AN ABSTRACT OF THE THESIS OF

Amie M. Shovlain for the degree of Master of Science in Forest Resources
presented on June 9, 2005.

Title: Oregon Spotted Frog (*Rana pretiosa*) Habitat Use and Herbage (or Biomass) Removal from Grazing at Jack Creek, Klamath County, Oregon

Abstract approved:

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William J. Ripple   Deanna H. Olson

We evaluated the effects of herbage removal from livestock grazing on Oregon spotted frog (*Rana pretiosa*) habitat use by monitoring frog locations in grazed and matched ungrazed treatments across a range of grazing intensities at Jack Creek, Fremont-Winema National Forest, Oregon. Thirteen cattle exclosures were deployed along Jack Creek in the summer of 2003. Movements were monitored using radio telemetry on adult frogs (N = 24 frogs) within treatments sites from July through October 2004. Individual frogs were located 1 to 28 times ($\bar{x}$ = 11.7) and were tracked from 1 to 74 days $\bar{x}$ = 35.8 days). A 10-pin point intercept frame was used to estimate relative differences in removed vegetation cover. This difference between ungrazed treatments and paired grazed controls was used as a measure of grazing pressure at treatment sites, and examined in relation to frog habitat preference. Pin measurements ranged from an average monthly difference of -1.2 to 2.97 pin hits between an exclosure and its control. As pin differences increased by one unit, the odds of finding a frog in the exclosure increased by a factor of 1.62 ($F_{1,4}$ = 3.90, p = 0.05) with an approximate 95% confidence interval of 1.00 to 2.74 . Based on the proportion of time frogs

spent inside exclosures, there was evidence that as grazing pressure increased, frogs preferred ungrazed livestock exclosures.

Secondary objectives of this study were to describe migration routes and identify overwintering sites of the *R. pretiosa* population on Jack Creek. From August to mid-December 2003, frogs (N = 36) were tracked from 5 to 92 days ($\bar{x}$ = 49.5 days) and located 2 to 39 times ($\bar{x}$ = 23.2 times). In mid-October, individuals were located in sheltered areas along the creek such as willow root complexes and abandoned beaver runs. Frogs also were found in deep (130 cm) pools associated with active springs and individuals in these areas were active within the pools under 5 cm of ice.

Using mark-recapture techniques and deployment of cattle exclosures, we examined 1) frog migration and 2) grazing effects on frog habitat use for the Jack Creek *R. pretiosa* population in 2003-2004. Ultimately, a more complete understanding of the natural history of this species and how anthropogenic activities affect amphibians such as *R. pretiosa* will aid managers in mitigating potential adverse affects, especially in riparian systems, and contribute to recovery and restoration strategies.

Oregon Spotted Frog (*Rana pretiosa*) Habitat Use and Herbage (or Biomass) Removal from Grazing at Jack Creek, Klamath County, Oregon

by
Amie M. Shovlain

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CONTRIBUTION OF AUTHORS

Dr. Deanna H. Olson was involved with the design and writing of Chapter two. Dr. Gregg M. Riegel provided field assistance for the biomass sampling during the pilot project.

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CHAPTER 1
INTRODUCTION

Substantial attention has been given to global amphibian declines (Hayes and Jennings, 1986; Blaustein and Wake, 1990; Wake, 1991; Corn, 2000; Semlitsch, 2002; Green, 2003). Contributing factors to losses include habitat degradation, introduction of non-native species, disease, environmental contaminants, and atmospheric conditions (Alford and Richards, 1999; Blaustein and Kiesecker, 2002). Most declines are documented for pond-breeding species; ranids are one of four families that significantly contribute to the total number of rapidly declining species (Stuart et al., 2004).

These global trends are reflected by patterns emerging in the western United States. Ranid declines have been documented in closely related sister-species groups such as the California red-legged frog (*Rana aurora draytonii*), Cascades frog (*R. cascadae*), Columbia spotted frog (*R. luteiventris*), Foothill yellow-legged frog (*R. boylii*), Oregon spotted frog (*R. pretiosa*), Mountain yellow-legged frog (*R. muscosa*), Northern leopard frog (*R. pipiens*), and Northern red-legged frog (*R. aurora aurora*) (Corn and Fogleman, 1984; Hayes and Jennings, 1986; Blaustein and Wake, 1990; Bradford, 1991; Fellers and Drost, 1993; Bradford et al., 1994; Stebbins and Cohen, 1995; Hayes et al., 1997; McAllister and Leonard, 1997; Knapp and Mathews, 2000; Davidson et al., 2001).

There is considerable concern over the declining populations of *R. pretiosa* in the Pacific Northwest (McAllister and Leonard, 1997; Hayes et al., 1997; Corn, 2000). *R. pretiosa* is an endemic species, historically ranging from southwestern British Columbia to northeast California (McAllister and Leonard, 1997). Population declines have reduced the *R. pretiosa* range by 79% to 90% (Hayes et al., 1997; McAllister and Leonard, 1997). Of 35 total known populations of *R. pretiosa*, 29 are from Oregon where the species is listed as a State "Critical" species. The species may be listing as threatened or endangered is pending if immediate conservation actions are not taken.

A remnant population of *R. pretiosa* was first documented on Jack Creek (Chemult Ranger District, Fremont-Winema National Forest, Oregon) in the spring of 1996 (Hayes, 1998). This population is geographically isolated in that the closest population within the Klamath watershed is approximately 30 kilometers downstream on the Williamson River and aquatic connectivity via the stream network between the populations often goes subsurface under the porous pumice. The Klamath Basin group of *R. pretiosa* is genetically the most distinct of four identified groups across its range (Blouin, 2000) making the Jack Creek population genetically isolated. Both geographic and genetic isolation heighten the risk of local extinction and natural recolonization is unlikely because these frogs appear typical of many amphibians regarding physiological constraints, poor dispersal abilities, and high site fidelity (Blaustein et al., 1994a).

In addition to geographic and genetic isolation, the following have been identified by the Chemult Ranger District as threats most pertinent to the Jack Creek population: water quality deterioration; climatic drought cycles; vulnerability to pathogens; severely altered habitat due to livestock grazing; absence of beaver to create new suitable habitats; and succession of marsh and meadow habitats to lodgepole pine (*Pinus contorta* var. *murrayana*) as a result of fire exclusion (USDA, 2004). As lodgepole pine increases in dominance, the water table continues to lower due to leaf area of this evergreen tree (versus deciduous shrubs and herbaceous species) and transpiration rates limited only by near-freezing soil temperatures. Many of these perceived threats to *R. pretiosa* at Jack Creek are related to their habitat conditions. According to the Jack Creek Watershed Assessment (2004), soil compaction is common, erosion rates have increased, water quality tests exceed state standards for coliform bacteria, and overall channel condition is considered to be in a downward trend.

Recent studies have revealed adverse affects to other ranids from abiotic agents such as pesticides, decreased pH levels, increased nitrate levels, and UV-B radiation (Blaustein et al., 1994b; Marco and Blaustein, 1999; Marco et al., 1999; Hatch and Blaustein 2000; Davidson et al., 2001). Other studies suggest vulnerability to biotic factors such as pathogens (Kiesecker and Blaustein 1997a), introduced bullfrogs (*Rana catesbeiana*) (Nussbaum et al., 1983; Kiesecker and Blaustein, 1997b; Kiesecker et al., 2001a; Pearl et al., 2004), introduced exotic fish (Knapp et al., 2001; Knapp and Matthews 2000; Pilliod and Peterson, 2001; Bradford, 1989; Bradford et al., 1993) and the potential of exotics transferring pathogens to amphibians (Kiesecker et al., 2001b). These environmental stressors, both abiotic and biotic, are not thought to be mutually exclusive and interactions among them may affect amphibians at the population level (Alford and Richards, 1999; Blaustein and Kiesecker, 2002; Blaustein et al., 2003). These factors remain understudied for *R. pretiosa*, although introduced fishes and bullfrogs are a concern at other sites (Hayes et al., 1997), embryos show some resilience to ambient UV-B radiation (Blaustein et al., 1999), and nitrates and nitrite have been shown to negatively affect *R. pretiosa* in a lab experiment (Hatch and Blaustein, 2000). Mass mortality episodes at nearby populations of other amphibian species have been tied to water mold infections such as *Saprolegnia ferax*, (Blaustein et al., 1994c), hydrological changes (McAllister and Leonard, 1997; Adams, 1999; Kiesecker et al., 2001a) and UV-B radiation (Blaustein et al., 1998, 2001). Understanding the relative roles of these various potential threats is critical to conservation of the Jack Creek population.

