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The Biology of Amphibians and Reptiles in Old-Growth Forests in the Pacific Northwest

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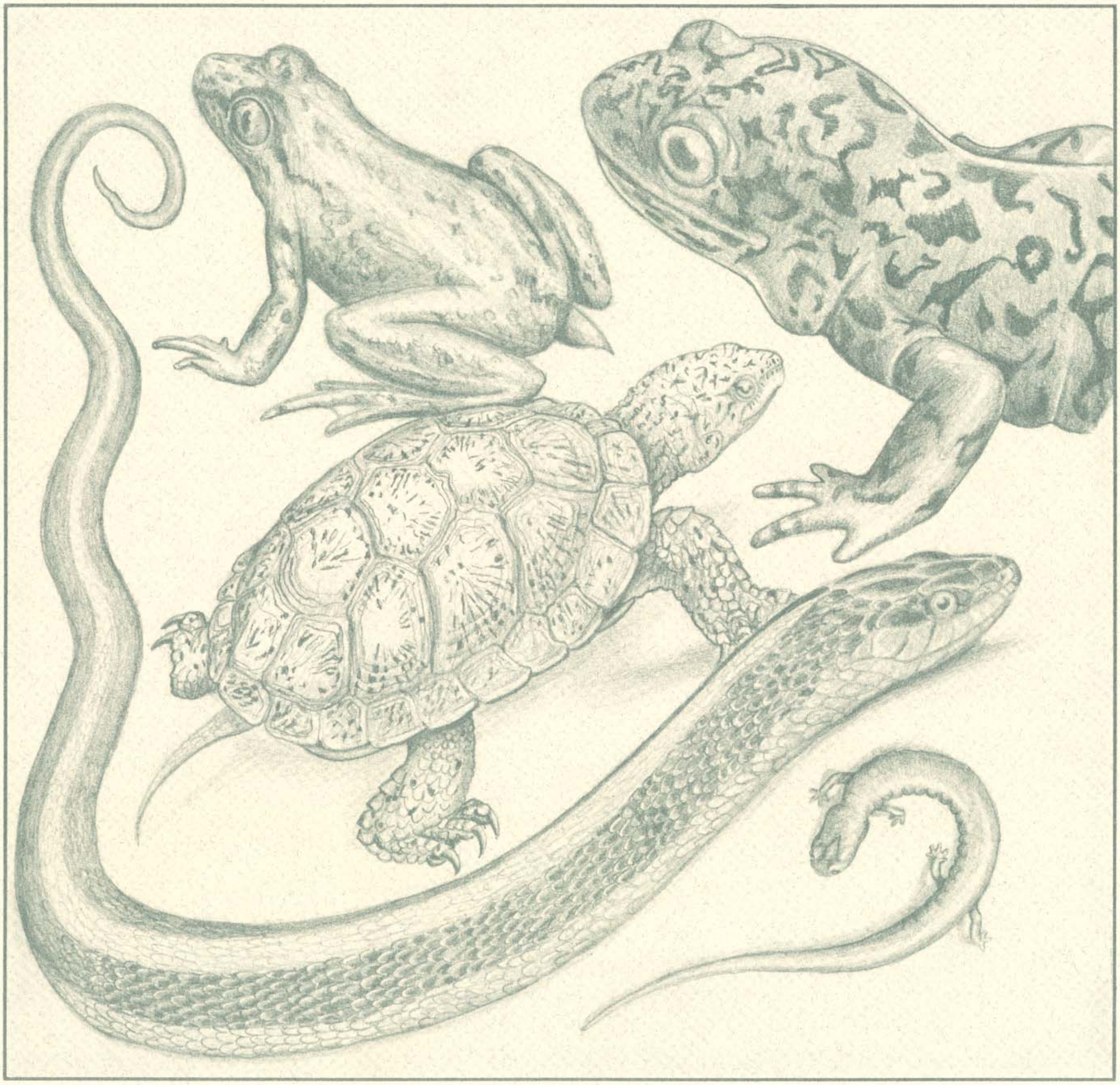

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Abstract

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The amphibian and reptile fauna of older forest ecosystems in the Pacific Northwest includes several endemic species, species with unique behavioral and ecological characteristics, and species whose populations have been in decline in recent years. We review the biology of these species and include information on their distinguishing characteristics, behavior, and ecology. Herpetofaunal associations with forest characteristics and the impact of habitat loss are addressed.

Keywords: Amphibian, reptile, old-growth forest, Pacific Northwest, ecology.

Contents

Introduction

The National Science Board (1989) recently concluded that there exists an ongoing and unprecedented loss of the variety and numbers of species worldwide and that this catastrophic loss in biodiversity requires immediate attention. Some biologists estimate that as much as one-fourth of the total biodiversity on earth may become extinct in the next 20 to 30 years (McNeely and others 1990). Rates of extinction have increased greatly in recent times due to human interference (McNeely and others 1990, Wilson 1988). Habitat destruction, overharvesting, chemical pollution, introduced (exotic) species, and climatic change are among the major threats to biodiversity (Ehrlich 1988, McNeely and others 1990, Soule' 1986). A continual loss of biodiversity can have far-reaching ecological, economic, social, medical, and ethical consequences (for example, Green and Losos 1988, Oldfield 1984, Soule' 1986, Wilson 1988). Members of all taxonomic groups are affected, and threatened species exist in all the vertebrate classes.

As part of the overall biodiversity crisis, several recent reports have suggested that many species within the vertebrate classes Amphibia and Reptilia are undergoing population declines and range reductions (Beebee 1992, Blaustein and Wake 1990, Blaustein and others 1994a, Phillips 1990, Vial and Saylor 1993). The declines of some species are especially perplexing because they are disappearing in areas of the world that are devoid of obvious habitat destruction, pollution, and exotic competitors or predators.

Amphibians and reptiles are important components in many ecosystems. They can occupy key trophic positions in food webs of both aquatic and terrestrial systems. As adults, they can be top carnivores, and as larvae or juveniles, they may be the major food source of many other species including birds, mammals, fish, and invertebrates. In some forest ecosystems, amphibians may comprise the major component of the vertebrate biomass (for example, Burton and Likens 1975, Bury 1988). Moreover, under certain conditions, amphibians may be good "bioindicators" of environmental stress because of various aspects of their life histories, including their physiological and behavioral characteristics, morphogenetic patterns, and aspects of their population biology. The decline in amphibians may be an early warning signal that, ultimately, other organisms also may be in danger of decline and extinction.

There is growing concern over the impact of potential losses in biodiversity in the Pacific Northwest, particularly in forest systems/The herpetofauna of these forests can reach relatively high densities and comprise the dominant component of faunal biomass (for example, Bury 1988). Additionally, some forest species are unique and extremely interesting, such as the giant salamanders *(Dicamptodon* species) which are thought to be the largest terrestrial salamanders, the tailed frog *(Ascaphus truei)* whose males have copulatory organs, the Cascades frog *(R. cascadae)* whose larvae may aggregate in schools composed primarily of relatives, and the sharptail snake *(Contia tenuis),* a rare slug-eating specialist.

The forest-dwelling amphibian and reptile fauna of the Pacific Northwest includes several endemic species (Nussbaum and others 1983), many of which are species of concern. Fifteen percent of the native amphibian species in the Western United States are listed as candidates for threatened or endangered species status (Walls and others 1992). In the Pacific Northwest, amphibian populations of several species apparently have become locally extinct, and the ranges of other species have become drastically reduced (Blaustein and Wake 1990; U.S. Department of the Interior, Fish and Wildlife Service 1991). Fifty-four percent of the native Oregon amphibian species are listed as Sensitive, and 46 percent of the native amphibians of Washington State are in the Special Concern category (Walls and others 1992). Several species of amphibians, including the Western spotted frog *(Rana pretiosa),* red-legged frog *(R. aurora),* and the Cascades frog *(R. cascadae), are* candidates for the Federal endangered species list. Many other species are listed on the threatened lists of the states of California, Idaho, Oregon, and Washington. The ecological status of reptiles in the Pacific Northwest is less clear. Many reptiles, however, are listed on the threatened lists of California, Idaho, Oregon, and Washington. Almost half of the 62 species of amphibians and reptiles found in the Pacific Northwest are listed as requiring special status on state lists due to dwindling numbers. Many species of concern are forest-dwelling animals. Some of these species are intimately tied to old-growth forests and are sympatric with other animals and plants that have sensitive or threatened status, including northern spotted owls *(Strix occidentalis)* and the Pacific yew *{Taxus brevifolia* Nutt.).

The increasing loss of old-growth forest habitat may have detrimental effects on the herpetofauna of the Pacific Northwest. These effects recently have been put into perspective in studies of salamander populations in eastern North America. For example, in central New York State, Pough and others (1987) reported that salamander abundances in recently disturbed habitats were significantly reduced in comparison to old-growth. Petranka and others (1993) reported that captures of salamanders in mature forest stands were five times higher than those in recent clearcuts in the Southeastern United States. Their conservative estimate is that clearcutting in U.S. National Forests in western North Carolina results in the loss of about 14 million salamanders annually. Moreover, they suggested that clearcutting is chronically reducing regional populations in the Southeast by more than a quarter of a billion salamanders. Although numbers of amphibians lost in response to timber harvest have not been estimated in the Pacific Northwest, associations of amphibian population abundances with older forest age classes have been reported for many species (for example, papers in Ruggiero and others 1991).

In this monograph, we provide detailed information on the current status, ecological characteristics, behavior, and geographical range of the majority of amphibian and reptile species inhabiting old-growth forests of the Pacific Northwest. We have attempted a more technical-review of the biology of each species than one would obtain from a field guide. The geographical coverage concentrates on species inhabiting Oregon, Washington, northern California, and southern British Columbia. We include. however, species that may inhabit other Western states and Canadian provinces but which are found in the main area of coverage. Moreover, we include information on species from studies conducted outside the Pacific Northwest. Many species have patchy or disjunct distributions. The range maps (see appendix figs. 1-25) have been redrawn from published accounts (for example, Bury and others 1991 a, 1991b; Leonard and others 1993; Nussbaum and others 1983; Stebbins 1985) and represent the approximate ranges of the species in their widest distribution. We include historical site records in many of our range map constructions.

We have integrated recent reports assessing the viability of amphibians and reptiles in forests of the Pacific Northwest. For example, we have summarized the findings of many of the papers in Ruggiero and others (1991), which examined associations of amphibians and reptiles with forest characteristics, including stand age. Lehmkuhl and Ruggiero (1991) quantitatively assessed the extinction risk of vertebrates, including reptiles and amphibians. We also include information from the Report of the Scientific Analysis Team (Thomas and others 1993) on associations of amphibians with old-growth forests. Thomas and others (1993) identified a "short list of species considered to be "close associates" of old-growth stands. They also conducted qualitative viability assessments of amphibians under five different forest management designs and proposed mitigation measures for species of "special concern." An additional qualitative risk assessment can be found in the Report of the Forest Ecosystem Management Assessment Team (FEMAT 1993). This report provides an evaluation of the viability of amphibians closely associated with late-successional forests, occurring on Federal lands in the range of the northern spotted owl, under nine land management options. FEMAT (1993) divided this subset of Pacific Northwest amphibians into Riparian Associates, species that would benefit from buffer zones surrounding aquatic habitats, and upland Terrestrial Associates. They also provided the proportion of ranges of species on Federal lands, and proposed mitigation measures for higher viability. We summarize Pacific Northwest amphibian species found in older forest ecosystems and their risk assessments in table 1.

This monograph is written primarily so that professionals can obtain relatively detailed information and references on the forest-dwelling amphibian and reptile fauna of the Pacific Northwest. We believe the information in this monograph will be especially useful for those interested in managed forests: state and Federal staff biologists; wildlife biologists; and those interested in the ecology, behavior, and evolution of amphibians and reptiles. This monograph would be useful in conjunction with field guides that cover the Pacific Northwest region (especially Green and Campbell 1984, Leonard and others 1993, Nussbaum and others 1983). We feel that the information on amphibians and reptiles we provide will aid; in the preservation of the natural biodiversity of the Pacific Northwest region in general, and amphibians and reptiles in particular. This is especially important now, as the biodiversity of the planet is decreasing rapidly.

Northwestern Salamander *(Ambystoma gracile)*

Description

Ambystoma gracile is a medium to large salamander, with males ranging in size up to a total length of 228 mm and females to 248 mm (Nussbaum and others 1983). Terrestrial adults are dark brown above and grayish to light brown below, they have conspicuous parotoid glands behind the eyes and a rounded glandular ridge along the dorsal edge of the tail. Both the parotoid glands and glandular ridge tend to be a lighter brown than the remaining ground color. Close examination of terrestrial adults reveals many tiny light spots over the dorsolateral surfaces, which are the openings of poison or granular glands (Nussbaum and others 1983). Small irregular whitish or yellowish spots and blotches occur on the dorsal areas of northern individuals in British Columbia (Snyder 1963).

Table 1—General habitat types of amphibians found in older forest ecosystems* and other habitats in the Pacific Northwest[a]

Amphibian	Habitat type			Viability risk assessment	
	Ponds and lakes	Streams	Terrestrial	Thomas and others	Lehmkuhl and Ruggiero
Salamanders (order Caudata):					
**Dicamptodon* species	L,P,M	L,P,M	M	Medium to high (2)	High (9)
**Rhyacotriton* species		L,M		Medium to high (5)	High (9)
**Ambystoma gracile*	L,P,M	L,P,M	M	Medium to high (2)	Medium (6)
Ambystoma macrodactylum	L,M		M		
Ambystoma tigrinum	L,P,M		M		
**Aneides ferreus*			X	Medium to high (3)	High (10)
**Aneides flavipunctatus*			X	Medium to high (2)	
Batrachoseps attenuatus			X		
**Batrachoseps wrighti*			X	Medium to high (2)	High (9)
**Ensatina eschscholtzii*			X		Low (3)
**Plethodon dunni*			X[b]	Medium (2)	Moderately high (7)
**Plethodon elongatus*			X	Medium to high (4)	
**Plethodon larselli*			X	Medium to high (5)	High (9)
**Plethodon stormi*			X	Medium to high (5)	High (9)
**Plethodon vandykei*			X[b]	Medium to high (5)	High (9)
**Plethodon vehiculum*			X		Moderately high (8)
**Taricha granulosa*	L,P,M	L,M	M	Medium (2)	Medium (6)
Frogs and toads (order Anura):					
**Bufo boreas*	L,M	M	M		
Bufo woodhousei	L,M	L,M	M		
**Hyla [=Pseudacris] regilla*	L,M	L,M	M		
Pseudacris triseriata	L,M	L,M	M		
**Ascaphus truei*		L,M	M	Medium to high (4)	Moderately high (7)
**Rana aurora*	L,M	L,M	M		Moderately high (8)
**Rana boylii*		L,M	M		
**Rana cascadae*	L,M	L,M	M		Moderately high (8)
Rana catesbeiana[c]	L,M	L,M	M		
Rana clamitans[c]	L,M	L,M	M		
Rana pipiens	L,M		M		
**Rana pretiosa*	L,M	L,M	M		
Rana sylvatica	L,M	L,M	M		
Spea [=Scaphiopus] intermontana	L,M		M		

[a] Risks to viability are summarized from assessments by Lehmkuhl and Ruggiero (1991, quantitative risk rating shown in parentheses, 10 = highest risk of extinction) and Thomas and others (1993, qualitative risk assessments of "close associates" with old-growth forests were conducted for National Forests within the range of the northern spotted owl, number of 5 forest management options with indicated risk shown in parentheses). L = larvae, M = metamorphs, P = paedomorphs, X = lungless salamanders (no aquatic life-history stage).

[b] Semiaquatic woodland salamander.

[c] Introduced species.

Sexually mature or paedogenetic larvae are common in this species, particularly at higher elevations (Snyder 1956,1963; Sprules 1974a). Others (Eagleson 1976, Smith Watney 1941, Sprules 1974b) have documented neoteny in this species. These larvae range in size from 65 to 105 mm in snout-vent length (SVL, Nussbaum and others 1983). They are of the pond type (conspicuous dorsal fin reaching to head and large "staghorn" gills), with a deep brown to greenish-brown ground color, and usually a row of light lateral line spots low on each side (Nussbaum and others 1983. Snyder 1963). The parotoid glands and the glandular ridge on the tail are evident as roughened skin areas (Stebbins 1985). The systematics of *A. gracile* may be complex (Titus 1990), thereby requiring additional morphological and genetic data.

Recently hatched larvae show concentrations of darker pigment along the base of the dorsal fin, which may be interrupted by light blotches (Stebbins 1951,1985). Pond larvae have 7 to 10 gill rakers on the antehor face of the third gill arch. Larvae usually metamorphose in their second year of life at around 50 mm SVL, or they may become paedogenetic in their second or third year.

According to Farner and Kezer (1953), Lindsey (1966), and Nussbaum and others (1983), eggs are deposited in single, firm, rounded, gelatinous masses 80 to 150 mm in diameter, attached to vegetation up to 1 m or more below the water surface. The clutch size varies from 40 to 270 eggs, and individual ova are 1.5 to 2.5 mm in diameter, with light brown dorsal poles. Snyder (1956) stated, however, that egg masses were deposited in small clusters of 15 to 34 eggs or larger masses of up to 143 eggs. A few were attached to grass stems, but most lay on the bottom. Snyder (1956) suggested that egg masses of neotenic individuals differed greatly from those of metamorphosed individuals; neotenic egg masses were much looser. Eggs hatch in 30 to 60 days, dependent on water temperature. According to Brown (1976), embryos of *A. gracile* have the slowest rate of development compared with four other species of *Ambystoma* and three Northwest frog species *(Ascaphus truei, Rana aurora,* and *Hyla regilla).*

Range and Habitat

This salamander ranges from the southwestern tip of Alaska through coastal British Columbia, Vancouver Island, and western Washington, and Oregon to northwestern California. Although two subspecies are recognized, *A. g. decorticatum,* the British Columbia salamander, and *A. g. gracile,* the brown salamander, this designation is controversial (Titus 1990). The British Columbia salamander shows the light dorsal spots mentioned previously and has four bones in the fourth hind toe. It occurs northward from near Seymour Inlet in British Columbia. The brown salamander is unspotted, has only three bones in the fourth hind toe. and occupies the remainder of the species range (Nussbaum and others 1983). After a comparison of the allozyme variation in the two subspecies, Titus (1990) suggested that we should not recognize subspecies.

Northwestern salamanders have terrestrial and aquatic life history stages. They occur in various habitats, including coniferous forests, inland valleys, and subalpine areas, to an elevation of 3100 m (Eagleson 1976, Farner and Kezer 1953, Nussbaum and others 1983). They require relatively permanent quiet bodies of water for reproduction (for example, ponds, lakes, and slow parts of streams) and are absent from areas devoid of such waters.

Ecology and Behavior

Terrestrial adult *A. gracile* are seldom encountered because they are largely nocturnal and spend much of their lives in subterranean retreats (burrows, etc.). they most often are seen as they cross roads and trails enroute to breeding waters on rainy nights in early spring. Stebbins (1985) advised looking for them under rocks and logs, adjacent to water, but the effectiveness of these searches may be quite seasonal. In aquatic habitats, the larvae hide in bottom mud or under bottom debris during the day, but emerge at night to feed (Nussbaum and others 1983). They feed on various invertebrates (Henderson 1973) and perhaps on other amphibian species (Peterson and Blaustein 1991). In laboratory experiments, *A. gracile* preferred to eat frog tadpoles over toad tadpoles, probably because toad tadpoles are noxious (Peterson and Blaustein 1991). Trout and aquatic beetle larvae prey on *A. gracile* larvae (Nussbaum and others 1983).

Taylor (1977) recognized four age classes in Fay Lake, Oregon (elevation 1166 m), as follows: young of the year (<25 mm SVL); 1-year-olds (30 to 45 mm SVL); 2-year-olds (50 to 55 mm SVL); and 3 years and older (>60 mm SVL). In Fay Lake, no salamander of this species was found in water deeper than 1.3 m, but eggs were found at 4 m. *Ambystoma gracile* have survived with trout for at least 25 years in Fay Lake, and Taylor (1977) suggested that some salamanders behaviorally avoid predation by fish.

Efford and Mathias (1969) studied roughskin newt *(Taricha granulosa)* and Northwestern salamander populations in Marion Lake, a 14-ha lake in British Columbia. The average density of *A. gracile* was 175 per ha but reached densities of 1,678 per ha around the edge of the lake. Almost the entire population was paedogenetic. Egg-laying occurred in March, April, and May, and females laid every year, laying an average of 50 eggs per clutch. The young matured late in their second year. The authors considered the species to have a high reproductive rate, a high growth rate, and a high turnover rate, and felt that *A. gracile* made a considerable contribution to the energy flux in the lake.

Breeding occurs as early as late January or February (south coast) to as late as July (northern high lakes). Courtship was described by Knudsen (1960). During mating, males grasp females from above, using both front and rear legs, which is unique among members of the genus *Ambystoma* (see discussion in Knudsen 1960, Nussbaum and others 1983). Paedogenes reproduce every year at low,elevations, but may skip a year at higher elevations.

Relation to Old-Growth and Potential Impact of Habitat Loss

Although this species appears to occur widely through Northwestern forest areas, some associations with forest age have been reported. Aubry and Hall (1991), working in the southern Washington Cascade Range, found that these animals were five times more abundant in older forest systems than in younger forests. These results differ from those reported by Bury and Corn (1988a) working in the same area, but during the spring rather than the fall. These results suggest that this salamander may have seasonal patterns of habitat use or activity. Aubry and Hall (1991) reported that Northwestern salamanders were associated with older, flatter, cooler, and drier stands with a deeper litter layer, surface water, and snags. Bury and others (1991 a) found this species was more abundant in cool old-growth in the Cascade Range, but not the Coast Range. Corn and Bury (1991) surveyed 50 forest stands in the Oregon Coast Range and found that these salamanders did not differ in numbers among old-growth, mature and young stands, but were absent from clearcuts. They reported that Northwestern salamanders occurred significantly more often in eastern stands of the Oregon Coast Range, and found no association with old-growth moisture class.

Ambystoma gracile was determined to be a species of medium risk of extinction by Lehmkuhl and Ruggiero (1991). Thomas and others (1993) identified Northwestern salamanders as being closely associated with old-growth forest conditions. The viability of these salamanders was rated to be at medium to high risk under two of the five forest management alternatives considered by this Scientific Analysis Team (Thomas and others 1993). These salamanders use both aquatic and terrestrial habitats and could benefit from the protection offered by riparian reserves.

Giant Salamanders *(Dicamptodon* spp.)

Giant salamanders are probably the largest terrestrial caudate amphibians, and several species currently are recognized. Nussbaum (1970) described the first cryptic species within the genus *Dicamptodon (D. copei),* and Good (1989) detailed the biochemical evidence used to describe additional enigmatic taxa within *D. ensatus:* Pacific giant salamanders *(D. tenebrosus),* California giant salamanders *(D. ensatus),* and Rocky Mountain giant salamanders *(D. aterrimus).* These species will be discussed collectively unless data are available to clearly distinguish among these recently described forms. Detailed historical accounts of *Dicamptodon* are provided by Anderson (1969) and Nussbaum (1976).

Description

Metamorphosed adults can reach 170 mm SVL and 340 mm total length (Nussbaum 1976, Nussbaum and others 1983, Stebbins 1985). Populations are found at elevations ranging from sea level to 2160 m (Nussbaum and others 1983). Most, individuals have a dark dorsal ground color overlayed with a distinctive marbled mottling.

Premetamorphic individuals have typical mountain brook characteristics: streamlined body, inconspicuous dorsal tail fin, and gills which are reduced in surface area. These morphological features may be adaptations to the clear, cold streams, ponds, and lakes characteristic of significant portions of the landscape in the Pacific Northwest. All larvae of the *ensatus* complex may be distinguished from D. *copei* by their longer legs and larger heads. Larvae can reach sizes of 205 mm SVL and 351 mm total length (TL, Nussbaum 1976, Nussbaum and others 1983, Stebbins 1985).

Metamorphosis can differ both within and among populations. *Dicamptodon copei* normally do not metamorphose in nature (Nussbaum 1970, 1976; Nussbaum and others 1983; Stebbins 1985). Metamorphosis in other giant salamanders is variable. In some populations, individuals always seem to undergo metamorphosis, whereas other populations may be comprised of both individuals that metamorphose and those that do not (Nussbaum 1970, 1976; Nussbaum and others 1983). Size at maturity for D. *copei* ranges from 65 to 77 mm SVL (Nussbaum 1970, 1976; Nussbaum and others 1983). Individuals assigned to the *ensatus* group attain sexual maturity at about 115 mm SVL whether they are larvae or adults. The ecological and genetic control of metamorphosis in these animals is not well understood.

The clutch size in the *ensatus* group ranges between 135 and 200 eggs. Ova are about 6.5 mm in diameter and are deposited in water and attached by gelatinous pedicels to the ceilings of "nest chambers" underneath cut banks, coarse woody debris, and rocks (Nussbaum 1969). The clutch size of D. *copei* tends to be smaller than that of other *Dicamptodon.* It ranges from 25 to 115 eggs, and mean ovum size is 5.5 mm, which is also smaller than the mean size reported for the *ensatus* group (Nussbaum and others 1983).

Range and Habitat

Giant salamanders are found in northwestern California, Oregon, Washington, and extreme southwestern British Columbia. Good's (1989) D. *ensatus* is found in the San Francisco Bay area, and his *D. tenebrosus* from lower Sonoma County, California, through southwestern British Columbia. Nussbaum's (1970) D. *copei* is found in the Columbia River Gorge (both Oregon and Washington sides), the Olympic Peninsula, the Willapa Hills, and the southeastern Washington Cascade Range. Disjunct populations inhabiting the Rocky Mountains of Idaho and Montana (see range map) have been designated *D. aterrimus* (for example, Good 1989).

Adults are common in many areas but are nocturnal and secretive. They can be found in moist coniferous forests under bark, logs, rocks, and wandering about on the forest floor. During the breeding season, they can be found in or near streams. They also occur in talus slopes associated with road cuts throughout most of their range (Nussbaum and others 1983; Stebbins 1985; Beatty, Storm, personal observation). In Oregon and California, Hawkins and others (1983) found that aquatic *Dicamptodon* densities were correlated with substrate composition, and observed salamanders only in high gradient streams with coarse substrates. In one study (Bury and others 1991b), Cope's giant salamanders were taken most frequently from pool habitats, whereas Pacific giant salamanders were found equally in pools and riffles. Larvae were in deeper water than adults, and both life history stages were found under rock cover, with larger adults under larger rocks (Bury and others 1991b).

Ecology and Behavior

Reproduction—Breeding seems to occur in the spring for the *ensatus* group (Nussbaum and Clothier 1973, Nussbaum and others 1983, Stebbins 1985). Reproduction may occur at all times of the year in *D. copei* (Nussbaum and others 1983, Stebbins 1985), but probably occurs most frequently in fall, spring, and summer. Clutch frequency is presumably biennial for all giant salamanders (Nussbaum and others 1983). Females apparently guard eggs, a behavior that may have evolved to thwart predation on eggs and embryos by congeners (Nussbaum and others 1983).

Egg development varies and depends on thermal regimes in specific habitats. Because most oviposition sites are in secluded microhabitats within cold, clear, lotic, and lentic biological systems, developmental rates of embryos are relatively long. For example, Nussbaum and others (1983) reported that *D.* copei clutches maintained at 8 °C in the laboratory required 240 days to develop from blastula to feeding hatchlings. Hatching occurs when embryos reach about 34 to 37 mm in total length (Nussbaum 1969, Nussbaum and others 1983). Larvae emerge from eggs with well-provisioned yolk sacs allowing them to forgo feeding for as long as 9 months (Nussbaum and others 1983).

Predators and prey—Larval giant salamanders feed on various aquatic invertebrates and vertebrates (fish, tadpoles, and conspecifics; Antonelli and others 1972). Metamorphic *Dicamptodon* have a reputation for being voracious predators. Stomach analyses revealed that they eat terrestrial invertebrates as well as many kinds of vertebrates (for example, snakes, shrews, and birds; Metter 1963, Nussbaum and others 1983, Stebbins 1985). Predators on larval *Dicamptodon* include fishes, weasels, water shrews, and other giant salamanders. Western aquatic garter snakes *(Thamnophis couchii)* may be important predators of *Dicamptodon* in northwestern California streams (Lind 1990, Lind and Welsh 1990).

Population dynamics—Little is known about the population dynamics of adults or larvae. Nussbaum and Clothier (1973) found variation in the population structure of larval *Dicamptodon* in five categories of streams: regularly intermittent, potentially intermittent, small permanent, medium permanent, and large permanent.

Relation to Old-Growth and Potential Impact of Habitat Loss

Giant salamanders seem to be sensitive to land management practices, yet associations with forest age are not clear in all studies. Giant salamander abundance was not associated with forest age class (old, mature, and young) or moisture class in several studies (Bury and others 1991 a, 1991b; Corn and Bury 1991; Gilbert and Allwine 1991; Welsh and Lind 1991). They were, however, more abundant in warmer, wetter stands (Bury and others 1991 a) and were significantly associated with aspect (Bury and others 1991 a), moss, and fern cover (Gilbert and Allwine 1991).

The effects of logging on stream amphibians was examined by Corn and Bury (1989). They compared logged versus nonlogged reaches of streams in areas where stream gradients were high and low. In logged situations, they found high densities of giant salamanders only in high-gradient portions of the streams. In uncut stream reaches, giant salamanders were found in both high- and low-gradient areas. They attributed these results to the increased levels of fine sediment present in low-gradient, logged areas. Fine substrates appear to fill cracks and crevices in the streams, thereby altering critical microhabitats used by these animals. Additionally, Hawkins and others (1983) examined the relations of salamanders and physical habitat characteristics of streams. Giant salamanders were found only in high-gradient streams characterized by coarse substrate.

