D. tenebrosus* remain unknown. Available evidence is derived primarily from site-scale occupancy, density, and short-term demographic studies rather than standardized, long-term monitoring, limiting inference about population stability and persistence. Local larval abundance and occupancy vary widely among streams and among years, and it remains unclear how consistently observed density patterns reflect stable breeding populations versus dynamic local extinction–recolonization processes (Ferguson 1998; Steele et al. 2002).
Demographic parameters remain incompletely quantified and strongly biased toward larval stages. While mark–recapture data demonstrate pronounced age-specific and seasonal variation in apparent larval survival, comparable estimates for older larvae, metamorphs, terrestrial adults, and paedomorphic adults are largely unavailable, limiting inference about recruitment, turnover,

and lifetime reproductive contribution (Sagar et al. 2007). The relative frequency and spatial distribution of alternative developmental pathways (metamorphosis versus paedomorphosis) likely vary with habitat type and hydroperiod, but these strategies have not been quantified systematically across Oregon or across the species' range (Nussbaum and Clothier 1973; Ferguson 1998).

Genetic studies document substantial population differentiation at broad geographic scales and suggest some gene flow among nearby headwater drainages, but Oregon-specific phylogeographic resolution and within-state population structure remain limited relative to management needs (Good and Wake 1992; Auteri et al. 2022).

Columbia torrent salamander (*Rhyacotriton kezeri*)

Local abundance and spatial heterogeneity: Available information indicates that *R. kezeri* populations are spatially uneven and discontinuously distributed across headwater stream networks, though overall population size and long-term trends remain unknown. Surveys in managed forests of Oregon's Coast Range detected the species in approximately 58% of sampled headwater streams, indicating incomplete occupancy even within broadly suitable habitat (Russell et al. 2004). Similar patterns have been reported in Washington, where *R. kezeri* occurred in 53% of surveyed perennial headwater streams in 50–65-year-old managed stands, further supporting patchy distribution across headwater networks (Wilkins and Peterson 2000). Within occupied streams, abundance varies markedly among sites. In the Oregon Coast Range, relative salamander abundance at the landscape scale ranged from 0 to 4.77 individuals per linear meter of stream (mean = 0.47 salamanders/m), demonstrating pronounced among-site variability in local population size (Russell et al. 2004). At the stream-reach scale, mean density was estimated at 2.24 ± 0.89 salamanders/m², indicating substantial fine-scale heterogeneity in local abundance even within occupied watersheds (Russell et al. 2004).

Demographic and life history variation: Demographic information for *R. kezeri* is limited, with most inference drawn from patterns of abundance and life-history stage composition rather than direct estimates of survival or recruitment. Available evidence indicates a slow life history characterized by multi-year larval development, often lasting two to four years (Nussbaum and Tait 1977; Nussbaum et al. 1983; Russell et al. 2004). Life-stage composition within occupied streams is strongly skewed toward aquatic juveniles. Larvae comprised approximately 60% of captures at the landscape scale and 63% of captures at stream reach scale, indicating that populations are typically numerically dominated by larval and juvenile stages (Russell et al. 2004), likely reflecting a combination of true demographic structure associated with small clutch sizes and multi-year larval development, and perhaps detection bias favoring aquatic larvae over more cryptic or less frequently sampled adults.

Population genetics: Genetic evidence indicates that population connectivity in *R. kezeri* is strongly constrained by landscape features. Large streams and rivers function as barriers to gene flow; notably, no genetic exchange was detected between *R. kezeri* and *R. variegatus* where their ranges approach near the Little Nestucca River, despite close geographic proximity (Good and Wake 1992). Population genetic analyses further indicate relatively low genetic diversity within *R.*

kezeri populations, likely reflecting the species' restricted distribution and limited connectivity among headwater watersheds (Emel et al. 2019). Landscape-genetic analyses demonstrate that land cover and road density significantly influence genetic structure, with forested habitats facilitating connectivity and developed or non-forested areas associated with increased genetic differentiation (Emel et al. 2019). Fragmentation effects vary spatially across the species' range, reflecting heterogeneity in forest cover and road density (Emel et al. 2019). A recent rangewide genomic study of the sister species *R. cascadae* identified six genetically distinct populations and documented that major rivers, including the Columbia River, do not always function as complete phylogeographic barriers, with some populations showing shared ancestry across river boundaries (Cousins et al. 2026). These findings provide broader context for interpreting population structure in *R. kezeri*, whose range abuts that of *R. cascadae* to the west, and suggest that the biogeographic history of the Rhyacotritonidae may be more complex than previously described.

Population diversity data gaps: Rangewide population size and long-term trends for *R. kezeri* remain unknown. Available evidence is derived primarily from site-scale occupancy and relative abundance surveys conducted over limited time frames, rather than standardized, long-term monitoring, constraining inference about population stability and persistence. Occupancy is incomplete across headwater stream networks, and local abundance varies widely among occupied sites; however, it remains unclear whether occupied channels represent stable demographic units or whether occupancy and density fluctuate substantially over longer temporal scales (Russell et al. 2004; Wilkins and Peterson 2000).

Demographic parameters are incompletely quantified and are inferred primarily from life-stage composition rather than direct estimates of survival or recruitment. Available evidence indicates prolonged larval development, often lasting multiple years, and populations numerically dominated by larval and juvenile stages; however, adult abundance and survival are poorly characterized, limiting assessment of population diversity.

Genetic studies indicate relatively low within-population diversity, strong constraints on connectivity imposed by rivers, land cover, and road density, and sensitivity of population structure to landscape fragmentation. However, genetic sampling remains spatially limited across Oregon and across the species' full range, restricting inference about watershed-scale population structure and the generality of observed fragmentation effects (Good and Wake 1992; Emel et al. 2019).

southern torrent salamander (*Rhyacotriton variegatus*)

Local abundance and spatial heterogeneity: Available information indicates that *R. variegatus* populations are spatially heterogeneous across their range, with occupancy strongly dependent on local habitat conditions, though overall population size and trends remain unknown. In northern California, the species was detected in 80.3% of surveyed headwater streams in managed forest landscapes (Diller and Wallace 1996). In contrast, occupancy in the Klamath Mountains of northern California was substantially lower when sites were selected randomly

(28.2–36.8%), but increased to 46.6–62.3% at sites with suitable microhabitat characteristics, indicating strong patchiness and habitat filtering at the landscape scale (Welsh and Lind 1992). Local abundance and density vary widely among occupied sites. In Lincoln County, Oregon, Nussbaum and Tait (1977) documented 216 larvae within a 16.5 m² area, corresponding to a mean density of 12.9 larvae/m² (95% CI: 8.7–17.1). Across California, densities in suitable habitat ranged from 1 to 50 individuals per 10 m² plot, with a mean of 0.68 individuals/m² (SD = 0.89) (Welsh and Lind 1996). In managed forests of northern California, salamander densities ranged from 0.014 to 5.0 individuals/m² depending on sampling scale and habitat type, with mean densities of approximately 0.12 individuals/m² in randomly selected stream reaches and approximately 0.28 individuals/m² in targeted microhabitat surveys, illustrating pronounced among-site variability in local population size (Diller and Wallace 1996).

Demographic and life history variation: Demographic information suggests a slow life history characterized by prolonged development and delayed maturity. Southern torrent salamanders typically require approximately 3–3.5 years to complete larval development, followed by an additional 1–1.5 years to reach sexual maturity, and egg incubation alone may last up to approximately 290 days, resulting in a generation time approaching five years in some individuals (Nussbaum and Tait 1977; Nussbaum et al. 1983; Tait and Diller 2006). Available demographic data from California indicate an approximately even sex ratio and populations numerically dominated by juveniles, with juveniles comprising approximately 80% of captures (Welsh and Lind 1992). Estimated annual survival for *R. variegatus* in California was 0.44 (SE = 0.76), consistent with slow turnover and strong age structure (Welsh and Lind 1992).