The USDA Forest Service has been proactive in providing a greater understanding of the frog population ecology on Jack Creek. From 1997 to 2002, the Chemult Ranger District surveyed the Jack Creek population in a mark-recapture study to determine rough population estimates, growth rates, and summer habitat use information. Egg mass surveys also have been conducted since 1999 to determine oviposition sites and numbers of breeding females.

Population estimates from the mark-recapture study suggest that this population is experiencing a downward trend (USDA, 2004). These studies have identified livestock grazing to be a potential risk factor of immediate concern. This anthropogenic disturbance could be mitigated if it were determined to have adverse effects on this species.

Livestock grazing alters ecologic function and is a prominent management activity in the American west (Fleischner, 1994; Trimble and Mendel; 1995) that often coincides with frog habitats. Highly aquatic amphibian species, such as *R. pretiosa* (Dumas, 1966), could be affected by grazing in riparian zones through changes in vegetation composition and structure; increased water temperature, nutrients, and bacteria; alteration of stream channel morphology; and direct trampling. The spotted frogs of the northwest are of particular concern in this regard due to their restricted distributions (Hayes, 1994; Hayes et al., 1997; McAllister and Leonard, 1997). However, current research assessing grazing impacts on spotted frogs in the northwest is limited to observational studies (e.g. Munger et al., 1997, 1998; Bull and Hayes, 2000; Bull et al., 2001). Our study seeks to evaluate the effects of livestock grazing on *R. pretiosa* behavior through a designed experiment allowing for causal inferences.

Secondary objectives of our study aim to describe fall migration routes and identify overwintering sites of the *R. pretiosa* population on Jack Creek. Few studies have described amphibian movement patterns and potential seasonal changes in habitat use. In addition to protection of summer foraging and breeding sites, protection of anuran overwintering sites are of growing concern due to their role in maintaining population persistence (Sinsch, 1990; Hayes et al., 1997; Matthews and Pope, 1999; Pilliod et al. 2002; Semlitsch, 2002). Cascades frogs (*Rana cascadae*), a sister species group of spotted frogs to the north of Jack Creek occupy both breeding and non-breeding sites (Brown, 1997). Recent work on *R. luteiventris* and *R. muscosa* documented seasonal migration distances over 1 km and the use of different habitats for breeding, foraging, and overwintering

(Mathews and Pope, 1999; Pope and Mathews, 2001; Bull and Hayes, 2002; Pilliod et al., 2002). Watson et al. (2003) ascertained that *R. pretiosa* also uses seasonally different aquatic habitat types. If such a complex life history were detected for Jack Creek *R. pretiosa,* it may indicate a different suite of risk factors not related to the summer foraging sites. Identifying critical seasonal habitats requires a better understanding of the local year-round habitat availability and use patterns of these frogs.

Although frogs have been captured in selected areas along Jack Creek during the summer, a full understanding of their habitat use year-round is needed. In particular, are frogs restricted to riparian areas in fall and winter? Also, does livestock grazing affect *R. pretiosa* habitat use? Using mark-recapture techniques and deployment of cattle exclosures, we examined these two questions at the Jack Creek *R. pretiosa* population in 2002-2004.

The remainder of this thesis is organized as follows: Chapter two is a manuscript that will be submitted to a journal for publication; Chapter three contains general conclusions of this thesis; and the three appendices are the data used for analysis, pin hit averages by plot by month, and the pilot project respectively.

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CHAPTER 2

OREGON SPOTTED FROG (*RANA PRETIOSA*) HABITAT USE AND HERBAGE (or BIOMASS) REMOVAL FROM GRAZING AT JACK CREEK, KLAMATH COUNTY, OREGON

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Abstract

We evaluated the effects of livestock grazing on Oregon spotted frog (*Rana pretiosa*) habitat use by monitoring frog locations in grazed and matched ungrazed treatments across a range of grazing pressures at Jack Creek, Fremont-Winema National Forest, Oregon. Thirteen cattle exclosures were deployed along Jack Creek in the summer of 2003. Movements were monitored using radio telemetry on adult frogs (N = 24 frogs) within treatments sites from July through October, 2004. Individual frogs were located 1 to 28 times ($\bar{x}$ = 11.7) and were tracked from 1 to 74 days ($\bar{x}$ = 35.8 days). A 10-pin point intercept frame was used to estimate relative differences in removed vegetation cover. This difference between ungrazed treatments and paired grazed controls was used as a measure of grazing pressure at treatment sites and examined in relation to frog habitat preference. Pin measurements ranged from an average monthly difference of -1.2 to 2.97 pin hits between an exclosure and its control. As pin differences increased by one unit, the odds of finding a frog in the exclosure increased by a factor of 1.62 ($F_{1,43} = 3.90$, $p = 0.05$) with an approximate 95% confidence interval of 1.00 to 2.74. Based on the proportion of time frogs spent inside exclosures, there was evidence that as grazing pressure increased, frogs preferred ungrazed livestock exclosures.

Secondary objectives of this study were to describe migration routes and identify overwintering sites of the *R. pretiosa* population on Jack Creek. From August to mid-December, 2003, frogs (N = 36) were tracked from 5 to 92 days ($\bar{x}$ = 49.5 days) and located 2 to 39 times ($\bar{x}$ = 23.2 times). In mid-October, individuals were located in sheltered areas along the creek such as willow root complexes and abandoned beaver runs. Frogs also were found in deep (130 cm) pools associated with active springs, and individuals in these areas were active within the pools under 5 cm of ice.

Introduction

Considerable attention has been given to global amphibian declines (Hayes and Jennings, 1986; Blaustein and Wake, 1990; Wake, 1991; Corn, 2000; Semlitsch, 2002; Green, 2003). Contributing factors to global losses include habitat modification, introduction of non-native species, disease, environmental contaminants, and atmospheric conditions; with habitat alteration and destruction being the most thoroughly documented (reviewed in Alford and Richards, 1999; Blaustein and Kiesecker, 2002). Habitat modification is similarly a key concern relative to amphibian losses in the US West.

Concerns for western US amphibians has resulted in numerous assessments of status and potential threats over the last 15 years (e. g. Bradford et al., 1994; Munger et al., 1996; Hayes et al., 1997; McAllister and Leonard, 1997; Corn, 2000; Knapp and Matthews, 2000). An emerging pattern among western species exhibiting losses is that they are predominantly pond-breeding amphibians and many are ranid frogs. Ranids are one of four families significantly contributing to the total number of rapidly declining species globally (Stuart et al., 2004). Ranids on state lists of species of concern in the US West include *Rana aurora, R. boylii, R. cascadae, R. draytonii, R. luteiventris, R. muscosa,* and *R. pretiosa,* which are all pond-breeders or oviposit in slower portions of streams. While various contributing factors are named for each species and sometimes per location, habitat alteration is a concern for all. Furthermore, recent information on some western ranids suggests that they use much more of the landscape than just aquatic breeding sites (Brown, 1997; Bull and Hayes, 2001; Pope and Matthews, 2001; Pilliod et al., 2002; Watson et al., 2003) and that population structure is highly dependent on these interconnected aquatic and terrestrial habitats (Funk et al., 2005). Understanding the role of habitat alterations to animals at discrete breeding, foraging, and overwintering areas is a complex and crucial issue for ranid conservation.

