Bruneau Hot Springsnail 2004 Range Wide Survey

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INTRODUCTION

The purpose of this study was to locate and measure physical characteristics of thermal spring habitats containing Bruneau Hot Springsnails (*Pyrgulopsis bruneauensis*) in the Bruneau Hot Springsnail recovery area. This report presents information gathered 17– 19 November 2004 and February 3, 2005 regarding the present distribution and relative abundance of Bruneau Hot Springsnails (*Pyrgulopsis bruneauensis*) in thermal springs, seeps, and thermal upwellings along a 6.5–km reach of Bruneau River, Idaho. Additionally, information is presented regarding specific conductance and temperature of the springs. *P. bruneauensis* is a spring dwelling snail endemic to thermal springs along Bruneau River southeast of Mountain Home (Mladenka and Minshall 2001). The present study and previous surveys conducted in 1991, 1993, 1996, and 2003 documented *P. bruneauensis* presence and spring conditions upstream and downstream of Bruneau River confluence with Hot Creek; however, surveys completed in 1998, 2000, and 2002 only addressed sites upstream of Hot Creek.

METHODS

Study Area

P. bruneauensis were surveyed along approximately 6.5-km of the Bruneau River (USGS 7.5 minute quadrangles: Hot Spring, Crowbar Gulch). This reach comprises the designated Recovery Area as described in the Recovery Plan for the Bruneau Hot Springsnail (USFWS 2002). The Recovery Area is defined as the intersection of Bruneau River with the southern boundary of Township 08 South, Range 06 East, Section 12 and continues downstream (including Hot Creek from its confluence with Bruneau River to Indian Bathtub) to the intersection of Bruneau River with the northern boundary of Township 07 South, Range 06 East, Section 35 of Owyhee County, Idaho (Figure 1).

The survey area consisted of shoreline habitat on the east and west banks of Bruneau River and the tributary Hot Creek. Shoreline habitat along Bruneau River consisted of geothermal spring seeps running through fractured basalt and cobble-boulder substrates mixed with fine sediments from both upland and riverine deposits. Geothermal spring seeps originating from the regional geothermal aquifer underlying the Bruneau – Grand View area of southwestern Idaho, emerge from the ground (rheocrene habitats) or small basalt cliffs (madicolous habitats) and flow from several centimeters to several meters before reaching Bruneau River. Aquatic habitat in Hot Creek consists of a narrow (approximately 1-2 m wide) stream channel with sand to gravel substrates, near vertical banks in some places (much less vertical relief in others), and overhanging vegetation. Water depths in Hot Creek ranged from several centimeters to > 0.5 meters. Water temperatures of thermal spring habitats along Bruneau River and in Hot Creek varied from 11° C to 40° C. Riparian vegetation consisted of grasses, sedges, forbs, shrubs including poison ivy and poison oak, narrow-leaf cottonwood, willow, hackberry, and occasional junipers.

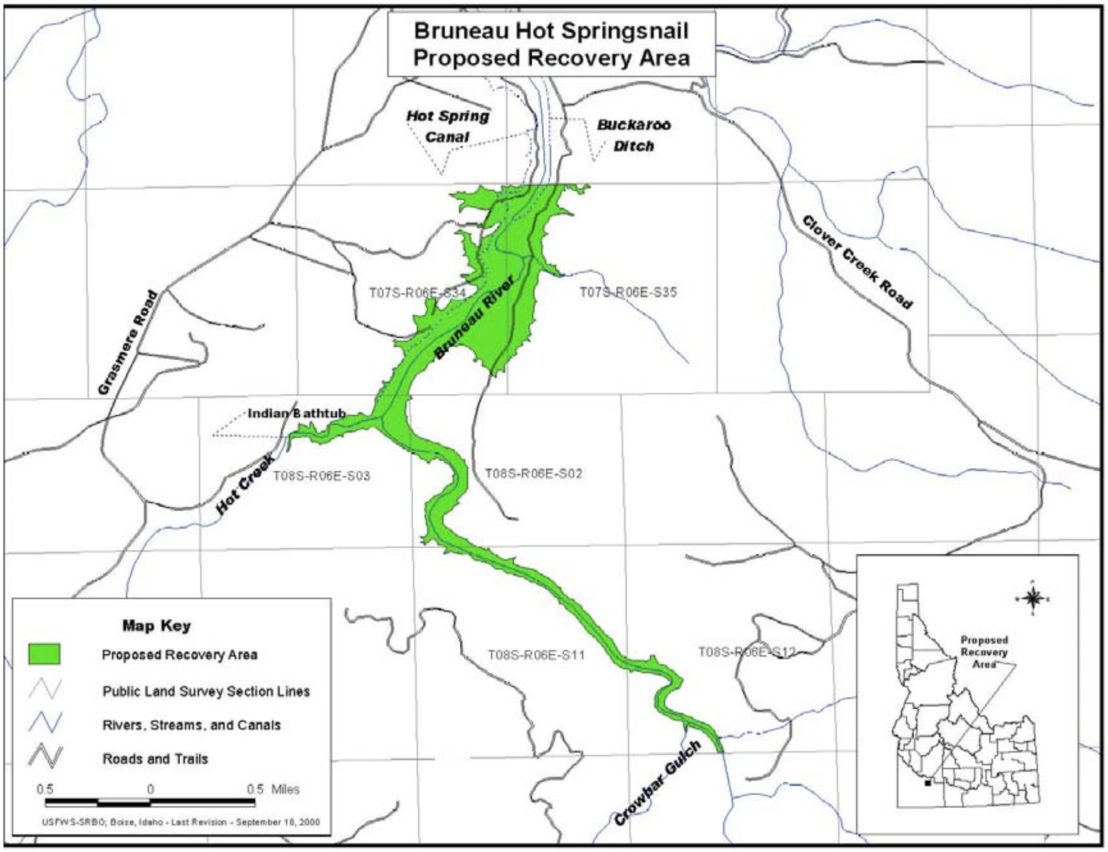

Figure 1. Recovery area for the Bruneau hot springsnail. (USFWS 2002)

