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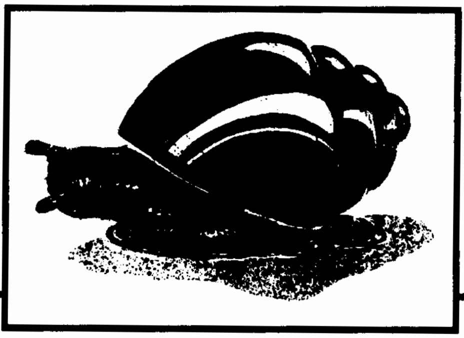

1996 Monitoring Report: Bruneau Hot-Spring Springsnail *(Pyrgulopsis bruneauensis)*

by
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ANNUAL MONITORING REPORT

Bruneau Hot-spring Springsnail (*Pyrgulopsis bruneauensis*)

Prepared for

U. S. Bureau of Land Management

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SUMMARY

This report presents the 1996 monitoring results from four sites near the Indian Bathtub that contain, or have contained, populations of the Bruneau Hot-spring Springsnail (*Pyrgulopsis bruneauensis*) and compares them with results from previous years. Three of these sites were monitored in 1990 and 1991 by Mladenka (1992), in 1992 by Robinson et al. (1992), in 1993 by Royer and Minshall (1993), and in 1994 and 1995 by Varricchione and Minshall (1995a, 1996). An additional seep at Site 3 (New Seep) was included in the 1994 and 1995 springsnail monitoring efforts.

A flood in the summer of 1991 contributed much silt, sand, and gravel to Hot Creek. In particular, Indian Bathtub was reduced to less than one-half its size before the flood because of sediment addition. Available habitat in the immediate vicinity of Indian Bathtub was reduced because of this and other sedimentation events (Mladenka 1992). Hot Creek springsnail populations were reduced drastically in Hot Creek (Site 1) by a major runoff event in July 1992 (Royer and Minshall 1993) and have since failed to recover. As of December 1996, there is no evidence to suggest that springsnails have recolonized Hot Creek since July 1992. It is recommended that experiments be conducted to assess the potential for successful transplantation of springsnails to Hot Creek (Site 1). Habitat improvement and

spring-flow augmentation in the local area also are recommended.

Population fluctuations at Sites 2 and 3 (Original and New Seeps) may be related to temperature variability. Temperatures at Site 2 were fairly stable. Temperatures at Site 3 (both Original and New Seeps) were often below 24°C and may have affected local springsnail reproductive success. Both Sites 2 and 3 (Original Seep) maintained springsnail densities similar to those in previous years. Densities at Site 3 (New Seep) were more variable. Other springsnail habitat parameters (food resources, water chemistry) appeared to remain fairly consistent with previous monitoring years. Still, some habitat may become reduced in quality if bacterial-algal complexes expand further into rockface seep habitat. Under present conditions, maintenance of adequate spring-flow appears to be the most important factor for assuring the success of springsnail populations at Sites 2 and 3 (Original and New Seeps).

INTRODUCTION

The springsnail *Pyrgulopsis bruneauensis* is an endemic species inhabiting a complex of related hot springs near the Bruneau River south of Mountain Home, Idaho. The snail's habitat has diminished considerably in recent years because of agricultural-related groundwater mining in the area (Berenbrock 1993). Hershler (1990) provided a complete taxonomic description of *P. bruneauensis*. Mladenka (1992) focused on the life history of *P. bruneauensis*, providing the groundwork on which this monitoring study is based. Mladenka (1992) found only two studies addressing the biology of *P. bruneauensis*: Taylor (1982) described the taxonomy of the snail and Fritchman (1985) studied its reproduction in the laboratory.

Mladenka (1992) found temperature to be important in the distribution of *P. bruneauensis*. Experiments showed the thermal tolerance range for the snails to be 11-35°C. Reproduction occurred between 20° and 35°C. Snail growth and reproduction was retarded at cool temperatures (<24°C). Under suitable conditions, recruitment and growth may occur at all times of the year. Sexual maturity could occur within two months and maximum size could be reached within four months under suitable temperature conditions. The sex ratio was 1:1. The snails showed little preference for current or substratum type. Rockface seeps had highly variable temperatures, but never exceeded thermal maximum temperatures. Hot Creek maintained temperatures that were less variable, but often above the springsnail thermal maximum temperature (35°C) (Mladenka 1992).

Mladenka (1992) noted that the snail population may have declined by 50% from earlier estimates of abundance and by 100% in local areas such as the Indian Bathtub and Hot Creek. Gut analyses performed on two Hot Creek fish taxa, *Gambusia* and *Tilapia*, showed that their diets consisted of organic matter and insects, but not of *P. bruneauensis* (Varricchione and Minshall 1995b). This report presents the continued biomonitoring of Mladenka's (1992) study sites through December 1996. Data for 1996 was not collected between January and May due to a lack of funding.

METHODS

Site Description

Mladenka (1992) described in detail the three original springsnail study sites (1, 2, and 3 Original Seep). Figure 1 shows the locations of the three study sites with respect to the Bruneau River. Figure 2a shows a map view of Site 1 at Hot Creek and an adjacent rockface seep. Figures 2b and 2c show front views of the hot-spring study areas (Sites 2 and 3 respectively). Royer and Minshall (1993) recommended that the Site 3 location be divided into two sub-sites: the Original Seep (right side) and a New Seep (left side) (Fig. 2c). These two seeps are

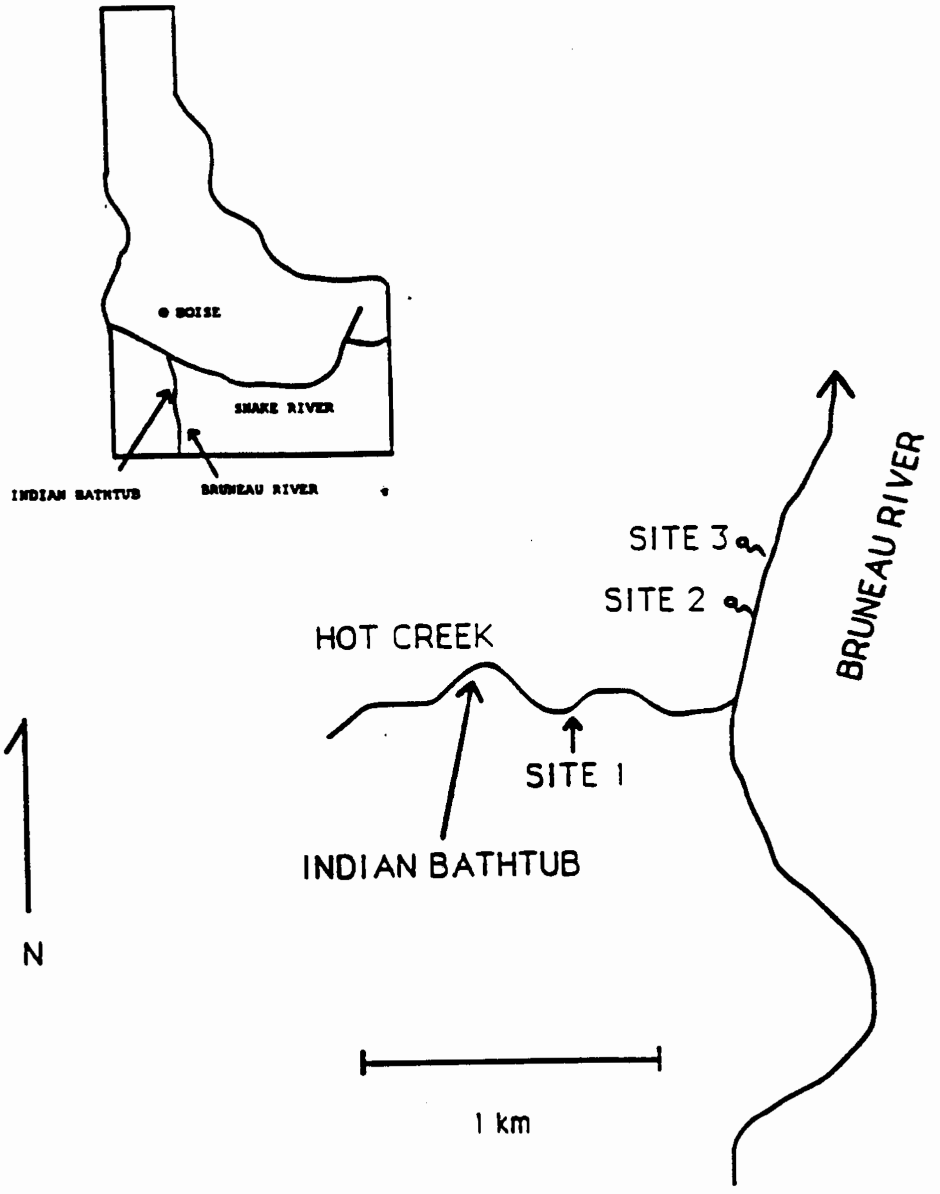

Figure 1. Map showing the locations of the Bruneau hot-spring springsnail study sites. The flow of water between Indian Bathtub and about 100 m upstream of Site 1 is primarily subsurface flow. (Reprinted from Mladenka 1992).

