Oviposition Ecology of the Oregon Spotted Frog at Beaver Creek, Washington

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EXECUTIVE SUMMARY

Wetlands in the floodplain of Beaver Creek, a Thurston County tributary to the Black River, support one of only four known Oregon spotted frog (*Rana pretiosa*) populations in Washington. To better understand the habitat requirements of this state-listed endangered species, oviposition (egg-laying) sites were located and characterized through measurement of water depth, temperature, and vegetation composition and structure. For comparison, available habitat nearby was similarly characterized.

The winter period of 2000-2001 prior to oviposition was one of the three driest in the past 20 years. As a result, shallow surface waters were limited and most of the surface water available to frogs was in areas that normally hold water through most of the year. In these conditions, we observed unusually high embryonic survival because water levels did not recede and leave eggs exposed to freezing or drying conditions.

Eleven oviposition sites composed of 58 egg masses were found. The two sites with the majority (59%) of the egg masses were both disturbed sites. One had been treated by mechanical removal of all vegetation the previous summer. The other was in the tracks of an off-road vehicle that had driven through the wetland about two years prior. Most oviposition occurred in a narrow range of water depth averaging 5.9 cm (2.3 in). Daytime surface water temperatures at the time of oviposition averaged 16.0° C. (60.8°F.). However, the initiation of breeding activity may have been related to gradual warming of the more stable subsurface waters where spotted frogs appear to spend the majority of their time during late winter. Here, water temperatures averaged $7-9^\circ$ C. ($45-48^\circ$F.) on days when oviposition was initiated.

Oregon spotted frogs selected areas with low vegetation dominated by reed canarygrass or, less frequently, slough sedge. Vegetation structure was either cropped low or pressed flat by vehicle tires or the elements (wind and snow), conditions which allowed full exposure of the water's surface to the sun. Floating or submerged vegetation did not deter oviposition by spotted frogs but emergent vegetation, which projected over the water's surface, was avoided.

INTRODUCTION

The Oregon spotted frog (*Rana pretiosa*) is listed as endangered in the State of Washington. The Oregon spotted frog population at Beaver Creek in Thurston County is one of two populations in the Black River watershed, populations which are believed to be distinct though knowledge of the geographic extent of these two populations is incomplete. The other Thurston County population, perhaps best referred to as the Dempsey Creek/upper Black River population, has been studied extensively (Watson and others 2000) though new subpopulations were discovered in 2001. The Beaver Creek population was included in this study of oviposition ecology and breeding habitat use in concert with similar investigations at Dempsey Creek/upper Black River and Trout Lake in Klickitat County. Washington Department of Fish and Wildlife, Washington Department of Transportation, and The U.S. Fish and Wildlife Service provided funding for this study.

METHODS

Study Area

This study was conducted in wetlands on property known as the old Pacific Powder site, formerly an explosives manufacturing site which is currently owned by Citifor Corporation. The Citifor parcel, located 3 miles northwest of the town of Tenino in Thurston County, Washington, is part of the Black River watershed, which is a tributary of the Chehalis River. Beaver Creek, which drains the Citifor parcel, is a complex of emergent marsh, stream, beaver pond, drainage ditch, and riparian habitat bordered by glacial outwash prairie and forest at 220 feet elevation in the Puget Sound lowlands of Washington (Figure 1).

The Field Effort

Our investigation focused on emergent wetland habitats, and these habitats were dominated by herbaceous vegetation, though patches of scrub-shrub (hardhack and willow) and forested (alder and conifers) habitats were also present in some areas. Species of grasses, sedges (*Carex* sp.), and rushes (*Juncus* sp.) were the dominant plants in the breeding habitats we studied.

Figure 1. Study area with oviposition locations labeled, Beaver Creek Washington.

The field portion of the study began with deployment of temperature loggers in January of 2001. Retrieval of temperature loggers marked the end of the field component on May 9, 2001. Our goal was to locate all oviposition sites within a 30-acre former agricultural field drained by ditches, and as many oviposition sites as possible in other areas of the Beaver Creek floodplain wetlands. The former agricultural field was the study site for Heather White's master's thesis investigating the influence of vegetation height on Oregon spotted frog breeding habitat selection. Her experiment involved 32 treatment circles randomly located within 30 m of oviposition sites identified in previous years. In treatment circles, all vegetation was removed using a brush cutter. Each treatment circle had a paired control circle adjacent to it. Those treatment and control circles that achieved suitable water depths (meaning there were areas where the water was less than 8 cm deep) by mid-January were equipped with Stowaway Tidbit® (Onset Computer Corporation) temperature loggers. These temperature loggers were advertised as being accurate to within $0.2\ ^{\circ}$C., and functional within a range from -4 to $37\ ^{\circ}$C. We set the loggers to store a temperature once per hour, on the hour. Once frogs started laying eggs, we placed additional temperature recorders under three of the communally laid clusters of egg masses. Daytime mean temperatures were calculated from the twelve temperature values logged during the interval 0700 to 1800.

Heather's work necessitated finding all oviposition sites in her study area. In addition, she used Gee's Crayfish traps to trap and mark frogs as part of a population assessment. Egg mass searches began on the same day that traps were initially set, 20 February. From this date on, searches for eggs occurred every day, until 25 March.

We conducted walking surveys throughout the previously identified breeding habitats to look for freshly laid spotted frog egg masses. We measured a variety of variables at sites where spotted frogs laid eggs (i.e., use sites) to characterize the habitats associated with these sites and we tracked the hatching success of the egg mass(es). We also collected similar data from plots that represented habitat availability, to assess habitat selection by spotted frogs. When egg masses were located we would collect data on the number of egg masses, their stage of development, and a number of site characteristics (e.g., water temperature, water depth, vegetation structure) around the egg mass(es) and in a 1m x 1m use plot. Site characteristic measurements were also taken at the four corner plots of a larger plot (5m x 5m; centered on the use plot) that served as an assessment of habitat availability (i.e., availability sites). Vegetation structure was characterized using four structural descriptors. "Emergent" described vegetation rooted in the substrate and growing vertically through the water column. "Submergent" described vegetation wholly beneath the water's surface. "Floating" described vegetation that floated on the water's surface. Lastly, "prostrate" described vegetation rooted in the substrate but laid over horizontally. These four structural types were not always clearly mutually exclusive and were applied according to a judgement of the "best fit" for the vegetation being classified.