Habitat alteration is of particular concern in the Pacific Northwest where the decline of the Oregon spotted frog (*Rana pretiosa*) is likely the most severe among amphibians in the region (Corn, 2000). Populations of *R. pretiosa* have become isolated through habitat fragmentation and are believed to be extirpated from 79% to 90% of their historic range (Hayes et al., 1997; McAllister and Leonard, 1997). Currently, the U.S. Fish and Wildlife Service regards *R. pretiosa* as a candidate species for listing under the Endangered Species Act. Jack Creek (Klamath County) on the Fremont-Winema National Forest, is one of 24 *R. pretiosa* populations known in Oregon, and one of 7 known in the Klamath Basin (Figure 1). Jack Creek is fed by a system of perennial springs. Spring breeding and summer foraging sites have been established along Jack Creek, however precise overwintering locations and potential migration routes have not been documented. The Jack Creek population is geographically isolated in that the closest population within the Klamath watershed is approximately 30 km downstream on the Williamson River. Aquatic connectivity via the stream network between the populations often goes subsurface under porous pumice. This population is also genetically isolated in that the Klamath basin group of *R. pretiosa* is genetically the most distinct of four identified groups across its range (Blouin, 2000). Both geographic and genetic isolation may further enhance the risk of local extinction. Understanding habitat requirements and the effects of habitat change due to anthropogenic factors is essential in developing effective management strategies for the protection of this endemic amphibian species. Anthropogenic disturbances to habitats at Jack Creek include livestock grazing, fire suppression and removal of beaver from the system.

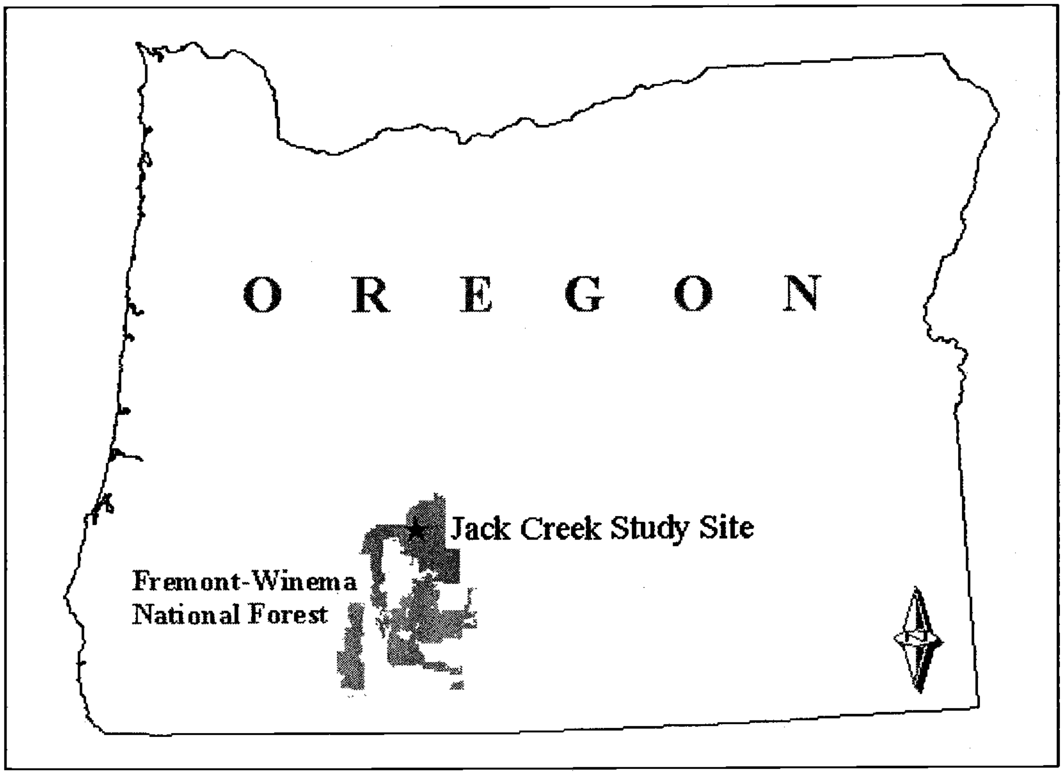

Figure 1. Location of Jack Creek *R. pretiosa* population on the Fremont-Winema National Forest in Oregon.

Livestock grazing can have a profound effect on riparian vegetation, water quality, and geomorphology (reviewed in Kauffman and Krueger, 1984; Trimble and Mendel, 1995); however, there are inconclusive data linking those changes to effects on ranid frogs (Munger et al,. 1997, 1998; Bull and Hayes, 2000). The magnitude of effects of livestock grazing on *R. pretiosa* is likely complex and site-specific; factors include the condition of the landscape, varying grazing regimes, and unique population characteristics. At Jack Creek, livestock grazing occurs on both private and public lands from July to October.

Our study addresses two objectives related to habitat use by *R. pretiosa* at Jack Creek. First, we experimentally evaluated the effects of livestock grazing on frog summer habitat use. We deployed livestock exclosures and monitored frog locations (mark-recapture and radiotracking) in grazed and matched ungrazed treatment plots across a range of grazing intensities at known frog microhabitats of historically high summer use. Understanding frog responses to grazing will contribute to development of appropriate management strategies to protect these animals. Second, to explore the potential variety of habitats used by frogs within the Jack Creek landscape, we investigated movements and habitats used by frogs among seasons by radiotracking them at Jack Creek from the end of the summer season into December. If there is temporal variation in habitat use by frogs, this broader spatial area may need to be considered in land management planning.

Materials and Methods

In the summer, the *R. pretiosa* population at Jack Creek occurs along the stream in a reach extending about 1.5 km. In this area, Jack Creek's width ranges from 1 to 5 meters, runs at a low gradient (<2%) and is characterized as a ribbon of variably sized marshy habitat. Riparian, mesic graminoid meadow and dry meadow are the three main vegetation types within the meadow. Water sedge (*Carex aquatilis*) dominates the riparian areas adjacent to the creek while Blister sedge (*Carex vesicaria*), Analogue sedge (*Carex simulata*), Slender-beak sedge (*Carex athrostachya*), and Nebraska sedge (*Carex nebrascensis*) are present. Jack Creek is a cold air drainage basin with extremes in soil temperature and is subsequently dominated by lodgepole pine (*Pinus contorta* var. *murrayana*) plant communities in the upland, with *P. contorta* encroaching into the meadow (USDA, 2004). Willows in the meadow appear old and are depauperate with limited flowering. This is a common trait of a heavily browsed willow (Brookshire et al., 2002). Historically, beaver occupied the area, as evident by old beaver chews, oxbows and collapsed beaver runs, but have not been documented in the last 30 years (USDA, 2004). The Jack Creek *R. pretiosa* population is at the highest known elevation for the species, 1,597 to 1,658 m, and is one of five known populations that is not in contact with exotic aquatic predators, such as fishes or bullfrogs (*R. catesbeiana*), or exotic vegetation such as reed canary-grass, (*Phalaris arundinacea*; Hayes, 1998).

Livestock Grazing Treatment

Jack Creek flows through private land and land administered by the USDA Forest Service. Since the 1800's, livestock have grazed these lands. The first grazing permit was issued in 1909, but previously cattle and sheep grazed the area in much larger and undocumented numbers. Currently, the Jack Creek grazing permit restricts grazing from July 1st to October 1st and allows approximately 365 cow/calf pairs on 1,571 acres of riparian area which is considered suitable for grazing, but encompasses and additional 2,035 acres of land with wet soils which are also grazed. Wet soils are considered unsuitable for grazing (Kovalchick, 1987). Although native ungulates are present in the watershed, there is little evidence of recent herbivory in the riparian zone where livestock congregate and the frogs occur and few ungulate pellets were found during the study. Jack Creek supplies the area's only water source for most of the year. For this reason, grazing pressure is particularly high and linear movements of cattle along the stream corridor make stream and riparian habitats particularly susceptible to disturbance.

