AN ABSTRACT OF THE THESIS OF

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Intermittent, headwater streams recently have been recognized as important components of forest ecosystems and have been provided increased protection by the Northwest Forest Plan. However, few studies have examined their distribution, dynamics, and ecological roles, such as habitat for wildlife. My goal was to provide additional information on the ecology of intermittent streams in the Pacific Northwest. I examined and compared hydrologic, water quality, and physical characteristics of 16 intermittent streams in old-growth and young forest stands in the central Cascade Range in western Oregon. I documented amphibian communities and habitat associations in these streams during spring and summer. I used comparisons of current habitat conditions and amphibian communities between stand types to gain insight into potential impacts of timber harvesting on these stream systems.

Of the streams surveyed in old-growth and young forest stands, relatively few (23%) were designated as intermittent based on my definition which included presence of a definable channel, evidence of annual scour and deposition, and lack of surface flow along at least 90% of the stream length. Intermittent streams in old-growth stands exhibited the following characteristics: (1) annual flow pattern in which streams started to dry in May and June and were mostly dry by July; (2) lengthy annual flow durations (range 6 - 11 months); (3) cool and stable daily stream temperatures; (4) primarily coarse substrates, such as cobbles and pebbles; (5) streamside vegetation comprised of predominantly coniferous overstories, and plant species associated with uplands or dry site conditions, such as Oregon-grape and salal, as well as riparian areas or wet site

site conditions, such as Oregon-grape and salal, as well as riparian areas or wet site conditions, such as red alder, oxalis, red huckleberry, and vine maple (Steinblums et al. 1984, Bilby 1988); and (6) low to moderate densities of large wood, mostly moderately- and well-decayed. Study streams in young forest appeared to dry about one to two months later than the streams in old growth but had similar annual flow durations. They also were characterized by higher daily stream temperatures, similar diel fluctuations, finer substrates, more deciduous overstory and herbaceous understory cover, and lower densities of moderately-decayed large wood. Differences in habitat conditions between stand types may be attributed to timber harvesting as well as discrepancies in physiographic and geological factors, such as elevationgradient, and soil type.

Amphibian communities in spring and summer were comprised primarily of the Cascade torrent salamander (Rhyacotriton cascadae), Dunn's salamander (Plethodon dunni), and Pacific giant salamander (Dicamptodon tenebrosus). Amphibian communities in streams in young forest stands exhibited different species composition and seasonal patterns in total density from those in old growth. Cascade torrent salamanders and Dunn's salamanders maintained similar densities and biomass between spring and summer by potentially adopting drought avoidance strategies. Species differed in their use of habitat types and associations with habitat features. In general, amphibian species were positively correlated with percent surface flow, water depth, intermediate-sized substrates and negatively associated with overstory canopy cover, elevation, and wood cover.

Results of my study suggest that intermittent streams may warrant protection for their potential effects on downstream habitat and water quality and for their role as habitat for aquatic species, such as amphibians. Streamside vegetation should be maintained along intermittent channels to provide shade protection for water temperature regulation and sources of large woody debris and other allochthonous energy input, to help stabilize slopes, and to minimize erosion and sedimentation. At a minimum, intermittent stream channels should receive protection from physical disturbance during timber harvesting operations. However, since intermittent stream systems are highly variable, management should address individual site conditions and vary accordingly.

Amphibian Communities and Physical Characteristics of Intermittent Streams in Old-Growth and Young Forest Stands in Western Oregon

by

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CHAPTER 1
INTRODUCTION

Historically, species-specific and economically-driven multiple-use approaches have dominated natural resource management in the Pacific Northwest. The loss and degradation of late-successional forests and aquatic habitats, and the decline of fish and wildlife species associated with these ecosystems, most notably the northern spotted owl (Strix occidentalis caurina), have generated considerable concern over traditional forest management practices (Forest Ecosystem Management Assessment Team [FEMAT] 1993). Increased concern over management of adequate habitat for the northern spotted owl resulted in timber harvest injunctions on federal lands administered by the U. S. Forest Service and the Bureau of Land Management within the owl's range in 1991 and 1992, respectively (Thomas et al. 1993). These events and changing public interests have resulted in a shift toward ecosystem and landscape-level management approaches and to the designation of new multiple-use priorities that stress the importance of conservation of biological diversity (FEMAT 1993, Thomas et al. 1993). The Record of Decision for the Northwest Forest Plan (USDA Forest Service and USDI Bureau of Land Management [ROD] 1994a) established a regional, ecosystem-based management plan that strives to incorporate multiple use and conservation on public lands.

Using an ecosystem approach, the Northwest Forest Plan recognizes the importance of managing for a diversity of terrestrial and aquatic communities and habitats, including those which traditionally may have received little attention, and maintaining connectivity among these systems. The Northwest Forest Plan's Aquatic Conservation Strategy (USDA Forest Service and USDI Bureau of Land Management [FSEIS] 1994b, ROD 1994), which incorporates a Riparian Reserve system, reflects this approach by providing protection for aquatic and riparian ecosystems along entire drainage networks, including intermittent, headwater streams. Headwater streams generally refer to low-order channels, such as first- and second-order tributaries, that represent the uppermost parts of drainage networks (Bury 1988, Bury and Corn 1988a). First-order streams are the smallest, unbranched tributaries in watersheds, and second-order streams are produced by the confluence of two first-order tributaries (Strahler 1957). Many headwater streams exhibit intermittent flow (Everest et al. 1985). Intermittent streams generally flow during the wet season but dry up during some part of the year (Hewlett and Nutter 1969, Satterlund and Adams 1992). These streams historically have received little attention from researchers and resource managers (Williams and Hynes 1976, Towns 1985, Boulton and Suter 1986), but recently have been recognized as important ecological components of watersheds in the Pacific Northwest (FEMAT 1993). Based on topographic maps and limited field data, the Forest Ecosystem Management Assessment Team (1993) estimated that intermittent streams may comprise an average of 60% of total stream miles, with densities ranging from 18 to 93%, on national forests and Bureau of Land Management districts in western Oregon and Washington and northern California. Headwater streams, in general, store, process, and function as the primary sources of water, nutrients, vegetative material, wood, and sediment for higher-order streams and, as a result, are thought to be greatly responsible for downstream water quality and habitat (Swanson and Lienkaemper 1978, Everest et al. 1985, Beschta and Platts 1986, Naiman et al. 1992, FEMAT 1993).

The goal of the Northwest Forest Plan's Aquatic Conservation Strategy is to restore and maintain the ecological health and “natural” disturbance regimes of watersheds and aquatic ecosystems (ROD 1994). This strategy focuses on maintaining and restoring the physical integrity, water quality, sediment regime, flow regime, and riparian plant communities necessary for healthy aquatic systems as well as providing habitat for native aquatic and riparian-dependent species (ROD 1994). Riparian Reserves are buffer zones along aquatic and unstable areas within which land use activities, such as timber harvesting, road construction, mining, grazing, and recreation, are managed to meet Aquatic Conservation Strategy objectives (ROD 1994). However, the delineation and management of Riparian Reserves along intermittent streams have caused some confusion and controversy for a number of reasons. Intermittent streams can be difficult to identify in the field given (1) their generally small channels, (2) the lack of surface water during dry periods (ROD 1994), and (3) geographic (i.e., across sites) as well as temporal (intra- and interannual) variability in flow duration and pattern. Intermittent stream flow may last a few weeks or months each year to nearly year round; in wet years, these streams may exhibit perennial flow (Satterlund and Adams 1992). As a result, determining when to designate a stream as intermittent can be challenging and crucial for proper identification.

Intermittent and perennial streams also have not been designated using consistent criteria. These streams have had a variety of definitions and interpretations in the literature and among personnel working on this issue. Hewlett and Nutter (1969) classify perennial streams as those which flow for most (≥90%) of the year in a well-defined channel, whereas intermittent streams are those which generally flow for ≤50% of the year. The Oregon Forest Practices Act (Oregon Department of Forestry 1994), which applies to all non-federal forest lands in Oregon, considers a stream intermittent if it normally lacks summer surface flow after July 15. To address interannual variation in flow, intermittent streams have been defined as those which flow for a limited number of years over a certain period of time, for example, 3 years over a 10-year period (Barber pers. comm.). In addition to temporal intermittency, streams can be spatially intermittent. Delucchi and Peckarsky (1989) differentiate among permanent, intermittent and temporary streams by defining permanent streams as those with permanent flow along the entire stream length; intermittent streams as those in which only parts of the stream dry; and temporary streams as those in which the entire bed dries. Dieterich (1992) uses temporal and spatial criteria to define intermittent streams as those with a permanently-flowing section above a summer-dry section and continuous flow over five months. The Northwest Forest Plan incorporates channel characteristics and defines intermittent streams as "any non-permanently flowing drainage feature having a definable channel and evidence of annual scour and deposition" (ROD 1994). This definition includes ephemeral streams, which flow only in direct response to precipitation or snowmelt (Satterlund and Adams 1992), if they meet these criteria (ROD 1994).

Finally, the delineation and management of effective Riparian Reserves require knowledge of the basic ecological conditions, processes, and interactions in aquatic ecosystems, particularly in terms of erosion, hydrology, vegetation, channel morphology, water quality, human uses, and species and habitats (Regional Interagency Executive Committee (RIEC) 1995). However, little information is available on the ecology of intermittent streams and associated riparian areas as well as land use impacts on these systems. Few studies have been conducted on intermittent streams in coniferous forests of the Pacific Northwest (e.g., Lehmkuhl 1971, Tew 1971, Muller 1990, Dieterich 1992); worldwide, studies have been conducted on agricultural lands, in temperate deciduous forests, and in arid and semi-arid regions. Studies on intermittent streams have focused primarily on their physical, chemical, and hydrological attributes, and invertebrate faunas (see reviews in Boulton and Suter 1986 and Dieterich 1992). Intermittent streams tend to exhibit larger fluctuations in physical and chemical attributes, such as water temperature and pH, than do perennial streams, mostly as a result of dramatic seasonal differences in stream flow (Williams and Hynes 1977). However, a strong connection with subsurface water can lead to smaller fluctuations (Dieterich 1992). Despite seemingly harsh and variable habitat conditions, studies of invertebrate faunas in intermittent streams have documented diverse communities, with unique species and comparable or higher species richness than perennial streams in some cases (see review in Boulter and Suter 1986). Dieterich (1992) found a minimum of 207 invertebrate species in 6 summer-dry streams in western Oregon, including at least 10 new species. He also found 25% more species in two summer-dry streams than in an adjacent perennial stream.

Currently, little is known about the role of intermittent streams as habitat for aquatic vertebrates, such as fish and amphibians. Intermittent streams have provided habitat for some fish and amphibian species (Stehr and Branson 1938: Ohio, John 1964: Arizona, Harrel et al. 1967: Oklahoma, Hoyt 1970: Kentucky, Williams and Coad 1979: Ontario, Dieterich 1992: Oregon, Meador and Matthews 1992: Texas, Hubble 1994: Washington, Holomuzki 1995: Kentucky). Since intermittent streams may represent a significant proportion of overall channel length and can support rich invertebrate faunas, they may function as important habitat for aquatic vertebrate predators. Stehr and Branson (1938) found large numbers of young fishes, as many as 600 in a single pool, in the lower section of an intermittent stream in Ohio. They hypothesized that this stream may provide favorable habitat due to an abundance of food as well as low stream velocities and minimal competition and predation from larger fishes. Williams and Coad (1979) found only 12 of 50 potential fish species in three intermittent streams in Southern Ontario, Canada, but they also reported advantages, such as abundant food supply, earlier spring breeding, and reduced predation, for the species in these streams.

Amphibians also recently have been recognized as important ecological components of Pacific Northwest forests and have been provided increased protection by the Northwest Forest Plan (FEMAT 1993, ROD 1994). The Pacific Northwest contains the second highest number of amphibian species in the United States, of which many are endemic to the region (Nussbaum et al. 1983). Many live in, but are not restricted to, moist, cool forested environments and use aquatic and riparian habitats at various stages in their life history for breeding sites, food, and cover (Corn and Bury 1990, Walls et al. 1992). Aquatic and semi-aquatic amphibians are the dominant vertebrates and may function as top predators and abundant prey in many small, headwater streams (Murphy 1979, Murphy and Hall 1981, Bury and Corn 1988a). As a result, they have been identified as one group of animals which should benefit from Riparian Reserves along headwater streams and should be considered when delineating these buffers (ROD 1994, RIEC 1997). However, aquatic amphibian studies have focused primarily on perennial, headwater streams; amphibian communities in intermittent streams have not been specifically examined.

Headwater streams are strongly influenced by the terrestrial and riparian environments and are most directly impacted by land use activities, such as timber harvesting (Vannote et al. 1980, Beschta and Platts 1986). Impacts of timber harvesting on headwater streams include increased sedimentation and water temperatures, and reduced inputs of large wood (Levno and Rothacher 1967, Meehan et al. 1969, Brown and Krygier 1970, Swift and Messer 1971, Beschta 1978, Swanson and Lienkaemper 1978, Bilby 1988, Corn and Bury 1989, Brooks et al. 1991). Intermittent stream channels also have been physically altered by timber harvesting operations. Amphibians may be sensitive to and greatly affected by timber harvesting. Lower species richness and lower density and/or biomass of amphibians have been found in perennial, headwater streams in second-growth and recently harvested forest stands than those in uncut forest stands in Oregon (Bury and Corn 1988a, Corn and Bury 1989) and Washington (Kelsey 1995), respectively. Amphibian species in these streams may be negatively impacted by timber harvesting impacts such as increased sedimentation (Bury and Corn 1988a, Corn and Bury 1989). Therefore, gaining a better understanding of management impacts on intermittent streams and amphibians in headwater systems is crucial for the protection. This information also has obvious economic implications in that constraints on land use activities, such as timber harvesting, within Riparian Reserves would result in substantial revenue loss (Kelsey 1995).

My overall goal was to provide additional information on the ecology of intermittent, headwater streams and aquatic amphibian communities in the Pacific Northwest, as well as insight into possible long-term impacts of timber harvesting on these systems. I defined intermittent streams, or stream reaches, as those which meet the Northwest Forest Plan's criteria and dry up along ≥90% of their channel length (i.e., from channel initiation to tributary junction with a perennial stream, road, or stand edge) during some part of the dry season. I adopted such a conservative definition in an attempt to ensure that study streams were intermittent given that site selection was based on only one field visit during a single year. The basic approach for this study involves examining and comparing intermittent streams in old-growth (≥195 yrs) and young, second-growth (28 - 45 yrs) forest stands in the foothills of the central Cascade Mountain Range in western Oregon. Differences between the streams in old-growth and young forest stands cannot be definitively attributed to timber harvesting given the observational nature of this study. However, this study does provide information on current conditions of intermittent streams in these two stand types, which can provide insight into potential reference conditions, trends, and timber harvesting impacts as well as help generate hypotheses that can be tested in future studies.

The second chapter of this thesis examines hydrologic, water quality, and physical characteristics of intermittent, headwater streams in old-growth and young forest stands, specifically annual stream flow pattern and duration, stream temperature, substrate composition, large wood, and riparian forest characteristics. I selected these characteristics since they can be directly affected by timber harvesting, can greatly impact aquatic biota, and are the primary focus of riparian management strategies (Levno and Rothacher 1967, Meehan et al. 1969, Brown and Krygier 1970, Swift and Messer 1971, Beschta 1978, Swanson and Lienkaemper 1978, Bilby 1988, Corn and Bury 1989, Brooks et al. 1991, ROD 1994). I also present results from a field inventory of intermittent and perennial, headwater streams to provide information on intermittent stream density and designation. The third chapter investigates amphibian communities in these streams during wet and dry seasons, and examines micro- and macrohabitat features that may be associated with amphibian abundance. The final chapter integrates findings from the two previous chapters, attempts to provide new insight into the ecological role of intermittent streams in watersheds as well as timber harvesting impacts, and discusses their management and research implications.

CHAPTER 2
PHYSICAL AND HYDROLOGICAL CHARACTERISTICS OF INTERMITTENT STREAMS IN WESTERN OREGON

INTRODUCTION

Historically, researchers and resource managers have paid little attention to intermittent, headwater streams (Stehr and Branson 1938, Williams and Hynes 1976, Towns 1985, Boulton and Suter 1986). However, intermittent streams recently have been recognized as important components of forested watersheds in the Pacific Northwest (ROD 1994). Headwater streams, such as first- and second-order tributaries (Strahler 1957), comprise most of the overall channel length within a drainage (Benda et al. 1992). These streams often exhibit intermittent flow (Everest et al. 1985), that is, generally flowing during the wet season but dry during some part of the year (Hewlett and Nutter 1969, Satterlund and Adams 1992). The Forest Ecosystem Management Assessment Team (1993) estimates that intermittent streams may comprise an average of 60% of total stream miles, with densities ranging from 18 to 93%, on national forests and Bureau of Land Management districts in western Oregon and Washington and northern California. Headwater streams, in general, store, process, and function as the primary sources of water, nutrients, vegetative material, wood, and sediment for higher-order streams and, as a result, are thought to be greatly responsible for downstream water quality and habitat (Swanson and Lienkaemper 1978, Everest et al. 1985, Beschta and Platts 1986, Naiman et al. 1992, FEMAT 1993). Intermittent streams also provide habitat for rich, and in some cases unique, invertebrate faunas (see review in Boulton and Suter 1986, Dieterich 1992) as well as fish and amphibian species (Stehr and Branson 1938, John 1964, Harrel et al. 1967, Hoyt 1970, Williams and Coad 1979, Dieterich 1992, Meador and Matthews 1992, Hubble 1994, Holomuzki 1995).

In the Pacific Northwest, new perspectives on watershed health and management have recognized the importance of protecting and maintaining connectivity among all components of aquatic ecosystems, including intermittent streams (Naiman et al. 1992, ROD 1994). Riparian buffers represent the primary form of protection for intermittent streams. Land use activities within these buffers are managed to maintain and restore the ecological health of intermittent streams as well as aquatic ecosystems downstream (ROD 1994). However, few studies have been conducted on intermittent streams in the Pacific Northwest (e.g., Lehmkuhl 1971, Tew 1971, Muller 1990, Dieterich 1992). As a result, little information is available on the ecology of intermittent streams and associated riparian areas as well as land use impacts on these systems. Knowledge of the basic ecological conditions and processes associated with intermittent streams is crucial for the development and implementation of sound and effective management strategies.

Intermittent streams have had a variety of definitions and interpretations in the literature and among personnel working on this issue. Satterlund and Adams (1992) describe intermittent streams as those which may flow for a few weeks or months each year to nearly year round; in wet years, streams may exhibit perennial flow. Hewlett and Nutter (1969) classify intermittent streams as those which generally flow for ≤50% of the year. The Oregon Forest Practices Act (Oregon Department of Forestry 1994) considers a stream intermittent if it normally lacks summer surface flow after July 15. Streams also can be spatially intermittent. Delucchi and Peckarsky (1989) differentiate among permanent, intermittent and temporary streams by defining permanent streams as those with permanent flow along the entire stream length; intermittent streams as those in which only parts of the stream dry; and temporary streams as those in which the entire bed dries. Dieterich (1992) uses spatial and temporal criteria to define intermittent streams as those with a permanently-flowing section above a summer-dry section and continuous flow over five months. The Northwest Forest Plan (ROD 1994) incorporates channel characteristics and defines intermittent streams as "any non-permanently flowing drainage feature having a definable channel and evidence of annual scour and deposition." This definition includes ephemeral streams, which flow only in direct response to precipitation or snowmelt (Satterlund and Adams 1992), if they meet these criteria (ROD 1994).

Physical and hydrological characteristics of intermittent streams in the Pacific Northwest have not been well-documented but are important in structuring biological communities and determining contributions to downstream habitat. Headwater streams in this region are generally characterized by the following: coarse, unsorted sediments, steep gradients (>10%), a stair-step longitudinal profile, little distinct riparian vegetation, high degree of shading, little incoming solar radiation, and relatively cool and stable water temperatures (Naiman et al. 1992). Also, large wood can be extremely abundant and may represent the primary factor determining aquatic habitat characteristics in small streams (Swanson and Lienkaemper 1978, Bilby 1988). Highly variable and/or unpredictable flow regimes characterize intermittent streams across the country (Poff and Ward 1989). Intermittent streams also tend to exhibit larger fluctuations in physical and chemical attributes, such as water temperature and pH, than do perennial streams (Williams and Hynes 1977). However, a strong connection with subsurface water can lead to smaller fluctuations in attributes such as stream temperature (Dieterich 1992).

Terrestrial and riparian environments along headwater streams greatly influence their structure and function (Bilby 1988). Therefore, land use activities along headwater streams, such as timber harvesting, can have significant impacts on their hydrology, water quality, and physical characteristics (Bilby 1988). Timber harvesting can lead to increased annual water yields and changes in stream flow patterns, such as higher winter and summer flows (Harr et al. 1982, Keppeler and Ziemer 1990, Brooks et al. 1991). The shading provided by streamside forests has a significant influence on net heat exchange and water temperature in small streams (Naiman et al. 1992). Removal of the riparian overstory leads to increased solar insolation, which, in turn, results in increased maximum stream temperatures, particularly during the summer (Levno and Rothacher 1967, Meehan et al. 1969, Brown and Krygier 1970, Swift and Messer 1971, Bilby 1988). Minimum or winter stream temperatures have not been affected, due to ice cover, or have decreased following canopy removal, due to heat loss from evaporation and conduction or convection at the stream surface (Meehan et al. 1969, Reinhart et al. 1963 in Meehan et al. 1969, Beschta and Platts 1986, Naiman et al. 1992). Logging operations, such as skidding and yarding, that result in soil compaction or the removal of vegetative cover and exposure of mineral soil can dramatically increase soil erosion and sedimentation in streams (Beschta 1978, Brooks et al. 1991). Riparian, or streamside, environments also are important sources of organic material, such as large wood, for these low-order streams (Bilby 1988, Gregory et al. 1991). Streams in second-growth stands following timber harvest have been characterized by reduced concentrations and recruitment of large wood (Swanson and Lienkaemper 1978). Intermittent stream channels also have been physically altered by timber harvesting operations as a result of their small channel width and lack of surface water during the dry season.

Changes in stream flow patterns, water yields, and stream temperatures generally have been considered short-term effects that last only until streamside vegetation returns or canopy cover is re-established (Brown and Krygier 1970, Swift and Messer 1971, Harr et al. 1982, Bury and Corn 1988a, Keppeler and Ziemer 1990). Keppeler and Ziemer (1990) found that summer flows returned to pre-treatment levels within five years. Stream temperature in different types of forest returned to pre-treatment levels within 4 to 8 years after logging (Brown and Krygier 1970, Swift and Messer 1971). However, increased sedimentation and reduced input of large wood represent long-term impacts and may last for decades (Beschta 1978, Swanson and Lienkaemper 1978, Murphy et al. 1981, Bury and Corn 1988a, Corn and Bury 1989). Timber harvesting also can have long-term impacts on riparian vegetation, such as the replacement of conifers with hardwoods, which, in turn, may lead to long-term changes in stream flow (Hicks et al. 1991). The short- and long-term effects of timber harvesting may have significant impacts on resident and downstream aquatic biota (Murphy et al. 1981, Bilby 1988, Bury and Corn 1988a, Corn and Bury 1989).