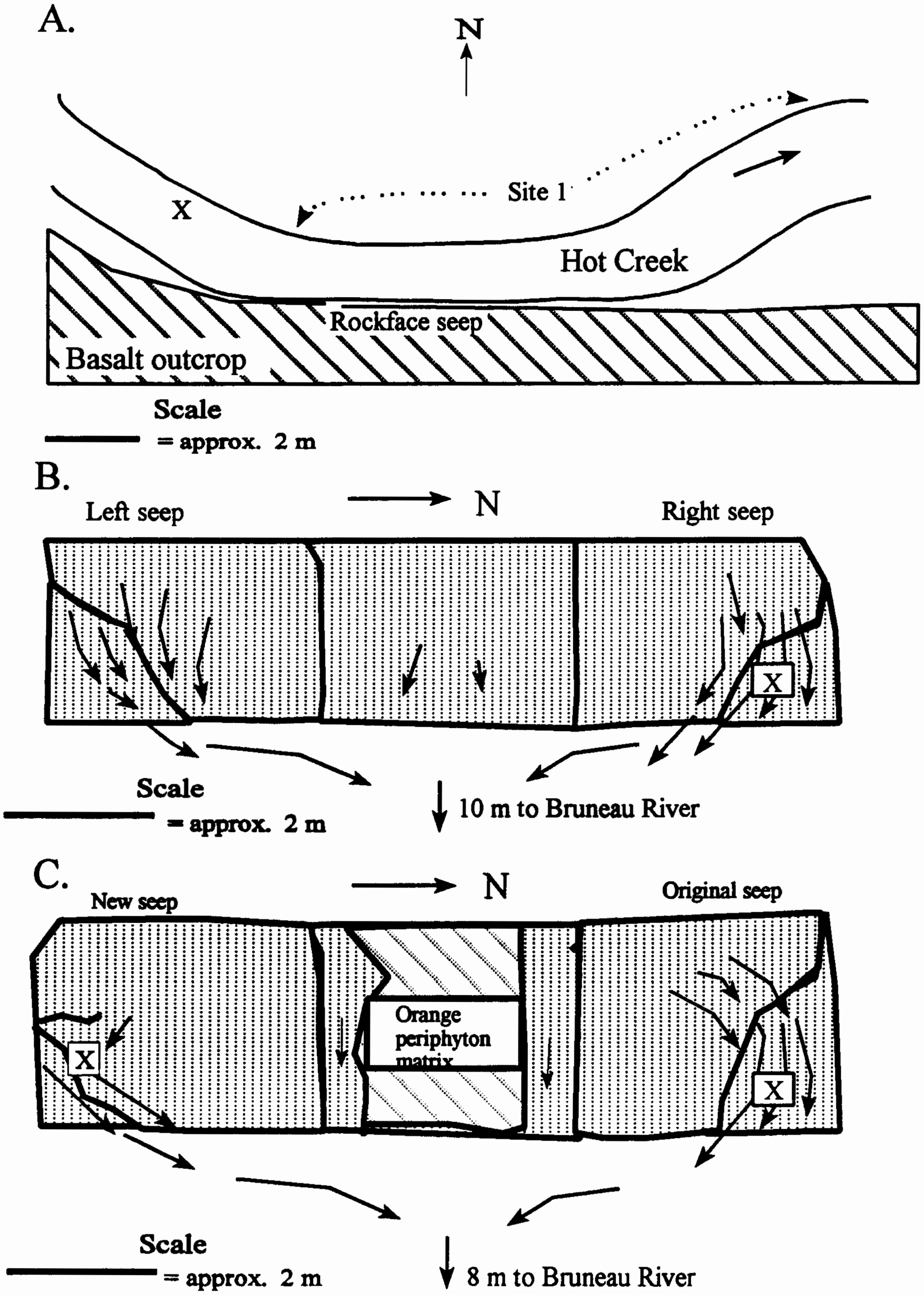

Figure 2. Temperature data logger locations for each of the study sites. Data loggers are represented by "x". A. Map view of Site 1 (Hot Creek). B. Front view of Site 2 rockface. C. Front view of Site 3 rockface (Original and New Seeps). Features are not drawn to scale.

approximately 4 m apart from each other and each "seep" has a distinct spring-flow. Their populations were monitored separately during 1994, 1995, and 1996. Site 2 is also comprised of two "seeps", but their population data were combined to remain consistent with previous monitoring reports. The purpose of the division of Site 3 was to allow the 1994, 1995, and 1996 Original Seep data to remain consistent with data from previous years and to allow for the inclusion of a recently discovered springsnail population into monitoring efforts. In a later section, this report evaluates the worth of continuing to monitor Sites 3 Original and New Seeps separately.

Both spring-rockface and stream habitats were examined for *P. bruneauensis* at Site 1, while only spring-rockface habitats were monitored at Sites 2, 3, and 3 New Seep. "Spring-flow-covered rockface", or "SFC rockface", was defined as madicolous habitat, or rockface covered by a thin layer of running water. "Rockface wetted but lacking flow", or "rockface W/LF", was defined as moist rockface adjacent to spring-flow-covered rockface. Snails occur in both types of habitats.

Study quadrats were established at each site for monitoring purposes. To estimate *P. bruneauensis* size-distribution and density-fluctuation inside a study quadrat, a meter stick (baseline) was positioned flush against the rockface and parallel to direction of spring-flow. Ten transects, each perpendicular to the meter stick, were established at 10-cm intervals along the baseline. Random number lists were used to determine random rockface-sampling locations for springsnail size and density monitoring. The random numbers were used to determine the distance across a transect each sample would be taken or monitored.

Environmental conditions were measured or monitored at the study quadrat (± 1 m) of each site on a monthly basis. These parameters included discharge and stream habitat at Hot Creek (Site 1), flow-covered- and wetted-rockface (Sites 2, 3, and 3 New Seep), water chemistry, water temperature, and food availability (periphyton abundance). Stream substrate size (particle diameter) data was obtained from a 50-m reach of Hot Creek (Site 1 ± 25 m) beginning in June 1995 and continuing on an annual basis.

Size Distribution

To determine if the Site 1 springsnail population was recovering from previous flood events, arbitrary creek substrate and spring-rockface locations within a 50-m reach of Hot Creek (Site 1 ± 25 m) were examined, without magnification, for the presence of *P. bruneauensis*.

Within the sampling quadrats at Sites 2, 3, and 3 New Seep, springsnails were washed from random locations into a petri dish using streams of water from a squirt bottle. The sizes of the snails were determined on site using a Bausch and Lomb dissecting microscope. The microscope ocular was marked with 0.14-mm units (under 7x magnification). Snail lengths were rounded to the nearest 0.14-mm unit (i.e. a snail whose length was 8.8 units long was noted as being in the 9-unit, or 1.26 mm, size class). Sample size was 100 for both sites 2 and 3. Beginning in 1994, Site 3 was subdivided into the Original Seep (n=50) and the New Seep (n=50).

Population Fluctuations

Density was not measured at Site 1 because springsnails have not been found there since flooding that occurred in July 1992. Springsnail density was measured at the rockface sites (Sites 2, 3, and 3 New Seep). Densities were estimated as the number of springsnails present within the circumference of a petri dish (9 cm diameter) at 10 random locations within the sampling quadrat. Densities were reported as the number of snails per m^2. A small Garrity flashlight (2 AA batteries, PR 104 bulb) was used to help distinguish the snails from the dark rockface.

Discharge, Temperature, and Water Chemistry Fluctuations

Stream water velocities were measured across a permanent transect at Site 1 (Hot Creek) using a small Ott C-2 current meter. This transect was moved slightly upstream or downstream (1 or 2 m) if the instream vegetation was too thick to allow proper operation of the current meter. Stream discharge was determined using the methods described in Platts et al. (1983). Spring-flow and wetted-rockface estimates at the rockface study quadrats adjacent to Site 1 were not possible because of the large amount of vegetation obscuring the rockface.

The amount of potential snail habitat at the other study quadrats was estimated by establishing a horizontal transect across each quadrat at the 50% height mark. The length of the transect which passed over spring-flow-covered or wetted habitat was measured. These values were compared with the width of the transect to obtain estimates of the percentage of the quadrat area covered by spring-flow and the percentage of the quadrat rockface that was moist.

Because of the frequent breakage or loss associated with using maximum/minimum thermometers in earlier monitoring years, miniature temperature data loggers were used at all sites beginning in 1994. Internal sensor loggers (Onset Hobo-Temp HTI-05+37) were used from 18 February 1994 to 26 September 1994, and then were replaced with external sensor data loggers (Onset StowAway-Temp STEB02-05+37) on 26 September 1994 at Sites 1, 2, and 3 Original Seep. Beginning in November 1996, an additional logger was installed at Site 3 New Seep. Data loggers were downloaded and relaunched approximately every three months, in the laboratory, using LogBook for Windows v.2.03 software (Onset Instrument Corp.).

Figure 2a shows the location of the temperature data logger submersed in Hot Creek. The logger was located 2 m upstream of Site 1 to reduce the potential for vandalism (riparian vegetation was closer to the streambank in this location). A rockface groundwater seep adjacent to Hot Creek at Site 1 had been previously known to support a population of *P. bruneauensis*. Currently, this seep is overgrown with grasses which inhibit the observation of springsnails that may still exist on the rockface. Figures 2b and 2c show the locations of the temperature data loggers at Site 2 and Site 3, respectively. A data logger was added to Site 3 New Seep in November 1996 to obtain more accurate temperature information for that particular location (Fig. 2c). Water depth at the seep study sites was quite shallow. Therefore, small pits were excavated immediately below the seep outflows in order to submerge the loggers in hot-spring water. The loggers were hidden by cobble substrate to reduce the potential for vandalism.

Water chemistry parameters were measured for all the study sites. pH was measured, in the field, using an Orion pH meter (Model 290A). The pH meter was calibrated in the field to standard solutions (Orion pH 7.00 and pH 10.01 buffer solutions) during each monitoring visit. Conductivity (µS/cm) was measured, in the field using an Orion conductivity meter (Model 126). Water samples, for all sites, were collected in 250-ml plastic bottles, kept on ice until returned to the laboratory, and then frozen until processed. In the laboratory, samples were thawed at room temperature and shaken by hand (approximately 10 sec) to resuspend any solids. Alkalinity and hardness were determined using procedures described in Standard Methods for the Examination of Water and Wastewater (APHA, 1992).

Periphyton Levels

Periphyton samples were taken from rock substrata collected within 1 m of the study quadrats. For each sample, a modified syringe tube (3.14 cm^2) was placed on top of the substrate. Closed-cell foam, attached to the base of the modified syringe tube, formed a seal between the tube and the substrate to prevent the loss of periphyton samples. Approximately 5 ml of spring or creek water was added to the tube to create a slurry. A modified toothbrush was used to dislodge periphyton from the rock, and a dropper was used extract the periphyton slurry from the tube. The periphyton slurry was concentrated onto Whatman GF/F glass microfibre filters held in a Nalgene filter holder (Nalge No.

310-4000). A Nalgene hand vacuum pump (Nalge No. 6131-0010) was used to create the suction necessary to remove the water from the slurry. For each sample, this procedure was repeated 3 times to remove all periphyton from the substrate. Periphyton samples were placed on ice, returned to the laboratory, and kept frozen until processed. In the laboratory, periphyton filters were analyzed for the presence of chlorophyll a (corrected for the presence of phaeophytin a) on a Gilford Instruments spectrophotometer (Model 2600) using procedures described in Standard Methods for the Examination of Water and Wastewater (APHA, 1992). Methanol was substituted for acetone as the solvent used in the analyses (Marker et al. 1980). Chlorophyll a, an indicator of the presence of algal organisms, was expressed as mg chlorophyll a per m^{-2}.

The remaining periphyton material from each sample was used in the determination of algal biomass (expressed as g ash-free dry mass (AFDM) per m^2). The material was dried at 50°C for 24 h, cooled to ambient temperature in a desiccator, weighed on a Sauter balance (Model AR1014) to the nearest 10^{-4}g, combusted in a muffle furnace at 550°C for a minimum of 3 h, rehydrated, redried at 50°C, cooled to ambient temperature in a desiccator, and then reweighed. The difference in weights equaled the AFDM of the sample.

Habitat Assessment at Hot Creek

Beginning in March 1995, stream habitat assessment at Hot Creek (Site 1) was conducted monthly using the Idaho Department of Health and Welfare's Habitat Assessment Field Data Sheet for lowland streams (Appendix A; Robinson and Minshall 1995). The parameters assessed included bottom substrate/instream cover, pool substrate characterization, pool variability, canopy covering, channel alteration, deposition, channel sinuosity, lower bank channel capacity, upper bank stability, bank vegetation protection, streamside cover, and riparian vegetative zone width. Also, 100 random measurements of substrate size were made in Hot Creek on an annual basis within a 50-m reach of Hot Creek (Site 1 ± 25 m). In 1995, an attempt was made to quantify embeddedness of the subtrate in Hot Creek (Varricchione and Minshall 1996). However, this attempt was done incorrectly because very fine gravels (0.5-1.0 cm diameter particles) were included as materials which were embeddeded. Future changes in habitat parameters should reflect recovery from prior land use activities and recovery from earlier flooding and sediment deposition events in Hot Creek. Also, changes in these parameters, with time, should reflect any habitat improvements that may be conducted in the area.

