

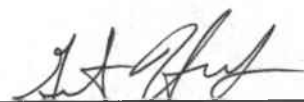
**Impact of Stream Corridors on Breeding Populations of
*Rana luteiventris***

Submitted in Partial Fulfillment of the Requirements for Graduation with
Honors to the Department of Natural Sciences at Carroll College, Helena,
Montana

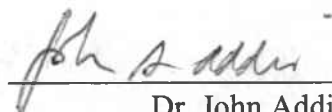
Fredrick James Bartoletti
April 10, 2000



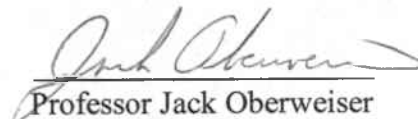
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Abstract

The biodiversity on Earth is in a state of decline. Because the full extent of the problem is not known, model systems are needed as environmental indicators.

Amphibians are considered good indicators of wetland ecosystems. Many authors have agreed that a key factor driving population dynamics in a fragmented landscape is the ability of animals to move between habitat fragments. I studied the effects that a stream corridor has on the patch occupancy of breeding populations of western spotted frog (*Rana luteiventris*). I quantified landscape and habitat parameters in both Lump Gulch and Gravelly Range landscapes. The Lump Gulch landscape consisted of wetlands connected by stream corridors, whereas the Gravelly Range landscape consisted of glaciated kettle ponds, with no stream connectance. The area of wetland sites and the distance between sites did not have an influence on the patch occupancy of the different landscapes. By eliminating these factors my results suggest that stream corridors significantly influence the distribution of *Rana luteiventris* by providing a means to occupy and reoccupy wetland sites. In essence, the stream corridors between patches are precious resources and it is imperative that we preserve these habitats which are a means of dispersal across landscapes.

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Introduction

Wilson (1988) estimated that there are approximately 1,392,485 described species on Earth, and between 5 and 30 million are still waiting to be discovered. Global biodiversity is most often defined as the number of species on Earth, although biologists also consider genetic and ecosystem diversity. With all of the living organisms in the world no two are genetically alike and no two function in an ecosystem in the same way. However biodiversity is currently declining. This decline is important in many ways. Exploding human populations are degrading the environment at an accelerating rate, especially in tropical countries, which are hosts to a large number of the existing species. Biodiversity is being lost through extinction caused by the destruction of natural habitats. This loss comes at a time when science is discovering new uses for our natural resources in ways that can relieve both human suffering and environmental destruction.

Because the full extent of biodiversity is not known but presumably extensive, biologists often focus on model systems that are hopefully representative of whole ecosystems. Amphibians are considered good indicators of wetland ecosystems for the following reasons: They live in definable habitats and are often locally abundant so they provide good sample sizes (Stebbins and Cohen 1995). Amphibian populations are especially prone to local extinction and recolonization processes (Wilbur 1984). Because amphibians are sensitive to both terrestrial and aquatic impacts, their thin permeable skin makes them susceptible to chemical changes in the environment. With the exception of terrestrial salamanders (Hairston 1987), breeding populations of many amphibians are spatially discrete and fluctuate strongly due to variation in factors that regulate populations of larvae, adults, or both (Gill 1978). Physiological constraints may further

render amphibians the animal taxon least able to cope with the environmental changes associated with habitat loss and fragmentation (Gibbs 1998). Furthermore, amphibians from many separated parts of the world seemed to be declining (Stebbins and Cohen 1995). For this reason, amphibians may well represent populations that are most dependent on the maintenance of dispersal connections and landscape linkages in human-altered environments. Therefore they are a good model system in the study of the biodiversity crisis.