This study had three specific objectives. My first objective was to provide initial data on the hydrology, water quality, and physical characteristics of intermittent streams in old-growth and young, second-growth forest stands in the Oregon Cascade Range. I examined annual stream flow pattern and duration, stream temperature, substrate composition, large wood, and streamside vegetation. I selected these characteristics since they can be directly affected by timber harvesting, can greatly impact aquatic biota, and are the primary focus of riparian management strategies (Levno and Rothacher 1967, Meehan et al. 1969, Brown and Krygier 1970, Swift and Messer 1971, Beschta 1978, Swanson and Lienkaemper 1978, Bilby 1988, Corn and Bury 1989, Brooks et al. 1991, ROD 1994). My second objective was to compare habitat characteristics between the two stand types to examine potential timber harvesting impacts. Differences between the streams in old-growth and young forest stands cannot be definitively attributed to timber harvesting given the observational nature of this study. However, this study does provide information on current conditions of intermittent streams in these two stand types which can provide insight into potential trends and impacts. I expected intermittent streams to exhibit similar habitat characteristics and trends as those which have been documented for perennial, headwater streams. Finally, few reliable estimates of intermittent stream density in the Pacific Northwest, particularly on federal lands, are available because: (1) they have not been systematically designated, inventoried, or monitored using consistent criteria; and (2) reliable and cost-effective inventory and monitoring methods have not yet been developed (FEMAT 1993). I conducted a field inventory of intermittent and perennial, headwater streams in selected old-growth and young forest stands as part of the site selection process. I present these results to provide information on intermittent stream density and designation.

METHODS

Study Area

The study was conducted on public lands, federally administered by the Bureau of Land Management (BLM), in the foothills of the central Cascade Range in Linn County, Oregon (Figure 2.1). Climate in the Pacific Northwest is maritime and is characterized by mild, wet winters and cool, dry summers. Annual precipitation in the western Cascades ranges from 70 to over 350 cm (Harr 1976). Precipitation is mainly in the form of rain at lower elevations and snow at higher elevations (above 900 m; Harr 1976). Soils range from deep and moderately deep, well-drained silty clay loams to gravelly, cobbly, or stony loams (USDA Soil Conservation Service 1987). These soils have been derived from volcanic parent material, in the form of tuffs and breccias, and basic igneous rock, such as basalt and andesite (Franklin and Dyrness 1988). Topography consists of steep slopes and deeply-incised drainages.

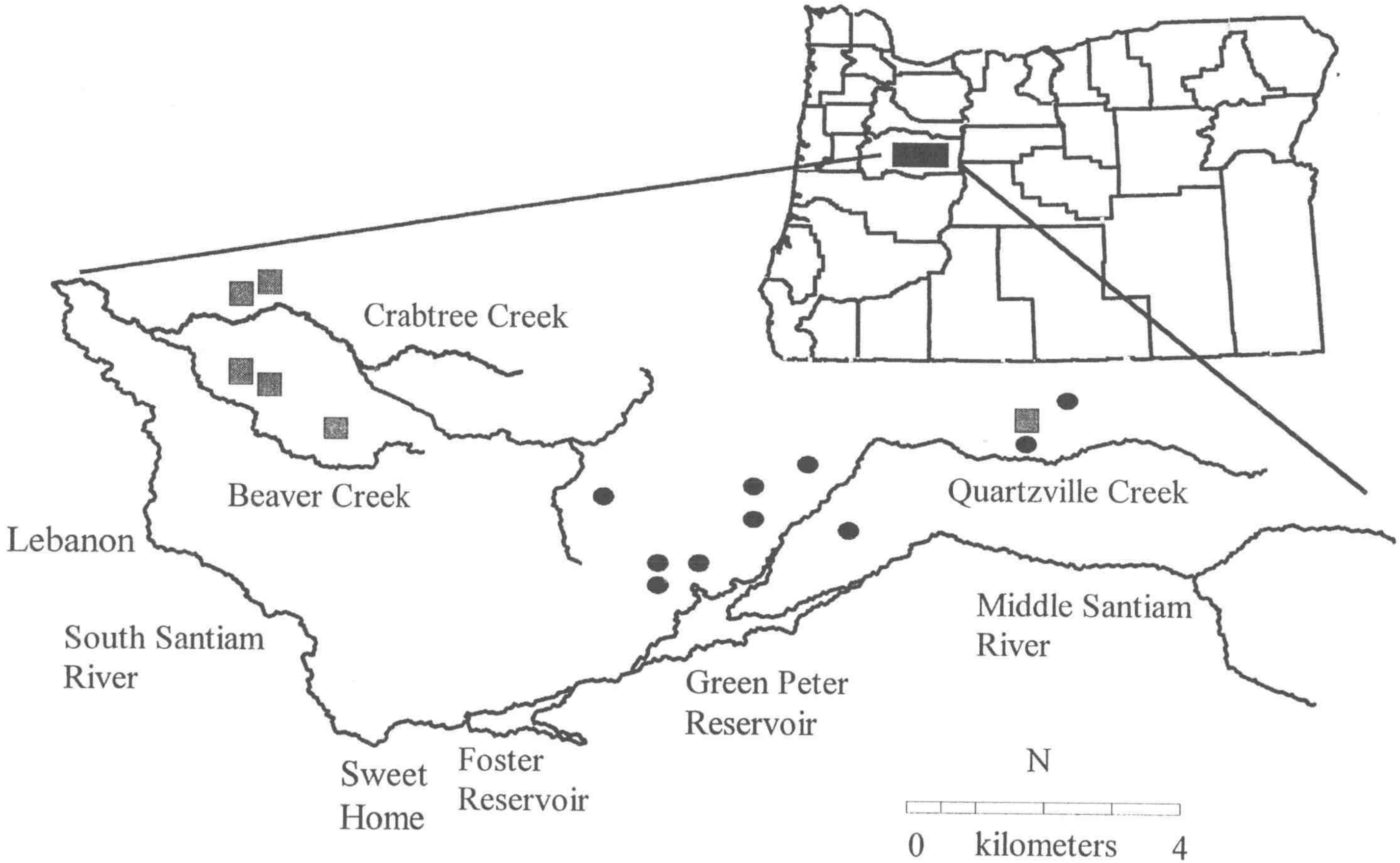

Figure 2.1. Map showing general location of study area within Oregon (upper right) and location of study sites relative to major streams and towns. Intermittent, headwater streams along Beaver and Crabtree Creeks were located in young (28 - 45 yrs) forest stands (■), and all study sites except one stream along Green Peter Reservoir and Quartzville Creek were located in old-growth (≥195 yrs) stands (●).

Western hemlock (Tsuga heterophylla) and Douglas-fir (Pseudotsuga menziesii) dominate the overstory in most of the study area (Franklin and Dyrness 1988). Vine maple (Acer circinatum), dwarf Oregon-grape (Berberis nervosa), salal (Gaultheria shallon), huckleberries (Vaccinium spp.), and swordfern (Polystichum munitum) are common understory species (Franklin and Dyrness 1988). A mosaic of public and private land ownerships and seral stages characterizes the surrounding landscape. The public lands are predominantly second-growth, mixed young and mature stands that either have naturally regenerated after wildfires or clearcut harvesting or are even-aged young stands that have been intensively managed, with scattered pockets of remnant old growth.

Stream Inventory

I identified old-growth and young forest stands in the study area based on stand age, or time since establishment, and stand history from BLM records. Old-growth stands had to be at least 195 years old and had never been harvested. Intermittent streams in these stands represented reference conditions to which logged sites were compared. Young, second-growth forest stands had to range from 15 to 50 years following clearcut harvesting and were included only if they had re-established canopy closure. These stands represented the mid-seral stage of forest succession after logging. Intermittent streams in the young forest stands did not receive any riparian protection during timber harvesting and exemplified long-term conditions following harvesting. I selected stands at low to mid-elevations (<1200 m) that contained predominantly Douglas-fir and western hemlock, had similar stand histories, and were in close proximity to one another.

I identified first-order, or unbranched, tributaries in the appropriate forest stands from BLM maps and field reconnaissance. I field inspected and surveyed these streams in 1994 during the dry season from 11 August to 12 October. I designated streams as intermittent only if they met the Northwest Forest Plan's definition and if ≤10% of the stream length (i.e., distance from channel initiation to tributary junction with a perennial stream, road, or stand edge) contained surface flow at the time of field inspection.

I designated streams as perennial if >10% of the stream length had flow. I adopted such conservative flow criteria to designate intermittent streams in an attempt to ensure intermittency given only one field visit during a single year. These flow designations were based on the assumption that intermittent streams would be dry, whereas perennial streams would still exhibit surface flow during this time period when stream flows are usually at their lowest levels. I also recorded the number of instances in which a stream was identified on BLM maps, but no definable channel was evident at the site.

Study Streams

I selected 16 intermittent streams, 10 in old growth and 6 in young forest stands (Table 2.1), from those identified during the stream inventory to intensively monitor and survey. Streams selected for the study were required to have at least 50 m of sampleable channel and to be at least 50 m away from any road, perennial flow, or stand edge. All old-growth stands were at least 195 years old except for one stream of which the lower half was in a 135 year old stand. The young forest stands ranged in age from 28 to 45 years. They were clearcut harvested with ground-based equipment, broadcast burned, and planted. One young forest stand also was aerially sprayed for brush and hardwood control and pre-commercially thinned. Three pairs of streams (1 pair in old growth and 2 pairs in young forest) were found in the same stands (Table 2.1). One stream reach in young forest was immediately upstream and separated by 50 m from one of the study reaches in old growth (Upper and Lower Yellowbottom). All streams were first-order tributaries except for one second-order reach in old growth; stream order designations were based on field conditions. The streams in old growth were at higher elevations, due to the history of logging in the study area, and were generally wider and steeper than the streams in the young forest stands (Table 2.1). The underlying soils also may have differed between stand types according to soil maps (USDA Soil Conservation Service 1987), with primarily gravelly, cobbly, or stony loam soils in the old-growth stands and silty clay loam soils in the young forest stands.

Table 2.1. Stand age, location, and physical characteristics of intermittent, headwater streams in old-growth and young forest stands in the central Cascade Mountain Range in western Oregon that were selected and sampled for the study.

Stream	Stand age	Stand location	Watershed	Aspect	Elevation (m)	Stream length (m)	Mean width (m)	Mean gradient (%)
Beverly Creek	195+	T11S R4E S5	Lower Quartzville	SE	1006	138.61	0.84	55
Boulder Creek	195+	T11S R3E S36	Lower Quartzville	SW	610	243.56	0.51	27
Boulder Ridge	195+	T11S R4E S32	Lower Quartzville	W	976	260.87	0.83	29
Dogwood	195+	T12S R3E S3	Lower Quartzville	E	530	496.71	1.06	29
Lower Whitcomb	195+	T12S R2E S14	N. Green Peter	S/SW	793	86.42	0.45	36
Lower Yellowstone	195+	T11S R3E S27	Lower Quartzville	N/NW	701	326.87	0.61	66
W. Whitcomb 1A	195+	T12S R2E S15	N. Green Peter	SE	915	292.02	0.78	53
W. Whitcomb 1B	195+	T12S R2E S15	N. Green Peter	SE	915	158.22	0.46	61
White Rock	135/195+	T11S R3E S19	N. Upper Crabtree	S/SW	1146	310.17	0.58	7
Lower Yellowbottom	195+	T11S R4E S19	Lower Quartzville	SW	503	147.97	0.42	29
Beaver Creek 2A	45	T11S R1E S33	Lower Crabtree	S	305	316.45	0.49	14
Beaver Creek 3B	45	T11S R1E S33	Lower Crabtree	S	305	259.99	0.47	12
Church Creek 2A	29	T11S R1E S17	Lower Crabtree	N/NW	244	177.78	0.45	12
Church Creek 3A	28/29	T11S R1E S17	Lower Crabtree	NW	305	286.53	0.44	13
Green Mountain	45	T11S R1E S35	Lower Crabtree	S	549	543.60	0.64	19
Upper Yellowbottom	33	T11S R4E S19	Lower Quartzville	SW	640	120.85	0.45	71
Mean (SD)								
Old-growth (n = 10)	195+				810 (217)	246.14 (120.26)	0.65 (0.21)	39 (19)
Young (n = 6)	38				391 (162)	284.20 (146.20)	0.49 (0.08)	23.5 (23)

Habitat Sampling

Hydrologic Regime

I monitored stream flow with monthly visits from November 1994 to September 1995 to determine the pattern and duration of annual stream flow. I defined stream flow as the percentage of stream length that contained surface flow, which included residual or standing pools of water, rather than volume of flow. I visually estimated stream flow or calculated it from length measurements of habitat units in the stream channel. Several of the streams in old growth were inaccessible due to snow or other logistical constraints and were not checked in November and December 1994 and April 1995; I assumed stream flow during these months was similar to that of the previous month. Also, due to logistical constraints, I surveyed only 6 streams in late January 1995 and the remaining 10 streams in early February as well as 6 streams in mid- to late May and the remaining 10 streams in June; for the analysis, I combined stream flow estimates for January and February as well as for May and June. I designated streams as "dry" as soon as $\leq$10% of the stream length contained surface flow. I defined annual stream flow duration as the number of months of >10% stream flow per water year (October 1 - September 30).

Stream Temperature

In 1995, I measured stream temperature throughout the flow period with StowAway water temperature data loggers (Onset Instruments, MA). I installed data loggers in streams between 29 January and 10 February. I placed data loggers in deep riffles at the downstream end of the stream reaches by attaching them to reinforcement bars which were driven into the stream's substrate and then covering them with wood or rock. The data loggers recorded water temperature every hour and remained in the streams for the duration of their surface flow. All data loggers were removed by September 1995. I used LogBook software (Onset Instruments, MA) to download the temperature data into the computer. Flow durations and, hence, temperature sampling periods differed among the streams. In order to standardize sampling periods for stream temperature comparisons, I only used temperature measurements that were recorded between 12 February and 17 July. I examined and compared daily mean, minimum, and maximum water temperatures (°C) between stand types for this sample period. Since these measures of stream temperature can be influenced by elevation, I also compared diel, or diurnal, fluctuations in stream temperature to account for potential elevational effects. I was unable to relocate the data logger in one of the streams in old-growth and assumed it had been either buried or washed downstream. Therefore, temperature comparisons were based on only 15 streams.

Substrate Composition

I derived estimates of each stream's substrate composition (% of stream covered by substrate type) by sampling randomly selected habitat units throughout the length of each channel during the spring of 1995. Prior to sampling, I surveyed streams and classified them into habitat units of five different types: pool, riffle, dry, mixed, and waterfall (Figure 2.2). Distinct habitat units were identified only if the length of the habitat type equalled or exceeded one channel width, and the habitat type comprised most of the channel width (McCain et al. 1990). I defined pools as standing or slow-water channel units. Riffles were low or high-gradient, fast-water channel units. Dry habitat comprised those parts of the stream from which surface flow was absent, but small, remnant pockets of water and/or moist substrate may have been present. Mixed habitat units were designated when two or more habitat types occurred in approximately equal proportions across the channel width (e.g., riffle interspersed with pools). Waterfalls were habitat units in which surface flow exhibited vertical or near vertical drop.

I selected habitat units for substrate sampling using a stratified random design. I divided each stream into four sections of equal length, from which I randomly selected 12 units total (3 from each section), or however many were available, of each habitat type (Figure 2.2). When three units of a particular habitat type were not available within a stream section, I selected additional units from adjacent sections. I sampled habitat units up to 20 m in length in their entirety. I divided habitat units that exceeded 20 m in length into upper and lower halves, and randomly selected one for sampling. Within

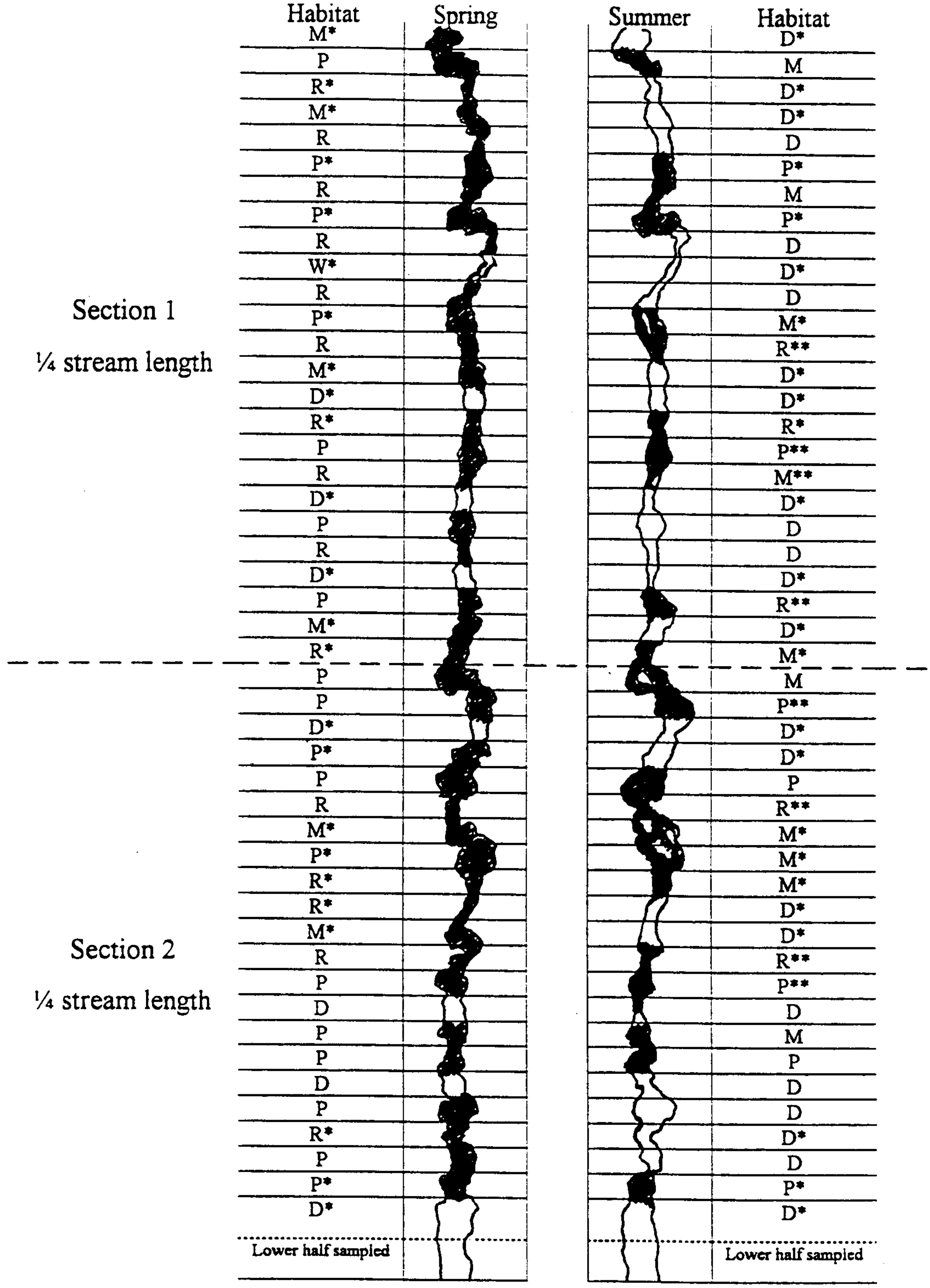

Figure 2.2. Schematic diagram of stream classification and habitat unit selection in intermittent streams in old-growth and young forest stands in the Cascade Range in western Oregon during spring and summer 1995. Habitat types are: D=Dry, M=Mixed, P=Pool, R=Riffle, and W=Waterfall. *Units selected for habitat sampling **Additional units sampled in summer.

each habitat unit selected for sampling, I visually estimated the relative amounts (%) of the following substrate types, based on diameter size categories described by Platts et al. (1983): fine sediment (< 0.06 mm), sand (0.06 - 2.0 mm), gravel (2.0 - 16.0 mm), pebble (16.0 - 64.0 mm), cobble (64.0 - 256.0 mm), boulder (>256.0 mm), and bedrock. Using these percentages, I calculated the proportion of total sampled length and, subsequently, the total available length of each habitat type covered by each substrate type. By pooling estimates from all habitat types, I derived a weighted percentage of total stream length covered by each substrate type.

Streamside Vegetation

I characterized streamside vegetation along study streams between July 18 and August 4, 1995. My riparian sampling protocol was modified from that used by the Environmental Monitoring and Assessment Program (Klemm and Lazorchak 1994). I sampled overstory trees (>5.0 m high) in 15 m x 10 m plots and understory (0.5 - 5.0 m high) and ground (<0.5 m high) vegetation in 10 m x 10 m subplots that were placed adjacent and perpendicular to the channel on both banks at the headwater, middle, and downstream end of each study stream (6 plots per stream). I systematically placed plots at these six locations to try to characterize potential variation in vegetation along the entire stream. I categorized the overstory into large (≥30 cm in dbh) and small (<30 cm in dbh) coniferous and deciduous trees. Within each category, I recorded the number and species of overstory trees and visually estimated percent canopy cover. I categorized understory and ground vegetation into woody shrubs and saplings and non-woody herbs, grasses and forbs, with an additional category for groundcover that included bare ground or duff. I recorded the dominant species and estimated percent cover for each of these categories. I calculated and analyzed the mean percent cover provided by each vegetation layer for the six sample plots combined.

Large Wood

I quantified the amount of large wood (diameter ≥30 cm), by decay class and length categories, that was at least partially in or over the active channel along the entire length of each stream during riparian vegetation sampling (see Klemm and Lazorchak 1994). I modified the five-class system for categorizing the decomposition of Douglas-fir logs, developed by Maser et al. (1979), into the following three decay classes: least decayed (decay class 1); moderately decayed (decay classes 2 and 3); and well-decayed (decay classes 4 and 5). I recorded the number of logs within three length categories: 1.5 - 5 m, 5 - 15 m, and >15 m; however, I combined these three categories within each decay class for the final analyses. I determined the total density of large wood (no. logs / total stream length) and that within each decay class.