GIS Mapping

Locations of north and south boundaries of the Recovery Area, and each geothermal spring seep were recorded in the field using a Trimble XRS Pro Global Positioning Receiver (GPS). Data were post-corrected to ± 1 meter (2rdms) using Trimble Pathfinder Office software. Corrected information was exported from Pathfinder Office as an ESRI shapefile point theme. The shapefile was imported into ArcGIS 8.3 ArcMap and combined with other geospatial layers. Maps were produced with ArcGIS to display existing geothermal spring seeps and seeps occupied by varying densities of *P. bruneauensis* (available upon request).

Presence and Relative Abundance

Field biologists systematically and intensively searched both banks of Bruneau River for geothermal springs/seeps. Each spring site and Hot Creek was carefully inspected for presence of *P. bruneauensis*. Occurrence of *P. bruneauensis* at each site was recorded as high density, medium density, low density, or absent. Density was based on the number of snails counted in a 60.8-cm^2 circle placed in the area of highest snail concentration in each spring. Low, medium, or high density ($353/m^2$ (±293), $1618/m^2$ (±693), and $9941/m^2$ (±4983), respectively) was assigned as described in Mladenka and Minshall (1996).

Information collected for geothermal spring seeps and Hot Creek included: water temperature, specific conductance, habitat type (rheocrene or madicolous), and presence or absence of *Tilapia zilli*. Discharge was measured in Hot Creek using a Price Pygmy velocity meter and physical measurements of the wetted channel. Numerous habitats were photographed for comparison with previous survey photographs.

Springsnail sampling in the Bruneau River

P. bruneauensis was found in the bottom of the Bruneau River during November 2003 surveys in water which appeared to be very cold (<5^{o}C) and unassociated with thermal rheocrene habitats (Mladenka and Minshall 2003). However, at that time, we did not have a temperature probe that was capable of detecting the influence of thermal upwelling.

We resurveyed the snail population February 7, 2005 that was found on the bottom of the Bruneau River from surveys conducted in November 2003. The downstream extent of the river colony was found by inserting the 10cm metal probe of a Reotemp© digital temperature meter into the benthos and looking for areas of thermal upwelling. Once the bottom of the thermal upwelling zone was determined, benthic thermal measurements were taken every meter until no thermal readings were detected. We placed a PVC plot square (0.25 m^2) on the river bottom every 10m and all snails were counted. Any apparent thermal upwelling zones were measured for temperature. After the entire extent of the upwelling zone was determined, the boundaries of the entire polygon were recorded using GPS. *P bruneauensis* was found to be distributed throughout the majority of the polygon. We calculated mean density from the plot square data and multiplied by the polygon area to determine the number of individuals within the thermal upwelling zone.

RESULTS

P. bruneauensis were present at 90 out of 156 sites (Table 1). Of these sites, 77 were low density, 11 were medium density, and 2 were high density (Table 1). More occupied sites (54) existed upstream of Hot Creek than below (36 sites). Most occupied sites upstream of Hot Creek were located on the river's west side (50), while 40 were located along the river's east bank. Only eight occupied sites were found on the river's west bank downstream of Hot Creek, while 28 sites were found along the east bank in this area. In addition to occupied sites, sixty-six (66) unoccupied spring sites were located in the survey area. Most of these (25) were found downstream of Hot Creek along the river's west side.

Mean water temperature of all sites was 27.0 (± 7.3)° C (Table 2). Water temperatures at individual sites ranged from 11.0° C to 40.0° C; however, snails at the highest temperature spring were only found in the mixing zone with Bruneau River. Water temperatures in Bruneau River ranged from 5.4° C near the upstream boundary of the recovery area to 11.5° C on the downstream end. The highest temperature measured at any spring was 40.0° C (*P. bruneauensis* absent)(Table 2). Air temperature during the survey varied from 5° C to 10° C, with weather being partly cloudy with moderate wind.

Table 1. Number of number of hot springs, with their relative densities, and orientation to Hot Creek.

	No. of sites	% of total	Upper West	Upper East	Lower West	Lower East
absent	66	42.3%	16	7	25	17
low	77	49.4%	31	11	8	27
medium	11	7.1%	10	0	0	1
high	2	1.3%	1	1	0	0
total	156					

Table 2. Mean, median, standard deviation, maximum, and minimum statistics given for Hot Spring water temperature, specific conductance, measured wetted spring width and depth, and Hot Spring area.

	spring temp ^{o}C	conductivity $\mu S/cm^2 @ 25^{o}C$	wetted width cm	flowing width cm	flowing depth cm	flow area (w*d) cm^2
mean	27.0	320.1	241.9	79.4	4.2	528.4
median	29.0	293.5	180.0	28.0	2.0	42.5
stan dev	7.3	190.7	257.1	230.4	4.5	1891.0
max	40.0	1301.0	2000.0	1600.0	22.0	14000.0
min	11.0	180.0	4.0	4.0	0.5	2.0

Specific conductance is a measurement of the particles carried in the water to conduct an electrical charge and is an indicator of parent geology that thermal groundwater travels through. Mean specific conductance for all sites was 320 (± 190) (Table 2). Minimum specific conductance measured was 180 µS @ 25° C, while maximum specific conductance was 1301 µS @ 25° C (Table 2).