Population genetics: Genetic studies indicate pronounced population structure in *R. variegatus* across its geographic range, with strong differentiation among regions consistent with long-term isolation in headwater environments. Phylogenetic analyses identify three major evolutionary lineages corresponding to northern Oregon, central Oregon, and northern California, reflecting deep lineage separation shaped by historical river barriers and climatic processes (Good and Wake 1992; Wagner 2000; Miller et al. 2006). Major river systems, including the Yaquina River in Oregon and the Smith River in California, act as phylogeographic breaks between clades and serve as barriers to gene flow (Miller et al. 2006).

A geographically disjunct population occurs in the western Cascades between the Willamette and Umpqua Rivers. Large streams and rivers, including the Yaquina, Smith, and Willamette Rivers, function as barriers to connectivity among clades (Good and Wake 1992; Miller et al. 2006; Wagner et al. 2006). Landscape-genetic analyses confirm high levels of genetic structure across the species' range, with populations in the northern portion of the range exhibiting greater fragmentation than those to the south (Emel and Storfer 2015; Emel et al. 2019). A rangewide genomic analysis of the sympatric sister species *R. cascadae* found broadly similar patterns of strong population structure delineated in part by major rivers, but demonstrated that river barriers are not always complete, with populations sharing ancestry across the Columbia River (Cousins et al. 2026). This finding, combined with the identification of a previously unknown divergent *R. cascadae* lineage in northwestern Washington, suggests that the dispersal history of

the Rhyacotritonidae inferred from earlier allozyme studies may be incomplete, and that comparable cryptic structure could exist within *R. variegatus* lineages.

Forested land cover and intact forest canopy are associated with greater genetic connectivity, while developed or non-forested land cover and road density are associated with increased genetic differentiation (Emel and Storfer 2015; Emel et al. 2019). Field observations indicate that most individuals are detected within a few meters of flowing water, with rare observations up to approximately 160 m (525 ft) from permanent streams, suggesting limited terrestrial movement away from headwater channels under wet conditions (Welsh and Lind 1992; Leppin et al. 2020). Although *R. variegatus* populations are known to persist following forest disturbance (e.g., Kroll et al. 2008; Olson and Ares 2022), the mechanisms by which connectivity is maintained or re-established after disturbance remain poorly understood.

Population diversity data gaps: Rangewide population size and long-term trends for *R. variegatus* remain unknown. Available evidence is derived primarily from site-scale occupancy and density surveys that vary in sampling design and microhabitat targeting, limiting inference about baseline conditions, temporal stability, and comparability among regions. Occupancy and local abundance are strongly influenced by microhabitat suitability, and reported densities span a wide range; however, it remains unclear how consistently these metrics reflect stable breeding populations versus localized concentrations detected under favorable sampling conditions (Welsh and Lind 1992, 1996; Diller and Wallace 1996; Nussbaum and Tait 1977).

Demographic parameters are incompletely quantified and are inferred primarily from life-stage composition rather than direct estimates of survival or recruitment. Available evidence indicates prolonged larval development and populations numerically dominated by larval and juvenile stages, but adult abundance and survival are poorly characterized, limiting assessment of population diversity (Welsh and Lind 1992; Nussbaum and Tait 1977; Tait and Diller 2006). Genetic studies document deep regional structure, strong phylogeographic breaks associated with major rivers, and spatially variable fragmentation effects across the species' range. However, Oregon-specific resolution remains uneven, particularly for the geographically disjunct western Cascades population, and the extent to which Oregon populations differ in genetic diversity, effective population size, and sensitivity to fragmentation is not well resolved from the available evidence (Good and Wake 1992; Miller et al. 2006; Wagner et al. 2006; Emel and Storfer 2015; Emel et al. 2019).

coastal tailed frog (*Ascaphus truei*)

Local abundance and spatial heterogeneity: Available information indicates that *A. truei* populations are spatially heterogeneous across their range, with substantial variation in occupancy and local abundance among watersheds and stream networks. Rangewide population size and long-term trends remain unknown, and inference is complicated by imperfect detectability and strong life-stage bias in survey observations. Many surveys disproportionately detect larvae and metamorphs, which experience high mortality and therefore provide limited insight into adult population size or long-term population stability (Hayes and Quinn 2015; Chelgren and Adams 2017).

Local abundance varies widely among occupied sites. In Oregon, some populations persist at consistently low densities over decades (e.g., Bull Run Lake; Corkran 2012), whereas others exhibit very high larval abundances where local habitat conditions are favorable. For example, Bury and Adams (1999) recorded hundreds of larvae and metamorphs across multiple Coast Range streams, and Chelgren and Adams (2017) captured and marked approximately 3,500 tadpoles along the Trask River, illustrating the potential for locally dense larval populations. Across studies, populations are typically numerically dominated by larvae, with substantially fewer metamorphs, juveniles, and adults detected (Adams 1993; Bury and Adams 1999; Hayes et al. 2006; Kroll et al. 2008; Corkran 2012).

Demographic and life history variation: Demographic information for *A. truei* indicates a life history characterized by prolonged larval development and delayed recruitment to the adult population. Larval periods typically range from approximately one to four years, depending on local thermal and hydrologic conditions (Hayes and Quinn 2015). Reproductive output is relatively low for an anuran, with clutch sizes typically on the order of several dozen eggs; estimates based on dissections of gravid females and hormone-induced ovulation suggest mean egg complements of approximately 57 eggs (range roughly 28–98), while field-observed clutches are often smaller (Karraker et al. 2006). Metamorphs and juveniles experience high mortality, and adults are infrequently detected in most survey efforts, contributing to uncertainty in estimates of adult abundance, survival, and population turnover (Hayes et al. 2006; Chelgren and Adams 2017). Life-stage composition within populations is therefore strongly skewed toward larvae, with adults representing a small and cryptic component of the population. This life-history structure limits inference about effective population size and demographic stability based solely on larval abundance, particularly in the absence of long-term mark–recapture data for adult frogs (Hayes and Quinn 2015).

Population genetics: Phylogeographic analyses of mitochondrial DNA reveal a deep divergence between *A. truei* and its congener *A. montanus*, which occurs further inland to the Rocky Mountains. This divergence is interpreted as the result of long-term isolation following uplift of the Cascade Mountains during the late Miocene to early Pliocene and supports recognition of the two taxa as separate species rather than population structure within *A. truei* itself (Nielson et al. 2001).

Oregon-specific genetic structure within *A. truei* has not been formally evaluated. The species' long larval period (Hayes and Quinn 2015), strong headwater habitat specialization, and limited routine adult movement suggest the potential for restricted dispersal and pronounced population structure across its range (Daugherty and Sheldon 1982; Hayes et al. 2006). However, genetic evidence indicates that populations are not strictly confined to stream networks. In Olympic National Park and Olympic National Forest, Spear and Storfer (2008) documented high genetic connectivity across unconnected river basins, providing evidence for population exchange via terrestrial movements. Closed forest cover and low solar radiation were positively associated with gene flow, suggesting that intact forested landscapes facilitate overland dispersal (Spear and Storfer 2008). Field observations further indicate that metamorphs, juveniles, and adults can

make short terrestrial movements (generally <100 m) into or across stream-adjacent habitats during cool, wet conditions (Hayes and Quinn 2015).

Fine-scale genetic structure within stream networks can nevertheless be strongly altered by forest management. In a paired but unreplicated comparison of adjacent streams in coastal British Columbia, Wahbe et al. (2005) found significantly lower genetic diversity (expected heterozygosity reduced by >25%) in *A. truei* larvae from a clearcut stream relative to an old-growth stream within the same watershed. Larvae in the clearcut exhibited no decline in genetic similarity with increasing distance along a 180-m stream transect, whereas larvae in the old-growth stream showed a strong pattern of isolation by distance, consistent with localized reproduction and limited downstream mixing. These patterns were interpreted as evidence of a recent genetic bottleneck (i.e., loss of genetic diversity due to population contraction) or founder event (i.e., establishment by a limited number of individuals) following logging, coupled with altered dispersal behavior and reduced effective population size in the clearcut population (Wahbe et al. 2005).