Data Analyses

I used two-sample t-tests to determine whether stream and riparian characteristics differed between intermittent streams in old-growth and young forest stands (SAS Institute 1990). I applied Levene's test of homogeneity of variance (Levene 1960 in Snedecor and Cochran 1989) to test the null hypothesis that sample groups had equal variances. When variances were unequal, I used an approximate t-statistic based on the assumption of unequal variances (SAS Institute 1990). Satterthwaite's (1946) approximation was used to calculate the degrees of freedom associated with the approximate t-statistic (SAS Institute 1990). A significance level of 0.05 was used for all tests. All probability values were two-sided. In order to account for potential impacts of site differences between the two stand types, I qualitatively compared habitat conditions in a site in young forest (Upper Yellowbottom) with those in the study reach immediately downstream that was in an old-growth stand (Lower Yellowbottom). I also qualitatively compared habitat conditions in Upper Yellowbottom with those in the other streams in old growth and young forest.

RESULTS

Stream Inventory

I inspected a total of 122 first-order streams in six watersheds (Table 2.2). All old-growth stands were at least 195 years old; three stands were at least 295 years old.

Table 2.2. Headwater stream classification in old-growth (≥195 yrs) and young (28 - 45 yrs) forest stands in the central Cascade Mountain Range in western Oregon.

Stand type	Stands inspected	Streams inspected	Intermittent streams	Perennial streams	No definable channel	Unknown/flow not recorded
Old-growth	30	71	18	33	17	3
Young	17	51	10	11	21	9
Total	47	122	28	44	38	12

Young forest stands ranged in age from 27 to 45 years following clearcut harvesting, with a mean age of 36 years. Thirty-six percent of the streams inspected were identified as perennial, and 23% were identified as intermittent (Table 2.2). Eight of the perennial streams actually started with dry sections that ranged from 15 to 76 m; the rest of the perennial streams had surface flow throughout most of the channel length and did not have distinct dry sections. Stream distributions appeared to differ by stand type; almost twice as many perennial streams compared to intermittent streams were identified in old-growth stands, whereas equal numbers of intermittent and perennial streams were designated in young forest stands (Table 2.2). I was unable to locate definable channels (i.e., no evidence of scour and deposition) in the field for 31% of the streams that were identified on BLM maps. However, it also was common to find both intermittent and perennial streams in the field that were not on BLM maps. Stream flow estimates or designations were not recorded for 10% of the streams inspected.

Habitat Characterization

Hydrologic Regime

Intermittent streams in old-growth and young forest stands displayed similar annual stream flow patterns, particularly during the winter (November to January/ February) and late summer (July to September) (Figure 2.3). However, mean monthly stream flow (percent surface flow) differed between old-growth and young forest stands during spring and early summer months (March and May/June, respectively). Streams in old growth exhibited less surface flow during these months and appeared to dry earlier than streams in young forests, which did not exhibit reduced stream flows until July. Upon closer examination, I discovered that the streams in young forest were sampled in May or early to mid-June, whereas four of the 10 streams in old growth were sampled in late June. Thus, the difference in mean monthly stream flow between stand types in May/June may have been related to this discrepancy in timing. I analyzed flow estimates for streams sampled in May and streams sampled in early to mid-June separately. Mean flow estimates for the streams in young forest stands, 90% in May and 81% in June

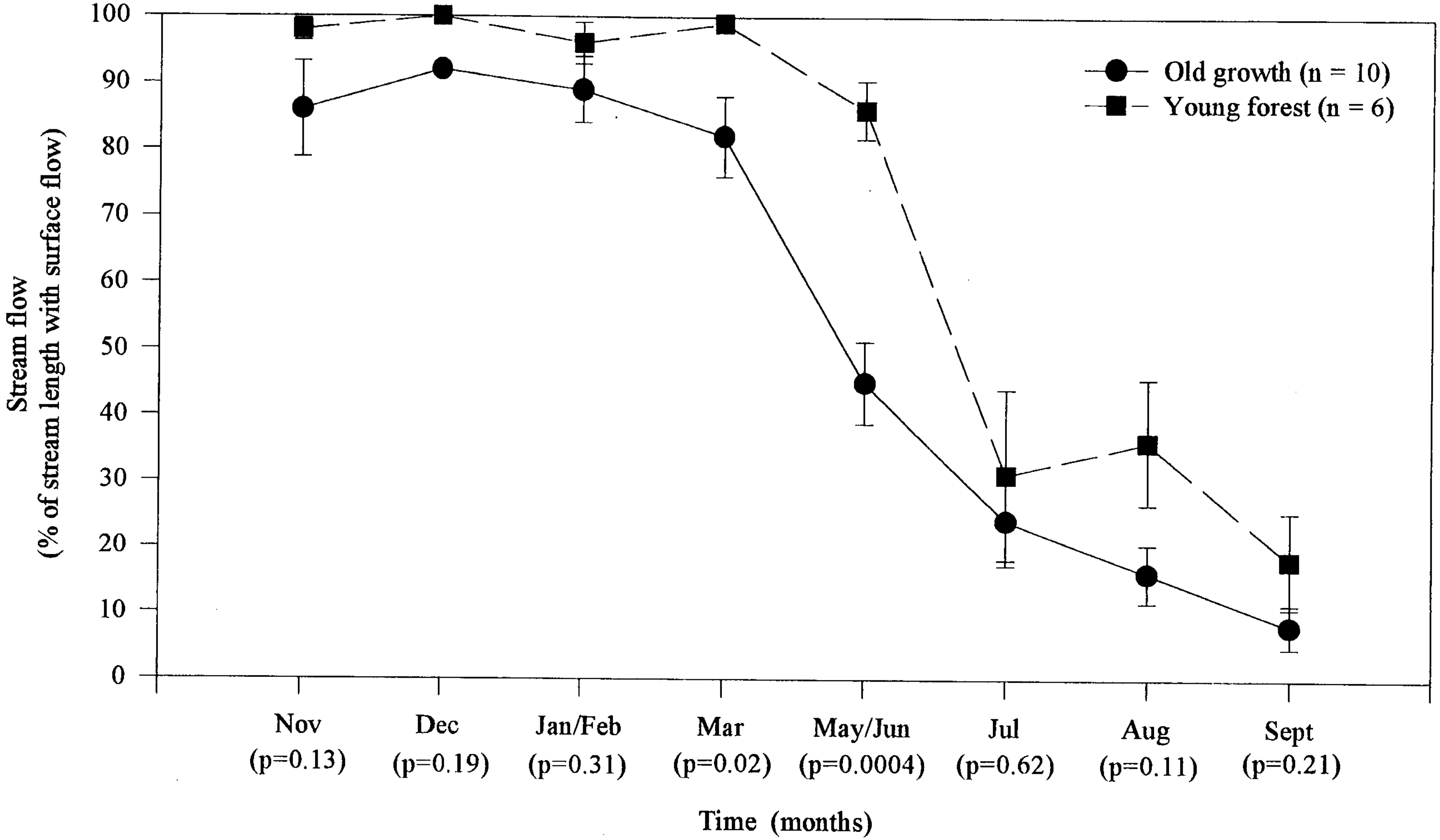

Figure 2.3. Mean (± SE) monthly stream flows from November 1994 - September 1995 for intermittent streams in old-growth and young forest stands in the central Cascade Range in western Oregon. Comparisons were made between stand types within each month. P-values for November, December, March, and August were based on approximate t-statistics.

(n = 3, range in May 80 - 90%, range in June 68 - 92%), still appeared to be higher than those for the streams in old growth, 35% in May and 47% in June (n = 3, range in May 4 - 62%, range in June 38 - 57%). Also, stream flows, particularly during the dry season, appeared to increase or decrease rapidly (e.g., within 2 - 5 days) with changes in precipitation.

Mean annual flow duration (no. months of >10% stream flow/water year) did not differ between old-growth and young forest stands (p = 0.34). Annual stream flow duration for streams in the old-growth stands averaged 9 months (range 6 to 11 months). Flow duration for streams in the young forest stands averaged 10 months (range 8 to 11 months). Six of the 16 streams monitored, 3 in old-growth and 3 in young forest, maintained over 10% stream flow throughout the year and did not dry entirely as they had done in 1994, when the streams were originally surveyed and selected. However, these six streams were mostly dry by the end of the summer, with only 15% to 43% of their channel lengths exhibiting surface flow.

Stream Temperature

Daily stream temperatures differed between the streams in old-growth and young forest stands but were very stable in both stand types during the sample period. Mean daily mean, minimum, and maximum water temperatures were about 3°C higher in the streams in young forest than those in old growth (Table 2.3). I used the median instead of the mean to characterize diel fluctuations in water temperature in each stream since fluctuations in many of the study streams exhibited positively skewed distributions. Median diel fluctuations in water temperature were <1°C for all but one study stream and did not differ between stand types (Table 2.3).

Substrate Composition

Substrate composition differed between old-growth and young forest stands. Streams in old-growth stands were characterized by higher percentages of boulders (p = 0.002), whereas streams in young forest had higher percentages of fine sediments (p = 0.01), sand (p = 0.001), and gravel (p = 0.02) (Figure 2.4). The p-value for boulder

Table 2.3. Means for daily mean, minimum, and maximum water temperatures as well as median diel temperature fluctuations in intermittent streams in old-growth (≥195 yrs) and young forest (28 - 45 yrs) stands in the central Cascade Range in western Oregon during the sampling period from February 12 to July 17, 1995. P-values for daily mean, minimum, and maximum stream temperatures were based on approximate t-statistics.

	Mean (°C)	Range (°C)	SE	p
Daily mean stream temperature				
Old growth (n = 9 streams)	6.6	4.8 - 8.3	0.42	0.0001
Young forest (n = 6 streams)	9.4	8.4 - 9.9	0.23	
Daily minimum stream temperature				
Old growth (n = 9 streams)	6.2	4.5 - 8.1	0.44	0.0001
Young forest (n = 6 streams)	9.1	8.2 - 9.7	0.21	
Daily maximum stream temperature				
Old growth (n = 9 streams)	7.1	4.9 - 8.6	0.42	0.0002
Young forest (n = 6 streams)	9.6	8.6 - 10.13	0.25	
Median diel fluctuations				
Old growth (n = 9 streams)	0.6	0.2 - 1.2	0.11	0.65
Young forest (n = 6 streams)	0.5	0.3 - 0.6	0.05	

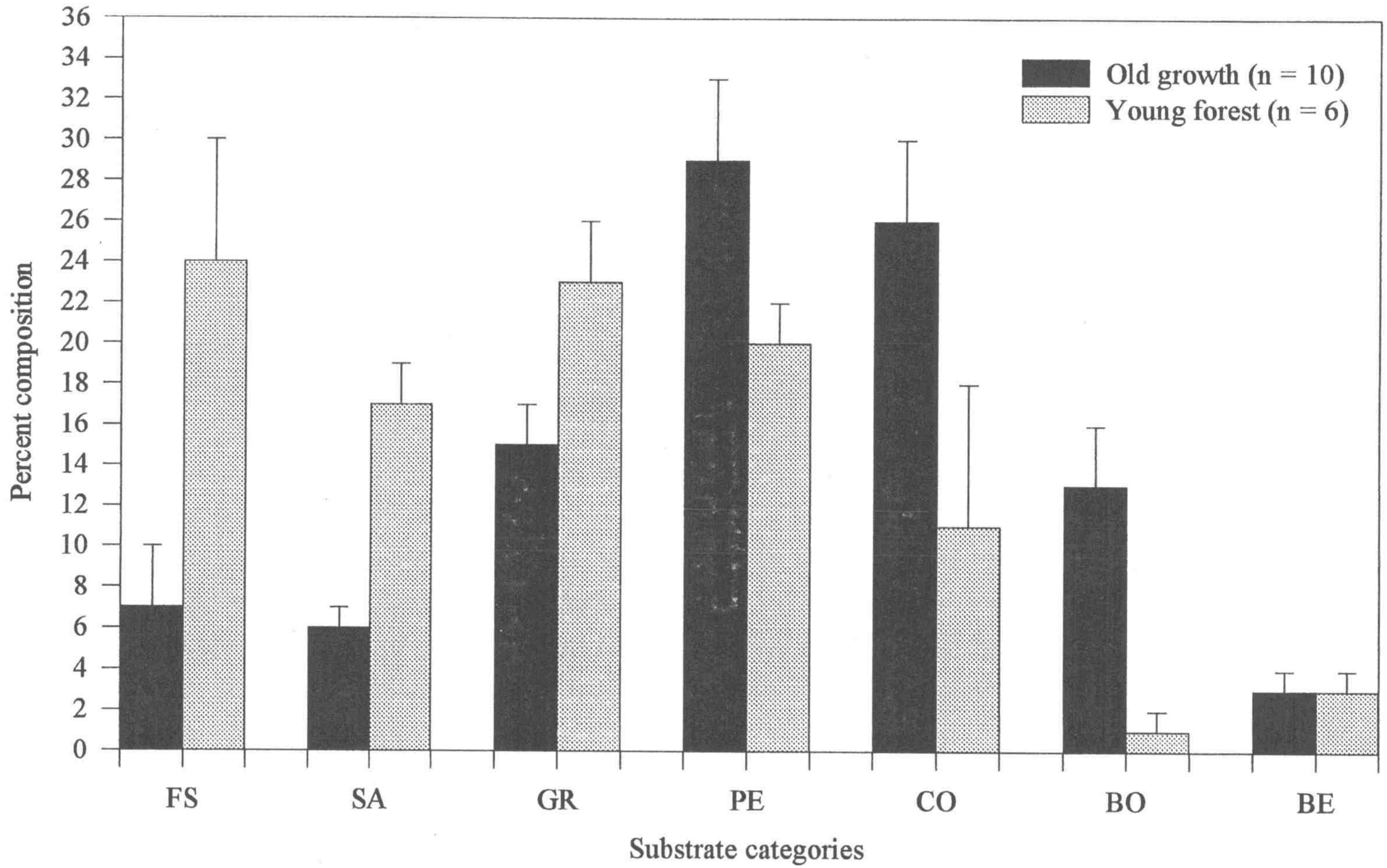

Figure 2.4. Mean (± SE) percent substrate composition of intermittent, headwater streams in old-growth and young forest stands in the central Cascade Range in western Oregon. Substrate categories are the following: FS = fine sediment, SA = sand, GR = gravel, PE = pebble, CO = cobble, BO = boulder, and BE = bedrock.

was based on an approximate t-statistic. There also was evidence that streams in old growth had higher percentages of pebbles ($p = 0.09$) and cobbles ($p = 0.06$). Mean percentages of bedrock did not differ between stand types ($p = 0.79$).

Streamside Vegetation

Based on the six plots sampled per stream, the mean percentage of total overstory cover along intermittent streams was similar between old-growth and young forest stands ($p = 0.14$), but overstory composition differed (Figure 2.5). Total overstory deciduous cover was higher along streams in the young forest ($p = 0.003$), and there was evidence that total overstory coniferous cover was higher along streams in old growth ($p = 0.07$) (Figure 2.5). These differences in deciduous and coniferous overstory cover resulted from the cover provided by large deciduous and coniferous trees ($p = 0.004$ and $p = 0.05$, respectively) (Figure 2.5). Large deciduous trees were present in small numbers in 3 and absent in 7 of the 10 streams in old-growth stands. Small coniferous and deciduous trees provided similar amounts of cover along streams in both stand types ($p = 0.53$ and $p = 0.11$, respectively). Overstory conifers along intermittent streams in old growth consisted primarily of large Douglas-fir and both large and small western hemlock, whereas large and small conifers along the streams in young forest were predominantly Douglas-fir. Large deciduous trees in both stand types were primarily bigleaf maple (Acer macrophyllum) with some red alder (Alnus rubra) in the young forest. Small deciduous overstory trees in both stand types were mainly bigleaf maple, red alder, and vine maple. White alder (Alnus rhombifolium) also was found along some of the streams in young forest.

Total understory cover for the six sample plots was higher in young forest than in old-growth stands ($p = 0.04$) (Figure 2.6a). The understory along the streams in old growth and young forest had similar percentages of woody vegetation ($p = 0.53$), but young forest stands had much higher percentages of non-woody understory vegetation ($p = 0.001$) (Figure 2.6a). Woody vegetation was comprised of a mixture of overstory regeneration and common understory shrubs, predominantly vine maple, Oregon-grape, and red huckleberry (Vaccinium parvifolium). Western hemlock regeneration was

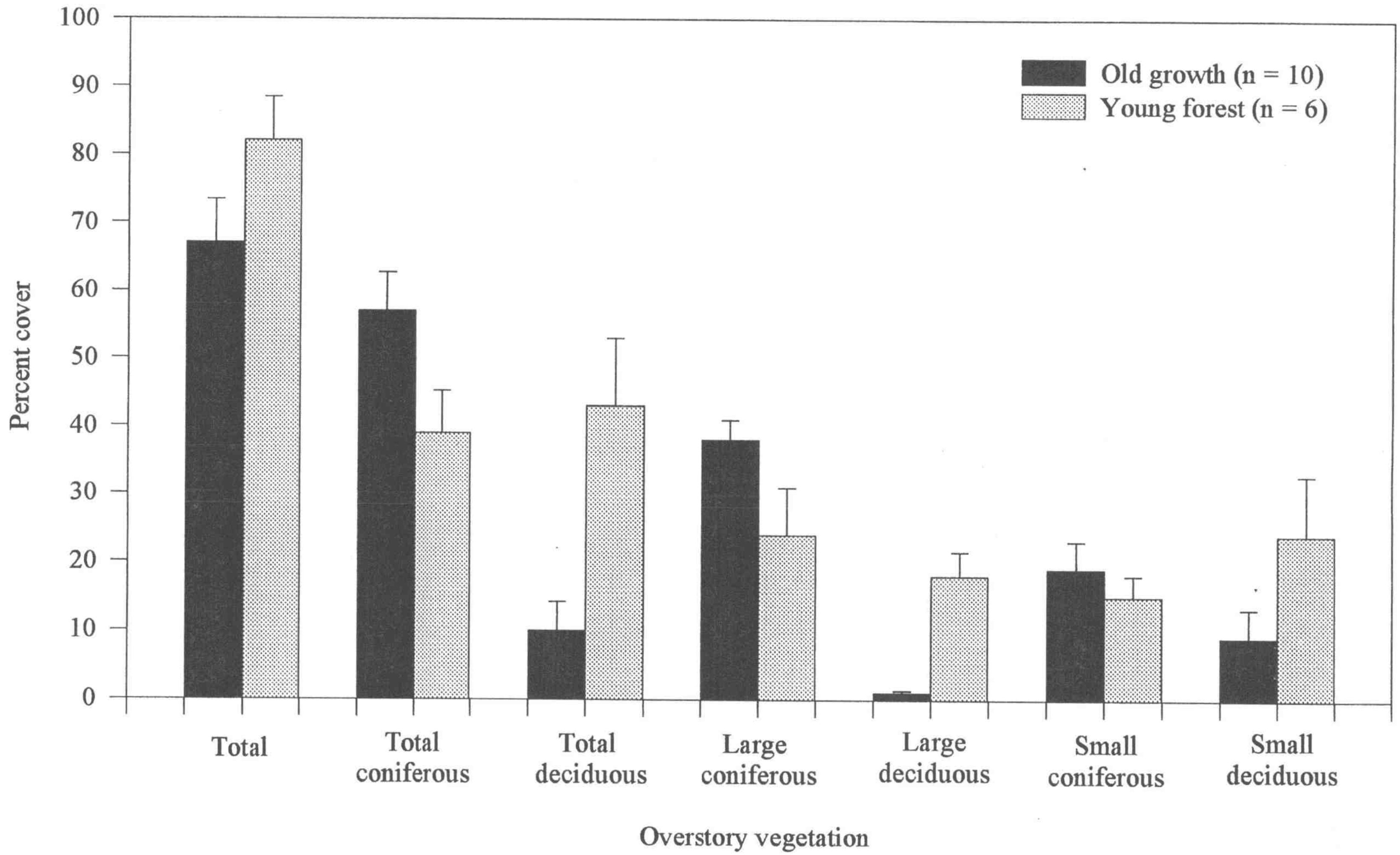

Figure 2.5. Mean (± SE) percent cover provided by overstory vegetation in six 15- x 10-m sample plots along intermittent, headwater streams in old-growth and young forest stands in the central Cascade Range in western Oregon.

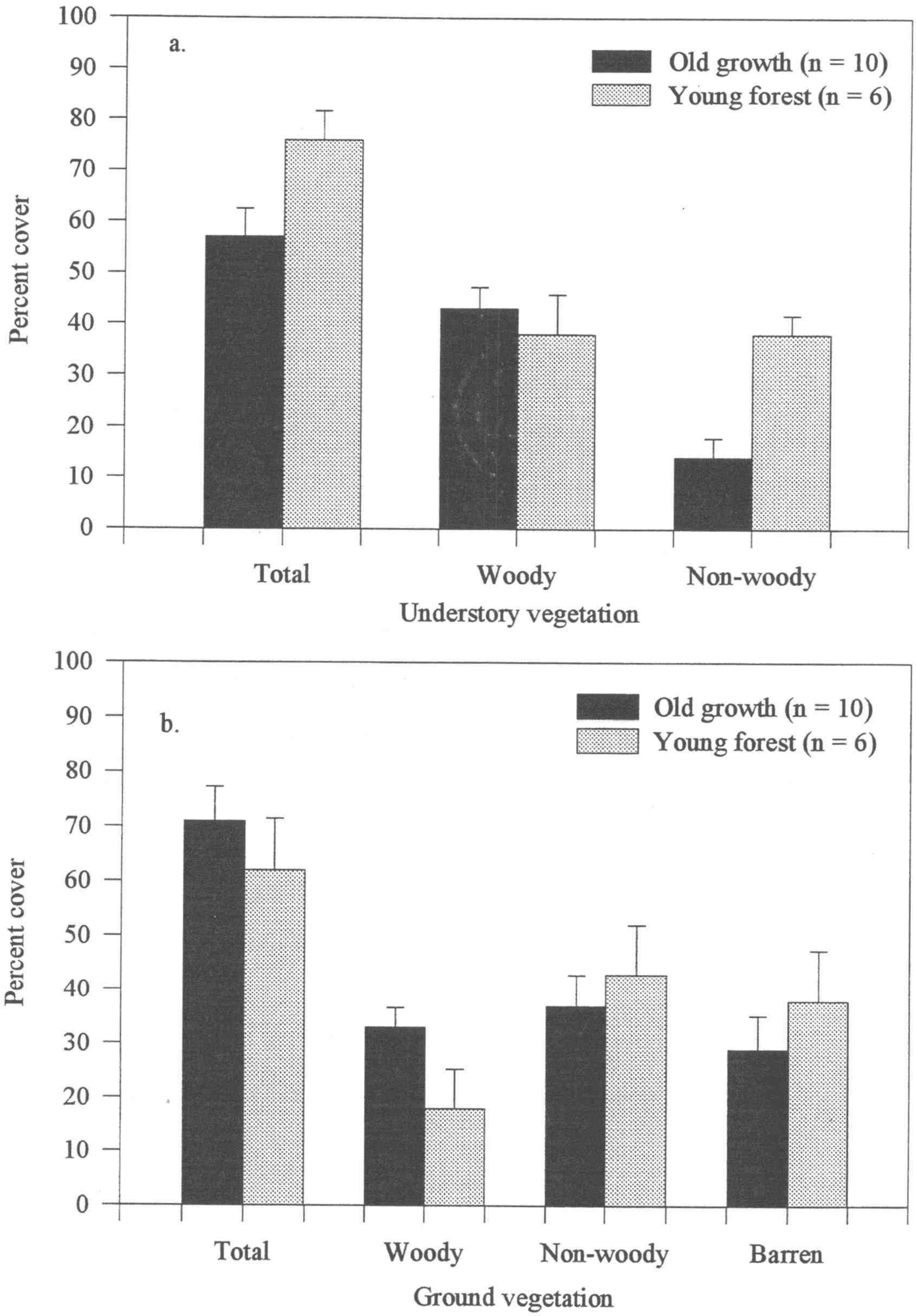

Figure 2.6. Mean (± SE) percent cover of (a) understory and (b) ground vegetation in six 10- x 10-m plots along intermittent, headwater streams in old-growth and young forest stands in the central Cascade Range in western Oregon.

abundant along all the streams in old growth but was dominant in only one stream and present in three other streams in young forest. Red alder was more abundant and common in the understory along the streams in young forest. Douglas-fir regeneration was present along only three streams in old growth and two streams in young forest. Swordfern dominated the non-woody understory vegetation in both stand types.