RESULTS

Size Distribution

From 1990 to 1993, snail size structure was monitored at three study sites: Site 1 (Hot Creek), Site 2 (upper spring rockface), and Site 3 (lower spring rockface) (Mladenka 1992). As suggested by Royer and Minshall (1993), a new seep at the southern edge of Site 3 was included in springsnail monitoring for 1994, 1995, and 1996.

Site 1 (Hot Creek)

Site 1 (Hot Creek) population density was reduced to nearly zero in July 1992 and had not begun to recover, as of December 1996 (Figs. 3g, 6). The flood in July 1992 probably resulted in the death of younger snails and skewed the size distributions in July and September 1992 (Fig. 3c). Mean population size distribution data suggests that when the springsnails were present (1990-1992), life histories appeared to be correlated with season and a single cohort of individuals moved from juvenile classes in the winter to mature classes in the summer (Fig. 5a).

Site 2 (Upper Spring Rockface)

This population maintained a size distribution that was

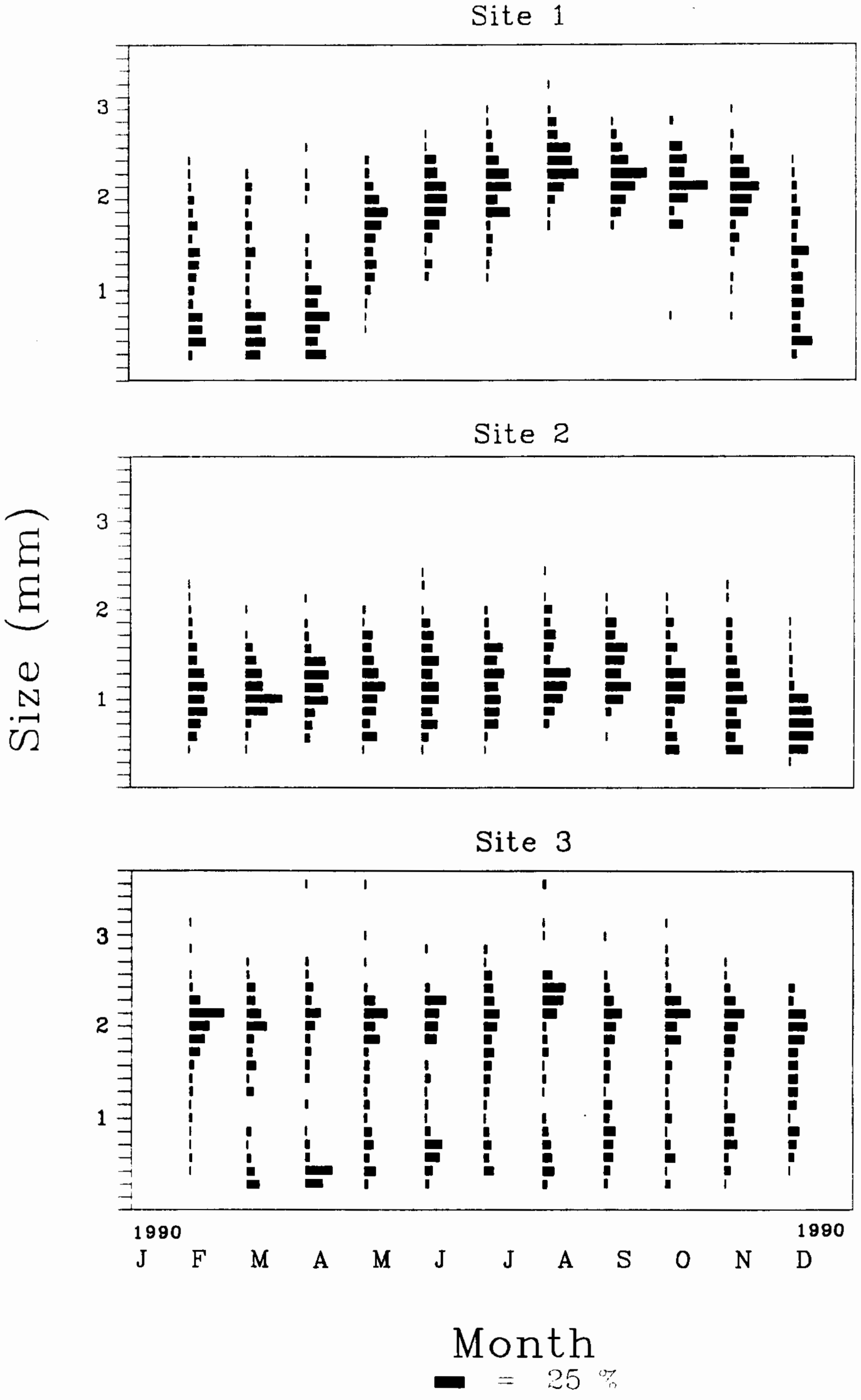

Figure 3a. Size histograms for the Bruneau Springsnail study sites. Horizontal tick marks represent 0.14mm size classes. Solid bars represent relative abundance of snails for a particular size class (n=100 for each sample).

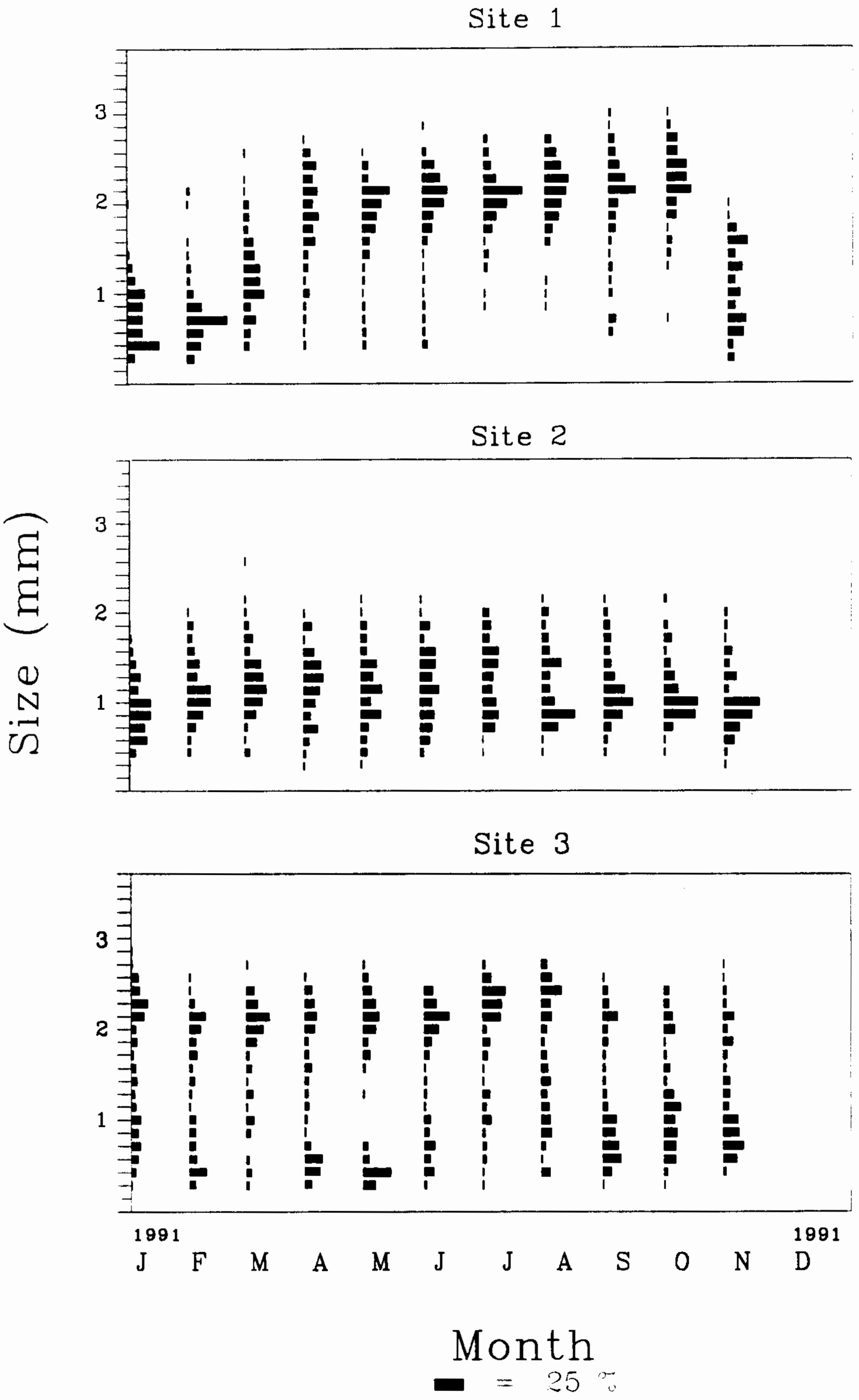

Figure 3b. Size histograms for the Bruneau Springsnail study sites. Horizontal tick marks represent 0.14mm size classes. Solid bars represent relative abundance of snails for a particular size class (n=100 for each sample).