Flow in Hot Creek, measured downstream of long term monitoring Site 1, was 0.011 m^3/s. Discharge measured at Site 1 from 1990 through 2004 ranged from approximately 0.01 to 0.025 m^3/s (Figure 3).

Water temperature in the thermal upwelling zone measured February 2005 ranged from 10.1 to 33.4 ^{o}C while water temperature of the Bruneau River ranged from 3.3 to 3.8 ^{o}C (Table 3). Mean water temperature was 27.4 ^{o}C (SD = 5.3) (Table 3). Density was taken from 9 locations and ranged from 32 to 76 ind/m^2 and had a mean of 53.5 ind/m^2 (sd = 15). The thermal upwelling polygon in the river had an area of 510 m^2, which when multiplied by the average density from the plot square data (Table 3) estimates over 27,000 individuals within this area on the bottom of the Bruneau River. This number is likely high because springsnails were not distributed uniformly. After inserting the metal temperature probe into the substrate, it was apparent that a benthic crust is directing hot water to specific areas of upwelling.

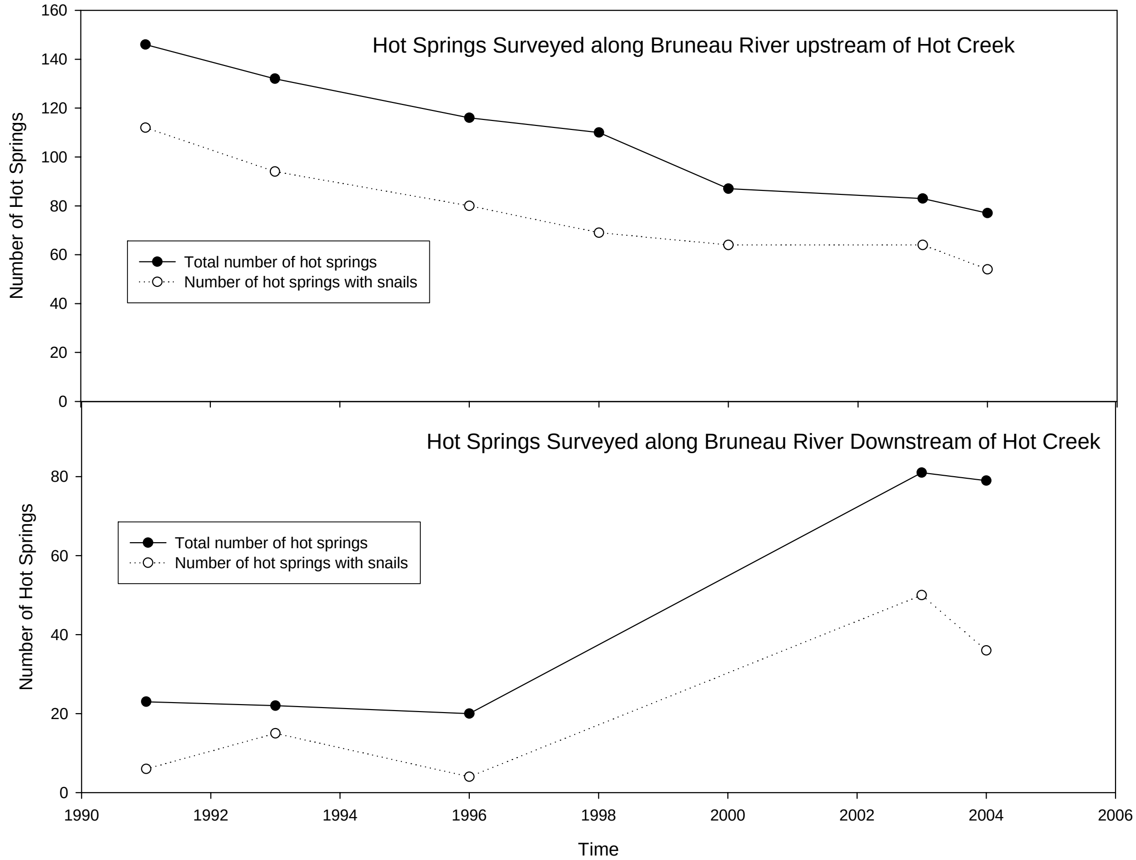

Figure 2. Total number of hot springs discharging along the Bruneau River upstream and downstream of Hot Creek for each year surveyed.

	water temp °C	density #/m^2
Min	10.1	32.0
max	33.4	76.0
mean	24.7	53.5
median	25.1	50.0
sd	5.3	15.0

Table 3. Descriptive statistics for a thermal upwelling zone that was found in the Bruneau River proper which contained Bruneau Hot Springsnails. Also shown is an aerial color image of the Bruneau River with the area of thermal upwelling.