Total ground cover was not different between old-growth and young forest stands ($p = 0.42$) (Figure 2.6b). Although mean percentage of non-woody ground cover and mean percentage of barren or bare dirt were similar between stand types ($p = 0.56$ and $p = 0.42$, respectively), there was evidence that mean percentage of woody ground cover was different ($p = 0.06$) (Figure 2.6b). Dominant woody species in the ground cover along streams in both stand types included vine maple, Oregon-grape, red huckleberry, and salal as well as trailing blackberry (Rubus ursinus) in the young forest. Some western hemlock and red alder regeneration was found in the ground cover along the streams in old-growth and young forest, respectively. Douglas-fir regeneration was minimal in both stand types. The most prevalent non-woody ground cover species were redwood sorrel (Oxalis oregana) and vanilla-leaf (Achlys triphylla) in old-growth stands, and redwood sorrel and small bedstraw (Galium trifidum) in young forest stands. A number of woody and herbaceous species associated with moist forest conditions, streamside areas, or permanent water also were present in the understory and ground vegetation along the streams in both old-growth and young forests, although species composition differed between stand types (Appendix A).

Large Wood

Large wood density was low to moderate in study streams and appeared to differ between stand types as well as decay class. There was evidence that the mean total large wood density (no./m) was higher for intermittent streams in old growth than in young forest ($p = 0.06$) (Figure 2.7). Newly-recruited or least-decayed large wood density was not compared between stand types statistically since only one log in this category was found in the streams in young forest. Six streams in old growth contained minimal amounts of large wood in this category. The density of moderately-decayed large wood

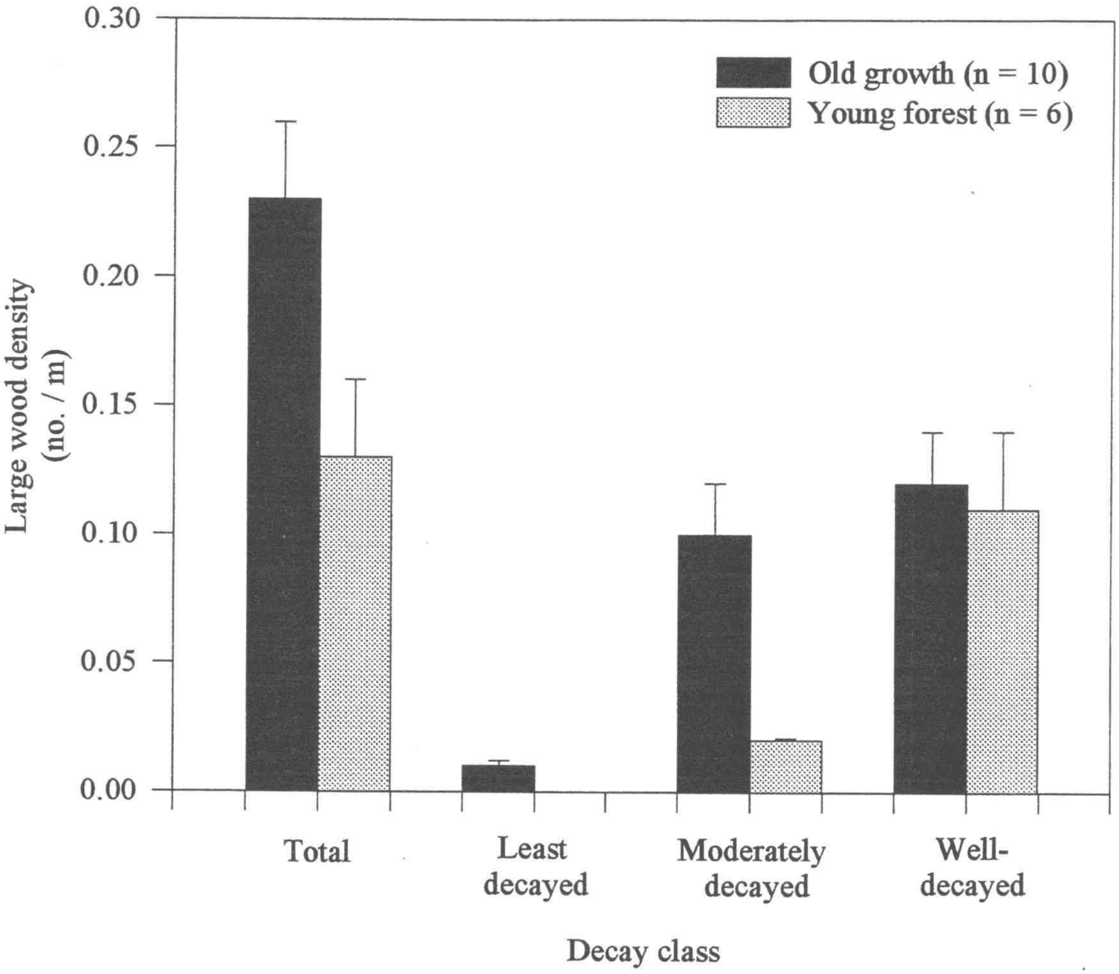

Figure 2.7. Mean (± SE) density of large wood in intermittent, headwater streams in old-growth and young forest stands in the central Cascade Range in western Oregon. The mean density of least-decayed large wood in the streams in young forest is not shown since only one log in this decay class was found in these streams.

differed between the streams in old growth and young forest (p = 0.003) (Figure 2.7); large wood in this category was about four times higher in the streams in old growth than in young forest. However, the density of well-decayed large wood did not differ between the streams in old growth and young forest (p = 0.92) (Figure 2.7).

Paired Site Comparisons - Upper and Lower Yellowbottom

The Upper Yellowbottom reach in young forest and the Lower Yellowbottom reach in old growth exhibited similar stream temperatures and substrate composition, but differed in streamside vegetation characteristics and large wood densities. These two stream reaches were similar in elevation, length, and channel width but differed in average gradient (see Table 2.1). Similar to Lower Yellowbottom and study streams in old growth, Upper Yellowbottom had a much higher percentage of cobbles and lower percentages of fine sediment, sand, and gravel than the other streams in young forest (Table 2.4). However, Upper Yellowbottom was characterized by large wood densities comparable to those in young forest, with a lower density of moderately-decayed large wood but a higher density of well-decayed large wood than those found in Lower Yellowbottom (Table 2.4). Upper Yellowbottom also had higher percentages of large and total coniferous canopy cover, woody and total understory cover, and woody and non-woody ground cover than Lower Yellowbottom (Table 2.4). Percent surface flow in Upper Yellowbottom was similar in the fall and winter (November to January/February) but higher in the spring (March and May/June) and lower in the summer (July and September) than that in Lower Yellowbottom (Table 2.4).

DISCUSSION

Effective protection and management of intermittent streams require accurate identification of these systems and information on their distribution and dynamics as well as land use impacts. Of the streams surveyed in old-growth and young forest stands, relatively few (23%) were designated as intermittent based on my definition which included presence of a definable channel, evidence of annual scour and deposition, and lack of surface flow along at least 90% of the stream length. Intermittent streams in

Table 2.4. Physical and hydrological characteristics of Upper Yellowbottom (33 yrs) and Lower Yellowbottom (≥195 yrs) in 1995. Ranges of habitat values for intermittent streams in old-growth and young forest stands in the central Cascade Range in western Oregon also are provided for comparison.

Habitat variable	Upper Yellowbottom	Lower Yellowbottom	Range in Young forest	Range in Old growth
Stream temperature (°C)				
Avg daily min	8.2	8.1	8.9 - 9.7	4.5 - 8.1
Avg daily mean	8.4	8.3	9.1 - 9.9	4.8 - 8.3
Avg daily max	8.6	8.6	9.4 - 10.1	4.9 - 8.6
Median diel fluctuations	0.3	0.5	0.3 - 0.6	0.3 - 1.2
Substrate (%)				
Fine sediment	6	1	11 - 49	0 - 34
Sand	7	3	13 - 21	0.3 - 16
Gravel	11	18	21 - 32	6 - 23
Pebble	20	26	14 - 24	19 - 55
Cobble	46	44	0.1 - 12	5 - 40
Boulder	8	3	0 - 2	0.2 - 21
Bedrock	5	0	0 - 8	0 - 23
Large wood density (no./m)				
Least decayed	0.00	0.00	0.00 - 0.003	0.00 - 0.02
Moderately decayed	0.01	0.11	0.01 - 0.06	0.02 - 0.20
Well-decayed	0.20	0.09	0.04 - 0.16	0.03 - 0.25
Streamside vegetation (%)				
Total overstory cover	70	35	57 - 97	40 - 97
Total coniferous cover	62	26	23 - 53	40 - 90
Total deciduous cover	8	9	19 - 69	0 - 35
Large coniferous cover	56	18	8 - 24	28 - 48
Large deciduous cover	7	3	15 - 32	0 - 32

Table 2.4. Continued.

Habitat variable	Upper Yellowbottom	Lower Yellowbottom	Range in Young forest	Range in Old growth
Small coniferous	6	8	10 - 28	8 - 45
Small deciduous	7	1	4 - 54	0 - 32
Total understory cover	93	73	62 - 86	34 - 93
Woody understory cover	71	49	18 - 39	24 - 62
Non-woody understory cover	23	23	35 - 47	2 - 32
Woody ground cover	52	33	3 - 22	13 - 49
Non-woody ground cover	28	51	19 - 73	8 - 62
Percent surface flow				
November 1994	90	100	100	50 - 100
December 1994	100	100	100	70 - 100
January/February 1995	100	100	80 - 100	50 - 100
March 1995	100	80	98 - 100	60 - 100
May/June 1995	83	57	68 - 98	4 - 78
July 1995	32	54	2 - 92	2 - 56
August 1995	62	44	5 - 62	0 - 44
September 1995	0.7	28	2 - 43	0 - 28
Flow duration (months)	10	11	8 - 11	6 - 11

old-growth stands exhibited the following characteristics: (1) annual flow pattern in which streams started to dry in May and June and were mostly dry by July; (2) lengthy annual flow durations; (3) cool and stable daily stream temperatures; (4) primarily coarse substrates, such as cobbles and pebbles; (5) streamside vegetation comprised of predominantly coniferous overstories, and plant species associated with uplands or dry site conditions, such as Oregon-grape and salal, as well as riparian areas or wet site conditions, such as red alder, oxalis, red huckleberry, and vine maple (Steinblums et al. 1984, Bilby 1988); and (6) low to moderate densities of large wood, mostly moderately- and well-decayed. Study streams in young forest appeared to dry about one to two months later than the streams in old growth but had similar annual flow durations. They also were characterized by higher daily stream temperatures, similar diel fluctuations, finer substrates, more deciduous overstory and herbaceous understory cover, and lower densities of moderately-decayed large wood.

Intermittent Stream Distribution and Classification

Estimates of intermittent stream density can vary depending on the criteria by which these streams are defined or designated. For example, my requirement for intermittent streams to dry up along at least 90% of their channel length yielded a relatively small number of streams given previous estimates of intermittent stream density (see FEMAT 1993). This result was particularly surprising since precipitation data indicated that rainfall in the study area during the 1993 to 1994 water year, prior to the stream inventory, was among the lowest in the past 20 years (Oregon Climate Service 1996). However, resource managers often operationally define intermittent streams as channels with <100% surface flow (Olson pers. comm.). Use of this definition would have increased the number of streams that I designated as intermittent and would lead to higher estimates of intermittent stream density, in general. Also, the designation of intermittent streams based on the presence of a definable channel and evidence of scour and deposition can be subjective and can vary among individuals. Finally, discrepancies between estimates of intermittent stream density based on maps and field estimates may exist since the stream inventory identified a number of streams on BLM maps that were not present in the field as well as streams in the field that were not on BLM maps. Although my process for designating streams as intermittent or perennial was based on a single site visit, I believe that it provided an adequate initial attempt at discriminating between the two flow regimes. This was supported by the observation that study streams were again mostly dry by the end of the 1994 - 1995 water year, which also was much wetter than the previous year. However, given their highly variable nature, it remains possible that streams designated as perennial may have dried later in the season and would have been designated as intermittent.

Poff and Ward (1989) classify intermittent streams into three categories (i.e., harsh intermittent, intermittent flashy, and intermittent runoff) based on flow variability and predictability. I propose a potential framework by which intermittent streams, and streams in general, also can be classified or defined along a temporal and spatial continuum. For example, perennial streams would be classified as those with low or zero temporal and spatial intermittency (Figure 2.8). Most of the intermittent streams monitored in this study were characterized by relatively high spatial but low temporal intermittency (Figure 2.8), that is, streams dried up along most of the channel length (>50%) but only for a short period of time (e.g., 3 months) during the 1994 to 1995 water year. Poff and Ward's (1989) harsh intermittent category refers to streams with long periods of zero flow and very low annual flow, which generally occur in the arid and semi-arid Southwest. These streams may be classified as those with high temporal and spatial intermittency (Figure 2.8). Ephemeral streams, which usually flow only for brief periods of time after precipitation events, also would probably be characterized by high temporal and spatial intermittency (Figure 2.8).

Habitat Characteristics and Comparisons between Stand Types

The intermittent streams in old-growth and young forest stands examined in this study appear to exhibit physical characteristics similar to those in perennial, headwater streams in the two stand types. Differences in stream flow, water temperature, substrate composition, streamside vegetation, and large wood have been attributed to timber harvesting in previous studies. However, in this study, many of the habitat differences

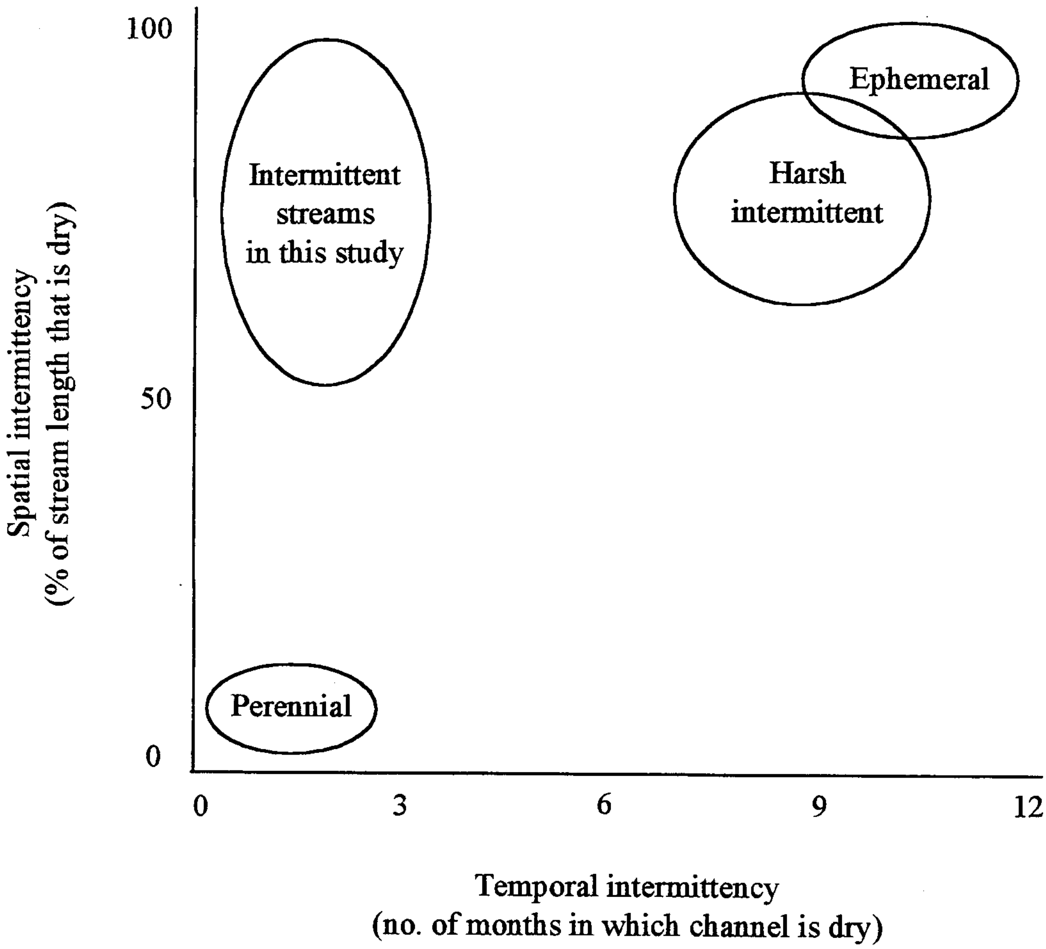

Figure 2.8. Conceptual framework for classification of intermittent streams along a temporal and spatial continuum. Examples are given of how different types of streams would fit within this framework.

between the streams in old-growth and young forest stands also may be attributed to differences in physiographic and geological factors, such as elevation, gradient, and underlying soils. Comparisons between Upper and Lower Yellowbottom seem to provide further evidence that site factors may provide likely explanations for some of the habitat differences between stand types.

Abundance of riparian-associated plant species, including some associated with permanent moisture (see Appendix A), along the intermittent streams in this study was unexpected, and may have been due to the persistence of some surface flow along these channels for most of the water year. However, species composition of these streamside communities also suggests that these streams may be located in forest stands that typically occupy extremely moist and productive sites within the western hemlock vegetation zone (Dyrness et al. 1974). Therefore, intermittent streams with shorter flow durations or located on drier sites may contain fewer riparian species.

High percentages of deciduous overstory cover and total understory cover are characteristic of streamside communities in young forest in the early stages of riparian succession. Shrubs and hardwoods quickly recolonize riparian areas following disturbance (Campbell and Franklin 1979, Andrus and Froehlich 1988, Minore and Weatherly 1994). Red alder is an aggressive, fast-growing, and short-lived tree that usually is the first to colonize and dominate disturbed riparian areas (Andrus and Froehlich 1988, Corn and Bury 1989, Minore and Weatherly 1994, Pojar and MacKinnon 1994). It is eventually replaced by bigleaf maple, Douglas-fir, and western hemlock as the stand matures and the canopy closes (Campbell and Franklin 1979). Conifers tend to dominate riparian areas along small streams that have remained undisturbed for over a century (Campbell and Franklin 1979, Minore and Weatherly 1994). The abundance of conifers in the overstory and understory along the streams in old growth reflects this trend. Conifers in riparian areas also tend to increase with elevation, stream gradient, and side slope gradient (Andrus and Froehlich 1988, Minore and Weatherly 1994). Thus, conifers may have been more prevalent along the streams in old growth since they were generally at higher elevations and had steeper gradients and side slopes than the streams in young forest. Higher percentages of coniferous overstory cover along Upper Yellowbottom than along Lower Yellowbottom and other streams in young forest further suggest that differences in overstory composition between stand types may be attributed to or compounded by differences in elevation and gradient.

Although coniferous overstory trees were abundant along the streams in young forest, conifer regeneration along these streams was minimal. Studies have found that conifer regeneration is scarce on recently disturbed riparian areas due to intense shrub competition, particularly along small streams (Campbell and Franklin 1979, Minore and Weatherly 1994). Riparian communities dominated by red alder have succeeded to shrub-dominated communities in some areas (Hibbs pers. comm. 1997). Therefore, the nature and frequency of disturbances, such as timber harvesting, can have important repercussions on the structure and composition of riparian vegetation.

Intermittent streams in old growth may have started to dry earlier than the streams in young forest for several possible reasons. Differences in stream flow may have been due to differences in soils and/or gradient between stand types. Coarser-textured soils, which may have characterized the old-growth stands, tend to exhibit higher hydraulic conductivity than finer-textured soils, which may have characterized the young forest stands (Beschta pers. comm.). Thus, drainage from hillslope soils during unsaturated conditions may have flowed into and out of the stream channels in old growth more quickly than the streams in the young forest during the spring and early summer. Steeper stream and side slope gradients in the old-growth stands also may have contributed to more rapid drainage into and out of these stream channels. Finally, reduced stream flow in old-growth stands during spring and early summer may have been due to the predominance of coniferous trees along these streams. Coniferous trees retain their foliage and cause soils and streams to lose water by evapotranspiration throughout the winter, whereas deciduous trees lose their foliage and are not transpiring during the winter. For example, Krygier (1971) found that Douglas-fir exhibited much greater evapotranspiration than Oregon white oak (Quercus garryanna) in the two-month period prior to full leafing of oak. Trees along the stream channel also appear to have the most or more impact on stream flow than trees upslope (Beschta pers. comm.). Therefore, the streams in old growth may have experienced more water loss during the winter, thereby exhibiting reduced surface flows by early spring, whereas the streams in young forest did not experience reduced surface flows until early summer when rainfall decreased and foliage returned to deciduous trees. This could explain why streams in old growth and young forest differed in stream flow pattern but not annual flow duration.