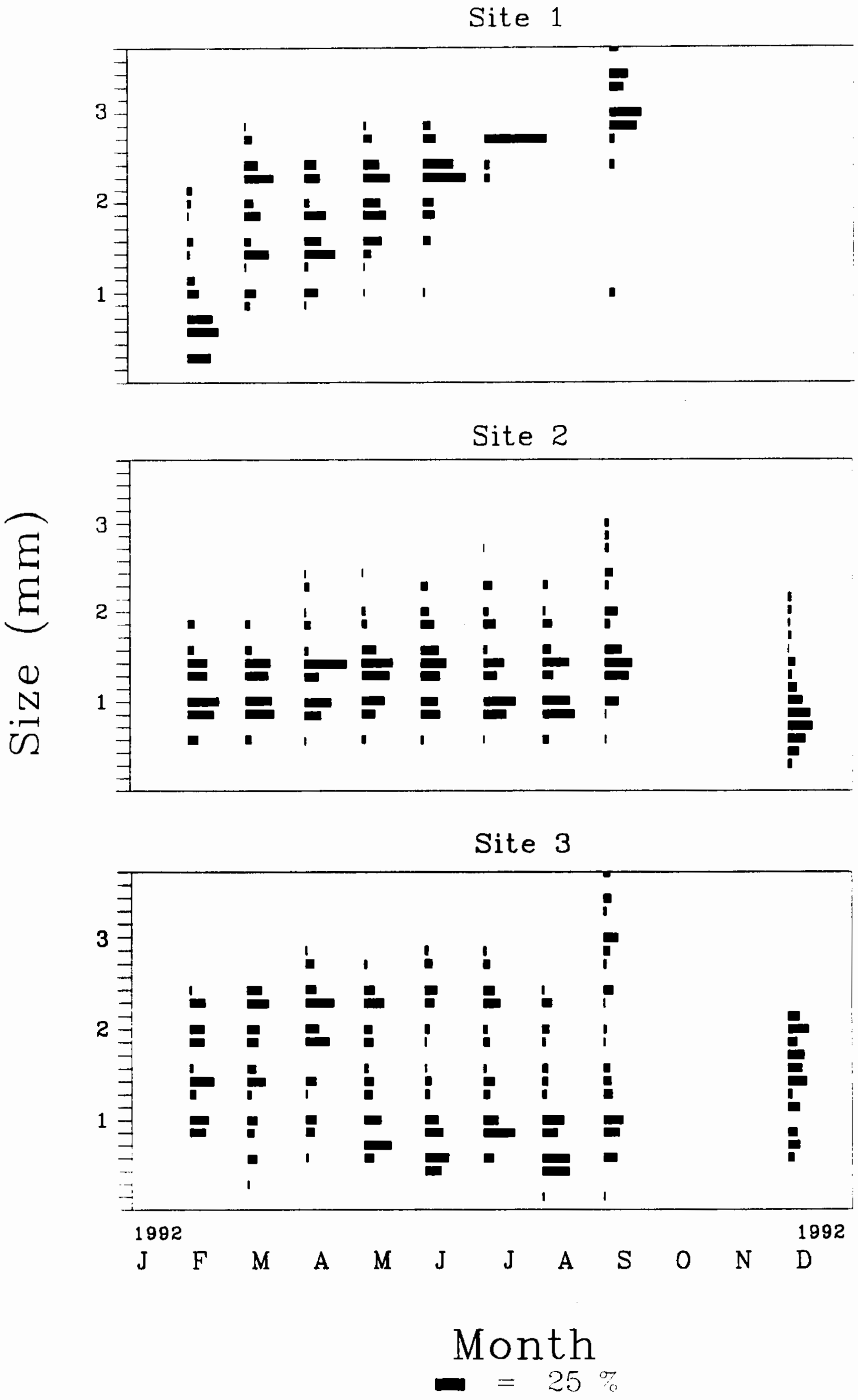

Figure 3c. Size histograms for the Bruneau Springsnail study sites. Horizontal tick marks represent 0.14mm size classes. Solid bars represent relative abundance of snails for a particular size class (n=100 for each sample). In July, 92% of the snails at Site 1 were found in the 2.66 mm size class (an out of range value for this figure).

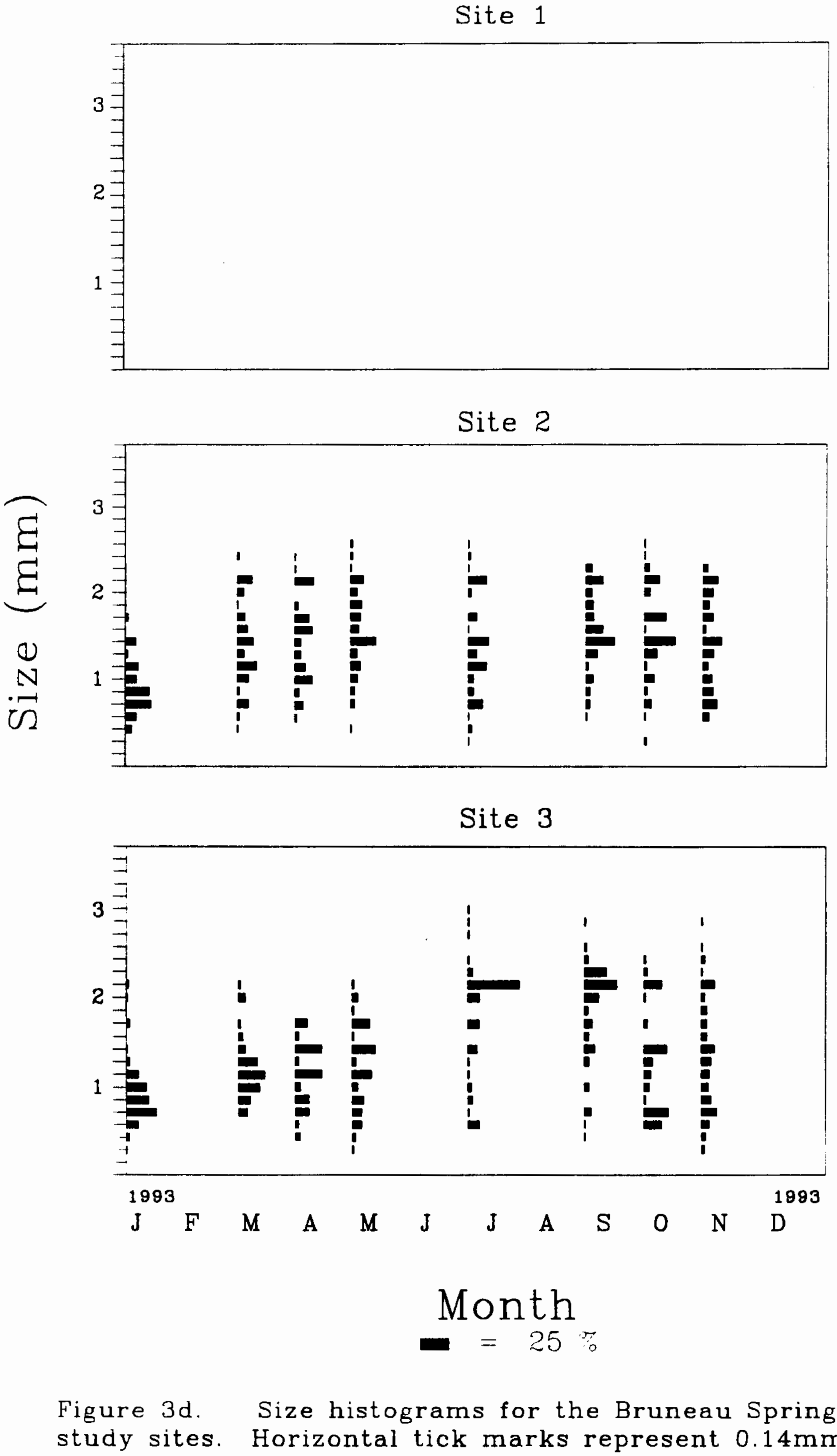

Figure 3d. Size histograms for the Bruneau Springsnail study sites. Horizontal tick marks represent 0.14mm size classes. Solid bars represent relative abundance of snails for a particular size class (n=100 for each sample).

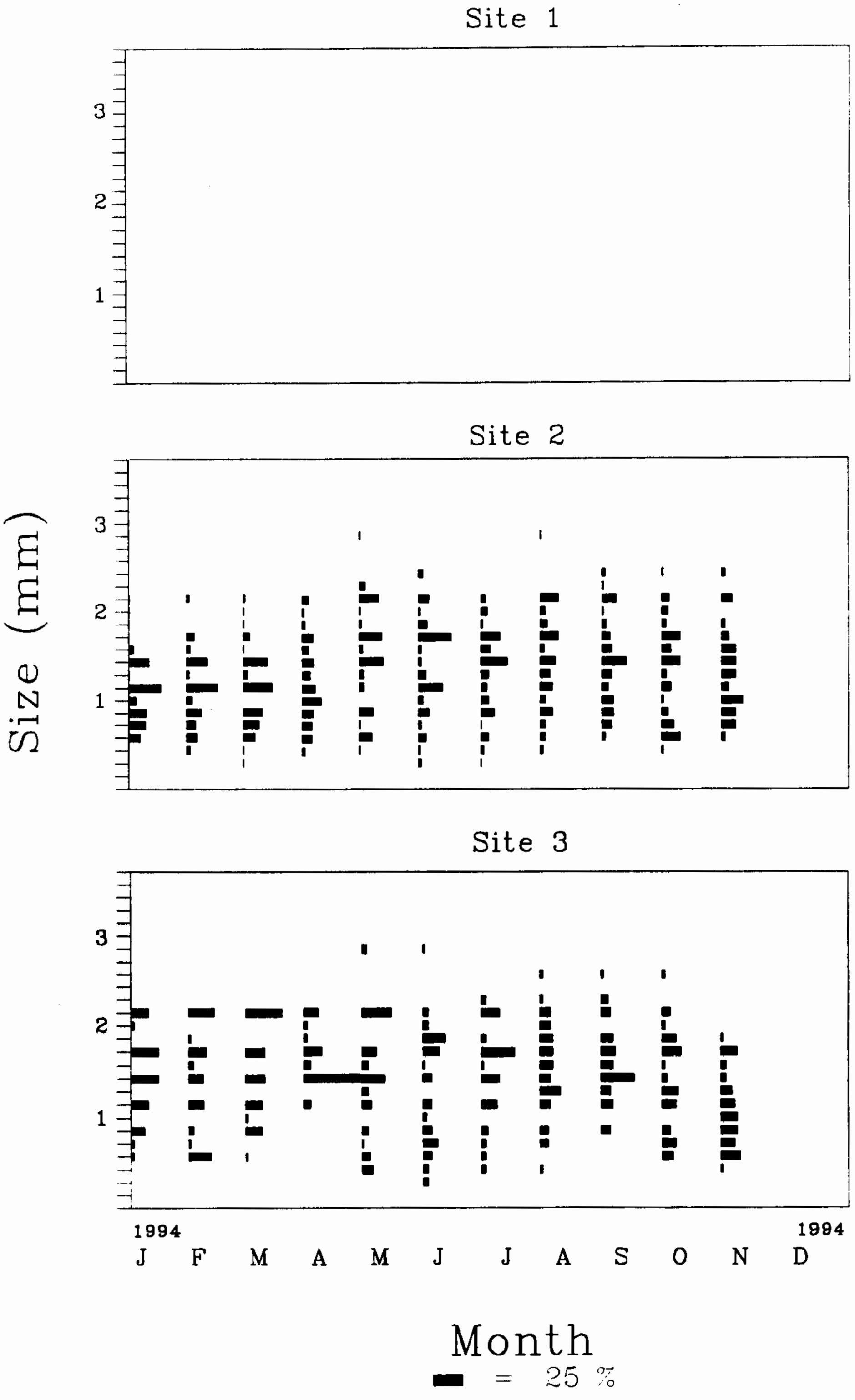

Figure 3e. Size histograms for the Bruneau Springsnail study sites. Horizontal tick marks represent 0.14mm size classes. Solid bars represent relative abundance of snails for a particular size class [n=100 for Site 2; n=50 for Site 3; n=50 for Site 3 New Seep (Fig. 4)].