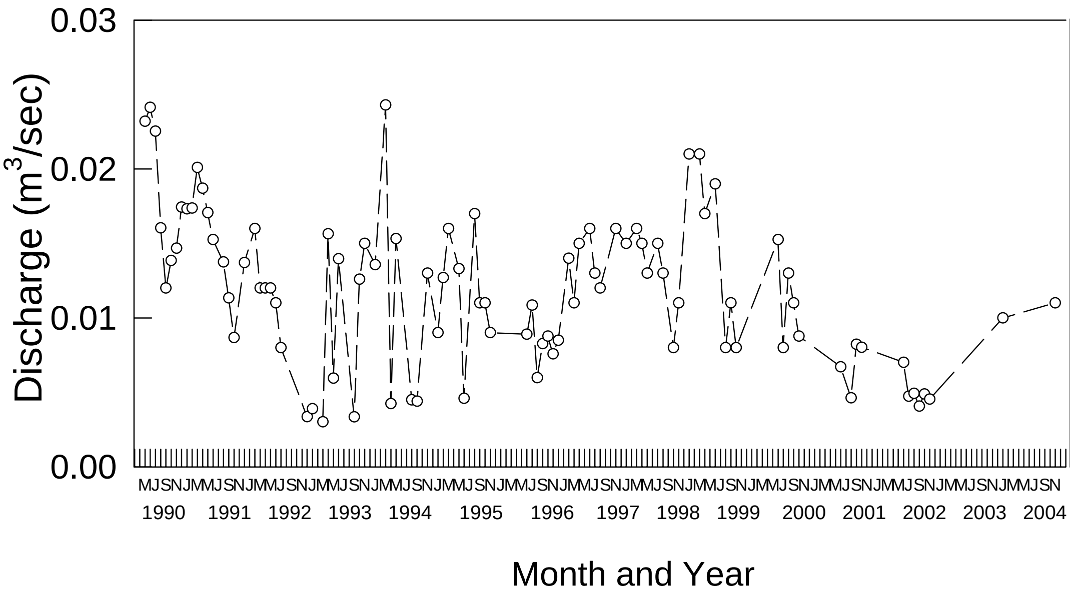

Figure 3. Discharge versus time for Hot Creek

DISCUSSION

Number of Sites

The 90 occupied sites located this year were less than any other survey (91, 93, 96, and 03) where all sites upstream and downstream of Hot Creek were surveyed (123, 121, 110, and 123). Simple linear regression performed on the total number of hot springs found upstream of the confluence of Hot Creek (Figure 4) shows that hot springs at the present rate of decline are expected to disappear around 2018. I acknowledge that a straight line extrapolation as a prediction of when hot springs upstream of Hot Creek will go dry is tenuous, however the regression provides a good fit to the available data ($r^2 = 0.97$) and suggests a significant decline of hot springs and that immediate action is needed to stabilize the thermal aquifer that underlies the Bruneau Valley.

Mladenka and Minshall (2003) recommended that a “site” needed to be defined for consistency in enumeration of hot springs and seeps. In many areas, numerous seeps can be found within a few meters of each other. In 2004, U.S. Fish and Wildlife Service personnel made an effort to more accurately enumerate each spring site by defining a site as any seep or spring that was not contiguous with another seep or spring by way of wetted substrate. Identifying each flowing seep or spring as a site could have led to an overestimation sites since there is no minimum size for a site to be counted.

Regardless of possible inconsistencies in site enumeration, it appeared that many springs and seeps were similar to what was observed in 2003. However, after comparing the 2003 and 2004 GPS point data, 23 sites were found in 2004 that were not found in 2003 or that were a distance greater than 30 meters from any 2003 GPS point location. A possible explanation would be that springs and seeps are discharging at lower elevations down river in response to declining aquifer levels.

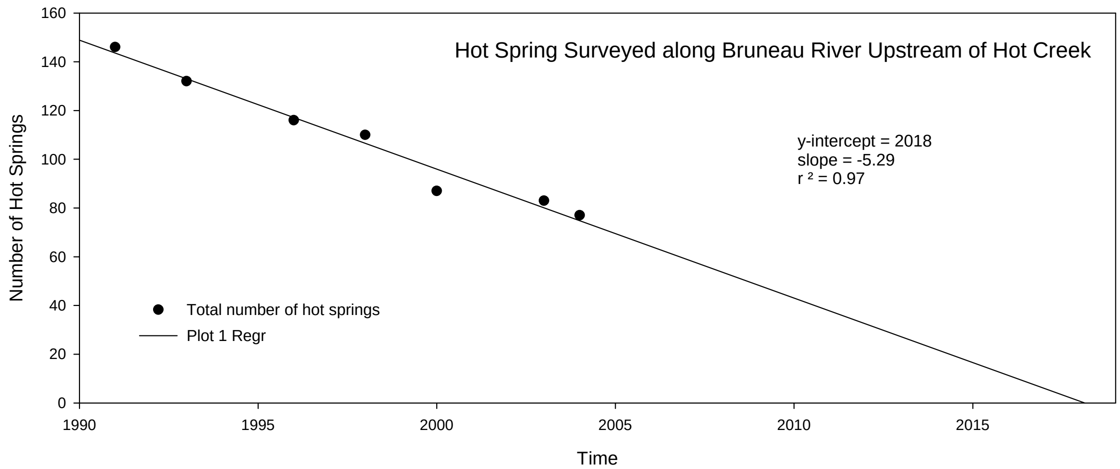

Figure 4. Simple linear regression of all surveyed hot springs upstream of the confluence of Hot Creek.

Relative Density

Only 90 of the 156 sites located had *P. bruneauensis* present. At many low density sites less than 10 individual snails were found. Even though significant effort was expended looking for snails at each site, variation in site characteristics (*e.g.* substrate, vegetation, and flows) could have affected our ability to locate snails. However, there were clear differences in snail densities among low and medium density sites. Since it was nearly impossible to enumerate all snails in each spring due to vegetation and rock cover, estimating density in the most populated area visible gives an estimate of maximum population density for each site. Snail density upstream of Hot Creek has decreased compared to surveys of 1991, 1993, 1996, and 2003 (Figure 2). Two high density and 11 medium density sites (of 90 total occupied sites) were located during this survey, compared to 11 high and 43 medium density sites (of 110 total occupied sites) located in 1996. The number of high and medium density sites shows a decreasing trend since 1991, while numbers of low density and sites without snails is increasing (Figure 5).