After establishing a use plot, we would revisit each use plot to assess changes in the number of egg masses present, egg mass development according to a generalization of stages from Gosner (1960), embryo mortality, and site conditions such as water temperature and depth. Our characterization of developmental stages lumped Gosner stages 1-5 into early development, stages 6-18 into mid development, and stages 19 and beyond into the hatched category. Revisits at most sites were conducted until the eggs hatched.

Rainfall

The winter of 2000-2001 proved to be one of the driest on recent record (Table 1). Over the past 20 years, only one winter (1984-5) had lower rainfall during the three months that normally precede the egg-laying period (Dec.-Feb.), though the winter of 1992-3 had nearly identical rainfall during this period. As a result, there was little to no water in areas that typically had pools of shallow surface water.

Table 1. Twenty years of rainfall data, cm (in), from the Olympia Airport, 5 miles north of the study area (WRCC web site).

Winter	Dec	Jan	Feb	Mar	Apr	Three Mo. Total (Dec-Feb)	Five Mo. Total (Dec-Apr)
1981-2	21.8 (8.6)	19.8 (7.8)	25.1 (9.9)	11.9 (4.7)	9.9 (3.9)	66.8 (26.3)	88.6 (34.9)
1982-3	26.9 (10.6)	25.4 (10.0)	18.0 (7.1)	16.8 (6.6)	5.8 (2.3)	70.4 (27.7)	93.0 (36.6)
1983-4	18.5 (7.3)	17.8 (7.0)	14.0 (5.5)	16.3 (6.4)	9.4 (3.7)	50.0 (19.7)	75.2 (29.6)
1984-5	12.7 (5.0)	0.8 (0.3)	8.9 (3.5)	10.4 (4.1)	6.6 (2.6)	22.4 (8.8)	39.4 (15.5)
1985-6	6.4 (2.5)	30.7 (12.1)	17.3 (6.8)	5.8 (2.3)	7.4 (2.9)	54.6 (21.5)	67.6 (26.6)
1986-7	13.2 (5.2)	21.3 (8.4)	9.1 (3.6)	18.0 (7.1)	7.9 (3.1)	43.4 (17.1)	69.6 (27.4)
1987-8	23.1 (9.1)	13.2 (5.2)	6.1 (2.4)	14.5 (5.7)	12.4 (4.9)	42.4 (16.7)	69.3 (27.3)
1988-9	13.2 (5.2)	13.7 (5.4)	10.7 (4.2)	20.1 (7.9)	6.4 (2.5)	37.6 (14.8)	64.0 (25.2)
1989-0	14.5 (5.7)	36.8 (14.5)	21.6 (8.5)	8.9 (3.5)	8.4 (3.3)	72.9 (28.7)	90.2 (35.5)
1990-1	12.7 (5.0)	13.7 (5.4)	14.7 (5.8)	10.9 (4.3)	19.8 (7.8)	41.1 (16.2)	71.9 (28.3)
1991-2	10.9 (4.3)	23.9 (9.4)	10.7 (4.2)	3.8 (1.5)	13.2 (5.2)	45.5 (17.9)	62.5 (24.6)
1992-3	13.5 (5.3)	13.7 (5.4)	0.5 (0.2)	12.7 (5.0)	17.0 (6.7)	27.7 (10.9)	57.4 (22.6)
1993-4	15.2 (6.0)	9.7 (3.8)	9.7 (6.4)	12.2 (4.8)	4.6 (1.8)	41.1 (16.2)	57.9 (22.8)
1994-5	29.2 (11.5)	14.7 (5.8)	15.5 (6.1)	17.0 (6.7)	6.9 (2.7)	59.4 (23.4)	83.3 (32.8)
1995-6	19.6 (7.7)	18.3 (7.2)	28.2 (11.1)	6.6 (2.6)	19.3 (7.6)	66.0 (26.0)	91.9 (36.2)
1996-7	29.0 (11.4)	23.4 (9.2)	12.7 (5.0)	30.0 (11.8)	12.2 (4.8)	65.0 (25.6)	107.2 (42.2)
1997-8	14.0 (5.5)	26.4 (10.4)	12.7 (5.0)	14.5 (5.7)	3.0 (1.2)	53.3 (21.0)	70.6 (27.8)
1998-9	33.0 (13.0)	31.0 (12.2)	39.4 (15.5)	17.8 (7.0)	3.6 (1.4)	103.4 (40.7)	124.7 (49.1)
1999-0	25.4 (10.0)	20.6 (8.1)	14.7 (5.8)	13.0 (5.1)	6.1 (2.4)	60.7 (23.9)	79.8 (31.4)
2000-1	10.7 (4.2)	8.9 (3.5)	7.4 (2.9)	9.9 (3.9)	9.7 (3.8)	26.9 (10.6)	46.5 (18.3)

RESULTS

Oviposition sites

We located 11 sites where Oregon spotted frogs laid egg masses (i.e., oviposition sites). We recorded habitat use data and habitat availability data for all sites where spotted frogs laid at least one egg mass. Five (45%) of the 11 use sites consisted of a single egg mass, three (27%) consisted of between two and five egg masses, and the remaining three (27%) use sites consisted of seven or more egg masses (range: 7-20) (Figure 2, Table 2). In the Beaver Creek floodplain, we found a total of 58 egg masses.

We observed egg masses for the first time on 6 March. We estimate that oviposition occurred from 6 March to 21 March. Of the 11 use sites identified during the study, 4 (36%) were found during 6-9 March, 7 (64%) were found during 19-23 March. Mean date for finding new egg mass sites was 16 March.