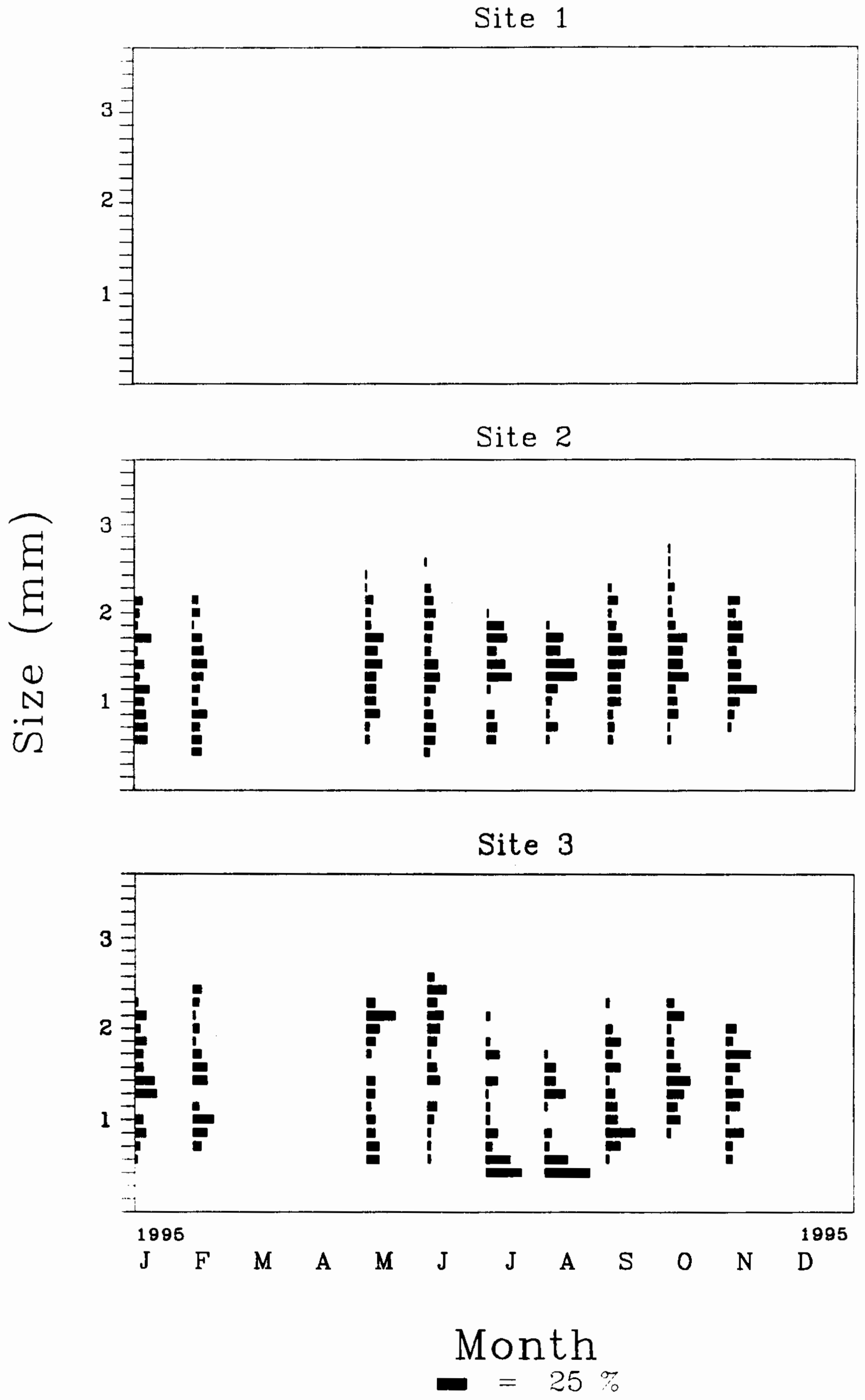

Figure 3f. Size histograms for the Bruneau Springsnail study sites. Horizontal tick marks represent 0.14mm size classes. Solid bars represent relative abundance of snails for a particular size class [n=100 for Site 2; n=50 for Site 3; n=50 for Site 3 New Seep (Fig. 4)].

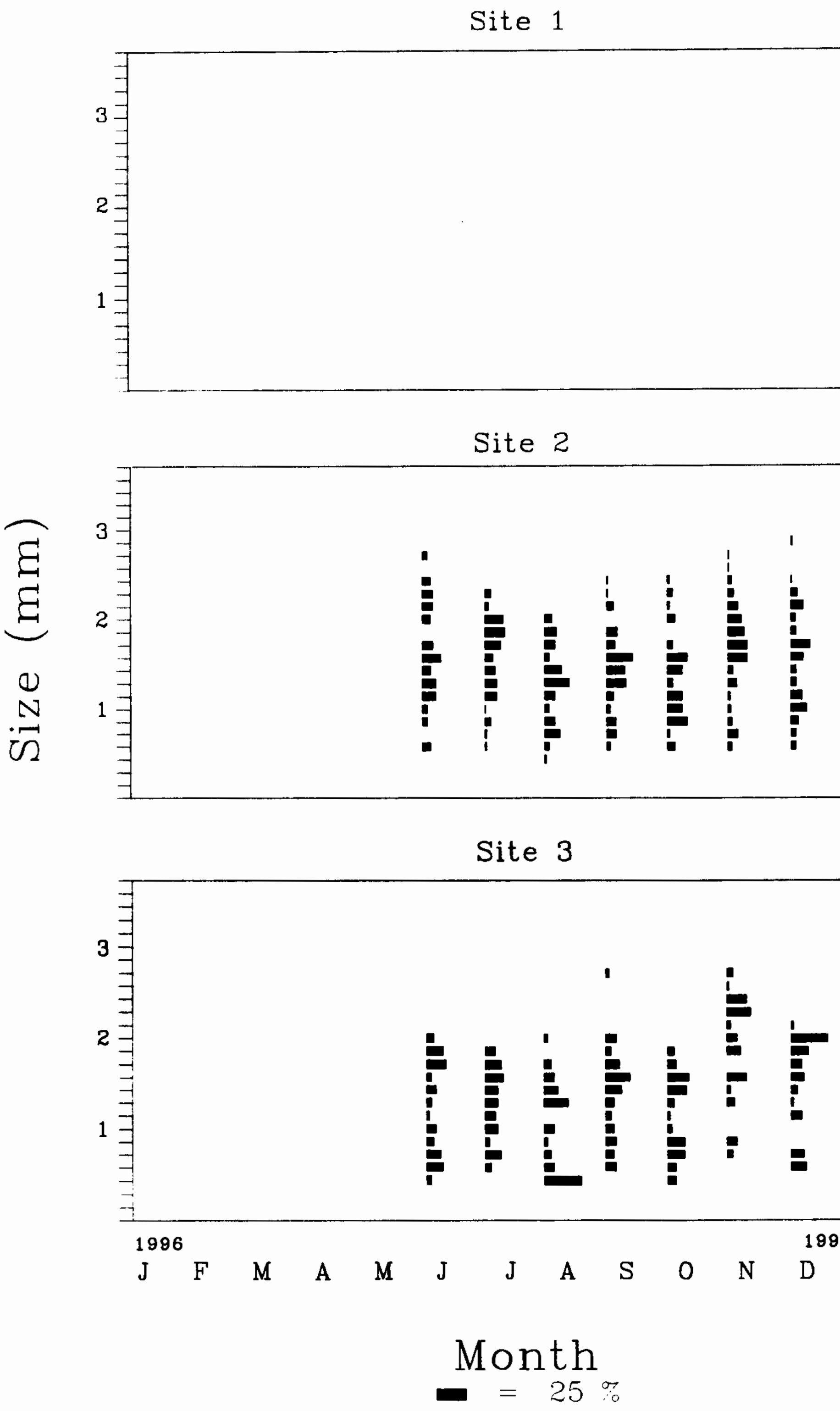

Figure 3g. Size histograms for the Bruneau Springsnail study sites. Horizontal tick marks represent 0.14mm size classes. Solid bars represent relative abundance of snails for a particular size class [n=100 for Site 2; n=50 for Site 3; n=50 for Site 3 New Seep (Fig. 4)].

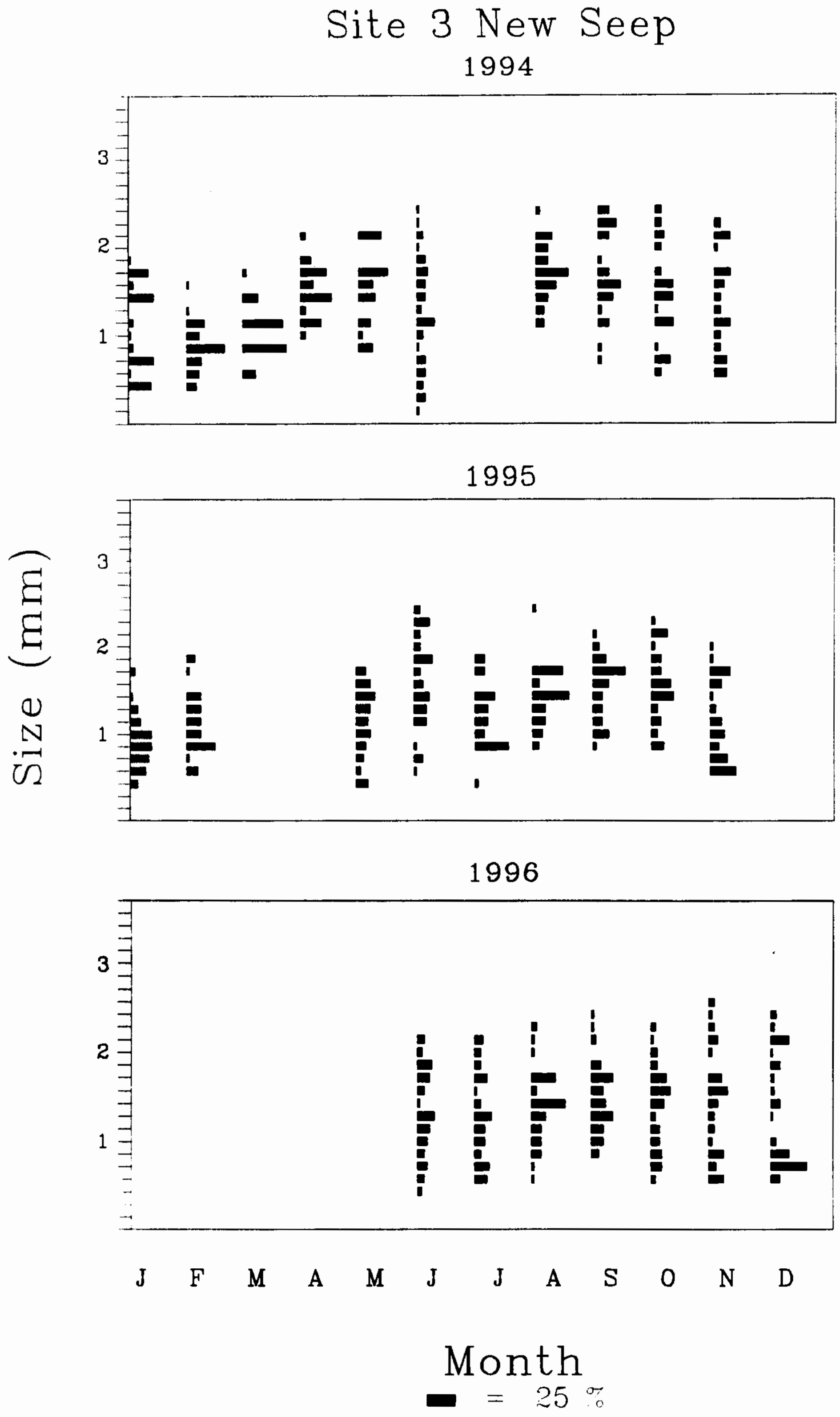

Figure 4. Size histograms for the Bruneau Springsnail study site 3 New Seep. Horizontal tick marks represent 0.14 mm size classes. Solid bars represent relative abundance of snails for a particular size class (n=50 for each sample).