Stream temperature results indicate an elevational effect but not a stand effect. Minimum stream temperature, particularly in small tributaries, basically reflects temperature of the soil or subsurface flow, and is greatly influenced by elevation, whereas daily fluctuation in stream temperature is driven by meteorological factors such as the input of solar radiation (Beschta pers. comm.). Therefore, differences in minimum as well as mean and maximum stream temperatures mainly reflect differences in elevation between the streams in old growth and young forest; mean daily minimum stream temperatures were highly negatively correlated with elevation (Pearson correlation $\rho = -0.97$; $p = 0.0001$). Similar diel fluctuations in water temperature between stand types suggest that study streams in old growth and young forest were receiving comparable shade protection, despite differences in the structure and composition of the streamside vegetation. This suggests that timber harvesting does not appear to have a long-term impact on water temperature in the study streams. Corn and Bury (1989) also did not find any difference in stream temperature between 60- to 500-year-old uncut forest stands and 14- to 40-year-old logged stands with re-established canopies in the Oregon Coast Range. The small diel fluctuations observed in these streams may indicate close connections with subsurface water.

Studies have documented greater concentrations of fine sediments (i.e., silt, sand, and gravel) in streams in 14- to 40-year-old forest stands following timber harvest and greater concentrations of coarser substrates (i.e., cobble and boulder) in streams in uncut stands (Beschta 1978, Bury and Corn 1988a, Corn and Bury 1989). These studies have attributed increased sedimentation in the streams in second-growth stands to logging practices. I found similar trends in substrate composition. However, substrate differences in this study may have been due to the potential difference in soil type between old-growth and young forest stands. Similar substrate compositions between Upper and Lower Yellowbottom provide further evidence that substrate differences may be related to underlying soils rather than timber harvesting. The streams in young forest also may have accumulated more fine substrates due to their low flow volumes and lower gradients than the streams in old growth (Murphy et al. 1981).

Large wood results were consistent with trends from previous studies on perennial streams; however, direct comparisons with estimates from other studies could not be made due to discrepancies in large wood definitions (e.g., >10 cm diam and >1 m long; Ursitti 1991), channel size, and/or units of measurement (e.g., volume or biomass). The predominance of well-decayed large wood in the streams in young forest is most likely due to residual debris from the original stand, since most of the large wood in small streams in second-growth stands comes from pre-disturbance stands and can remain in streams for 25 to 100+ years (Swanson et al. 1976, Swanson and Lienkaemper 1978). Large wood recruitment tends to be reduced in streams in young forest since trees of sufficient size are not yet available for input. For example, red alder, found along the streams in young forest, tends to be short-lived (Pojar and Mackinnon 1994) and may not reach large diameters. It also is possible that some partially-decayed large wood was salvaged from the streams in young forest during timber harvesting. It may take centuries for large wood concentrations, particularly coniferous debris, in second-growth stands to reach levels characteristic of those in old growth (Swanson and Lienkaemper 1978). The current structure and composition of the streamside vegetation in the young forest stands, particularly the large deciduous and shrub component and lack of conifer regeneration, indicate that these streams may be faced with a similar situation. The small amount of least-decayed large wood in both stand types may have been due to a tendency for logs to progress quickly from this decay class into the moderately-decayed category; logs may be in the least-decayed category for five to seven years and in the moderately-decayed category for 60 to 100 years (Harmon pers. comm.).

Conclusions and Management Implications

Standard and explicit criteria for defining and designating intermittent streams need to be developed and implemented. Intermittent streams have been defined and designated in a number of ways in the literature and among personnel working on this issue, which can lead to inaccurate or inconsistent identification and density estimates of these streams. The Northwest Forest Plan provides a standard definition of intermittent streams for federal lands, but it needs further clarification. For example, streams can be defined or classified in terms of temporal and spatial intermittency. Stream surveys denoting flow or drought conditions during the dry season, from July to September, can be an effective first attempt at designating intermittent streams in the field; however, it may take multiple visits within and among years to more accurately designate and monitor intermittent streams since these streams can be highly variable in flow spatially and temporally. Habitat characteristics, such as riparian vegetation, may provide information on stream flow regimes, such as flow duration. These associations need to be investigated further. Stream inventory results suggest possible discrepancies between current management databases and field conditions (e.g., streams depicted on maps but not in the field or vice versa). Thus, some comprehensive field inventories should be conducted, at least initially, to collect and verify information on intermittent and perennial stream densities and distributions as well as associated site conditions.

Although habitat differences between the streams in old growth and young forest cannot be definitively attributed to timber harvesting, current habitat conditions in the study streams can provide insight into potential timber harvesting impacts and management strategies. Stream channels in the young forest stands were comprised primarily of fine sediment, sand, and gravel and may be fairly susceptible to on-site damage in terms of physical alterations during harvesting operations. Physical alteration of these stream channels may, in turn, contribute sediment to downstream areas. Increased sedimentation may negatively impact aquatic organisms such as amphibians by filling in substrate crevices which may represent important microhabitats (Bury and Corn 1988a, Corn and Bury 1989). Streams in young forest stands also were characterized by low recruitment of large wood. Loss of large wood in these streams may reduce nutrient levels and available habitat for plants, and aquatic invertebrates and vertebrates (Harmon et al. 1986). Leaving some trees along these streams during timber harvesting may provide a source of large wood for these channels and downstream areas during stand re-establishment. Intermittent streams at lower elevations may be characterized by higher stream temperatures than those at higher elevations, especially during the summer when stream flow is reduced; thus, maintaining shade protection along low-elevation streams may be particularly crucial. However, intermittent streams may not require much vegetation for sufficient shade protection and temperature regulation given their generally small channel widths and potential for strong connections with subsurface water. Therefore, management practices that minimize physical disturbance and maintain some vegetation along the channel (e.g., riparian buffers and alternative silvicultural techniques such as thinning) may provide adequate protection for intermittent streams. However, this needs to be investigated further. As headwater tributaries, intermittent streams may represent important sources of water, sediment, nutrients, and organic material for downstream habitat and aquatic biota. Effective and appropriate management of intermittent streams should address specific on-site habitat conditions as well as implications for aquatic ecosystems downstream and overall watershed health.

CHAPTER 3
AMPHIBIAN COMMUNITIES IN INTERMITTENT STREAMS IN OLD-GROWTH AND YOUNG FOREST STANDS IN WESTERN OREGON

INTRODUCTION

Amphibians recently have been recognized as potentially important components of forest ecosystems and watersheds due to their abundance and ecological roles (Bury 1988, Bury and Corn 1988a, Corn and Bury 1989, Forest Ecosystem Management Assessment Team (FEMAT) 1993). Burton and Likens (1975) and Hairston (1987) estimate that amphibian biomass and trophic level energy per hectare of forest equalled or exceeded that of birds, small mammals, and all other vertebrate predators in the Hubbard Brook Experimental Forest and in southern Appalachian deciduous forests, respectively. Aquatic and semi-aquatic amphibians are the dominant vertebrates in many small, headwater streams (Murphy 1979, Murphy and Hall 1981, Bury 1988, Bury and Corn 1988a). They may function as top predators and/or abundant prey in these systems (Murphy and Hall 1981, Walls et al. 1992). Due to their small size and slow metabolism, amphibians, in general, are able to forage on smaller prey or food items that are not exploited by birds or small mammals, converting them efficiently into biomass that is subsequently consumed by larger vertebrates (Feder 1983).

Both aquatic and terrestrial amphibians can be sensitive to and greatly affected by environmental perturbations and land use activities (Bury 1983, Pough et al. 1987; Bury and Corn 1988a, 1988b; Corn and Bury 1989; Depuis 1993, Petranka et al. 1993, Kelsey 1995, Vesely 1995). Some amphibians have strict physiological constraints, low mobility, small home ranges, and highly specific habitat requirements (Corn and Bury 1989, FEMAT 1993). Many species display a high degree of site fidelity, returning to home ranges and breeding sites after displacement or dispersal (Duellman and Trueb 1994). Some also have complex life cycles (e.g., aquatic eggs and larvae and terrestrial adults) which expose them to numerous terrestrial and aquatic threats (Walls et al. 1992, FEMAT 1993).

The tailed frog (Ascaphus truei), Cascade torrent salamander (Rhyacotriton cascadae), Pacific giant salamander (Dicamptodon tenebrosus), and Dunn's salamander (Plethodon dunni) are the species most commonly associated with small, headwater streams in the Oregon Cascade Range (Bury and Corn 1988a, Bury et al. 1991). These species are endemic to the Pacific Northwest (Nussbaum et al. 1983, Bury 1988) and often occur in the same streams. Larvae of tailed frogs and Cascade torrent salamanders require cool, flowing permanent water, and juveniles and adults are closely tied to the stream environment (Nussbaum and Tait 1977, Nussbaum et al. 1983, Bury and Corn 1988a, Walls et al. 1992). Pacific giant salamanders also have aquatic larvae, but juveniles and adults can be found both in streams and on land (Nussbaum et al. 1983, Bury and Corn 1988a, Bury et al. 1991, Walls et al. 1992). This species is more widely distributed and has broader habitat requirements than the Cascade torrent salamander (Bury and Corn 1988a, Puchy and Marshall 1993). Dunn's salamanders are considered semi-aquatic, lack a larval stage, and also are widely distributed (Nussbaum et al. 1983, Puchy and Marshall 1993).

Timber harvesting can have significant impacts on headwater streams and aquatic amphibian communities (Bilby 1988, Bury and Corn 1988a, Corn and Bury 1989). Forestry practices have been cited as one of the primary threats to tailed frogs and Cascade torrent salamanders which are listed as sensitive species in Oregon (Marshall et al. 1996). Short-term effects of logging include changes in stream flow and increased solar insolation and stream temperatures, which, in turn, lead to increased primary production and invertebrate populations (Murphy and Hall 1981; Murphy et al. 1981; Hawkins et al. 1982, 1983). These conditions usually last only until the canopy is re-established (Brown and Krygier 1970, Swift and Messer 1971, Bury and Corn 1988a, Keppeler and Ziemer 1990). Short-term impacts may positively affect Pacific giant salamanders, due to the increased food base (Murphy and Hall 1981, Murphy et al. 1981, Hawkins et al. 1983), and may negatively affect tailed frogs and torrent salamanders, as a result of reduced large wood volume and/or their low temperature tolerances (Bury and Corn 1988a, Kelsey 1995). Long-term effects of timber harvesting involve alteration of the stream's physical habitat, in terms of increased sedimentation and reduced input of large wood, and may last for decades (Beschta 1978, Swanson and Lienkaemper 1978, Murphy et al. 1981, Hawkins et al. 1983, Bury and Corn 1988a, Corn and Bury 1989). Increased sedimentation may have significant negative impacts on aquatic amphibian populations by filling in substrate crevices which represent important microhabitats (Bury and Corn 1988a, Corn and Bury 1989). Large wood provides cover and nutrients and helps maintain channel characteristics (Swanson and Lienkaemper 1978, Bilby 1988). Lower volumes of large wood may reduce available in-stream habitat for tailed frogs and Pacific giant salamanders (Kelsey 1995). The ultimate impact of timber harvesting on aquatic amphibian communities will depend on their response to both short- and long-term effects of logging (Murphy 1979).

Aquatic amphibian studies have focused on perennial, headwater streams (see Bury 1988, Bury and Corn 1988a, Corn and Bury 1989, Bury et al. 1991). However, many headwater streams exhibit intermittent or temporary flow (Everest et al. 1985). Intermittent streams historically have received little attention from researchers and managers but recently have been recognized as potentially important ecological components of watersheds. These streams may represent a significant proportion of the overall channel length in watersheds, have been found to support rich and, in some cases, unique macroinvertebrate faunas, and may function as important habitat for vertebrate predators (Boulton and Suter 1986, Dieterich 1992, FEMAT 1993). A few amphibian species have been found in intermittent streams (Stehr and Branson 1938, Towns 1985, Dieterich 1992, Holomuzki 1995). However, amphibian communities in intermittent, headwater streams have not been specifically examined.

My goal was to provide an initial understanding of amphibian communities in intermittent streams and potential impacts of timber harvesting on these systems. Amphibian communities in intermittent streams in old-growth and young, managed forest stands in the Oregon Cascade Range were examined. The specific objectives of my study were to: (1) document and compare species composition, species richness, and abundance, in terms of density and biomass, of amphibian communities in intermittent streams in old-growth and young forest stands; (2) examine amphibian communities in relation to seasonal flow regimes (i.e., during wet and dry seasons) within a given year in both stand types; and (3) investigate species-specific associations with micro- and macrohabitat features. I hypothesized that amphibian communities and habitat relationships in intermittent streams would be comparable to those in perennial, headwater streams during the wet season. I also hypothesized that amphibian communities in intermittent streams in old growth or during the wet season would contain greater species richness and abundances than those in young forest or during the dry season.

METHODS

Study Area

The study was conducted on public lands, federally administered by the Bureau of Land Management (BLM), in the foothills of the central Cascade Range in Linn County, Oregon (see Figure 2.1). Annual precipitation in the western Cascades ranges from 70 to over 350 cm (Harr 1976). Precipitation is mainly in the form of rain at lower elevations and snow at higher elevations (above 900 m; Harr 1976). Topography consists of steep slopes and deeply-incised drainages. Western hemlock (Tsuga heterophylla) and Douglas-fir (Pseudotsuga menziesii) dominate the overstory in most of the study area (Franklin and Dyrness 1988). Vine maple (Acer circinatum), dwarf Oregon-grape (Berberis nervosa), salal (Gaultheria shallon), huckleberries (Vaccinium spp.), and swordfern (Polystichum munitum) are common understory species (Franklin and Dyrness 1988). A mosaic of public and private land ownerships and seral stages characterizes the surrounding landscape. The public lands are predominantly second-growth, mixed young and mature stands that either have naturally regenerated after wildfires or clearcut harvesting or are even-aged young stands that have been intensively managed, with scattered pockets of remnant old growth.

Study Streams

I examined amphibian communities and habitat conditions in 16 intermittent streams, 10 in old-growth and 6 in young, second-growth forest stands (see Table 2.1).

I identified streams from a field inventory that was conducted during the dry season in 1994, from 11 August to 12 October. During the stream inventory, I designated streams as intermittent only if they had definable channels with evidence of annual scour and deposition (ROD 1994) and if $\leq 10\%$ of the stream length (i.e., from channel initiation to tributary junction with a perennial stream, road, or stand edge) contained surface flow. I used such a conservative flow criterion in an attempt to ensure intermittency given only one field visit during a single year and no previous flow data. Streams selected for the study were required to have at least 50 m of sampleable channel and to be at least 50 m away from any road, perennial flow, or stand edge. Old-growth stands were at least 195 years old, except for one stream of which the lower half was in a 135 year old stand, and had never been harvested. Amphibian communities and habitat in intermittent streams in these stands represented reference conditions to which logged sites were compared. The young, second-growth forest stands ranged in age from 28 to 45 years and had re-established canopy closure. They were clearcut harvested with ground-based equipment, broadcast burned, and planted. One young forest stand also was aerially sprayed for brush and hardwood control and pre-commercially thinned. The streams in these young forest stands did not receive any protection during timber harvesting and exemplified long-term conditions following harvesting. All streams were first-order tributaries except for one second-order reach in old growth; stream order designations were based on field conditions. The streams in old growth were at higher elevations, due to the history of logging in the study area, and were generally wider and steeper than the streams in the young forest stands (see Table 2.1). Old-growth and young forest stands also may have differed in soil type, with primarily gravelly, cobbly, or stony loam soils in old growth and silty clay loam soils in the young forest (USDA Soil Conservation Service 1987).

Three pairs of streams (1 pair in old-growth and 2 pairs in young forest) were found in the same stands (see Table 2.1). The streams in each of these pairs were at least 50 m apart and separated by a ridge. One stream reach in young forest was immediately upstream and separated by 50 m from one of the study reaches in old-growth (Upper and Lower Yellowbottom). I sampled streams in the same stands and adjacent streams simultaneously or on consecutive days, except in one case when streams were sampled 10 days apart. Given their strong association with water and limited dispersal distances, we assumed that amphibians did not move between streams in the same stands during a sampling period, and that these streams represented independent samples.

Amphibian Sampling

Amphibian sampling was conducted in 1995 during late spring, 15 May to 2 July, when surface flow was present, and summer, 18 August to 3 September, when surface flow was reduced or absent. I used a habitat-based amphibian sampling protocol modified from one proposed by Welsh et al. (in press). Prior to sampling, I surveyed and classified streams into habitat units of five different types: pool, riffle, dry, mixed, and waterfall (see Figure 2.2). Distinct habitat units were identified only if the length of the habitat type equalled or exceeded one channel width, and the habitat type comprised most of the channel width (McCain et al. 1990). Pools were defined as standing or slow-water channel units. Riffles were low or high-gradient, fast-water channel units. Dry habitat comprised those parts of the stream from which surface flow was absent, but small, remnant pockets of water and/or moist substrate may have been present. Mixed habitat units were designated when two or more habitat types occurred in approximately equal proportions across the channel width (e.g., riffle interspersed with pools).. Waterfalls were habitat units in which surface flow exhibited vertical or near vertical drop.

I numbered and flagged habitat units with wire stakes and measured the length of each habitat unit during the survey. I selected units for amphibian and habitat sampling using a stratified random design. I divided each stream into four sections of equal length, from which I randomly selected 12 units total (3 from each section), or however many were available, of each habitat type (see Figure 2.2). When three units of a particular habitat type were not available within a stream section, I selected additional units in adjacent sections. I sampled habitat units up to 20 m in length in their entirety. I divided habitat units that exceeded 20 m in length into upper and lower halves, of which I randomly selected one for sampling. I sampled the same habitat units in the spring and summer. I also sampled additional pools, riffles, and mixed units in the summer to try to obtain 12 units of each of these habitat types since many of the spring units dried and/or were reclassified as different habitat types.

I sampled streams from the downstream end up toward the headwaters to minimize disturbance of subsequent sample units. I used an area-constrained search method in which all moveable cover (e.g., rocks, wood) and crevices were systematically searched and removed; I replaced all cover items after sampling (see Bury and Corn 1991). I captured organisms by hand, with aquarium nets, or with wire mesh nets placed at the downstream end of the habitat unit. I recorded species, age class/stage, sex (when discernible), total length, snout-vent length, and wet weight for each specimen. After the entire habitat unit was searched and all animal measurements were taken, I returned specimens to the stream at their capture site.

Habitat Sampling

I conducted habitat sampling concurrently with amphibian sampling. Within each habitat unit selected for amphibian sampling, I recorded average width and microhabitat features such as mean and maximum water depth, substrate composition, and wood cover. I measured water depth in the center of the channel at the top, middle, and bottom of each habitat unit to obtain an average. I visually estimated substrate composition in terms of relative amounts (%) of fine sediment (<0.06 mm in diameter), sand (0.06 - 2.0 mm), gravel (2.0 - 16.0 mm), pebble (16.0 - 64.0 mm), cobble (64.0 - 256.0 mm), boulder (> 256.0 mm) and bedrock, based on substrate size categories described by Platts et al. (1983). I also visually estimated the percent of each sample unit covered (i.e., directly in the unit or overhanging the channel) by small (diameter <30 cm) and large (diameter ≥30 cm) wood. I measured several macrohabitat or stream level habitat variables, such as stream temperature, annual stream flow duration, percent surface flow, large wood density, and riparian vegetation. I measured stream temperature within each sampled habitat unit with a hand-held thermometer during spring and summer sampling, and calculated average stream temperature from unit measurements. See Chapter 2 for a more detailed description of how macrohabitat variables were measured.

Data Analyses

I analyzed species composition, species richness (no. species), amphibian density (no./m^2), and amphibian biomass (grams/m^2) at the stream or sample reach level, that is, for sample units of all habitat types along a stream combined, to examine overall similarities and differences between stand types and seasons. I also derived and analyzed estimates of average amphibian density (no./m), in terms of stream length, for the entire reach by calculating the sum of the total density of each habitat type (no./m) weighted by the proportion of stream length available of that habitat type in the stream. Stream estimates were weighted to account for potential differences in density among habitat types. I examined amphibian use of specific habitat types as well as relationships between stand types and seasons within and among habitat types. Habitat level analyses required comparable numbers of units of the various habitat types. Since more than 12 dry units were sampled in each stream in the summer, only those units that had been dry in the spring as well as new units randomly selected from those that had been sampled in the summer to obtain a total of 12 were included in the analyses.

I used split-plot analysis of variance to compare species richness, density, and biomass between stand types and seasons at the stream and habitat levels. Stand represented the whole-plot factor, and season was treated as the split-plot factor. Variance was sufficiently unequal among habitat types such that stand type and season comparisons were analyzed within each habitat type, and only qualitative comparisons were made among habitat types. Species richness, amphibian density, and biomass data were square-root transformed to better meet the assumptions of the analysis of variance. Transformed means and 95% confidence intervals were back-transformed to report richness, density, and biomass estimates for stand types, habitat types, and seasons on the original measurement scale.

I also used split-plot analysis of variance to compare percent surface flow, stream temperature, and mean and maximum water depth between stand types and seasons. I used two-sample t-tests to compare sampling effort, substrate composition, small and large woody debris cover, and macrohabitat conditions between streams in old-growth and young forest. For the t-tests, I applied Levene's test of homogeneity of variance (Levene 1960 in Snedecor and Cochran 1989) to test the null hypothesis that sample groups had equal variances. When variances were unequal, I used an approximate t-statistic (SAS Institute 1990). Satterthwaite's (1946) approximation was used to calculate the degrees of freedom associated with the approximate t-statistic (SAS Institute 1990).

I used correlation analysis to determine habitat attributes which may be related to amphibian abundance, and the general nature of those relationships. I also examined graphical representations (i.e, scatterplots) of the data to evaluate habitat relationships. I investigated relationships between amphibian density and microhabitat features (i.e., substrate composition, water depth, and wood cover) at the habitat unit level. I examined amphibian relationships with macrohabitat features at the stream level, specifically elevation; flow duration; percent surface flow during sampling; stream temperature; total large wood density; total, coniferous, and deciduous riparian overstory cover; and total riparian understory and ground cover. I selected these habitat features because aquatic amphibians are likely or have been found to respond to them. I analyzed habitat relationships by species, stand type, and season. Since amphibian and some habitat data had skewed distributions, especially at the unit level, I used Spearman's coefficient of rank correlation to assess relationships. An alpha-level of 0.05 was used for all analyses; all p-values were two-sided.

RESULTS

On average, I sampled 52% of both total habitat units and total stream lengths in old-growth stands, and 39% of total habitat units and 47% of total stream lengths in young forest stands during spring and summer. Sampling effort was similar between stand types and seasons; mean stream length and area sampled were similar between stand types ($p = 0.38$ and $p = 0.32$, respectively) and seasons ($p = 0.43$ and $p = 0.38$, respectively) (Table 3.1). One stream in an old-growth stand (Boulder Ridge) exhibited

Table 3.1. Spring (May 15 - July 2) and summer (August 18 - September 3) sampling effort in terms of total and mean number of habitat units, length, and area sampled in intermittent, headwater streams in old-growth and young forest stands in the central Cascade Range in western Oregon.