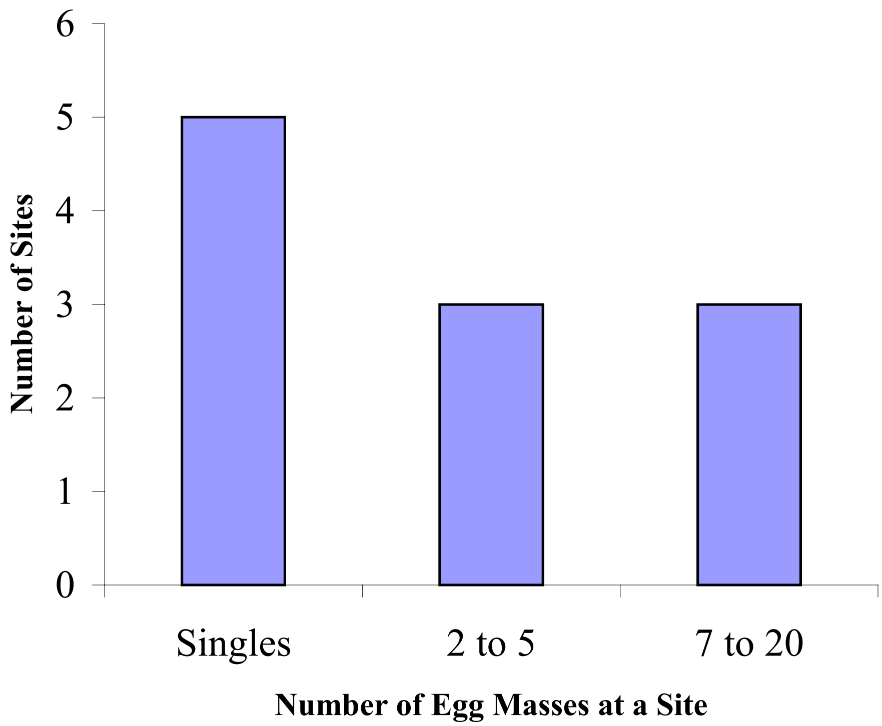

Figure 2. Frequency distribution of sites by number of egg masses, Beaver Creek Washington, 2001.

Table 2. Oviposition sites in Beaver Creek Washington, 2001. Temperature, hatching success, water depth and vegetation at oviposition sites

Site Name	UTM-X	UTM-Y	# of egg masses	Estimated Hatching Success (%)
Treatment Circle T45-1	507122	5193328	14	99
Treatment Circle T45-2	507121	5193326	4	99
North of island-1	507075	5193257	20	99
North of island-2	507073	5193256	5	99
Treatment Circle T22	507058	5193279	1	100
Midway	507041	5193347	1	0
Swale Meadow-1	507720	5192396	1	Unk
Swale Meadow-2	507705	5192389	3	Unk
Swale Meadow-3	507719	5192406	1	Unk
Pond	507597	5192620	7	Unk
Mid-Creek	507570	5192620	1	Unk

We obtained water temperatures at six sites that were discovered very soon after the initiation of oviposition (four of them found on 6 and 9 March, the other two on 21 March). Mean surface water temperature at these 6 sites, immediately following initiation of oviposition, was 16.0 $\pm$ 1.9 $^\circ$ Celsius. Relative to the surface temperatures taken during field visits, our temperature loggers, which were placed close to the substrate, recorded a moderated temperature profile, reflecting the highly variable temperature regimes within the water column. This is well illustrated by one of Heather White's treatment sites, called the T45 pool, which had temperature loggers in place near the substrate at the deepest part of the pool (~15 cm deep) as well as under the communally deposited egg cluster (~5 cm deep). The logger under the eggs recorded warmer temperatures during daylight hours but, at night, temperatures were frequently colder (Figure 3).

Two of our treatment circles (T45 and T22) were used by Oregon Spotted Frogs for oviposition. In the 3 m diameter circle known as T45, two distinctly separate communal egg clusters were initiated, the first on 6 March, the second on 9 March. In T22, a single egg mass was laid on 21 March. In all three instances, oviposition was initiated on days when temperature loggers near the substrate recorded mean daytime temperatures in the 7-9 $^\circ$C. range (Table 3). Looking at water temperatures over a longer time frame, oviposition occurred over a period when minimums rarely fell below 5 $^\circ$C. (Figure 4).

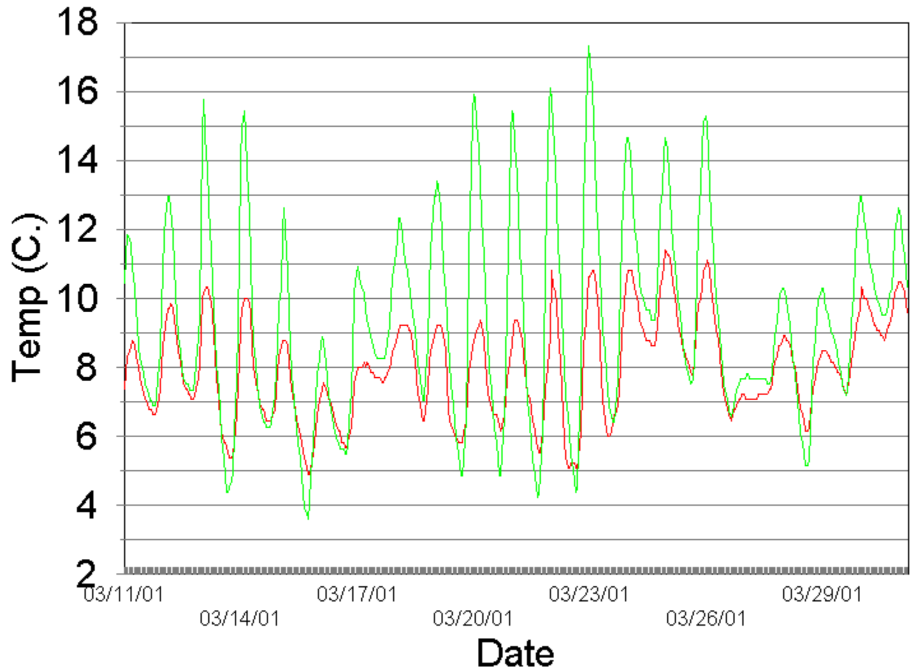

Figure 3. Temperature profiles in deepest part of T45 pool (red line) and under communally laid egg cluster (green line) in same pool but shallower water, Beaver Creek Washington 2001

