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Livestock effects on reproduction of the Columbia spotted frog

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Abstract

We evaluated reproduction and recruitment of the Columbia spotted frog (*Rana luteiventris* Thompson) in 70 ponds used by beef cattle and in 57 ponds not used by beef cattle in northeastern Oregon. No significant differences were detected in the number of egg masses or recently metamorphosed frogs in grazed and ungrazed sites. No pond characteristic measured could predict egg mass numbers, but percent aquatic vegetation and dissolved oxygen had some ability to predict recently metamorphosed frog numbers. Both variables explained 65% of the variability in recently metamorphosed frog numbers in grazed ponds. At ungrazed ponds, 4 additional variables (presence of fish, elevation, percent of rock, and conductivity) were required to achieve the same level of variability in predicting recently transformed frog abundance. The egg mass volume was larger at grazed than at ungrazed ponds suggesting that grazed ponds may have a greater food abundance or larger (older) individuals.

Key Words: livestock grazing, northeastern Oregon, *Rana luteiventris* Thompson

Resumen

Evaluamos la reproducción y la iniciación de la rana "Columbia spotted" (*Rana luteiventrisi* Thompson) en 70 estanques utilizados por ganado bovino para carne y en 57 estanques no utilizados por bovinos para carne localizados en el nordeste de Oregon. No se detectaron diferencias significativas en el numero de masas de huevecillos o de ranas recientemente metamorfoseadas entre los sitios con y sin apacentamiento. Las características de los estanques que fueron medidas no pudieron predecir el numero de masas de huevecillos, pero el porcentaje de vegetación acuática y el oxigeno disuelto tienen cierta capacidad para predecir los números de ranas recientemente metamorfoseadas. Ambas variables explicaron el 65% de la variabilidad de ranas recientemente metamorfoseadas en los estanques de sitios con apacentamiento. En estanques de sitios sin apacentamiento, 4 variables adicionales (presencia de peces, elevación, porcentaje de rocas y conductividad) se requirieron para lograr el mismo nivel de variabilidad para predecir la abundancia de ranas recientemente transformadas. El volumen de la masa de hevecillos fue mayor en los estanque de sitios con apacentamiento que en los de sitios sin apacentamiento, lo que sugiere que en los estanques de áreas con apacentamiento puede haber una mayor abundancia de alimento o individuos mas viejos.

Global amphibian declines have precipitated the need to determine the status of many amphibian populations and identify factors influencing those populations. The recently described Columbia spotted frog (*Rana luteiventris* Thompson) (Green et al. 1997) is known to reproduce in and occupy aquatic habitats associated with riparian zones (Turner 1960) and has experienced some declines within its range (Hovingh 1993, Munger et al. 1996). Grazing is a prominent feature in many of these aquatic ecosystems, including northeastern Oregon (Kauffman et al. 1983, Green and Kauffman 1995). The influence of livestock on the physical characteristics (Bohn and Buckhouse 1986), vegetation (Roath and Krueger 1982, Sedgewick and Knopf 1991, Allen and Marlow 1994), fishes (Platts 1981), and avifauna (Thomas et al. 1979, Mosconi and Hutto 1982) in riparian ecosystems is reasonably well studied and could influence spotted frog habitat. Beyond discussions of potential impacts (Horusp et al. 1993, Jennings and Hayes 1994, Hayes 1997), the influence of livestock on amphibians has been only recently addressed. In southwestern Idaho, Munger et al. (1994) found that sites with adult Columbia spotted frogs had significantly less grazing pressure than sites without spotted frogs, but he found no differences in a subsequent year (Munger 1996).

This paper describes our preliminary assessment of the relationship between grazing and the Columbia spotted frog in northeastern Oregon. Using the number and volume of egg masses and number of recently metamorphosed juveniles to assess spotted frog reproduction and recruitment, respectively, we measured biotic and abiotic variables at 127 breeding sites of Columbia spotted frogs to determine differences between grazed and ungrazed sites.

Methods

Egg Masses (Reproduction)

We searched for Columbia spotted frog breeding sites in 5 major watersheds (Grande Ronde River, Eagle Creek, John Day River, Malheur River, and Wallowa River) in Union, Umatilla, Baker, Grant, and Wallowa counties. Spotted frogs were known

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to occur in these watersheds based on historical records (Ferguson 1952, 1954; Ferguson et al. 1958; unpublished data on file at Pacific Northwest Research Station, La Grande, Ore.). We selected specific watersheds to search based on several criteria: presence of a perennial stream with quiet water in the form of ponds, marshes, and backwaters nearby; streams with a wide valley bottom (< 10% gradient) and open meadows adjacent to coniferous forests (forest types of ponderosa pine [*Pinus ponderosa* Dougl. ex Laws], lodgepole pine [*P. contorta* Dougl. ex Loud], or mixed conifer); within 2 km of a road; and on public land or on private land for which we had permission to search. Beef cattle grazing occurred in some of each watershed sometime between June and October, although significant portions of each watershed were currently ungrazed. Grazing systems had typically been in place within each watershed for at least 5 years.