In contrast, population genetic analyses conducted near the southern extent of the species' range in Mendocino County, CA, found no consistent evidence of recent genetic bottlenecks despite extensive, long-term forest management (Aguilar et al. 2013). Rather, populations exhibited strong genetic structuring primarily at the watershed scale, retained moderate levels of genetic diversity, and appeared to be at mutation–drift equilibrium. In this region, genetic connectivity was more strongly associated with the presence of cool, moist refugia and stream-connected habitats than with forest age or harvest history (Aguilar et al. 2013). These results indicate that genetic responses of *A. truei* populations to forest management are not uniform across the species' range and may differ substantially depending on regional climate, disturbance history, and landscape context.

Population diversity data gaps: Rangewide population size and long-term trends for *A. truei* remain unknown. Inference is constrained by imperfect detectability and strong life-stage bias in most surveys, which disproportionately detect larvae and metamorphs rather than adults. Because larval abundance can be locally high while adult detections remain low, larval counts alone provide limited insight into effective population size, adult survival, and long-term demographic stability, particularly in the absence of long-term adult mark–recapture data (Hayes and Quinn 2015; Hayes et al. 2006; Chelgren and Adams 2017).

Although local abundance varies widely among Oregon watersheds, including examples of persistent low-density populations and sites with very high larval densities, standardized monitoring sufficient to evaluate temporal trends, population persistence, and comparability among watersheds remains limited in the available evidence (Corkran 2012; Bury and Adams 1999; Chelgren and Adams 2017). Demographic parameters for later life stages remain largely unquantified.

Phylogeographic analyses support species-level divergence between *A. truei* and *A. montanus*, but fine-scale population genetic structure within Oregon has not been evaluated. As a result,

genetic differentiation among Oregon watersheds, elevations, or ecoregions remains uncertain. While genetic evidence from the Olympic Peninsula indicates that populations may exchange individuals across watersheds in intact forested landscapes, the extent to which similar patterns occur in Oregon is unknown without targeted, Oregon-focused genetic sampling (Nielson et al. 2001; Spear and Storfer 2008).

B.4. Habitat Associations

Stream-associated amphibians are habitat specialists whose occupancy and distribution are constrained by local hydrologic, thermal, and structural conditions, particularly within headwater stream networks. This section synthesizes documented associations between the five focal amphibian species and key stream, microhabitat, and riparian forest features, drawing on peer-reviewed studies and agency syntheses. Emphasis is placed on habitat variables that have been empirically linked to occurrence or relative abundance, including stream size and permanence, channel gradient, substrate composition, hydrologic refugia, riparian canopy cover, and water temperature (e.g., Olson et al. 2007). Across stream-associated amphibians, channel gradient is frequently identified as an important habitat correlate, reflecting its influence on substrate stability, reduced retention and increased flushing of fine sediments, and hydrologic energy in cold, headwater channels, although the strength and consistency of this relationship vary among taxa and study contexts (Kroll 2009). In addition to physical habitat features, biotic context, including the presence of fish or crayfish, has been examined as a potential correlate of occupancy for some stream-associated amphibians. Crayfish presence shows a strong negative association with tailed frog (*Ascaphus truei*) occupancy, whereas fish presence has been discussed as a secondary, context-dependent contributor to observed occupancy patterns for torrent salamanders (*Rhyacotriton spp.)*, acting largely in conjunction with stream size and channel gradient; however, in both cases, mechanistic roles remain incompletely resolved (Kroll et al. 2008; Kroll 2009).

Across taxa, all five species are most frequently associated with cold, shaded headwater environments characterized by coarse substrates and persistent surface or subsurface moisture, although the degree of specialization and tolerance varies among species. Torrent salamanders (*R. kezeri* and *R. variegatus*) represent the most microhabitat-restricted taxa, typically occupying seeps, splash zones, and low-order headwater channels where stable moisture conditions are maintained. While surface-flow intermittency is generally associated with reduced abundance, both species may persist in short, wetted reaches within otherwise intermittent channels, particularly where channel-connected seeps or subsurface flow provide localized hydrologic refugia (Ojala-Barbour et al. 2024). *Dicamptodon copei* shows similarly strong associations with cool, steep-gradient headwaters and coarse substrates, whereas *D. tenebrosus* exhibits greater ecological flexibility, occurring across a broader range of stream orders and aquatic habitat types, including larger streams and groundwater-influenced reaches. In contrast, *A. truei* is tightly associated with fast-flowing, high-gradient cobble and bedrock channels with permanent surface flow, reflecting its obligate reliance on lotic conditions throughout larval development.

Although numerous studies have examined relationships between amphibian occurrence or relative abundance and stream or riparian conditions, generalization across regions is limited by differences in study design, spatial scale, and analytical approaches. Across taxa, most habitat associations summarized below are derived from site- or reach-scale studies conducted within a limited number of watersheds. As a result, inference about habitat suitability is strongly scale-dependent, and relationships observed at

local scales may not generalize across entire headwater networks or management-relevant spatial extents. Differences in sampling design, spatial coverage, and analytical treatment of imperfect detection further constrain direct comparison among studies and taxa. Accordingly, habitat associations are presented as relative patterns supported across available studies, rather than as definitive thresholds or prescriptions expected to apply uniformly across Oregon's managed forest landscapes.

Quantitative thresholds for many key habitat variables (e.g., channel gradient, canopy cover, flow permanence, temperature) remain poorly constrained across the entire range of these species. *R. kezeri* represents a partial exception, as recent habitat-suitability modeling quantified relationships between occupancy and hydrologic, topographic, and canopy variables across both reach and watershed scales (Thurman et al. 2025), providing empirical support for patterns previously described qualitatively. For the remaining taxa, habitat–landscape relationships are documented more inconsistently and are often derived from single-region studies, underscoring the need for caution when extrapolating across Oregon's managed forest landscapes. Accordingly, habitat associations summarized below emphasize relative patterns observed across studies, rather than definitive thresholds applicable across watersheds or management contexts.

Habitat associations are outlined below for each species across three consistent dimensions: stream characteristics, microhabitat associations, and riparian forest context. These summaries draw on available evidence for each taxon. For each species, we also identify key data gaps and sources of uncertainty that limit inference at watershed or management-relevant scales. To facilitate comparison across species and to emphasize areas of convergence and divergence in habitat use, Table B.4 summarizes these local habitat associations across the same three domains. This framework is intended to synthesize current evidence rather than define rigid habitat thresholds.

Table B.4. Habitat association evidence framework.