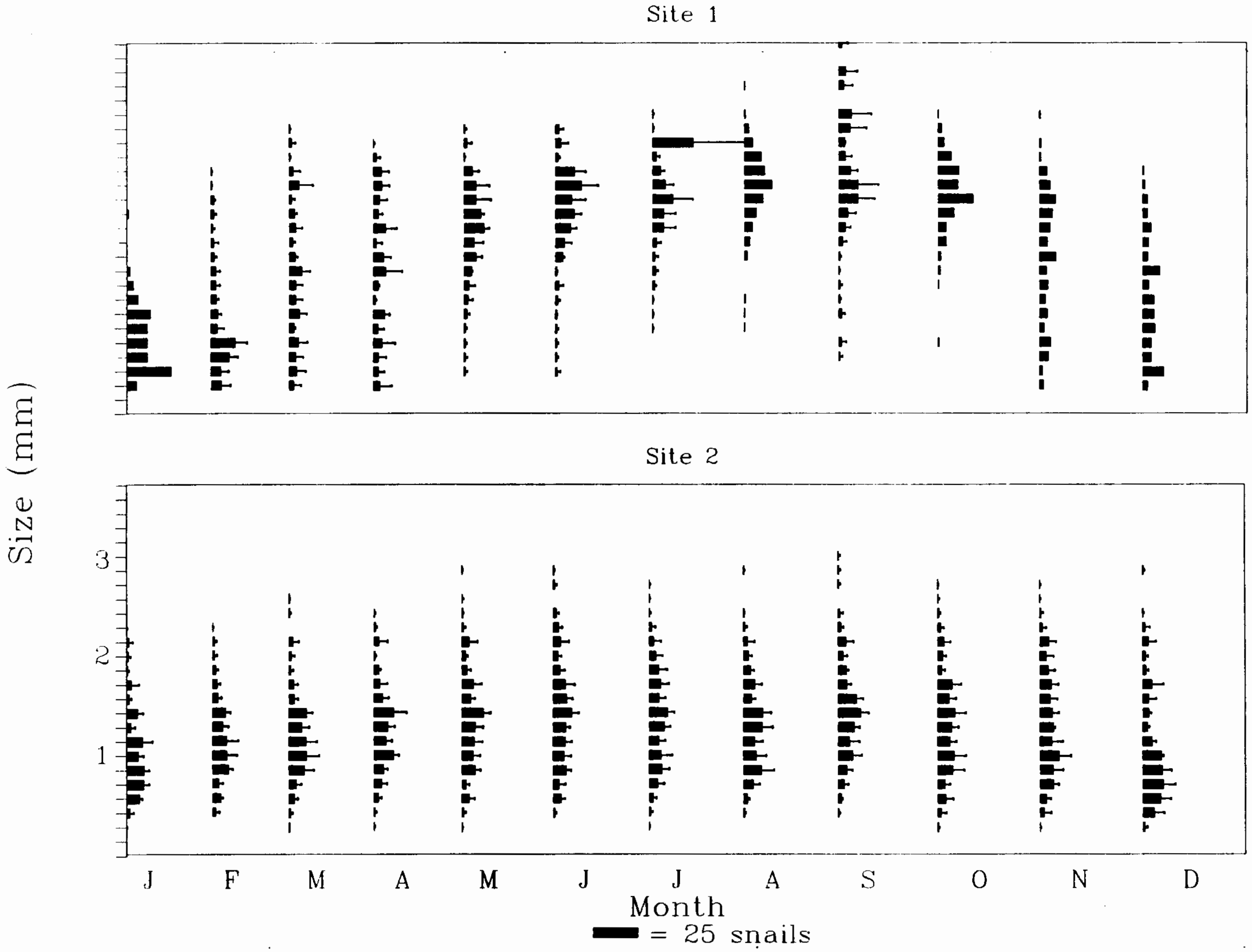

Figure 5a. Size histograms for Bruneau Springsnail study sites 1 and 2 based upon data from 1990–1996. Horizontal tick marks represent 0.14mm size classes. Error bars represent one standard deviation from the mean. Figures lacking error bars did not have enough sets of data to determine standard deviations.

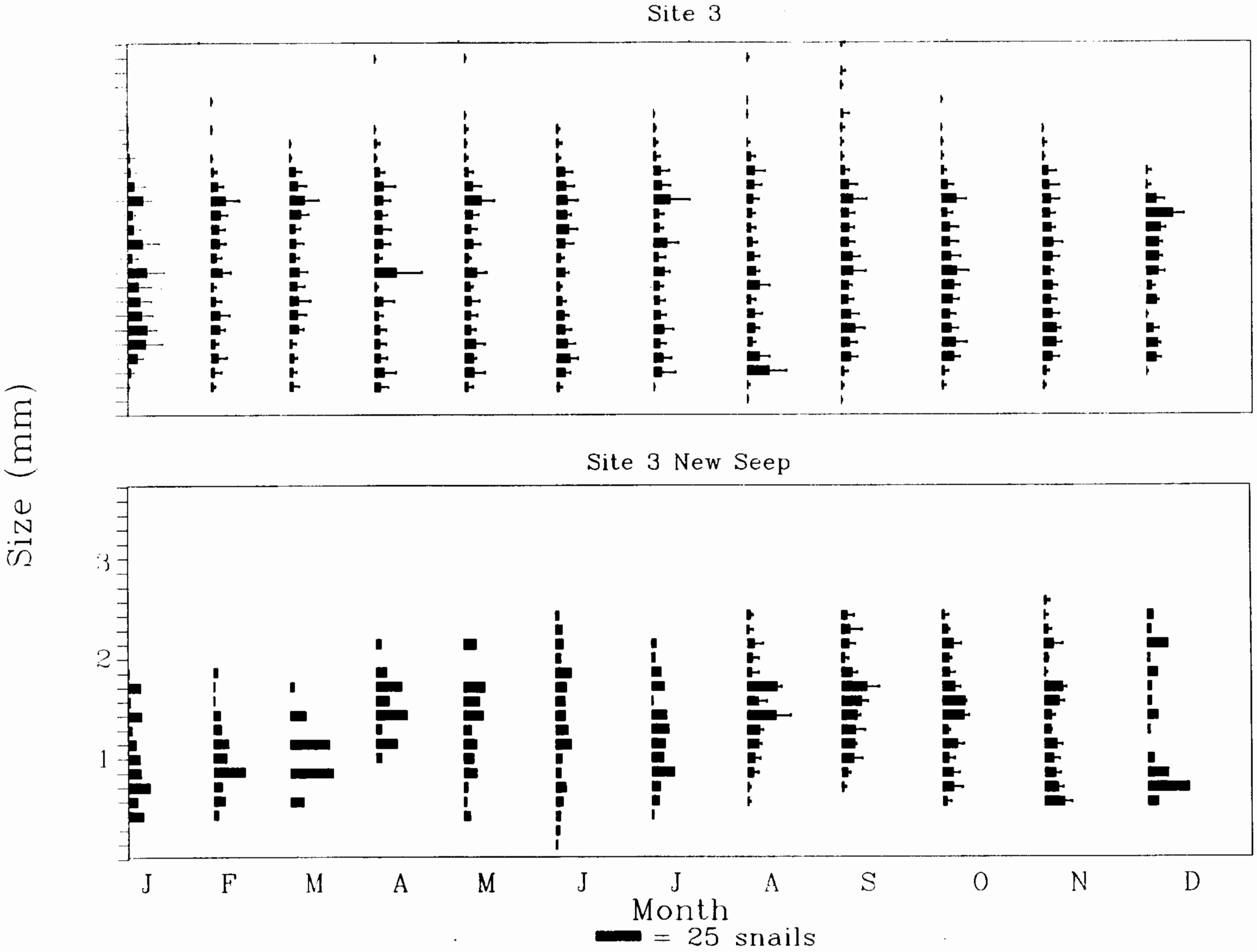

Figure 5b. Size histograms for Bruneau Springsnail study sites 3 and 3 New Seep based upon data from 1990–1996. Horizontal tick marks represent 0.14-mm size classes. Error bars represent one standard deviation from the mean. Figures lacking error bars did not have enough sets of data to determine standard deviations.

relatively even across size classes between June and December 1996 (Fig. 3g). November was an exception, having a large proportion of its population in size classes larger than 1.5 mm. Mean population distribution data (Fig. 5a) showed juveniles to be most prevalent in the cooler months (e.g. January and December), although recruitment appeared to occur at all times of the year.

Site 3 (Lower Spring Rockface)

There were no clear size distribution trends between June and December 1996, although the colder months (November and December) did have a larger proportion of indviduals in the $\geq$ 2 mm size classes (Fig. 3g). Mean population size distribution data for the springsnail population at Site 3 (Original Seep) does not show clear trends associated with season (Fig. 5a). Individuals appear to be dispersed fairly evenly across the size classes each month.

Site 3 (New Seep)

Between June and December 1996, the springsnail population at Site 3 New Seep appeared to be evenly distributed across the different size classes (Fig. 4). However, there was a marked increase in the proportion of juveniles in December (Fig. 4). Mean population size distribution data suggest that the New Seep population had fairly constant proportions of individuals distributed across the different size classes during all seasons, although there was a slight increase in the presence of juveniles and a decrease in the presence of mature size classes during the cold months (January-March and December) (Fig. 5b). There was a noticeable lack of individuals > 2 mm at Site New Seep when compared to the other sites.