	No. streams	No. habitat units sampled		Stream length sampled (m)		Stream area sampled (m^2)	
		Spring	Summer	Spring	Summer	Spring	Summer
Total							
Old growth	10	368	287	1357.6	1256.9	1787.7	1717.9
Young forest	6	224	216	626.3	629.1	440.0	446.8
Mean							
Old growth	10	37	29	135.8	125.7	178.8	171.8
Young forest	6	37	36	104.4	104.8	73.3	74.5

only 4% surface flow during spring sampling, when streams were supposed to exhibit wet season flow conditions. Amphibians and habitat characteristics in this stream were noted but not included in any of the final analyses; therefore, results presented here were based on only 15 streams.

Stream Characteristics

Percent surface flow differed between stand types and seasons ($p = 0.001$ and $p = 0.0001$, respectively) (Table 3.2). This may have been due to differences in soil type and/or gradient between the streams in old growth and young forest. Mean and maximum water depths of sample units did not differ between stand types ($p = 0.86$ and $p = 0.87$, respectively), but differed between spring and summer ($p = 0.0001$). Stream temperatures differed between old growth and young forest ($p = 0.01$), most likely due to differences in elevation, and between spring and summer ($p = 0.0001$), although there was some evidence of an interaction between stand type and season ($p = 0.08$). In general, woody debris provided little cover over habitat units in both stand types. Mean percent cover provided by small wood was slightly higher for the sampled units in young forest stands ($p = 0.04$), while cover provided by large wood was similar between stand types ($p = 0.51$). Streams in the young forest compared to those in old-growth stands were characterized by: (1) similar annual flow durations and total overstory and ground cover; (2) higher percentages of deciduous overstory and understory cover, fine sediment, sand, and gravel; and (3) lower total densities of large wood and lower percentages of coniferous overstory cover, pebble, cobble, and boulder. Means and p-values for these habitat features and comparisons were reported in Chapter 2. These results included the Boulder Ridge site. Although exact values of means differed without this site, statistical results remained essentially the same.

Amphibian Comparisons - Stream Level

Amphibian communities in spring and summer were comprised primarily of the Cascade torrent salamander, Dunn's salamander, and Pacific giant salamander (Table 3.3). The Cascade torrent salamander was the most abundant species overall,

Table 3.2. Habitat characteristics of intermittent, headwater streams in old-growth and young forest stands in the central Cascade Range in western Oregon during spring and summer sampling.

Variable	Old growth (n = 9)		Young forest (n = 6)	
	Mean	SE	Mean	SE
Flow duration (months)	10	0.4	10	0.5
Percent surface flow				
Spring	50	4.7	86	4.4
Summer	18	4.7	36	9.6
Stream temperature (°C)				
Spring	8.9	0.69	10.4	0.27
Summer	10.9	0.49	13.9	0.51
Mean water depth (cm)				
Spring	2.6	0.38	2.5	0.20
Summer	0.6	0.16	0.6	0.11
Maximum water depth (cm)				
Spring	5.1	0.79	4.5	0.40
Summer	1.1	0.26	1.1	0.14
Small woody debris (% cover)	9	2.3	16	1.9
Large woody debris (% cover)	3	1.0	4	1.2

Table 3.3. Summary of amphibian species, numbers of individuals, and biomass that were found in intermittent streams in old-growth (n = 9) and young forest (n = 6) stands in the central Cascade Range in western Oregon during the spring and summer of 1995.

	Spring 1995						Summer 1995					
	Old growth		Young forest		Total		Old growth		Young forest		Total	
Species	No.	Biomass	No.	Biomass	No.	Biomass	No.	Biomass	No.	Biomass	No.	Biomass
Cascade torrent salamander (*Rhyacotriton cascadae*)	188	236.1	27	48.0	215	284.1	190	204.8	1	0.6	191	205.4
Dunn's salamander (*Plethodon dunni*)	34	29.0	46	46.9	80	75.9	68	63.0	27	20.8	95	83.8
Pacific giant salamander (*Dicamptodon tenebrosus*)	30	56.0	13	29.5	43	85.5	14	41.2	0	0.0	14	41.2
Rough-skinned newt (*Taricha granulosa*)	4	29.8	0	0.0	4	29.8	1	13.0	0	0.0	1	13.0
Tailed frog (*Ascaphus truei*)	2	10.0	0	0.0	2	10.0	1	4.3	0	0.0	1	4.3
Pacific treefrog (*Hyla regilla*)	1	3.5	0	0.0	1	3.5	0	0.0	0	0.0	0	0.0
Western redbacked salamander (*Plethodon vehiculum*)	0	0.0	0	0.0	0	0.0	2	0.9	0	0.0	2	0.9
TOTAL	259	364.3	86	124.4	345	488.7	276	327.1	28	21.4	304	348.5

representing about 60% of total amphibian captures and biomass during both spring and summer; of these, over 90% were larvae. This species was found in 6 of 9 and 5 of 9 streams in old growth during spring and summer, respectively, but in only 1 of 6 streams in young forest during both seasons. The stream reach in young forest in which torrent salamanders occurred was immediately upstream from a stream reach in old growth which contained high densities of this species.

The Dunn's salamander was the second-most abundant and the most frequently occurring species, found in 7 of 9 streams in old growth and 5 of 6 streams in young forest during both seasons. It was the predominant species in the streams in young forest. Most individuals of this species also were assumed to be juveniles based on their size. The Pacific giant salamander occurred slightly more frequently in old growth, since it was found in three streams in old growth and only one stream in young forest in the spring, and in one stream in old growth in the summer. One adult Pacific giant salamander was found, and the remainder were larvae. Several incidental species were found only in old growth. In addition, an adult tailed frog and two ensatinas were found at the Boulder Ridge site in the spring and summer, respectively, and an adult red-legged frog was found in a habitat unit in old growth that was not selected for sampling in the spring. These four individuals were not included in the analyses.

Six species were found in the streams in old growth during spring and summer, as a result of the incidental species, whereas only three species in the spring and two species in the summer were found in the young forest (see Table 3.3). Most streams in old growth contained two or more species in the spring, while most in young forest contained only one species (Figure 3.1). However, by summer, most streams in old growth and young forest contained only one or two species. Estimated species richness did not differ between stand types ($p = 0.27$) or seasons ($p = 0.20$) (Table 3.4).

Different relationships in total amphibian densities were observed between stand types. The estimated total amphibian density (no./m^2) for the sample reaches in old growth during summer (0.18) was comparable to old-growth (0.17) and young forest (0.16) densities in the spring (Table 3.4). However, estimated total density for the sample reaches in young forest in the summer (0.06) was much lower than old-growth

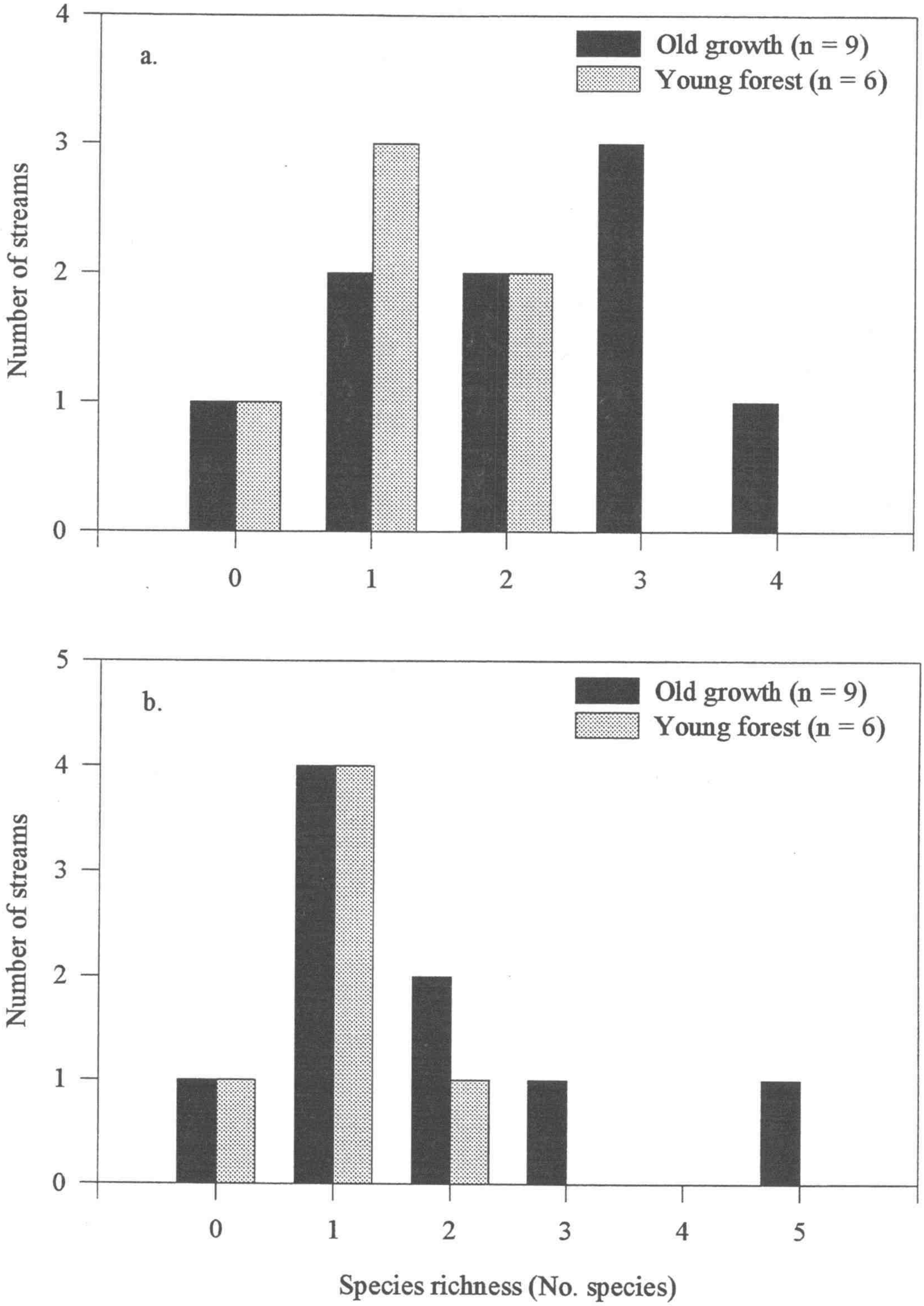

Figure 3.1. Species richness distributions in intermittent, headwater streams in old-growth (≥195 yrs) and young (28 - 45 yrs) forest stands in the central Cascade Range in western Oregon during (a) spring and (b) summer.

Table 3.4. Estimated species richness (no. species) and estimated amphibian densities (no./m^2) and biomass (g/m^2) in intermittent streams in old-growth and young forest stands in the central Cascade Range in western Oregon during spring and summer of 1995. Estimated weighted total amphibian densities (no./m) also are provided. Estimates represent back-transformed means.

	Spring 1995				Summer 1995			
	Old growth (n=9)		Young forest (n= 6)		Old growth (n = 9)		Young forest (n = 6)	
	Estimate	95% CI	Estimate	95% CI	Estimate	95% CI	Estimate	95% CI
Species richness	2	1 - 3	1	0.2 - 2	1	1 - 3	1	0.2 - 2
Total								
Density	0.17	0.03 - 0.45	0.16	0.01 - 0.50	0.18	0.03 - 0.46	0.06	0.01 - 0.29
Biomass	0.23	0.04 - 0.59	0.22	0.01 - 0.66	0.18	0.02 - 0.48	0.03	0.03 - 0.29
Weighted total density	0.18	0.05 - 0.40	0.12	0.01 - 0.35	0.13	0.02 - 0.32	0.03	0.004 - 0.19
Cascade torrent salamander								
Density	0.10	<0.001 - 0.41	0.01[a]	0.01 - 0.12	0.09	<0.001 - 0.38	0.001[a]	0.001 - 0.005
Biomass	0.12	<0.001 - 0.48	0.03[a]	0.02 - 0.22	0.10	0.001 - 0.43	<0.001[a]	<0.001 - 0.003
Dunn's salamander								
Density	0.03	0.003 - 0.08	0.08	0.02 - 0.18	0.04	0.01 - 0.09	0.05	0.01 - 0.13
Biomass	0.02	0.001 - 0.06	0.08	0.02 - 0.18	0.02	0.001 - 0.07	0.03	0.002 - 0.10
Pacific giant salamander[b]								
Density	0.002	<0.001 - 0.01	0.002	0.002 - 0.02	<0.001	<0.001 - 0.001	0.00	.
Biomass	0.004	<0.001 - 0.02	0.005	0.004 - 0.04	0.001	<0.001 - 0.005	0.00	.

[a] 5 of 6 streams contained no individuals of this species; 6th stream was near stream in old-growth stand that contained high densities of this species.
[b] Present in only 3 of 9 streams in old growth; 1 of 6 streams in young forest in the spring; and 1 stream in old growth in the summer.

densities during both seasons and young forest density in the spring. Half of the streams in old growth actually had slightly higher total densities in the summer than in the spring, whereas all the streams in young forest had lower total densities in the summer. This interaction between stand type and season was found to be significant ($p = 0.02$). Total biomass estimates (g/m^2) for sample reaches displayed similar trends as total density but differed between spring and summer for both stand types ($p = 0.01$; Table 3.4). Estimated total densities (no./m) for entire streams were comparable to estimated densities for sample reaches but also exhibited a seasonal difference for both stand types ($p = 0.02$; Table 3.4).

Since the Cascade torrent salamander was found in only one stream in young forest stands, density and biomass comparisons between stand types were not analyzed statistically for this species. During spring and summer, torrent salamander density (0.52 and 0.02, respectively) and biomass (0.92 and 0.01, respectively) in the stream reach in young forest were much lower than density (1.64 and 1.67, respectively) and biomass (1.84 and 2.04, respectively) in the old-growth section downstream. Also, density and biomass in the reach in young forest were lower in the summer than in the spring, while the reach in old-growth maintained comparable concentrations of the Cascade torrent salamander between seasons. Estimated torrent salamander densities and biomass within old-growth stands were similar between spring and summer ($p = 0.92$ and $p = 0.86$, respectively) (Table 3.4). Estimated Dunn's salamander densities and biomass did not differ significantly between stand types ($p = 0.33$ and $p = 0.20$, respectively) or seasons ($p = 0.59$ and $p = 0.28$, respectively) (Table 3.4). Pacific giant salamander density and biomass were not compared statistically since this species occurred in only a few streams and in very low densities in both stand types and seasons.

Amphibian Comparisons - Habitat Level

Cascade torrent salamanders were the predominant species in pools, riffles, and mixed units in old-growth stands during spring and summer, and the most abundant species in riffles in young forest stands in the spring (Tables 3.5 and 3.6). Dunn's salamanders were the predominant species in dry habitat in both stand types and seasons.

Table 3.5. Amphibian species and numbers of individuals that were found in five different habitat types in nine intermittent streams in old growth and six intermittent streams in young forest stands in the central Cascade Range in western Oregon during spring 1995.

	Spring 1995									
	Old growth (n = 353 units)					Young forest (n = 224 units)				
Species	Pool (n=105)	Riffle (n=102)	Mixed (n=46)	Waterfall (n=23)	Dry (n=77)	Pool (n=72)	Riffle (n=71)	Mixed (n=35)	Waterfall (n=10)	Dry (n=36)
Cascade torrent salamander (Rhyacotriton cascadae)	73	73	39	0	3	6	15	5	0	1
Dunn's salamander (Plethodon dunni)	1	3	6	0	24	10	8	14	0	14
Pacific giant salamander (Dicamptodon tenebrosus)	21	9	0	0	0	1	12	0	0	0
Rough-skinned newt (Taricha granulosa)	1	0	0	0	3	0	0	0	0	0
Tailed frog (Ascaphus truei)	1	0	1	0	0	0	0	0	0	0
Pacific treefrog (Hyla regilla)	1	0	0	0	0	0	0	0	0	0
TOTAL	98	85	46	0	30	17	35	19	0	15

Table 3.6. Amphibian species and numbers of individuals that were found in five habitat types in nine intermittent streams in old growth and six intermittent streams in young forest stands in the central Cascade Range in western Oregon during summer.

	Summer 1995									
	Old growth (n = 272 units)					Young forest (n = 216 units)				
Species	Pool (n=67)	Riffle (n=48)	Mixed (n=43)	Waterfall (n=6)	Dry (n=108)	Pool (n=61)	Riffle (n=26)	Mixed (n=55)	Waterfall (n=2)	Dry (n=72)
Cascade torrent salamander (Rhyacotriton cascadae)	78	93	18	1	0	1	0	0	0	0
Dunn's salamander (Pethodon dunni)	3	6	5	0	54	6	2	9	0	10
Pacific giant salamander (Dicamptodon tenebrosus)	11	2	0	0	1	0	0	0	0	0
Rough-skinned newt (Taricha granulosa)	0	0	0	0	1	0	0	0	0	0
Western redbacked salamander (Plethodon vehiculum)	0	0	0	0	2	0	0	0	0	0
Tailed frog (Ascaphus truei)	0	1	0	0	0	0	0	0	0	0
TOTAL	92	102	23	1	58	7	2	9	0	10

They also were the primary species in pools and mixed units in young forest stands. Pacific giant salamanders were found only in pools and riffles. On average, only one species was found in each habitat type in streams in old-growth and young forest stands during spring and summer. Multiple species occurred in some habitat units (8% of all occupied units), but most units (91%) contained only one species.

Amphibian density and biomass in waterfalls were not analyzed since only one individual was found in this habitat type. Estimated total amphibian densities did not differ between stand types or seasons within dry, mixed, and pool habitat types, but did exhibit a seasonal difference in riffle habitat for both stand types (Figure 3.2). However, graphical data indicated a potential seasonal difference only for riffles in young forest stands. Closer examination of the data revealed that animals were found in riffle habitat in only one stream in young forest stands during the summer. Estimated total amphibian biomass displayed similar trends and did not differ between stand types or seasons within any of the habitat types (Figure 3.3).

Although variance and distributions were unequal among habitat types, graphical representations indicated that amphibian densities and biomass in pools and riffles were generally higher than those in dry and mixed habitats in both stand types and seasons, particularly in old-growth stands (Figure 3.2 and 3.3). Total density and biomass estimates in pools and riffles seemed to exhibit different trends than those in dry and mixed units. Estimated amphibian densities and biomass in dry and mixed habitat were comparable between stand types and seasons, or were slightly reduced in the summer. However, estimated total densities and biomass in pool and riffle habitat appeared to be higher in old growth than in young forest during spring and summer and appeared to exhibit a much larger seasonal effect in the streams in young forest (Figure 3.2 and 3.3).

Amphibian-Habitat Relationships

Amphibian species occupied very small percentages (range 8 - 34%) of total habitat units sampled during spring and summer in both stand types. Since large numbers of unoccupied units, or zero densities, are inappropriate to use in correlations and can highly influence the analyses, I conducted the unit-level correlation analyses

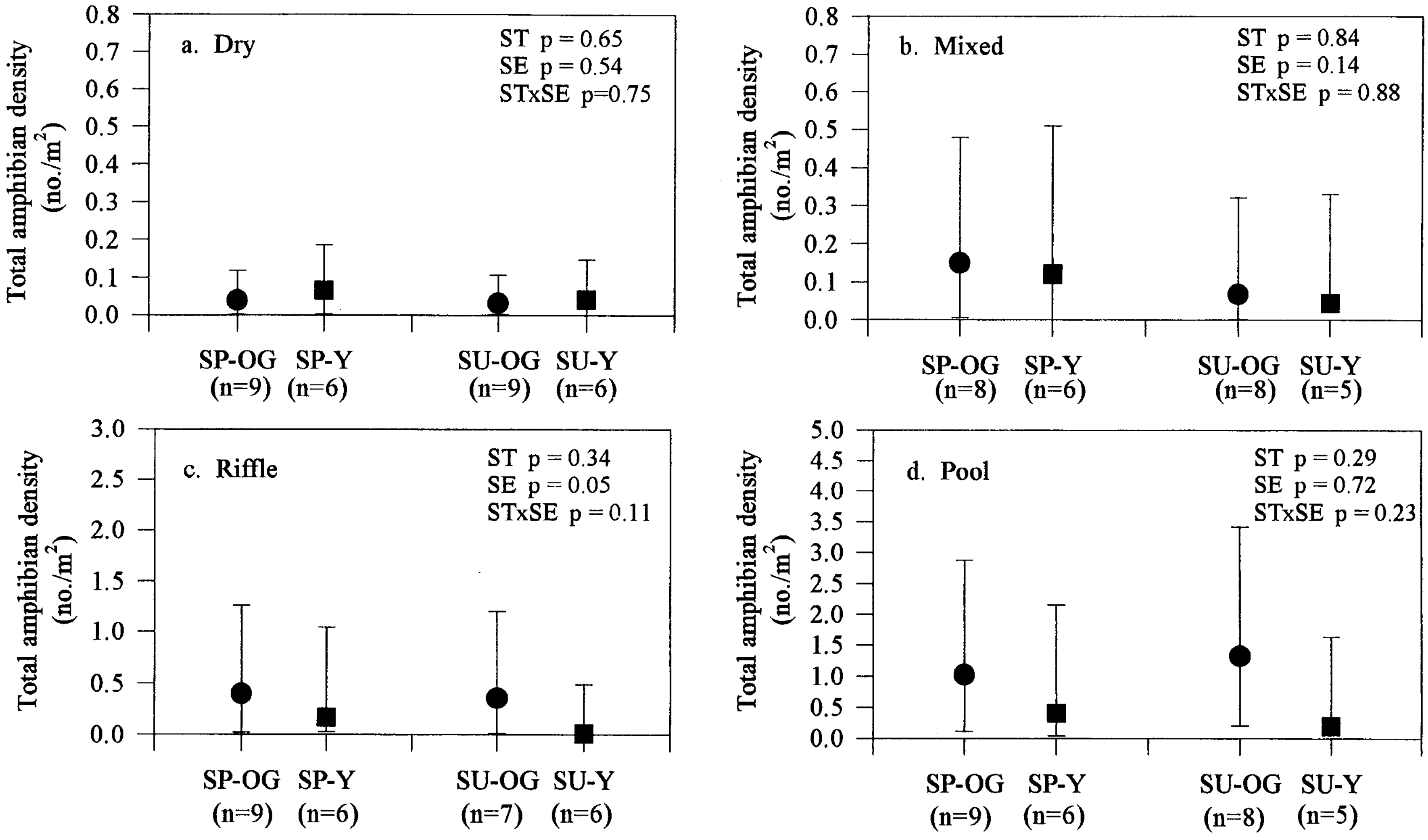

Figure 3.2. Estimated total amphibian densities and 95% CI for (a) dry, (b) mixed, (c) riffle, and (d) pool habitat types in intermittent streams in old-growth (OG) and young (Y) forest stands in the central Cascade Range in western Oregon, during spring (SP) and summer (SU) of 1995. P-values are given for each habitat type: ST = stand, SE = season, and ST x SE = stand-by-season interaction.