Species	Stream characteristics	Microhabitat associations	Riparian forest context
Cope's giant salamander (*Dicamptodon copei*)	Cool, perennial 1st–3rd order headwater streams; most frequent in small, high-gradient channels; reduced abundance in intermittently dry reaches; neoteny common in cold or high-elevation streams	Pools and low-velocity habitats; coarse substrates (cobble, gravel interstices), under rocks, banks, and woody debris; cold summer temperatures	Shaded streams in coniferous or mixed forests; riparian canopy influences stream temperature and moisture; weak direct association with forest type or stand age
coastal giant salamander (*Dicamptodon tenebrosus*)	Broad distribution across headwater networks; common in 2nd–3rd order streams; occurrence varies with substrate and geology; abundance declines with channel drying and increases in groundwater-influenced reaches	Coarse substrates (especially boulders); pools and shaded reaches; abundance related to pool area and substrate size; sensitive to warming	Persists across somewhat broader range of forest ages than other NW stream associated amphibians, including managed forests; associations mediated through riparian shading, moisture, and channel stability rather than stand age
Columbia torrent salamander (*Rhyacotriton kezeri*)	Cold, low-order headwater streams with persistent surface flow or subsurface moisture; highest occurrence in steep-gradient channels with stable flow; absent from larger streams; abundance often highest near channel origins.	Spring-fed channels, seeps, and splash zones with coarse, permeable gravel–cobble substrates; low fine-sediment accumulation; strong association with hydrologic refugia and continuous surface–subsurface flow.	Shaded, moist headwater environments in coniferous forests; occupancy mediated primarily by riparian shading and hydrologic buffering; abiotic landform features (e.g., gradient, geology) often as important as forest age.
southern torrent salamander (*Rhyacotriton variegatus*)	Cold, low-order headwater streams with persistent surface or subsurface moisture; highest abundance in steep, high-relief channels with coarse substrates; reduced occurrence with warming or seasonal drying.	Spring-fed channels, seeps, and splash zones with coarse gravel–cobble substrates and abundant interstitial spaces; larvae aquatic in percolating gravels, adults concentrated in splash zones and turbulent stream margins.	Shaded, moist headwater environments with intact riparian canopy; higher densities in uncut forests; forest age effects possibly variable and mediated through shading, moisture, and sediment control.
coastal tailed frog (*Ascaphus truei*)	Cold, fast-flowing, shaded perennial headwater streams; breeding and development restricted to permanently flowing channels with coarse substrates; patchy occupancy influenced by flow permanence and sediment inputs	Larvae cling to cobble and bedrock in riffles and cascades; adults use riffles, pools, and waterfall margins; sensitive to fine sediment and elevated temperatures during early life stages	Occurs most frequently in older forests but persists in managed stands where riparian shading, coarse substrates, and permanent flow remain intact; forest age effects mediated by hydrologic and thermal context

Cope's giant Salamander (*Dicamptodon copei*)

Stream characteristics: *D. copei* is restricted to cool, perennial first- through third-order headwater streams, most commonly occurring in smaller, high-gradient channels within forested landscapes (Adams and Bury 2002; Roni 2002; Kroll et al. 2010; Foster and Olson 2014). The species is frequently associated with steep reaches and is rarely documented in intermittent or low-gradient streams. Within occupied streams, *D. copei* is often found in pool habitats and other low-velocity areas rather than in fast-flowing riffles (Foster et al. 2015). In a study of both *D. copei* and *D. tenebrosus*, Ojala-Barbour et al. (2024) found that relative abundance was lower at the very upper ends of headwater streams and in first-order reaches, increased slightly downstream within headwater channels, declined sharply where channels dried, and was higher in reaches influenced by groundwater seeps. Neoteny is common, particularly in colder or higher-elevation streams, allowing populations to persist permanently in aquatic environments (Nussbaum et al. 1983; Wagner 2014).

Microhabitat associations: Individuals occupy coarse-substrate microhabitats within streams, including interstitial spaces among cobble and gravel, areas beneath rocks, undercut banks, and in-stream coarse woody debris, which provide cover and foraging opportunities (Nussbaum et al. 1983; Adams and Bury 2002) In Olympic Peninsula streams, *D. copei* abundance was highest at intermediate levels of in-channel coarse woody debris, with densities peaking near ~10% substrate coverage (Adams and Bury 2002). Stream temperatures at occupied sites are characterized by cold water temperatures, with field observations typically reporting summer temperatures ranging from approximately 7.5–13.0 °C and mean values near 11 °C (Foster et al.2015), but laboratory studies report physiological stress responses at temperatures ≥21 °C (70 °F) (Wagner 2014).

Riparian forest context: *D. copei* is associated with shaded streams in coniferous or mixed forests, primarily through the influence of riparian canopy on stream temperature and moisture regimes rather than through direct associations with specific forest types or stand ages (Adams and Bury 2002; Steele et al. 2002; Bisson et al. 2002). Reductions in canopy cover can increase stream temperatures beyond tolerated levels and may degrade habitat quality for this species (Bull and Wales 2001; Adams and Bury 2002).

Habitat data gaps: Evidence linking *D. copei* occurrence or relative abundance to stream gradient, groundwater influence, longitudinal position, and thermal regime is drawn from multiple independent studies; however, these relationships have rarely been evaluated using common analytical frameworks or consistently detection-corrected approaches. Quantitative limits for key variables, such as field-based thermal tolerances, frequency or duration of seasonal drying, and minimum stream size supporting population persistence, remain poorly constrained, limiting cross-watershed comparison and management inference.

Evidence for microhabitat associations is similarly based on descriptive or site-specific analyses, with limited evaluation of how variation in substrate composition, coarse woody debris, or habitat complexity influences occupancy or abundance beyond individual study sites. As a result,

the generality of reported microhabitat relationships across broader spatial extents remains uncertain.

Riparian influences on *D. copei* habitat use are inferred largely through effects on stream temperature and moisture rather than through direct relationships with forest composition or stand age. Although canopy reduction is known to elevate stream temperatures beyond tolerated levels, few studies explicitly integrate riparian forest attributes with in-stream habitat conditions or population responses at watershed scales. Consequently, the role of riparian structure in mediating habitat suitability for *D. copei* across Oregon landscapes remains incompletely characterized.

Although some studies have explicitly accounted for imperfect detection using occupancy or network-based modeling approaches (e.g., Kroll et al. 2008; Ojala-Barbour et al. 2024), many investigations relating *D. copei* occurrence or abundance to stream and microhabitat features rely on uncorrected presence or relative abundance data, constraining inference about the strength and comparability of reported habitat relationships.

coastal giant salamander (*Dicamptodon tenebrosus*)

Stream characteristics: *D. tenebrosus* occurs across a broader portion of stream networks, occurring across a wider range of conditions than many other headwater stream-associated amphibians (Olson and Weaver 2007), and is often the dominant amphibian in second- and third-order streams across mixed conifer–hardwood forests (Welsh and Lind 2002). Kroll et al. (2008) sampled 141 perennial streams across commercial forest landscapes in western Oregon and Washington and found that detection-corrected occupancy of *Dicamptodon* spp. (*D. tenebrosus* and *D. copei*) varied with stream substrate type, with higher occupancy in streams associated with consolidated geologies; however, analyses did not resolve quantitative thresholds for stream size, gradient, or temperature. Although *D. tenebrosus* is not confined to steep-gradient headwaters and has been documented across a range of stream orders and channel conditions, stream gradient remains an important predictor of local presence and abundance, likely reflecting its role in maintaining coarse substrates and facilitating the flushing of fine-sediments (Kroll 2009; Dudaniec and Richardson 2012). Furthermore, its association with stream gradient likely reflects the combined influence of physical habitat structure and biotic context, including prey availability and interactions with competitors or predators, rather than gradient alone (Neal et al. 2024). In a study of both *D. tenebrosus* and *D. copei*, Ojala-Barbour et al. (2024) found that relative abundance increases with higher stream order, is reduced in the uppermost headwater reaches, and declines sharply with channel drying, but is elevated in reaches influenced by groundwater seeps.

Microhabitat associations: Relative abundance has been consistently associated with coarse substrate composition, particularly the proportion of boulders, which highlights the importance of physical stream structure at the reach scale (Dudaniec and Richardson 2012). The species is associated with narrow, shaded stream channels, pools, medium-coarse substrates, and slow water relatively undisturbed forest sites (Welsh and Lind 2002). Reach-scale studies in fish-bearing headwater streams of the northern Oregon Coast Range documented consistent

occupancy in second-growth forests, with abundance and biomass best explained by pool area and substrate size, not canopy cover, wood volume, or fish density (Neal et al. 2024). Experimental flow-reduction and warming manipulations further support the importance of local hydrologic conditions for *D. tenebrosus*. In a before–after control–impact experiment in a second-order stream at the H.J. Andrews Experimental Forest, Maffia et al. (2025) diverted approximately 50% of streamflow to create low-flow conditions and passively warmed a separate reach by ~0.41–0.63 °C (~0.7–1.1 °F). Salamander abundance declined across all reaches over the summer, but the low-flow reach showed a net positive salamander response while the warmed reach showed a net decline. This pattern was opposite to that of cutthroat trout, which increased in the warmed reach and declined under reduced flow (Maffia et al. 2025). Based on larval individuals sampled from forested streams in the western Oregon Cascades, coastal giant salamanders exhibit critical thermal maxima near 29 °C (84 °F) (Bury 2008).