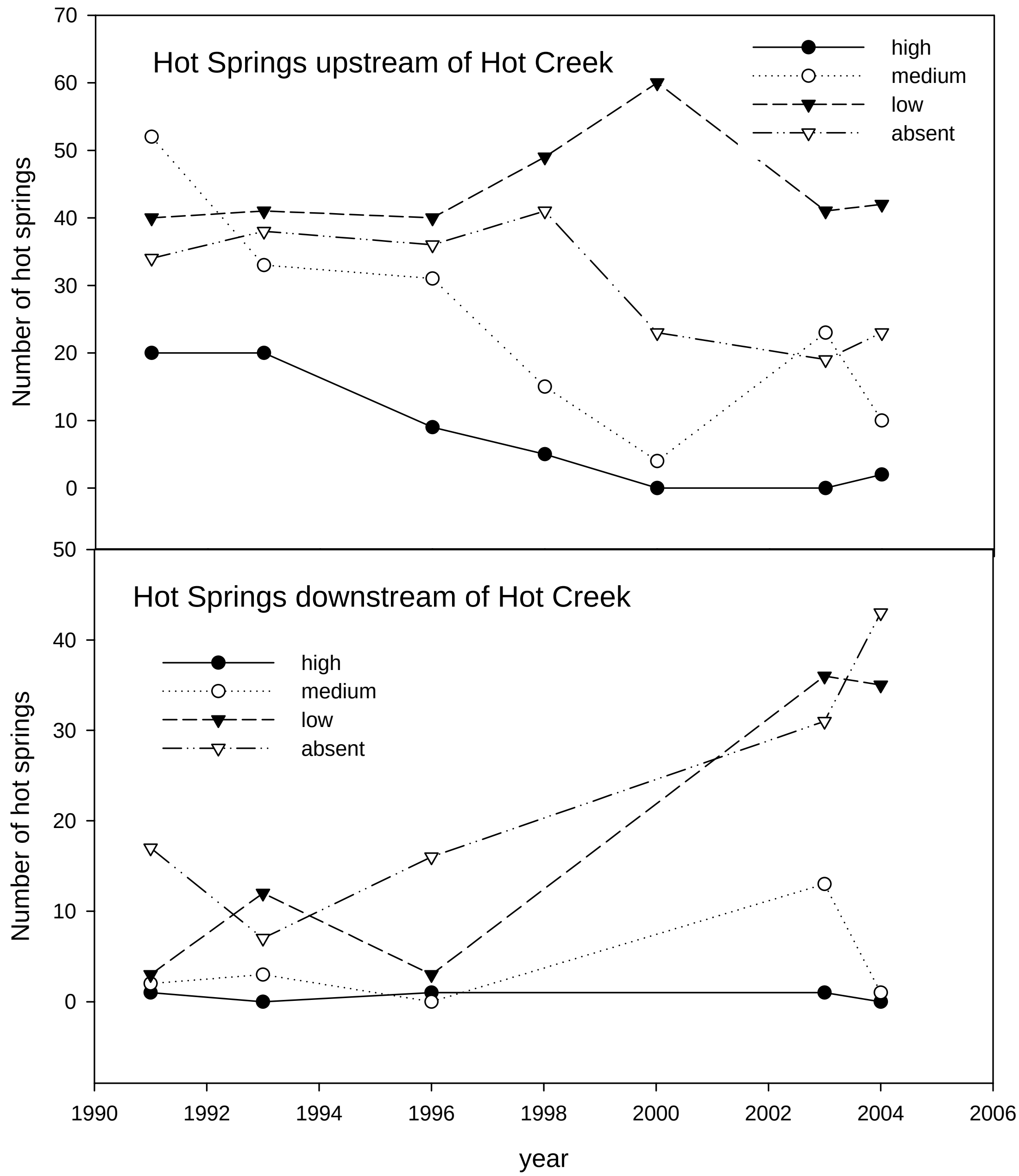

Figure 5. Relative density of *P. bruneauensis* for each year surveyed for the area upstream of Hot Creek and downstream of Hot Creek.

Other Observations

Tilapia zilli, a known snail predator (Myler 2000), was present in Hot Creek and in mixing zones with Bruneau River at a few other sites, but appeared to be less abundant than surveys conducted from 1998 to 2003. *Gambusia* also were present in Hot Creek and in some nearby spring confluences with Bruneau River. Generally, sites upstream of Hot Creek appeared in good condition with good quality adjacent riparian habitat. Many hot spring locations downstream of the confluence of Hot Creek had been trodden by livestock and substrates appeared more embedded in fine sediments.

Investigation of Thermal upwelling zones in the Bruneau River proper

P. bruneauensis were located in at least 3 locations in Bruneau River proper. At these locations, *P bruneauensis* were associated with thermal upwellings. As we had observed fewer hot springs discharging upstream of Hot Creek and more hot springs discharging downstream of Hot Creek, it appears that more thermal water also may be upwelling through the bed of the Bruneau River. Upwelling zones in the Bruneau River may have the potential to support *P bruneauensis* populations. However, effects from predation (*e.g. Tilapia*, *Gambusia* and other fish) and disturbance (*e.g.* scouring from spates and runoff events) may hinder snail survival because of lack of refugia.