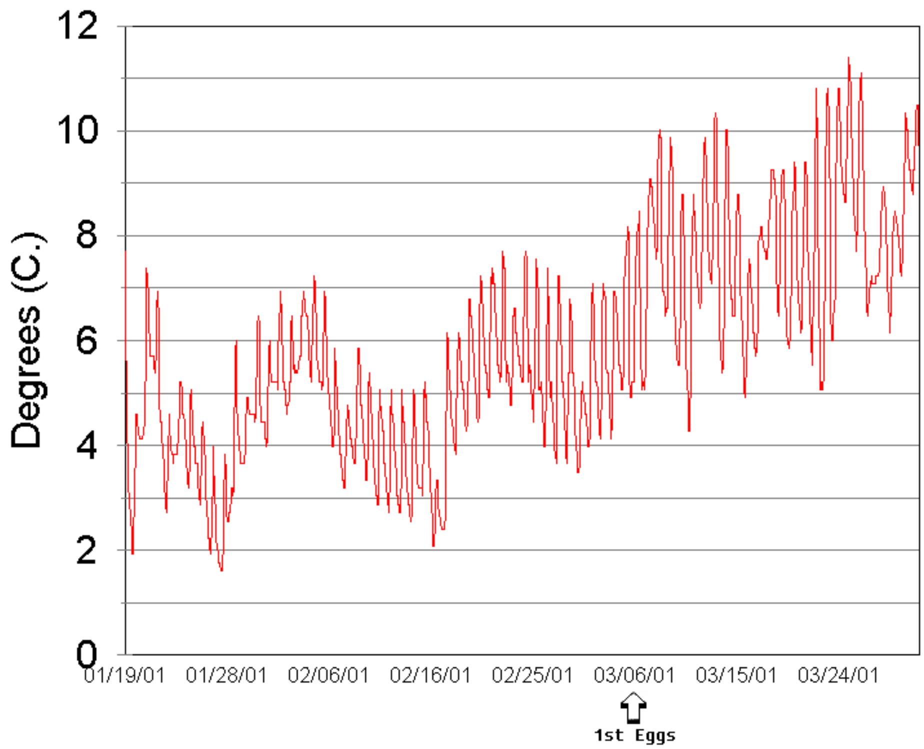

Figure 4. Temperature profile at oviposition site (pool T45) prior to and during egg-laying and tadpole development, Beaver Creek Washington 2001.

Table 3. Daylight period temperatures (recorded on the hour, 0700-1800) at the substrate of oviposition sites in the days prior to oviposition. Oviposition on 6 and 9 March was initiated at the T45 pool and on 21 March at the T22 pool.

Date (March)	Mean Daytime Temp (°C)	Daytime Low, High	Date (March)	Mean Daytime Temp (°C)	Daytime Low, High
1	4.3	3.5, 5.2	13	8.6	9.9, 10.0
2	5.8	4.0, 7.1	14	7.3	9.9, 10.0
3	5.9	4.1, 7.1	15	7.2	6.5, 8.8
4	5.9	4.1, 6.9	16	6.0	4.9, 7.6
5	6.9	5.1, 8.0	17	6.8	5.7, 8.2
$ 6	7.1	5.2, 8.3	18	8.6	7.7, 9.2
7	7.3	5.1, 9.1	19	8.6	6.5, 9.2
8	9.1	9.9, 10.0	20	7.8	5.8, 9.2
$ 9	8.6	6.6, 9.0	$ 21	7.1	6.2, 9.4

$ Date of initiation of egg-laying at new location

Eggs laid on 6 March at both the T45 pool and the North of island pool began hatching on March 24, indicating an 18 day embryonic development period. Those laid on 9 March in the T45 pool began hatching on 24 March as well, indicating a 15 day development period.

Hatchling tadpoles were observed at five (83%) of the six use sites in the former agricultural field, whereas one of the six sites (17%) had a single egg mass that completely failed to hatch (the embryos in this single egg mass never reached mid-development stage and may have been infertile). The other five egg-laying sites in the Beaver Creek floodplain were difficult to access due to distance from roads and trails and density of vegetation. These sites were visited once or twice. Water conditions, which were low when frogs initiated oviposition but remained relatively constant due to rainfall afterwards, provided for unusually high hatching success. Of the egg masses monitored through to hatching, mortality of embryos was negligible. A single egg mass at the site called Midway failed to develop at all, perhaps due to infertility. Predation did not appear to contribute toward mortality of eggs or egg masses. One egg mass in a remote location called Swale

Meadow appeared likely to desiccate prior to hatching but we did not return to the site to verify its fate.

Spotted frogs laid egg masses in shallow water areas with a mean depth of 5.9 $\pm$ 2.3 cm. There was no significant difference in the depth selected for oviposition and the depths available within the 1m x 1m use plot, (p=0.34, paired t-test), where the average depth was 7.3 $\pm$ 5.1 cm. At the scale of the availability plot (four corners of 5m x 5m grid), mean water depths were also not statistically different (p=0.14, two sample t-test, unequal variances). However, mean water depth in availability plots was 19.8 $\pm$ 51.5 cm indicating the wide variability of water depths available to the frogs.

Species composition in the marsh plant community was dominated by reed canarygrass (*Phalaris arundinacea*). Reed canarygrass provided the highest vegetation cover in all 11 use plots. In 8 out of 11 plots, it covered over 80% of the plot. Reed canarygrass was the dominant plant in availability plots as well. Greater than half of the use plots had 100% coverage of vegetation over the bottom sediments (i.e., 100% areal coverage). Slough sedge (*Carex obnupta*) was the only sub-dominant plant of any significance, providing more than 20% vegetative cover in one instance and less than 20% cover in 3 additional instances. Duckweed (*Lemna minor*) contributed minor vegetative cover (<20%) in two instances and cattail (*Typha latifolia*) similarly was less than 20% cover in one instance. These three species, plus hardhack (*Spiraea douglasii*), were the most important subdominant species in availability plots as well.

In 4 of 11 use plots, the primary structural form of the dominant reed canarygrass was floating. There were three instances where the dominant structural form was prostrate and two instances each where it was submerged and emergent. In use plots where a subdominant plant was recorded, the primary structural form was emergent. In contrast, 20 of 33 availability plots had dominant plants in a prostrate structural form, followed by 11 of 33 dominated by an emergent structural form. A greater percentage of habitat availability plots were dominated by prostrate and emergent structural forms as compared to use plots (Table 4).

Table 4. Percentage of use and availability plots that were dominated by one of four structural forms, based on the primary and secondary structural forms of the dominant and subdominant plants.