Riparian forest context: *D. tenebrosus* can persist in managed and second-growth forest landscapes, reflecting ecological plasticity (Olson and Weaver 2007), and occurs across a wide range of forest ages, with forest age alone being a poor predictor of density or occurrence (Welsh and Lind 2002). At the stand scale, occupancy of *Dicamptodon* spp. was found to increase with stand age in commercial forests, although stand age was treated as a coarse correlate rather than a mechanistic driver, and detection probabilities <1 introduce uncertainty into the inferred relationship (Kroll et al. 2008). Even following high-severity wildfire and post-fire salvage, densities of this species are more closely linked to landscape position than to riparian disturbance in the short term (Swartz et al. 2025).

The species is closely associated with moist riparian environments, and shaded conditions likely play an important role in maintaining suitable thermal and hydrologic conditions, even where populations occur in harvested or regenerating forests. In British Columbia, at the northern range margin of this species, relative abundance increases with forest age, likely through indirect effects on stream stability, sediment dynamics, and substrate availability rather than direct effects of overstory conditions alone (Dudaniec and Richardson 2012). Retention of intact riparian forest conditions is likely important for maintaining suitable microclimates and for sustaining terrestrial movement pathways used by adult *D. tenebrosus*, with genetic evidence suggesting movement contributes to connectivity among headwater drainages (Olson et al. 2007; Johnston and Frid 2002; Auteri et al. 2022).

Habitat data gaps: Evidence linking *D. tenebrosus* occurrence or relative abundance to stream characteristics, including stream order, channel gradient, substrate composition, groundwater influence, and local hydrologic conditions, is supported across multiple independent studies. However, quantitative thresholds for key variables such as temperature limits, drying frequency, substrate composition, and pool availability remain poorly constrained, limiting comparison across watersheds and management contexts.

Evidence for microhabitat associations is similarly derived largely from reach-scale or site-specific studies. While relationships with coarse substrates, pool area, and local hydrologic conditions are consistently reported, few studies have evaluated how variation in these features influences

occupancy or abundance across broader spatial extents. As a result, the generality of reported microhabitat relationships beyond individual study systems remains uncertain.

Riparian influences on *D. tenebrosus* habitat use are inferred primarily through effects on stream shading, moisture, channel stability, and sediment dynamics rather than through direct relationships with forest age or composition (Welsh and Lind 2002; Olson and Weaver 2007). Reported relationships vary regionally, including patterns observed near the northern range margin of the species (Dudaniec and Richardson 2012), and few studies explicitly integrate riparian forest attributes with in-stream habitat conditions or population responses at watershed scales. Consequently, uncertainty remains in how forest structure mediates habitat suitability for *D. tenebrosus* across Oregon landscapes.

Although some studies have explicitly accounted for imperfect detection using occupancy or network-based modeling approaches (e.g., Kroll et al. 2008; Ojala-Barbour et al. 2024), many investigations relating *D. tenebrosus* occurrence or abundance to stream and microhabitat features rely on uncorrected presence or relative abundance data. This heterogeneity in analytical approaches constrains inference about the strength, consistency, and comparability of reported habitat relationships.

Columbia torrent salamander (*Rhyacotriton kezeri*)

Stream characteristics: *R. kezeri* is a headwater obligate restricted to cold, perennial streams, seeps, and splash zones in small montane watersheds (Good and Wake 1992; Russell et al. 2004). Occupied streams with higher densities are typically low-order channels with steep gradients (e.g., >20%) and stable perennial flows (Wilkins and Peterson 2000; Russell et al. 2004; Kroll et al. 2008). The species is absent from larger streams and rivers and remains closely tied to headwater environments at the watershed scale (Good and Wake 1992), with no detections in watersheds >13.5 ha in a SW Washington study (Wilkins and Peterson 2000). While fish presence was not a top-ranked covariate in occupancy models for torrent salamanders in 1st–3rd order stream segments, Kroll et al. (2008) suggested that trout in low-gradient reaches may contribute to observed gradient–occupancy relationships, emphasizing that such patterns should be interpreted cautiously given the descriptive nature of occupancy models. Although surface flow intermittency reduces relative abundance, *R. kezeri* may persist in short, wetted reaches within predominantly dry headwater channels where channel-connected seeps or subsurface flow provide localized moisture refugia (Wilkins and Peterson 2000; Ojala-Barbour et al. 2024). Across Oregon and Washington forests, occupancy is consistently and positively associated with channel gradient and, in some landscapes, basalt-dominated geology, which supports coarse substrates and cold, well-oxygenated flows (Russell et al. 2004; Kroll et al. 2008). In a northwestern Oregon study of managed forests, Columbia torrent salamanders were detected in streams where June–July temperatures were consistently below 12°C (Russell et al. 2004).

Rangewide habitat-suitability modeling identifies baseflow stability, summer moisture balance, and canopy cover as important predictors of occurrence (Thurman et al. 2025), indicating that broader hydrologic and climatic settings influence where this species is found. Within headwater systems, abundance is often greatest near channel origins and uppermost reaches, declining

downstream even where streams remain perennial (Russell et al. 2004; Wilkins and Peterson 2000). Within occupied streams, *R. kezeri* exhibits pronounced patchy distribution, with individuals absent from substantial portions of otherwise suitable channels, particularly in lower-gradient reaches (Russell et al. 2004). Habitat associations for *R. kezeri* have been shown to be strongly scale-dependent, where landscape-level patterns reflect broad landform and hydrologic constraints but stream- and reach-scale occupancy is more variable and may be underestimated when surveys are confined to short, randomly selected reaches (Russell et al. 2004).

Microhabitat associations: At the reach scale, *R. kezeri* most frequently occurs in spring-fed channels, seeps, and splash zones where substrates are coarse and permeable and water remains in continuous contact with saturated surfaces (Good and Wake 1992; Russell et al. 2004). Higher torrent salamander abundance has been associated with streambeds dominated by gravel or cobble with minimal fine sediment accumulation, particularly in higher-gradient reaches where fine sediments are less likely to accumulate (Stoddard and Hayes 2005; Kroll et al. 2008). In the Oregon Coast Range, Columbia and southern torrent salamanders analyzed as a combined group showed reduced occurrence in reaches with a high proportion of small substrate (<32 mm) (Stoddard and Hayes 2005). By contrast, in southwestern Washington, the presence of R. kezeri was not significantly associated with substrate size or underlying lithology in this managed landscape, and instead was more closely linked to local topographic conditions, including steep channel gradients (>20%), small basin areas (<13.5 ha), higher elevations, and north-facing aspects associated with cooler, wetter microclimates (Wilkins and Peterson 2000; Stoddard and Hayes 2005). Relative abundance is strongly associated with hydrologic refugia, particularly channel-connected seeps, and declines with increasing channel drying (Ojala-Barbour et al. 2024).

Riparian forest context: *R. kezeri* are frequently associated with mature or late-successional coniferous forests that maintain cool, humid microclimates and stable headwater hydrology (Nussbaum et al. 1983; Bury and Corn 1988; Corn and Bury 1989). However, forest age alone is not a sufficient predictor of occupancy. In a study across Oregon and Washington, a quadratic relationship with stand age was found across *Rhyacotriton* spp, with lowest occupancy in recent clearcuts and highest occupancy in intermediate-aged forests, particularly where steep gradients and favorable geologic conditions were present (Kroll et al. 2008). Several studies indicate that abiotic landform features explain occupancy as well as or better than vegetation age, suggesting that topographic context and geomorphic controls on hydrology and microclimate (e.g., stream size and gradient, headwater position, and aspect) are more influential than stand age per se (Russell et al. 2004; Olson and Ares 2022).