There are many possible explanations as to why amphibians are declining. Because they are declining around the world, it is important to consider the global impacts. There are possible widespread atmospheric and climatic effects resulting from the increasing human pollution that may be affecting amphibians. The thinning of the ozone layer allows for an increase in the penetration of ultraviolet light. Blaustein et al. (1994) provided evidence that UV radiation in a temperate zone can contribute to amphibian population declines and some species are more susceptible than others. Dispersal of biocides and other chemicals, acid precipitation and global warming which result from increased atmospheric carbon dioxide and other gases are other possible answers to global decline (Stebbins and Cohen 1995).

There is also a wide range of human caused local effects. The direct use of biocides and pesticides, heavy metals, radioactivity, and the thousands of other chemicals released in the industrial age, habitat losses to crop agriculture, overgrazing, landfills, and other human development can all have an effect (Stebbins and Cohen 1995). On and off-road vehicle kills, deforestation, wetlands drainage, water diversion, pollution effects and water demands of mining and treated and untreated sewage, introduction of competitors

and predators, and gathering for human usage (Stebbins and Cohen 1995) all contribute to amphibian declines at the local level.

Impacts on a few local populations may threaten populations at a regional or metapopulation scale. A metapopulation is a population that is spatially subdivided into groups of local subpopulations that are connected by dispersal (Krohne 1997). A conceptually important assumption is that all local populations have a significant risk of extinction. The metapopulation is assumed to persist in a stochastic equilibrium between local extinctions and colonizations of suitable habitat patches (Moilanen and Hanski 1998). The probability of local extinction depends on a number of factors: population size via patch size, migration to and colonization of empty patches, and the way the spatial structure of the landscape is perceived by the organism (Brown and Kodric-Brown 1977).

Spatial variation in the environment can conceivably affect metapopulation dynamics in many different ways (Murphy et al. 1990). At the level of a single patch, habitat quality may affect both the probability of local extinction and the probability of the colonization of an empty patch. Landscape structure between the patches may affect the migration rate in general (Åberg et al. 1995), and it may affect the connectivity of particular pairs of patches (Wiens 1997). Therefore the regional population may persist while local populations are going extinct. Metapopulation studies are now becoming more diverse, with connections to other branches of ecology such as landscape ecology (Hanski and Simberloff 1997). A landscape approach may help assess the ability of a species to persist.

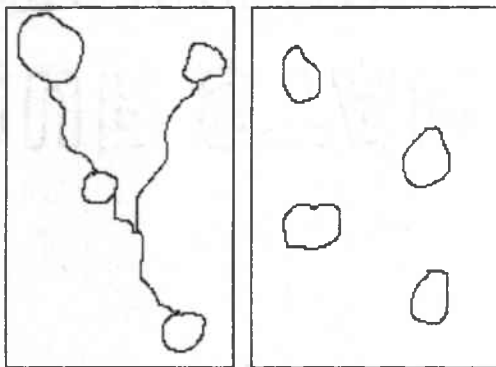
Landscape ecology is the study of the reciprocal effects of spatial pattern on ecological processes (Turner 1989); it promotes the development of models and theories of spatial relations, the collection of new types of data on spatial pattern and dynamics, and the examination of spatial scales rarely addressed in ecology. It regards spatial heterogeneity as a central causal factor in ecological systems, and it considers spatial dynamics and ecology's founding concern with the temporal dynamics of systems to be of equal importance (Pickett and Cadenasso 1995).

There are two major approaches to landscape ecology, reflecting differences in scale (Pickett and Cadenasso 1995). The most common approach is the elucidation of the interactions among the elements of a matrix, especially adjacent ones. This approach addresses the fine-scale mechanisms behind the dynamics and structure of the matrix. The second approach focuses on the coarse-scale dynamics and behaviors of the matrix as a whole. These two approaches are complimentary, and both recognize a spatial mosaic with discrete elements (Pickett and Cadenasso 1995). Landscape ecology has begun to determine the mechanisms behind the relations of spatial pattern and ecological processes.

Many amphibians breed in water but live a great portion of their lives in terrestrial habitats. These wetland habitats exist in a matrix of more upland habitat types. Therefore, wetlands are patchily distributed across a matrix of unsuitable habitat for amphibians. Little is known about these spatial mosaic habitats and how they influence amphibian metapopulations.