Treatment plots for our exclosure experiment were located at historically high density frog sites. Mark-recapture efforts and egg mass surveys conducted on *R. pretiosa* over the last five years at Jack Creek by the Chemult Ranger District were analyzed with Spatial Analyst in ArcGIS™ to identify high density capture sites along Jack Creek. Such sites generally were centered on pools ranging from approximately 60 to 150 cm deep with runs separating the pools. Thirteen plots were deployed along Jack Creek prior to release of cattle in the summer of 2003 (Figure 2).

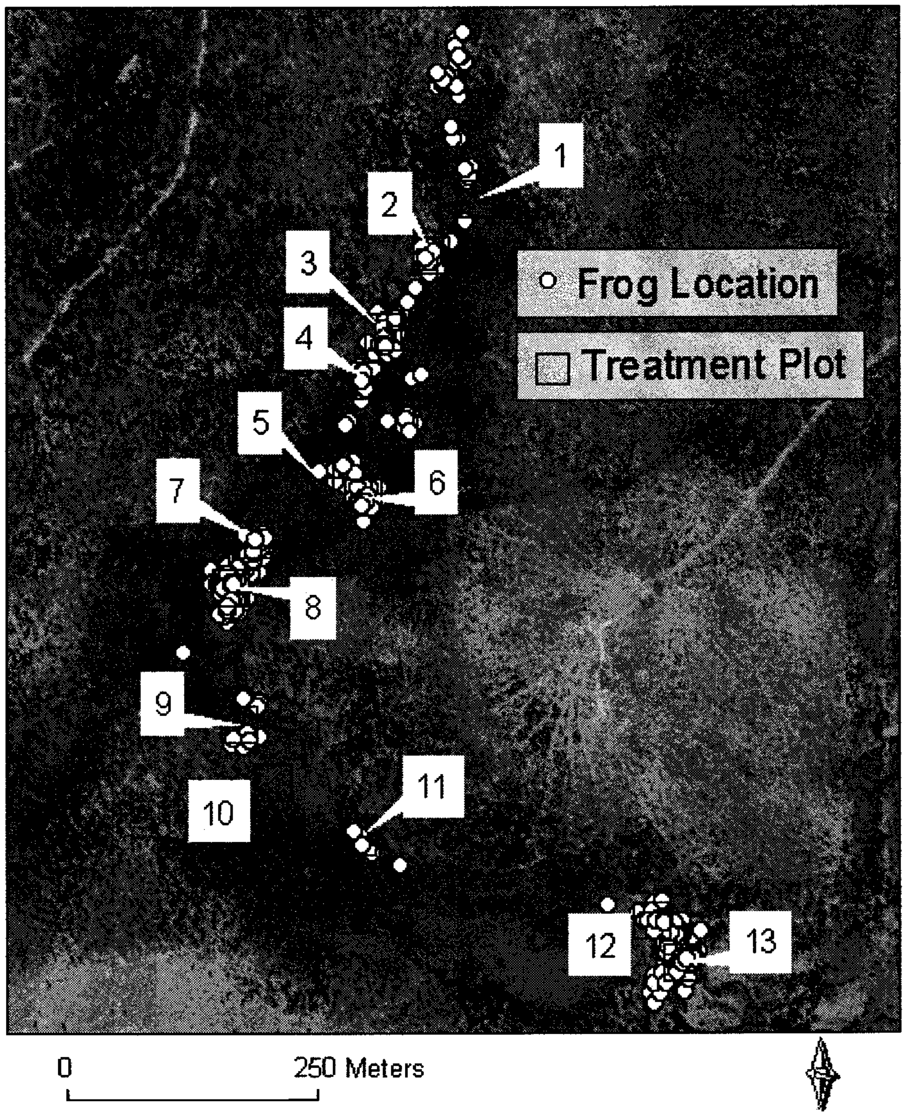

Figure 2. Map of Jack Creek, Klamath County and the 13 Treatment Plots along the Creek

Site selection was not random, but included a systematic distribution of plots at the highest density sites along the entire stream network. Each plot consisted of a 15 x 15 m cattle exclosure and an adjacent 15 x 15 m control area (Figure 3). Exclosures were frog-permeable and were randomly assigned to be either upstream or downstream of the center of the plot. The location of the exclosure with respect to the control (upstream or downstream) was randomized in order to draw causal inferences for exclosure effects.

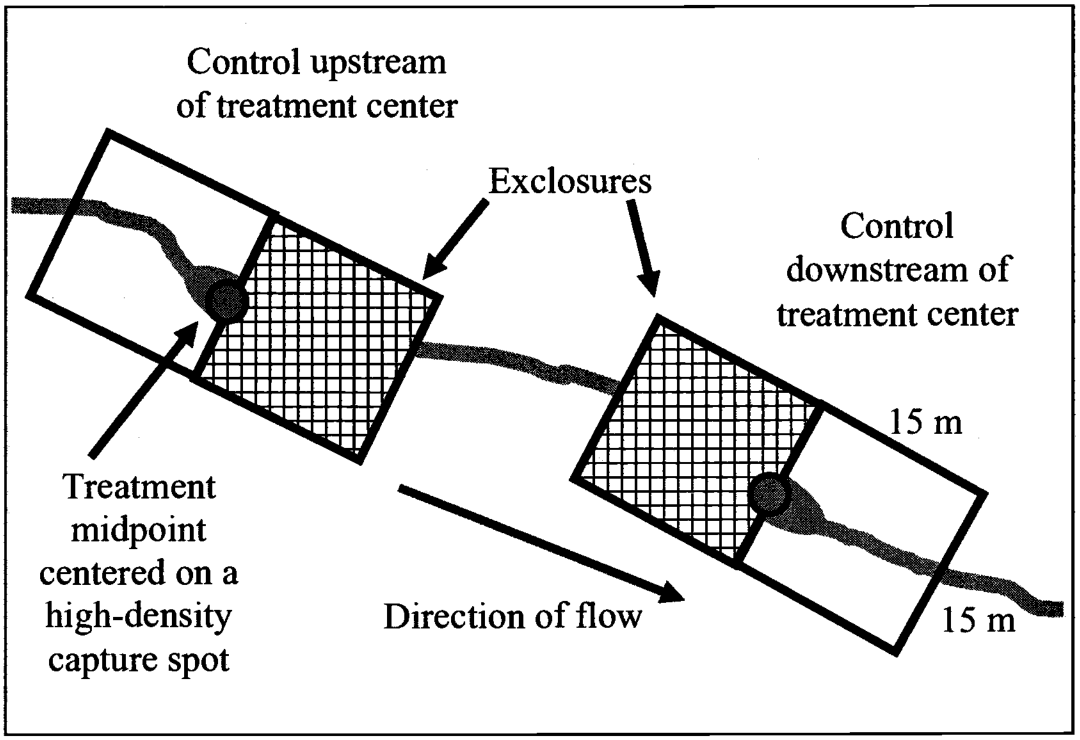

Figure 3. Illustration of treatment plot pair demonstrating plot layout along Jack Creek.

In July through September 2004, Visual Encounter Surveys (VES; Crump and Scott, 1994) were conducted to locate frogs along Jack Creek. All adult frogs were captured and measured (snout-urostyle length (SUL), leg length, and weight). All frogs ≥ 45 mm SUL received a Destron Passive Inductance Transponder (PIT) tag. Radio transmitters (Holohil Systems Ltd.; BD-2, 1.3 g and 1.88 g) were attached to frogs that weighed a minimum of 13 g or 18 g, depending on the transmitter used, in order to remain below 10% of the body mass (Heyer et al., 1994). We attached transmitters to a satin ribbon waist-belt and sewed the ends together without using glue. In 2003, we found that gluing the ends of the ribbon, to prevent fraying, created a rigid area that caused sores and in some cases, abrasions. Frogs were released at their original capture site. Frogs with transmitters were located every 2-5 days and an attempt was made to recapture and measure these frogs at least once a month. Frogs without transmitters were opportunistically captured and measured throughout the season and weekly weight changes were compared to transmittered frogs using t-tests (two sided, $\alpha = 0.05$). A Destron Mini Portable ® reader was used to read PIT tags of captured frogs without transmitters. Movements were monitored using radio telemetry (Telonics, TR-2 receiver) from July through September, 2004. Locations of all captured frogs and transmittered frogs were documented using CyberTracker™ Software through the duration of the transmitter life (7-17 weeks), until a frog slipped its belt, or the belt was removed due to an abrasion or substantial weight loss. Cybertracker™ is a data collection system that integrates GPS technologies with a hand held data logger.