Habitat data gaps: Evidence linking *R. kezeri* occurrence or abundance to stream characteristics, including channel gradient, stream size, substrate composition, summer temperature, and hydrologic stability, is supported across multiple studies or sites. However, quantitative thresholds for key variables, such as tolerance to seasonal drying, minimum stream size, and field-based thermal limits, could be further constrained, limiting comparison across watersheds and management contexts.

Evidence for microhabitat associations is similarly derived largely from reach-scale or site-specific studies. While strong relationships with coarse, permeable substrates and hydrologic refugia (e.g., channel-connected seeps and persistent subsurface flow) are consistently reported, fewer studies have evaluated how variation in these features influences occupancy or abundance across broader spatial extents. As a result, the generality of reported microhabitat relationships beyond individual study systems remains uncertain.

Associations with riparian forest context are supported primarily through inferred effects on topographic configuration, microclimate regulation, and hydrologic buffering rather than through direct effects of forest age alone (Russell et al. 2004; Olson and Ares 2022). Although non-linear relationships between stand age and occupancy have been documented in some landscapes (Kroll et al. 2008), few studies explicitly integrate riparian forest attributes with in-stream or microhabitat conditions at watershed scales. Consequently, uncertainty remains in how forest structure mediates habitat suitability for *R. kezeri* across Oregon landscapes.

Although some studies have explicitly accounted for imperfect detection using occupancy-based approaches (e.g., Kroll et al. 2008), many investigations relating occurrence or abundance to stream and microhabitat features rely on uncorrected presence or relative abundance data. This heterogeneity in analytical treatment constrains inference about the strength, consistency, and comparability of reported habitat relationships across spatial contexts.

southern torrent salamander (*Rhyacotriton variegatus*)

Stream characteristics: *R. variegatus* occupies cold, small headwater streams, seeps, and springs, and is absent from larger stream channels (Good and Wake 1992; Welsh and Lind 1996; Diller and Wallace 1996). The species includes channels with seasonally intermittent surface flow where persistent subsurface moisture provides refugia, and torrent salamanders show a clear association with intermittent headwater stream reaches (Olson and Ares 2022). These small streams serve as breeding, larval, and dispersal habitat within watersheds (Good and Wake 1992; Emel and Storfer 2015). Abundance and occupancy in both adult and juvenile torrent salamanders are positively associated with higher stream gradients (Diller and Wallace 1996; Wilkins and Peterson 2000; Stoddard and Hayes 2005; Kroll et al. 2008). Although fish presence was not a top-ranked covariate in occupancy models for torrent salamanders in 1st–3rd order stream segments, Kroll et al. (2008) suggested that trout in low-gradient reaches may contribute to observed gradient–occupancy relationships, emphasizing that such patterns should be interpreted cautiously given the descriptive nature of occupancy models.

Southern torrent salamanders exhibit low thermal tolerance relative to most amphibians. Field surveys document occurrence primarily in streams where summer water temperatures are ≤15°C (59°F), with highest abundances recorded at sites with temperatures between approximately 8-13°C (46-55°F) (Welsh and Lind 1996). Laboratory experiments on Oregon populations found mean critical thermal maxima of 26.7°C (80°F) for larvae and 27.9°C (82°F) for adults, among the lowest values reported for any amphibian (Bury 2008). Unpublished thermal tolerance experiments indicated signs of physiological stress at approximately 17°C (63°F) (Bury 2008;

Welsh and Lind 1996). Reduced occurrence or abundance is consistently associated with warmer stream temperatures and seasonal drying (Welsh and Lind 1996).

Microhabitat associations: Larvae and adults occupy well-shaded seeps and stream margins characterized by cold, clear, well-aerated water (Good and Wake 1992; Welsh and Lind 1996). Larvae are entirely aquatic and may occur at high densities in gravel substrates with percolating water, whereas adults preferentially use large rocks and are most abundant in splash zones of waterfalls and turbulent stream margins (Good and Wake 1992; Welsh and Lind 1996). In the Oregon Coast Range, southern and Columbia torrent salamanders analyzed as a combined group showed reduced occurrence in reaches with a high proportion of small substrate (<32 mm) (Stoddard and Hayes 2005). Adults may occasionally move through moist upland riparian forest during wet conditions, but post-metamorphic individuals typically remain within a few meters of stream channels, with only rare movements documented far from surface water during wet conditions (Welsh and Lind 1996; Leppin et al. 2020). *R. variegatus* avoids open water and strongly prefers gravel, pebble, and cobble substrates that provide cover and interstitial spaces for foraging and predator avoidance (Good and Wake 1992; Welsh and Lind 1996; Stoddard and Hayes 2005). Optimal microhabitats contain a diversity of coarse particle sizes, abundant interstitial crevices, and variable flow conditions (Welsh and Lind 1996).

Riparian forest context: *R. variegatus* is strongly associated with intact riparian canopy cover, which moderates stream temperature, maintains humidity, and limits sediment inputs. Ideal habitat conditions include forests with large conifers, abundant moss, and high canopy closure characteristic of late-seral stands (Welsh and Lind 1996; Nussbaum et al. 1983). In western Oregon, densities and biomass were significantly higher in uncut forests compared with logged forests (Corn and Bury 1989), While accounting for imperfect detection, Kroll et al. (2008) found that occupancy across *Rhyacotriton* species on managed forests in western Oregon and Washington exhibits a quadratic relationship with stand age, peaking in stands of intermediate-age and declining in both younger and older age classes. Regardless of forest age, downed wood and forest cover provide the cool, moist microclimate required for terrestrial activity and short-distance dispersal (Emel et al. 2019; Olson and Burton 2019). In the northern portion of the species' range, forest fragmentation has been associated with increased genetic differentiation among populations (Emel et al. 2019).

Habitat data gaps: Evidence linking *R. variegatus* occurrence or abundance to stream characteristics, including channel gradient, stream size, substrate composition, summer temperature, and flow permanence, is supported across multiple studies. However, quantitative thresholds for key variables, such as tolerance to seasonal drying, thermal exposure under field conditions, and fine-sediment accumulation, remain unconstrained, limiting comparison across watersheds and management contexts.

Evidence for microhabitat associations is similarly derived largely from reach-scale or site-specific studies. While strong relationships with coarse gravel–cobble substrates, abundant interstitial spaces, and splash-zone or seep habitats are consistently reported, fewer studies have evaluated how variation in microhabitat structure and sediment conditions influences occupancy or

abundance across broader spatial extents. As a result, the generality of reported microhabitat relationships beyond individual study systems remains uncertain.