Cope's giant salamander is on Oregon's Sensitive Vertebrate list and is a State Monitor species on Washington's 1992 list of Species of Special Concern. Lehmkuhl and Ruggiero (1991) gave giant salamanders a high-risk score. Thomas and others (1993) identified giant salamanders as being closely associated with old-growth forest conditions. The viability of these salamanders was rated to be at medium to high risk under two of five forest management alternatives considered by this Scientific Analysis Team. Mitigation measures for giant salamanders include stream and riparian protection.

Torrent Salamanders *(Rhyacotriton* spp.)

Until recently, the Olympic salamander was considered to be the sole member of the subfamily Rhyacotritoninae of the family Dicamptodontidae (Edwards 1976, Frost 1985). Based on osteological, morphological, and biochemical information, Good and Wake (1992) have erected a new family (Rhyacotritonidae) and described four species of *Rhyacotriton.* These salamanders are now called torrent salamanders: the Olympic torrent salamander *(R. olympicus),* the Columbia torrent salamander *(R. kezeri),* the Cascade torrent salamander *(R. cascadae),* and the southern torrent salamander *(R. variegatus).*

Description

These are small salamanders: males range to about 95 mm TL, with the females reaching nearly 100 mm TL. They have large eyes, such that the horizontal diameter is equal to or greater than the distance from the anterior of the eye to the tip of the snout. The dorsal coloration is brown above, more or less mottled with black spots, depending on the area surveyed. Ventral surfaces are bright yellow with few to many black spots. In live specimens, white flecks (guanophores) may be evident; on the sides. Males have squared lobes adjacent to the vent (Nussbaum and others 1983).

The larvae occur in the gravel of streams and seeps and range from 14 to 44 mm SVL They are typical stream larvae (short gills, flattened bodies, and small fins confined to the tail). They are tannish brown dorsally and cream to light yellow ventrally; small black dots are scattered over the dorsum and venter (Nussbaum and others 1983).

Range and Habitat

These salamanders range from the Olympic Peninsula of northwestern Washington southward to Mendocino, California, in humid coastal forests west of the Cascade Range crest (Anderson 1968). *Rhyacotriton olympicus* is restricted to the Olympic Peninsula in Clallam, Grays Harbor, Jefferson, and Mason Counties, Washington (Good and Wake 1992). *Rhyacotriton variegatus* occurs from northwestern California (Mendocino County) northward through the Coast Range of Oregon to the Little Nestucca River and the Grande Ronde Valley in Polk, Tillamook, and Yamhill Counties, Oregon. An isolated population near Steamboat, Douglas County, Oregon, is assigned by Good and Wake (1992) to *R. variegatus* rather than *R. cascadae* (see description of the range of *R. cascadae* below). The range of *R. variegatus* is parapatric to that of *R. kezeri,* which is found in the Coast Range of Oregon and Washington from the zone of contact with *R. variegatus* along the Little Nestucca River and the Grande Ronde Valley in Oregon north to the Chehalis River in Grays Harbor County, Washington. *Rhyacotriton cascadae* is found on the western slopes of the Cascade Range from north of Mount St. Helens, south to northeastern Lane County, Oregon. They generally occur below 1220 m in elevation (Marshall and others 1992).

Torrent salamanders are found in and near small, rapidly flowing, well-shaded permanent streams with clear, cold (usually 6 to 10 °C) water (Stebbins 1951). They are found "especially in mossy gravel or splash zones of rocky, tumbling brooks" (Thomas and others 1993). They are found more frequently under cover objects in riffle habitats than in pools (Bury and others 1991b). They are seldom more than 1 m from free-running water (Nussbaum and Tail 1977). Small cold (8 to 12 °C in summer) streams with water seeping through moss-covered gravel are preferred habitats. Larvae occur in small mountain streams, spring heads, and seepages from sea level to about 1200 m (Nussbaum and others 1983).

Torrent salamanders apparently require relatively low ambient temperatures. Brattstrom (1963) gave body temperatures of 26 specimens in nature as 5.8 to 9.6 °C, averaging 7.7 °C. Water temperatures in a larval site near Fall Creek in western Oregon varied from 5.5 °C in January to 11 °C in July (Nussbaum and Tail 1977). Adults occasionally may be found under objects a few meters from water after heavy rains, but this is unusual (Nussbaum and others 1983). Torrent salamanders are very sensitive to loss of body water, tolerating a loss of only 19.4 percent of initial body weight, compared to 29.0 to 32.9 percent for other species (Nussbaum and others 1983).

Ecology and Behavior

Courtship and mating occur throughout the active season (Nussbaum and others 1983). Eggs may be laid at almost any time, but apparently most are laid in May, based on examination of collected females. Females may have one clutch per year. Only two nests have been reported, neither of which was attended by an adult (see discussion in Nussbaum and others 1983). These nests were deep within narrow rock cracks with cold (8.3 and 9.1 °C) water flowing over them. The ova measured 3.6 to 4.5 mm in diameter and were pure white. Eggs kept at 8 °C in the dark hatched after 210 to 290 days and, after a period of yolk absorption, larvae needed to feed in 295 to 360 days. This is the longest embryonic period known for an egg-laying salamander. The larval period is about 3.5 years, with metamorphosis occurring at 33 to 44 mm SVL. They become sexually active after another 1.0 to 1.5 years. See Nussbaum and others (1983) for further details.

Relation to Old-Growth and Potential Impact of Habitat Loss

Rhyacotriton spp. are relatively widespread in the Pacific Northwest and are most likely to occur in or adjacent to higher order, cold streams in forested areas. They seem to be sensitive to land management practices and have associations with old-growth forest conditions. Corn and Bury (1991) captured significantly more torrent salamanders in old-growth stands than in mature or young stands. Welsh (1990) and Welsh and Lind (1991) also found these salamanders to be significantly more abundant on old-growth forest sites. Although Bury and others (1991b) did not find these salamanders to be associated with forest age, they reported a trend of increasing densities with forest age class. Associations with forest moisture class were not found (Bury and others 1991a, Corn and Bury 1991).

Thomas and others (1993) considered these salamanders to be sensitive to increased temperatures and sedimentation. They suggested mitigation measures of buffer zones on small streams and headwaters, and identified torrent salamanders as being closely associated with old-growth forest conditions. The viability of these four species was rated to be at medium to high risk under four to five forest management alternatives considered (Thomas and others 1993). The FEMAT (1993) report identified the Columbia torrent salamander, in particular, to be at a relatively higher risk of extirpation. Having only approximately 6 percent of its range on Federal lands, land management practices on state and private lands are of concern for this species (FEMAT 1993). Marshall and others (1992) list these salamanders as having Sensitive status in Oregon due to the effects of logging, and the Olympic salamander was classified as a State Monitor species in Washington in 1992. Lehmkuhl and Ruggiero (1991) gave *Rhyacotriton* spp. a high-risk score.

Clouded Salamander *(Aneides ferreus)*

Description

This is a moderately sized lungless salamander. Adults may be 80 mm SVL (Nussbaum and others 1983, Stebbins 1985, Wake 1966a). The toes have square tips, and the animals have a light gray venter with a darker mottled dorsum. The mottling is infused with many guanophores of various colors. The limbs are longer than those of the black salamander. According to Wake (1966a), adults can be classified into two different color phases, but Beatty (1978) found no evidence of this phenomenon. The jaw muscles are enlarged in males, thereby giving the head a more triangular appearance in comparison to females (Nussbaum and others 1983). These salamanders are arboreal with prehensile tails (Wake 1966a). Although no subspecies are recognized (Nussbaum and others 1983; Stebbins 1985; Wake 1966a, 1966b), morphological (Beatty 1978) and cytological (Kezerand Sessions 1979, Sessions and Kezer 1987) data suggest that there may be two distinct forms: the California-Vancouver group and the Oregon group. Vancouver Island populations are more similar to California populations than to those found in Oregon. Detailed reviews of clouded salamanders are presented by Wake (1966a, 1966b, 1974).

Range and Habitat

Clouded salamanders are found from Sonoma County, California, north to the Columbia River. They can be found from sea level to nearly 1700 m. They are not found in the state of Washington, but disjunct populations occur on Vancouver Island, British Columbia.

Aneides ferreus is a forest salamander (Nussbaum and others 1983) associated with two microhabitat types in the Pacific Northwest: rock-faces (talus) and logs. They use two different age classes of large downed logs. In one case, the animals use the space between the bark and the wood in relatively young logs that are just beginning to decompose. Older logs in later stages of decomposition, but with intact outer portions, can be important refuges (Beatty, personal observation; see also Bury and Corn 1988a; Gilbert and Allwine 1991). Such logs provide nest sites and refuges with suitable moisture and temperature regimes for salamanders. Corn and Bury (1991) showed that clouded salamander densities were positively correlated with log decay class and were found most often in Douglas-fir *(Pseudotsuga menziesii* (Mirb.) Franco) logs, under the bark or inside the log.

Ecology and Behavior

Storm (1947) described the morphology of clouded salamander eggs and young. Female clouded salamanders produce egg clutches every other year (Beatty, personal observations). The clutch size ranges from 8 to 24 (Nussbaum and others 1983), and averages about 18 on Vancouver Island (Stelmock and Harestad 1979). Eggs are deposited in decaying logs or in rock crevices and most often are guarded by adults of both sexes (Nussbaum and others 1983, Stebbins 1985, Beatty, personal observation). There is one record of a communal nest discovered on Vancouver Island. Males become mature in their third year and females in their fourth.

Agonistic encounters among *A. ferreus* involve aggressive and submissive behaviors common to other *Aneides* and *Plethodon* species (Staub 1993). Escalated aggression may involve biting that could lead to injury. Staub (1993) found scars present on 31 of 98 clouded salamanders captured and suggested that aggression was common in nature. Males had a higher frequency of scarring than females, with more scars on the head and fewer on the tail than expected.

In a study of chemical communication among salamanders, Ovaska and Davis (1992) concluded that clouded salamanders did not seem to distinguish odors of fecal pellets. They found some differences, however, between the sexes in time spent inside burrows marked with fecal pellets. The use of chemical signals by clouded salamanders for spacing, territoriality, and reproduction needs further study.

The prey of this species consists almost exclusively of arthropods, as prey size is probably gape-limited (Storm and Aller 1947, Whitaker and others 1986). Clouded salamander diets can include a high proportion of ants: ants were found in over half of the stomachs from Oregon specimens (N = 63), and ants comprised the main part of the diet of specimens from Vancouver Island, British Columbia (Nussbaum and others 1983).

Relation to Old-Growth and Potential Impact of Habitat Loss

Clouded salamanders do not appear to be an old-growth obligate, but suitable habitat can be found in older stands. Gilbert and Allwine (1991) found over 90 percent of their captures (N = 50) in mature and old stands (>80 years old). In contrast, Welsh and Lind (1991) surveyed 240 individuals and found no association with forest age. They found, however, that clouded salamanders were associated with cool moist forest conditions, presence of seeps, canopy cover, and decayed woody debris. Woody debris associations also were reported by Corn and Bury (1991). Gilbert and Allwine (1991) found associations with fern cover.

In Oregon, these salamanders are considered Sensitive species due to loss of large, decaying, downed snags from timber management practices (Marshall and others 1992). Lehmkuhl and Ruggiero (1991) suggested that clouded salamanders were species of high risk. Thomas and others (1993) identified clouded salamanders as being closely associated with old-growth forest conditions, and their viability was rated at medium to high risk under three of the five forest management alternatives considered.

Black Salamander *(Aneides flavipunctatus)*

Description

Adult black salamanders are moderately large plethodontids (to 93 mm SVL). Their limbs are relatively short, and toes are not flattened (Lynch 1974, Nussbaum and others 1983, Stebbins 1985). The strengthened head and jaw morphology of *Aneides* distinguishes it from other plethodontids. The dorsum of most individuals is black, and sometimes conspicuous white spots are present. Juveniles are brassy green in color, and adults, in certain populations in the northwestern portion of the species' range, retain much of the juvenile coloration (Larson 1980, Lynch 1981). Most authors (Lynch 1981, Stebbins 1985) recognize two subspecies, *A. f. flavipunctatus* and *A. f. niger.* A detailed description of the species is presented by Lynch (1974) and Wake (1974).

Range and Habitat

The range of this species *(A. f. flavipunctatus)* extends from just north of the San Francisco Bay area through much of northwestern California. It barely enters extreme southwestern Oregon in the Applegate Valley, Jackson County, Oregon. Disjunct populations assigned to *A. f. niger* can be found south of San Francisco Bay in Santa Cruz, Santa Clara, and San Mateo Counties, California.

This species is probably the most "aquatic" of the genus, which has three west coast species (Nussbaum and others 1983, Stebbins 1985). It can be collected very close to creeks and streams as well as in talus associated with roads. Away from free water, this animal can be found usually on the ground under logs, bark, and other types of surface debris (Lynch 1981). Lynch (1974, 1981) noted that the southern subspecies is active year-round, whereas northern populations are active on the surface only when moisture and temperature are not limiting (fall, part of winter, and spring).

Lynch (1974, 1981) reported populations from sea level to about 1000 m, and Nussbaum and others (1983) reported collections to at least 1700 m. The black salamander is sympatric over much of its range with the other western *Aneides (ferrous* and *lugubris)* but does not exhibit arboreality as do the latter two species.

Ecology and Behavior

Little is known about reproduction. Females seem to mature at about 56 mm SVL and males at about 50 mm. Ten eggs is the average clutch size (Nussbaum and others 1983). Leonard and others (1993) report a female attending a nest of 15 eggs in July in Santa Clara County, California. The nest was subsurface about 38 cm. Like most plethodontids, females probably produce a clutch of eggs every other year. Mating most likely occurs in fall and spring.

Behaviors displayed during agonistic encounters were studied by Staub (1993). Both males and females displayed agonistic, defensive, and submissive behaviors. Aggressive displays included contact behaviors that could potentially inflict injuries. For example, these salamanders exhibited a forceful bite-hold behavior during which the aggressor pinned the other animal. Field-captured individuals showed a high frequency of scarring (35 percent scarred, N = 244), thereby suggesting that aggression is common in nature (Staub 1993).

Analysis of feeding habits has not been documented. Based on the food items found in stomachs of closely related species (Whitaker and others 1986), black salamanders are probably opportunistic feeders on small arthropods.

Relation to Old-Growth and Potential Impact of Habitat Loss

Black salamanders may be somewhat dependent on old-growth, especially in the northern portion of the range. Much of the literature reports that these animals are found in coniferous forests, especially in areas close to streams (for example, Marshall and others 1992). Welsh and Lind (1991) found black salamanders (N = 62) did not have a significant association with forest age (young, mature, and old stands) but were most abundant in mature stands. Thomas and others (1993) included black salamanders on their list of close associates with old-growth forest conditions and rated their viability to be at medium to high risk in two of the five management alternatives. Riparian reserves could offer protection for this species because they are often found close to creeks and streams. This species is listed as Sensitive in Oregon due to its limited range and its need for status clarification (Marshall and others 1992).

California Slender Salamander *(Batrachoseps attenuatus)*

Description

This species has a distinctive wormlike appearance. It has a slender body, measuring 3.1- to 5.2-cm SVL (Maslin 1939, Stebbins 1985), and a long tail that can be two times its SVL and 50 percent of its biomass (Hendrickson 1954, Maiorana 1977b). Maslin (1939) found the average total length of 79 females was 9.9 cm (range of those with intact tails 7.1 to 13.6 cm, N = 74). There are 18 to 22 costal grooves (Nussbaum and others 1983). The legs are short, with 10 to 12 costal folds between adpressed limbs (Stebbins 1985). In California, variation has been observed in tail per SVL and limb per SVL ratios (Hendrickson 1954). In comparison to congeners, this species has a narrower head, shorter limbs, and longer body and tail (Hendrickson 1954, Maiorana 1976). There are four toes on both the front and hind feet, characteristic of the genus *Batrachoseps.*

There is sexual dimorphism of the head and neck. Relative to females, the male lower jaw is more pointed, the snout is narrow and more square, and the premaxillary teeth are larger, projecting beyond the edge of the closed mouth (Stebbins 1985). Male premaxillary teeth and neck muscles become larger during the summer as male breeding morphology develops (Maiorana 1977b).

Color variation was described by Hendrickson (1954). Ventral ground coloration is dark brown, gray, or black with fine white speckling. The ventral portion of the tail may be lighter than the belly (Stebbins 1985). A dorsal stripe may be present, with its coloration differing geographically, ranging from reddish brown, brown, and tan, to yellowish. In the redwood belt of northwestern California, dorsal stripes are generally reddish, whereas in Curry County, Oregon, they appear to be dull gray (Nussbaum and others 1983). Along the northern California coast, a black border runs down each side of the dorsal stripe (Hendrickson 1954).

In comparison to adults, juveniles have relatively longer limbs (Nussbaum and others 1983), larger heads, and shorter tails and trunks (Maiorana 1976). For example, juvenile tails can be 50 percent shorter relative to their SVL than adults (Maiorana 1976). Young may weigh 0.01 to 0.02 g (Maiorana 1976) and hatchlings are 1.6 to 1.7 cm in total length (Nussbaum and others 1983).

Maslin (1939) and Storer (1925) provided details of *B. attenuatus* eggs and nests. Eggs are about 4 mm in diameter, spherical, unpigmented, and are surrounded by a capsule adding 2 mm to the egg diameter. The capsule is comprised of three layers: the outer layer is damp and tough, the middle layer is a semirigid jelly, and the inner layer is a viscous jelly. Eggs are deposited in a continuous chain, attached by gelatinous strands measuring about 12 mm long. The strands can break, thereby leaving a gelatinous peduncle on one side of an egg and a gel remnant on the other side. From the examination of ovarian egg development in females from counties near San Francisco Bay, a single female seems to lay about 12 eggs in a clutch (Maslin 1939). In contrast, Maiorana (1976) reported that females produced 4 to 5 eggs per year in a forest habitat and 7 to 8 eggs per year in a woodland habitat. Communal nests of up to 74 eggs have been found (Maslin 1939).

Range and Habitat

The California slender salamander occurs along the coast from central California to southwestern Oregon, south of the Rogue River in the western half of Curry County (Leonard and others 1993). It also occurs in the Sierran foothills of California, from the American River drainage to Big Chico Creek, and in disjunct populations in the Sacramento Valley and Shasta County, California (Stebbins 1985).

Throughout its range, this salamander occurs in various habitats, including! grassland, chaparral, woodland, and forest (Stebbins 1985). In northwestern California and southwestern Oregon, it occurs in humid coastal redwood or mixed-evergreen forests (for example, Leonard and others 1993, Nussbaum and others 1983). In northwestern California, Welsh and Lind (1991) found that abundance was negatively associated with elevation and distance from the coast. These salamanders are semifossorial (for example, Maiorana 1976). They can be found under surface debris (stones, boards, logs, and leaf litter) in damp, shady locations (Hubbard 1903), or in wet conditions (Storer 1925, Hendrickson 1954, Maiorana 1976). In dry conditions, they retreat underground (Storer 1925) or within large woody material (Leonard and others 1993). They are apparently unable to create their own burrows, relying on existing subsurface crevices and burrows (Hendrickson 1954, Maiorana 1976, Storer 1925).

Ecology and Behavior

California slender salamanders are active on the surface from fall to spring during suitable moisture and temperature conditions (for example, Maiorana 1976). Suitable surface conditions on the north coast of California occur during the wet season, beginning in September to November and lasting an average of 8 to 9 months (Maiorana 1976). Both increased humidity and rain may induce salamander surface activity (Hendrickson (1954). Dessication is probably an important source of mortality for this salamander (Maiorana 1977a, Storer 1925). Hendrickson (1954) found that *B. attenuatus* was less active at temperatures below about 10 °C. The reduced lipid storage areas of smaller salamanders (for example, smaller tail per SVL ratios) may result in their being energetically disadvantaged relative to adults and subsequently more active during suboptimal conditions of low temperatures or rainfall to continue feeding (Maiorana 1976). Both diurnal and nocturnal activity have been observed. Cunningham (1960) considered these animals to be photophobic to strong illumination.

Oviposition occurs in fall, with hatching occurring in spring (Maiorana 1976, Maslin 1939). Climate affects hatching time and juvenile growth (Maiorana 1976). In forests, reproductive maturity is at 3.5 years and 82 percent of the females reproduce every year with four to five eggs each (Maiorana 1976). In apparently more favorable woodland habitat, maturity is a year earlier and clutch sizes are seven to eight eggs (Maiorana 1976). Communal nests can occur, probably in areas where suitable nesting sites are scarce (Maslin 1939). Maslin (1939) reported females near newly deposited eggs, although brooding is not known for this species (Maiorana 1976).

This salamander lives several years and seems to be generally sedentary. The adult lifespan seems to be 2 to 6 years (Maiorana 1976) and some individuals may live for 10 years (Hendrickson 1954). In a 2-year mark-recapture study in Berkeley, California, Hendrickson (1954) found low dispersal: 59 percent of recaptures did not move from a "home" cover piece, around which their "normal cruising radius" was estimated to be about 1.5 m. Hendrickson mapped the nonexclusive home ranges of these salamanders. Cunningham (1960) suggested that the home range of *Batrachoseps* was a function of both body size and microenvironment. Territoriality is not known for these animals (Cunningham 1960).

Microhabitat provided by cover objects seems to be important for this species. Welsh and Lind (1991) reported that *B. attenuatus* in forests were associated primarily with downed woody material such as logs, snags, and bark. Such cover or other types of physical habitat complexity can provide refuge from unsuitable temperature and moisture conditions (for example, Bury 1983, Maiorana 1977a). These salamanders often are found in pairs under the same cover object (Nussbaum and others 1976). Cunningham (1955) found *B. attenuatus* up to about 2.1 m above the ground between tree trunks and loose bark. Population densities up to one individual per 1.5 m^2 have been reported (Nussbaum and others 1983).

The tail of the California slender salamander has received much attention with regard to its autotomy and function. Hubbard (1903) stated that these salamanders drop their tail readily. Maiorana (1977a) stated the opposite after a mark-recapture study during which salamanders were handled without the incidence of tail loss. However, Maiorana (1977b) reported that 28 to 48 percent of the salamanders at her study site in Berkeley, California, had tail breaks annually. She found no sex or size differences in tail-loss frequencies. Hubbard (1903) reported that tail breaks could occur at any point along the length of the tail by a mechanism of unlocking/the vertebrae, rather than a break in the centrum as in lizards. Maiorana (1977b) found that tail loss exceeded 30 percent of the tail only half of the time. Hendrickson (1954) measured tail regeneration rates and found that they averaged 1.3 mm per month (range 0.7 to 2.6 mm per month) over a 2-year period, a rate that greatly exceeded SVL growth. In a laboratory experiment, Maiorana (1977b) removed tails of test animals and found tail regeneration was 2.6 mm per month when salamanders were kept unfed at 13 °C.

The tail is a site for energy storage, providing important reserves for maintenance, growth, and reproduction. Maiorana (1977b) presented three lines of evidence that suggest tail loss inhibits reproduction. First, breeding failure was associated with tail breakage: adults that failed to breed in three habitat types (redwood forest, conifer woodland, and eucalyptus woodland) had shorter tails than breeding adults of similar trunk length. Second, tail loss was associated with delayed maturity: immature salamanders that were of similar trunk length to breeding adults had shorter tails. Third. tail loss was associated with reduced reproductive output (ovarian egg number and male neck musculature). Maiorana (1977b) found that the mean tail volume of adults decreased by 29 percent during the dry season when there is no feeding, yet females are producing eggs and males are developing breeding morphology. Egg production is done in increments and one to several ova may be resorbed if tails are short or thin (Maiorana 1976). From 20 to 30 percent of the variation in clutch size Was explained by female tail length and tail fatness (Maiorana 1976).

Predators and prey—This salamander probably feeds at the surface in moist conditions (Hendrickson 1954, Maiorana 1976) when prey are apparently more available (Maiorana 1978). The diet is primarily small invertebrates. Several studies have found prey to include mites, flies, springtails, and snails (for example, Adams 1968, Bury and Martin 1973, Lynch 1985, Maiorana 1978). Additional prey include aphids and thrips (Maiorana 1978), amphipods (Nussbaum and others 1983), millipedes (Leonard and others 1993), earthworms, beetle larvae, and weevils (Storer 1925). Bury and Martin (1973) examined the stomach contents of 36 *B. attenuatus* and found about 11 items in each individual, a relatively large number of small prey in comparison to some other salamanders. The dominant food items were springtails (23 percent of items), mites (23 percent), spiders (17 percent), adult flies (14 percent) and snails (12 percent). Feeding may be selective by prey size and taxon (Maiorana 1978), and larger individuals seemed to eat larger prey (Lynch 1985, Maiorana 1978). Lynch (1985) compared the prey sizes of *B. attenuatus* and three sympatric plethodontid salamanders and suggested that they partition their prey by size; prey sizes were more different than would be expected from salamander body-size differences alone. Digestion is slow, and prey may remain in the stomach for several days (Maiorana 1978).

Natural predators are not well known. Cunningham (1960) reported that ring-necked snakes *(Diadophis punctatus)* feed primarily on slender salamanders. In a laboratory study, Hubbard (1903) found that a garter snake *(Thamnophis elegans)* and a ring-necked snake ate these salamanders with slight gaping, a general response to distasteful prey (Hubbard 1903). One snake regurgitated after eating three to four *B. attenuatus.* Although glands are present all over the skin of this salamander, they exhibited relatively little poison secretion during predator attacks. In captivity, garter snakes, king snakes, and a mockingbird were reported to have died after eating *Batrachoseps* (for example, Cunningham 1960). Maiorana (1977a) found a slender salamander carcass apparently partially eaten by flatworms.

In addition to tail autotomy (for example, Maiorana 1977a) and skin toxins (for example. Cunningham 1960), behavioral displays may provide predator escapes for this salamander. When disturbed in nature, this salamander usually assumes and can remain in a coiled position (Brame and Murray 1968, Brodie and others 1974) or may rapidly curl and uncurl (Hubbard 1903, Storer 1925). Brodie and others (1974) considered coiling "immobility" and the coiling and uncoiling a "flash display." Immobility could reduce the likelihood or intensity of predator attack, although data supporting this hypothesis are unavailable (Brodie and others 1974). Brodie and others reported that eight of nine salamanders found in the field were in immobile coils, and five of nine maintained an immobile posture for 10 minutes. Immobility seemed to be a precursor to active defensive behavior. Coiling could be mimicry of millipedes (Brodie and others 1974, for *P. larselli)* and is similar to snake postures (Brame and Murray 1968). Cunningham (1960) found that *B. pacificus* often attempted to coil around objects, after which they could be difficult to capture. Brodie and others (1974) reported that the flash display can propel a salamander along the ground and described an individual flipping 60 cm away and then freezing in an uncoiled position. Such rapid movement could confuse a predator. Cunningham (1960) noted that this behavior was used by juveniles more often than by adults.

Miscellaneous—California slender salamander erythrocytes are predominantly nonnucleated (for example, Eisen 1897, Emmel 1920, Villolobos and others 1988). Among nonmammalian terrestrial vertebrates, only some plethodontid salamanders have been found with this condition (Villolobos and others 1988). Emmel (1924) considered that enucleated red blood cells were related to the lungless condition. Villolobos and others (1988) found its occurrence in species with derived, diminuitive body features and relatively large cells.

California slender salamanders seem to have high salinity tolerance (Jones and Hillman 1978, Licht and others 1975). Licht and others (1975) found that the salinity tolerance of salamanders from beach populations naturally exposed to saline conditions was higher than inland populations. Inland salamanders were able to acclimate to 30 percent salt water solutions (about isosmotic with the blood), whereas beach salamanders survived for a month in 40 percent salt water solutions. Within populations, larger individuals had greater resistance to saline conditions, and previous exposure to low salinity increased tolerance to higher salinity conditions. Jones and Hillman (1978) examined saline tolerance and osmoregulation in this species. Their inland salamanders acclimated to 600 m-osmol NaCl and 400 m-osmol sucrose solutions. Saline acclimation involved sodium uptake and urea accumulation. After long-term saline exposure, urine urea concentration dropped from levels equal to plasma urea to one-fourth plasma levels. They found that when dehydrated, this salamander showed a water balance response by reducing urine production by 50 percent and increasing cutaneous uptake of water by twofold to threefold.

Relation to Old-Growth and Potential Impact of Habitat Loss

In northwestern California and southwestern Oregon, California slender salamanders are associated with older forest age classes and habitat features. Welsh and Lind (1991) found significantly fewer of these salamanders in young stands (<99 years) in comparison to mature (100-200 years) and old (>200 years) forest age classes. In terms of abundance, these salamanders were a dominant component of the 31 species ampled in this study: 1,046 of 6,419 individuals captured were *B. attenuatus.* Among 21 sites in the Coast Range, the greatest amount of variation in the abundance of these salamanders was explained by elevation and distance from the coast, both variables having negative associations with salamander numbers. Additional significant habitat variables associated with these salamanders included large trees, rock cover, small conifers, sound-log volume, and presence of seeps. During time-constrained searches, 89 percent of captures of this salamander were in association with logs, snags, and bark, and 11 percent were found among rocks or in the litter layer. Size and age of downed woody material (both conifers and hardwoods) seemed important for these animals: salamanders were captured more often than expected in association with the smallest size class of downed wood (0 to 0.5 m^2), the two largest size classes (5 to 10 and 10 to 25 m^2), and decay class 4 logs (completely on the ground, having little or no bark, and punky wood). Conversely, they were captured less often than expected in association with intermediate sizes of conifers (0.5 to 5 m^2), conifer decay classes 1, 2, and 3 (new treefalls to logs sagging near the ground with sloughing bark and no large branches), and hardwood decay classes 1 and 2 (new treefalls to slightly sagging logs with bark but no twigs). In Welsh and Lind's (1988) preliminary analysis, they identified a potential bias of sampling methods with regard to this species: although time-constrained searches yielded high numbers of captures in mature, old wet and old mesic stands, pitfall trapping captured fewer salamanders in old wet stands. They suggested that slender salamanders may have reduced surface activity in wet old stands because the relatively complex forest floor provides foraging opportunities in protected areas.