For the purpose of this analysis, the following were assumed: 1) frog behaviors are independent since communal behaviors among frogs are not known (Watson et al., 2003); 2) transmitters have no effect on frog preference to treatments; and 3) treatment preference by frogs does not differ between day and night hours.

A 10-pin point intercept frame adapted from Sharrow and Tober (1979) was used as an index of the difference of the removed vegetation cover between plots (Poissonet et al., 1973) and an estimate of grazing pressure in the riparian zone at individual treatment sites. The purpose of this sampling method is to estimate relative differences in grazing pressure between treatment plots and does not allow exact removed biomass estimates. Simultaneous biomass sampling is necessary to establish an actual biomass index. The pin frame was 90 centimeters tall and consisted of 10 pins inclined at a 45° angle to the ground. Three randomly placed frame samples were taken in each exclosure and each control once a month (July through September). These samples were taken from the riparian zone which was determined to be within one meter of the water's edge and within the *Carex* spp. community. As a pin was lowered through the vegetation, every contact with a piece of vegetation was recorded as a pin hit. Pin hits were totaled and averaged over the 3 frame samples for each month. The difference of the total pin hits between exclosures and controls estimates the relative difference in vegetation cover between the treatments and the controls during that month and was used as a measurement of grazing pressure.

Vegetation heights and cow pat counts were also taken for each plot, each month. Three vegetation height samples were taken at random locations within the riparian zone for each exclosure and each control. The difference of vegetative height between the exclosure and control was considered to be another indicator of relative grazing pressure at each treatment plot. The total number of cow pats was counted in each exclosure and each control and were also considered to be an indicator of relative grazing pressure at each treatment plot.

Only plots used by frogs and only frog locations that were within plots were used for the remainder of the grazing analysis. Logistic regression was conducted in SAS Version 9.1® using the procedure PROC GENMOD to determine if the proportion of locations inside an exclosure was associated with the estimated grazing pressure of the matched control. The proportion of locations in an exclosure was determined by radiotelemetry and represents the ratio of number of times frog *j* was located in the exclosure (y_{ij}) over the total number of times frog *j* was located in either the exclosure or the control (m_{ij}) for each month *i*. A full model including differences of pin hits, vegetation height, cow pat counts and date was fit using logistic regression. A reduced model was fit using the variable explaining the most variation, and was used for the remainder of the analysis.

The model final model is: $Y_{ij} \sim \text{Binomial}(p_i, m_{ij})$

$$g(p_i) = \log\left(\frac{p_i}{1-p_i}\right) = \beta o + \beta_1 X_1$$

Where p_i is the probability that a frog is found in an exclosure in month i, β_o and β_1 are linear coefficients associated with the explanatory variable, X_1 = difference in vegetation pin hits between exclosures and grazed plots by month. The overdispersion parameter in the final model was estimated to be 3.86, accounting for the potential lack of independence of measurements made on the same frog.

Seasonal Migration

Seasonal migration movements were monitored using VES and radio telemetry on adult *R. pretiosa* from August through December, 2003. Radio transmitters were attached to frogs with the same methodologies used for the grazing objective and all frogs $\geq$ 45 mm SUL received a PIT tag for unique identification. An attempt was made to put transmitters on frogs distributed throughout the length of Jack Creek in order to capture migration behaviors that may be associated with particular sections of the creek. General habitat information was collected at each frog location (e.g., stream depth, vegetation). Frogs were released at their original capture site. Transmittered frogs were located every 2-5 days and an attempt was made to measure these frogs at least once a month. In early December, an attempt was made to remove belts before access to Jack Creek was no longer possible due to winter weather conditions.

Results

Livestock Grazing Treatment

Of 40 frogs captured, 31 were adults and 24 were fitted with radio transmitters (11 males and 13 females). Transmitters represented 6.3 % (SE 0.3) of female and 7.1 % (SE 0.2) of male body weight. Difference in averaged bi-weekly weight change between transmittered and non transmittered frogs was not significant (t_{25} = 0.28, p = 0.8). Belt loss occurred on 16 individuals and 5 of those frogs were re-captured and given a new transmitter. Three (13%) transmittered frogs developed abrasions on their sides and we immediately removed their belts.

Sores ranged from mild skin excoriations to open wounds over one or both hips. To treat sores we removed the belt and applied Bactine® to the area. We found one frog skeleton with a transmitter still attached; its cause of death remains unknown. We located another transmitter in the upland, at the entrance to a rock crevice next to a shed snakeskin. This frog was assumed to be predated by a garter snake (*Thamnophis* spp.) which are important predators of post-metamorphic *R. pretiosa* (Licht 1986).

Transmittered frogs were located a total of 346 times. Individuals (N = 24) were located 1 to 28 times ($\bar{x} = 14.2$, SE 1.8) and were tracked from 1 to 74 days ($\bar{x} = 35.0$, SE 2.9). We detected use in nine of the thirteen pairs of plots and only plots with detected use were included in this analysis (Table 1). Of the parameters, cow pat count, pin count, date and vegetation height, pin count was the single best predictor of frog preference to exclosures and was used for the remainder of the analysis (Table 2).

TABLE 1. Total Number of Times a Frog was Located at each Treatment Plot for each Month with Locations inside the Cattle Exclosures in Parentheses.

Treatment plot	Month			Total
	July	Aug	Sept	
1	0	0	0	0
2	6 (5)	4 (3)	0	10 (8)
3	8 (2)	12 (0)	2 (0)	22 (2)
4	0	1 (0)	4 (4)	5 (4)
5	2 (1)	3 (2)	0	5 (4)
6	0	8 (4)	4 (0)	12 (4)
7	1 (1)	13 (11)	13 (6)	27 (18)
8	12 (0)	21 (0)	10 (6)	43 (6)
9	2 (1)	0	0	2 (1)
10	0	0	0	0
11	0	0	0	0
12	0	5 (4)	5 (3)	10 (7)
13	8 (7)	43 (37)	44 (37)	95 (81)
Total	39 (17)	110 (61)	82 (56)	231 (134)

TABLE 2. F-Statistics and P-values for Significance of Cow Pat Count, Date, Pin Count, and Vegetation Height as single best predictors in Logistic Regression.

Explanatory Variable	F Statistic	*P*
Cow Pat Count	0.51	0.475
Date	0.87	0.418
Pin Count	3.9	0.048
Vegetation Height	2.42	0.12

Pin measurements ranged from an average monthly difference of -1.2 to 2.97 pin hits between an exclosure and its control at plots used by frogs. As pin differences increased by one unit, the odds of finding a frog in the exclosure increased by a factor of 1.62 ($F_{1,43}$=3.90, p=0.05) with an approximate 95% confidence interval of 1.00 to 2.74 (Figure 4).