Associations with riparian forest context are supported primarily through inferred effects on stream shading, microclimate regulation, and sediment control rather than through direct effects of forest age alone (Welsh and Lind 1996; Olson and Ares 2022). Although higher densities and biomass have been documented in uncut forests (Corn and Bury 1989), and non-linear relationships between stand age and occupancy have been reported across *Rhyacotriton* species (Kroll et al. 2008), few studies explicitly integrate riparian forest attributes with in-stream or microhabitat conditions at or across watershed scales. Consequently, uncertainty remains in how forest structure mediates habitat suitability for *R. variegatus* across Oregon landscapes. Although some studies have accounted for imperfect detection using occupancy-based approaches (e.g., Kroll et al. 2008), many investigations relating occurrence or abundance to stream and microhabitat features rely on uncorrected presence or relative abundance data. This heterogeneity in analytical treatment constrains inference about the strength, consistency, and comparability of reported habitat relationships across spatial contexts.

coastal tailed frog (*Ascaphus truei*)

Stream characteristics: *A. truei* is strongly associated with cold, fast-flowing, shaded perennial headwater streams and are commonly described as headwater obligates, breeding and developing almost exclusively within small, permanently flowing channels (Hayes et al. 2006; Hayes and Quinn 2015). They are highly aquatic, sensitive to dehydration, and require a narrow thermal range (approximately 5–18 °C; 41-64 °F), remaining closely associated with streams throughout their life cycle (Hayes and Quinn 2015; Washington Herp Atlas 2017). Reproductive activity and early development are closely tied to cold-water conditions: mean water temperatures at oviposition sites are approximately 11–13°C (52–55°F), and embryonic development proceeds under similar cold-water conditions in the field (Karraker et al. 2006; Palmeri-Miles et al. 2010). Embryonic development is optimized near 12°C (54°F) based on laboratory data (Karraker et al. 2006). Eggs die at sustained temperatures above 18.5°C (65°F) and larvae and adults experience mortality at sustained temperatures of 22°C (72°F) (Bury 2008). Estimates derived from populations sampled across the Pacific Northwest show that coastal tailed frogs exhibit low thermal tolerance relative to most amphibians, with critical thermal maxima near 29.6°C (85°F) for larvae (Bury 2008).

Occupied streams typically occur in catchments exceeding ~50 ha and are at least ~1 m wide (Hayes et al. 2006; Kroll et al. 2010). Occupancy is patchy within and among watersheds, reflecting the species' narrow hydrologic and substrate requirements and sensitivity to local habitat conditions, including flow permanence and sediment inputs (Hayes and Quinn 2015; Welsh and Lind 2002; Stoddard and Hayes 2005). Long larval periods (1–4 years) further constrain the species to cool, well-oxygenated streams with permanent hydroperiods (Hayes and Quinn 2015). Detection-corrected occupancy modeling across commercial forests in Oregon and Washington further indicates that *A. truei* occupancy is negatively associated with the presence of crayfish and exhibits a quadratic relationship with bankfull channel width (lowest at small and large widths) (Kroll et al. 2008).

Microhabitat associations: Adults use a variety of stream mesohabitats, including riffles, pools, and waterfall margins, while larvae cling to cobble and bedrock surfaces in high-gradient channels for foraging and refuge and are sensitive to increased fine sediment loads that reduce interstitial space (Stoddard and Hayes 2005; Hayes and Quinn 2015). These coarse substrates provide refugia from predators such as stream-dwelling giant salamanders and salmonids, and turbulent flow conditions may further reduce predation risk (Stoddard and Hayes 2005; Welsh and Lind 2002). Laboratory experiments demonstrated that larvae preferentially select smooth rocks larger than approximately 55 mm in diameter (Altig and Brodie 1972), a finding consistent with field observations documenting highest larval densities on cobble and boulder substrates (Hayes and Quinn 2015). Within occupied streams, larvae are more frequently associated with shallow, turbulent microhabitats such as riffles and cascades than with pools (Welsh and Lind 2002).

Riparian forest context: Detections of *A. truei* are often more frequent in older forest stands, particularly where mature riparian canopies maintain cool, shaded stream conditions and stable coarse substrates (Welsh and Lind 2002; Hayes and Quinn 2015). However, the species also occurs in younger managed forests when key riparian and instream attributes remain intact, such as canopy cover, stream shading, and coarse substrate availability (Stoddard and Hayes 2005; Kroll et al. 2008; Hayes and Quinn 2015). Detection-corrected occupancy modeling across commercial forests in Oregon and Washington indicates a positive but non-exclusive association between *A. truei* occupancy and stand age, with substantial occupancy observed in younger stands, particularly in the absence of crayfish and under favorable stream conditions (Kroll et al. 2008). Collectively, these findings indicate that forest seral stage alone is not a consistent predictor of occupancy, and that maintenance of cool stream temperatures, low sediment loads, and permanent flow appears more important than stand age per se for supporting occupancy and reproduction (Stoddard and Hayes 2005; Kroll et al. 2008; Hayes and Quinn 2015). In a long-term before–after, control–impact experiment, coastal tailed frog densities did not differ at 2 years post-harvest, but larval and post-metamorphic densities were lower 7–8 years after forest harvest across all riparian buffer treatments, including continuous buffers (McIntyre et al. 2025).

Habitat data gaps: Evidence linking *A. truei* occurrence to stream characteristics, including stream size, channel gradient, substrate composition, flow permanence, and thermal regime, is supported across multiple studies. However, quantitative thresholds for key variables, particularly tolerance to fine sediment, thermal exposure under field conditions, and hydrologic alteration, remain poorly constrained, limiting comparison across watersheds and management contexts. Evidence for microhabitat associations is similarly derived largely from reach-scale or site-specific studies. While strong relationships with coarse substrates, turbulent flow conditions, and cold-water microhabitats are consistently reported for larvae and adults, relationships between microhabitat degradation and population persistence, especially across the species' prolonged larval period, have rarely been evaluated beyond local scales. As a result, uncertainty remains regarding how localized changes in substrate condition, sediment loading, or thermal regime translate into long-term population outcomes (Stoddard and Hayes 2005; Hayes and Quinn 2015).

Although occupancy is often higher in older forests, detection-corrected analyses indicate that forest seral stage alone is not a sufficient predictor of occupancy (Kroll et al. 2008; McIntyre et al. 2025), and few studies explicitly integrate riparian forest attributes with in-stream habitat conditions or population responses at watershed scales. Consequently, uncertainty remains in how riparian forest structure mediates habitat suitability and population persistence for *A. truei* across Oregon landscapes.

Although some studies have accounted for imperfect detection using occupancy-based approaches (e.g., Kroll et al. 2008), many investigations relating occurrence or abundance to stream and microhabitat features rely on uncorrected presence or relative abundance data. This heterogeneity in analytical treatment constrains inference about the strength, consistency, and comparability of reported habitat relationships across spatial contexts.

B.5. Torrent Salamander Population Status and Trends

Assessing population status and trends for torrent salamanders is important for evaluating the persistence of headwater-associated amphibians on private forestlands regulated under the Oregon Forest Practices Act. The Columbia torrent salamander (*Rhyacotriton kezeri*) and southern torrent salamander (*R. variegatus*) are cold-water specialists associated with perennial headwater streams, exhibit limited dispersal capacity, and occur in patchy distributions shaped by local hydrology, substrate, and riparian conditions. Following taxonomic revision by Good and Wake (1992), *R. kezeri* and *R. variegatus* are recognized as two of four genetically distinct torrent salamander species endemic to the Pacific Northwest, replacing the earlier treatment of all torrent salamanders as a single species (*R. olympicus*). *R. kezeri* is restricted to the northern Oregon Coast Range and adjacent Washington populations, whereas *R. variegatus* occupies a broader geographic range extending through western Oregon into northern California (see Distribution section).

Despite their conservation relevance, direct information on population size, demographic rates, or long-term trends is lacking for both species. Available evidence is derived primarily from studies reporting occupancy, detection frequency, and relative abundance at stream-reach or watershed scales across gradients of forest condition and hydrologic permanence. These studies provide insight into patterns of occurrence and localized persistence but do not support quantitative assessment of population trends at watershed or rangewide scales. Moreover, because changes in occupancy or detection do not necessarily reflect changes in population size, survival, or recruitment, observed patterns should not be interpreted as direct evidence of population increase or decline. Consistent with AMPC Question 2, this section evaluates available evidence bearing on population status and relative trends, while explicitly identifying limitations that preclude quantitative trend estimation. Because many of the limitations on inference reflect shared methodological constraints rather than species-specific differences, data gaps are summarized jointly for both torrent salamander species following the species summaries.