Species	Growth Form	% Submerged Use	% Submerged Avail	% Floating Use	% Floating Avail	% Prostrate Use	% Prostrate Avail	% Emergent Use	% Emergent Avail
Domin.	Prim.	18	3	37	3	27	61	18	33
Domin.	Second.	0	0	0	0	0	0	100	100
Subdom.	Prim.	0	0	0	8	0	0	100	92

DISCUSSION

The initiation of oviposition by Oregon spotted frogs at Beaver Creek may have been related to substrate depth water temperature which reached a daytime mean greater than 6 °C. on 5 March, the day before the first eggs of the season were discovered. The lower lethal limit of Oregon spotted frog embryos is at, or not far below, this temperature (Licht 1971) though embryos obviously survive this temperature if it is of brief duration.

Five of 11 use sites consisted of one egg mass. Two sites had 59% (34) of the egg masses documented at all use sites combined (n=58). One of these sites was a treatment circle where all of the vegetation had been removed in late summer. The other was in tire tracks of a vehicle that had driven through the wetland prior to the 2000 breeding season, flattening the reed canarygrass and exposing shallow, open water. This location was an important oviposition site in 2000 as well. The majority of the reproductive effort is invested in very restricted areas; where adverse environmental conditions or some calamity could have great effect. Conversely, specific habitat qualities of the use site, or the presence of other/many-other egg masses may increase survival, perhaps by speeding embryonic development to get to the more motile and, presumably, less vulnerable tadpole life stage.

At Beaver Creek, spotted frogs were found laying eggs in shallow, open water habitats, often at the water's edge adjacent to a predominantly upland habitat. Within this marsh and edge habitat (at the availability plot scale), spotted frogs selected areas with submerged, floating, or prostrate vegetation, apparently avoiding standing, emergent vegetation. This may be an adaptation for finding sites that allow for maximum exposure of the egg mass to sunlight, and as a consequence a shorter incubation time and reduced risk of freezing or desiccation. At the scale of the use plot, there was no detectable selection for water depth or temperature. At the scale of the availability plot, there was similarly no detectable selection for water depth though available water depths were extremely variable and the inability to detect selection was likely due, in part, to the small sample of oviposition sites.

The high hatching success rate during the year 2001 appears to have resulted from unusually low winter rainfall, followed by periodic rain events after oviposition. Frogs were forced to lay eggs in areas with a traditionally long hydroperiod. In these areas, spring rains did maintain water levels, allowing most egg masses to escape freezing and desiccation. Our observations of breeding habitat and egg-laying ecology during 2001 may be somewhat atypical because of these unusual hydrologic conditions.

Given the preliminary nature of our work and the hydrologically unusual year, we recommend that the study be continued for at least one more year. Our findings, as compared to the locations of oviposition sites in previous years, indicate that water levels may significantly influence where frogs lay eggs within the Beaver Creek floodplain. Annual variation may translate into subtle or substantial differences in habitat use or oviposition behavior that we will need to understand to protect this endangered species.

CONCLUSION

For breeding, this study suggests that optimal Oregon spotted frog habitat includes 3.6-8.2 cm (1.4-3.2 in) deep water that attains daytime substrate temperatures averaging $7-9\,^{\circ}$C. ($45-48\,^{\circ}$F.) during the late winter period (mid-February to mid-March). In addition, vegetation structure within suitable breeding waters must provide for nearly complete exposure of the water's surface to sunlight, a condition usually provided by low, close-cropped vegetation or vegetation that has been laid flat. In a natural system, these conditions are indicative of early vegetational succession brought about by the scouring effects of flooding, the activities of beaver or other herbivores, the effects of fire, or that of significant winter snow accumulation.

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Appendix 1. Raw data for T45-1 (Propane Tank egg-laying area)

Table 1. Use Plot and Availability Plot data, collected 6 March, 2001

Plot	Mean Depth	Water Temp	Prim. Sp.	Cover[a] Class	Mean Ht	Form[b] 1	% by Form	Form 2	% by Form	Second Sp.	Cover Class	Mean Ht	Form 1	% by Form	Form 2	% by Form
USE	5.2	19	*Phalaris*	<1	4	e	100			*Carex obnupta*	<1	7	e	100		
NW	0	9.6	*Phalaris*	4	35	e	100									
SW	0	9.8	*Phalaris*	4	30	e	100									
SE	0.8	14.6	*Phalaris*	3	6	e	100									
NE	8	15.1	*Phalaris*	1	25	e	100									

[a] Cover Classes - 1 = 20-40%; 2 = 41-60%; 3 = 61-80%; 4 = 81-100%
[b] Growth Forms - e = emergent; p = prostrate; s = submergent; f = floating

Table 2. Egg-laying site data

Date	Unexpanded Eggs Present?	# of Masses[a] E/M/H	Dist to Shore (m)	Mean Depth (cm)	Mean Temp (EC.)	% Egg Mort	Pool[b] Size
6 Mar	y	7/0/0	15	4.0	20.0	0	2
7 Mar	y	6/7/0	15	3.4	20.3	0	2
10 Mar	n	1/13/0	15	2.7	11.9	0	2
11 Mar	n	0/14/0	15	5.3	10.4	0	2
14 Mar	n	0/14/0	15	2.0	15.2	0	2
16 Mar	n	0/14/0	15	2.3	9.5	0	2
17 Mar	n	0/14/0	15	2.4	11.8	0	2
18 Mar	n	0/14/0	15	3.2	11.5	0	2
20 Mar	n	0/14/0	15	4.2	18.8	1	2
21 Mar	n	0/14/0	15	4.3	18.1	1	2
22 Mar	n	0/14/0	15	3.2	19.0	1	2
24 Mar	n	0/7/7	15	3.4	14.9	1	2
27 Mar	n	0/0/14	15	6.4	7.2	1	2
29 Mar	n	0/0/14	15	6.4	13	1	2
1 Apr	n	0/0/14	15	7.2	13	1	2
9 Apr	n	0/0/14	15	6.2	16.2	?	2

[a] E = Early development, Gosner stages 1-5; M =Mid-development, Gosner stages 6-18; H =Hatching, Gosner stages 19-22

[b] 1 = 0-10 m^2; 2 = 11-100 m^2; 3 = 101-10,000 m^2; 4 = >10,000 m^2

Appendix 2. Raw data for T45-2 (Propane Tank egg-laying area)