Many authors have suggested that a key factor driving population dynamics in a fragmented landscape is the ability of animals to move between habitat fragments. Gibbs

(1998) found that some amphibians will cross substantial areas of open land to reach breeding pools if not blocked by a physical barrier, and that streambeds acted as conduits for the movement of two of the four species of amphibians that he studied. I studied the effects that a stream corridor has on the patch occupancy of breeding populations of the western spotted frog (*Rana luteiventris*). Two wetland areas were compared. The Lump Gulch area consisted of a landscape of many local populations connected by streams (Fig. 1), which hypothetically would help in dispersal and maintain the viability of local populations. The Gravely Range area consisted of a landscape of many local populations that were completely isolated from each other (Fig. 1). These patches were kettle ponds that had no inlet or outlet streams, and this would hypothetically make dispersal more



difficult for amphibians.

Figure 1. Drainage basin with ponds connected by streams as in Lump Gulch (left), and kettle landscape with no stream connectance as in the Gravely Range.

I compared patch (wetland) occupancy patterns on these two landscapes to assess the importance of stream corridors to *Rana luteiventris* metapopulations. I wanted to test whether or not the stream corridors had an influence on the distribution of *Rana luteiventris*.

Materials and Methods

I quantified landscape and habitat parameters in both Lump Gulch and Gravely range landscapes. The Lump Gulch landscape consisted of drainage basins connected by stream corridors. The Gravely range landscape consisted of glaciated kettle ponds, which have no stream connectance.

The habitat type was recorded as permanent or temporary lake/pond, marsh or spring, and origin (man made, beaver, or natural). The maximum depth of the site was measured and recorded as greater or less than two meters. Then I made a visual scan of the area looking for an inlet/outlet stream and the order of the stream according to the topographical map. First order streams have no tributaries, second order have tributaries that are only first order, etc.

I made a visual inspection of the site by walking the perimeter of the wetland area and quantified the number of individuals of each herp species (adults, larvae, or egg masses), or fish. While making the visual inspection the maximum diameter of the north/south and east/west axis were taken using a range finder and a compass. The formula $(d_1/2+d_2/2)/2=r$ was used to calculate the average radius, where d_1 and d_2 refer to the north/south and east/west diameters respectively. The formula πr^2 was then used to calculate the total area. If the site had a large portion greater than one meter deep then the deep-water area was measured and subtracted from the total area to give an area of water less than one meter deep.

While walking the perimeter the substrate type and littoral vegetation were sampled randomly using a 0.25m^2 grid in each of four quadrates (NW, NE, SW, SE). One grid sample was taken per quadrate for all sites where the maximum diameter was

less than 10 m. At sites where the maximum diameter was between 10-20m, two grid samples were taken per quadrant, and for sites with a maximum diameter greater than 20m three grid samples were taken per quadrat. Grids were divided into 100 equal size cells and substrate and vegetation were categorized for each cell. I classified substrate categories as follows: fine inorganic (<0.5mm), sand (0.5-2mm), small gravel (3-10mm), large gravel (11-100mm), cobble (101-300mm), boulder (>300mm), bedrock (unbroken), muck (fine organic <1mm), coarse detritus (5-50mm), wood (>50mm). Littoral vegetation types were classified as free-floating plants, rooted floating plants, emergent plants, and submergent plants. After the plant type and substrate were recorded, a count of the number of cells occupied by each substrate and plant type was recorded.

I used a meter tape laid out three meters perpendicular from the shore to classify riparian vegetation in each of the four quadrates. All serial classes of plants were recorded along the intercept length to the nearest cm. The Riparian classes included: grass, forb, deciduous shrub/sapling, coniferous shrub/sapling, deciduous tree, and coniferous tree. The type and distance of the nearest tree from each quadrant (one per quad) was measured.