Columbia torrent salamander (*Rhyacotriton kezeri*)

Population status: Population size and long-term trends for *R. kezeri* remain unknown. At the stream scale, the species was detected in 58% of sampled first-order headwater streams in managed forests of Oregon's Coast Range (Russell et al. 2004) and in approximately 53% of sampled perennial headwater streams in managed forests of southwestern Washington (Wilkins

and Peterson 2000). These estimates represent observed detections and do not explicitly account for imperfect detection. Within occupied streams, relative abundance estimates indicate substantial spatial variability. In Oregon, landscape-scale abundance ranged from 0 to 4.77 individuals per linear meter of stream (mean = 0.47 individuals/m), with larvae comprising 59.6% of captures (Russell et al. 2004). At finer spatial scales, randomly selected 10-m reach surveys detected salamanders in approximately half of sampled reaches and reported mean abundance of 2.24 ± 0.89 individuals/m², with larvae comprising 62.6% of captures. These reach-scale estimates similarly reflect indices of relative abundance rather than detection-corrected density. Detection-corrected occupancy modeling in managed forests of Oregon and Washington reported high occupancy of torrent salamanders (*Rhyacotriton* spp.), exceeding 80% in stands of intermediate age and moderate channel gradient; however, estimates were derived from a combined analysis of four *Rhyacotriton* species, with species identity included as a model covariate rather than as independently modeled populations (Kroll et al. 2008). Recent rangewide habitat-suitability modeling relates observed occurrence of *R. kezeri* to climatic, hydrologic, and forest-structure variables, including stream gradient, summer water balance, streamflow permanence, and riparian canopy cover (Thurman et al. 2025). Although this modeling framework provides a consistent basis for comparing relative occurrence across watersheds, estimates are based on observed detections and do not explicitly model imperfect detection. \

Trends and pressures: Quantitative population trend data are limited. Historical landscape modeling estimated substantial reduction in suitable habitat since Euro-American settlement, attributed primarily to riparian canopy loss and forest fragmentation (Kagan et al. 1999). Field studies and occupancy analyses consistently report higher occurrence where perennial headwater flow and riparian shading are retained, and lower detection probabilities in recently harvested or hydrologically altered headwaters (Bury and Corn 1988; Kroll et al. 2008; Olson and Ares 2022). However, these patterns describe variation in occurrence and habitat association rather than direct evidence of population decline.

southern torrent salamander (*Rhyacotriton variegatus*)

Population status: Population size and rangewide trends for *R. variegatus* remain unknown. At the stream scale, the species has been frequently detected in headwater streams with suitable habitat conditions. Detection-corrected occupancy modeling in managed forests of Oregon and Washington reported high occupancy of torrent salamanders (*Rhyacotriton* spp.), exceeding 80% in stands of intermediate age and moderate channel gradient; however, estimates were derived from a combined analysis of four *Rhyacotriton* species, with species identity included as a model covariate rather than as independently modeled populations (Kroll et al. 2008). In northern California, *R. variegatus* was detected in 80.3% of surveyed headwater streams on managed forest lands (Diller and Wallace 1996).

In contrast, surveys conducted at randomly selected sites within the Klamath Mountains documented substantially lower detection frequencies (28.2–36.8%), with detections increasing to 46.6–62.3% at sites meeting specific microhabitat criteria (Welsh and Lind 1992), indicating strong sensitivity of observed occupancy to site selection and habitat conditions. Reported densities vary widely with habitat quality and sampling design. In Lincoln County, Oregon, high

larval densities (mean 12.9 larvae/m²) were recorded in favorable headwater habitat (Nussbaum and Tait 1977). Across California, densities ranging from 1 to 50 individuals per 10 m² plot (mean 0.68 individuals/m²) have been reported in suitable habitat (Welsh and Lind 1996), while lower mean densities (0.28 individuals/m²) were documented in randomly selected managed forest streams (Diller and Wallace 1996). These estimates describe local relative abundance within surveyed reaches and do not provide estimates of population size beyond sampled areas. Watershed-scale surveys that explicitly accounted for imperfect detection reported near-ubiquitous occupancy of torrent salamanders (*Rhyacotriton* spp.) in third-order watersheds within intensively managed forests of Oregon and Washington, indicating that reach-scale absences may not reflect watershed-level absence and providing a baseline for future comparisons of relative occupancy (Kroll et al. 2010).

Trends and pressures: Quantitative population trend data are not available. Landscape-scale modeling indicates substantial historical loss of suitable habitat since Euro-American settlement, particularly in the Coast Range and Klamath Mountains (Kagan et al. 1999). Field studies consistently report reduced occupancy or abundance in recently harvested or hydrologically altered headwaters and higher persistence where perennial flow and riparian shading are retained (Corn and Bury 1989; Welsh and Lind 1996; Kroll et al. 2008; Olson and Ares 2022). Although some studies describe persistence or reappearance in managed landscapes as riparian conditions recover, direct evidence of recolonization dynamics remains limited.

Population data gaps (Columbia and southern torrent salamanders)

No time-series datasets currently exist to evaluate population trajectories, extinction risk, or recolonization dynamics for either *R. kezeri* or *R. variegatus* at watershed or rangewide scales. Available information for both species is derived primarily from single-period or short-term surveys conducted in limited portions of their respective ranges, restricting inference about temporal change. Most estimates of occupancy and abundance are based on observed detections and relative abundance indices rather than detection-corrected occupancy or density. An exception is watershed-scale surveys conducted in intensively managed forests of Oregon and Washington that explicitly accounted for imperfect detection and reported near-ubiquitous occupancy of torrent salamanders (*Rhyacotriton* spp.) in third-order watersheds, indicating that reach-scale absences may not reflect watershed-level absence and providing a baseline for future comparisons of relative occupancy (Kroll et al. 2010). Separately, reach-scale detection-corrected occupancy modeling across commercial forest streams in Oregon and Washington estimated high occupancy for Columbia and southern torrent salamanders in intermediate-aged stands at moderate channel gradients, although these estimates were also derived from a combined analysis of multiple *Rhyacotriton* species rather than modeled independently (Kroll et al. 2008). However, these estimates were not species-specific, were geographically limited, and do not include repeated measures necessary to assess trends through time. More recently, ongoing multi-year survey efforts in the northern Oregon Coast Range are beginning to resample standardized locations and incorporate detection-corrected occupancy approaches at watershed scales (Garcia et al. 2025); however, these efforts are still underway and thus not summarized here.

More broadly, although detection-corrected occupancy methods for stream-associated amphibians are well established and feasible at reach to watershed scales using repeat in-stream surveys, comparable approaches for estimating abundance, demographic rates, or population change at larger spatial extents remain limited. Capture-based abundance estimates are generally restricted to localized stream reaches, egg-based surveys are rarely feasible at scale, and emerging environmental DNA (eDNA) approaches show promise for improving detection but currently lack validated relationships with abundance or life-stage–specific demographic parameters. For *R. kezeri* specifically, recent rangewide habitat-suitability modeling provides a spatially consistent framework for assessing relative occurrence across its restricted geographic range (Thurman et al. 2025). While this work represents an important advance for spatial inference, it is based on observed detections and does not explicitly account for imperfect detection or temporal replication. Consequently, repeated surveys using comparable methods would be required to evaluate trends or changes in occupancy over time. Similarly, genome-wide population genomic approaches have now been applied to *R. cascadae* (Cousins et al. 2026) but comparable analyses are lacking for both *R. kezeri* and *R. variegatus*, limiting inference about cryptic population structure, effective population size, and evolutionary significant units relevant to conservation planning.

Overall, the absence of standardized, repeat-visit monitoring frameworks or hierarchical modeling approaches constrains the ability to distinguish true absence from non-detection, evaluate change over time, or compare estimates across forest management. In addition, while localized demographic and life-history studies exist and are summarized elsewhere in this review, these efforts are generally short-term and reach-scale and are not designed to support inference about population trajectories across watersheds or ownerships, particularly under variation in streamflow permanence and thermal conditions.