Table 1. Use Plot and Availability Plot data, collected 9 March, 2001

Plot	Mean Depth	Water Temp	Prim. Sp.	Cover[a] Class	Mean Ht	Form[b] 1	% by Form	Form 2	% by Form	Second Sp.	Cover Class	Mean Ht	Form 1	% by Form	Form 2	% by Form
USE	6.9	15.5	Phalaris	4	0	e	100			Carex obnupta	1	5	e	100		
NW	8.1	12	Phalaris	4	30	p	100									
SW	0	-	Phalaris	4	45	e	50	p	50							
SE	9.4	8	Phalaris	4	45	p	100									
NE	5.4	13	Phalaris	4	5	p	100			Carex obnupta	1	10	e	100		

[a] Cover Classes - 1 = 20-40%; 2 = 41-60%; 3 = 61-80%; 4 = 81-100%
[b] Growth Forms - e = emergent; p = prostrate; s = submergent; f = floating

Table 2. Egg-laying site data

Date	Unexpanded Eggs Present?	# of Masses[a] E/M/H	Dist to Shore (m)	Mean Depth (cm)	Mean Temp (EC.)	% Egg Mort	Pool[b] Size
9 Mar	n	2/0/0	10	6.2	15.2	0	2
10 Mar	y	1/2/0	15	6.2	11.4	0	2
11 Mar	n	0/3/0	15	3.1	11.3	0	2
14 Mar	n	0/4/0	15	5.5	15.0	0	2
16 Mar	n	0/4/0	15	6.1	9.2	0	2
17 Mar	n	0/4/0	15	6.2	11.0	0	2
18 Mar	n	0/4/0	15	7.5	10.7	0	2
20 Mar	n	0/4/0	15	8.1	17.2	1	2
21 Mar	n	0/4/0	15	8.9	16.0	1	2
22 Mar	n	0/4/0	15	8	18.4	1	2
24 Mar	n	0/2/2	15	6.6	13.4	1	2
27 Mar	n	0/1/3	15	9.6	7.2	1	2
29 Mar	n	0/1/3	15	10.1	12.0	1	2
1 Apr	n	0/1/3	15	10.1	12.8	1	2
9 Apr	n	0/0/4	15	11.4	15.1	-	2

[a] E = Early development, Gosner stages 1-5; M =Mid-development, Gosner stages 6-18; H =Hatching, Gosner stages 19-22

[b] 1 = 0-10 m^2;   2 = 11-100 m^2;   3 = 101-10,000 m^2;   4 = >10,000 m^2

Appendix 3. Raw data for North of Island-1

Table 1. Use Plot and Availability Plot data, collected 6 March, 2001

Plot	Mean Depth	Water Temp	Prim. Sp.	Cover[a] Class	Mean Ht	Form[b] 1	% by Form	Form 2	% by Form	Second Sp.	Cover Class	Mean Ht	Form 1	% by Form	Form 2	% by Form
USE	5	15.4	Phalaris	1	5	s	100			Carex obnupta	1	10	e	100		
NW	0.8	10.0	Phalaris	4	20	p	100									
SW	0	-	Phalaris	4	15	p	100			Carex obnupta	1	60	e	100		
SE	0	-	Phalaris	4	30	p	100			Carex obnupta	1	15	e	100		
NE	0	-	Phalaris	4	35	e	100			Carex obnupta	1	50	e	100		

[a] Cover Classes - 1 = 20-40%; 2 = 41-60%; 3 = 61-80%; 4 = 81-100%
[b] Growth Forms - e = emergent; p = prostrate; s = submergent; f = floating

Table 2. Egg-laying site data

Date	Unexpanded Eggs Present?	# of Masses[a] E/M/H	Dist to Shore (m)	Mean Depth (cm)	Mean Temp (EC.)	% Egg Mort	Pool[b] Size
6 Mar	n	9/0/0	1	4.0	15.2	0	1
7 Mar	n	7/9/0	1	3.9	16.0	0	1
8 Mar	n	2/16/0	1	3.5	15.0	0	1
9 Mar	n	2/18/0	1	4.5	13.2	0	1
10 Mar	n	0/20/0	1	3.6	11.4	0	1
11 Mar	n	0/20/0	1	4.2	11.4	0	2
14 Mar	n	0/20/0	1	3.6	15.3	0	2
16 Mar	n	0/20/0	1	5.2	9.0	0	2
17 Mar	n	0/20/0	1	5.1	11.9	1	2
18 Mar	n	0/20/0	1	5.3	11.5	1	2
20 Mar	n	0/20/0	1	5.2	18.9	1	2
21 Mar	n	0/20/0	1	5.4	17.5	1	2
22 Mar	n	0/20/0	1	6.2	17.9	1	2
24 Mar	n	0/5/15	1	4.6	14.7	1	2
27 Mar	n	0/0/20	1	7.8	7.0	1	2
29 Mar	n	0/0/20	1	7.8	12.3	1	2
1 Apr	n	0/0/20	2	8.6	16.5	1	2
9 Apr	n	0/0/20	-	8.8	13.2	-	2

[a] E = Early development, Gosner stages 1-5; M =Mid-development, Gosner stages 6-18; H =Hatching, Gosner stages 19-22

[b] 1 = 0-10 m^2;   2 = 11-100 m^2;   3 = 101-10,000 m^2;   4 = >10,000 m^2

Appendix 4. Raw data for North of Island-2

Table 1. Use Plot and Availability Plot data, collected 6 March, 2001

Plot	Mean Depth	Water Temp	Prim. Sp.	Cover[a] Class	Mean Ht	Form[b] 1	% by Form	Form 2	% by Form	Second Sp.	Cover Class	Mean Ht	Form 1	% by Form	Form 2	% by Form
USE	7.2	15.4	Phalaris	4	-	s	100									
NW	5.4	9.4	Phalaris	4	15	p	100									
SW	8.2	8	Phalaris	4	20	p	100									
SE	6.8	10.9	Phalaris	4	20	p	100			Carex obnupta	1	30	e	100		
NE	11.2	11	Phalaris	4	45	p	100			Carex obnupta	1	45	e	100		

[a] Cover Classes - 1 = 20-40%; 2 = 41-60%; 3 = 61-80%; 4 = 81-100%
[b] Growth Forms - e = emergent; p = prostrate; s = submergent; f = floating