Two other studies reported *B. attenuatus* associations with forest age. During field collections in Humbolt County, California, Bury and Martin (1973) found *B. attenuatus* was common in an old-growth redwood forest and a secondary redwood-Douglas-fir forest, but few were captured in open areas of "abandoned pasture land, railroad line, and log landings that were cleared from the redwood forest." Bury (1983) reported that the abundance and biomass of *B. attenuatus* was associated with the age of redwood forests in northwestern California. He found that this salamander was 10 times more abundant in old growth (mean = 34 salamanders per 0.125-ha plot, range from 18 to 61) than in matched sites logged 6 to 14 years previously (mean 3.3 salamanders per 0.125-ha plot, range from 1 to 9). Bury found that logged plots had large numbers of cover items and concluded that cover supply was not responsible for the differences in amphibian abundances seen between the old-growth and logged stands. Rather, he attributed the differences to microclimatic, vegetational, and other changes associated with logging. For example, he suggested that areas opened by timber harvest are subject to greater light penetration to the forest floor which leads to increased soil temperatures and evaporative water loss, and greater variation in temperature and humidity. Such conditions could be unsuitable for the California slender salamander, a species for which Hendrickson (1954) proposed should serve as a more sensitive indicator of vital limits and of optimum climate than would most other urodeles.

Thomas and others (1993) considered *B. attenuatus* on their "long list" of species associated with old-growth forests but did not include it on their "short list" of close associates for viability assessment. Lehmkuhl and Ruggiero (1991) and FEMAT (1993) did not include this species in their viability assessments.

Oregon Slender Salamander *(Batrachoseps wrighti)*

Description

This is a medium-sized (37- to 56-mm SVL) salamander, with a usually reddish-brown, uneven-edged dorsal stripe from head to tail tip. The stripe fades to a duller color in older animals. Ground color of the back adjacent to the stripe and of the sides is black or dark brown. The ventral color is slate black, covered with large white flecks or spots. There are only four toes on the hind feet and 4.5 to 7.5 costal folds between adpressed limbs (Nussbaum and others 1983; Stebbins 1985; Storm, Beatty, personal observation). An unusual "giant specimen, collected near Crown Point in the Columbia Gorge, Oregon, measured 60.1 mm SVL and had a total length of 118.2 mm (Brame 1964). Hatchlings are about 14 mm SVL and 19 mm in total length.

Range and Habitat

An Oregon endemic, *B. wrighti occurs* along the forested west slopes of the Cascade Range from the Columbia River south to southern Lane County, and ranges in elevation from about 15 m in the Columbia Gorge to near 1340 m. The species recently has been collected in Wasco County, Oregon, extending its distribution east of the Cascade Range crest (Kirk and Forbes 1991, Nussbaum and others 1983, Stebbins 1985). This species frequents heaps of wood fragments, rotting logs and stumps, and recent lava flows (Nussbaum and others 1983, Stebbins 1954a).

Ecology and Behavior

Substrate temperatures where salamanders were found in May varied from 10.8 to 13.8 °C (Nussbaum and others 1983). Stebbins (1951) gives good details of his collection sites, indicating microhabitat preferences. Members of this species often are found clumped, with two or more being together under the same object. When disturbed, they usually coil the body in a watchspringlike coil, and if further disturbed, they flip about violently by coiling and uncoiling the body. If seized by the tail, *B. wrighti* can shed it at any segment. Near Hidden Lake, Lane County, 13 percent of the adults lacked tails or were regenerating them (Nussbaum and others 1983; Stebbins 1951; Storm, Beatty, personal observations), thereby suggesting high predation pressure.

Reproduction—Adult females examined in April, May, and early June usually had large eggs, and many contained spermatophore remnants in their cloacae (Nussbaum and others 1983). Stebbins (1951) collected a gravid female on 21 April and later induced her to lay eggs on May 25 and 27. Individual eggs were connected by a slender gelatinous strand. Kept in a dark room at 12 °C, young hatched about 4.5 months after laying. Females have been found with their clutches during April, May, and June in hidden nests under bark and in decaying logs (Nussbaum and others 1983, Stebbins 1951). Tanner (1953) reported egg sizes to average about 8.5 mm in diameter. Clutch sizes range from 3 to 11 (mean 6.3) eggs, based on 38 gravid females. Clutch frequency is unknown. Females mature at about 35 mm SVL and males at around 33 mm SVL (Nussbaum and others 1983).

Relation to Old-Growth and Potential Impact of Habitat Loss

The Oregon slender salamander probably is most common in mature fir forests on west slopes of the Cascade Range but also occurs in second-growth forests and in fairly recent lava flows a few miles west of Santiam Pass, Linn County. They seldom are found in clearcuts but have been collected under surface debris in open second-growth forests during a damp spring. *Batrachoseps wrighti* also is found under the bark of decaying fir logs or deep within such logs (Nussbaum and others 1983; Storm, Beatty, personal observations). In late spring and summer, they retreat to underground refugia (Nussbaum and others 1983).

Bury and Corn (1988a) found *B. wrighti* in damp to wet old-growth, in mature forests, and in clearcuts. Within these areas, they found 62.3 percent inside logs and 87 percent in or near logs (under bark, etc.). To quote Bury and Corn, 'The Oregon slender salamander seems to be associated with coarse woody debris in older decay classes, which is a characteristic feature of old-growth forests." Gilbert and Allwine (1991) also found this salamander to use older decay classes of logs. Herrington (1988) observed *B. wrighti* in talus habitats more often than in nontalus. They may live their entire life cycles within talus habitats (Herrington 1988). Gilbert and Allwine (1991) found these salamanders to be twice as abundant in mature and old stands, in comparison to young forests (30 to 80 years old). They reported that Oregon slender salamanders were associated with the wet portion of the moisture gradient in the Oregon Cascade Range and were negatively associated with grass cover.

This species has Sensitive status in Oregon due to timber management practices (Marshall and others 1992). Thomas and others (1993) considered this species as an old-growth associate of medium to high risk in two of five management alternatives. Lehmkuhl and Ruggiero (1991) gave this salamander a high-risk score. Retention of downed woody material was proposed as a mitigation measure for this species by the FEMAT (1993) report. Further studies of the precise ecological requirements of *B. wrightiare* needed.

Ensatina *(Ensatina eschscholtzii)*

Description

Ensatina is a medium-sized (62- to 75-mm SVL) plethodontid salamander, recognized by its basally constricted tail (Nussbaum and others 1983, Stebbins 1985). Males have an enlarged upper lip (Stebbins 1985) and longer, slimmer tails than those of females (Nussbaum and others 1983, Stebbins 1985).

Ensatinas are polytypic and have been used by many students of evolutionary biology as a classic example of a Rassenkreis or "ring species" (Wake and others 1986). Currently, seven subspecies are recognized: *eschscholtzii, croceater, klauberi, oregonensis, platensis, picta,* and *xanthoptica* (Wake and Yanev 1986). *Ensatina eschscholtzii* exhibits relatively elevated levels of genetic variation as revealed by starch-gel electrophoresis (Wake and Yanev 1986, Wake and others 1986). The color of these animals is highly variable (Stebbins 1954a, 1954b, 1985) and can be classified into two groups: blotched and unblotched (sensu Stebbins 1949). For purposes of this document, discussion will concentrate on the unblotched subspecies *oregonensis* and *picta,* and the blotched subspecies *platensis.*

Eggs are about 4 to 7 mm in diameter. Hatchlings are about 20 mm SVL and have a bluish ground color with many different colored guanophores (pigment cells; Nussbaum and others 1983; Stebbins 1954a, 1954b, 1985).

Range and Habitat

The subspecies *oregonensis* ranges from southern British Columbia south to Sonoma County, California. The subspecies *picta* is found in extreme northwestern California and adjacent areas in coastal Oregon. The subspecies *platensis* occurs in the Sierra Nevada, but intergrades between it and *oregonensis* may occur as far north as Jackson County, Oregon (Nussbaum and others 1983).

In northern parts of their range, these animals are found in coniferous and deciduous forests of different ages (Nussbaum and others 1983; Stebbins 1985; Storm, Beatty, personal observations). In these habitats, they can be found under surface debris, in decaying logs, and in small mammal burrows. They also can be collected in and around clearcuts, log landings, and along readouts in stabilized talus or under surface debris. As climatic zones shift south and east of the San Francisco Bay area, the salamanders are associated with oak chaparral (Nussbaum and others 1983; Stebbins 1954a, 1985).

Ecology and Behavior

These animals are active when temperature-humidity regimes are favorable (cool to mild and wet). In west-central Oregon, they can be found from the beginning of the rainy season in the fall through late spring. At the onset of the dry season, Ensatinas retreat underground probably via root paths, seeps, or animal burrows to moist cool refugia (Nussbaum and others 1983; Stebbins 1954a, 1985; Storm, Beatty, personal observations).

Courtship occurs in fall and spring, taking place on the surface at night (Stebbins 1954a, 1985). Their courtship behavior has been termed "rather typically plethodontid" by Nussbaum and others (1983) and begins as the male rubs a female with his chin and nose. followed by the female straddling the tail of the male and picking up a spermatophore deposited on the substrate by him with the lips of her cloaca. Oviposition occurs underground in spring. Females guard the eggs, and the eggs are incubated through late spring and summer. Hatching occurs about 3 to 5 months after the eggs are laid. Sexual maturity is attained during the third year (Stebbins 1954a).

Ensatinas have a distinctive defensive posture that involves arching their backs and tails when surprised. A white, noxious mucous is secreted from concentrations of poison glands on the tail. The basally constricted tail autotomizes readily, presumably allowing the animal to escape predation (Nussbaum and others 1983; Stebbins 1951, 1954a,1985).

These salamanders feed primarily on invertebrates, as do most other caudate amphibians (Altig and Brodie 1971, Nussbaum and others 1983). They are eaten by garter snakes and Steller's jays (Nussbaum and others 1983, Stebbins 1985).

Relation to Old-Growth and Potential Impact of Habitat Loss

These animals inhabit old-growth, yet they commonly are found in many other habitats in the Coast and Cascade Ranges. Welsh and Lind (1991) found that these salamanders were significantly more abundant in old stands than in young and mature forests. In contrast, Ensatina abundance did not differ with forest age class in other studies (Corn and Bury 1991, Gilbert and Allwine 1991). Aubry and Hall (1991) most often found them in young stands and dryer old-growth. Welsh and Lind (1991) found abundance decreased with increasing moisture in old stands. Gilbert and Allwine (1991) also found that Ensatinas were associated with dry forest sites; they were positively associated with bare soil and negatively associated with moss cover. Several studies show their associations with type and decay class of woody debris (for example, Aubry and Hall 1991, Corn and Bury 1991. Gilbert and Allwine 1991, Welsh and Lind 1991). Corn and Bury (1991) also reported an association with litter depth and rocky slopes. Welsh and Lind (1991) reported that these salamanders were associated with canopy cover.

Lehmkuhl and Ruggiero (1991) determined that Ensatina was at a relatively, low risk of extinction. Thomas and others (1993) considered Ensatina on their "long list" of species to evaluate as old-growth forest associates but not on their "short list" of "close associates" with old-growth forest conditions. The viability of Ensatina under the forest management alternatives considered by Thomas and others (1993) was not assessed.

Dunn's Salamander *(Plethodon dunni)*

Description

This is a moderately large (to 150-mm TL) salamander with two phalanges in the fifth hind toe and a greenish dorsal stripe, which may be more or less invaded by dark melanophores (Storm and Brodie 1970a). The dorsal band does not reach the end of the tail. Many small irregular flecks of the band color occur on the sides, which contrast with the brown or black ground color. Costal grooves number 14 to 16 (usually 15), and there are 2.5 to four (usually three) costal folds between adpressed limbs. Toes are unwebbed (Storm and Brodie 1970a).

Plethodon dunni is distinguished from sympatric congeneric species as follows: *P. elongatus,* faint red-brown dorsal stripe, 17 to 20 costal grooves; *P. larselli,* short fifth toe, red-orange venter; *P. vandykei,* yellowish dorsal stripe, usually 14 costal grooves, webbed toes; *P. vehiculum,* even-edged dorsal stripe extending to end of tail, usually 16 costal grooves (Storm and Brodie 1970a).

A melanistic variant of this species occurs in a limited part of its range, extending southwest from western Benton County into Lincoln County and northern Lane County, Oregon (the Mary's Peak salamander). These animals have no dorsal stripe as adults and are dark brown dorsally with up to 20 to 25 scattered flesh-colored areas about 0.5 mm in diameter (Storm and Brodie 1970a). Brodie (1970) designated this as a new species, *Plethodon gordoni.* Stebbins (1985) regarded it as an unstriped morph of *P. dunni,* as did Feder and others (1978), based on an analysis of allozyme variation. Nussbaum and others (1983) suggested that the two forms differed in more than color and believed critical evidence for two species would involve seeing if individual females can produce striped and unstriped young.

Range and Habitat

Plethodon dunni occurs west of the crest of the Cascade Range from Pacific County, Washington, southward through western Oregon to northern Del Norte County, California. It occurs in the Columbia River Gorge to at least 13.2 km west of Hood River, Hood River County. It ranges from sea level to about 1000 m (Leonard and others 1993), and is increasingly restricted coastward south of Lane County, probably by the hot dry summers. It is absent from most of the Willamette Valley, Oregon (Storm and Brodie 1970a).

Plethodon dunni is semiaquatic and is usually associated with rocks. It is found in moss-covered rock rubble or seepages, under rocks and logs on shady streambanks, or in moist talus (for example, Bury and others 1991b, Stebbins 1985). The salamanders retreat deep into rock crevices and burrows during hot, dry, or near freezing conditions. On warm (about 10 °C), moist or rainy nights, they may wander on the surface or can be found under surface debris. Substrate temperatures at collection sites averaged 10.4 °C (range 4.0 to 17.0 °C; Nussbaum and others 1983).

Plethodon dunni seems to have different microhabitat requirements than its similar sympatric congener, *Plethodon vehiculum.* Dumas (1956) found that *dunni* preferred a wet substratum (versus moist) and selected a narrower range of temperatures than its congener. The mean temperature selected by P. *dunni,* however, was not significantly different from that chosen by *P. vehiculum.* Dumas (1956) also found that these animals selected areas of about the same relative humidity when allopatric, but in sympatry, Dunn's may force the red-backed salamander to areas with lower humidities. *Plethodon dunni* seemed to have weak moisture perception, and in the absence of other strong stimuli, tended to move upslope (Dumas 1956).

Ecology and Behavior

The reproductive biology of this species is poorly known. Remnants of male spermatophores have been found in female cloacae in November (Beatty, Storm, personal observations) and in April and October (Nussbaum and others 1983). so courtship and mating may occur in fall and spring. Females with enlarged egg cells can be found in almost any month, thereby indicating a prolonged laying period (Nussbaum and others 1983). Stebbins (1951) induced a female to lay eggs in his laboratory in late May. Dumas (1956) found a grapelike cluster of nine eggs with a female *dunni* within a few centimeters of them on July 6. Taken to the laboratory, mold eventually destroyed the last embryo by September 10, at a SVL of about 16 mm.

Intraspecific and interspecific chemical communication was studied by Ovaska and Davis (1992). They found that *P. dunni* distinguished fecal pellet odors of conspecifics (males and females) and of *P. vehiculum,* but not of P. *vandykei.* Dunn's salamanders avoided burrows marked with conspecific pellets and defended home areas, thereby supporting the occurrence of territoriality in this species. Interestingly, Dunn's salamanders spent more time in burrows than other plethodontids examined; however, the biological significance of this was not examined. These salamanders occasionally destroyed fecal pellets of congeners, a behavior also observed in territorial *P. cinereus* (Jaeger and Home 1988). Ovaska and Davis (1992) suggested that fecal pellet destruction could speed their odor evaporation, dissipating old territorial markers, and facilitating territorial marking by new, replacement pellets.

Relation to Old-Growth and Potential Impact of Habitat Loss

Plethodon dunni is probably widespread in Oregon forests of the Coast Range and northern Cascades, to about 760 m. It prefers wet substrates, usually streamside rocks, outcrops with crevices, or stabilized talus. Any habitat disturbances that deplete moisture and raise substrate temperatures will be harmful to these salamanders.

Dunn's salamander is not a strict old-growth associate. No difference in captures among forest age classes have been found (Bury and others 1991 b, Corn and Bury 1991). Corn and Bury (1991) found, however, that these salamanders were associated with steep slopes, presence of talus, and high latitudes. Gilbert and Allwine (1991) found associations of Dunn's salamander with fern cover, bare rock, and soil cover, and a negative association with grass cover. Corn and Bury (1989) found Dunn's salamanders occurred more often in logged stands when uncut timber was present upstream.

Lehmkuhl and Ruggiero (1991) determined that *P. dunniwas* at a medium risk of extinction. Dunn's salamanders were identified as close associates of old-growth forest conditions by Thomas and others (1993). Their viability was at medium risk under two of the five forest management alternatives considered. Riparian reserves would offer protection for this salamander. This is a State Candidate species in Washington, under status review.

Del Norte Salamander *(Plethodon elongatus)*

Description

Del Norte salamanders are characterized by a modal number of 18 costal grooves, a reddish dorsal stripe, and usually 6.5 to 7.5 costal folds between adpressed limbs in adults. Ground color is dark brown or black, and the even-edged dorsal stripe, when not obscured by dark pigment, usually extends to the tip of the tail (Brodie and Storm 1971). Maximum length is 73 mm SVL.

Plethodon elongatus can be distinguished from sympatric or adjacent species as follows: *P. dunni* (the only sympatric congener) has an irregular-edged green dorsal stripe and a shorter body (usually 15 costal grooves) with longer limbs (one to four costal folds between adpressed limbs); *P. vehiculum* is shorter than *elongatus* and usually has 3.5 to 4.5 costal folds between adpressed limbs; *P. stormi* usually has 17 costal grooves, four to 5.5 costal folds between adpressed limbs, a broader head, more teeth and olive-tan or yellowish-tan dorsal color (Brodie and Storm 1971).

Stebbins (1985) lists *P.* storm/as a subspecies of *elongatus.* This is based ion the finding of an apparent hybrid population between *P. elongatus* and *P. stormi,* about 14.5 km west of Seiad Valley, Siskiyou County, California (Brodie and Storm 1971). In this monograph, *P. stormi* is considered separately.

Range and Habitat

This salamander occurs in humid coastal forests from near Port Orford, Curry County and Powers, Coos County, Oregon, to near Orick, Humboldt County, California. It is found inland to near Salyer, Trinity County and Seiad Valley, Siskiyou County, California, from sea level to around 1200 m (Stebbins 1985).

The Del Norte salamander often is found in rock rubble of old riverbeds, road fills, rock outcrops, and moss-covered talus. It generally occurs in drier situations than does Dunn's salamander (Stebbins 1985). It occurs in upland habitat, slope valleys, and riparian areas (Thomas and others 1993). In a study of talus use by amphibians, Herrington (1988) found that *P. elongatus* occurred almost entirely in forested talus areas. It retreats to deeper crevices in talus during hot, dry conditions or cold periods, but may occur under surface objects during warm, wet weather.

Ecology and Behavior

Little is known of the ecology and behavior of this species. Stebbins (1951) pointed out that the ranges of *P. elongatus* and *P. vehiculum* do not overlap, and suggested that their niches may be too similar for them to coexist. Based on limited data, females lay eggs in the spring and remain with them in a hidden nest. Hatching seems to occur in the autumn. A female with 10 eggs in a grapelike cluster was found in late July, in a cavity under a redwood post (Livezey 1959). Eighteen gravid females from Siskiyou County, California, contained 3 to 11 (average 7.9) large eggs, averaging 5.1 mm in diameter (Nussbaum and others 1983).

Relation to Old-Growth and Potential Impact of Habitat Loss

Plethodon elongatus has a fairly limited distribution in southwestern Oregon and northwestern California. Within its range, it most often occurs in moist (not wet) situations, usually associated with talus or rock outcrops in older forests (Herrington 1988). Raphael (1988) found *P. elongatus* was most abundant in mature and old-growth forests. Abundance seemed correlated with a hardwood understory. Welsh and Lind (1988) found this species to have a higher abundance in older forest stands and a lower relative abundance on drier stands. Welsh (1990) considered the Del Norte salamander (along with the Olympic salamander and the tailed frog) to be a relictual species long-associated with elements of the Arcto-Tertiary Geoflora, because they now survive in older forests. Welsh and Lind (1991) found these salamanders to have significant associations with old-growth forests, and old-mesic stands, in particular. Rocky substrate was an important element associated with Del Norte salamander occurrence, and associations with woody debris size and decay classes were found (Welsh and Lind 1991). Welsh (1990) stated that the close association of *P. elongatus* with old-growth forests probably is due to the presence of microhabitat and microclimate factors that occur only there and that the species has evolved within habitats existing only in these forests. Raphael (1988) estimated that removal of old-growth fir forest within the range of *P. elongatus* would result in a 75-percent reduction of *P. elongatus.*

Thomas and others (1993) suggested that Del Norte salamanders needed specific conservation measures in the upland forest matrix, including protection of populations from ground-disturbing activities and canopy disturbance. They identified Del Norte salamanders as being closely associated with old-growth forest conditions, rating viability of these salamanders at medium to high risk under four of the five forest management alternatives they considered. The FEMAT (1993) report recommended protection of occupied sites as mitigation for this species. Del Norte salamanders are listed with Sensitive status in Oregon due to their dependence on old-growth forest conditions and their fragmented distribution (Marshall and others 1992).

Larch Mountain Salamander *(Plethodon larselli)*

Description

This salamander was first described as a subspecies of Van Dyke's salamander *Plethodon vandykei* (Burns 1954; see also Burns 1962). It is a small- to medium-sized plethodontid with a dorsal stripe varying in color from yellow to red and with moderate to heavy infusions of melanophores into the color of the stripe. There is only one phalange on the outer toe of the hind feet. The feet have a very small amount of webbing, and the venters of these animals range in color from pink to dark red (Burns 1964, Nussbaum and others 1983, Stebbins 1985).

This species seems closely related to *P. vandykei* based on most morphological features as well as its current range. Highton and Larson (1979), however, present biochemical evidence indicating that the closest phylogenetic relative may be *P. neomexicanus,* a Rocky Mountain relict from New Mexico. Both *P. larselli* and *neomexicanus* share at least one diagnostic morphological character, the single phalange on the outer toe of the back feet (Nussbaum and others 1983, Stebbins 1985).

Range and Habitat

The Larch Mountain salamander has a restricted range (Herrington and Larsen 1985). It is found primarily along a 60-km stretch of the Columbia River Gorge in Washington and Oregon. Aubry and others (1987) recently extended the range in two areas of the central Cascade Range of Washington. Within its range, this salamander seems to have narrow habitat requirements: stabilized talus ranging in size between 1 and 6 cm with soil deposits in the interstices. "Mossy talus protected by overstory canopy" may be important habitat features (Thomas and others 1993).

Ecology and Behavior

Little is known of the ecology of this salamander. Herrington and Larsen (1987) studied the reproductive biology of these animals and found that males become sexually mature at 3.5 years at SVLs of 39 to 42 mm. Females mature at SVLs >43 mm at age 4. Clutch size averages 7.33 (range: 2 to 12) and eggs may be deposited biennially or in cycles greater than 2 years. Courtship behavior has not been observed, but based on data presented by Herrington and Larsen (1987), mating occurs in fall and occasionally in spring. No clutches of eggs have ever been reported for this species. These animals seem to feed opportunistically on small invertebrates (Altig and Brodie 1971, Nussbaum and others 1983).

Relation to Old-Growth and Potential Impact of Habitat Loss

Herrington and Larsen (1985) make a solid case for a direct, dependent relation between this salamander and Pacific Northwest old-growth forests. For example, they write that one of their sites (Mabee Mines Road in Skamania County, Washington) occurred on two talus slopes separated by a creek. One talus slope had been clearcut 10 years before their study began, and no *P. larselli* were found on the cut-over area. In the intact forest within the talus slope directly across the creek from the cut slope, a population of Larch Mountain salamanders was found. *Plethodon larselli* has an extremely limited range and narrow habitat requirements. The species appears to be an old-growth obligate within most areas of its range.

Herrington and Larsen (1985) pointed out that the Columbia River Gorge is a geographic area with many potential land-use practices, several of which could be detrimental to populations of these salamanders. Any land-use practice impacting moisture regimes in suitable stabilized talus slopes probably will cause populations of *P. larsellHo* vanish. Logging, harvesting talus for road building, and housing developments could all adversely affect the status of this species. Maintaining canopy closure and avoiding ground disturbing activities is recommended for this species (Thomas and others 1993).

Despite having discovered new populations in Washington, Herrington and Larsen (1985) recommended that this species be listed as threatened. Marshall and others (1992) reported this to be a category 2 species on the U.S. Fish and Wildlife Service Notice of Review (U.S. Department of the Interior, Fish and Wildlife Service 1991). Lehmkuhl and Ruggiero (1991) gave this species a high-risk score. Larch Mountain salamanders were viewed as close associates of old-growth conditions by Thomas and others (1993), and their viability was at medium to high risk under all five forest management alternatives they considered. Protection of occupied sites has been recommended as a mitigation measure for this species (FEMAT 1993).

Siskiyou Mountains Salamander *(Plethodon stormi)*

Description

This is a short-limbed, long-bodied *Plethodon,* closely related to *P. elongatus,* with a modal number of 17 costal grooves, an olive-tan dorsal stripe in juveniles and usually four to 5.5 costal folds between adpressed limbs in adults. Ground color is black in juveniles, but light purplish-brown in adults. An olive-tan dorsal stripe usually extends to midway on the tail. Light flecking is very heavy on the head, sides, and limbs. Hatchlings measure 17 to 18 mm SVL. Mean SVL of 62 mature males was 58.9 mm (47.2 to 69.8 mm) and of 41 females, 61.9 mm (56.0 to 69.9 mm; Nussbaum and others 1983). Brodie (1971) found a large specimen measuring 76 mm SVL (see also Brodie 1970).

Plethodon stormi is distinguished from *P. elongatus* by the following characteristics: modal number of costal grooves, olive-tan dorsal stripe, relatively longer legs (usually four to 5.5 folds between adpressed limbs), light flecking on back, and a wider, shorter head (Brodie 1971). Individuals from about 14.5 km west of Seiad Valley, Siskiyou County, California, thought to be intergrades with *P. elongatus,* resemble *P. stormi* in some features, but the diagnostic characteristics of head shape and pigmentation indicate they are *P. elongatus* (Brodie and Storm 1971).

Range and Habitat

Plethodon stormi occurs in Jackson County, Oregon, and northern Siskiyou County, California. It is not sympatric with any other *Plethodon* but occurs within about 14.5 km of *P. elongatus* (Brodie 1971). Populations of *P. stormi occur* in forested habitats and are closely associated with talus deposits and fissured rock outcrops. Individuals occasionally may be found under forest floor debris, but only during the wettest weather and always near talus. Populations of *stormi are* most dense on heavily wooded, north-facing slopes with talus (Leonard and others 1993, Nussbaum and others 1983).

Ecology and Behavior

Soil temperatures where *P. stormi* have been collected during daytime were from 3.5 to 11.3 °C (mean 5.7 °C; Nussbaum and others 1983). Individuals are nearest the surface in spring (March to April) and fall (September to early November). Even in dry summer weather, however, some may come to the surface to feed at night. They often lie with their heads near the opening of their shelter and dart forward to snap up a moth or beetle. During wet weather, they may crawl over the surface of a talus slope (Nussbaum and others 1983).

Both sexes are thought to mature at 5 to 6 years of age (Nussbaum and others 1983). Males contain mature sperm in spring and autumn and should be capable of courtship and mating in both seasons. No evidence of spermatophores in the cloacae of females has been found. Limited data indicate that females lay every other year in the spring, probably depositing their eggs in cavities deep in talus (Nussbaum and others 1983). A sample of 37 mature females had 2 to 18 (mean 9.2) enlarged ovarian eggs. Eggs probably hatch in the fall (Nussbaum and others 1983).

Relation to Old-Growth and Potential Impact of Habitat Loss

This woodland salamander lives in more xeric habitats than other western *Plethodon* species, and most *Plethodon stormi* specimens are found on north-facing slopes or in heavily shaded areas (Brodie 1971, Nussbaum and others 1983). These animals require cool moist retreats which would be found where talus or other suitable rock forms occur in older forests (Leonard and others 1993), thereby making them susceptible to forest destruction.

This is a Sensitive Vertebrate in Oregon, where it has a restricted distribution and timber management has adverse effects (Marshall and others 1992). This species is listed as threatened in California. It is a category 2 species on the U.S. Fish and Wildlife Service Notice of Review (U.S. Department of the Interior, Fish and Wildlife Service 1991). Thomas and others (1993) recommended protection of all populations of Siskiyou Mountains salamanders by avoiding disturbance to talus and adjacent overstory trees, especially on moist north-facing slopes. Likewise, the FEMAT (1993) report recommended protection of occupied sites. Thomas and others (1993) identified Siskiyou Mountain salamanders as being closely associated with old-growth forest conditions and rated the viability of these salamanders at high risk under all five forest management alternatives they considered. A high-risk score was given to this species by Lehmkuhl and Ruggiero (1991).

Van Dyke's Salamander *(Plethodonvandykei)*

Description

This animal is a robust, long-legged plethodontid. It has 14 costal grooves and 0.5 to three intercostal folds between adpressed limbs (for example, Leonard and others 1993). It has moderately webbed toes and can have a jagged dorsal stripe. Parotoid glands are present but inconspicuous (Leonard and others 1993). Van Dyke's salamander is polymorphic. Ground color is either black, yellow, or pinkish (Brodie and Storm 1970. Nussbaum and others 1983, Stebbins 1985). Adults can reach 10.2 cm in total length (Leonard and others 1993). A detailed description of the species and a literature review are provided by Brodie and Storm (1970).