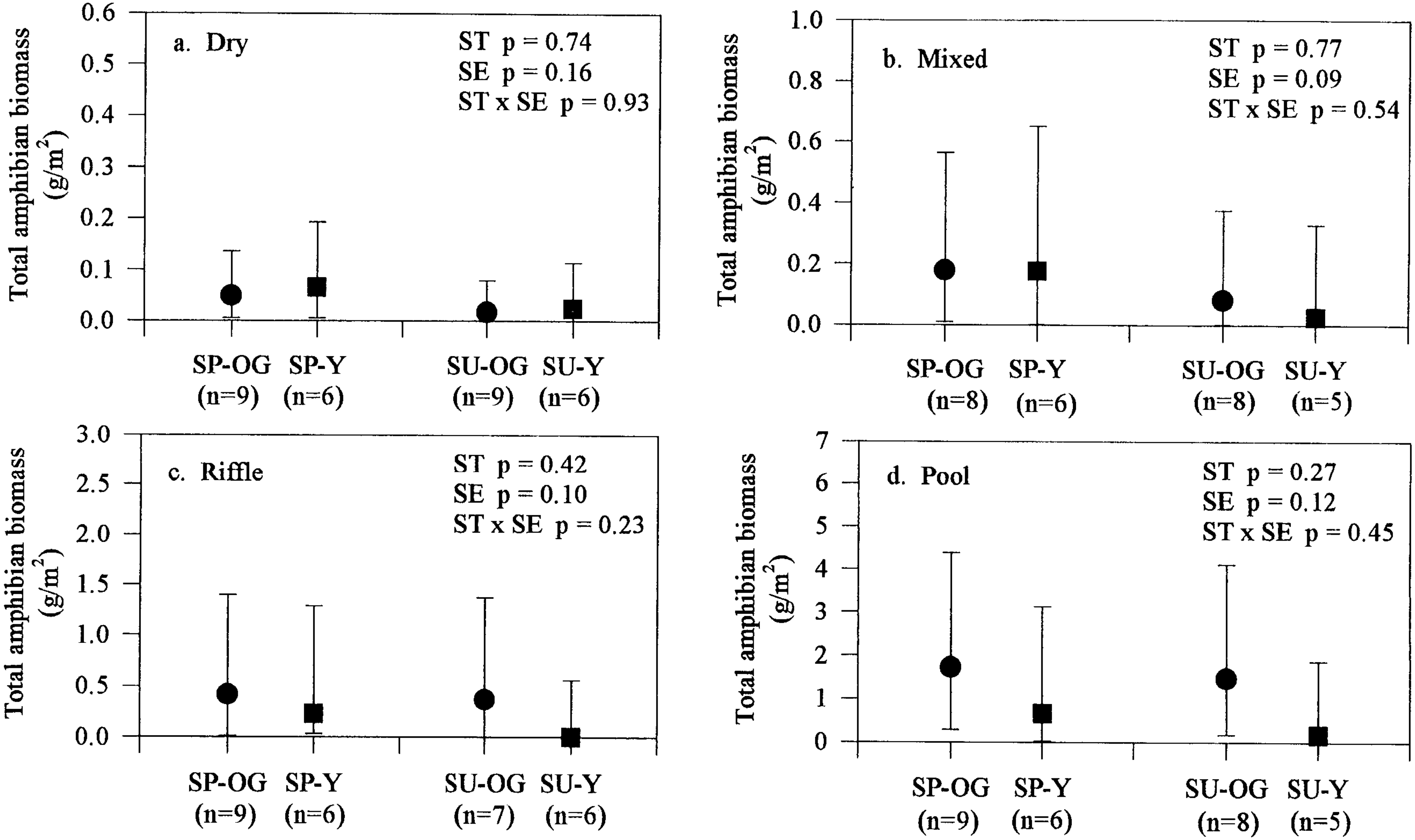

Figure 3.3. Estimated total amphibian biomass and 95% CI for (a) dry, (b) mixed, (c) riffle, and (d) pool habitat types in intermittent streams in old-growth (OG) and young (Y) forest stands in the central Cascade Range in western Oregon, during spring (SP) and summer (SU) of 1995. P-values are given for each habitat type: ST = stand, SE = season, and ST x SE = stand-by-season interaction.

using only the habitat units that contained amphibians. Therefore, these analyses examined potential relationships between amphibian abundance and habitat only within the range of conditions in which individuals occurred; relationships across the full range of available habitat conditions could not be assessed. Spring and summer densities of the Pacific giant salamander and summer densities of the Cascade torrent salamander in the young forest were not included in any correlation analyses since these individuals occupied only one or two units, or no individuals were found. Waterfalls also were excluded from these analyses. Densities of Pacific giant salamanders in old growth were not included in stream-level correlation analyses since this species occupied only three streams in the spring and one stream in the summer.

Relationships between Amphibian Stream Densities and Macrohabitat

Densities of Cascade torrent salamanders in old growth and Dunn's salamanders in both stand types were positively correlated with annual stream flow duration and/or percent surface flow (Table 3.7, Figure 3.4). The streams in which Cascade torrent salamanders occurred were characterized by the longest annual flow durations and highest percentages of stream flow in the summer among those in old growth. Dunn's salamander densities were negatively correlated with total and coniferous overstory cover but appeared to be positively correlated with deciduous overstory cover as well as total understory and ground cover (Table 3.7, Figure 3.4). Cascade torrent salamander abundance in old growth was negatively correlated with coniferous cover and also appeared to be negatively correlated with total overstory cover (Table 3.7, Figure 3.4). Densities of Dunn's salamanders and Cascade torrent salamanders in old growth in the spring were positively correlated with large wood density and stream temperature, respectively (Table 3.7). Both species were negatively correlated with elevation.

Relationships between Amphibian Unit Densities and Microhabitat

Cascade torrent salamander densities in habitat units in old growth were positively correlated with cobbles (i.e., % of unit covered by cobbles) but negatively correlated with smaller and larger substrates (Table 3.8). However, the correlation

Table 3.7. Summary of Spearman rank coefficients (ρ) and p-values for significant correlations between amphibian density and macrohabitat features in nine intermittent streams in old growth (OG) and six streams in young (Y) forest stands in western Oregon.

Species	Stand	Season	Variable	ρ	P
Cascade torrent salamander	OG	Spring	Coniferous cover	-0.80	0.01
			Total overstory cover	-0.60	0.09
			Flow duration	0.74	0.02
			Elevation	-0.63	0.07
	OG	Summer	Coniferous cover	-0.67	0.05
			Total overstory cover	-0.61	0.08
			Percent surface flow	0.95	0.0001
			Flow duration	0.90	0.001
			Elevation	-0.68	0.05
Dunn's salamander	OG	Spring	Coniferous cover	-0.73	0.03
			Deciduous cover	0.63	0.07
			Total overstory cover	-0.84	0.04
			Percent surface flow	0.58	0.10
			Total large wood density	0.69	0.04
			Elevation	-0.67	0.05
	OG	Summer	Total understory cover	0.63	0.07
	Y	Spring	Total overstory cover	-0.84	0.04
	Y	Summer	Percent surface flow	0.83	0.04
			Total understory cover	0.94	0.005
			Total ground cover	0.77	0.07

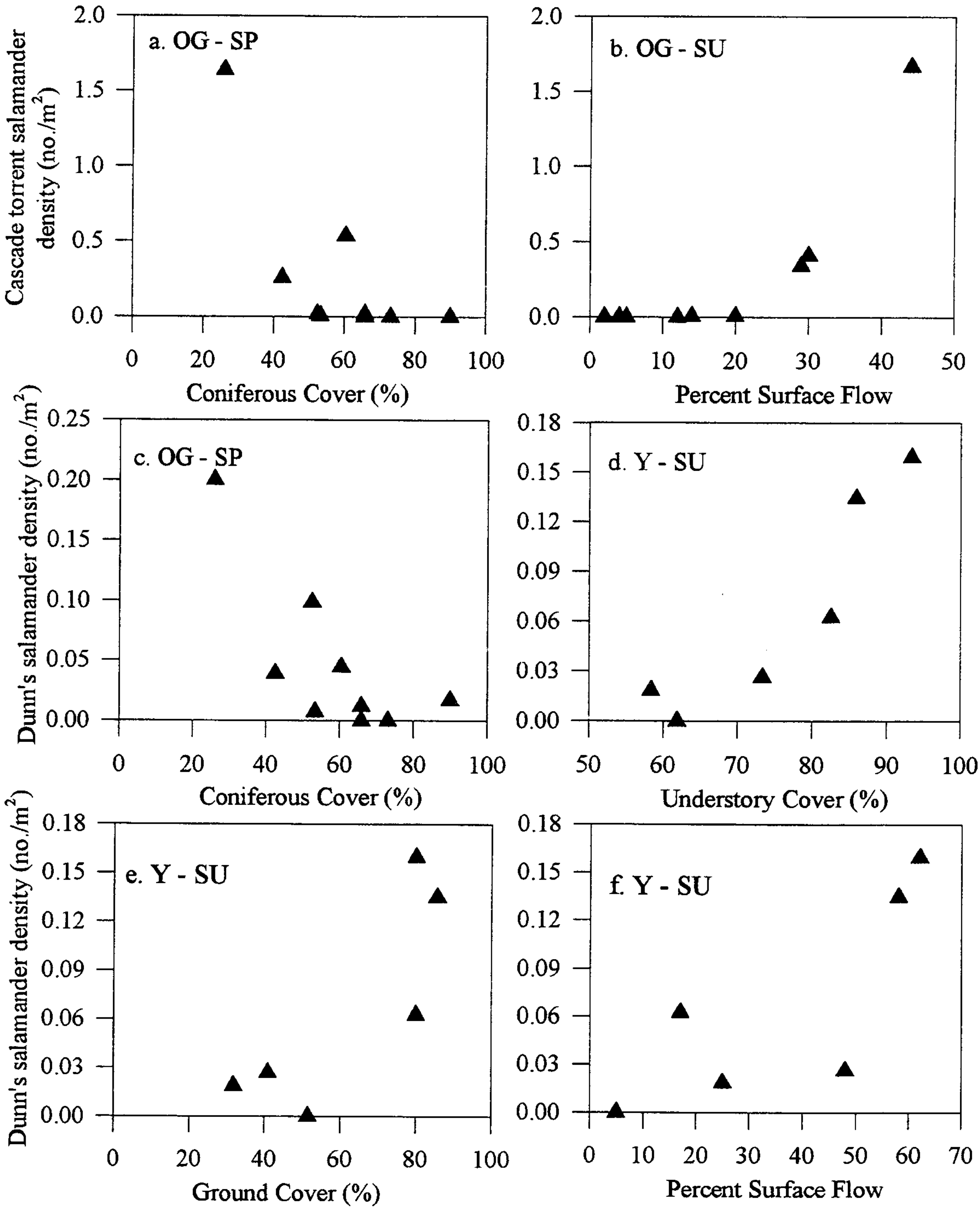

Figure 3.4. Scatterplots of amphibian densities at the stream level versus selected macrohabitat variables that were significantly correlated with densities in intermittent streams in the central Cascade Range in western Oregon: (a) coniferous overstory cover and (b) percent surface flow for Cascade torrent salamanders in old growth (OG) during spring (SP) and summer (SU), respectively; and (c) coniferous overstory, (d) total understory, and (e) total ground cover as well as (f) percent surface flow for Dunn's salamanders in old growth and young forest (Y) during spring and summer.

Table 3.8. Summary of Spearman rank coefficients (ρ), p-values, and sample sizes for significant correlations between amphibian density and microhabitat features in nine intermittent streams in old growth (OG) and six streams in young forest (Y) stands in the central Cascade Range in western Oregon.

Species	Stand	Season	Variable	ρ	P	n
Cascade torrent salamander	OG	Spring	Percent fine sediment	-0.24	0.05	68
			Percent boulder	-0.35	0.003	68
			Small wood cover (%)	-0.48	0.0001	68
			Large wood cover (%)	-0.25	0.04	68
			Mean water depth (cm)	0.41	0.006	67
			Maximum water depth	0.32	0.01	68
	OG	Summer	Percent cobble	0.25	0.05	58
			Percent boulder	-0.31	0.02	58
			Percent bedrock	-0.38	0.003	58
			Small wood cover	-0.36	0.005	58
			Mean water depth	0.48	0.0001	58
			Maximum water depth	0.25	0.06	58
	Y	Spring	Percent gravel	-0.57	0.02	17
			Small wood cover	-0.59	0.01	17
Dunn's salamander	OG	Spring	Maximum water depth	0.54	0.01	23
	OG	Summer	Percent gravel	0.38	0.02	36
			Percent boulder	-0.51	0.002	36
			Large wood cover	-0.58	0.0002	36
			Mean water depth	0.49	0.002	36
			Maximum water depth	0.41	0.01	36
	Y	Summer	Percent gravel	0.53	0.02	19
			Percent pebble	-0.54	0.02	19
			Percent cobble	-0.54	0.02	19
Pacific giant salamander	OG	Summer	Percent boulder	-0.92	0.001	8

coefficient for cobble was fairly small ($\rho = 0.25$), and graphical representation of the data did not show obvious trends (Figure 3.5). Correlation coefficients for fine sediment, boulder, and bedrock also were small (Table 3.8), but habitat units in which Cascade torrent salamanders occurred were characterized by relatively low percentages of these substrates (range 0 - 50%; Figure 3.5). Cascade torrent salamander densities in young forest in the spring were negatively correlated with gravel (Table 3.8). They occurred in habitat units that had high percentages of cobble (range 30 - 70%) and low percentages of fine sediment and sand (range 0 - 10%).

Cascade torrent salamander densities also were negatively correlated with percent cover provided by small and large wood (Table 3.8). They occurred primarily in habitat units that had ≤20% small wood cover (Figure 3.5) and no large wood cover. Torrent salamanders in old growth were positively correlated with mean and maximum water depths (Table 3.8). These correlations remained significant even when dry units were excluded. However, correlation coefficients and graphical representations indicated weak relationships with water depths (Table 3.8, Figure 3.5).

Dunn's salamander densities were positively correlated with gravel in both stand types and negatively correlated with pebbles, cobbles, and boulders (Table 3.8). Scatterplots of the data provided evidence for these relationships (Figure 3.6). Dunn's salamander densities in old growth in the summer were negatively correlated with large wood cover. Most occupied units did not have any large wood cover. Dunn's salamanders also were positively correlated with mean and maximum water depth; however, these correlations were no longer significant when dry habitat units were excluded (Table 3.8).

Pacific giant salamanders were found in only eight habitat units in old growth in the summer, and densities were negatively correlated with percent boulder (Table 3.8). This species occupied habitat units that contained small percentages of boulder (range 0 - 35%). These units also were characterized by small percentages of fine sediment (range 0 - 10%), sand (range 0 - 20%), and gravel (range 5 - 25%), intermediate percentages of cobble (range 20 - 60%), and little wood cover (range 0 - 2% for small wood, 0 - 25% for large wood).

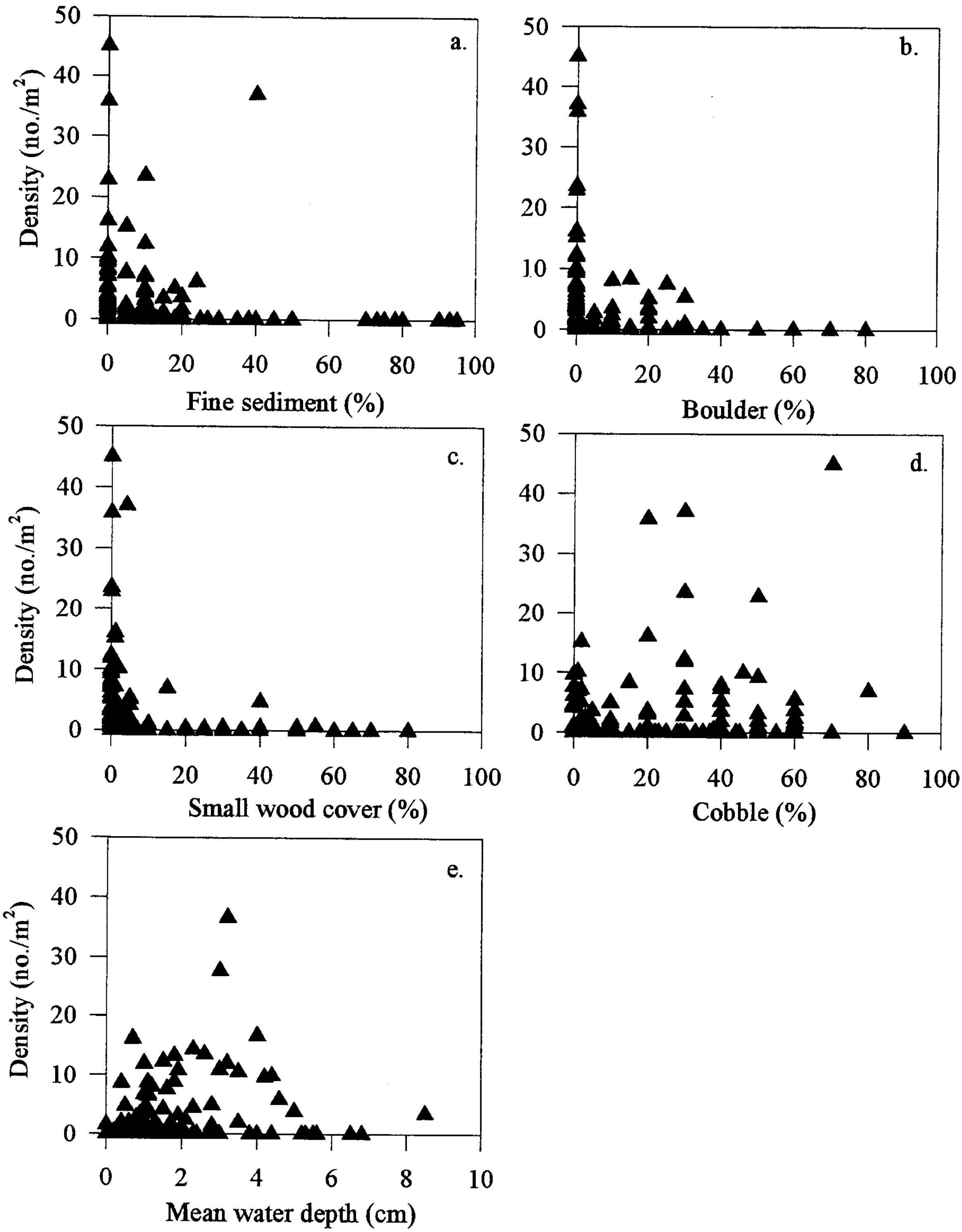

Figure 3.5. Scatterplots of unit densities of Cascade torrent salamanders versus selected microhabitat variables that were significantly correlated with density in intermittent streams in old-growth stands in the central Cascade Range in western Oregon, specifically (a) fine sediment, (b) boulder, and (c) small wood cover in the spring; and (d) cobble and (e) mean water depth in the summer. Plots include data from unoccupied units (i.e., zero densities).

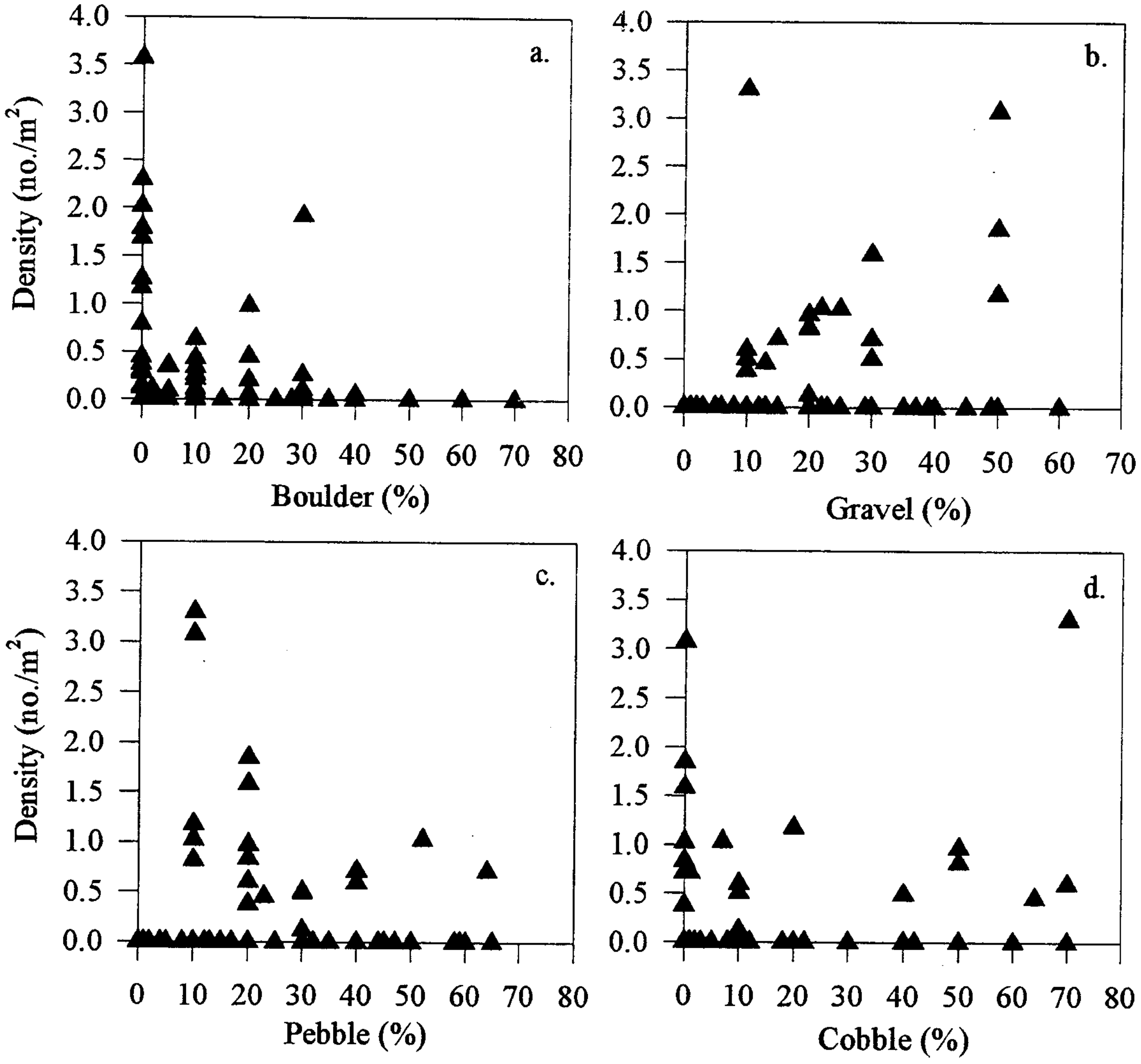

Figure 3.6. Scatterplots of unit densities of Dunn's salamanders versus selected microhabitat variables that were significantly correlated with density in intermittent streams in the central Cascade Range in western Oregon: summer densities versus (a) percent boulder in old growth, and (b) percent gravel, (c) percent pebble, and (d) percent cobble in young forest. Plots include data from unoccupied units (i.e., zero densities).