Table 2. Egg-laying site data

Date	Unexpanded Eggs Present?	# of Masses[a] E/M/H	Dist to Shore (m)	Mean Depth (cm)	Mean Temp (EC.)	% Egg Mort	Pool[b] Size
6 Mar	y	1/0/0	5	7.0	15.4	0	1
7 Mar	n	2/1/0	5	5.0	15.4	0	1
9 Mar	n	1/3/0	5	7.0	13.0	0	1
10 Mar	n	0/4/0	5	6.9	10.8	0	1
11 Mar	n	0/5/0	3	6.4	11.0	0	2
14 Mar	n	0/5/0	3	6.4	12.0	0	2
16 Mar	n	0/5/0	3	7.1	8.9	0	2
17 Mar	n	0/5/0	3	8.5	12.0	0	2
18 Mar	n	0/5/0	3	8.9	12.0	0	2
20 Mar	n	0/5/0	3	7.9	17.6	0	2
21 Mar	n	0/5/0	3	8.3	16.6	0	2
22 Mar	n	0/5/0	3	9.5	17.2	1	2
24 Mar	n	0/1/4	3	9.6	12.9	1	2
27 Mar	n	0/0/5	3	11.2	7.1	1	2
29 Mar	n	0/0/5	3	12.1	12.3	1	2
1 Apr	n	0/0/5	3	4.6	13.6	1	2
9 Apr	n	0/0/5	3	13.2	17.1	-	2

[a] E = Early development, Gosner stages 1-5; M =Mid-development, Gosner stages 6-18; H =Hatching, Gosner stages 19-22

[b] 1 = 0-10 m^2;   2 = 11-100 m^2;   3 = 101-10,000 m^2;   4 = >10,000 m^2

Appendix 5. Raw data for T22 (North of Island egg-laying area)

Table 1. Use Plot and Availability Plot data, collected 21 March, 2001

Plot	Mean Depth	Water Temp	Prim. Sp.	Cover[a] Class	Mean Ht	Form[b] 1	% by Form	Form 2	% by Form	Second Sp.	Cover Class	Mean Ht	Form 1	% by Form	Form 2	% by Form
USE	10.5	16.1	Phalaris	4	0	f	90	e	10	Carex obnupta	1	25	e	100		
NW	None															
SW	None															
SE	12.0	14.0	Phalaris	1	30	p	100			Carex obnupta	2	30	e	100		
NE	None															

[a] Cover Classes - 1 = 20-40%; 2 = 41-60%; 3 = 61-80%; 4 = 81-100%
[b] Growth Forms - e = emergent; p = prostrate; s = submergent; f = floating

Table 2. Egg-laying site data

Date	Unexpanded Eggs Present?	# of Masses[a] E/M/H	Dist to Shore (m)	Mean Mean Depth (cm)	% Egg Temp (EC.)	Pool[b] Mort	Size
21 Mar	n	0/1/0	10	10.0	16.1	0	2
22 Mar	n	0/1/0	10	9.0	17.8	0	2
24 Mar	n	0/1/0	10	7.5	13.6	0	2
27 Mar	n	0/1/0	10	10.5	6.7	0	2
29 Mar	n	0/1/0	10	13.0	11.6	0	2
1 Apr	n	0/1/0	10	11.5	13.3	0	2
9 Apr	n	0/0/1	10	13.0	15.7	0	2

[a] E = Early development, Gosner stages 1-5; M =Mid-development, Gosner stages 6-18; H =Hatching, Gosner stages 19-22

[b] 1 = 0-10 m^2;   2 = 11-100 m^2;   3 = 101-10,000 m^2;   4 = >10,000 m^2

Appendix 6. Raw data for Midway

Table 1. Use Plot and Availability Plot data, collected 21 March, 2001

Plot	Mean Depth	Water Temp	Prim. Sp.	Cover[a] Class	Mean Ht	Form[b] 1	% by Form	Form 2	% by Form	Second Sp.	Cover Class	Mean Ht	Form 1	% by Form	Form 2	% by Form
USE	10.0	14	Phalaris	1	10	p	100									
NW	10.2	15	Phalaris	3	15	p	100									
SW	6.4	15.1	Phalaris	4	20	p	100			Carex obnupta	1	20	e	100		
SE	14	14.2	Phalaris	3	20	p	100			Carex obnupta	1	25	e	100		
NE	20	13.4	open water													

[a] Cover Classes - 1 = 20-40%; 2 = 41-60%; 3 = 61-80%; 4 = 81-100%
[b] Growth Forms - e = emergent; p = prostrate; s = submergent; f = floating

Table 2. Egg-laying site data

Date	Unexpanded Eggs Present?	# of Masses[a] E/M/H	Dist to Shore (m)	Mean Depth (cm)	Mean Temp (EC.)	% Egg Mort	Pool[b] Size
21 Mar	n	0/1/0	20	9.0	14.0	0	2
22 Mar	n	0/1/0	15	9.5	17.1	20	2
24 Mar	n	0/1/0	15	10.0	14.1	20	2
27 Mar	n	0/1/0	15	13.0	7.3	20	2
29 Mar	n	0/1/0	15	11.0	11.6	20	2
1 Apr	n	0/1/0	15	12.0	11.9	20	2
9 Apr	n	0/1/0	1	12.5	16.3	90	2

[a] E = Early development, Gosner stages 1-5; M =Mid-development, Gosner stages 6-18; H =Hatching, Gosner stages 19-22

[b] 1 = 0-10 m^2;   2 = 11-100 m^2;   3 = 101-10,000 m^2;   4 = >10,000 m^2

Appendix 7. Raw data for Mid-creek.