We searched for egg masses between 22 March and 20 May 1997. The date a particular site was searched depended on water temperature. We conducted 1 search at each site when the water temperature exceeded 8°C, which was the water temperature above which successful embryonic development could occur (Johnson 1965). Each site with eggs was revisited weekly to count egg masses until no additional egg masses were recorded in 2 successive visits. Eggs hatched in 13–23 days, depending on the water temperature (Morris and Tanner 1969). The number of egg masses at each breeding site were counted if individual masses could be distinguished. The length, width, and depth of individual masses were measured to estimate their volume. Egg masses that occurred in the same stream but were in separate bodies of water (where larvae could not interact) were considered independent samples.

Only standing water or very slowly moving water was searched for egg masses and adults by walking along the edge of the stream and checking all oxbows, backwaters, pools, marshy areas, and adjacent ponds using a modified form of the basic visual-encounter survey (Scott and Woodward 1994, Thoms et al. 1997). Searches were focused in shallow water (< 30 cm) because Columbia spotted frog egg masses occur in these situations (Turner 1960, Morris and Turner 1969, Hovingh 1993, Munger et al. 1996).

We classified each site as a *pond excavated for livestock or wildlife, gravel pit, dredge tailings, marsh, oxbow, beaver pond,* or *other*. We recorded *elevation, surface area of breeding site* (m^2), *maximum water depth* (m), and *distance to a permanent stream*. Substrate of the pond was identified as *mud, cobble,* or *stone*. The percent of water surface area that contained *algae, suspended vegetation,* and *open water* were recorded at each site. Ground cover within 2 m of the pond edge was recorded as the percent of *grass, shrub,* or *rock*. The presence of *beavers* (*Castor canadensis* Linnaeus) was noted.

Recently Metamorphosed Individuals (Recruitment)

We selected 54 of the 127 breeding sites based on accessibility and grazing activity to assess frog recruitment; 29 were ungrazed, and 25 were grazed sites. We searched for recently metamorphosed individuals between July and September by walking the perimeter of each breeding site and counting juvenile frogs seen in water or on land. Searches continued at 1-week intervals until metamorphs were no longer metamorphosing. The maximum number of recently metamorphosed juveniles at each site was used for the analysis.

In August, we recorded the same habitat characteristics measured during the spring. Water quality variables (pH, conductivity, nitrates, and dissolved oxygen) were measured at each site. Duration and intensity of grazing varied considerably among sites, so evidence of livestock activity was recorded in 3 ways: degree of utilization, number of dung pats, and trampling (hoofprint density). All 3 characteristics were given a rating from 0 to 3 with 0 = none, 1 = slight evidence, 2 = moderate evidence, and 3 = extensive evidence.

To determine abundance of potential predators, we recorded the number of garter snakes observed at ponds on each visit but used the maximum number recorded on any visit as the independent variable. The presence and kind of fish were recorded. We sampled aquatic invertebrates by taking 8 sweeps with a dip net at each site and counting leeches (Hirudinea), giant water bugs (Homoptera: Belostomatidae), diving beetles (Coleoptera: Dytiscidae), and backswimmers (Homoptera: Notonectidae).

Analyses

Mann-Whitney tests (Conover 1980) were used to compare the number of egg masses, volume of egg masses, number of recently metamorphosed individuals, and ratio of recently metamorphosed individuals per egg mass in grazed and ungrazed sites. Nonparametric Spearman's rank correlations (Conover 1980) were used to determine the relationship between number of egg masses and elevation for all sites and for grazed and ungrazed sites. Simple linear regressions were used to compare: (1) number of egg masses and elevation for grazed and ungrazed sites, (2) mean egg mass volume and elevation for grazed and ungrazed sites, and (3) mean egg mass volume and elevation for sites with ≥ 3 egg masses at grazed and ungrazed sites. Kruskal-Wallis nonparametric ANOVAs (Conover 1980) were used to compare number of egg masses, mean egg mass volume, number of recently metamorphosed juveniles, and the ratio of recently metamorphosed juveniles per egg mass among pond types. The habitat characteristics that best predicted number of egg masses and abundance of recently metamorphosed juveniles were identified using a stepwise logistic regression using all ponds combined, only grazed ponds, and only ungrazed ponds.