DISCUSSION

Amphibian Communities in Intermittent Streams

Amphibian communities were comprised of species associated with perennial, headwater streams as well as incidental species typically found in ponds, larger streams, and/or terrestrial habitat. However, studies have found that Pacific giant salamanders and tailed frogs are the most common and abundant amphibians in perennial, headwater streams in uncut forest stands (Corn and Bury 1989, Bury et al. 1991), whereas intermittent stream communities appear to be dominated by Cascade torrent salamanders and Dunn's salamanders. Murphy (1979) reported a longitudinal gradient of vertebrates from first- to third-order streams in which amphibians upstream were replaced by fish downstream. A similar longitudinal gradient may exist among aquatic amphibians. Such a gradient could be attributed to species-specific habitat associations, which may be due to morphological and/or physiological constraints. Due to their small size, Cascade torrent salamanders usually occur in shallow, slow-moving water and seeps (Nussbaum et al. 1983, Welsh and Lind 1996), which are characteristic of intermittent streams. Dunn's salamanders also occur in seeps and along stream banks (Nussbaum et al. 1983, Bury et al. 1991), and are able to use the shallow water and dry portions of intermittent streams. In contrast, Pacific giant salamanders and tailed frogs frequently inhabit deeper pools and riffles (Nussbaum et al. 1983, Walls et al. 1992, Blaustein et al. 1995), which are usually found in larger, perennial, headwater streams.

Amphibian species also may be using different parts of the stream network as a competition and/or predation avoidance strategy. Large larval Pacific giant salamanders feed on fish, tadpoles, and smaller giant salamander larvae (Nussbaum et al. 1983), and most likely prey on other small aquatic amphibian species as well. Thus, Cascade torrent salamanders and Dunn's salamanders may use shallow water characteristic of intermittent and smaller, headwater streams to reduce risk of predation by Pacific giant salamanders. For example, Pacific giant salamanders were found with Cascade torrent salamanders and/or Dunn's salamanders in only 9 of 21 habitat units that contained more than 1 amphibian species. Also, these Pacific giant salamanders were generally comparable in size to Cascade torrent and Dunn's salamander individuals in these units and may not have been of sufficient size to prey upon these other species.

Amphibian densities and biomass in the intermittent streams I studied are lower than most estimates that have been reported in perennial streams in the Pacific Northwest (Nussbaum and Tait 1977, Bury 1988, Bury and Corn 1988a, Bury et al. 1991). However, densities and biomass for Cascade torrent salamanders and Dunn's salamanders are comparable to those that have been documented in perennial streams in the central Oregon Cascades (Bury et al. 1991). I may have recorded such low amphibian densities and biomass because my study streams represent fairly harsh environments and probably the extreme upper ends of the channel network, particularly in terms of high spatial intermittency. Although density and biomass estimates at the stream level were relatively low, amphibian communities were comprised predominantly of larvae and juveniles which suggest that intermittent streams may function as important larval rearing habitat, particularly for the Cascade torrent salamander and Dunn's salamander. It is unclear whether these larvae and juveniles hatched from eggs that were laid in or near these streams, or whether they migrated from downstream or upland areas. Surprisingly few adults, especially of Cascade torrent salamanders, were found in these streams. Longitudinal gradients of age or size classes within specific amphibian species also may exist in watersheds. Intermittent streams may provide suitable habitat for small larvae and juveniles in terms of their low flow volumes and velocities, whereas larger stream channels with higher flows may be more suitable for larger larvae or juveniles and adults. Amphibian larvae and juveniles also may inhabit intermittent streams since they may be characterized by few, if any, predators such as fish and large, juvenile or adult, Pacific giant salamanders.

Habitat Relationships

Correlations between amphibian density and macrohabitat features generated more distinct trends and relationships than correlations with microhabitat features. Positive relationships between Cascade torrent salamander and Dunn's salamander densities and percent surface flow in the summer and/or flow duration indicate these species' association with water. Negative correlations with riparian overstory, particularly coniferous overstory cover, were surprising for the Cascade torrent salamander, since this species has been positively associated with total and coniferous cover (Welsh and Lind 1996). The stream in old growth that contained the highest density of Cascade torrent salamanders had the lowest percentages of total and coniferous overstory cover. Since primary production is generally low in headwater streams, intermediate levels of shade may lead to increased solar input, higher levels of primary productivity, a larger food base, and, subsequently, higher amphibian densities. Greater densities of Cascade torrent salamanders and Dunn's salamanders at lower elevations in old growth may be correlated with their relationships with coniferous overstory cover, which tends to increase with elevation (Minore and Weatherly 1994). Positive correlations between Dunn's salamander densities and deciduous overstory cover as well as total understory and ground cover also may simply be a result of this species' negative correlations with total and coniferous overstory cover. It is possible that total understory and ground cover may influence microclimatic conditions with which Dunn's salamanders, which tend to occur along stream banks, may be associated.

Correlation results suggest that amphibian species may be associated with intermediate-sized substrates. In the units in which they occurred, Cascade torrent salamanders were apparently more abundant in units with higher percentages of cobble and lower percentages of fine sediment, gravel, boulder, and bedrock. Corn and Bury (1989) found that the mean size of rocks used for cover by southern torrent salamanders (Rhyacotriton variegatus) in a study in the Oregon Coast Range was cobble-sized rocks. Welsh and Lind (1996) found that high percentages of cobble and gravel, together, served as a good predictor of southern torrent salamander abundance, and that percent sand, a finer substrate, was negatively associated with abundance of this species in northwestern California. Correlation results indicate that Dunn's salamanders were more abundant in units with greater percentages of gravel and smaller percentages of pebble, cobble, and boulder. All three species occurred in habitat units that consistently had low percentages of fine sediment as well as boulders and bedrock. Coarse substrates are believed to provide interstitial crevices for foraging and cover from potential predators

(Welsh and Lind 1996). Fine sediments and sand reduce the availability of these interstitial spaces (Bury and Corn 1988a, Corn and Bury 1989). However, Welsh and Lind (1996) found that southern torrent salamanders were positively associated with fine sediment and proposed that this substrate material may support invertebrate prey for this species. Also, the size of rocks used for cover may be commensurate with species size (Bury et al. 1991), which may explain why amphibians tended to be more abundant in units with more cobble and/or gravel but not boulders.

Correlations between Cascade torrent salamander densities and water depth further indicate this species' close association with water. Cascade torrent salamanders were positively correlated with water depth and were found mainly in pools and riffles compared to other habitat types. Positive relationships with water depth may represent a possible method for selecting units that have greater likelihoods of containing residual water during the dry season.

Amphibian densities may have been negatively correlated with small and large wood cover for several reasons. Small wood was predominantly in the form of twigs, branches, and small slabs of bark, which may not provide as effective cover as substrate. Small pieces or shreds of bark from well-decayed bark slabs in habitat units also may prevent or limit accessibility to crevice spaces and other hiding cover. Species may have been negatively correlated or not correlated with large wood cover since overall, little was available in the sampled units. Ability to detect animals also may have been reduced in units covered with large logs or slabs of bark.

Correlation results provide insight into general amphibian-habitat relationships or trends, but additional analyses are needed for a more accurate assessment of specific habitat relationships. The correlation results and habitat relationships only apply to habitat units in which animals were found. Correlation analyses did not account for habitat conditions in the other units. Also, the correlation analyses examined amphibian relationships with only one variable at a time. Accurate assessment of amphibian habitat selection and associations must take into account all available habitat as well as responses to multiple variables at the same time.

Comparisons between Old-Growth and Young Forest

Streams in young forest were characterized by lower total species richness, a shift in species composition, and a more pronounced seasonal effect on total amphibian density and biomass. Pre-harvest data on stream conditions and amphibian communities are not available to determine whether differences between old-growth and young forest stands should be attributed to timber harvesting or to natural stand or stream dynamics. Cascade torrent salamanders were the dominant species in the streams in old growth, whereas Dunn's salamanders were dominant in the streams in young forest. Corn and Bury (1989) found that southern torrent salamanders and Dunn's salamanders as well as Pacific giant salamanders and tailed frogs occurred more frequently and in higher densities in first-, second- and third-order streams in uncut forest stands (60 - 400 yrs) than in logged forest stands (14 - 40 yrs) in the Oregon Coast Range. Dunn's salamanders may be associated with habitat features, such as percent gravel and total understory cover, that allow them to use intermittent streams in young forests. Results from the correlation analyses suggest that Cascade torrent salamanders may have occurred less frequently in streams in young forest due to lower percentages of cobbles and higher percentages of fine sediment. The one stream in young forest in which this species did occur may represent an outlier since it was upstream of a stream reach in old growth and was characterized by substrate composition more similar to those in old growth than in young forest. However, it is unclear whether Cascade torrent salamanders in this stream reach occurred there before it was logged and have persisted since then due to favorable habitat conditions, or whether they recolonized this stream reach from the downstream old-growth section, which contained an extremely high concentration of Cascade torrent salamanders. Corn and Bury (1989) also found that presence of uncut timber upstream can influence the occurrence and persistence of amphibians in streams in harvested areas. There is anecdotal evidence that Cascade torrent salamanders generally occur above approximately 305 m (1000 ft) and below 914 m (3000 ft) (Applegarth pers. comm. in RIEC 1997). Thus, Cascade torrent salamanders may have occurred less frequently and in lower densities in the streams in young forest since most (4 of 6) were located at or below their lower elevational limit

(244 and 305 m). Torrent salamander densities in old growth also appear to follow this elevational gradient, in which the highest densities occurred in the streams located between approximately 500 to 700 m and the lowest densities were recorded in the streams that were located near or above the upper elevational limit.

The most common trend observed and most significant result was that intermittent streams in old-growth stands were able to maintain comparable amphibian densities and biomass between spring and summer whereas communities in young forest stands exhibited reduced densities and biomass in the summer. Variance may have been slightly unequal for density and biomass comparisons, particularly between old-growth and young forest estimates in the summer; however, the data still seem to demonstrate a stronger seasonal effect in the young forest. Cascade torrent salamanders and Pacific giant salamanders occurred in much lower numbers or were absent from the streams in young forest in the summer. This may have occurred due to higher summer stream temperatures in conjunction with little appropriate substrate cover in the streams in young forest. Densities and biomass of Dunn's salamanders, however, did not differ between old-growth and young forest stands during spring or summer. Finally, amphibian communities were highly variable. Density and biomass differed significantly among streams within a stand type as well as between stand types.

Comparisons between Wet and Dry Seasons

Similar species richness, densities and biomass at the stream and habitat levels were documented during spring and summer, particularly in old growth, despite significantly reduced summer flows. These results suggest that amphibians can use intermittent streams during periods of reduced flow. They may utilize "drought avoidance strategies" similar to those used by some invertebrates in intermittent streams, such as using residual water units, hiding under rocks or leaf litter, or burrowing into the subsurface (Delucchi and Peckarsky 1989). Cascade torrent salamanders were able to persist in small, relatively isolated pools and maintain similar densities in streams in old growth during the summer. Nussbaum and Tait (1977) found that Cascade torrent salamanders tended to stay in the same stream sections or move only short distances upstream. Dunn's salamanders were found under rocks or wood. Although individuals were not marked, often the same species or similar densities were found in specific streams or habitat units, suggesting that some of the same individuals were found during spring and summer.

Conclusions and Management Implications

Intermittent, headwater streams can provide habitat for a diversity of amphibian species during wet and dry seasons. Amphibian communities in intermittent streams in old-growth and young forest stands differed in species composition, total species richness, and total density and biomass during the dry season as well as within and among habitat types. Some of these differences may be attributed to species-specific habitat associations. Amphibians were able to persist in streams during the dry season by adopting drought avoidance strategies. Similar amphibian communities, habitat associations, and timber harvesting impacts have been documented in perennial, headwater streams. Sampling protocols for intermittent streams need to account for relatively low densities and differential use of habitat types.

Effective protection and management of intermittent streams require more information on their specific role(s) as amphibian habitat and the relative importance and influence of various environmental attributes on amphibian community structure. Although low densities were documented in this study, the predominance of larvae and juveniles suggest that intermittent streams may provide important breeding and/or larval rearing habitat. However, it also may be possible that amphibian populations in these streams represent "sink" rather than "source" populations. Intermittent streams examined in this study may represent particularly harsh environments given their high degree of spatial intermittency. Correlations between amphibian densities and flow duration and/or percent surface flow suggest that intermittent streams that maintain higher percentages of stream flow over longer periods of time may be characterized by richer amphibian communities (e.g., greater densities and/or biomass). Therefore, different types of or conditions in intermittent streams may warrant different levels of protection and management.

CHAPTER 4
SUMMARY

Ecology of Intermittent, Headwater Streams

Vannote et al. (1980) stated that, for drainage networks, "headwater streams represent the maximum interface with the landscape." Intermittent streams are complex systems that appear to represent such an interface between aquatic and terrestrial ecosystems. The occurrence of intermittent streams and the duration and pattern (i.e., volume and timing) of their stream flow are largely controlled by climatic conditions and landscape features, such as topography, geology, and soil characteristics. Flow duration and pattern as well as landscape features determine the composition and structure of streamside vegetation, which, in turn, influence water temperature and the input of woody debris and other organic material. Habitat conditions in intermittent streams greatly affect the physical attributes of downstream reaches (Beschta and Platts 1986).

Williams and Hynes (1977) claimed that intermittent streams exhibit greater variations in both physical and chemical parameters than those found in perennial streams. The most significant variation is the drastic reduction in stream flow between wet and dry seasons, from 100% of stream length in the fall and winter to less than 10% of stream length in the summer. This can lead to changes in the distribution and availability of habitat types, from pools and riffles during flow conditions to seeps, isolated pools, and dry habitat during drought conditions. Water temperatures in some streams exhibited relatively large ranges between flow and drought conditions. Studies also have documented elevated pH and dissolved oxygen levels in isolated habitat units, particularly pools, in the summer (Williams and Hynes 1977).

Macroinvertebrate communities in intermittent streams are primarily determined by flow duration, summer-drought conditions, and microhabitat pattern (Dieterich 1992). The amphibian species in the intermittent streams I studied demonstrated strong associations with water or moisture and appear to be constrained in ways similar to invertebrate communities. However, despite drought conditions and large fluctuations in physico-chemical parameters, macroinvertebrates, fish and amphibians are able to inhabit intermittent streams by adopting a number of survival or drought avoidance strategies

(Stehr and Branson 1938, Williams and Hynes 1977, Williams and Coad 1979, Towns 1985, Boulton and Suter 1986, Dieterich 1992, Meador and Matthews 1992, Hubble 1994, Holomuzki 1995). Strategies for invertebrate species include using residual pools, burrowing into the subsurface, hiding under rocks or leaf litter, and migrating downstream (Williams and Hynes 1977). Amphibian species examined in this study appear to exhibit similar drought avoidance strategies. Flow and habitat conditions in intermittent streams may be highly variable between wet and dry seasons within a given year but may be fairly consistent among years, which may influence community structure.

Intermittent streams may represent favorable habitat for species that can survive associated flow and drought conditions (Stehr and Branson 1938, Williams and Coad 1979, Dieterich 1992). Since these streams represent unsuitable habitat for many species, they may be characterized by abundant food supplies and reduced predation or competition among species that can occur in these systems (Stehr and Branson 1938, Williams and Coad 1979). The River Continuum Concept (Vannote et al. 1980) states that "from headwaters to mouth, the physical variables within a river system represent a continuous gradient of physical conditions ... resulting in a continuum of biotic adjustments." Results from my study suggest longitudinal gradients among aquatic amphibian species as well as among age or size classes within a particular species may exist along stream networks. A longitudinal gradient also may exist among amphibians and fish, with Cascade torrent salamanders and Dunn's salamanders as the dominant vertebrate predators in intermittent streams, shifting to Pacific giant salamanders and fish in perennial streams. These gradients may result from species-specific habitat associations as well as biotic interactions such as competition and predation. Amphibian species also appear to be using or selecting different habitat and partitioning resources, as well as exhibiting different habitat selection strategies within intermittent streams.

Long-term Effects of Timber Harvesting

Intermittent streams in old-growth and young forest stands exhibited differences in their physical and hydrological characteristics. Most of these differences have been documented in previous studies on perennial, headwater streams and have been attributed to impacts of timber harvesting. However, habitat conditions in these streams were most likely the result of disturbance as well as specific site attributes. Therefore, given the observational nature of this study, lack of pre-harvest data, and discrepancies in physiographic and geological factors, differences between the streams in old growth and young forest could not be definitively attributed to timber harvesting. Current habitat conditions suggest that substrate composition, large wood recruitment, and stream temperature in the study streams may be particularly susceptible to timber harvest impacts. Also, streamside plant communities are the result of disturbance and re-establishment, depending upon site availability, differential species availability, and differential species performance. Thus, timber harvesting also may have long-term impacts on the successional development of streamside vegetation.

Amphibian communities also differed between intermittent streams in old-growth and young forest stands. Amphibian communities in intermittent streams may be structured by disturbance and habitat. Peckarsky (1983) and Poff and Ward (1989) suggest that intermittent streams may represent harsh conditions, and that stream communities may be structured primarily by physical and chemical features or abiotic processes. Therefore, differences in amphibian communities between old growth and young forest may be attributed to microhabitat features, such as substrate. Elevation also may influence species' occurrences and densities. Moisture, temperature, and an amphibian's tolerances of these two environmental conditions are the primary factors determining amphibian distributions (Duellman and Trueb 1994). Consequently, community structure and most habitat associations may based on, or related to, these physiological constraints. Positive correlations between amphibian densities and flow duration, percent surface flow, and water depth in my study demonstrate these amphibian species' association with water.

Implications for Management and Research

Results of my study suggest that intermittent streams may warrant protection for their potential effects on downstream habitat and water quality and for their role as habitat for aquatic species, such as amphibians. In general, streamside vegetation should be maintained along intermittent channels to provide shade protection for water temperature regulation and sources of large woody debris and other allochthonous energy input, to help stabilize slopes, and to minimize erosion and sedimentation. At a minimum, intermittent stream channels should receive protection from physical disturbance during timber harvesting operations. Riparian Reserves prescribed by the Northwest Forest Plan should provide adequate protection for intermittent streams on federal lands. However, intermittent streams and associated amphibian communities are highly variable and dynamic. Effective design and management of Riparian Reserves should acknowledge and characterize individual site conditions and vary accordingly. For example, streams with steep side slopes may be characterized by very little riparian vegetation but may require wide buffers for slope stability to minimize risk of debris flows. Low-gradient streams in young, second-growth forest stands at low elevations may be characterized by warmer stream temperatures, increased sedimentation, and minimal conifer regeneration due to intense understory shrub competition. These streams may require more management protection, such as wider buffers to maintain more vegetation for shade protection and supply of large wood. The use of alternative silvicultural techniques, such as thinning, which do not remove all overstory vegetation in stands and along streams may provide sufficient amounts of shade and large wood such that buffer size may be reduced or minimized. Streams in mature stands with large conifers also may receive sufficient protection from vegetation remaining after thinning. Protection of intermittent streams for amphibian communities should focus on minimizing physical alterations to the channel, targeting streams with longer flow durations, and maintaining connections among streams with amphibian populations.

This study represents a first attempt at characterizing intermittent stream systems and how they have been impacted by timber harvesting. Impacts of timber harvesting on intermittent streams need to be evaluated experimentally, controlling for differences in site factors, particularly elevation. However, historical patterns of timber harvesting may make it difficult to find comparable or paired sites. Short- and long-term impacts of timber harvesting need to be further investigated with larger sample sizes and on a larger geographic scale. The effectiveness of different types and sizes of buffer strips also need to be evaluated experimentally (e.g., see Vesely 1995). The ability of amphibian populations to persist in streams after timber harvesting and the importance of connectivity with potential source areas also need to be addressed. Finally, the role of intermittent streams in watersheds or in the overall landscape as well as its role as habitat for aquatic organisms, such as amphibians, need to be investigated further.

Intermittent, headwater streams have largely been ignored because they have had little economic or recreational value. However, data from my study and other studies on intermittent streams suggest that these streams may provide important resources for on-site as well as downstream aquatic habitat. During flow conditions, these streams should provide similar functions as perennial, headwater streams. Reduced flow and drought conditions can lead to highly variable and relatively harsh stream conditions, but also may result in a range of environments which may provide suitable and unique habitat for organisms. Therefore, particularly from a watershed perspective, intermittent streams merit consideration in conservation and management efforts as well as further investigation.

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APPENDIX

Appendix A. List of plant species found in or associated with streamside areas, permanent water, or moist soil conditions that were found along intermittent streams in old-growth and young forest stands in the central Cascade Range in western Oregon. These associations were based on information provided by Campbell and Franklin (1979), Steinblums et al. (1984), and Pojar and MacKinnon (1994).

Trees:	Red alder (Alnus rubra)
	Pacific dogwood (Cornus nuttallii)
	Bitter cherry (Prunus emarginata)
	Western redcedar (Thuja plicata)
Shrubs:	Red huckleberry (Vaccinium parvifolium)
	Twinflower (Linnaea borealis)
	Salmonberry (Rubus spectabilis)
	Thimbleberry (Rubus parviflorus)
	Stink currant (Ribes bracteosum)
	Vine maple (Acer circinatum)
	Nootka rose (Rosa nutkana)
Non-woody vegetation:	Coast boykinia (Boykinia elata)
	Piggy-back plant (Tolmiea menziesii)
	Fireweed (Epilobium angustifolium)
	Northern starflower (Triemtalis latifolia)
	Pacific waterleaf (Hydrophyllum tenuipes)
	Cooley's hedge-Nettle (Stachys cooleyae)
	Redwood sorrel (Oxalis oregana)
	Small bedstraw (Galium trifidum)
	Skunk cabbage (Lysichiton americanum)
	Deer fern (Blechnum spicant)
	Sword fern (Polystichum munitum)
	Lady fern (Athyruim filix-femina)
	Maidenhair fern (Adiantum pedatum)
	Vanilla-Leaf (Achlys triphylla)
	Three-leaved goldthread (Coptis trifolia)