RECOMMENDATIONS

The data presented in this report suggest that the number of thermal springs in the recovery area continue to decline. The total number of thermal sites with springsnails is declining and many sites previously with high and medium densities of snails are becoming rare are switching to low and absent. Furthermore, in response to the declining geothermal aquifer, the number hot springs upstream of Hot Creek, where water quality is adequate, are declining. Although, downstream of Hot Creek, many hot springs appear the same as in early surveys, there are irrigation diversions, livestock grazing, increased sedimentation, and recreation. This stresses the importance of the habitat upstream of Hot Creek and that stabilization of the thermal aquifer is paramount to the survival of this species.

In order to maintain consistency among surveys, the term “site” needs to be precisely defined in a manner where individual sites can easily be determined and enumerated during field surveys (Mladenka and Minshall 2003, Mladenka 1996, Myler and Minshall 1998). In 2004, we defined a site in the following manner: a site is any thermal spring/seep containing *P. bruneauensis* and sites that are interconnected via wetted substrate resulting from thermal seepage or flows were considered a single site unless there is >1 meter of dry ground separating the seepage or flows. Additional factors that can potentially influence the number of hot spring sites that manifest themselves along the Bruneau River are: physical water levels (higher water levels in the Bruneau River submerge hot springs, while lower river levels can bias survey results to what appears to be more hot springs), water table irrigation recovery (the thermal aquifer rises 4-6 feet when irrigation pumps are shut off for winter and gradually drop the a similar distance while the pumps are running), and date of sampling. In order to account for all of these variables, exact dates of sampling, river stage, and well data need to be correlated against the total number of sites to reduce the amount of sampling variation.

Further investigation is needed to determine the extent of *P. bruneauensis* populations’ dispersal capabilities. It has been postulated that *P. bruneauensis* drift in Bruneau River may contribute towards reestablishing populations in unoccupied thermal habitats

(Mladenka 1992). Snails can survive for short periods (days, weeks) in less than optimal river-like conditions (Mladenka 1992); however, it is unclear whether *P. bruneauensis* can survive long-term (and maintain viable populations) outside thermal habitats. However, elevated river temperatures resulting from summer heat and added effects of hot water entering the river can raise river temperatures above the known thermal preference of 11^{o}C. More study is needed to determine how *P. bruneauensis* disperses in the Bruneau River and what factors increase the species vulnerability there.

In the long-term, stabilization of the thermal aquifer is needed to conserve the Bruneau Hot Springsnail. We recommend the FWS work with the State of Idaho and privat landowners to explore possible opportunities to conserve thermal groundwater which affects recovery of the snail by creating partnerships, purchasing conservation easements, and other best management practices that limit the use of thermal groundwater.

ACKNOWLEDGMENTS

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LITERATURE CITED

Mladenka, G.C. 1992. The ecological life history of the Bruneau hot springs snail (*P. bruneauensis*). Final report to the U.S. Fish and Wildlife Service, Boise Field Office. 116 pp.

Mladenka, G.C. and G.W. Minshall. 1996. Report on the re-survey of the Bruneau hot springsnail sites. Report to U.S. Fish and Wildlife Service, Boise, Idaho. 11 pp.

Mladenka, G.C. and G.W. Minshall. 2001. Variation in the life history and abundance of three populations of Bruneau hot springsnails (*P. bruneauensis*). Western North American Naturalist 61: 204-212.

Mladenka, G.C. and G.W. Minshall. 2003. Report on the re-survey of the Bruneau hot springsnail sites. Report to U.S. Fish and Wildlife Service, Boise, Idaho. 11 pp.

Myler, C.D. and G.W. Minshall. 1998. Report on the 1998 re-survey of the Bruneau hot springsnail sites. Unpublished report submitted to: U.S. Fish and Wildlife Service, Boise Field Office, Boise, Idaho. 14 pp.

U.S. Fish and Wildlife Service. 2002. Recovery plan for the Bruneau hot springsnail (*P. bruneauensis*). Region 1, Portland, Oregon. 52 pp.

Site ID	Orientation to Hot Creek	Fish pres/abs	Snail density see methods	Substrate	Water temp °C	conductivity $\mu S/cm^2 @ 25^oC$	wetted width cm	flowing width cm	flow depth cm	flowing area cm^2
u1w	UW	absent	low	silt	33	332	NA	60	3	180
u2w	UW	absent	low	sand	31	327	NA	40	10	400
u3w	UW	absent	low	sand	27	317	NA	14	7	98
u4w	UW	absent	low	sand	16	247	160	NA	NA	
u5w	UW	absent	low	boulder	19	247	240	10	1	10
u5w-2	UW	absent	low	boulder	19	247	240	10	1	10
u6w	UW	absent	low	sand	31	297	80	10	2	20
u7w	UW	absent	low	sand	28	315	200	15	1	15
u8w	UW	absent	low	sand	27	311	100	10	1	10
u9w	UW	absent	absent	boulder	34	309	NA	25	9	225
u10w	UW	absent	absent	boulder	34	309	70	100	4	400
u11w	UW	absent	low	sand	34	309	120	21	4	84
u12w	UW	absent	absent	boulder	35	306	150	60	10	600
u13w	UW	absent	low	boulder	34	305	NA	26	6	156
u14w	UW	absent	absent	boulder	14	239	20	NA	NA	
u15w	UW	absent	absent	boulder	32	311	90	60	3	180
u16w	UW	absent	low	boulder	33	308	NA	20	3	60
u17w	UW	absent	low	boulder	31	303	NA	30	5	150
u18w	UW	absent	low	silt	25	264	300	NA	NA	
u19w	UW	absent	low	silt	32	709	NA	48	12	576
u20w	UW	absent	absent	boulder	34	290	NA	60	20	1200
u21w	UW	absent	absent	silt	20	204	NA	15	3	45
u22w	UW	absent	absent	silt	32	302	NA	10	3	30