Results and Discussion

We located 127 Columbia spotted frog breeding sites across a 5-county area in eastern Oregon. Seventy (55%) ponds were grazed by cattle; the remaining 57 (45%) were ungrazed. Thirty-nine percent of the breeding sites were *dredge tailing ponds*, 24% were *oxbows*, 17% were *excavated for livestock* or *wildlife*, 14% were *marshes* near streams, 3% were created by *beaver dams*, 2% were in *gravel pit ponds*, and 1% was a natural spring-fed pond. Breeding sites were typically small; 92% had a surface area <2,500 m^2 and only 8% were 2,500-30,000 m^2. Thirty-four percent of the ponds were <1 m deep while the remainder were 1-5 m deep. All ponds had a fine benthic substrate (mostly mud).

Egg Masses

The number of egg masses at grazed sites was not statistically different from the number at ungrazed sites (Table 1). Breeding sites occurred between 922 and 1,860 m in elevation. The elevational distribution of grazed and ungrazed ponds differed primarily because all grazed sites were below 1,500 m. At grazed sites there was a weak, but significant inverse correlation ($p = 0.03$, adjusted $r^2 = 0.06$) between number of egg masses and elevation. At ungrazed sites, a weak but significant positive correlation ($p = 0.05$, $r^2 = 0.05$) existed between number of egg

Table 1. Mean values, standard errors, and ranges of independent and dependent variables measured at Columbia spotted frog breeding ponds in northeastern Oregon, 1997.

		Ungrazed			Grazed	
Variable	N	$\bar{x} \pm$ SE	Range	N	$\bar{x} \pm$ SE	Range
Dependent						
No. egg masses	58	6.9 ± 2.34	1–25	65	6.9 ±2.52	1–30
Egg mass volume (cm^3)*	41	762 ± 18.44	340–1,872	55	888 ± 19.8	261–2,142
Egg mass volume at sites < 1,200 m (cm^3)*	9	688 ± 165.3	340–1,872	29	954 ± 77.7	261–2,172
No. transfomed frogs	29	57 ± 20.62	0–563	25	39 ± 10.15	1–230
Independent						
Elevation (m)	58	1,317 ± 24.67	922–1,860	68	1,184 ± 16.78	940–1,470
Surface area (m2)	55	1,434 ± 546.67	8–30,000	68	1,079 ± 323.42	12–19,872
Water depth (m)	54	1.5 ± 0.27	0.5–5	67	1.2 ± 0.11	0.2–5
Distance to stream (m)	58	80 ± 26.93	0–1,000	48	61 ± 15.01	0–600
Aquatic vegetation (%)	56	44 ± 4.07	0–100	68	47 ± 3.98	0–100
Algae (%)	56	11 ± 2.64	0–80	68	10 ± 2.24	0–80
Cattails (%)*	29	7 ± 2.09	0–40	25	4 ± 2.82	0–60
Utilization[1]*	47	0 ± 0.02	0–1	66	1.3 ± 0.11	0–3
Trampling[1]*	49	0.2 ± 0.08	0–1	67	0.9 ± 0.12	0–3
Dung pats[1]*	49	0.1 ± 0.06	0–1	68	1.3 ± 0.09	0–3
pH	29	8.2 ± 0.16	6.0–10.6	23	8.1 ± 0.20	6.6–10.4
Conductivity (µS/cm)	29	151 ± 15.48	14–376	25	144 ± 16.28	59–473
Nitrates (ppm)	29	0.1 ± 0.1	0.1–0.1	25	0.1 ± 0.01	0–0.1
Dissolved oxygen (ppm)	29	7.7 ± 0.70	1.0–16.0	25	6.2 ± 0.79	1.0–16.2

* Significant at $p < 0.05$.
[1]These variables were coded from 0 to 3, indicating relative abundance of each variable.

masses and elevation. Number of egg masses did not differ among pond types. Egg mass volume differed significantly between grazed and ungrazed sites (Mann-Whitney U: Z = –2.07, p = 0.04) (Table 1). No relationship existed between mean egg mass volume and elevation for either grazed or ungrazed sites. Because of variability in egg mass volume and at many sites only one egg mass was available to measure, we compared the relationship between mean egg mass volume and elevation at sites where 3 or more egg masses were measured. A significant relationship was displayed between mean egg mass volume and elevation for both grazed (p = 0.02, adjusted r^2 = 0.15) and ungrazed sites (p < 0.01, adjusted r^2 = 0.24) with volume increasing with elevation. Because egg mass size increased with elevation and more grazed sites were present at lower elevations, we compared egg mass size at all sites and at sites with 3 or more egg masses at or below 1,200 m and above 1,200 m. The only significant comparison was between grazed and ungrazed sites at or below 1,200 m (Mann-Whitney U: U = 69, U' = 192, p = 0.03).