Percent coverage estimations for each sampling location for each quadrat were summed and divided by the total number of sampling locations for the site. This was done for substrate, littoral, and riparian habitat data. Distance between sites was calculated using UTM coordinates from a GPS unit and the Pythagorean principle.

I compared the Lump Gulch landscape with the Gravely range landscape with respect to the number of breeding populations of *Rana luteiventris*. To eliminate the possibility that anything other than stream corridors could explain breeding patterns, I

used a Mann-Whitney U test to calculate Z statistics to compare the following landscape attributes: total wetland area, distance to nearest neighbor (di), and distance to nearest occupied neighbor (do). I used this non-parametric analysis for all tests because of heterogeneity invariance for the emergent and submergent vegetation calculations. The software program STATISTICA was used for all statistical analysis.

Results

Breeding patch occupancy for *Rana luteiventris* in the Lump Gulch and Gravely Range wetland were very different. The Lump Gulch drainage had 12 occupied sites out of 12 sites. In contrast the Gravely Range had only 3 occupied sites out of 12.

Wetland area was not significantly different between the two landscapes (Table 1).

Table 1. Z statistic and p value comparing area (m²), distance to nearest neighbor (Di) (m), and distance to nearest occupied neighbor (Do) (m) of the Lump Gulch and Gravely range areas.

Variables	Z Statistic	p Value
Area	1.73	0.08
Di	4.04	<0.001
Do	2.71	0.006

A slight but not significant difference was observed in the areas of the two wetland locations (Fig. 2). On the other hand there was statistically significant differences between the Lump Gulch and Gravely range locations in both distance to the nearest neighbor (Di), and in the distance to the nearest occupied neighbor (Do), (Table 1, Fig. 3, Fig. 4).

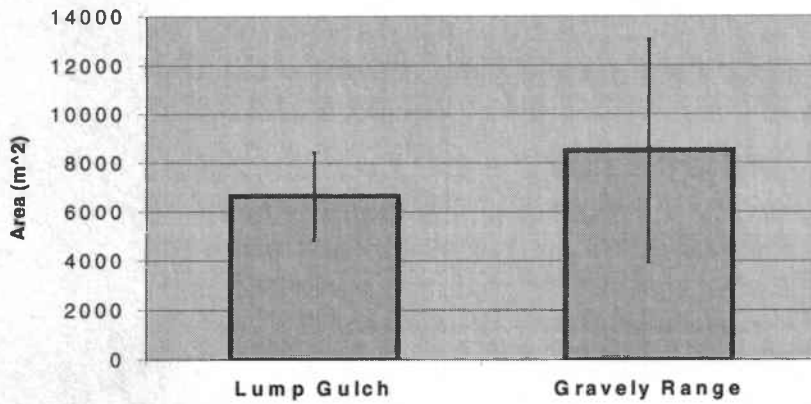


Figure 2. Comparison in the areas of the wetland patches in the Lump Gulch Drainage and in the Gravely Range. Non-significant results shown by overlapping bars.

Table 2. Adjusted Z statistic and p Value comparing the means of emergent and submergent vegetation in the Lump Gulch and Gravely Range areas.

Variable	Adjusted Z*	p Value
Emergent	0.866	0.39
Submergent	0.433	0.664

* Mann-Whitney U-test

There was no statistically significant difference in the mean values of emergent or submergent vegetation between the two locations (Table 2, Fig. 5, Fig. 6).