Historically, the species was thought to contain two subspecies, *P. v. vandykei* (all localities in Washington) and *P. v. idahoensis* (populations in northern Idaho and northwestern Montana, the Coeur d'Alene salamander). The Washington populations are variable in color, whereas the Rocky Mountain populations all have black ground color. Recently, Rocky Mountain populations have been found to be genetically distinct and have been recommended to be recognized as a full species *P. idahoensis* (Slater and Slipp) (Highton and Larson 1979, Howard and others 1993).

Range and Habitat

These salamanders exhibit a fragmented range from sea level to 1560 m (Nussbaum and others 1983). Populations in the state of Washington can be found in the Olympic Peninsula, the Willapa Hills, and the Cascade Range. Populations are patchily distributed and of low density (Brodie 1970, Brodie and Storm 1970). Not only are populations extremely fragmented throughout the range of this species, but in many areas with known populations, it is difficult to find animals except for brief periods in early spring and late fall.

Brodie and Storm (1970) suggested that *P. vandykei* is the most aquatic member of the genus. *Plethodon vandykei* can be collected along readouts in seepages under rocks and other surface debris and in headwater stream areas. They also can be collected at considerable distances from free water (Nussbaum and others 1983; Beatty, personal observation). In these situations, the salamanders can be found in stabilized talus well mixed with moist soil on north-facing slopes (Thomas and others 1993).

Ecology and Behavior

Sexual maturity occurs when animals measure about 45 mm SVL (Brodie and Storm 1970). Females with large developing ova may be collected at all times of the year. They probably oviposit every other year. Nussbaum and others (1983) reported that one nest discovered in the spring seemed to be very similar to other *Plethodon* nests. These salamanders probably oviposit in spring, females brood eggs during summer months, and young hatch in fall. According to Nussbaum and others (1983), courtship has been observed in spring, and females with spermathecae in their cloacae have been found in spring and fall. Lynch and Wallace (1987) observed complete courtship behavior in late summer and early fall (August to October) on wet rockfaces. The mating behavior was similar to that described by Stebbins (1954b) for *Ensatina.*

Predator-prey interactions are not well known for this species. In Rocky Mountain populations, aquatic insects are common prey of *P. idahoensis* in roadside seepages (Wilson and Larsen 1988).

Ovaska and Davis (1992) examined the use of odors for communication in Van Dyke's salamanders. They found that these salamanders distinguished fecal pellet odors of conspecific females and their congener *P. vehiculum,* but they did not distinguish fecal pellets of conspecific males. They suggested intraspecific and interspecific territorial defense was unimportant because *P. vandykei* did not avoid marked burrows, and laboratory observations suggest they have reduced home defense.

Relation to Old-Growth and Potential Impact of Habitat Loss

There is little recent published work on this salamander. Based on collections, reports in published works (Brodie 1970, Nussbaum and others 1983), and personal experience (Beatty, Storm, personal observervations) we believe that more natural history information is necessary to assess its relation to forest habitat conditions.

Although forest associations have not been well studied for this species, it can occur in old stands and is a species of concern due to its rarity. In Washington, this is a State Candidate species, under status review. Thomas and others (1993) recommended buffered habitats along headwater streams as protection measures for this species. They identified Van Dyke's salamander as being closely associated with old-growth forest conditions, and their viability was at high risk under all five forest management alternatives they considered. Lehmkuhl and Ruggiero (1991) gave this species a high-risk rating. In their risk assessment, the FEMAT (1993) report differentiated between Cascade Range and coastal-Olympic Peninsula populations. Although both groups were projected to be at risk of losses, Van Dyke's salamanders in the Cascade Range were rated with a greater likelihood of extinction.

Western Red-Backed Salamander *(Plethodon vehiculum)*

Description

Plethodon vehiculum is a medium-sized (to 115-mm total length) salamander with two phalanges in the fifth hind toe and usually an even-edged dorsal stripe. The stripe may be red, orange, yellow, green, or tan and extends to the tip of the tail. Some populations exhibit melanism or reduced melanism. The dark brown to black ground color is darkest along the stripe and lightens gradually ventrally. This ground color is not invaded by the band color on the sides. Costal grooves number 14 to 18 (usually 16) and there are three to 5.5 (usually four to 4.5) folds between adpressed limbs. The toes are unwebbed (Storm and Brodie 1970b).

Plethodon vehiculum can be distinguished from congeneric sympatric species as follows: *P. dunni,* dorsal stripe lacks an even margin and does not extend to tail tip, flecks of stripe color on sides of trunk; *P. elongatus,* shorter legs and more elongate body, with 6 to 8.5 costal folds between adpressed limbs; *P. larselli,* red-orange venter, short fifth toe on hindlegs; *P. vandykei,* 13 to 16 (usually 14) costal grooves, webbed toes, uneven stripe (Storm and Brodie 1970b).

Coastal populations of P. *vehiculum* usually have a relatively high degree of melanophore encroachment on the dorsal stripe and a high incidence of melanistic individuals. Groups with melanistic salamanders usually had many individuals, in which the entire dorsal area and sides resembled the band color (Brodie 1970).

Range and Habitat

This species occurs mainly west of the crest of the Cascade Range from southwestern British Columbia, including Vancouver Island, to the vicinity of Powers, Coos County and Rogue River, Curry County, Oregon. In Oregon, this species is;absent from the northern Cascade Range, except for a record near Boring, east of Portland; it occurs in the Cascade Range south of Oakridge, Lane County (Storm and Brodie 1970b).

Plethodon vehiculum is widespread in coniferous forests. It is often associated with relatively soft shale or sandstone outcrops and also inhabits decaying logs, burrows, bark piles and other surface debris. The species commonly is found on damp soil and less commonly in wet situations (Stebbins 1951). Considerable numbers were found in cleavage planes among dead leaves (Stebbins 1951).

Dumas (1956) compared the requirements of sympatric P. *vehiculum* and P. *dunni.* He found that *vehiculum* preferred a moist substratum (versus wet), selected a mean temperature of 10.4 °C and preferred a mean relative humidity of 89.1 percent, based on field measurements. Dumas also found that the western red-backed salamander had a weak moisture-perception ability and a tendency to move upslope in the absence of other strong stimuli. From this he inferred that during late spring and summer, as the moisture margin recedes deep into talus slopes and toward streams, the salamanders must stay near this margin to perceive it. If they wander too far from the moisture margin, mortality may occur.

Ecology and Behavior

Reproduction—In west-central Oregon, courtship occurs from November through early March, when temperatures are well above freezing. On Vancouver Island, British Columbia, mating seems to occur in October to November (Ovaska 1987). Eggs are laid in the spring, and development occurs during summer. Hatchlings emerging in fall are 13 to 15 mm SVL. Both sexes grow at a rate of about 10 mm SVL per year for the first 3 years. Males produce sperm every year, but females lay eggs every other year. Females near Corvallis, Oregon, lay 6 to 19 eggs (mean 10.4), and larger females lay significantly more eggs than smaller females (Nussbaum and others 1983). Mature eggs measure 4.0 to 5.0 mm in diameter (Nussbaum and others 1983, Peacock and Nussbaum 1973).

A nest site found in Lincoln County, Oregon, by Hanlin and others (1979) was located during May in moist stabilized talus at the base of a shear roadside basalt outcrop. Two clutches of eight and nine eggs were found about 12 cm apart, each attended by an adult; the sex of one adult was female and the sex of the other was undetermined.

Ovaska (1987) studied seasonal changes in agonistic behavior of western red-backed salamanders and found male-male aggression was escalated during mating. The behavioral repertoire of both males and females included agonistic (for example, biting and pushing), defensive, and submissive behaviors, although female agonistic behaviors occurred infrequently. Audible clicking sounds were produced by J'aw snapping, an apparent threat display. Dominant males usually were larger than subordinant males.

Relation to Old-Growth and Potential Impact of Habitat Loss

Plethodon vehiculum seems to be widespread through the forested areas west of the Cascade Range in the Northwest, with some studies showing associations with old-growth forest conditions. Corn and Bury (1991) showed that western red-backed salamander numbers were positively correlated with stand age, presumably because of the significant component of downed logs in older forest stands. In contrast, in the southern Washington Cascade Range, Aubry and Hall (1991) found more of these animals in younger forest stands. Likewise, Bury and others (1991 a) found these salamanders to be most abundant in young stands in the Coast Range. Aubry and others (1988) sampled 45 forest stands in the southern Cascade Range of Washington, ranging in age from 55 to 730 years, and encountered *Plethodon vehiculum* in all forest age and moisture classes. Occupied habitats range from rocky outcrops and talus accumulations to downed logs and other woody debris. They often are found on steeper slopes, in talus or under logs (Aubry and Hall 1991, Bury and others 1991 a, Corn and Bury 1991). They were captured most often in or under logs 10 to 30 cm in diameter and in intermediate stages of decay by Aubry and others (1988).

Lehmkuhl and Ruggiero (1991) considered *Plethodon vehiculum* to be a species at moderately high risk of extinction. Thomas and others (1993) considered western red-backed salamanders on their "long list" of species to evaluate as old-growth forest associates, but data were unavailable to consider them "close associates" with old-growth forest conditions. Their viability was not assessed by Thomas and others (1993).

Roughskin Newt
(Taricha granulosa)

Description

This is the only member of the family Salamandridae to occur in the Pacific Northwest. The conspicuousness of the roughskin newt may be tied to its toxicity and broad habitat use. It can be seen aboveground during the day in various aquatic and terrestrial habitats.

Generally, adults are easily recognized by their yellow-to-orange ventral coloration, lack of costal grooves, and rough, granular-appearing skin (Nussbaum and others 1983, Stebbins 1985). Dorsal coloration usually is unmottled, plain brown or olive, abruptly changing to the bright coloration on the ventral surface. Tan or black individuals have been described (Stebbins 1985), as well as a piebald morph (Nussbaum and others 1983) and scattered blotchy individuals (Stebbins 1985). Some newts in Crater Lake, Oregon, are all black below, the basis for previous subspecies classification of the Mazama newt (T. *g. mazamae,* Nussbaum and others 1983, Stebbins 1985). Aquatic adults can have smoother skin. appearing bloated in comparison to terrestrial-phase newts (Nussbaum and others 1983). This newt is the most aquatic species of its genus, and neotenic forms with rudimentary gills have been reported (Marangio 1978, Pimentel 1960).

Other key characteristics of adults are dark lower eyelids and relatively small eyes that do not extend to the edge of the head outline when viewed from above (Stebbins 1985). In comparison to other Pacific Northwest salamanders, the roughskin newt has unique tooth patterns. Adults have two longitudinally diverging (V-shaped) vomerine tooth rows in the roof of the mouth (Nussbaum and others 1983, Stebbins 1985). Larvae have no maxillary teeth (Nussbaum and others 1983).

Males are larger and may attain total lengths up to 184 mm, whereas females up to 154 mm have been recorded (Nussbaum and others 1983). Male tails and limbs are relatively longer than those of females, and male cloacal lips are larger and the cloacal opening longer than those of females (Nussbaum and others 1983). During the breeding season, males develop a suite of distinct morphological features: the skin becomes smooth, the vent becomes bulbous, the underside of the feet become darkened, and nuptial pads appear on the feet. Flattened male tails are reported by Stebbins (1985), whereas male tails were taller in one coastal Oregon pond (Janzen and Brodie 1989).

Eggs are laid singly on pond vegetation as firm, gelatinous capsules and can be scattered throughout a pond. The eggs are often attached to the undersurface of vegetation and under rocks (Pimentel 1952). Eggs are pigmented, tan dorsally and cream ventrally, and are about 1.8 mm in diameter. Eggs hatch in 20 to 26 days, and young are about 18 mm in total length at hatching after yolk absorption (Nussbaum and others 1983).

Pond larvae have light spots along their trunk which may be arranged in two rows, or spots may merge and appear as longitudinal stripes. Both front and hind limbs are present in pond larvae. Their long dorsal fin extends to their external gills or shoulders. They have five to seven gill rakers on the anterior side of their third gill arch. They may reach 75 mm at transformation at the end of their first summer. Where growing seasons are short, they may metamorphose during their second summer (Nussbaum and others 1983).

Range and Habitat

Roughskin newts range from southeast Alaska to central California, generally west of the crest of the Cascade Range, from sea level to 2800 m in elevation. They occur in a few ponds near Moscow, Idaho, and single specimens were reported in Montana and eastern Washington (Nussbaum and others 1983). Having both terrestrial and aquatic life history phases, they can occur in various habitats: farmlands, grasslands, woodlands, forests, ponds, lakes, and streams.

Ecology and Behavior

Reproduction—The breeding season varies geographically, but generally coincides with the warmer rains of late winter or early spring. Montane neotenic populations may breed in late fall (Marangio 1978). Suitable aquatic habitat for breeding may occur in ephemeral and permanent ponds and lakes, as well as streams in areas with slow-moving water. Pimentel (1960) reported that newts were more numerous in quiet water ponds and lakes than in streams. Quiet water with aquatic vegetation seems necessary for breeding, and sites with vegetation surrounding aquatic habitats may be preferred (Pimentel 1960). Males migrate to breeding ponds before females and leave ponds after females. Males seem to remain stationary until a female approaches (Janzen and Brodie 1989) and courtship begins.

Details of courtship behavior were described by Propper (1991) under controlled laboratory conditions. Three courtship stages were recognized: preinsemination, insemination, and postinsemination. Preinsemination involved male clasping of a female in dorsal amplexus with all four limbs, chin rubbing of the male submandibular gland over the female's nares, and male limb contractions. This stage lasted about 7 hours (range 40 minutes to 2 days) and probably induced sexual receptivity and synchronized male and female activities. Insemination was the mating stage of courtship. After fast male limb contractions, female raised head position, and air bubble expellation by both sexes, the male released his grasp of the female and positioned himself in front and perpendicular to her. The nares of the female were positioned near the cloaca of the male, and she moved to maintain this position as he moved. The male released a spermatophore onto the substrate and pivoted until the cloaca of the female was near the sperm gel capsule. She side-stepped until the sperm cap detached from the gelatinous base and adhered to her cloaca. The male resumed amplexus with the female during the postinsemination stage and remained clasped to her from 4 hours to 4 days. About a third of the pairs with a successful sperm cap transfer attempted a second transfer. Females receiving a second sperm cap apparently had absorbed the first. At natural breeding sites, females then deposit eggs singly on aquatic vegetation in quiet water.

Courtship can be interrupted by unpaired males which are commonly in excess at breeding ponds. Pond sex ratios can reach 50 males per female (Propper 1989). Pairs encountering an unpaired male are transported away from the potential intruder by the swift tail strokes of the male (Janzen and Brodie 1989). Displacement attempts by unpaired males resulted in multimale clasps of females on at least eight occasions in a single day of breeding (Janzen and Brodie 1989). Mating "balls" of multiple males clasping females have been frequently observed (Janzen and Brodie 1989; up to 20 males surrounding a female, Propper 1989). Janzen and Brodie (1989) conducted a 1-day field study and found size-dependent pairing patterns in breeding newts: non-pairing males were generally smaller than (1) pairing males, (2) males intruding in mating balls, and (3) males engaged in amplect mating balls.

Predators and prey—Newts are potentially important predators in aquatic systems. Larval diets are not well studied but may include zooplankton and aquatic invertebrates (Peterson and Blaustein 1991, 1992). Adults eat small invertebrates and vertebrates (Peterson and Blaustein 1991,1992). Their diet can include amphibian eggs *(Taricha, Ambystoma,* and *Rana,* Nussbaum and others 1983; and *Bufo,* Olson, personal observations) and larvae *(R. aurora,* Nussbaum and others 1983). Taylor (1984) suggested that the diet of the roughskin newt was similar to *A. gracile* in lakes where they co-occur. Although *A. gracile* numbers were reduced in lakes with trout, newt numbers were not affected by the presence of this potential predator (Taylor 1984). Due to their skin toxicity, newts are largely free of predators (Brodie 1968).

Skin toxin—The bright ventral coloration of the roughskin newt may be used as an aposematic (warning) display for antipredator defense. During attacks by predators, the roughskin newt may arch its back to show its brightly colored underside; this behavior is termed the unken reflex. The skin secretions of the newt contain tetrodotoxin, a highly poisonous neurotoxin also found in the puffer fish (Brddie 1968). Predation of newts by vertebrate predators is initially discouraged by their warning display, then by their distastefulness, and further by dramatic symptoms induced by the neurotoxin, including gasping, gaping, regurgitation, convulsions, and paralysis (Brodie 1968). Brodie (1968) investigated 30 species of potential newt predators and found small doses were lethal to most species of fishes, amphibians, birds, and mammals tested. He found only 0.0002 cc of back-skin killed white mice. Snakes were 200 times more resistant to the skin toxin, with garter snakes *(Thamnophis)* the least susceptible to the toxin. The common garter snake, *T. sirtalis concinnus,* was found to be the only potential predator examined that did not have fatalities upon consumption of adult newts. Human deaths have been reported from ingestion of a newt (for example, Bradley and Klika 1981).

Miscellaneous notes—Roughskin newts have been model study organisms in two fields of physiology: behavioral neuroendocrinology and cell biology. The courtship sequence of roughskin newts has been focal to the understanding of hormonal bases of reproductive behavior (for example, Moore 1990, Moore and Zoeller 1985, Propper and Moore 1991). The large size of roughskin newt lung epithelial cells have aided our understanding of cell motility (Cole and others 1991, Weaver and Hard 1985).

Field observations of large newt aggregations have been found in aquatic habitats and described as newt "rafts" (Nussbaum and others 1983). The development or significance of these aggregations has not been determined but seems unrelated to mating because they have been observed after the breeding season. Nussbaum and others (1983) report one dense raft in September to comprise 5,000 individuals in an area measuring 2 by 9.2 m.

Neotenic salamander populations seem to be associated with harsh conditions of the terrestrial environment (for example, Marangio 1978). Newts at Marangio's (1978) study site in the southern Oregon Cascade Range appeared to have the facultative ability for metamorphosis, rather than being permanently paedogenic.

Relation to Old-Growth and Potential Impact of Habitat Loss

Associations of newts with old-growth forests have been found. In the Coast Range of central Oregon, Corn and Bury (1991) reported a higher relative abundance of newts in old stands (150- to 525-year) than in mature (80- to 120-year) or young (40- to 75-year) stands. Similarly, Aubry and Hall (1991) found that roughskin newts were four to five times more abundant in old-growth forests (210- to 730-year) than mature (80- to 190-year) or young (55- to 75-year) stands in the southern Washington Cascade Range, and Welsh and Lind (1991) found a trend of higher abundances with forest age in northwest California and southwest Washington. Of 68 newts found by Raphael (1988) in northern California Douglas-fir forests, a trend of newt abundance with old-growth conditions was revealed although relative abundance estimates were low. In comparison to young forest age classes, <10 years, newt relative abundances were about doubled in forest age classes 50 to 150 years and >250 years, and quadrupled in forests 150 to 250 years.

In contrast, some studies have revealed newts were abundant in younger managed forests. Gilbert and Allwine (1991) found newts associated with young stands (30 to 80 years) in the Oregon Cascade Range and Corn and Bury (1991) found newt relative abundances were comparable between old-growth stands (150 to 525 years) and clearcuts (<10 years) along the central Oregon coast. These results indicate that associations with old-growth forests are not always straightforward. Factors other than forest age may contribute significantly to suitable habitat for roughskin newts.

Old-growth forest associations of roughskin newts seem to differ with forest characteristics including latitude, altitude, moisture conditions, and geographic location. Newts seem to have higher abundances at lower elevations (Aubry and Hall 1991, Bury and others 1991 a) and higher latitudes (Corn and Bury 1991, Gilbert and Allwine 1991). Newt associations with moisture conditions of old forests may be variable with location. In southern Washington, newts had lower abundances in wet old stands in comparison to moderate or dry old stands (Aubry and Hall 1991, Bury and others 1991 a). Along the Oregon coast, however, lower abundances were found in moderate moisture conditions (Bury and others 1991 a, Corn and Bury 1991) and in the Oregon Cascade Range, lower abundance was found in dry old forests (Bury and others 1991 a). General geographic trends in newt associations with forest conditions seem to be apparent: roughskin newts appear to have stronger associations with older forests in the southern Washington Cascade Range (Aubry and Hall 1991, Bury and others 1991 a) and the Coast Range, but not in the Oregon Cascade Range (Bury and others 1991 a).

Old-growth forests may offer important protected refugia for terrestrial individuals, yet terrestrial microhabitat requirements of the roughskin newt are not well known. Pimentel (1960) found surface activity of newts to be sporadic and associated with rainfall and favorable temperatures. Refugia may be areas offering suitable temperature-moisture regimes; they have been found subsurface under rocks, logs, bark, leaf litter, and in decaying wood (Nussbaum and others 1983, Stebbins 1985). Herrington (1988) found 5 of 37 *Taricha* in talus and suggested *Taricha* can use talus to survive adverse weather conditions and for winter dormancy. Roughskin newts probably can burrow (Pimentel 1960). Proximity of terrestrial refugia to breeding sites may be a critical component of roughskin newt suitable habitat (for example, Bury and others 1991 a, Welsh and Lind 1991). Newts generally emerge from subsurface sites and initiate land migrations during periods of rainfall and suitable temperatures before breeding in winter-spring and before winter dormancy in fall. Distance of terrestrial refugia from aquatic breeding sites may differ. Pimentel (1960) reported a male about 1.6 km from a surface water source, and considered any distance greater than about 0.4 km exceptional. He found that most newts went underground within 6 to 23 m of a pond. In contrast, Twitty (1966) reported that newts may move hundreds of meters to or from breeding sites. Twitty also found newts had a high degree of site fidelity; newts returned to aquatic sites after displacement of several kilometers. Specific traditionally used migration routes, or "highways," can exist between overwintering sites and breeding ponds (Pimentel 1960); however, their characteristics have not been well studied. Knowledge of newt habitat needs and migration patterns (including homing tendencies, distances moved, and dispersal corridors) may be important to consider to reduce mortality of newts from various land use practices. For example, homing could reduce dispersal to nontraditional sites and limit recolonization of sites under land management. Migration routes between traditional or suitable upland overwintering sites and downslope aquatic breeding sites could be affected by various land uses. In forests as well as other areas such as farmlands, road kills of newts is a common sight in spring after rains. Maintenance of the integrity of aquatic breeding sites, riparian buffers, dispersal corridors, and upland forested areas with microhabitat refugia would be protection measures for this species.

Roughskin newts were ranked as having a medium risk of extinction by Lehmkuhl and Ruggiero (1991). Thomas and others (1993) identified these newts as being closely associated with old-growth forest conditions; however, their viability was only at medium risk under two of the five forest management alternatives they considered.

Tailed Frog *(Ascaphus truei)*

Description

Tailed frogs are one of the most primitive of living frogs (Nussbaum and others 1983). They are one of a few anurans with a morphological adaptation for internal fertilization, and they seem to hold a key position in amphibian phylogeny (for example, Jamieson and others 1993). They are the only species of their genus, with their closest relative living in New Zealand, and are endemic to the Pacific Northwest (Nussbaum and others 1983).

Tailed frogs are relatively small (25- to 52-mm SVL). The males possess a small taillike copulatory organ. The hind toes of both sexes are dorsoventrally flattened. The outermost toe is wider and less tapered than the other toes. They have no ear drums, their pupils are vertically oval, and their skin may be warty or smooth. If warts are present, they may have sharp black tips. The overall body color is usually gray or brown, but there may be a reddish tinge, and some individuals may be almost black. Individuals may have dark lines or blotches. A dark eye line may be present. Detailed descriptions of this species are found in Behler and King (1979), Gordon (1939), Metier (1968b), Nussbaum and others (1983), Stebbins (1954a, 1966, 1985), and Wright and Wright (1949).

The tadpoles are distinguished by an oral disc that is modified into a sucking organ that enables them to cling to stream rocks in swift currents. The tadpoles are black or brown with or without lighter flecks (Nussbaum and others 1983). According to Nussbaum and others (1983), most larvae have a white spot at the tip of the tail.

The eggs are unpigmented and are about 4 to 5 mm in diameter (Stebbins 1954a). There are about 27 to 98 eggs per clutch (Nussbaum and others 1983, Stebbins 1954a). Hatchling larvae are 10 to 15 mm in total length (Nussbaum and others 1983).

Range and Habitat

Tailed frogs are found west of the crest of the Cascade Range, from British Columbia to northwestern California. They also are found in extreme northwestern Oregon and southeastern Washington with populations in northern Idaho and northwestern Montana. Tailed frogs may be found from sea level to over 2000 m. They usually are found near or in fast-flowing, permanent streams in forests, and may be abundant in headwater areas (Bury 1988). They also may be found, however, in more open areas (Behler and King 1979).

Ecology and Behavior

Reproduction—Tailed frogs seem to be voiceless, and it is not known how mates are attracted to one another (Nussbaum and others 1983, Stebbins 1966). Mating may occur in early spring (Slater 1931, Wernz 1969), June or July (Noble and Putnam 1931), or fall (Metier 1964a, Nussbaum and others 1983). Stebbins (1966) states that *A. truei* may breed from April through September. A male wilt lock its arms around the pelvic region of the female in an inguinal amplexus and insert its cloacal extension (tail) into the cloaca of the female. Copulation may last for 30 hours (Metter 1964b). Jamieson and others (1993) argued that internal fertilization was a primitive characteristic of amphibians, and that external fertilization was secondarily acquired (in anurans). Nussbaum and others (1983) stated that sperm may remain viable within the oviduct for at least 10 months and that fertilized eggs are deposited during July the year after mating. The eggs are deposited in a rosarylike string arranged in globular masses attached to the underside of stones within creeks (Nussbaum and others 1983, Stebbins 1954b, Wright and Wright 1949).

The larval period may last from 2 to 3 years, depending on the location (for example, Daugherty and Sheldon 1982a, Duellman and Trueb 1986, Nussbaum and others 1983). Laboratory experiments by Altig and Brodie (1972) showed that *A. truei* larvae preferred substrates with smooth rocks greater than 55 mm in diameter and that they avoid light. First-year tadpoles prefer temperatures below 10 °C, whereas second-year tadpoles prefer temperatures from 10 to 22 °C (DeVlaming and Bury 1970).

Predators and prey—Adults eat various invertebrates including snails, ticks, spiders, mites, and many insect species (Nussbaum and others 1983) found near creeks (Bury 1988). The larvae are aquatic filter feeders (Bury 1988) and feed on diatoms, conifer pollen, algae, and small insects (Nussbaum and others 1983). Pacific giant salamanders *(Dicamptodon)* are a major predator of *A. truei* tadpoles (Duellman and Trueb 1986, Metter 1963).

Population dynamics—Various aspects of the adult population dynamics of *A. truei* have been reported by Metier (1964a, 1967), Metter and Pauken (1969), and Daugherty and Sheldon (1982a, 1982b). Tailed frogs in Montana have one of the longest life histories ever described for anurans (Daugherty and Sheldon 1982a). Metamorphosis occurs at age 3, and breeding does not occur until age 7 or 8 (Daugherty and Sheldon 1982a). In Montana, it is estimated that *A. truei* may live longer than 14 years. Tailed frogs are highly philopatric (Daugherty and Sheldon 1982b). Gene flow between populations is relatively low (Daugherty and Sheldon 1982b, Metter and Pauken 1969). Tailed frogs can have patchy distribution patterns and can be locally abundant. Bury (1988) reported densities up to 9.5 per m^2 (mean 4.5 per m^2) in the southern Washington Cascade Range. He found 109 tailed frogs (95-percent larvae) in one 10-m stream reach. Populations of *A. truei may* be decimated by natural disasters such as floods that greatly reduce larval populations (Metter 1968a).

Relation to Old-Growth and Potential Impact of Habitat Loss

Of the anurans discussed in this report, *A. truei* is probably the species most likely to be affected by old-growth habitat loss and degradation. Tailed frogs are intimately associated with cool fast-flowing streams in forested areas and are commonly found within old-growth forests (Bury 1983; Bury and Corn 1988a, 1988b; Corn and Bury 1989; Raphael 1988; Welsh and Lind 1988). Bury (1983) found *A. truei on* undisturbed old-growth sites but none in logged areas. In the southern Washington Cascade Range, Aubry and Hall (1991) found tailed frogs more often in mature stands than in young stands. Bury and Corn (1988b) considered *A. truei {o be* "sensitive to timber harvest and that their survival may depend on protection of cool flowing streams that they require for breeding purposes and larval development. Tailed frogs are most often found in streams in logged stands when uncut timber still remains upstream (Corn and Bury 1989). Tailed frogs are likely to be affected by increased water temperature that occurs after timber harvest (Bury and Corn 1988b).

Because of the extreme philopatry and tendency for *A. truei* populations to be extremely disjunct (Daugherty and Sheldon 1982b), recolonization after local extinction may take a relatively long time. Some populations may, therefore, not readily recover from habitat destruction.

Thomas and others (1993) reiterate the importance of maintaining cool stream temperatures and reducing sedimentation as protection measures for this species. They recommend headwater stream protection through buffers as mitigation for this frog. Tailed frogs were rated to have medium to high risk to viability in four of the five management options considered by Thomas and others (1993). Lehmkuhl and Ruggiero (1991) considered this species to be at a moderately high risk of extinction.

Western Toad
(Bufo boreas)
Description

Western toads are relatively large anurans (55 to 125 mm SVL). Their overall color is variable and ranges from shades of green to dark brown to almost black: A light stripe runs down the middle of the back. The parotoid glands are oval, well-separated, and generally larger than the upper eye lids. Unlike frogs, toad skin seems dry and the back, sides, and upper legs are covered with glands that can exude toxin. The ventral surface is light in color (whitish or buff) with irregular dark marks on the abdomen. Detailed descriptions of this species are found in Behler and King (1979), Gordon (1939), Nussbaum and others (1983), Stebbins (1954a, 1966, 1985), and Wright and Wright (1949).