Site ID	Orientation to Hot Creek	Fish pres/abs	Snail density see methods	Substrate	Water temp ^{o}C	conductivity $\mu S/cm^2@25^oC$	wetted width cm	flowing width cm	flow depth cm	flowing area cm^2
u23w	UW	absent	low	cobble	34	256	NA	40	4	160
u24w	UW	absent	absent	silt	32	331	NA	5	1	5
u25w	UW	absent	absent	silt	36	315	NA	28	17	476
u26w	UW	absent	absent	silt	31	331	NA	28	4	112
u27w	UW	absent	absent	silt	34	304	NA	10	4	40
u28w	UW	absent	low	silt	29	237	100	14	1	14
u29w	UW	absent	absent	cobble	33	302	250	39	6	234
u30w	UW	tilapia	low	sand	35	286	300	30	7	210
u30w-2	UW	tilapia	low	sand	35	286	300	30	7	210
u31w	UW	absent	absent	silt	31	305	NA	50	6	300
u32w	UW	absent	low	silt	17	211	120	30	1	30
u33w	UW	absent	medium	boulder	34	268	NA	50	8	400
u34w	UW	absent	medium	sand	28	241	64	NA	NA	
u35w	UW	absent	medium	sand	28	230	300	20	1	20
u35w-2	UW	absent	medium	sand	28	230	300	20	1	20
u36w	UW	tilapia	medium	sand	24	359	500	30	13	390
u37w	UW	absent	low	silt	26	233	NA	40	2	80
u38w	UW	absent	absent	boulder	15	238	NA	180	7	1260
u39w	UW	absent	low	sand	31	298	60	30	3	90
u40w	UW	absent	absent	boulder	14	198	90	NA	NA	
u41w	UW	absent	low	sand	30	316	NA	28	1	28
u42w	UW	absent	low	boulder	33	218	50	10	4	40
u43w	UW	absent	low	boulder	33	1301	150	10	4	40

Site ID	Orientation to Hot Creek	Fish pres/abs	Snail density see methods	Substrate	Water temp °C	conductivity $\mu S/cm^2 @ 25^oC$	wetted width cm	flowing width cm	flow depth cm	flowing area cm^2
u44w	UW	absent	low	sand	33	299	30	13	3	39
u45w	UW	absent	medium	boulder	28	265	60	NA	NA	
u46w	UW	absent	low	sand	32	316	NA	47	8	376
u47w	UW	absent	low	sand	30	215	250	17	1	17
u48w	UW	absent	high	boulder	23	210	NA	100	1	100
u8w	UW	absent	low	boulder	15	197	400	NA	NA	
u49w	UW	absent	low	boulder	31	210	800	10	1	10
u49w-2	UW	absent	low	boulder	31	210	800	10	1	10
u50w	UW	absent	medium	boulder	32	209	4	10	1	10
u50w-2	UW	absent	medium	boulder	32	209	4	10	1	10
u51w	UW	absent	medium	boulder	30	207	300	8	2	16
u51w-2	UW	absent	medium	boulder	30	207	300	8	2	16
u52w	UE	absent	low	silt	19	258	NA	12	3	36
u53w	UE	absent	absent	sand	31	300	NA	80	6	480
u1e	UE	absent	low	boulder	29	336	NA	65	2	130
u2e	UE	absent	low	cobble	32	290	NA	25	2	50
u3e	UE	absent	absent	boulder	34	181	NA	33	2	66
u4e	UE	absent	high	boulder	27	253	NA	150	3	450
u5e	UE	absent	low	sand	32	266	NA	19	4	76
u6e	UE	absent	low	sand	23	245	NA	70	1	70
u7e	UE	absent	low	boulder	33	275	NA	57	8	456
u8e	UE	absent	low	boulder	35	200	NA	125	9	1125
u9e	UE	absent	low	sand	34	316	NA	12	8	96

Site ID	Orientation to Hot Creek	Fish pres/abs	Snail density see methods	Substrate	Water temp °C	conductivity $\mu S/cm^2 @ 25^oC$	wetted width cm	flowing width cm	flow depth cm	flowing area cm^2
u10e	UE	absent	low	boulder	35	302	NA	30	4	120
u11e	UE	absent	absent	silt	20	228	NA	15	1	15
u12e	UE	absent	absent	sand	29	344	NA	30	15	450
u14e	UE	absent	absent	sand	20	259	300	NA	NA	
u15e	UE	absent	absent	boulder	35	195	250	10	1	10
u16e	UE	absent	low	sand	35	309	150	29	8	232
u17e	UE	absent	low	silt	20	223	170	NA	NA	
u18e	UE	absent	absent	silt	11	180	NA	29	1	29
130w	LW	absent	absent	cobble	21	255	255	1400	10	14000
130w-2	LW	absent	absent	cobble	21	255	255	1400	10	14000
l31w	LW	absent	absent	boulder	Na	na	420	NA	NA	
l32w	LW	absent	absent	boulder	27	302	600	25	1	25
l33w	LW	absent	low	boulder	Na	na	300	NA	NA	
l34w	LW	absent	low	boulder	Na	na	320	NA	NA	
l35w	LW	absent	absent	silt	12	312	700	30	0.5	15
l36w	LW	absent	low	cobble	22	286	29	NA	NA	
l37w	LW	absent	absent	cobble	40	275	NA	70	8	560
l38w	LW	absent	low	cobble	35	299	NA	NA	NA	
l1w	LW	absent	absent	sand	33	340	NA	17	12	204
l2w	LW	absent	absent	cobble	37	311	NA	34	4	136
l3w	LW	absent	absent	silt	38	291	NA	10	3	30
l4w	LW	absent	absent	sand	38	311	NA	7	3	21
l5w	LW	absent	absent	boulder	40	na	NA	1600	1	1600