Table 1. Use Plot and Availability Plot data, collected 19 March, 2001

Plot	Mean Depth	Water Temp	Prim. Sp.	Cover[a] Class	Mean Ht	Form[b] 1	% by Form	Form 2	% by Form	Second Sp.	Cover Class	Mean Ht	Form 1	% by Form	Form 2	% by Form
USE	3.1	10.5	Phalaris	4	0	p	100									
NW	17.0	9.0	Phalaris	2	120	e	100			Salix sp.	2	200	e	100		
SW	6.5	9.0	Phalaris	3	6	p	100									
SE	3.0	10.1	Phalaris	4	38	e	100									
NE	3.3	8.4	Phalaris	3	18	e	100									

[a] Cover Classes - 1 = 20-40%; 2 = 41-60%; 3 = 61-80%; 4 = 81-100%
[b] Growth Forms - e = emergent; p = prostrate; s = submergent; f = floating

Table 2. Egg-laying site data

Date	Unexpanded Eggs Present?	# of Masses[a] E/M/H	Dist to Shore (m)	Mean Depth (cm)	Mean Temp (EC.)	% Egg Mort	Pool[b] Size
19 Mar	n	2/0/0	1	4.0	9.9	0	2

[a] E = Early development, Gosner stages 1-5; M =Mid-development, Gosner stages 6-18; H =Hatching, Gosner stages 19-22

[b] 1 = 0-10 m^2; 2 = 11-100 m^2; 3 = 101-10,000 m^2; 4 = >10,000 m^2

Appendix 8. Raw data for Pond

Table 1. Use Plot and Availability Plot data, collected 23 March, 2001

Plot	Mean Depth	Water Temp	Prim. Sp.	Cover[a] Class	Mean Ht	Form[b] 1	% by Form	Form 2	% by Form	Second Sp.	Cover Class	Mean Ht	Form 1	% by Form	Form 2	% by Form
USE	9.1	18.7	Phalaris	4	10	f	100									
NW																
SW																
SE	287.0	17.3	Typha	2	0	s	90	e	10							
NE	258.0	16.3	Phalaris	3	0	f	100									

[a] Cover Classes - 1 = 20-40%; 2 = 41-60%; 3 = 61-80%; 4 = 81-100%
[b] Growth Forms - e = emergent; p = prostrate; s = submergent; f = floating

Table 2. Egg-laying site data

Date	Unexpanded Eggs Present?	# of Masses[a] E/M/H	Dist to Shore (m)	Mean Depth (cm)	Mean Temp (EC.)	% Egg Mort	Pool[b] Size
19 Mar	n	0/7/0	0.03	5.8	11.7	0	3
23 Mar	n	0/7/0	0.2	8.0	19.6	0	3

[a] E = Early development, Gosner stages 1-5; M =Mid-development, Gosner stages 6-18; H =Hatching, Gosner stages 19-22

[b] 1 = 0-10 m^2;   2 = 11-100 m^2;   3 = 101-10,000 m^2;   4 = >10,000 m^2

Appendix 9. Raw data for Swale Meadow-1

Table 1. Use Plot and Availability Plot data, collected 23 March, 2001

Plot	Mean Depth	Water Temp	Prim. Sp.	Cover[a] Class	Mean Ht	Form[b] 1	% by Form	Form 2	% by Form	Second Sp.	Cover Class	Mean Ht	Form 1	% by Form	Form 2	% by Form
USE	0.9	10.9	Phalaris	4	5	p	85	e	15							
NW																
SW																
SE																
NE																

[a] Cover Classes - 1 = 20-40%; 2 = 41-60%; 3 = 61-80%; 4 = 81-100%
[b] Growth Forms - e = emergent; p = prostrate; s = submergent; f = floating

Table 2. Egg-laying site data

Date	Unexpanded Eggs Present?	# of Masses[a] E/M/H	Dist to Shore (m)	MeanMean Depth (cm)	% Egg Temp (EC.)	Pool[b] Mort	Size
19 Mar	n	1/0/0	0.08	3.5	10.8	0	1

[a] E = Early development, Gosner stages 1-5; M =Mid-development, Gosner stages 6-18; H =Hatching, Gosner stages 19-22

[b] 1 = 0-10 m^2;   2 = 11-100 m^2;   3 = 101-10,000 m^2;   4 = >10,000 m^2

Appendix 10. Raw data for Swale Meadow-2

Table 1. Use Plot and Availability Plot data, collected 23 March, 2001

Plot	Mean Depth	Water Temp	Prim. Sp.	Cover[a] Class	Mean Ht	Form[b] 1	% by Form	Form 2	% by Form	Second Sp.	Cover Class	Mean Ht	Form 1	% by Form	Form 2	% by Form
USE	1.8	20.7	Phalaris	4	0	f	90	e	10							
NW	64.0	12.0	Phalaris	4	50	e	100									
SW	76.7	7.5	Spiraea	3	210	e	100			Phalaris	1	150	e	100		
SE																
NE	110.0	9.8	Phalaris	2	15	p	75	e	25	Green algae	1	0	f	100		

[a] Cover Classes - 1 = 20-40%; 2 = 41-60%; 3 = 61-80%; 4 = 81-100%
[b] Growth Forms - e = emergent; p = prostrate; s = submergent; f = floating

Table 2. Egg-laying site data

Date	Unexpanded Eggs Present?	# of Masses[a] E/M/H	Dist to Shore (m)	Mean Depth (cm)	Mean Temp (EC.)	% Egg Mort	Pool[b] Size
19 Mar	n	3/0/0	0.04	1.9	10.9	0	1
23 Mar	n	3/0/0	0.1	2.8	17.8	5	1

[a] E = Early development, Gosner stages 1-5; M =Mid-development, Gosner stages 6-18; H =Hatching, Gosner stages 19-22

[b] 1 = 0-10 m^2; 2 = 11-100 m^2; 3 = 101-10,000 m^2; 4 = >10,000 m^2

Appendix 11. Raw data for Swale Meadow-3

Table 1. Use Plot and Availability Plot data, collected 23 March, 2001

Plot	Mean Depth	Water Temp	Prim. Sp.	Cover[a] Class	Mean Ht	Form[b] 1	% by Form	Form 2	% by Form	Second Sp.	Cover Class	Mean Ht	Form 1	% by Form	Form 2	% by Form
USE	200.0	15.2	Phalaris	4	15	p	90	e	10							
NW																
SW																
SE																
NE																

[a] Cover Classes - 1 = 20-40%; 2 = 41-60%; 3 = 61-80%; 4 = 81-100%
[b] Growth Forms - e = emergent; p = prostrate; s = submergent; f = floating

Table 2. Egg-laying site data

Date	Unexpanded Eggs Present?	# of Masses[a] E/M/H	Dist to Shore (m)	Mean Depth (cm)	Mean Temp (EC.)	% Egg Mort	Pool[b] Size
23 Mar	n	1/0/0	0.1	6.6	15.1	0	3

[a] E = Early development, Gosner stages 1-5; M =Mid-development, Gosner stages 6-18; H =Hatching, Gosner stages 19-22

[b] 1 = 0-10 m^2;   2 = 11-100 m^2;   3 = 101-10,000 m^2;   4 = >10,000 m^2