Bufo boreas tadpoles seem almost jet black in color. They may be lighter ventrally. They have relatively low tail fins, and the dorsal fin is about as high as the greatest height of the tail musculature (Nussbaum and others 1983). The fins generally are slightly pigmented, with the dorsal fin darker than the ventral fin. Metamorphic toads are about 12 to 13 mm SVL (Nussbaum and others 1983).

In Oregon, females may lay from 5,000 to 15,000 eggs per clutch (Blaustein 1988, Olson 1988, Samollow 1979), but in other parts of their range, they may lay 16,500 eggs per clutch (Stebbins 1954a). The eggs are laid in strings that are spread and intertwined around the eggs of other clutches and vegetation. The eggs are black and are about 1.5 to 1.7 mm in diameter. Tadpoles are relatively small at hatching (about 10 mm total length, Nussbaum and others 1983).

Range and Habitat

Western toads occupy various habitats from sea level to over 3600 m (Stebbins 1954a, 1985). They range from southern Alaska to Baja California, and are found as far east as Colorado and Utah. Individuals may be found in large lakes, small ponds, shallow marshes, and in forested areas some distance from water.

Ecology and Behavior

Reproduction—Depending on the location, reproduction may occur from late January through July (Nussbaum and others 1983, Olson 1988). Breeding sites are traditional locations, used year to year, usually in specific microhabitats at particular lakes or ponds. Males generally arrive first at breeding sites or synchronously with females. Hundreds of individuals may be present at their "explosive" breeding aggregations, where mating is often completed within a week (for example, Nussbaum and others 1983, Olson 1988, Olson and others 1986, Samollow 1979).

Males do not defend territories or give advertisement calls to attract mates. Rather, they move throughout the breeding area and clasp any toad encountered in a "scramble competition" for mates. Males have a release call, given when clasped by another male. Females do not seem to have the opportunity for direct mate choice, being readily clasped by males upon entering the breeding site. Displacement of paired males from females by unpaired males seems to be uncommon in Oregon populations (Olson 1988), unlike other anurans with explosive breeding (for example, Davies and Halliday 1977,1979).

Mating patterns in *B. boreas* are variable from year to year and from site to site (Olson 1988, Olson and others 1986). For example, both a large male mating advantage and size assortative mating may occur at breeding aggregations at some sites in some years. Field observations and experiments suggested nonrandom mating resulted from male-male exploitative competition for mates and female avoidance behaviors, and was tied to the body size structure of breeding populations (Olson 1988). In populations with a broad range of body sizes, small males apparently could not always effectively clasp large females as they attempted to avoid clasping.

In Oregon, adult breeding schedules may differ between the sexes (Olson 1992). Males could mate more than once a year and commonly bred in consecutive years, whereas females seemed to skip 1 to 3 years between breeding bouts (Olson 1988).

Larval ecology and behavior—Western toad tadpoles form huge aggregations in many parts of their range, with millions of individuals often comprising a school (see Blaustein 1988, O'Hara 1981, O'Hara and Blaustein 1982). Within a day, the aggregations break up, reform, and disperse to various areas of the lake or pond (see Blaustein 1988, O'Hara 1981, O'Hara and Blaustein 1982). The aggregations are composed of individuals from various clutches (kin groups). In experimental studies in the laboratory, *B. boreas* tadpoles preferred to associate with conspecifics but have only a rudimentary kin recognition system (the ability to discriminate between kin and nonkin; for a review, see Blaustein and O'Hara 1986a) when compared with frog tadpoles (see discussion in Blaustein and others 1990, O'Hara 1981, O'Hara and Blaustein 1982). Except under special circumstances, it is not likely that B. *boreas* tadpoles aggregate in kin groups. Compared with frog tadpoles of the Pacific Northwest, western toad tadpoles are habitat generalists (O'Hara 1981). Tadpoles generally seek the warmest portion of the water, and their black bodies are thought to absorb heat efficiently which enhances growth and development (O'Hara 1981).

Population dynamics—The structure and dynamics of western toad breeding populations is being studied in a continuing mark-recapture project that was initiated in 1982 (see Olson 1988, 1992; Olson and others 1986). Aggregations at aquatic breeding sites can be large (for example, 200 to 600 individuals) and generally have male-biased sex ratios. Yet, most females and some males do not breed every year, so nonbreeding terrestrial adults may add considerably to population counts. At some sites, toads have a high degree of site fidelity among years, thereby facilitating age structure estimations. Males seem to reach reproductive maturity at age 3, whereas the larger females probably begin breeding at 4 to 5 years. Breeding populations can be comprised of toads 3 to at least 11 years old. Age estimates revealed even numbers of males among five age classes (>3, 4, 5, 6, and 7 years), whereas older recaptured females (>4 to 5 year) were uncommon at breeding aggregations (Olson 1992).

The abundances of breeding toads varies among years and sites in Oregon (Olson 1988,1989,1992; Olson and others 1986). Western toad mass mortality episodes have been seen at several breeding sites in Oregon, and include all life history stages: eggs, larvae, and adults. For example, raven predation on vulnerable breeding adults may contribute significantly to some population losses (Olson 1988, 1992), and consecutive years of egg mortality from dessication (Blaustein and Olson 1991). ultraviolet radiation (Blaustein and others 1994a), and fungus infestation (Blaustein and others 1994b), and perhaps other causes, can result in population fluctuations and declines (Blaustein and others 1994a; Olson 1992).

Predators and prey—Western toads eat various invertebrates including flying insects, crayfish, sowbugs, and earthworms (Nussbaum and others 1983). Huge larval aggregations along lake margins communally forage, churning fine substrate as they proceed (Nussbaum and others 1983).

Western toads are eaten by birds, garter snakes, and aquatic insects (for example, Arnold and Wassersug 1978, Beiswenger 1981, Olson 1989). Vertebrate predators such as ravens eviscerate adult toads, leaving the toxic skin (Olson 1989). In experimental studies, *B. boreas* tadpoles were readily eaten by aquatic insects but were eaten with less frequency by salamander predators which probably find them noxious (Peterson and Blaustein 1991, 1992). Moreover, giant water bugs *(Lethocerus americanus)* induce the emission of an alarm substance in *B. boreas* tadpoles that causes the tadpoles to increase activity and avoid the area where predation occurred (Hews 1988).

Miscellaneous notes—Samollow (1980) documented natural selection between generations and within cohorts of western toads. His data support the concept of multiple-niche polymorphism. Samollow and Soule' (1983) reported a striking case of heterozygote survivorship among immature toads during winter.

Diel activity patterns are seasonal and vary ontogenetically. In one study in Washington, western toads displayed a nocturnal bimodal activity pattern (Hailman 1984). In another study, Lillywhite and others (1973) showed that newly metamorphosed *B. boreas* were diurnally active and bask in the sun for thermoregulation. Tracy and Dole (1969) found *B. boreas* can orient to breeding sites with the use of olfactory cues, and they found these toads to have homing ability.

Relation to Old-Growth and Potential Impact of Habitat Loss

Western toads are found in various habitats, including old-growth stands (for example, Aubry and Hall 1991, Gilbert and Allwine 1991, Welsh and Lind 1988). They are relatively difficult to sample outside of the breeding season. The relatively poor numbers obtained via pitfall trapping in certain studies (for example, Aubry and Hall 1991, Gilbert and Allwine 1991) may not truly reflect their abundance in certain habitats. It is unclear how *B. boreas* will respond to old-growth habitat loss. Because they can be locally abundant, can live in a relatively wide variety of habitat types, disperse overland, and live many years as adults, this species may be less affected by land use practices than other anurans. Massive mortality episodes (Blaustein and others 1994c, Carey 1993), however, may lead to extreme population losses (Olson 1992).

Thomas and others (1993) considered western toads on their "long list of species to evaluate as forest associates. Data were unavailable to consider them "close associates" with old-growth forest conditions, and their viability under the forest management alternatives was not assessed. Lehmkuhl and Ruggiero (1991) did not consider this species in their risk assessment.

Pacific Treefrog *(Hyla [=Pseudacris) regilla)*

The Pacific treefrog is ubiquitous in the Pacific Northwest. Detailed descriptions of this species are found in Behler and King (1979), Gordon (1939), Nussbaum and others (1983), Stebbins (1954a, 1966, 1985), and Wright and Wright (1949).

Description

Hyla regilla is a relatively small frog, measuring about 25 to 48 mm SVL (Nussbaum and others 1983, Wright and Wright 1949). Adult females are larger than males at some sites (Schaub and Larsen 1978) but not at other sites (Olson 1988). These frogs have enlarged terminal discs or adhesive "toe pads" at the ends of the digits. The overall body color varies greatly. Individuals may be brilliant light green, brown, red, gray, and almost black (Nussbaum and others 1983, Stebbins 1954a) but are usually shades of green or brown. Individuals may change from a dark phase to a light phase within a few minutes (Stebbins 1985). Adults have a black or dark brown eye stripe that extends from the nostril to behind the eye. Dark spots and longitudinal dark stripes or blotches may be present on the back, head, and legs, frequently forming an irregular triangle on the top of the head between the eyes. The ventral surface is usually white or pale yellow. Males have a gray or black throat in the region of the vocal sac during the breeding season.

Small masses of 9 to 70 eggs are deposited, usually attached to underwater vegetation (Nussbaum and others 1983). Females may lay up to 1,000 eggs per season (Jameson 1956) in several clutches (Perrill and Daniel 1983). Each egg is about 1.33 mm in diameter (Wright and Wright 1949) and is brown above and yellow below (Nussbaum and others 1983). Eggs hatch in about 1 month, and hatchling tadpoles are 6 to 8 mm in total length.

The tadpoles are brown dorsally with black markings. Ventrally, they are whitish with "coppery tinges" (Gordon 1939) or "iridescent." A top view indicates that the eyes are usually near or interrupt the head outline, and they have a relatively low arched dorsal fin (Nussbaum and others 1983). They can attain a premetamorphic length of 45 to 55 mm in 2 months in western Oregon (Nussbaum and others 1983). Just-transformed frogs measure 12.1 to 15.3 mm (Jameson 1956) and can grow almost 2 mm per week in summer.

Range and Habitat

This species is found from sea level to over 3000 m in various habitats, including coastal sloughs, old-growth forests, and deserts. Its range extends from southern British Columbia to Baja California, and from the Pacific coast to western Montana, Idaho, and Nevada. Although *H. regilla* is often found near water during breeding, it can be quite terrestrial.

Ecology and Behavior

O'Hara (1981) studied the habitat preferences and social behavior of *H. regilla* tadpoles. In the field, O'Hara (1981) found that *H. regilla* tadpoles do not disperse far from their hatching sites and are usually found in gently sloping shallow^ (usually less than 36 cm depth) among aquatic vegetation. Brattstrom (1962) noted that *H. regilla* formed aggregations in the warmest portion of ponds. In laboratory experiments, *H. regilla are* positively attracted to conspecifics which supports their tendency to form small loose aggregations in nature (Blaustein 1988, O'Hara 1981). *Hyla regilla,* however, prefer not to associate with kin over nonkin in laboratory experiments and probably do not form kin groups in nature (O'Hara and Blaustein 1988).

Reproduction—The Pacific treefrog has a prolonged breeding season in the Pacific Northwest. The breeding season lasts several weeks to months, depending on location, from January through July (for example, Schaub and Larsen 1978, Perrill 1984). Males congregate at breeding sites such as ponds, ditches, and flooded meadows, and chorus to attract females. Male calls may be given during the day (Schaub and Larsen 1978) but are commonly given at night in communal bouts (Perrill 1984; Schaub and Larsen 1978; Whitney and Krebs 1975a, 1975b).

Males seem to have a complex vocal communication system, with four distinct calls (Allan 1973, Snyder and Jameson 1965) functioning in a "three level" system of territorial defense (for example, Whitney and Krebs 1975a). First, a diphasic advertisement call attracts males and females to breeding sites (Allan 1973, Snyder and Jameson 1965) and is used by females for mate choice (Whitney and Krebs 1975b). Second, a monophasic call and a trill seem to function during male-male interactions, thereby resulting in a regular male spacing pattern at the breeding aggregations (Allan 1973, Whitney and Krebs 1975a). These calls can repel intruding males and may be considered displays signaling male territoriality. Lastly, a release call is given by a male when clasped by another male (Allan 1973). Male-male clasping may be an aggressive attack (Whitney and Krebs 1975a) or a misdirected mating attempt (Whitney 1980). Interspecific clasping by larger *Rana cascadae* effectively repels Pacific treefrog males from breeding sites (Olson 1988). There is considerable geographic variation in call characteristics (Snyder and Jameson 1965).

Three male mating tactics have been described (Perrill 1984). First, males may call and be site-specific. Calling bout leaders may initiate calls, call louder, call at a faster rate, and give calls when others are silent (Whitney and Krebs 1975b). Females may be differentially attracted to bout leaders (Whitney and Krebs 1975b). Second, satellite males do not call, but maintain positions near callers, intercepting females as they approach (Perrill 1984). Third, males may be opportunistic, not maintaining fixed positions but moving around the breeding site and adopting both calling and satellite tactics (Perrill 1984). Males clasp females in a dorsal axillary amplexus and may remain clasped for several hours (Nussbaum and others 1983).

Predators and prey—*Hyla regilla* eat various insects, including beetles, flies, leafhoppers and ants as well as spiders and isopods (Nussbaum and others 1983). Adults are preyed upon by garter snakes *(Thamnophis),* bullfrogs, birds, and mammals (Jameson 1956, Nussbaum and others 1983, Schaub and Larsen 1978). The larvae are eaten by aquatic insects and salamanders (Peterson and Blaustein 1991, 1992). *Hyla regilla* larvae are not known to be noxious to their predators (Peterson and Blaustein 1991,1992).

Population dynamics—In western Oregon, adults reach sexual maturity in less than 1 year (Jameson 1956). The sex ratio is skewed toward males (Jameson 1957). Juveniles do not disperse great distances, and many are probably preyed upon as they disperse (Jameson 1956). In at least one study, the survival rates of juveniles and adults from one year to the next was extremely low (0.18 percent for juveniles and 11 percent for adults; Jameson 1956). *Hyla regilla* are philopatric and can be found in the same pond from year to year (Jameson 1957). Schaub and Larsen (1978) found 72 to 90 percent of breeding Pacific treefrogs remained at the same pond, and about 20 percent of the frogs were sedentary within seasons, remaining within 10 m of a previous capture location. Adults are capable of homing at least 150 m (Jameson 1957).

Relation to Old-Growth and Potential Impact of Habitat Loss

In the Pacific Northwest, *H. regilla* may be found in or adjacent to old-growth forests (Bury 1983, Bury and Corn 1988a, Welsh and Lind 1988). Welsh and Lind (1988) found *H. regilla* primarily in undisturbed old-growth stands. By using various sampling techniques, Welsh and Lind (1991) found *H. regilla* more often in mature and old-growth forests than in young forests in northern California and southern Oregon. In contrast, Bury (1983) found *H. regilla* in disturbed habitat, which may reflect its propensity for invading open areas.

It is unclear how *H. regilla* will respond to old-growth habitat loss. Because they are relatively abundant and can live in a relatively wide variety of habitat types, this species may be less affected by old-growth habitat loss than other frog species. Lehmkuhl and Ruggiero (1991) did not conduct a risk assessment for this species. Thomas and others (1993) considered Pacific treefrogs on their "long list" of species to evaluate as old-growth forest associates, but they did not find these frogs to be "close associates" of old-growth forest conditions. Their viability under the forest management alternatives was not assessed.

Red-Legged Frog *(Rana aurora)*

Description

There are two distinct subspecies of red-legged frogs, *Rana aurora aurora* and *R. a. draytonii* (for example, see Hayes and Miyamoto 1984, Stebbins 1954a). The description included in this report concerns primarily R a. *aurora,* the subspecies found in the Pacific Northwest. Detailed descriptions of this species are found in Gordon (1939), Nussbaum and others (1983), Stebbins (1954a, 1966, 1985), and Wright and Wright (1949).

This is a medium- to large-sized frog. Females may reach 100 mm SVL, and males may be 70 mm SVL (Nussbaum and others 1983). The dorsal surface is reddish to olive in color with considerable flecking of small black spots that generally have indistinct edges. In some individuals, the flecks may be continuous and form a series of lines. The chest and abdomen may be gray or white. The undersurface of the hindlegs and the posterior portion of the abdomen are usually pink to red, although in some individuals they may be yellow (Stebbins 1954a). Red-legged frogs usually have a blackish to brown eye mask that extends from the nostrils to the angle of the jaw. The eye mask, however, may not be distinct in certain individuals (Stebbins 1954a). Red-legged frogs usually have a light lip line that extends from the eye to the shoulder that is bordered by the dark mask above (Nussbaum and others 1983). This species has relatively long legs. The heel of the adpressed leg extends to or beyond the nostril (Stebbins 1966). *Rana aurora* has longer hindlegs than *R. pretiosa,* a species with which it may be confused. Hind-toe webbing is reduced in R. aurora, and when the toes are spread, the edges of the webs are concave and reach only to the first joint of the longest toe (Nussbaum and others 1983). Males may have a greater development of webbing than females (Stebbins 1954a). Red-legged frogs have dorsolateral folds that are lacking in *R. pretiosa* (Nussbaum and others 1983).

The tadpoles are dark brown dorsally with small metalliclike flecks. The ventral surface is generally brassy to pink in color (Nussbaum and others 1983). The dorsal fin terminates at or is anterior to the spiracle. The dorsal fin is at least as high as the tail musculature.

Individual eggs are the largest known for any North American ranid, averaging 3.0 mm in diameter (Licht 1971). The eggs are deposited as a round globular mass of about 15 to 25 cm in diameter that is attached to submerged vegetation (Nussbaum and others 1983, Storm 1960). Egg deposition site may vary between *R. aurora* subspecies, with the Pacific Northwest form depositing entirely submerged masses and the southern subspecies depositing eggs at the water surface (Hayes and Miyamoto 1984). Between 500 and 1,100 eggs are laid per female (Blaustein 1988, Nussbaum and others 1983, Storm 1960).

Range and Habitat

Red-legged frogs are inhabitants of moist forests and riparian areas usually below 850 m in elevation in the Pacific Northwest (Nussbaum and others 1983, Stebbins 1966). They generally are found near permanent bodies of quiet water including small ponds, quiet pools along streams, reservoirs, springs, lakes, and marshes (Gordon 1939; Nussbaum and others 1983; Stebbins 1954a, 1966). Although Stebbins (1954a) described *R. aurora* as "highly aquatic," individuals may be found in forests considerable distances from water (Gordon 1939, Nussbaum and others 1983, Stebbins 1954a). Nussbaum and others (1983) reported individuals as much as 200 to 300 m from standing water and frequently inhabiting roads during rainy nights.

Ecology and Behavior

Reproduction—Breeding occurs relatively early in the year in Oregon and Washington in the western valleys and coastal areas (Nussbaum and others 1983). *Rana aurora* may breed in small temporary ponds, relatively large lakes, in potholes, in overflows of lakes and rivers, or in slow-moving portions of a river (for example, Brown 1975; Calef 1973a; Licht 1969a, 1969b, 1971; Nussbaum and others 1983; Storm 1960). Movement to breeding sites is temperature-dependent (Licht 1969a, 1971; Storm 1960). For example, near Corvallis, Oregon, frogs move to breeding areas in January when the air temperature reaches 10 °C (Storm 1960). Males arrive at the breeding sites first (Licht 1969a, Nussbaum and others 1983) which may be as early as December in the Willamette Valley, Oregon (Nussbaum and others 1983, Storm 1960). Males usually call while submerged (Brown 1975, Licht 1969a, Nussbaum and others 1983, Storm 1960). In Calef's (1973a) study of *R. aurora* reproduction in British Columbia, males did not defend territories. Nussbaum and others (1983) state, however, that males may exclude others from breeding and *R. aurora* is polygynous.

Predators and prey—A detailed list of the food items eaten by *R. aurora* in British Columbia can be found in Licht (1986a; see also Hayes and Tennant 1985, for a comparison with food items eaten by the southern subspecies in California). The food eaten by *R. aurora* differs with age and size of the frog and includes many insect species, arachnids, and molluscs.

Gregory (1979) and Licht (1986a) both concluded that *R. aurora* prefers to inhabit land for most of the day. When predators approach, however, *R. aurora* jumps into water and may remain there for long periods of time (Gregory 1979, Licht 1986a). Escape by jumping is extremely efficient in *R. aurora* which may help them escape from predation by snakes (Gregory 1979, Licht 1986a). In southwestern British Columbia, vertebrate predators on *R. aurora* adults and larvae include raccoons, great blue herons, belted kingfishers, garter snakes *(T. sirtalis),* northwestern salamanders *(A. gracile),* bullfrogs *(Rana catesbeiana),* roughskin newts *(T. granulosa),* cutthroat trout, red-tailed hawks, marsh hawks, hooded mergansers, great horned owls, red foxes, striped skunks, minks, and feral housecats. Invertebrate predators on larvae include giant water bugs, backswimmers, Dytiscid beetles, water scorpions, and odonate nymphs (Licht 1974).

Population dynamics—In a study of survivorship of *R. aurora* in British Columbia, Licht (1974) estimated that 5 percent of the eggs that were laid reached metamorphosis. After one season, there was only a 2.5-percent survivorship. Embryonic survival was generally high, whereas tadpoles suffered huge losses probably from predation (Licht 1974). Licht (1974) estimated that there was a 69-percent rate of survival in adults, and survival from eggs to sexual maturity was less than 1 percent. Licht concluded that predation was the major cause of mortality of *R. aurora* in all stages of development.

Although no long-term population studies of *R. aurora* have been conducted, observations from several biologists suggest that *R. aurora* populations are dwindling (Marshall and others 1992). For example. Nussbaum and others (1983) stated that *R. aurora* is less common than it once was in the Willamette Valley, Oregon. This species has declined greatly in California perhaps due to exploitation by humans and introduced bullfrogs *(R. catesbeiana*; Hayes and Jennings 1986; Jennings and Hayes 1985).

Larval ecology and behavior—Hatching time is dependent on water temperature (Brown 1975, Licht 1971, Storm 1960). The warmer the temperature, the more quickly hatching takes place (Licht 1971). Early embryos can tolerate temperatures from 4 to 21 °C, a narrow range compared with other ranids (Licht 1971). In western Oregon, hatching times of 35 to 49 days were recorded as the temperature fluctuated from 0 to 19 °C. Compared with other ranids, development from larvae to the adult form is long (Licht 1971). Time to metamorphosis and the size at metamorphosis differs with environmental conditions and locale (see Brown 1975). For example, *R. aurora* was 28.7 mm, 20-25 mm, and 22 mm at metamorphosis in studies conducted in Washington (Brown 1975), Oregon (Storm 1960), and British Columbia (Calef 1973a), respectively.

When larvae hatch, they generally remain near the egg mass for several days, either on the bottom or among vegetation (Brown 1975, Storm 1960). Hatching size in Oregon and Washington is 11 to 12.4 mm (Brown 1975, Storm 1960). Young larvae are tolerant of temperatures between 4 and 21 °C (Licht 1971, Nussbaum and others 1983). Calef (1973b) studied the natural mortality of *R. aurora* tadpoles in a lake in British Columbia. He found that survivorship had two phases; a rapid decline in numbers during the first 4 weeks after hatching followed by a less rapid decline, until about 5 percent of the population remained at metamorphosis, after about 11 to 14 weeks. Mortality was density-dependent, and predation was the major cause of mortality in Calef's (1973b) study.

To determine the importance of innate and learned components in the habitat selection of *R. aurora* tadpoles, Wiens (1970) conducted a series of laboratory experiments similar to those described in the *R. cascadae* account in this monograph. Wiens (1970) showed that *R. aurora* tadpoles could be conditioned to prefer certain substrates. *Rana aurora* tadpoles reared in featureless or square-patterned habitats showed no preference for either striped or square-patterned substrates. Larvae reared on striped-patterned substrates, however, preferred striped-patterned habitats. The preference for striped substrates was established during the first 14 to 17 days in the striped rearing habitat. This preference was retained after isolation from the substrate and could be reestablished in both young and old tadpoles. *Rana aurora* typically breeds in shallow ponds prone to summer drying or in areas where permanent ponds have overflowed (Storm 1960, Wiens 1970). Slender, emergent willow branches, cattails, weed branches, grasses, and other vegetation that are linear in structure are characteristic of these habitats, and they cast a linear shadow on the muddy substrate. Thus, the stripes that larval *R. aurora* responded to in Wiens' (1970) experiments may resemble the linear substrates and shadows found in their natural habitat.

In laboratory experiments, *R. aurora* tadpoles preferred to associate with kin over nonkin in early developmental stages but failed to show this preference in latter developmental stages (Blaustein and O'Hara 1986a, Blaustein and others 1993). As larvae develop, the production of the chemical used as a recognition signal is reduced, and the ability to perceive the signal is diminished (Blaustein and 'others 1993). Unfortunately, little is known about the tendencies of *R. aurora* tadpoles to form schools and the significance of the results of kin-recognition studies is questionable.

Relation to Old-Growth and Potential Impact of Habitat Loss

Although not restricted to old-growth habitat, *R. aurora* is frequently found in old-growth stands (for example, Bury and Corn 1988a). In southern Washington, Aubry and Hall (1991) found that *R. aurora* was most abundant in mature stands and least abundant in young stands. *Rana aurora* abundance was negatively associated with elevation, slope, talus, and rocky outcrops, and positively associated with all deciduous and broadleaved evergreen trees. Likewise, in Oregon and Washington, Bury and others (1991 a) found that *R. aurora* were most abundant at lower elevations with flatter slopes.

Populations of *R. aurora* seem to be declining in areas outside of old-growth. Bullfrog introductions, pesticides, and herbicides may be contributing to losses (Marshall and others 1992, Nussbaum and others 1983). Increased habitat loss due to depletion of old-growth forests that are inhabited by *R. aurora* can only have detrimental effects on their populations. This frog is classified as Sensitive in Oregon (Marshall and others 1992). Lehmkuhl and Ruggiero (1991) stated that *R. aurora* is at moderately high risk of extinction. Red-legged frogs were not considered by Thomas and others (1993) for evaluation as old-growth associates.

Foothill Yellow-Legged Frog *(Rana boylii)*

Description

Rana boylii is a relatively small- to medium-sized frog (up to 75 mm SVL, Nussbaum and others 1983). Many minute tubercles on its surface give the frog a "rough", toad-like appearance. There is complete hind-toe webbing. The edges between the toes are only slightly concave. The webbing extends to the tip of the longest toe. The tips of the longest toes are slightly expanded (Nussbaum and others 1983). The heel of the hindleg extends to the nostrils or beyond when the leg is stretched forward along the body (Nussbaum and others 1983). The dorsolateral folds are obscure. The tympanum is about half the size of the eye and is similar in color and roughened like the skin that surrounds it, thereby making it difficult to see (Nussbaum and others 1983). The overall body color may range from gray to brown to olive. Frogs differ in their intensity of mottling and spotting, and some are largely unspotted (Stebbins 1954a). Some individuals may be brick red in the dorsolateral fold areas (Nussbaum and others 1983). The concealed surfaces of the hindlegs and the posterior portion of the abdomen are usually yellow. The remainder of the abdomen is white (Behler and King 1979, Nussbaum and others 1983). Many individuals have a light patch across the top of the head that crosses a dark area on the upper eyelid (Behler and King 1979, Stebbins 1954a). Detailed descriptions of this species are found in Gordon (1939), Wright and Wright (1949), Stebbins (1954a. 1966, 1985), Zweifel (1968) and Nussbaum and others (1983).

Rana boylii tadpoles are deep olive in color (Gordon 1939). They usually have dark spots on the tail fin and musculature (Nussbaum and others 1983). The ventral surface is silver. The tail fin is lower than in most other tadpoles (Nussbaum and others 1983). The tadpoles are distinguished from all other ranid tadpoles in Oregon and Washington by the many labial tooth rows, six or seven anterior and five or six posterior to the mouth (Nussbaum and others 1983, see also Altig 1970).

The eggs are laid in round clumps where they are attached to rocks or gravel in the margins of streams and pools. Stebbins (1954a) and Nussbaum and others (1983) described the eggs as protruding through the jelly mass "like grapes." There may be from 100 to 1,000 eggs per clutch, and each egg is from 1.8 to 2.2 mm in diameter (Nussbaum and others 1983, Stebbins 1954a). Smaller clusters of eggs occur at higher elevations (Stebbins 1954a).

Range and Habitat

Rana boylii ranges from northwestern Oregon to northern Baja California. It is found west of the crest of the Cascade and Sierra Nevada Ranges. In California, it inhabits coastal foothill regions and is west of the central valley, south to Ventura County. Isolated populations occur in Los Angeles County (Zweifel 1968). Populations of *R. boylii* may be found as high as 1800 m above sea level (Zweifel 1955). *Rana boylii* is almost always found near streams or rivers, including intermittent streams that may be reduced to small potholes connected by trickles during the dry season (Fitch 1936, Nussbaum and others 1983, Stebbins 1985). *Rana boylii* is most common in streams that have a rocky or gravelly substrate, but they may be found in streams that have a muddy bottom (Nussbaum and others 1983).

Ecology and Behavior

Rana boylii usually breed in the streams and pools they inhabit (Nussbaum and others 1983). Breeding may occur from March through June (Fitch 1936, Nussbaum and others 1983, Stebbins 1954a, Wright and Wright 1949). Descriptions of the male voice are found in Stebbins (1954a, 1985) and Nussbaum and others (1983).

According to Nussbaum and others (1983), early literature suggests that *R. boylii* eggs can develop from 6 to 26 °C. At 20 °C, the eggs hatch in 5 days and the larvae are from 7.3 to 7.7 mm in total length (Nussbaum and others 1983). Overwintering of larvae probably does not take place (Zweifel 1955). Metamorphosis takes 3 to 4 months in California (Nussbaum and others 1983, Wright and Wright 1949), where they may be 22 to 27 mm at metamorphosis (Zweifel 1955).