Site ID	Orientation to Hot Creek	Fish pres/abs	Snail density see methods	Substrate	Water temp °C	conductivity $\mu S/cm^2 @ 25^oC$	wetted width cm	flowing width cm	flow depth cm	flowing area cm^2
I6w	LW	absent	absent	silt	30	278	40	5	1	5
I7w	LW	absent	absent	boulder	32	371	300	NA	NA	
I9w	LW	absent	absent	boulder	38	264	1000	360	1	360
I10w	LW	absent	absent	boulder	35	433	NA	200	13	2600
I11w	LW	absent	absent	cobble	32	252	NA	160	7	1120
I12w	LW	absent	absent	boulder	Na	na	105	NA	NA	
I13w	LW	absent	low	boulder	25	294	NA	10	1	10
I14w	LW	absent	low	boulder	28	245	200	10	1	10
I15w	LW	absent	absent	boulder	36	231	NA	10	2	20
I16w	LW	absent	absent	cobble	18	215	NA	200	22	4400
I17w	LW	absent	low	silt	17	303	300	87	6	522
I18w	LW	absent	absent	boulder	13	271	180	NA	NA	
I19w	LW	absent	absent	boulder	12	300	180	13	2	26
I20w	LW	absent	absent	boulder	14	337	300	10	1	10
I21w	LW	absent	absent	sand	16	229	NA	50	2	100
I22w	LW	absent	low	cobble	28	241	100	10	1	10
I23w	LW	absent	absent	cobble	13	210	2000	200	5	1000
I24w	LW	absent	absent	cobble	11	203	NA	250	13	3250
I20e	LE	absent	low	sand	23	389	160	28	6	168
I21e	LE	absent	low	silt	20	322	52	8	2	16
I22e	LE	absent	absent	sand	21	246	40	7	1	7
I23e	LE	absent	absent	sand	21	234	25	4	0.5	2
I24e	LE	absent	absent	sand	Na	na	330	NA	NA	

Site ID	Orientation to Hot Creek	Fish pres/abs	Snail density see methods	Substrate	Water temp °C	conductivity μS/cm^2@25°C	wetted width cm	flowing width cm	flow depth cm	flowing area cm^2
l24e-2	LE	absent	absent	sand	Na	na	330	NA	NA	
l25e	LE	absent	absent	silt	Na	na	40	NA	NA	
l26e	LE	absent	medium	sand	29	326	20	120	14	1680
l27e	LE	absent	low	sand	25	236	NA	NA	NA	
l28e	LE	absent	absent	sand	22	182	NA	NA	NA	
l29e	LE	absent	low	sand	25	211	NA	NA	NA	
l30e	LE	absent	low	sand	28	293	72	17	1	17
l31e	LE	absent	absent	silt	18	406	130	NA	NA	
l32e	LE	absent	low	silt	23	294	380	NA	NA	
l32e-2	LE	absent	low	silt	23	294	380	NA	NA	
l33e	LE	absent	absent	silt	Na	na	30	NA	NA	
l34e	LE	absent	absent	sand	Na	na	60	NA	NA	
l35e	LE	absent	absent	silt	12	244	120	10	0.5	5
l36e	LE	absent	absent	silt	Na	na	17	NA	NA	
l37e	LE	absent	low	silt	23	272	80	10	1	10
l38e	LE	absent	low	silt	20	325	150	NA	NA	
l39e	LE	absent	low	silt	Na	na	265	NA	NA	
l40e	LE	absent	low	silt	25	181	390	18	0.5	9
l1e	LE	absent	low	boulder	23	295	14	NA	NA	
l2e	LE	absent	low	boulder	17	326	110	NA	NA	
l3e	LE	absent	absent	boulder	19	358	120	NA	NA	
l4e	LE	absent	low	boulder	22	321	190	NA	NA	
l5e	LE	absent	low	boulder	30	245	180	85	1	85

Site ID	Orientation to Hot Creek	Fish pres/abs	Snail density see methods	Substrate	Water temp °C	conductivity $\mu S/cm^2@25^oC$	wetted width cm	flowing width cm	flow depth cm	flowing area cm^2
l6e	LE	absent	absent	boulder	11	1200	120	8	1	8
l7e	LE	absent	low	boulder	23	372	90	55	1	55
l8e	LE	absent	low	boulder	18	210	250	18	1	18
l8e-2	LE	absent	low	boulder	18	210	250	18	1	18
l9e	LE	absent	low	boulder	26	316	400	38	1	38
l10e	LE	absent	absent	boulder	24	317	300	20	1	20
l11e	LE	absent	low	boulder	30	397	400	40	1	40
l11e-2	LE	absent	low	boulder	30	397	400	40	1	40
l11e-3	LE	absent	low	boulder	30	397	400	40	1	40
l11e-4	LE	absent	low	boulder	30	397	400	40	1	40
l11e-5	LE	absent	low	boulder	30	397	400	40	1	40
l11e-6	LE	absent	low	boulder	30	397	400	40	1	40
l12e	LE	absent	low	boulder	35	1114	150	9	1	9
l13e	LE	absent	absent	silt	33	1142	NA	20	1	20
l13e-2	LE	absent	absent	silt	33	1142	NA	20	1	20
l13e-3	LE	absent	absent	silt	33	1142	NA	20	1	20
l14e	LE	absent	low	sand	18	186	68	NA	NA	
hotcreek	HC	tilapia	absent	silt	32	333	NA	200	19	3800