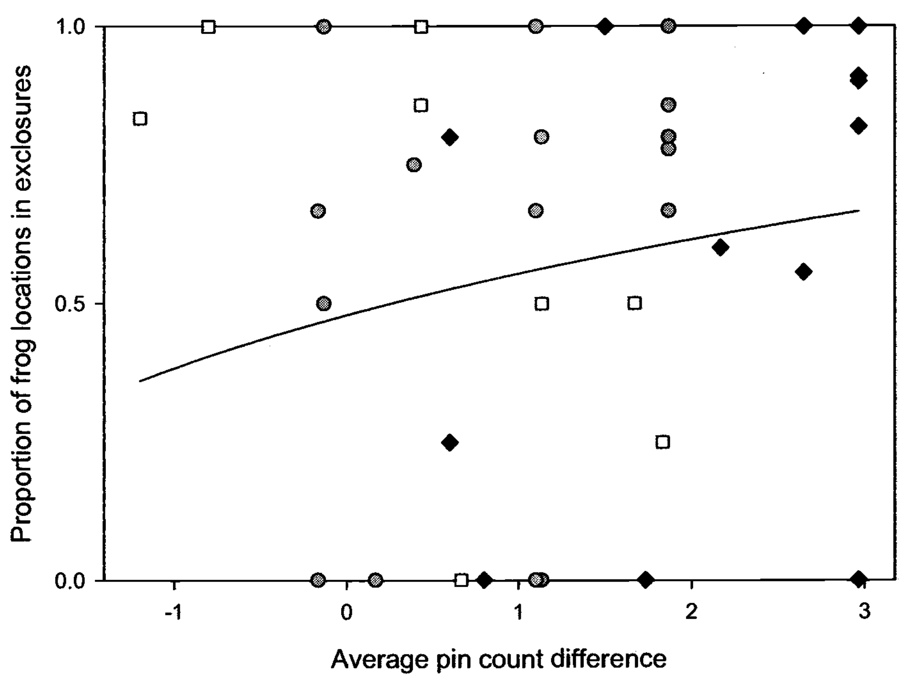

FIGURE 4. Scatter plot of proportion of locations in exclosures and pin count differences. White squares represent July, gray circles represent August, and black diamonds represent September. The line is the predicted probability of a frog being located in an exclosure.

Seasonal Migration

Of 69 frogs captured in 2003, 50 were adults and 36 were fitted with radio transmitters (8 males and 28 females). Transmitters small enough to be fit on males were limited, so there is some bias toward females in this study. Frogs were tracked from 5 to 92 days ($\bar{x}$ = 49.5) and located 2 to 39 times ($\bar{x}$ = 23.2). Nine (25 %) frogs developed abrasions from the belts. Three frog skeletons were found and the cause of death was undetermined. During the active foraging season (July to September), 22 of 30 (73%) transmittered frogs remained within 40 m of their original capture sites.

In October, two of the 14 remaining transmittered frogs moved more than 50 m from their summer foraging sites on October 4^{th} and 16^{th} respectively. The furthest movement distance recorded at the end of the survey (5 December) was approximately 120 m along the creek upstream from the summer foraging area. There were no observations of frogs moving over dry land.

Most belts were removed by the second week in November. Final locations for eight frogs may have been overwintering sites. Two of these individuals were located in sheltered areas along the creek such as willow root complexes and abandoned beaver runs. Once these frogs arrived at these sheltered, highly structured sites, movement was negligible for the remainder of the tracking period in 2003 (4 to 6 weeks). The other six frogs were located under muddy substrate and woody debris at the bottom of deep (1.3 m) pools associated with active springs. Individuals in these areas remained active within the pools under 5 cm of ice, at least until we took the belts off (mid-November) and observed movements were exceptionally sluggish. Three belts were not recovered before the onset of winter and one of those frogs had slipped its belt by the time it was recaptured in 2004.

Discussion

Livestock Grazing Treatment

Our data suggest *R. pretiosa* increased their use of livestock grazing exclosures as grazing pressure increased in adjacent grazed controls. Increased use of exclosures under heavier grazing pressure may be attributed to various ecological factors. Excessive livestock grazing can cause the loss of late seral species that have a higher ecologic functional status, reduce biomass production by compacting soil, and exacerbate stream bank erosion, which can alter habitat availability through increased sediment production, increased fluctuation in water temperature, increased water table depth, and changes in water quality (Kauffman & Kruger, 1984). Increased nitrate levels through livestock deposition of feces and urine also may affect frog preference to exclosures. High levels of nitrates have been shown to affect ranid behavior, development, and survival (Marco and Blaustein, 1999; Marco et al., 1999; Hatch and Blaustein, 2000) and may elevate levels of bacteria (Kauffman and Krueger, 1984) which could potentially create infections in frogs. The condition of emergent vegetation may be a key component in *R. pretiosa* microhabitat preference (Watson et al., 2003; Bull and Hayes, 2000). Livestock trampling and consumption of emergent and riparian vegetation may have a dietary effect on the frogs due to changes in macroinvertebrate communities. Adults opportunistically feed on invertebrates that are often closely associated with riparian vegetation such as aquatic emergents (Whitaker et al., 1981; Licht, 1986; Pearl et al., 2005). Pearl et al. (2005) observed *R. pretiosa* using floating and emergent vegetation to effectively ambush prey such as adult Odonata (dragonflies and damselflies) which oviposit among aquatic vegetation. Additionally, emergent vegetation may provide food for tadpoles (Morris and Tanner, 1969), and structure for basking and off shore predator avoidance (Leonard et al., 1993; McAllister and Leonard, 1997; Pearl et al., 2005). Removal of riparian vegetation also likely contributes to the loss of cover, potentially increasing vulnerability to predators, and exposure to different micro climates which may increase susceptibility to desiccation.

Under lower grazing pressure, the frogs in the study did not show a preference to exclosures or controls. When the difference of pin counts exceeded 1.5, 15 out of 19 (78.9%) frogs spent more than 50% of their time inside the exclosures. This apparent threshold may exist because a moderate degree of grazing may have created open water habitats through intermediate disturbances that were otherwise not conducive to frog use (Hayes et al., 1997; Hayes, 1998; McAllister and Leonard, 1997; Watson et al., 2003). Disturbances such as fire and American beaver (*Castor canadensis*) activity have historically maintained vegetation at an early seral structure and composition at Jack Creek (USDA, 2004), thereby creating open water habitats used by *R. pretiosa*. These disturbances, particularly those created by the beaver, have been absent in the area for as long as 30 years (USDA, 2004) and livestock grazing is now the major form of disturbance on Jack Creek, possibly serving as a surrogate to this natural disturbance. However, maintaining early seral vegetation structure is only one component of ecosystem function that overlaps with what beaver naturally do for a riparian system that may enhance frog habitat. Beaver provide Key Ecological Functions (KEF) by influencing biochemical pathways, stream productivity, hydrology, geomorphology, and vegetative conditions of riparian systems (Olson and Hubert 1984; Marcot and Heyden, 2001), ultimately providing frog habitat. The Jack Creek channel has degraded in elevation due to a reduction in sediment load, leading to streambank erosion and channel widening, which is a notable geomorphic concern that can be exacerbated by livestock use through the removal of bank vegetation (USDA, 2004). Reservoirs created by beaver dams trap alluvial sediments and can cause channels to aggrade through impoundment of water, alleviating the degraded channel condition and creating wet meadows (Naiman, 1988; Fouty, 2003). Beaver ponds have been shown to increase invertebrate biomass and density (McDowell and Naiman, 1986), which may benefit frogs through increased food availability.

The frogs at Jack Creek would likely benefit from a management strategy that adjusted livestock use during the season, depending on habitat condition. However, defining an exact threshold of grazing pressure is beyond the scope of this project and would merit future research. Also, since effects of livestock grazing are cumulative and remain on the landscape over long periods of time (Elmore and Beschta, 1987; Marlow, 1988), the effects of an alteration in the grazing regime will be most apparent in the long term. Additional studies that incorporated this time delay and also seasonal variation of grazing pressure will contribute understanding of this ecological complex question.