Rana boylii eat various insects as well as snails (Fitch 1936, Nussbaum and others 1983). Garter snakes *(Thamnophis)* prey heavily on tadpoles and adults (Fitch 1936, Nussbaum and others 1983, Zweifel 1955). Zweifel (1955) documented predation on *R. boylii* eggs by the roughskin newt *(Taricha granulosa)* and suggested that fish, birds, and mammals are other predators of this species.

Relation to Old-Growth and Potential Impact of Habitat Loss

Little is known of the natural history or current status of this frog in the Pacific Northwest. *Rana boylii* is a stream frog in forested ecosystems. It once was considered one of the most common frogs in southwestern Oregon, but its present distribution and abundance patterns are unknown (Nussbaum and others 1983). It has a Sensitive status in Oregon (Marshall and others 1992). In California, *R. boylii* is absent from many locations where it was historically present (Hayes and Jennings 1988, Moyle 1973). *Rana boylii may* inhabit old-growth stands in certain areas of southern Oregon (see Welsh and Lind 1988). In one study in northern California and southern Oregon, Welsh and Lind (1988) never found *R. boylii* in new growth; however, they suggested its absence may have been due to a sampling artifact. Welsh and Lind (1991) found *R. boylii* primarily in old- or young-forest stands, with reduced abundance in mature forest.

Loss of habitat will be detrimental to this species, and more studies are needed to enhance our knowledge of its overall ecology. Lemhkuhl and Ruggiero (1991) did not conduct a risk assessment of this species. Thomas and others (1993) considered *R. boylii* on their "long list of species to evaluate as old-growth forest associates. Data were unavailable to consider them "close associates" with old-growth forest conditions, and their viability under the forest management alternatives was not assessed.

Cascades Frog *(Rana cascadae)*

Description

The Cascades frog is medium sized, with males 50 to 58 mm and females 50 to 75 mm SVL. In Oregon, females are larger than males (Olson 1988, 1992). Adults are olive to olive brown dorsally with sharply defined dark splotches on the back. The lower sides are generally yellowish or cream colored. There are no abdominal markings. The hindfoot webbing is restricted, and one or two phalanges of the longest toe are free of the web. The head of the female may be more pointed than the head of the male. Generally, adult *R. aurora* and *R. pretiosa* are larger than *R. cascadae* (to 135 mm SVL), and *R. aurora* is red ventrally. *Rana cascadae* differs from *R. boylii* and *R. muscosa* by the presence of distinct dorsolateral folds, relatively smooth tympana, incompletely webbed toes, and a dark eye mask. Detailed descriptions of this species can be found in Altig and Dumas (1971), Stebbins (1985), and Nussbaum and others (1983).

There are several areas where *R. cascadae* and *R. pretiosa* are sympatric (Dunlap 1955, Green 1985). Natural hybridization between *R. cascadae and R. pretiosa was* reported by Green (1985) at one locality in Oregon. In addition, laboratory crosses between *R. cascadae* and *R. pretiosa* have been conducted (Dumas 1966, Haertel and Storm 1970). Despite hybridization, Green (1985, see also Case 1978) suggested that there were considerable genetic differences between these two species based on fixed allozyme differences. The hybridization in nature and the difficulty in identifying their juveniles may make positive identification of *R. cascadae* difficult in areas where the two species co-occur (Green 1985). In areas of overlap, positive identification may only be possible after chromosome and allozyme marker analyses are conducted. Experimental crosses between *R. cascadae* and *R. aurora* suggest that they are reproductively isolated and that hybridization between them is highly unlikely (Porter 1961).

The tadpoles of *R. cascadae* are generally dark brown, but on occasion they may be lighter in color, approaching green. The dorsal area may have a light mottling of small dark spots. The tail fins may have small dark flecks. The dorsal fin terminates posterior to the spiracle. Hatchling tadpoles measure about 13 mm in total length (Nussbaum and others 1983).

Eggs are deposited in round masses along pond margins. From 300 to 800 eggs per female are laid (Blaustein 1988, Nussbaum and others 1983, O'Hara 1981). Eggs are about 2.2 mm in diameter (Nussbaum and others 1983).

Range and Habitat

Rana cascadae is a montane species found in the Olympic Peninsula, Washington, and in the Cascade Range of Oregon, Washington, and northern California. It generally occurs above 800 m in montane meadows, marshes, and ponds. *Rana cascadae* often are found in relatively small bodies of water rather than in large lakes (Nussbaum and others 1983, O'Hara 1981. Sype 1975). They can be found in relatively small ephemeral pools or potholes without vegetation, in marshlike areas that are overflows of larger lakes, lakeshore alcoves, and along creeks (see for examples, O'Hara 1981, Olson 1992). On occasion, they are found away from water in forests (Nussbaum and others 1983).

Ecology and Behavior

Reproduction—Breeding begins as soon as the ice and snow melts (Nussbaum and others 1983, O'Hara 1981). In the north-central Oregon Cascade Range, *R. cascadae* breeds from March through June (for example, Olson 1988). This species is an explosive breeder. Breeding generally takes place within 1 week (for example, Briggs 1987, Olson 1988). Sites selected for breeding in the central Oregon Cascade Range are shallow, gently sloping margins of a pond or lake shore, generally over soft substrates, and protected from severe wave action (O'Hara 1981). Pond margins melting first are often the focal point of breeding activity. These microhabitats can have downed woody material such as logs which may act as thermal reservoirs elevating adjacent water temperatures (Olson 1992). Adults are philopatric and use the same sites for breeding from year to year (O'Hara 1981; Olson 1988, 1992). Males usually appear first at breeding sites (Briggs 1987, Nussbaum and others 1983). There is no overt territorial defense by males (Nussbaum and others 1983); however, male-male interactions on the water surface at breeding ponds can result in a regular dispersion pattern (Olson, personal observations). Males vocalize, which may attract females (Briggs 1987, Nussbaum and others 1983). At one pond in the central Oregon Cascade Range, male calls generally were given as males detected, approached, and clasped other frogs (Olson, personal observations). The relatively complex calls are described in detail by Briggs (1987).

The breeding schedule of males was estimated in a 5-year study of a marked adult population (Olson 1992). Half of the male frogs attended the breeding site in 1 year and about 30 percent attended two breeding seasons. Many males attending two to three breeding seasons skipped a year in their attendance at the site. One male remained at the site for 5 years.

As females approach breeding sites, they swim primarily underwater (Olson 1992). They are approached and clasped by males as they periodically surface within the area of male activity. The opportunity for female choice of mates needs further investigation. Females breed only once per year, laying their eggs in single isolated clutches or in communal masses (Blaustein 1988, Nussbaum and others 1983, Sype 1975). Occasionally, communal masses may contain clutches of eggs from dozens of females (Nussbaum and others 1983, Sype 1975). Eggs usually are laid in shallow water and may be partially exposed to the air (Nussbaum and others 1983). From 300 to 800 eggs per female are laid (Blaustein 1988, Nussbaum and others 1983, O'Hara 1981).

Egg development differs depending on thermal conditions. The water temperature in the center of egg masses is generally significantly higher than water only a few centimeters away (Briggs 1987). For example, Briggs (1987) noted that the temperatures at the centers of three isolated egg masses in shallow water averaged 21.4 °C, but the water 15 cm away from the masses averaged 18.2 °C. *Rana cascadae* tends to lay its eggs in microhabitats that are thermally optimal for maximal embryonic growth (O'Hara 1981; Olson 1988, 1992; Sype 1975; Wollmuth and others 1987). The limits of temperature tolerance of the prefeeding tadpole stages are from 6 to 27 °C (Sype 1975). In the laboratory, tadpoles go from hatching through metamorphosis in about 37.5 days at 23 °C (Nussbaum and others 1983). At this temperature, newly transformed froglets were 20 to 21 mm SVL. Size at metamorphosis, however, varies with temperature, food availability, and tadpole density; in the laboratory. SVL ranged from 15 to 30 mm at metamorphosis (Blaustein and others 1984). The larval life in nature in the Oregon Cascade Range is estimated to be about 2 months (Nussbaum and others 1983).

Larval ecology and behavior—On hatching, the tadpoles tend to remain near their oviposition sites (O'Hara 1981). Dispersal of tadpoles is limited, and they do not move much further than several meters from where they hatched (O'Hara 1981). Various features of the habitat (for example, substrate type, cold water) are barriers to tadpole dispersal (O'Hara 1981). In larger ponds, *R. cascadae* tadpoles prefer relatively warm, shallow water close to the shoreline with abundant vegetation (O'Hara 1981).

To determine the importance of innate and learned components in the habitat selection by *R. cascadae* tadpoles, a series of laboratory choice experiments were conducted by Wiens (1972) and O'Hara (1981). The experimental regimes were designed to schematically reflect the types of substrate and vegetation that the tadpoles would encounter in nature. In Wiens' study, *R. cascadae* tadpoles reared in featureless or striped-patterned environments showed no preference for either square-patterned or striped substrates. Tadpoles raised in a square-patterned environment, however, showed a significant preference for the square-patterned experimental regime. O'Hara (1981) conducted a series of preference experiments in which tadpoles were reared on a smooth tank bottom or with natural substrates such as sand, gravel, and rock. During choice tests, *R. cascadae* preferred fine-grained substrates over coarse-grained substrates, and tadpoles from different populations behaved similarly. Wild-caught tadpoles and those reared in a simple laboratory environment behaved alike. The results obtained for *R. cascadae* tadpoles by Wiens (1972) and by O'Hara (1981) are contradictory. Interestingly, in Wiens' study, *R. cascadae* tadpoles were influenced by the rearing regime, whereas in O'Hara's, they were not. Thus. the role of innate and learned components in *R. cascadae* tadpole habitat selection is questionable.

Much recent literature exists on the social behavior of *R. cascadae* tadpoles. In nature, *R. cascadae* tadpoles form relatively small, cohesive aggregations comprised generally of fewer than 100 individuals (Blaustein 1988, O'Hara 1981, O'Hara and Blaustein 1981). In laboratory tests, O'Hara (1981) showed that *R. cascadae* tadpoles preferentially school with conspecifics and can maintain schools via visual cues. Many laboratory studies have showed that there is a clear preference to associate with kin over nonkin and that *R. cascadae* schools may be composed primarily of related individuals (for example, Blaustein 1988; Blaustein and O'Hara 1981. 1982a, 1982b, 1983, 1986b, 1987; Blaustein and Waldman 1992; Blaustein and others 1984; O'Hara and Blaustein 1981, 1985). In field experiments, tadpoles formed schools composed primarily of kin (O'Hara and Blaustein 1985). Tadpoles can distinguish between kin of varying degrees of relatedness (Blaustein and O'Hara 1982a). Kin recognition is based on chemical cues (Blaustein and O'Hara 1982b). Kin recognition is retained after metamorphosis and juvenile froglets preferentially associate with siblings over unrelated individuals (Blaustein and others 1984).

Population dynamics–The growth and population structure of *R. cascadae* was assessed by Briggs and Storm (1970), Briggs (1978), and Olson (1992). The adult sex ratio is skewed toward males (Briggs and Storm 1970; Olson 1988, 1992). Males seem to grow slower than females, and they reach a shorter maximum length (Briggs and Storm 1970, Olson 1988). At one site in the central Oregon Cascade Range, males had a mean age of 1.66 years with a mortality rate of 0.41 per year, whereas females had a maximum age of 1.20 years with a yearly mortality rate of 0.54 (Briggs and Storm 1970). Age at sexual maturity has been estimated to be at least 3 years for males and 4 years for females (Briggs and Storm 1970, Olson 1992).

Breeding adult age structures seemed similar for males and females (Olsop 1992). Newly matured adults (age 3 males, age 4 females) comprised most of a breeding population (65 to 70 percent of the male population and 60 to 85 percent of the female population).

Predators and prey—*Rana cascadae* tadpoles display an alarm reaction to damaged conspecifics (Hews and Blaustein 1985). *Rana cascadae* tadpoles are palatable to their natural predators which include aquatic insects and salamanders (Peterson and Blaustein 1991, 1992). Fish, snakes, and birds are also predators of these tadpoles.

Rana cascadae is found in aquatic habitat within forests. Aubry and Hall (1991) found a trend of increasing frog abundance with stand age, and found that 'these animals were associated with well-decayed snags.

Relation to Old-Growth and Potential Impact of Habitat Loss

Populations of *R. cascadae* seem to be more difficult to find than historically. Their decline may have begun in the mid-1970s (Blaustein and Wake 1990, Wake 1991). Based on historical accounts, museum records, and extensive searches at 16 historical sites. Fellers and Drost (1993) concluded that Cascades frog populations in northern California have exhibited a precipitous decline for more than 15 years. Causes of these losses may include drought conditions, fish introductions, pathogens (see Blaustein and others 1994b), and habitat loss. Developing embryos are sensitive to ambient levels of ultraviolet radiation which may be increasing (Blaustein and others 1994a). Furthermore, *R. cascadae* populations seem to be sensitive to habitat fragmentation. Their high-altitude aquatic habitat is spatially and temporally heterogeneous, dispersal is limited by moisture-temperature conditions, and populations may periodically become extinct and then recolonized (Blaustein and others 1994c; Olson 1992). Anthropogenic disturbances further fragmenting their fragile habitats could heavily impact population integrity. Broad-based habitat protection currently may be warranted because this species is of special concern (Marshall and others 1992).

Lehmkuhl and Ruggiero (1991) suggested that *R. cascadae was* of moderately high risk of extinction from habitat loss or fragmentation. Thomas and others (1993) considered Cascades frogs on their "long list" of species to evaluate as old-growth forest associates. Their viability under the forest management alternatives was not assessed.

Western Spotted Frog *(Rana pretiosa)*

Description

This frog is characterized by relatively short legs and complete webbing between the toes. If a hindleg is pressed forward against the body, the heel generally does not reach the nostrils (Nussbaum and others 1983). When the hind toes are stretched apart, the edges of the webs are straight to convex, and the webbing reaches almost to the tip of the longest toe (Nussbaum and others 1983). Adults usually have large, dorsal, black spots with light centers and unclear edges (Nussbaum and others 1983). The overall body color of adults varies from light to dark brown. The groin is usually gray, and concealed hindleg surfaces and the lower abdomen may be yellow or red. Dorsolateral folds are usually present but not always well developed (Stebbins 1954a). Adults generally have a brownish eye mask that extends to the angle of the lower jaw (Stebbins 1954a). There is often a light-colored jaw stripe, and the eyes seem to turn slightly upward (Stebbins 1966). Juveniles generally lack the yellow or red abdomen (Stebbins 1966). Detailed descriptions of this species are found in Gordon (1939), Wright and Wright (1949), Dunlap (1951, 1955), Stebbins (1954a, 1966,1985), Turner and Dumas (1972), and Nussbaum and others (1983).

Natural hybridization between *R. cascadae* and *R. pretiosa* was reported by Green (1985) at one locality in Oregon. In addition, laboratory crosses between *R. cascadae* and *R. pretiosa* have been conducted (Dumas 1966, Haertel and Storm 1970). Despite hybridization, Green (1985, see also Case 1978) suggested that there are considerable genetic differences between these two species based on fixed allozyme differences. The hybridization in nature and the difficulty in identifying their juveniles may make positive field identification of *R. pretiosa* challenging in areas where the two species co-occur (Dunlap 1955, Green 1985).

The tadpoles vary in color from dark brown to green, often with a heavy mottling of brassy flecks on the body and near the proximal portion of the tail (Nussbaum and others 1983). Ventral surfaces are silver. The dorsal fin terminates posterior to the spiracle and is equal to or lower than the height of the tail musculature (Nussbaum and others 1983).

In British Columbia, egg masses are not attached to vegetation (Licht 1969b). Each egg mass is from 12 to 20 cm in diameter (Nussbaum and others 1983). There are about 700 to 1,500 eggs per clutch (Blaustein 1988, Nussbaum and others 1983). Eggs are from 2 to 2.31 mm in diameter (Licht 1969b, Nussbaum and others 1983) although Turner (1958) reported unusually large diameters of 10 to 12 mm.

Range and Habitat

The historical range of *R. pretiosa* was from extreme southeastern Alaska south to central Nevada and central Utah, east to western Montana and northwestern Wyoming. As will be discussed below, however, the present range may be greatly reduced. Western spotted frogs may be found as high as 3000 m in parts of their range (Stebbins 1954a). Stebbins (1966) and Nussbaum and others (1983) considered *R. pretiosa* to be a highly aquatic species found in marshes near the edges of ponds and lakes. Stebbins (1966) suggested that *R. pretiosa* is more common in relatively cold water habitats than in warm, stagnant ponds. In Wyoming, however, stagnant pools were used for mating (Turner 1958).

Rana pretiosa has become extremely rare in the western portion of its range (McAllister and Leonard 1990, 1991; McAllister and others 1993; Nussbaum and others 1983; Stebbins 1985). Populations of *R. pretiosa* are patchy and rare west of the Cascade Range in Washington and have not been found west of the Cascade Range in Oregon for at least 23 years (McAllister and Leonard 1990, 1991; McAllister and others 1993; Nussbaum and others 1983). One specimen, identified by McAllister and Leonard as *R. pretiosa,* was found near Olympia, Washington, in 1990, and no other specimen has been found at that site. One population of *R. pretiosa* has been found about 24 km west of the crest of the Cascade Range in Washington (McAllister and Leonard 1990, 1991). The status of this species in eastern Oregon and Washington is unknown (see McAllister and Leonard 1990, 1991). Causes for the decline of *R. pretiosa* are unknown although Nussbaum and others (1983) and Stebbins (1985) suggested that introduced bullfrogs *(R. catesbeiana)* may have contributed to losses. Kirk (1988) noted DDT poisoning killed adult *R. pretiosa* in Oregon.

Ecology and Behavior

Reproduction and development—In British Columbia, *R. pretiosa* emerge from overwintering sites early in February (Licht 1969b). Air temperatures of at least 5 °C are necessary for activity (Licht 1969b). Males arrive first at breeding sites and vocalize, apparently to attract females (Licht 1969b). The vocalizations are described in detail by Licht (1969b). In Utah, males emerge in March when air temperatures are at least 13 °C (Morris and Tanner 1969). In Wyoming, there are many more males than females at breeding sites (Turner 1958). Males are not territorial (Nussbaum and others 1983). Amplexus may last several days (Turner 1958).

In Wyoming, oviposition sites are usually in the shallow and warmest portion of the pond (Morris and Tanner 1969). In Wyoming and British Columbia, eggs are laid in the open in clear water not attached to vegetation (Licht 1969b, Morris and Tanner 1969). In British Columbia, eggs are deposited in the early afternoon (Licht 1969b). Many egg masses may be placed next to or on top of other egg masses (Licht 1969b).

The thermal tolerance of early embryos is about 6 to 28 °C in Oregon and British Columbia (Johnson 1965, Licht 1969b). Time to hatching is temperature-dependent and varies from about 55 hours at 28 °C to about 600 hours at 7 °C (Nussbaum and others 1983). In Wyoming, eggs hatch in about 2 weeks, but the time to hatching varies with local weather conditions and water temperature (Turner 1958). In Wyoming, the larvae are about 10 mm when they hatch (Turner 1958).

In Utah, the time from metamorphosis to hatching can vary from 122 to 209 days (Morris and Tanner 1969). Nussbaum and others (1983) suggested that tadpoles may metamorphose during their first season in coastal and western valley locations but overwinter as larvae in certain mountain and interior regions. These frogs probably reach sexual maturity in 2 years (Nussbaum and others 1983). In Wyoming, however, sexual maturity may not be reached until 4 years in males and 5 to 6 years in females (Turner 1960). Size at metamorphosis varies from 16 to 33 mm SVL (Nussbaum and others 1983, Turner 1960).

Predators and prey—A detailed list of the food items eaten by *R. pretiosa* in British Columbia, western Montana, and Oregon can be found in Licht (1986b), Miller (1978), and Whitaker and others (1983), respectively. The food eaten differs with age and size of the frog and includes many insect species, arachnids, and molluscs. Of special note is the work of Whitaker and others (1983) who suggested that management practices in Oregon may have altered the food items available for *R. pretiosa.* Frogs from managed sites had different diets than those at other sites. For example, more grasshoppers were eaten at sites where soil was compacted, presumably due to grazing livestock.

Turner (1960) suggested that predation pressure was relatively light on adults in Wyoming, with Northern harriers, garter snakes, and mink the major predators. *Rana pretiosa* avoids predation by jumping into water and remaining there for long periods of time (Licht 1986a). When water is not available, *R. pretiosa* jump in short weak circular jumps (Licht 1969b). *Rana pretiosa* do not jump as far as *R. aurora,* most probably because they have shorter hindlegs (Licht 1969b).

Miscellaneous notes—Intermittent aggregations of *R. pretiosa* larvae may form for feeding (Carpenter 1953). The social behavior of *R. pretiosa* tadpoles is poorly understood. Unlike the larvae of some other frogs, *P. pretiosa* do not preferentially aggregate with kin over nonkin (O'Hara and Blaustein 1988).

Relationship to Old-Growth and Potential Impact of Habitat Loss

While *R. pretiosa* is found in several habitat types, including those dominated by Douglas-fir, Ponderosa pine *(Pinus ponderosa* Dougl. ex Laws.), and semiarid to arid sites dominated by sagebrush (see Stebbins 1954a, 1966. 1985), the decline of *R. pretiosa* west of the Cascade Range is significant. Increased habitat loss in Oregon and Washington can only have a detrimental effect on *R. pretiosa* populations. The U.S. Fish and Wildlife Service listed *R. pretiosa* as a candidate for threatened and endangered status under the provisions of the Federal Endangered Species Act (Marshall and others 1992; McAllister and Leonard 1990, 1991). *Rana pretiosa* is listed as a candidate for the endangered species list in Washington and is considered a "species of concern" in Oregon.

This frog is not an old-growth forest obligate, but forested areas may represent important refugia from further population losses. Protection of western spotted frog populations is needed until status assessments are completed. Surveys for this species in Pacific Northwest forests need to be conducted, and forest management practices should include impact assessments for this species. Lehmkuhl and Ruggiero (1991) did not conduct a risk assessment of western spotted frogs. Thomas and others (1993) considered western spotted frogs on their "long list of species to evaluate as old-growth forest associates. Their viability under the forest management alternative was not assessed.

Sharptail Snake *(Contia tenuis)*

Description

This is a small (20- to 45-cm) secretive colubrid snake. It is reddish brown or grey dorsally, and its venter has an unusual banding pattern of alternating black and cream crossbars (Nussbaum and others 1983, Stebbins 1985). The tail is tipped by a sharp spine. It has enlarged teeth, in comparison to related genera (Stickel 1951, Zweifel 1955).

Juveniles measuring 10 to 12 cm in total length have been collected. They can have a vivid reddish-brown dorsum (Cook 1960). Hatchlings 8.9 to 10.4 cm in length have been found in fall (Brodie and others 1969).

Eggs can be cream to pale yellow (Cook 1960), and the pigmentation of the unhatched young is visible through the shell (Brodie and others 1969). Clutches may be laid communally because females produce three to five eggs and clutches up to nine eggs have been found (Brodie and others 1969). Eggs are deposited subsurface, and clutches have been excavated from rock outcrops and grass roots (Nussbaum and others 1983). Brodie and others (1969) found clutches 15 to 30 cm below the surface in cracks in rock outcrops, and Nussbaum and others (1983) reported eggs 7 to 15 cm subsurface. Eggs can measure from 7 by 20 to 28 mm (Cook 1960, Nussbaum and others 1983).

Range and Habitat

The sharptail snake has a patchy distribution, ranging from southern British Columbia to central California. Scattered populations exist throughout this range, but particularly north of Oregon. There are isolated populations on Vancouver Island, British Columbia, east of the crest in the Cascade Range in Washington, and in the

Washington Puget Sound area southwest of Tacoma (Nussbaum and others 1983, Stebbins 1985). In California, the range splits around the central valley (Cook 1960) with Sierra Nevada Range populations extending south to Pine Mountain and coastal populations ranging south to San Luis Obispo County (Stebbins 1985). In Western Oregon, this snake generally occurs at low elevations, but in other parts of its range it can be found up to 2010 m (Stebbins 1985).

Sharptail snakes can be found in various habitats, including forests, chaparral, and grassland (Stebbins 1985). Nussbaum and others (1983) report sharptail snakes frequently occur at the edges of coniferous or open hardwood forests. Cook (1960) synthesized the known historical occurrence of *Contia.* He reported collections from open meadows and pastures on the east edge of fir forests or among oaks near Corvallis, Oregon. In California, they were found in an oak-madrone woodland. They have been found in disturbed areas or suburbs; specimens have been collected in gardens and among yard debris (for example, tires, cement slabs; Cook 1960).

Stebbins (1954a) considered the activity patterns and habitats of sharptail snakes somewhat analogous to western plethodontid salamanders. They are more active near the surface during cooler wetter periods of spring and fall (Nussbaum and others 1983), like many Pacific Northwest amphibians. They seem to be adapted to relatively low temperature: they are active in temperatures of 10 to 17 °C (Nussbaum and others 1983) and have been found with food in their digestive tracts at 11 to 16 °C (Cook 1960). *Contia* often is found in moist areas: near streams, in or under rotting logs, under bark or rocks, or in talus slopes (Cook 1960, Herrington 1988, Nussbaum and others 1983, Stebbins 1985). They seldom are found on the surface (Cook 1960), but can be found under the surface litter of log landings and clearcuts, especially after rain. Their distribution may be directly related to moisture levels. Fitch (1936) reported nocturnal activity in a captive specimen from the Rogue River basin, Oregon. Declines near Stanford University, Palo Alto, California, in the 1920s may have been caused by the reduction in the water table (Cook 1960).

Ecology and Behavior

Reproduction—The breeding ecology and behavior of *Contia* is not well known. Eggs seem to be laid in June to July with hatching occurring from August to October (Cook 1960, Nussbaum and others 1983). Cook (1960) found two activity peaks for this snake coinciding with spring, summer, and fall. He attributed the fall increase in activity to the emergence of hatchlings in September. Brodie and others (1969) found 43 *Contia* eggs in September and October: one was spoiled, one was viable but unhatched, and 41 were hatched. Their report of six hatchlings near the eggs support a fall hatching period for this snake. Clutches of eight and nine eggs suggest communal oviposition, and one clutch has been found within 8 cm of *Pituophis* (gopher snake) eggs (Brodie and others 1969).

Oviposition seems to occur in cool, moist areas subsurface. Brodie and others (1969) found eggs in a small draw, halfway up a hillside, in rock outcrops or bunch grass roots. Frequency of occurrence of *Contia* in talus slopes suggests they may use talus for breeding, yet talus is more generally considered a microhabitat refuge (for example, Herrington 1988).

Predators and prey—The sharptail snake seems to be a specialist predator on small slugs. Cook (1960) quoted an unpublished report by Woodin from 1951, "of the 67 preserved specimens examined, slugs were found in 9, and no other identifiable remains were discovered." Woodin offered four *Contia* many invertebrate species as potential prey and found only small slugs were "immediately grasped and swallowed." Cook (1960) also reported that a sharptail snake collected by Stebbins disgorged a slug. Darling (1947) found gastropods 4 to 8 mm in length in 6 of 23 *Contia* collected near Corvallis, Oregon. Zweifel (1954) suggested that the long sharp teeth of this snake was advantageous for preying primarily on slugs. Cook (1960) considered slug abundance to be the greatest predictor of *Contia* distributions, and suggested that *Contia* distribution has been modified with changes in native and introduced slug abundances.

Although predators of *Contia* have not been reported, the sharp tail of this snake is thought to be used for antipredator defense. When handled, *Contia* can "press the tail spine against one's skin" (Nussbaum and others 1983). The effectiveness of this behavior to discourage predation has not been studied.

Aggregations—Field surveys occasionally uncover aggregations of sharptail snakes. Cook (1960) considered these snakes to be either gregarious or to concentrate in small suitable habitat. In areas with suitable habitat, they can obtain high densities. For example, 8 were found under a log in Lebanon, Oregon, and 11 under boards in Comptche, California, Mendocino County (Cook 1960).

Sharptail snakes do not seem to have stringent ties to old-growth forests because they occur in many habitat types, from disturbed suburbs to open woodlands. Surveys with adequate sample sizes, however, have not been conducted to fully address their habitat requirements. In a study of herpetofauna associations with forest age, Welsh and Lind (1991) reported 10 captures of sharptail snakes: 8 were in old-growth stands (>200 year), 1 in mature forest (100- to 200-year stands), and 1 in young stands (22- to 99-year stands). In contrast, Raphael (1988) found 22 of these snakes in northwestern California forests, with most occurring in young stands, <50 years old. They seem to be rare snakes, but their subsurface activities may bias sampling effectiveness. Their disjunct distribution pattern, their occurrence in old stands, and their microhabitat requirements similar to some terrestrial salamanders in old forests, lead us to believe forest conservation measures could benefit this species. This species is listed as Sensitive in Oregon (Marshall and others 1992).

Lehmkuhl and Ruggiero (1991) did not conduct a risk assessment of this species. Thomas and others (1993) considered sharptail snakes on their "long list of species to evaluate as old-growth forest associates. Their viability under the forest management alternatives was not assessed.

Western Aquatic Garter Snake *(Thamnophis couchii)*

The western aquatic garter snake is polytypic, with most authors recognizing six subspecies (Behler and King 1979, Nussbaum and others 1983, Stebbins 1985). One subspecies, the Oregon garter snake *(T. c. hydrophilus),* is restricted to the Pacific Northwest, occurring in southern Oregon and Northern California (Stebbins 1985).