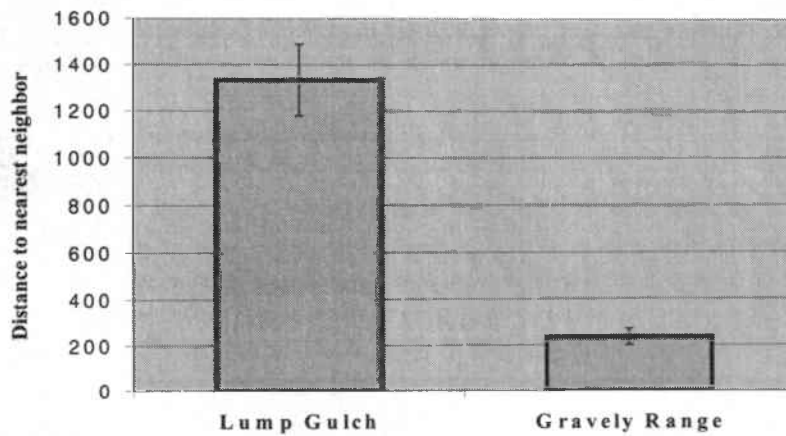


Figure 3. A comparison between the differences in the distance to the nearest neighboring patch in the Lump Gulch drainage and the Gravely Range. Significance is indicated by non-overlapping bars.

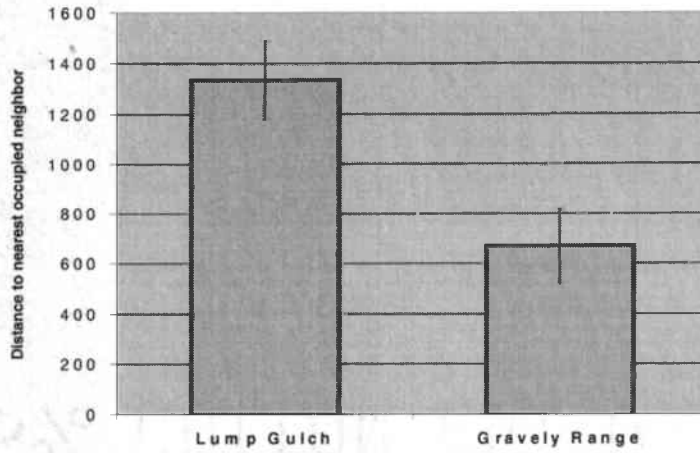


Figure 4. A comparison between the distance to the nearest occupied neighbor in the Lump Gulch drainage and in the Gravely Range wetland sites. Significance is indicated by non-overlapping lines.

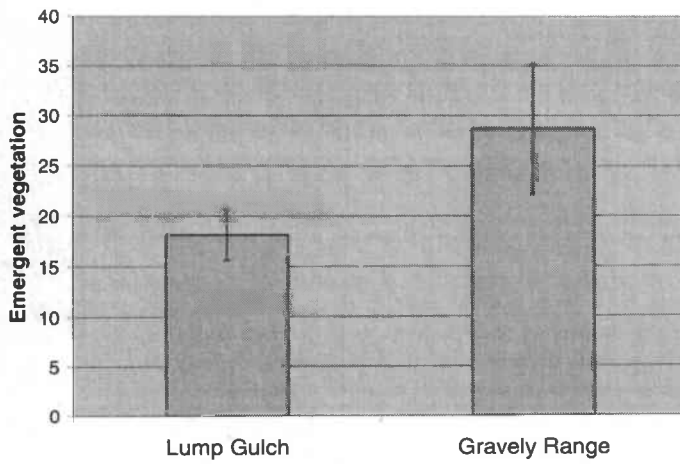


Figure 5. Comparison between the differences in mean value of emergent vegetation between the Lump Gulch and Gravely range.

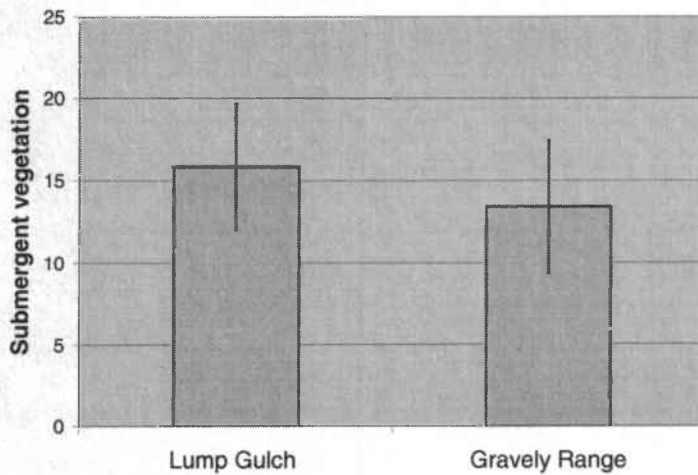


Figure 6. Comparison between the differences in mean value of submergent vegetation between the Lump Gulch and Gravely range.