Comparison of Average Monthly Snail Sizes Among Sites

An analysis of the average monthly snail sizes, based upon averages of the 1990-1996 data (Fig. 6) revealed distinct differences in population life histories among the study sites. Snails at Site 1 appeared to grow as a distinct cohort. The water temperatures at Site 1 were the warmest (often above the thermal maximum temperature of 35°C (Mladenka 1992) in the summer). Recruitment probably only occurred in the cool winter months, based upon the small average snail sizes found between January and March. The slope of the regression line (indicative of snail growth) for Site 1 (0.244; $p = 0.000$) (Fig. 6) is largely positive and represents a gradual aging of the population between January and August. September was the month when another cohort appeared to begin its development in Hot Creek (Fig. 5a), so Figure 6 does not take the months of September through December into account. Site 1 also had the largest size snails of all the study sites (Fig. 6). The populations at the other sites (2, 3, and 3 New Seep) do not exhibit such strong trends

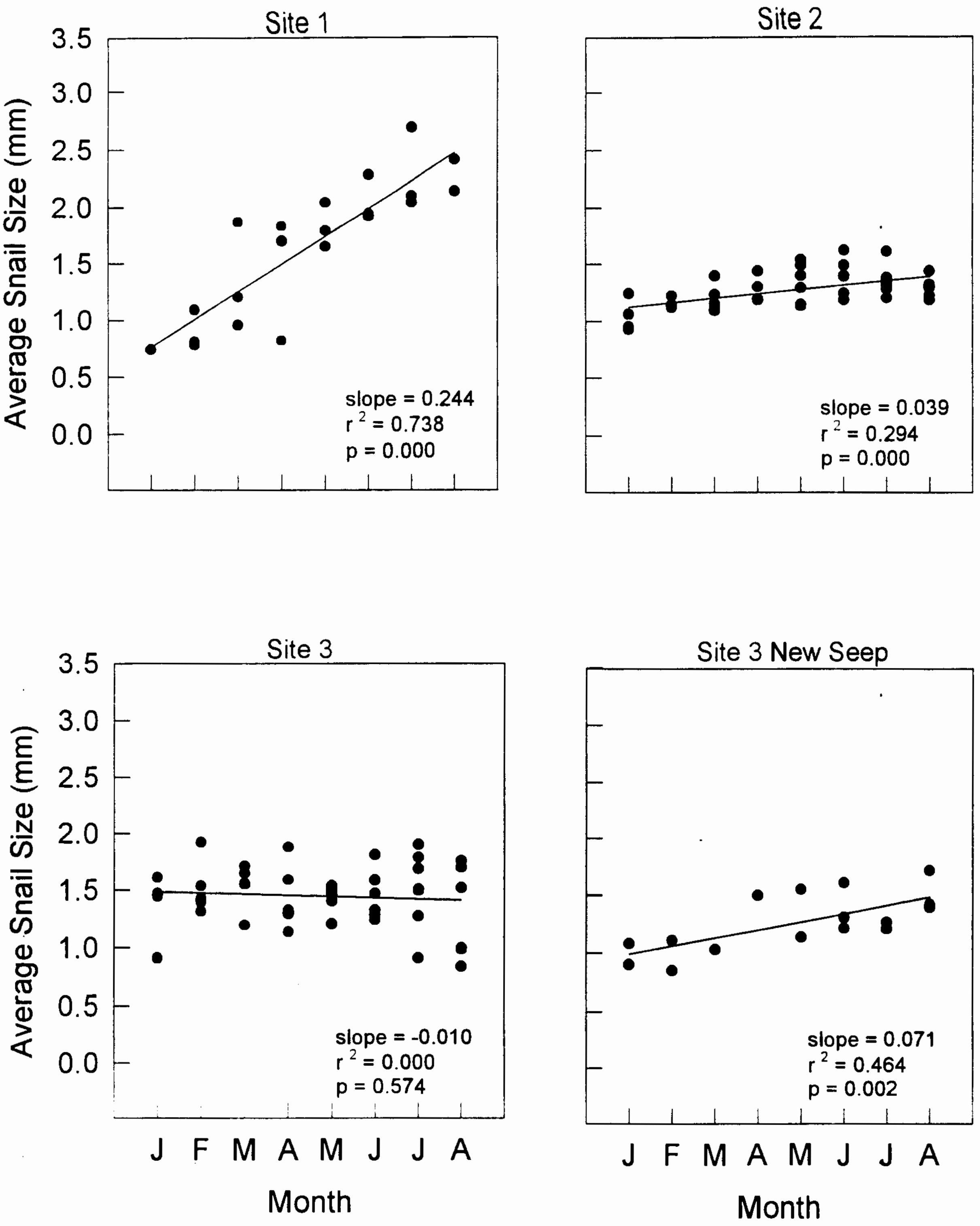

Figure 6. Average monthly Springsnail size (mm) for populations at study sites 1, 2, 3 (Original Seep) and 3 (New Seep). See text for explanation of months chosen for analyses. Monthly size data used was 1990 through 1992 (Site 1), 1990 through 1996 (Sites 2 and 3 Original Seep), and 1994 through 1996 (Site 3 New Seep).

when compared with Site 1 (analyzed between January and August for comparative purposes). Both Site 2 and Site 3 New Seep had significant regression lines ($p < 0.01$) with slightly positive slopes (0.039 and 0.071, respectively). Site 3 (Original Seep) data is very scattered and even exhibits a negative trend between January and August (slope = -0.01, $p = 0.574$).

Population Fluctuations

Site 1 (Hot Creek)

Storm flow in Hot Creek during July 1992 resulted in major channel scouring and sediment loading. As a result, Indian Bathtub was filled with sediment. The Hot Creek population of *P. bruneauensis* was reduced to nearly zero (Robinson et al. 1992). Snails have not been found in Hot Creek since 1993. It is likely that *P. bruneauensis* has been extirpated from this site (Fig. 7; Royer and Minshall 1993). A stream-side refugium that had retained snails (<10 individuals) in the past (Robinson et al. 1992) continued to do so in 1993. Royer and Minshall (1993) noted that in May 1993 this refugium became overgrown with dense terrestrial vegetation. These conditions have persisted, inhibiting observations, since that time.

Site 2 (Upper Spring Rockface)

The snail population at Site 2 maintained fairly constant

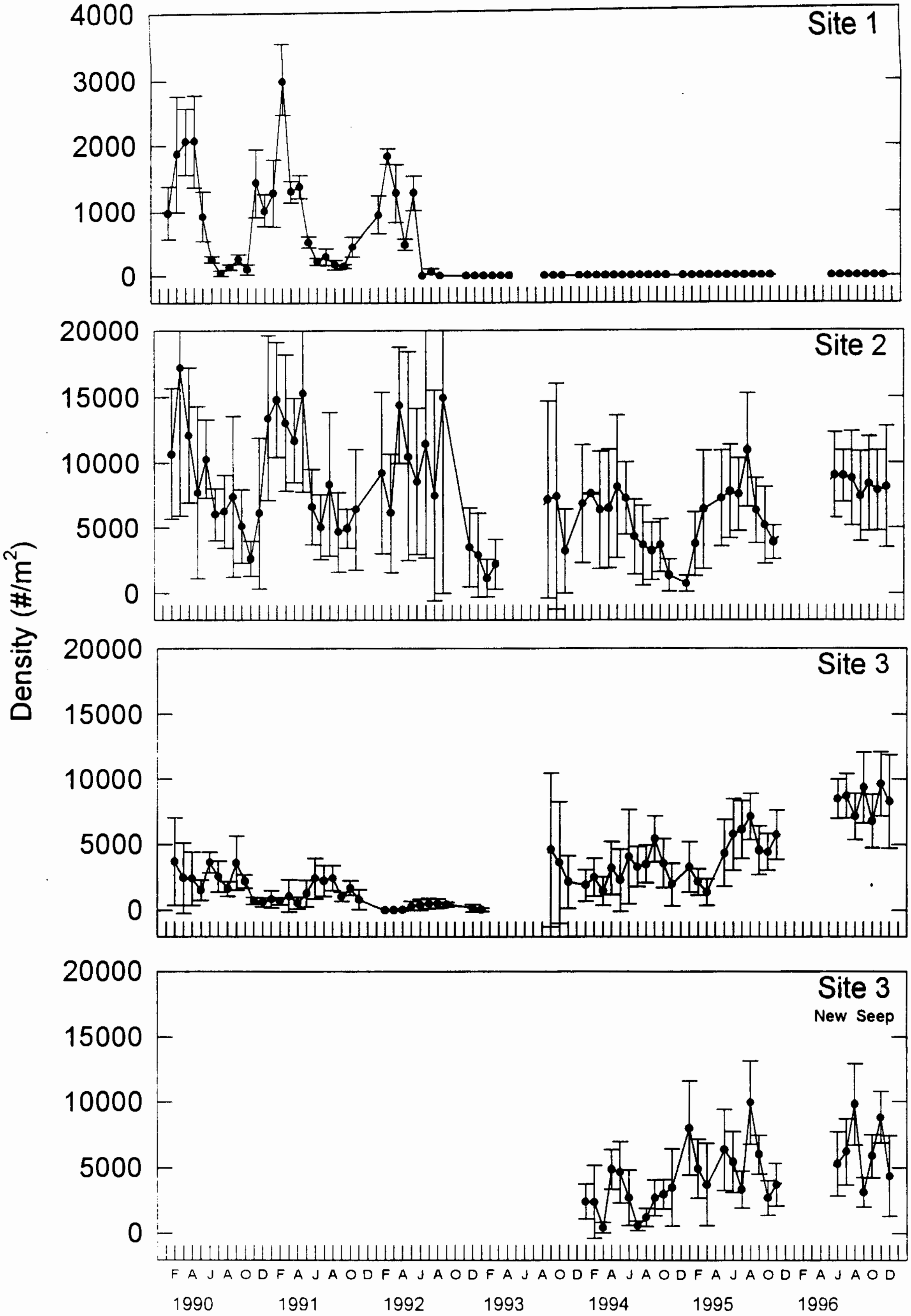

Figure 7. Mean density of the Bruneau Springsnail at the four study sites. Error bars represent one standard deviation from the mean. Note the different Y-axis for Site 1.

densities between June and December 1996 (Fig. 7). The highest density for Site 2 in 1996 was 9007 snails/m^2 in June and the lowest density for Site 2 was 7398 snails/m^2 in September (Fig. 6). Densities at Site 2 from 1990 to 1996 have generally been higher than the other study sites, although monthly estimates are highly variable. Typically, lower densities at Site 2 were found during colder months (September through February) (Fig. 7).

Site 3 (lower spring rockface)

In 1996, the Site 3 Original Seep springsnail population maintained fairly constant densities between June and December which were higher than previous monitoring years (Fig. 7). The highest snail population at this site was 9650 snails/m^2 in November while the lowest population was 6791 snails/m^2 in October (Fig. 6). The middle rockface area at Site 3 (Fig. 2) has very low springflows, and is covered with a very thick bacterial-algal complex which eventually made density estimates impossible without alteration of the habitat. This area was excluded from density estimates and is reflected by increased density estimates between October 1993 and December 1996 (Fig. 7).

Site 3 (New Seep)

Snail densities at Site 3 New Seep varied much more than Sites 2 and 3 Original Seep between June and December 1996 (Fig.

7). The highest density, 9793 snails/m^2, was recorded in August and the lowest density, 3145 snails/m^2, was recorded in September. Densities in 1996 were very similar to those estimated in previous years (Fig. 7). Currently, Site 3 (New Seep) does not provide a habitat suitable for the support of large populations of springsnails because of the small rockface area, large amount of shading, and low groundwater flow. Still, this seep does support a viable population. Improvement in habitat (e.g. augmentation of groundwater flow) would probably result in increased density and total population numbers.