Description

The Oregon garter snake has a dorsal grey ground color with two rows of alternating black spots which can become fused in older individuals. Unlike other garter snakes, a middorsal stripe is often faint or lacking in this species. Similarly, lateral striping is lacking, faint, or confined to the second or third scale row (Nussbaum and others

1983, Stebbins 1985). The venter is usually immaculate, and the rear portions of the body and the entire tail is often pink or purple. Dorsal scales are all highly keeled, and of the eight upper labials present, the sixth and seventh are not enlarged (Behler and King 1979, Nussbaum and others 1983, Stebbins 1985). This subspecies has a narrow head with a pointed muzzle, and usually has 8 supralabials and 10 lower labials (Fitch 1936).

The sexes differ in size, with males being smaller than females. Total lengths up to 84 cm have been reported, with SVL generally ranging from 33 to 58 cm for males and from 35 to 61 cm for females (Nussbaum and others 1983). In Del Norte County, California, SVL ranged from 45 to 70 cm (mean SVL 53.8 cm) for adults, 18.8 to 44.6 cm for juveniles, and 17.9 to 22.6 cm for neonates (Lind 1990).

Range and Habitat

The western aquatic garter snake is found in Oregon to Baja California, and east to Nevada (Behler and King 1979; Fitch 1936,1949; Stebbins 1985). Populations are found in various aquatic habitats from sea level to 2440 m (Stebbins 1985).

The Pacific Northwest form occurs from southwestern Oregon (Coos, Curry, Douglas, Josephine, and Jackson Counties) to northwestern California (Nussbaum and others 1983, Stebbins 1985). This subspecies uses permanent streams with rocky substrates (Fitch 1936) and fast-flowing clear water (Stebbins 1985). It is considered to be the most highly aquatic of the four garter snake species in the Pacific Northwest (for example, Nussbaum and others 1983, Stebbins 1985), spending more time foraging in water and underwater than northwestern congeners with aquatic tendencies (that is, *T. sirtalisand T. elegans,* Drummond 1983).

Stream microhabitats used by western aquatic garter snakes include both fast water and pools (Drummond 1983; Fitch 1940, 1941; Lind 1990). Stream margins are used for basking (Lind 1990). Fitch (1936) reported collecting 120 specimens from boulders along the edge of the water, midstream, and underwater.

Lind (1990) found that the stream microhabitats used by T. *couchii* for foraging were different among age classes. Neonates frequent shallow edgewaters of streams, juveniles use shallow riffles and edgewaters, and adults forage in a greater variety of habitats and primarily in faster-flowing deeper water (up to 0.5 m deep). Adults of other aquatic snakes also use deeper water than juveniles (for example, Scott and others 1989). Neonates and juveniles require cobbles and boulders along stream margins for their ambush foraging perches (for example, Lind 1990). Adult Oregon garter snakes move at faster rates than young individuals (Lind 1990). In congeners, similar size-dependent crawling speed has been found *(T. sirtalis,* Heckrotte 1967; *T. elegans.* Garland and Arnold 1983). Adults may have greater endurance than neonates (for example, Lillywhite 1987, Pough 1977). Microhabitat partitioning in *Thamnophis* may be related to ecological factors such as prey availability and predator exposure (Lind 1990).

Ecology and Behavior

Reproduction—Reproduction in this snake is poorly understood. Mating seems to occur in spring, and females give birth to 7 to 25 live young in late summer or early fall (Nussbaum and others 1983). Lind (1990) reported neonate observations in August and September in Hurdygurdy Creek, California.

Predators and prey—The Oregon garter snake is a diurnal predatory specialist on aquatic vertebrate prey and may play an important role as a predator in stream communities in southwestern Oregon and northwestern California. In the Rogue River basin, Fitch (1936) reported that prey included tishes (including salmonids) and amphibians (larvae and adults). Infrequent components of the diet may include newts (Fitch 1936. Fox 1952) and fish eggs (Drummond 1983). In northwestern California, Lind (1990) identified three vertebrate prey: steelhead trout *(Oncorhynchus mykiss), Dicamptodon* larvae and neotenes, and foothill yellow-legged frog larvae *(Rana boylii).* She found diets were different among age classes, with adults preying primarily on salamanders, juveniles on fish, and neonates on frog tadpoles (diet compositions: neonates [n = 10] - 30-percent fish, 60-percent frogs, 10-percent salamanders; juveniles [n = 62] - 69-percent fish, 26-percent frogs, 5-percent salamanders; adults [n = 14] - 21-percent fish, 29-percent frogs, 50-percent salamanders). Other aquatic snakes show similar ontogenetic patterns of prey preferences (for example, Mushinsky 1987). Lind and Welsh (1990) reported observations of predation by Oregon garter snakes on giant salamanders *(Dicamptodon)* in a northwestern California stream. They found snakes measuring 292 to 665 mm (SVL) ate neotenic or larval salamanders measuring 34 to 133 mm (SVL). One large female snake (SVL 578 mm, mass 92 g) ate a salamander (SVL 133 mm, mass 80.9 g) that was 88 percent of its body weight. Lind (1990) found smaller prey, to 50 mm in total length, were taken by neonates and juveniles. Captive specimens readily accepted Pacific treefrogs *(Hyla regilla),* and sympatric ranids *(Rana aurora, R. boylii)* were accepted but "with less enthusiasm" (Fox 1952). Although young bullfrog *(R. catesbeiana)* tadpoles were taken by the snakes, older metamorphs, juvenile frogs, and adult frogs were not taken, and their odor did not elicit feeding responses (Fox 1952). Fox (1952) found the odor of fish also produced active feeding responses, whereas newborn rats and mice did not elicit similar responses. Rats smeared with fish odor were eaten by some of these aquatic snakes, only to be regurgitated undigested and spoiling 2 to 3 days later. Fox (1952) noted that foraging garter snakes are prone to lunge and grab "anything that moves," and large snakes will swallow smaller relatives. However, cannibalism under natural conditions in Oregon garter snakes is not well documented.

Thamnophis couchii foraging includes sit-and-wait and active searching behaviors. Drummond (1983) described active underwater foraging: snakes crawled along the bottom of streams and actively searched for prey. Other aquatic foraging behaviors include craning over the water surface from emerging rocks and maintaining an ambush position on rocks over the water edge (Drummond 1983, Lind 1990). Drummond (1983) observed 202 underwater attacks on fish prey in an artificial pool and found most occurred during active pursuit (49-percent) or substrate crawling (27-percent) behaviors. These behaviors were also seen during field observations of three snakes. Lind (1990) found differences among age classes in foraging behavior. Neonates predominantly used sit-and-wait foraging tactics, poised in an ambush position along the stream margin. Adults were more active in their foraging, using underwater substrate crawling to search for prey. This behavior seemed much more effective at prey capture. Juveniles used both sit-and-wait behaviors and active searching.

Enhanced underwater vision seems to aid *T. couchii* foraging. Schaeffel and de Queiroz (1990) found that this snake can constrict its pupil to a size up to one-third the diameter when the snake is out of water. This presumably increases resolution of the eye by as much as a factor of three. Enhanced visual acuity underwater can explain the response of western aquatic garter snakes to prey at greater distances than congeners (Drummond 1983, Schaeffel and de Queiroz 1990).

Predation on the Oregon garter snake has not been examined in detail. Many potential predators exist, such as river otters, great blue herons, western red-tailed hawks, American osprey, and Steller's jay (Lind 1990).

Relation to Old-Growth and Potential Impact of Habitat Loss

The relation of this reptile to old-growth forest conditions is only implied because data to address this issue have not been published. Although some surveys have included reptiles in examinations of vertebrate relations to forest age in the Pacific Northwest (for example, Raphael 1988, Welsh and Lind 1991), the methods generally have not been effective to sample the Oregon garter snake. Most existing terrestrial and aquatic survey protocols (for example, for herptiles: Bury and Corn 1991, Corn and Bury 1990; for fish: Hankin 1986, Hankin and Reeves 1988) do not effectively survey for aquatic reptiles in streams and along stream margins. Several aspects of the ecology of these snakes suggest, however, the importance of maintaining the integrity of stream-forest systems. These snakes seem to require clean, clear water, boulders for basking and foraging, dense riparian vegetation, and an intact prey base of aquatic vertebrates. These conditions can be severely compromised with land management practices. The effects of timber harvest on streamside vegetation, water quality, substrate composition, and fish and amphibian populations may significantly impact snake populations. Oregon garter snake populations should be studied to address their reliance on forest conditions. Surveys specific for this snake should be conducted when land management practices are considered in this region. The status of another subspecies of this snake, T. c. *gigas,* is of concern in the San Joaquin Valley, California, due to both habitat destruction and collections for pets (for example, Dodd 1987).

Lehmkuhl and Ruggiero (1991) did not conduct a risk assessment of this species. Thomas and others (1993) considered western aquatic garter snakes on their "long list" of species to evaluate as old-growth forest associates. Data were unavailable, however, to consider them "close associates" with old-growth forest conditions. Their viability under the forest management alternatives was not assessed.

Western Pond Turtle *(Clemmys mamorata)*

Description

Clemmys marmorata is a medium-sized turtle, with adults measuring 110 to 210 mm in carapace length (Bury and Holland, in press; see also Nussbaum and others 1983). Males attain larger maximum sizes than females. Females have been found up to 192 mm (Bury and Holland, in press). They have a low and smooth carapace, which may be olive, dark brown, or black. Compared with females, males can have a lower relative shell height (Seeliger 1945). There is usually a pattern of spots, lines, or dashes of brown or black that radiate from centers of the carapace scutes. The plastron is yellowish and may be unmarked, but usually shows a pattern of dark blotches. Males have a concave plastron, whereas that of females is flat (Bury 1970, Ernst and Barbour 1972, Stebbins 1985). Additional sexually dimorphic features include a shorter, thicker male tail and a more posteriorly located male cloaca, at or beyond the margin of the carapace (Seeliger 1945). The skin is gray to light brown with some pale yellow on the neck, chin, forelimbs, and tail. The head may be plain or with spots or reticulations of black.

The eggs are white and elliptical in shape, and 32 to 42 mm in length by 20 to 23 mm in width (Nussbaum and others 1983). Hatchlings measure about 25 to 31 mm in carapace length (Bury and Holland, in press; Seeliger 1945) and are gray in the center of the plastron (Seeliger 1945).

Two subspecies have been recognized, the northwestern pond turtle *(C. m. marmorata)* and the southwestern pond turtle (C. *m. pallida,* Bury 1970, Ernst and Barbour 1972, Seeliger 1945, Stebbins 1985). Distinguishing features of the northwestern form are a pair of relatively large triangular inguinal plates and dull neck markings (Seeliger 1945). From morphometric variation, Holland (1992) identified three evolutionary groups of western pond turtles: a Columbia River form, a northern form extending south to central California, and a southern form.

Range and Habitat

Clemmys marmorata has a disjunct distribution pattern, particularly in the Pacific Northwest. Its current range seems to extend from Puget Sound, Washington (Holland, in press), to northwestern Baja California, principally west of the Sierra-Cascade crest (Bury 1970), from sea level to 1830 m (Stebbins 1985). The northern subspecies, *C. m. marmorata,* occurs south to the San Francisco Bay area, and the southern subspecies, *C. m. pallida,* ranges to northwestern Baja California (Bury 1970, Ernst and Barbour 1972, Seeliger 1945, Stebbins 1985). Intergrades have been examined in central California (Seeliger 1945). Records in Washington seem to be clustered around the southeastern edge of Puget Sound and along a small portion of the Columbia River (Nussbaum and others 1983). In the Willamette Valley of Oregon, Evenden (1948) found this species to be rare north of Salem, Marion County, and concluded from personal collecting and observations, reviewing of records, and correspondence that this (Salem latitude) may be the northern limit of this species. Isolated historical records from British Columbia and Idaho do not seem to represent extant populations (Holland, in press; Nussbaum and others 1983). Currently known distribution and abundance patterns of these turtles are summarized by Bury and Holland (in press) and Holland (in press), and include the following from Pacific Northwest sites: a few individuals have been found in the Puget Sound Region; small populations occur along the Columbia River; although turtles occur at many locations in the Willamette Valley, only a few sizeable populations (20 turtles) have been found; and turtles occur along the Willamette, Umpqua, Rogue, and Klamath Rivers, and in some coastal drainages in Oregon.

The western pond turtle inhabits marshes, sloughs, lakes, ponds, and slow-moving portions of creeks and rivers. They generally require emergent basking sites such as partially submerged logs, vegetation mats, rocks, or mud banks (Bury and Holland, in press; Nussbaum and others 1983). Western pond turtles also seem to be associated with sites providing underwater refuge, such as undercut banks, submerged boulders, and roots (Bury and Holland, in press). Evenden (1948) gave two records of pond turtles occurring in rapid-flowing, clear, cold, rock and gravel streams in the Cascade Range foothills. Additionally, it has been reported from brackish coastal waters (Ernst and Barbour 1972) and areas with no basking sites (Holland, in press).

Although these turtles are found almost exclusively near water, they use terrestrial habitats for nesting, overwintering, and dispersal. Nesting sites seem to occur in sunny locations, and can be hundreds of meters away from water (Storer 1930; over 400 m, Holland, in press). Overwintering in upland habitats, 15 to 480 m from water, occurs in the Pacific Northwest (Bury and Holland, in press; Holland 1993). Overland dispersal is not well documented, but turtles have been found along roads or in fields (Bury and Holland, in press; Nussbaum and others 1983), and moving distances greater than 1 km (Holland, in press).

Ecology and Behavior

The behavior and population ecology of western pond turtles was examined during a four-summer study in Trinity County. California, by Bury (1972). The study site was a creek at 610 m in elevation and in an area of woods (oak, ponderosa pine,;and a few Douglas-fir), chaparral, and open grassy areas. Some of the information gathered in this study, based on 578 marked and many unmarked turtles, is presented below.

The behavior of turtles included thermoregulatory activities and intraspecific interactions (see Bury 1972). Deep body temperatures rose sharply after emergence from water for basking, remained high (28 to 34 °C) during basking, and fell quickly after submergence. Turtles maintained optimal temperatures by changes of posture, orientation, position relative to sun and shade and "dunking" in water. They showed aggressive behavior toward one another during basking periods, probably related to spacing.

Western pond turtle abundances may vary geographically or among habitat types. There was a relatively high density of turtles at the Trinity County study site (214 per ha). Of 704 *C. marmorata* surveyed, 35.2 percent were juveniles, and no hatchlings were found. In contrast, of 145 sites recently surveyed in the Willamette Valley, only two had apparently healthy populations (Bury and Holland, in press). Previously, in two Willamette Valley ponds (1.5 to 2.0 ha), numbers of *C. marmorata* were estimated to be 75 and 180 (Nussbaum and others 1983). In Trinity County, the sex ratio was slightly male-biased: 246 males and 210 females. Male home ranges were much larger than females or juveniles. Estimates of home range size were as follows: adult males, 0.976 ha (2.41 acres); adult females, 0.248 ha (0.61 acre); and juveniles, 0.363 ha (0.90 acre).

Recent surveys in Trinity County have recaptured individuals 20 to 25 years after they were first marked (Bury and Holland, in press). Bury and Holland (in press) estimated that turtles may require 15 years to attain full adult sizes and that some recaptured adults are at least 40 years old (15+25 yr). Nussbaum and others (1983) also estimated that some turtles in a Corvallis, Oregon, pond were 30 to 40 years old.

Generally, the activity patterns of western pond turtles are temperature-dependent. In the southern part of their range, pond turtles may be active year-round (Bury and Holland, in press). In the Pacific Northwest, they seem to be most active on the water surface diurnally, spring through fall, when the water temperature is above 15 °C (Bury and Holland, in press), yet some activity occurs year-round (Holland in press). Evenden (1948) noticed their earliest surface occurrence was February 28 and their latest was November 18. Apparently, they are able to become active during sunnier spells in winter (Storm, personal observation). Overwintering locations seem to differ. Ernst and Barbour (1972) reported that pond turtles hibernate in the bottom mud of streams or ponds (communal overwintering has been reported, Holland, in press). Bury and Holland (in press) reported overwintering on land.

Western pond turtles can be extremely sensitive to disturbance. They can seek underwater cover when detecting as minimal an intrusion as an arm wave at 100 m (Bury and Holland, in press). Increased human activity near their habitat could adversely affect nesting or basking.

Reproduction—Few data exist regarding the courtship and mating of *C. marmorata.* Holland (1988) described a possible courtship sequence, observed underwater in August in San Luis Obispo County, California. On the substrate in about 2 m of water, a male approached a female, repeatedly scratched her carapace, and did coordinated limb-fanning in front of her. The apparent courtship was interrupted when the male detected the observer on the surface of the water.

Throughout their range, western pond turtles nest from late April through August, but the peak in Oregon is thought to be June to mid-July. The eggs are placed in an earthen nest in locations ranging from near the margin of a pond or stream (Rathbun and others 1992, Storer 1930) to 100 m above and 400 m away from water (Storer 1930; Holland, in press). Full sunlight on the nest site seems to be a requirement, such as open grassy areas with southern exposure (Rathbun and others 1992). Clutch size is 1 to 13 eggs (Holland 1991, Nussbaum and others 1983). Incubation time in nature is not well documented, but seems to range from 80 to over 100 days (Holland, in press). Eggs incubated at 30 °C hatched in 73 to 80 days (Feldman 1982). Eggs may hatch in the fall, but young may remain in the nest until spring rains (Feldman 1982; Holland, in press). Hatchlings measure about 25 to 31 mm in carapace length (Bury and Holland, in press), grow to about 60 mm in carapace length in 2 years, and measure about 140 mm in 10 years (Nussbaum and others 1983). Western pond turtles show secondary sexual characteristics at 100 to 120 mm plastron length (Bury 1972) and at 5 to 8 years (Bury and Holland, in press). Females in the Pacific Northwest may not reproduce until they are 10 to 14 years old (Holland 1991).

Western pond turtles may not have successful recruitment in many areas. Land use practices (for example, agriculture) may reduce nesting habitat or impact nesting success (Bury and Holland, in press; Storm, personal observations). Additionally. loss and degradation of suitable aquatic and terrestrial habitat, predator introductions, chemical pollution, and collecting for the pet trade can severely impact populations (Bury and Holland, in press).

Predators and prey—Western pond turtles are opportunistic predators, scavengers, and omnivores (Bury 1986). They apparently prefer animal tissue to plant material (Ernst and Barbour 1972). They primarily eat various aquatic invertebrates, but aquatic vertebrates (fish, frogs) can comprise up to 10 percent of their diets (Bury and Holland, in press). Vegetation in their diet may include algae, lily inforescences, and tule and cattail roots (Bury and Holland, in press; Holland, in press). Holland (1985) found several hundred Daphnia in stomachs of some individuals. They are able to capture food items on land, but most prey are captured or obtained by "gape-and-suck" in water (Bury 1986, Holland 1985). There were sex and age differences in types and amounts of food consumed in a northern California study (Bury 1986). Captive turtles have fed well on canned and fresh fish, liver, raw beef, and canned dog food (Ernst and Barbour 1972).

These turtles have various predators and parasites. Carnivorous mammals, such as river otters, raccoons, coyotes, and grey foxes, prey on adults (Bury and Holland, in press) and probably eggs (Holland, in press). Juveniles are eaten by bullfrogs *(Rana catesbeiana)* and fishes such as bass *(Micropterus* spp.) (for example, Moyle 1973, Holland 1991). Both external and internal parasites have been identified for western pond turtles (for example, Bury 1986, Holland, in press), but their effects are unstudied (Bury and Holland, in press). A large proportion (about 35 to 40 percent, Holland, in press) of turtles in a Columbia River population died of a respiratory disease in 1990-91 (Bury and Holland, in press).

Relation to Old-Growth and Potential Impact of Habitat Loss

In the Pacific Northwest, western pond turtles use both aquatic and terrestrial habitats of some forests. Bury (1988) considered western pond turtles to favor larger stream sizes and riverine zones, in comparison to cool shady riparian areas, because of their preference for more open and sunny habitat. Thus, as larger streams transect forested areas, or other suitable turtle habitat such as ponds occur in forests, an association with western pond turtles may be found. Such areas in the Pacific Northwest include aquatic habitats of the Willamette. Umpqua, Rogue, Klamath, Columbia Rivers, and coastal river basins (Holland, in press).

The impact of forest management on western pond turtles has not been examined. Land use practices, including resource management and recreational activities, along stream and pond shores and upland areas may affect nesting or nesting sites, and basking or basking sites, two critical components of western pond turtle life histories. Upstream activities may impact turtle populations if they change water conditions. For example, activities affecting river flows or temperatures may affect turtle thermoregulation, by altering either the temperature regime of the aquatic habitat or the availability of suitable basking sites for thermoregulation.

If western pond turtles are not recruiting successfully in many areas, it becomes very important to carefully protect existing populations. As populations on many managed lands suffer the impacts of multiple stressors, such as introduced fauna, chemical pollution, and habitat destruction, state and Federal lands can become increasingly important refuges.

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Metric and English Units of Measure

When you know:	Multiply by:	To find:
Centimeters (cm)	2.54	Inches
Meters (m)	3.281	Feet
Kilometers (km)	0.621	Miles
Kilograms (kg)	2.205	Pounds
Hectares (ha)	2.471	Acres
Celsius (°C)	1.8 and add 32	Fahrenheit

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Appendix

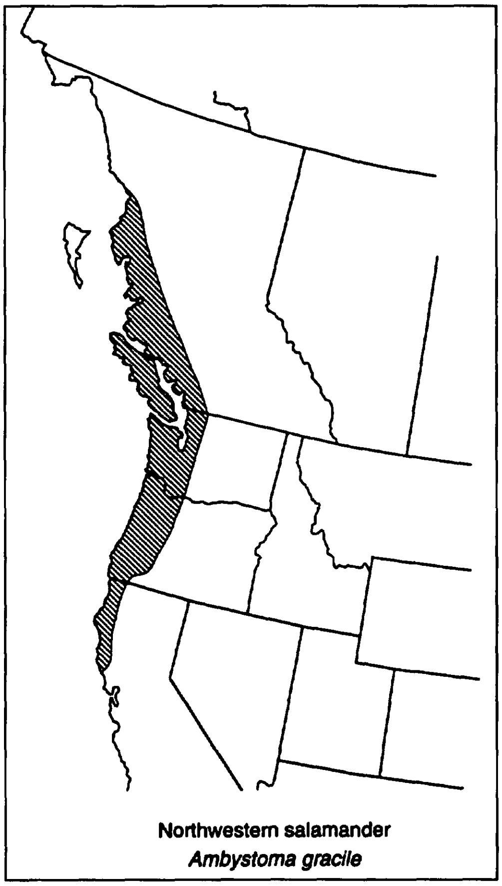

Figure 1—Northwestern salamander *(Ambystoma gracile)*.

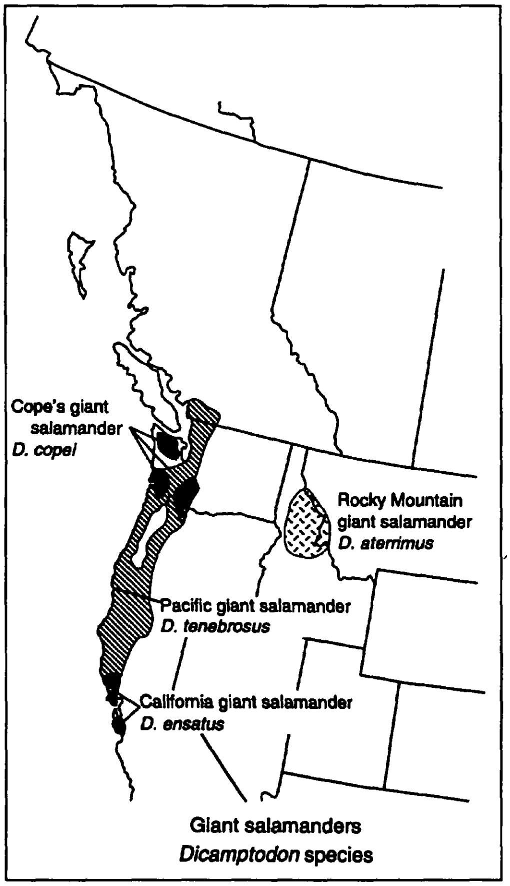

Figure 2—Giant salamanders (*Dicamptodon* species).

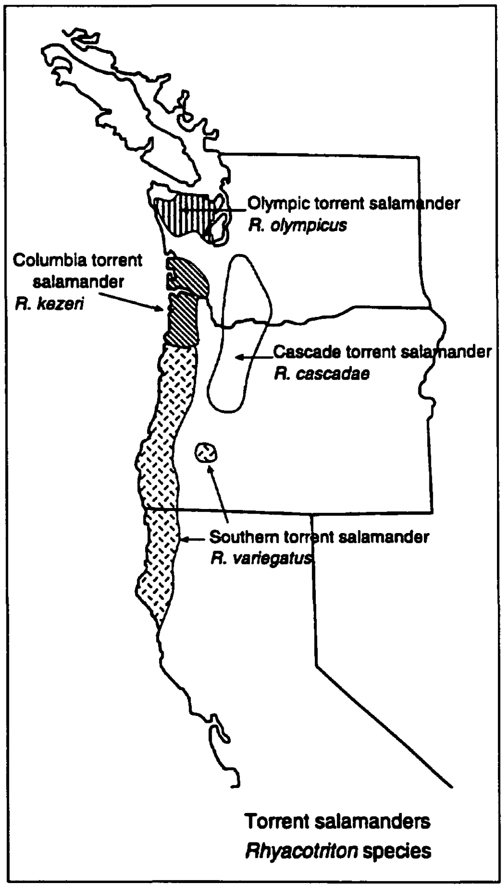

Figure 3—Torrent salamanders (*Rhyacotriton* species).

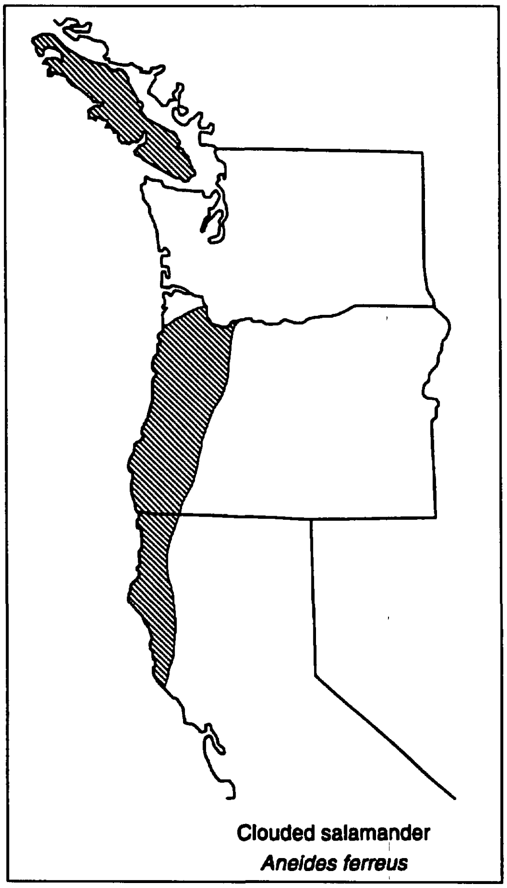

Figure 4—Clouded salamander *(Aneides ferreus).*

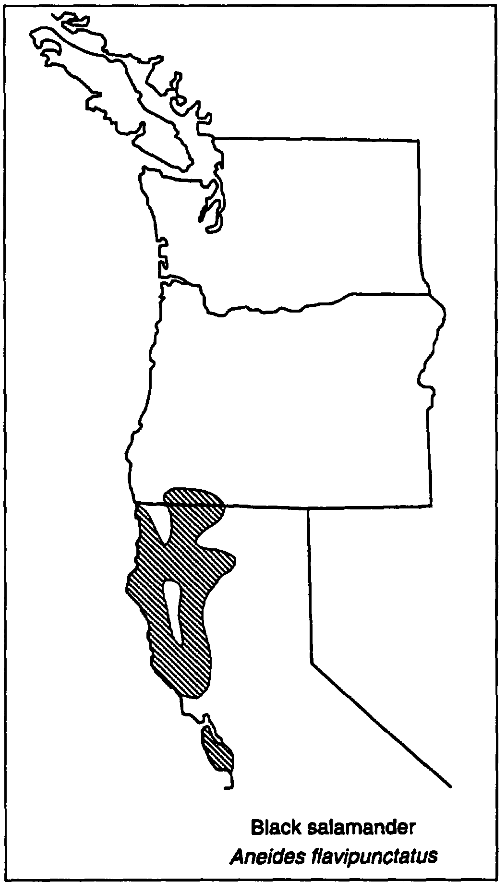

Figure 5—Black salamander *(Aneides flavipunctatus)*.

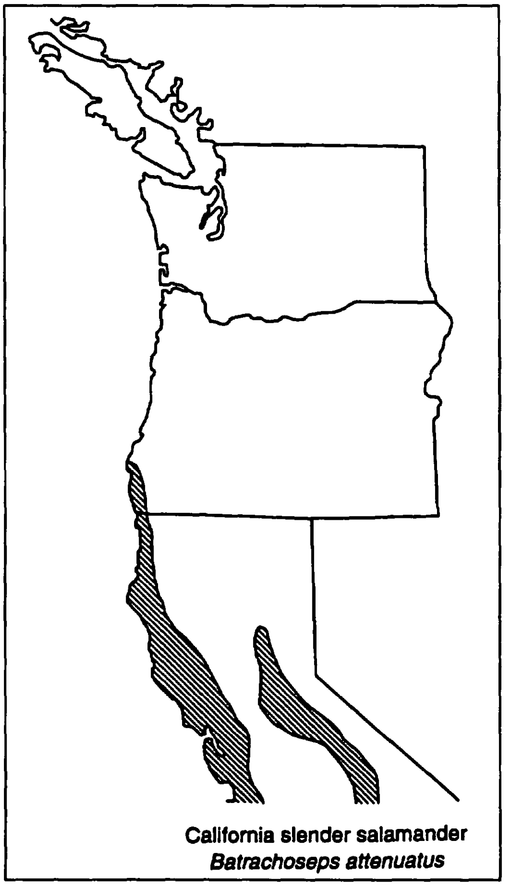

Figure 6—California slender salamander *(Batrachoseps attentuatus)*.