Discussion

My results suggest that stream corridors significantly influence the distribution of *Rana luteiventris*. Breeding populations were more prevalent in the stream connected Lump Gulch landscape than in the glaciated kettle ponds of the Gravely Range landscape. Although patch area and isolation may also influence occupancy patterns (Hokit et. al 1999), there was little difference in wetland size between the two landscapes. Isolation measured as the distance to the nearest patch and the distance to the nearest occupied patch, was significantly different between the two landscapes. However, both measures were significantly smaller in the Gravely Range than in the Lump Gulch landscape. This suggests that patches in the Gravely Range landscape should be less isolated than patches in the Lump Gulch landscape (barring the effects of corridors).

By eliminating area, and isolation as factors contributing to the difference in patch occupancy, I suggest that the difference in connectivity was the factor determining

occupancy patterns. This suggests that stream corridors connecting wetland patches provide a means of dispersal for *Rana luteiventris*, and help maintain breeding populations in each wetland site or patch. In the Gravely Range landscape there was no obvious topographic features that surrounded the individual sites, therefore the amphibians that emigrate out of these ponds would likely travel in random directions to look for new breeding sites. Traveling in random direction reduces the probability of finding new patches due to predation, and desiccation. This may explain why in the Gravely range only three of twelve wetland sites were occupied by breeding populations of *Rana luteiventris*. On the other hand the Lump Gulch drainage had interconnecting streams to act as corridors to guide migrating amphibians. This would allow for a much higher occupancy of different patches, and would explain why in the Lump Gulch drainage all twelve wetland sites were occupied by breeding *Rana luteiventris*.

As the landscape scale is expanded or if connectivity decreases, patch densities appear to reflect processes that affect survival and persistence of populations (Bowers et al 1997). Gibbs (1998) found that streambeds act as conduits for the movement of some species of amphibians, while other species are unaffected. Streambeds provide a moist microenvironment that would aid in travel and provide better cover and protection from desiccation and the predators of the area. *Rana luteiventris* is highly aquatic, and described as occurring near quiet permanent water, and with vegetation that indicates a permanent water source (Munger et al 1997). These studies support my findings that streambeds do act as corridors between patches.

Issues of landscape permeability have been examined for many animal taxa. Oxley et al. (1974) found that roadways inhibit the movements of small forest animals.

Munguira and Thomas (1992) found that blockages such as roadways slightly impeded species with closed populations. Gibbs (1998) found that some amphibians will cross substantial areas of open land to reach breeding pools if not blocked by a physical barrier, and that streambeds acted as conduits for the movement of two of the four species of amphibians that he studied. All of the results of these studies are similar to those for *Rana luteiventris*. This suggests that corridors between patches are important for the persistence of amphibian populations. If stream corridors were destroyed or degraded, I predict that the Lump Gulch wetland landscape areas would develop occupancy patterns similar to the Gravely Range landscape.

Relatively little is known about *Rana luteiventris* dispersal behavior. To gain better understanding of the dispersal of *Rana luteiventris*, future large-scale dispersal studies are needed. Also future studies may further examine the habitat differences between landscapes and assess the effects of such habitat differences on dispersal behavior.

Regardless, my study demonstrates the importance of stream corridors for *Rana luteiventris*. These streams may also be important for other amphibian species. Because the presence of corridors may influence the persistence of a species across a landscape, it is imperative that such habitat be preserved.

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