Seasonal Migration

Jack Creek *R. pretiosa* appear to have high micro-site fidelity and seem to be extremely restricted in distribution to near-stream habitats. Frogs exhibited high site fidelity particularly during the summer and early fall which is consistent with Watson et al. (2003), who found *R. pretiosa* significantly reduced movements during the summer foraging season. Most frogs remained within 40 m of capture locations and the maximum movement was only 120 m along the creek. These results contrast with recent work on *R. aurora draytonii, R. luteiventris* and *R. muscosa* that documented seasonal migration distances over 1 km (Engle, 2001; Pope and Mathews, 2001; Bull and Hayes, 2002; Pilliod et al., 2002; Bulger et al., 2003). These findings may make Jack Creek *R. pretiosa* habitat management less complex because dominant considerations would be to mitigate activities with potential adverse effects in the stream-riparian zone.

Jack Creek frogs used highly structured habitat during the late fall and possibly as overwintering sites. This may be a point of concern for this highly aquatic species with regards to Jack Creek's noted poor channel condition. Much of this structured habitat appears to be continually degraded through livestock grazing (Kauffman and Krueger, 1984). Beaver activity retains channel complexity (Naiman, 1988), and hence restoration of beaver in the creek system could be a management alternative to improve Jack Creek's channel condition and frog habitat. Beaver restoration could only be considered after the restoration of the willows, which are a major food source for the beaver. Willow restoration in itself may enhance frog habitat by reducing the downcutting and widening of the channel and increasing the sinuosity of the stream through bank stabilization.

Conclusion

Despite the ubiquity of livestock grazing throughout the American West, and the fact that it is arguably one of the more significant habitat alterations to riparian ecosystem function (Trimble and Mendel, 1995), very little attention has been given to its effects on amphibians (Munger et al,. 1997, 1998; Bull and Hayes, 2000). Oregon spotted frogs are of particular concern in the Pacific Northwest due to their limited distributions, current downward population trends, and coexistence with livestock management practices (Hayes et al., 1997; McAllister and Leonard, 1997; Corn, 2000). Livestock grazing is cited as a specific concern to Oregon spotted frogs at Jack Creek (USDA, 2004). This population may be particularly vulnerable to losses due to its isolation from other locations and other apparent ecological system changes due to fire suppression and loss of beaver (Hayes et al., 1997; Hayes, 1998; Blouin, 2000; USDA, 2004). In order to address potential mitigation measures to reduce risks to this species, studies of the effects of grazing on frogs at this site are warranted.

Although our study is limited in scope and scale, it provides preliminary investigation through experimentation into how livestock grazing can influence frog behavior. We hope it will inspire future research to address this complex ecological question. Although we found frogs responded to grazing, we cannot determine if grazing has either a positive or negative impact on the frogs. A negative effect could result from several mechanisms such as exposure to high levels of nitrates, which have been shown to be harmful to spotted frogs (Marco and Blaustein, 1999; Marco et al., 1999; Hatch and Blaustein, 2000). Positive effects of grazing could occur through habitat alterations such as creating open water habitats through intermediate disturbance that were otherwise not conducive to frog use (Hayes et al., 1997; McAllister and Leonard, 1997; Hayes, 1998; Watson et al., 2003). Moderate grazing levels, by livestock or wild ungulates, could be beneficial to maintenance of aquatic systems by stalling succession. In this way, grazing might alter vegetation similarly to low intensity fires or beaver activity, which also can forestall vegetation community succession (Naiman et al., 1988). However, the interaction of vegetation removal by beaver and intense herbivory by livestock or native ungulates can strongly suppress the regrowth of willow (Baker and Hill, 2003; Baker et al., 2005), making proper grazing management essential to the successful use of beaver as a mechanism for riparian restoration. The "intermediate disturbance hypothesis" of community structure proposes that biological diversity in some systems can be retained by infrequent or low intensity habitat alterations (e. g. Connell, 1978). It is likely that many frog habitats such as ephemeral ponds in meadows and low flowing stream systems such as Jack Creek are susceptible to change if the disturbance frequency or intensity that retains the system is altered. In the American West, both fire and beaver could be the natural disturbance agents that retain wetlands. This scenario might apply to Oregon spotted frogs at Jack Creek; however, additional studies would be needed to address the effectiveness of integrating these disturbances. In understanding the Jack Creek spotted frog population ecology in response to grazing, continued monitoring is needed and further investigation is warranted relative to effects on frog survival and reproduction under different grazing frequencies or intensities. Ultimately, understanding how anthropogenic activities affect amphibians such as *R. pretiosa* can aid managers in mitigating potential adverse affects, especially in riparian systems, and contribute to recovery and restoration strategies.

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CHAPTER 3
CONCLUSION

Conservation of amphibian species has been an important focus of ecological research on a global scale in the past decade. Synergistic environmental changes have been documented as being responsible for amphibian population declines, range restrictions, and species extinctions. These environmental effects range from climate change to introduction of exotic species. Habitat alteration is the factor most consistently discussed in the literature for its critical role in both amphibian declines and potential recovery (reviewed in Alford and Richards, 1999; Corn, 2000; Blaustein and Kiesecker, 2002).

Amphibian habitat alteration predominately has occurred with human development and includes a vast array of changes to aquatic systems resulting from urban development or agriculture. Agricultural effects include draining of wetlands, channelization of streams, loss of native riparian vegetation, and stream-riparian alteration by livestock grazing (e. g. Adams, 1999; McAllister and Leonard, 1997; Kiesecker et al., 2001). In particular, livestock grazing can affect habitat availability by altering vegetation composition and structure; increasing water temperature, nutrients, and bacteria; altering of stream channel morphology; (Kauffman and Krueger, 1984) and direct trampling.

Despite the ubiquity of livestock grazing throughout the American West, and the fact that it is arguably one of the more significant habitat alterations to riparian ecosystem function (Trimble and Mendel, 1995), very little attention has been given to its effects on amphibians (Munger et al,. 1997, 1998; Bull and Hayes, 2000). Oregon spotted frogs (*Rana pretiosa*) are of particular concern in the Pacific Northwest due to their limited distributions, current downward population trends, and coexistence with livestock management practices (Hayes et al., 1997; McAllister and Leonard, 1997; Corn, 2000). Livestock grazing is cited as a specific concern to Oregon spotted frogs at Jack Creek, Klamath County, Oregon (USDA, 2004). This population may be particularly vulnerable to losses due to its isolation from other locations and other apparent ecological system changes due to fire suppression and loss of beaver (Hayes et al., 1997; Hayes, 1998; Blouin, 2000; USDA, 2004). In order to address potential mitigation measures to reduce risks to this species, studies of the effects of grazing on frogs at this site are warranted.

Our study addressed two main objectives relative to grazing and frog habitat use at Jack Creek. First, we were interested in understanding how frogs responded to summer livestock grazing. Currently, the Jack Creek permit restricts grazing to approximately 365 cow/calf pairs from the 1st of July to early October. Using mark-recapture and radio tracking approaches, along with the deployment of cattle exclosures we documented frog habitat use relative to grazed and ungrazed areas. Second, our knowledge of frog habitat at this site is incomplete. While previous survey work in spring and summer has reported breeding and occurrences of these frogs in adjacent meadows and along the creek, fall to winter habitats have not been described. Recently, other ranid frogs have been reported to occur in the broader landscape surrounding breeding sites (e.g. Brown, 1997; Pope and Mathews, 2001; Pilliod et al., 2002). It is possible that Jack Creek serves as a breeding site and summer foraging site for frogs, but that they also disperse from the area for overwintering. Our second objective was to investigate habitat use and movements of frogs at the end of the active foraging period, to determine if areas away from Jack Creek were also important in the life history of this population. We tracked frogs using radio transmitters from August until the onset of winter to address this question.

Our data suggest *R. pretiosa* increased their use of livestock grazing exclosures as grazing intensity increased in adjacent grazed controls. Increased use of exclosures under heavier grazing pressure may be attributed to various ecological factors. For example, emergent vegetation may provide structure for basking and off shore predator avoidance (Leonard et al., 1993; McAllister and

Leonard, 1997; Pearl et al., 2005). Riparian vegetation may provide cover for frogs (Leonard et al., 1993; McAllister and Leonard, 1997) and habitat for aquatic macroinvertebrates that frogs feed upon (Pearl et al., 2005). The reduction of emergent and riparian vegetation through livestock trampling and consumption may affect microhabitat preference. However, under lower grazing pressure, the frogs in the study did not show a preference to exclosures or controls. A moderate degree of grazing does not appear to affect frog behavior, suggesting this intermediate disturbance level may be conducive to frog habitat use (Hayes et al., 1997; Hayes, 1998; McAllister and Leonard, 1997; Watson et al., 2003).