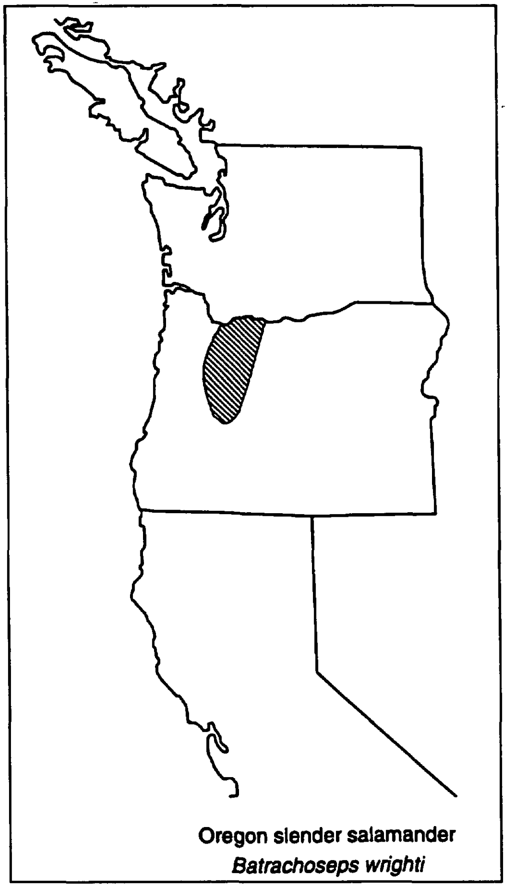

Figure 7—Oregon slender salamander *(Batrachoseps wrighti).*

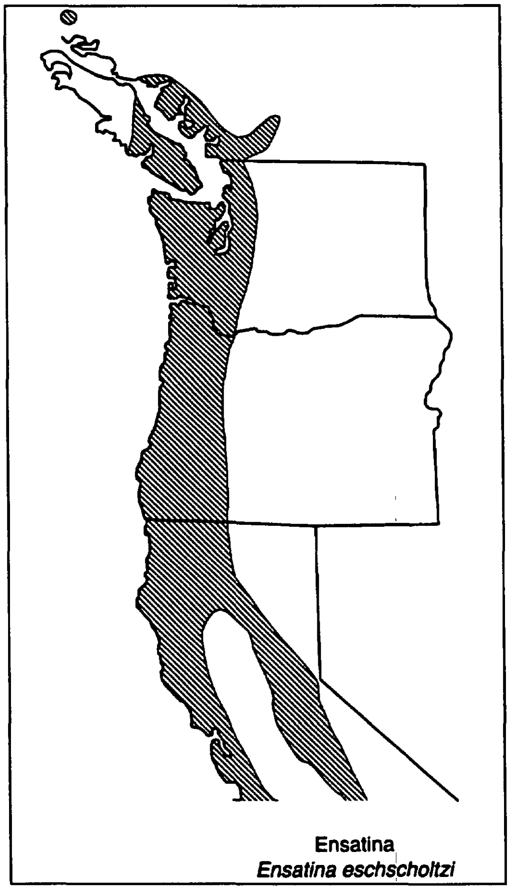

Figure 8—Ensatina *(Ensatina eschscholtzii).*

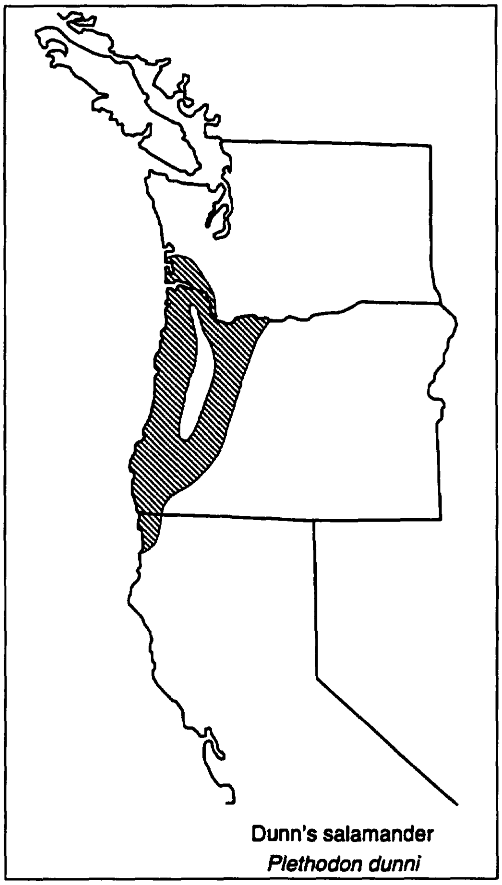

Figure 9—Dunn's salamander *(Plethodon dunni)*.

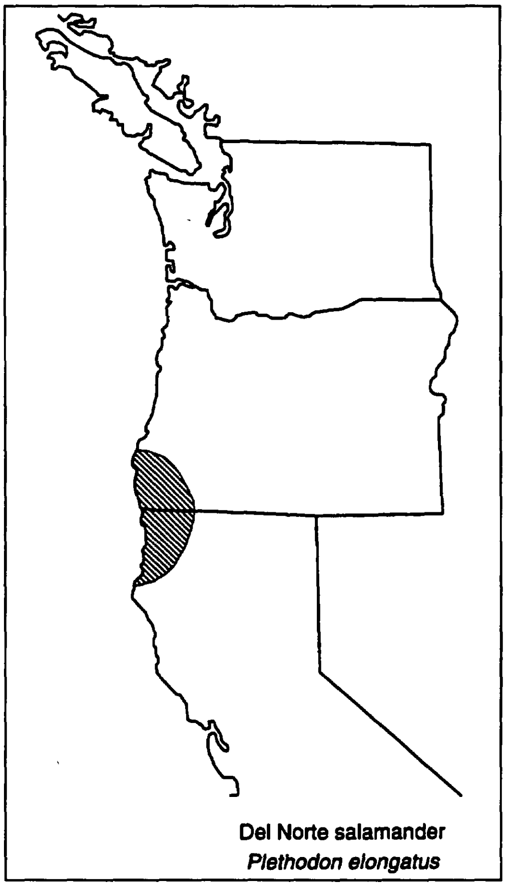

Figure 10—Del Norte salamander *(Plethodon elongatus)*.

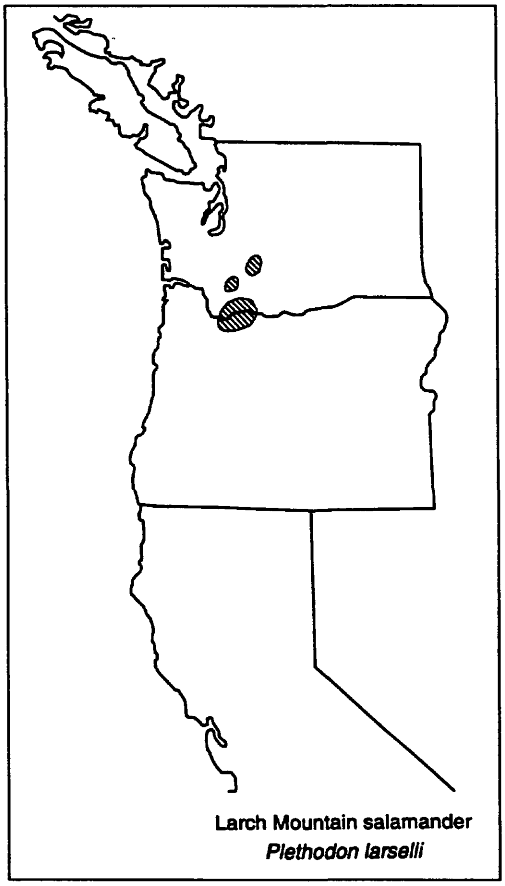

Figure 11—Larch Mountain salamander *(Plethodon larselli).*

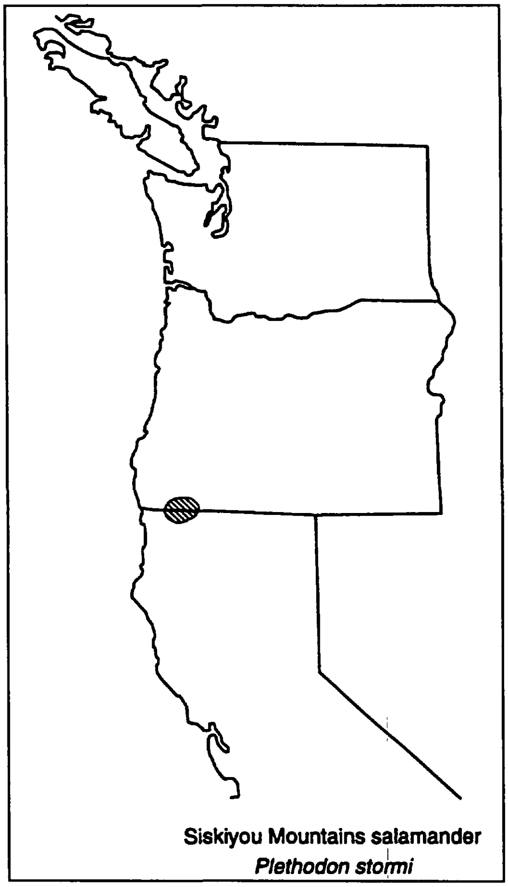

Figure 12—Siskiyou Mountains salamander *(Plethodon stormi).*

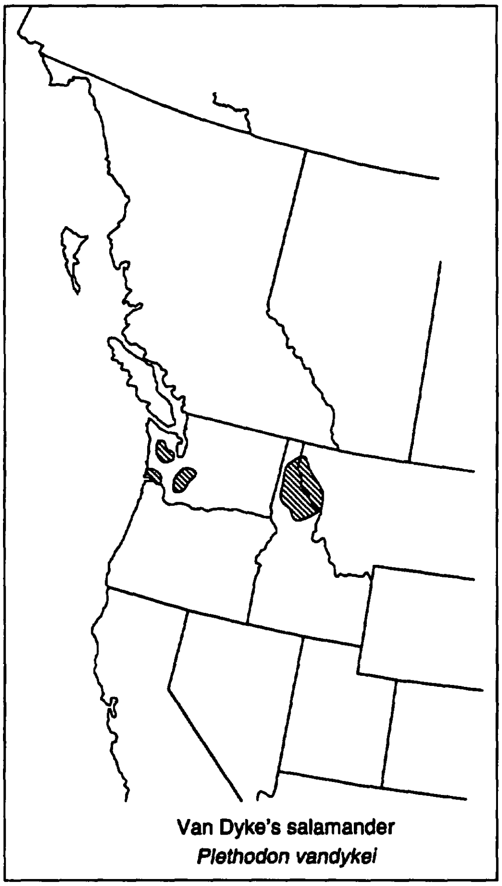

Figure 13—Van Dyke's salamander *(Plethodon vandykei).*

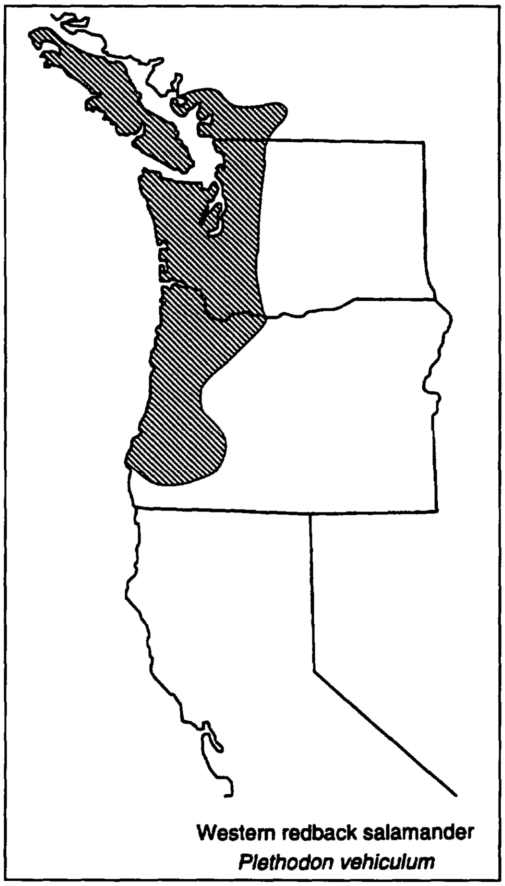

Figure 14—Western red-backed salamander *(Plethodon vehiculum).*

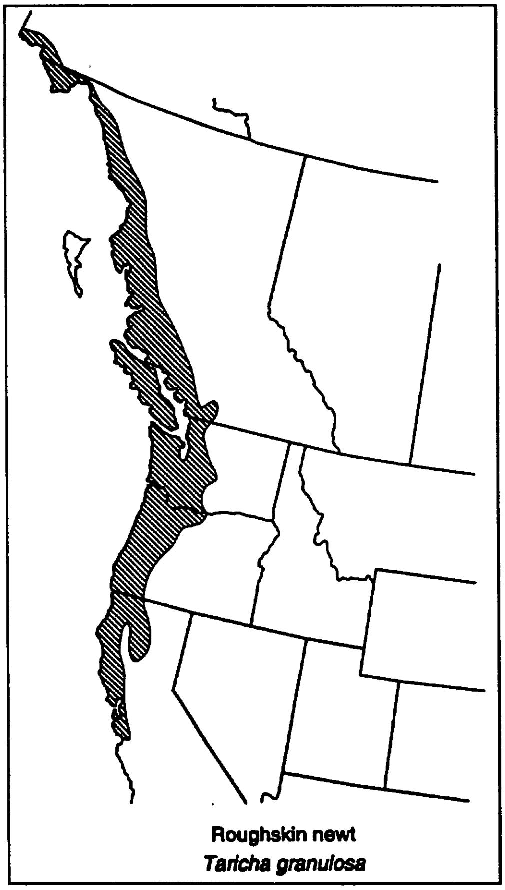

Figure 15—Roughskin newt *(Taricha granulosa)*.

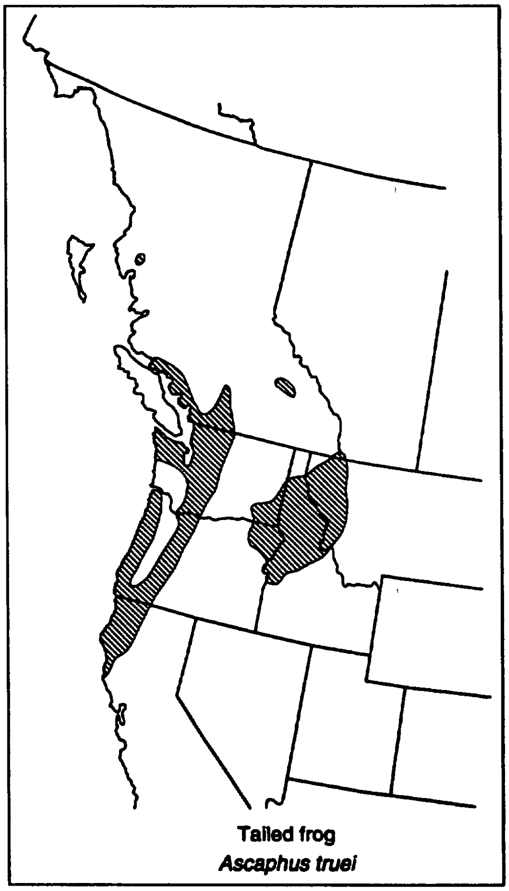

Figure 16—Tailed frog *(Ascaphus truei)*.

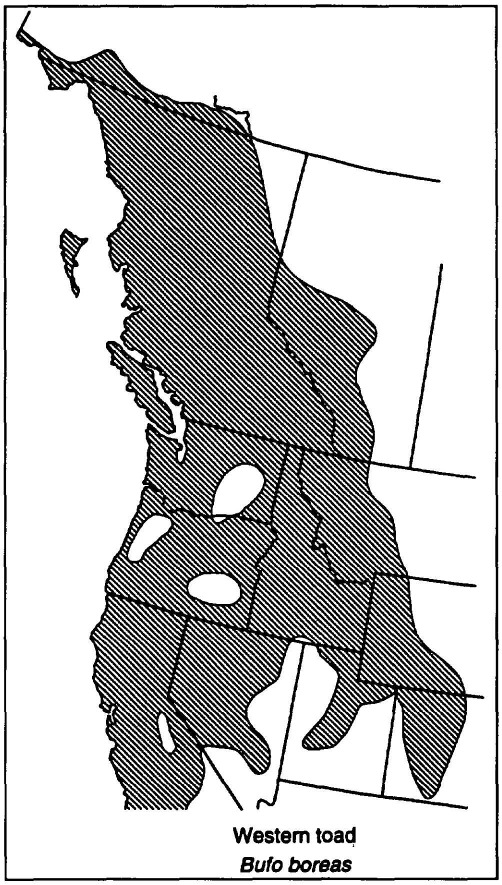

Figure 17—Western toad *(Bufo boreas).*

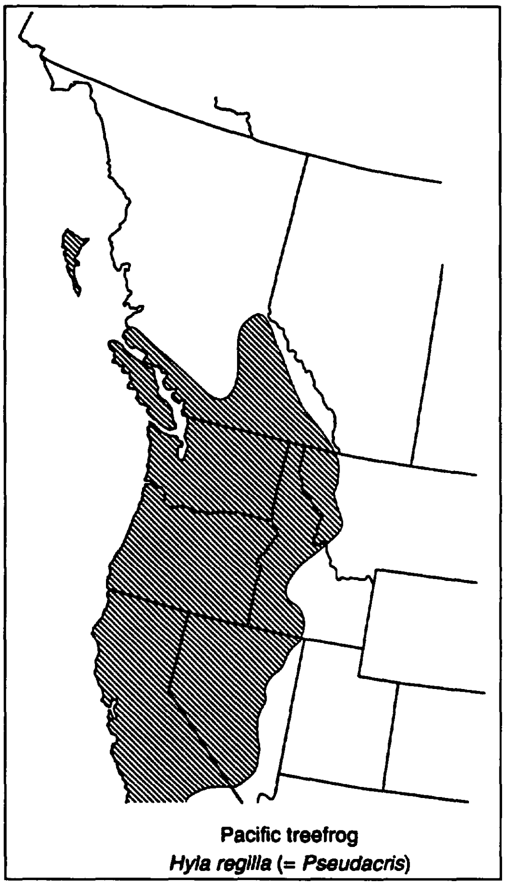

Figure 18—Pacific treefrog *(Hyla [=Pseudacris] regilla).*

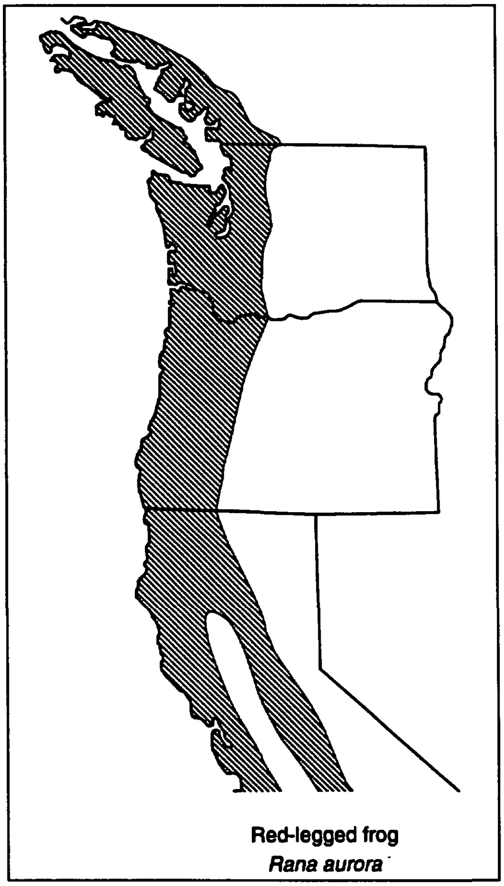

Figure 19—Red-legged frog *(Rana aurora).*

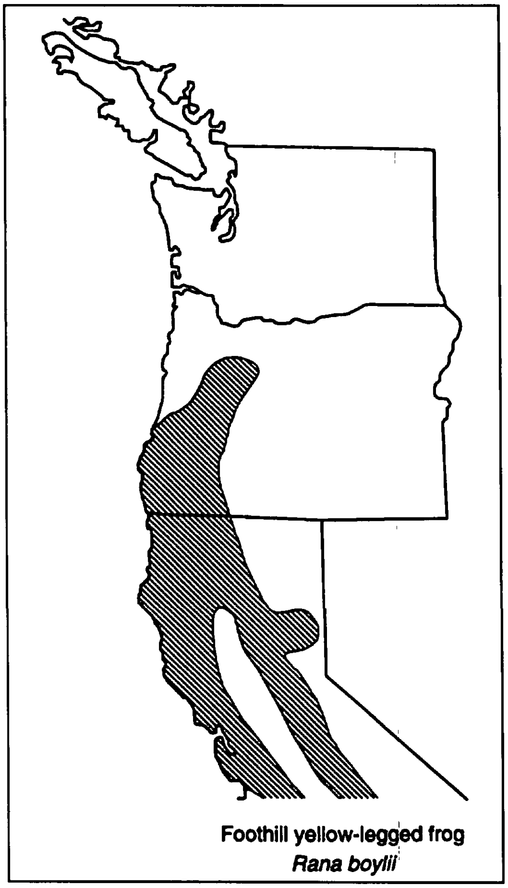

Figure 20—Foothill yellow-legged frog *(Rana boylii).*

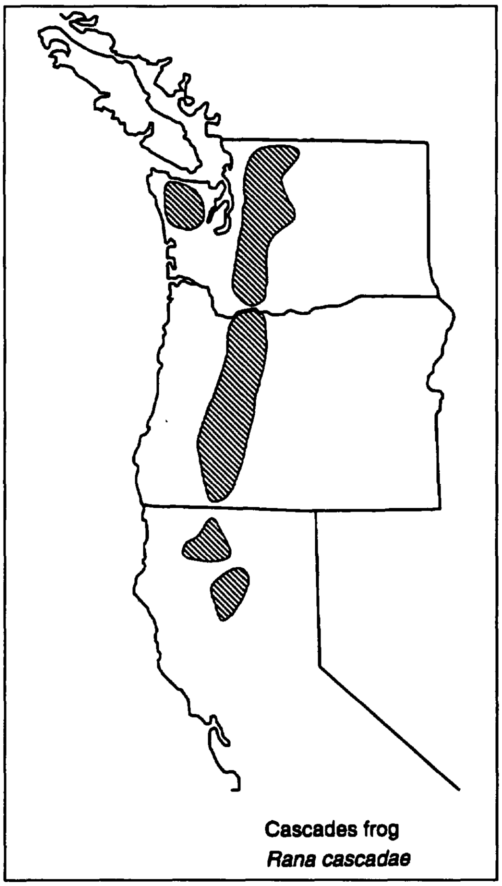

Figure 21—Cascades frog *(Rana cascadae)*.

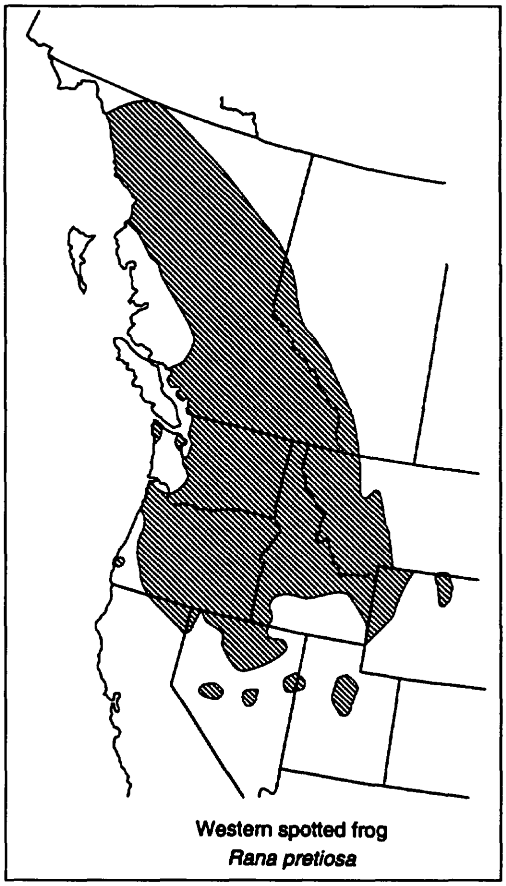

Figure 22—Western spotted frog *(Rana pretiosa)*.

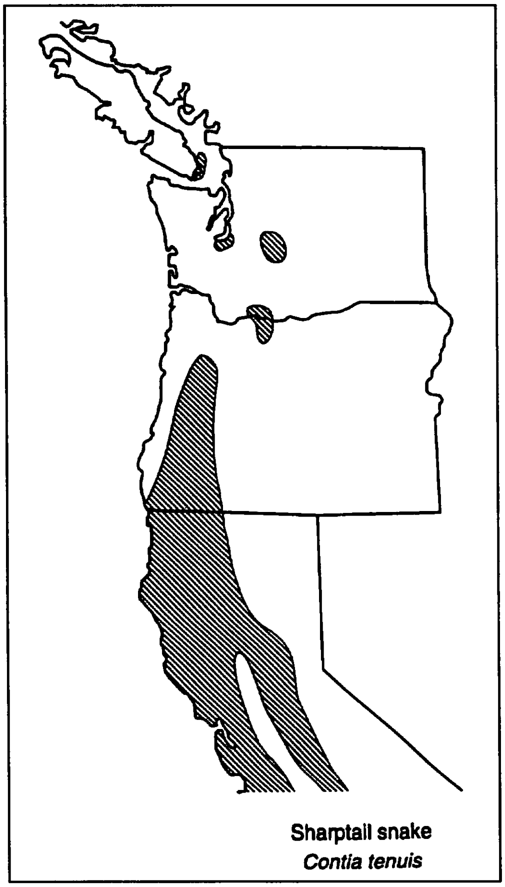

Figure 23—Sharptail snake *(Contia tenuis)*.

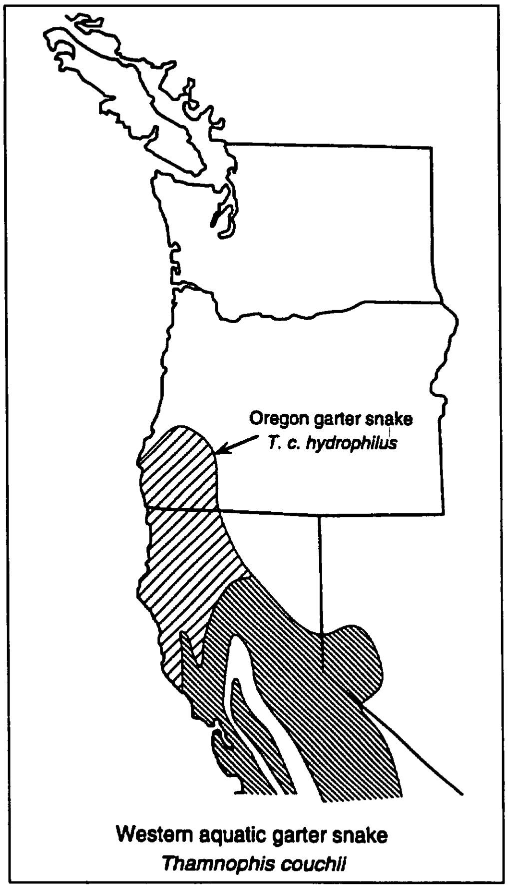

Figure 24—Western aquatic garter snake *(Thamnophis couchii)*.

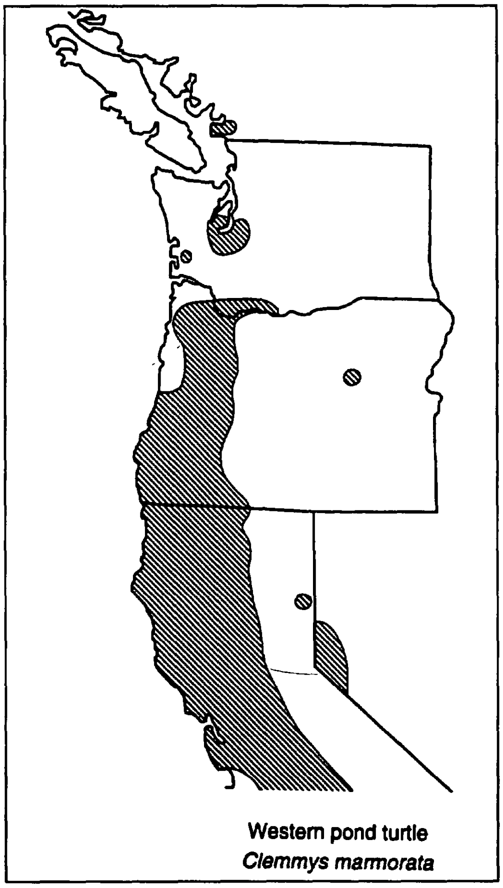

Figure 25—Western pond turtle
(Clemmys marmorata).

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Blaustein, Andrew R.; Beatty, Joseph J.; Olson, Deanna H.; Storm, Robert M. 1995. The biology of amphibians and reptiles in old-growth forests in the Pacific Northwest. Gen. Tech. Rep. PNW-GTR-337. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 98 p.

The amphibian and reptile fauna of older forest ecosystems in the Pacific Northwest includes several endemic species, species with unique behavioral and ecological characteristics, and species whose populations have been in decline in recent years. We review the biology of these species and include information on their distinguishing characteristics, behavior, and ecology. Herpetofaunal associations with forest characteristics and the impact of habitat loss are addressed.

Keywords: Amphibian, reptile, old-growth forest, Pacific Northwest, ecology.

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