The larger egg mass volume at grazed sites suggests that grazing did not have a negative effect, in addition to our observation that 6 of the 8 most productive sites (≥ 20 egg masses) were grazed. Because grazed sites were below 1,500 m, we considered the possibility that variation in egg mass volume might be influenced by elevation. The possibility of such a confounding factor was rejected because the data showed that egg mass volume increased with elevation. Larger egg masses may reflect larger females (Corn and Fogelman 1984), which could be a result of a more abundant food supply or an older population structure (Turner 1960).

No pond characteristics measured satisfactorily predicted the number of egg masses. The stepwise logistic regression selected elevation, percent aquatic vegetation, and percent open water as able to achieve a maximal predictive value of only 7% of the total variability.

Recently Metamorphosed Frogs

Neither the number of recently metamorphosed frogs nor the ratio of recently metamorphosed frogs to number of egg masses was significantly different between the 25 grazed and 29 ungrazed sites (Table 1). There were also no significant differences between grazed and ungrazed sites in water characteristics (dissolved oxygen, nitrates, pH, and conductivity). However, correlation analysis revealed that numbers of recently metamorphosed frogs were inversely correlated with the presence of fishes (Spearman's Rank, ρ = -0.41, p = 0.0028) for all sites. Longnose dace (*Rhinichthys cataractae dulcis* Valenciennes) and rainbow trout (*Oncorhynchus mykiss* Walbaum) were identified at the breeding sites with fish. Inverse correlations between frog larvae and fish have been demonstrated often (Hayes and Jennings 1988, Bradford 1989, Bradford et al. 1993) and may be reflected by the inverse correlation between recently metamorphosed frogs and fish in this study.

Numbers of recently metamorphosed frogs were positively correlated with garter snakes (Spearmans's Rank, ρ = 0.52, p < 0.01) for all sites. The common garter snake (*Thamnophis sirtalis* Linnaeus) and the wandering garter snake (T. *elegans vagrans* Baird and Girard) were present in about equal proportions at the ponds. Garter snakes were observed preying on recently metamorphosed frogs at several sites. Most of the predation by garter snakes occurred after or during metamorphosis, and after we had obtained our highest counts of frogs. It is likely that ponds with high numbers of metamorphosing frogs attracted more snakes than ponds with low numbers of frogs.

In comparisons of habitat variables between grazed and ungrazed sites, only percent cattails (Mann-Whitney U: Z = -2.37, p = 0.02), utilization (Z = -4.55, p < 0.01), trampling (Z = -4.97, p < 0.01), and dung pat density (Z = -5.01, p < 0.01) were significantly different (Table 1). A correlation analysis revealed that percent of cattails was positively correlated with pond size (Spearman's Rank, ρ = 0.37, p < 0.01).

Selected habitat characteristics were successful predictors of the abundance of recently metamorphosed frogs. For all 54 ponds, 5 variables were retained in the analysis with percent aquatic vegetation explaining 25% of the variability; the remaining 4 variables (dissolved oxygen, elevation, utilization, and pond depth) explained another 16% of the variability. In ungrazed ponds, 6 variables (fish, percent aquatic vegetation, elevation, percent of rock on shore, dissolved oxygen, and conductivity) explained 65% of the variability. In grazed ponds, percent aquatic vegetation explained 35%, and dissolved oxygen explained 30% of the variability. Percent aquatic vegetation and dissolved oxygen were the only variables that were retained in all models (combined, grazed, and ungrazed).

Percent aquatic vegetation, dissolved oxygen, and presence of fish all contributed significantly to predict the abundance of recently metamorphosed frogs, which may reflect a fundamental aquatic vegetation effect. Aquatic vegetation is known to provide shelter for frog larvae and metamorphs from fish and other predators (Licht 1969). Levels of dissolved oxygen are directly linked to coverage of aquatic vegetation (Carpenter and Lodge 1986).

Conclusions

These data failed to reveal that grazing had a negative effect on reproduction and recruitment of the Columbia spotted frog in northeastern Oregon. The high variability in the results of this study may be linked to the breadth of the grazing variable encompassing a broad range of conditions in landform features, water quality, vegetation, predators, and invertebrates. Future studies need to pay particular attention to measuring grazing intensity and timing to detect potential effects on Columbia spotted frogs.

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