We found that the frogs did not leave Jack Creek during the fall, but used highly structured habitat along the creek such as old beaver runs, willow root complexes, over hanging banks and woody debris at the bottom of pools associated with springs. Similar to Watson et al. (2003), the Jack Creek frog population appears to be more restricted to aquatic habitats than other ranids (e.g. Brown, 1997; Pope and Mathews, 2001; Pilliod et al., 2002), potentially making their habitat management less complex in mitigating management activities with potential adverse effects in the riparian zone.

Although our study is limited in scope and scale, it provides preliminary investigation through experimentation into how herbage removal from livestock grazing can influence frog behavior; hopefully inspiring future research addressing this complex ecological question. Although we found frogs responded to grazing, we cannot determine if grazing has either a positive or negative impact on the frogs. A negative effect could result from several mechanisms such as exposure high levels of nitrates, which have been shown to be harmful spotted frogs (Marco and Blaustein, 1999; Marco et al., 1999; Hatch and Blaustein, 2000). Similarly, positive effects of grazing could occur through habitat alterations such as creating open water habitats through intermediate disturbance that were otherwise not conducive to frog use (Hayes et al., 1997; McAllister and Leonard, 1997; Hayes, 1998; Watson et al., 2003). Moderate grazing levels, by livestock or wild ungulates, could be beneficial to maintenance of aquatic systems by stalling succession. In this way, grazing might function similarly to low intensity fires or beaver activity, which also can forestall vegetation community succession (Naiman et al., 1988). The "intermediate disturbance hypothesis" of community structure proposes that biological diversity in some systems can be retained by infrequent or low intensity habitat alterations (e. g. Connell, 1978). It is likely that many frog habitats such as ephemeral ponds in meadows and low flowing stream systems such as Jack Creek are susceptible to change if the disturbance frequency or intensity that retains the system is altered. In the American West, both fire and beaver could be those natural disturbance agents that retain wetlands. This scenario might apply to Oregon spotted frogs at Jack Creek, however additional studies would be needed to address the effectiveness of this type of approach. In understanding the Jack Creek spotted frog population ecology in response to grazing, continued monitoring is needed and further investigation is warranted relative to effects on frog survival and reproduction under different grazing frequencies or intensities. Ultimately, understanding how anthropogenic activities affect amphibians such as *R. pretiosa* will aid managers in mitigating potential adverse affects, especially in riparian systems, and contribute to recovery and restoration strategies.

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APPENDICES

Appendix A. Pin Count Differences per Frog per Month Used in Logistic Regression Analysis

Frog ID	Treatment plot	Date	Total locations	Locations in exclosures	PIN count difference
1	7	July	1	1	-0.80
1	7	August	9	9	-0.13
1	7	Sept	5	4	0.60
1	8	Sept	1	1	2.65
2	3	July	8	2	1.83
2	3	August	7	0	-0.17
2	3	Sept	2	0	1.73
2	4	August	1	0	0.17
3	2	July	6	5	-1.20
3	2	August	4	3	0.39
4	13	July	1	1	0.43
5	8	July	7	0	0.67
5	8	August	11	0	1.10
5	8	Sept	9	5	2.65
6	9	July	2	1	1.67
7	13	July	7	6	0.43
7	13	August	11	11	1.87
7	13	Sept	10	9	2.97
8	8	July	1	0	0.67
9	8	July	4	0	0.67
9	8	August	9	0	1.10
10	4	Sept	4	4	1.50
10	5	July	2	1	1.13
10	5	August	3	2	-0.17
10	6	August	3	0	1.13
10	6	Sept	4	0	0.80
11	13	August	5	5	1.87
11	13	Sept	8	8	2.97
13	8	August	1	0	1.10
14	12	August	1	1	1.10
14	13	August	9	7	1.87
14	13	Sept	11	10	2.97
15	12	August	3	2	1.10
15	13	Sept	1	1	2.97
16	3	August	5	0	-0.17
19	12	Sept	5	3	2.17
19	13	August	6	4	1.87
19	13	Sept	3	0	2.97
20	12	August	1	1	1.10
20	13	August	5	4	1.87
21	13	August	7	6	1.87
21	13	Sept	11	9	2.97
22	6	August	5	4	1.13
24	7	August	4	2	-0.13
24	7	Sept	8	2	0.60

Appendix B. Pin hit averages over three samples by month at each treatment in 2004.

	July		August		September	
Plot	Control	Exclosure	Control	Exclosure	Control	Exclosure
1	4.5	6.7	3.6	5.7	2.9	6.0
2	6.7	5.5	4.5	5.0	2.8	7.2
3	4.7	6.6	5.9	5.7	4.1	5.9
4	6.3	4.7	4.9	5.1	4.4	5.9
5	5.9	7.0	5.6	5.4	4.5	6.2
6	5.5	4.4	5.0	6.2	4.0	4.8
7	6.7	5.9	5.4	5.2	5.0	5.6
8	5.6	6.3	4.6	5.7	3.5	6.2
9	4.3	6.0	5.5	6.4	3.6	5.2
10	5.8	6.6	5.7	6.7	4.1	5.3
11	5.2	4.8	5.6	5.7	4.4	4.8
12	6.2	6.5	5.6	6.7	3.1	5.2
13	4.3	4.7	6.1	8.0	2.7	5.6

Appendix C. Pilot Project

In conjunction with the seasonal migration objective, a pilot project was conducted to test methodologies for the livestock grazing portion of this thesis. Methods were similar to those in Chapter 2 with the exception of the grazing pressure indicator used. After the cattle were removed in October, above ground vegetation taller than 2 cm was clipped in the riparian zone (vegetation within 1.5 meters from the water's edge) in each exclosure and each control. The area to be clipped was delineated by a 1 m^2 Polyvinyl Chloride Pipe (PVC) frame that was randomly placed along the corridor of the aquatic zone. The removed biomass was then dried and weighed for analysis. The difference of biomass weights between exclosures and matched controls was used as a measurement of grazing pressure for this analysis (Table 3).

TABLE 3. Biomass Weights at Treatment Plots in September, 2003

	Treatment		
Plot	Exclosure (g)	Control (g)	Difference (g)
1	147.6	34.8	112.8
2	67.2	28.5	38.7
3	86.4	86.4	0
4	45	28.3	16.7
5	130.9	101.7	29.2
6	99.3	93.5	5.8
7	211.5	45.2	166.3
8	110.4	72.4	38
9	95.3	89.1	6.2
10	234.5	120.9	113.6
11	156.3	88.5	67.8
12	147	68.1	78.9
13	144.8	75.9	68.9

We captured 51 individual adult frogs and 36 were fitted with radio transmitters (18 males and 28 females). Logistic regression was performed in SAS® to estimate the proportion of time each frog spent in an exclosure compared to the control, and whether this proportion depended on difference of biomass between the treatments and controls.

There was suggestive, but inconclusive evidence that as biomass difference increased by one unit, the odds of finding a frog in the exclosure decreased by a factor of 0.98 ($F_{1,20}$=3.43, p=0.08) with an approximate 95% confidence interval of 0.97 to 1. We felt this technique of estimating grazing intensity was biased in that it did not account for frog preference early in the year when grazing was minimal or non-existent. We decided to use a 10-pin point frame in 2004 instead of biomass sampling because it was not destructive to the habitat, allowing us to sample throughout the season. The drawback of this technique is that the results of the 10-pin point frame are not easily transferable to management decisions regarding biomass removal and ultimately stocking rates.