Rockface habitat

Some parts of the rockface study sites (Sites 2, 3, and 3 New Seep; Fig. 2) are covered by thick layers of periphyton. At Site 2 and Site 3 New Seep this periphyton is primarily composed of diatoms, green algae, and, most likely, warm-water-adapted bacteria. At Site 3 Original Seep, blue-green algae are also an important component of this periphyton. The middle rockface area at Site 3 (Fig. 2c) is almost completely covered with this periphyton matrix, and it is not monitored for springsnails, although they have been found to exist beneath the covering. At the study sites, snail densities have not been monitored where this periphyton is thicker than a 1-2 mm. Random samples within this thick periphyton complex at each of the sites indicate that snail densities are often less than a third of what they are in clear rockface areas. These thick layers appear to be spreading into damp areas where water is not flowing down the rockface. Future monitoring will need to monitor rockface cover by the bacterial-algal complex and springsnail densities under this complex to monitor future changes in springsnail habitat. As groundwater flows decrease, less rockface area will be covered by fast flowing water, and more habitat will probably be covered by the bacterial-algal complex. Given enough reduction in springflow, springsnail populations could be reduced to abundances that are too small to remain viable.

Discharge, Temperature, and Water Chemistry Fluctuations

Battery problems (purported as having 2-year lifespans) in the data loggers resulted in the loss of some of the temperature data for 1996. Because the monitoring in 1996 was not funded until June, data loggers were not retrieved until that time. Excess moisture in the Site 1 data logger resulted in the loss of Hot Creek temperature data from January through May 1996. Later in the year, a bad set of batteries resulted in data loss at all sites, despite testing in the laboratory prior to positioning in the field. The total temperature data lost included January through October (Site 1), July through October (Site 2), and August through October (Site 3 Original Seep) in 1996. Future precautions for avoiding data loss should include the use of more desiccant in the logger cases and more rigorous testing of batteries and logger instruments before placing in the field.

Site 1 (Hot Creek)

Discharge dropped after channel scouring and sediment loading in July 1992. Discharge after the start of 1993 fluctuated greatly, probably as a result of precipitation (Fig. 8). Reduced discharge in Hot Creek resulted in higher maximum water temperatures for 1992 (Mladenka 1992). This relationship did not hold as strongly between 1993 and 1996 (Fig. 8). Very low temperatures at Site 1 in 1993 were probably the result of thermometer exposure to air (Royer and Minshall 1993). In 1994, both minimum (31°C) and maximum temperatures (36°C) were recorded in May (Fig. 10). This most likely occurred when the height of the water in Hot Creek dropped and the top of the temperature logger case (internal sensor) became exposed to air (remedied on the next monitoring date). Temperatures in 1995 ranged from 33 to 35°C. During November and December 1996, temperatures ranged from 31 to 33°C (Fig. 10). There was no apparent change in water chemistry at Site 1 during 1996 (Fig. 11).

Site 2

At the left seep, the percent springflow-covered (SFC) rockface fluctuated between 20 and 25% for both 1995 and 1996

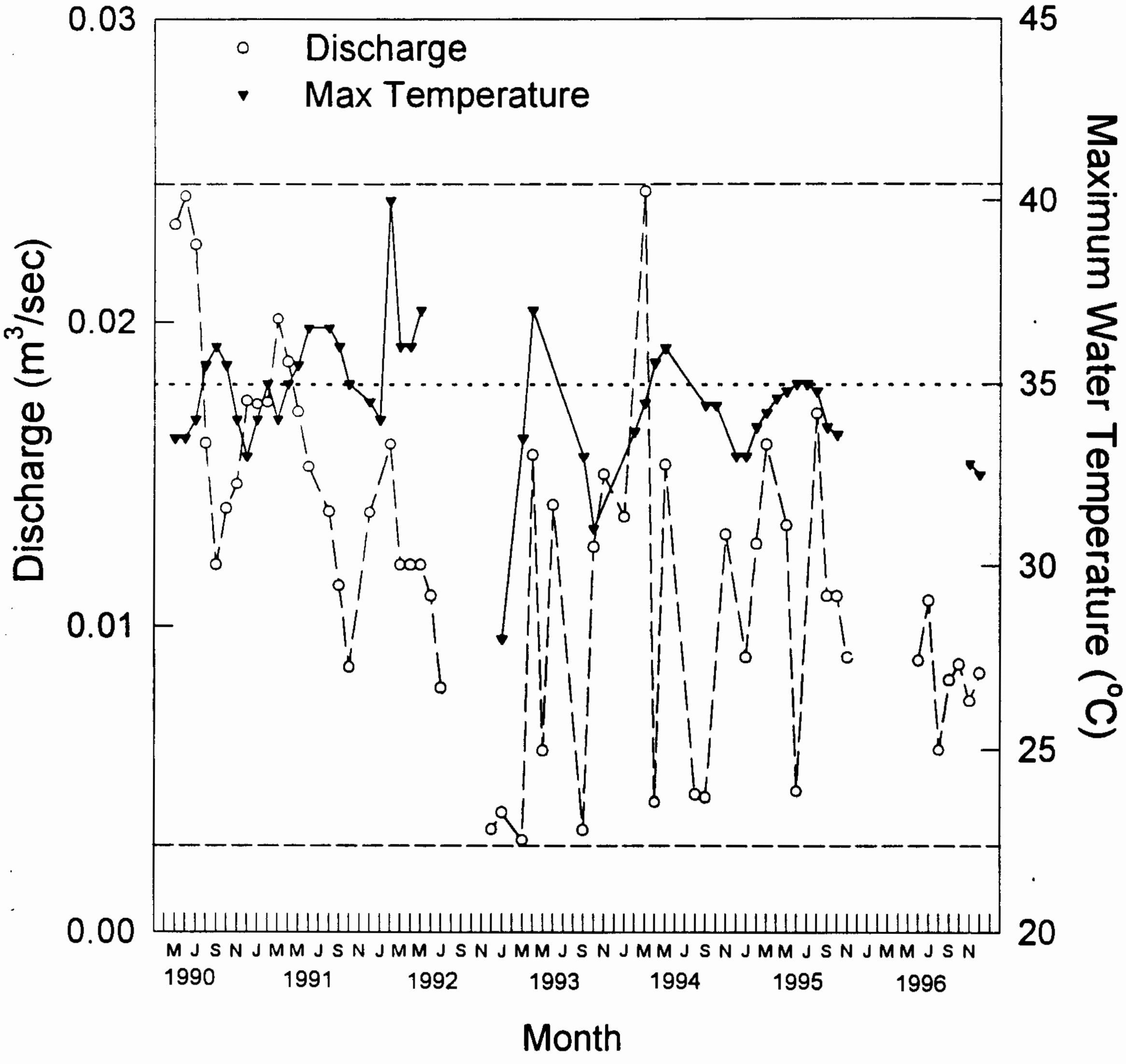

Figure 8. Discharge and maximum water temperatures for Site 1 (Hot Creek). Dashed horizontal lines indicate the maximum and minimum discharges measured at Hot Creek. Dotted horizontal line indicates thermal maximum temperature for *P. bruneauensis*.

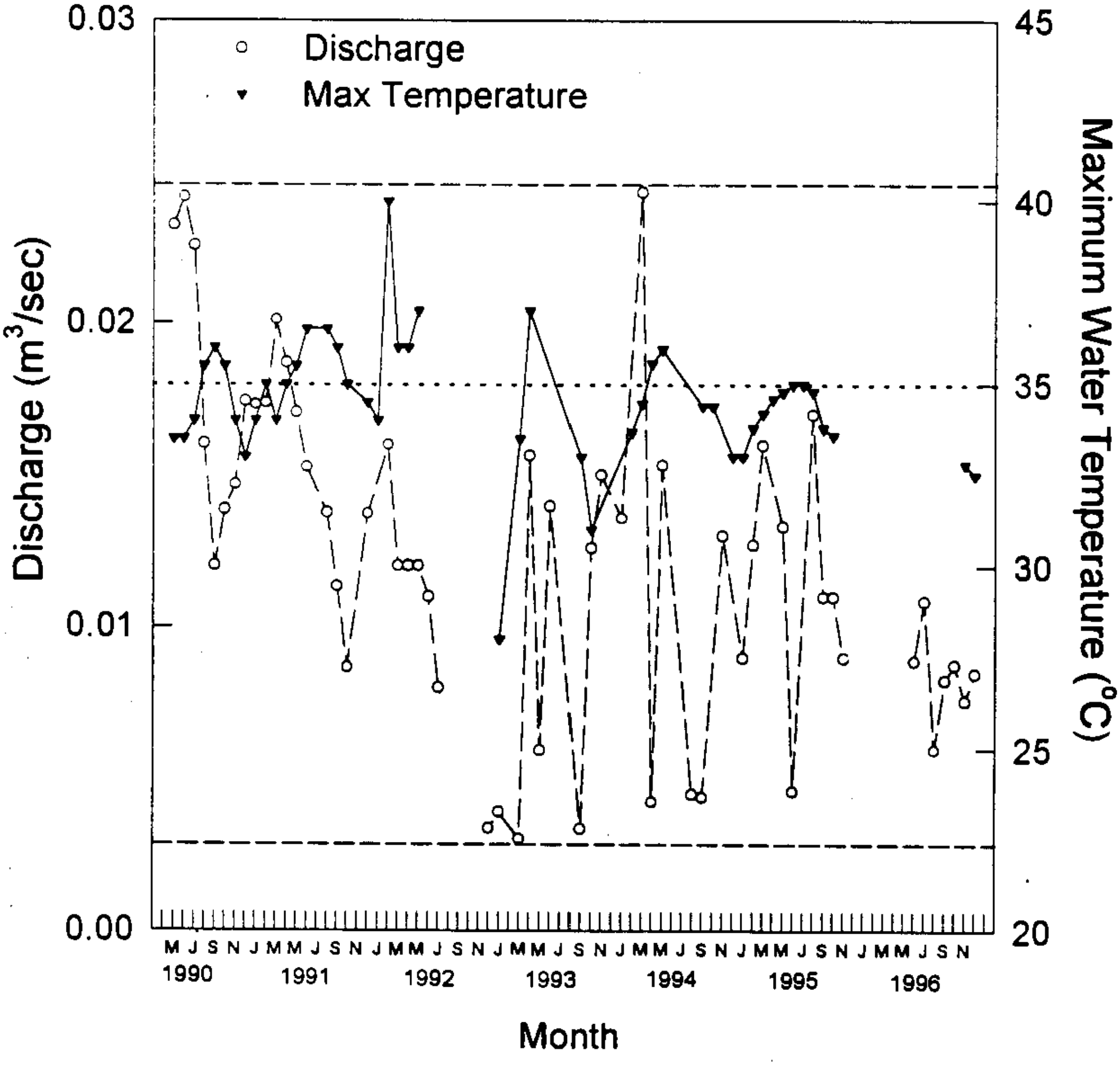

Figure 8. Discharge and maximum water temperatures for Site 1 (Hot Creek). Dashed horizontal lines indicate the maximum and minimum discharges measured at Hot Creek. Dotted horizontal line indicates thermal maximum temperature for *P. bruneauensis*.

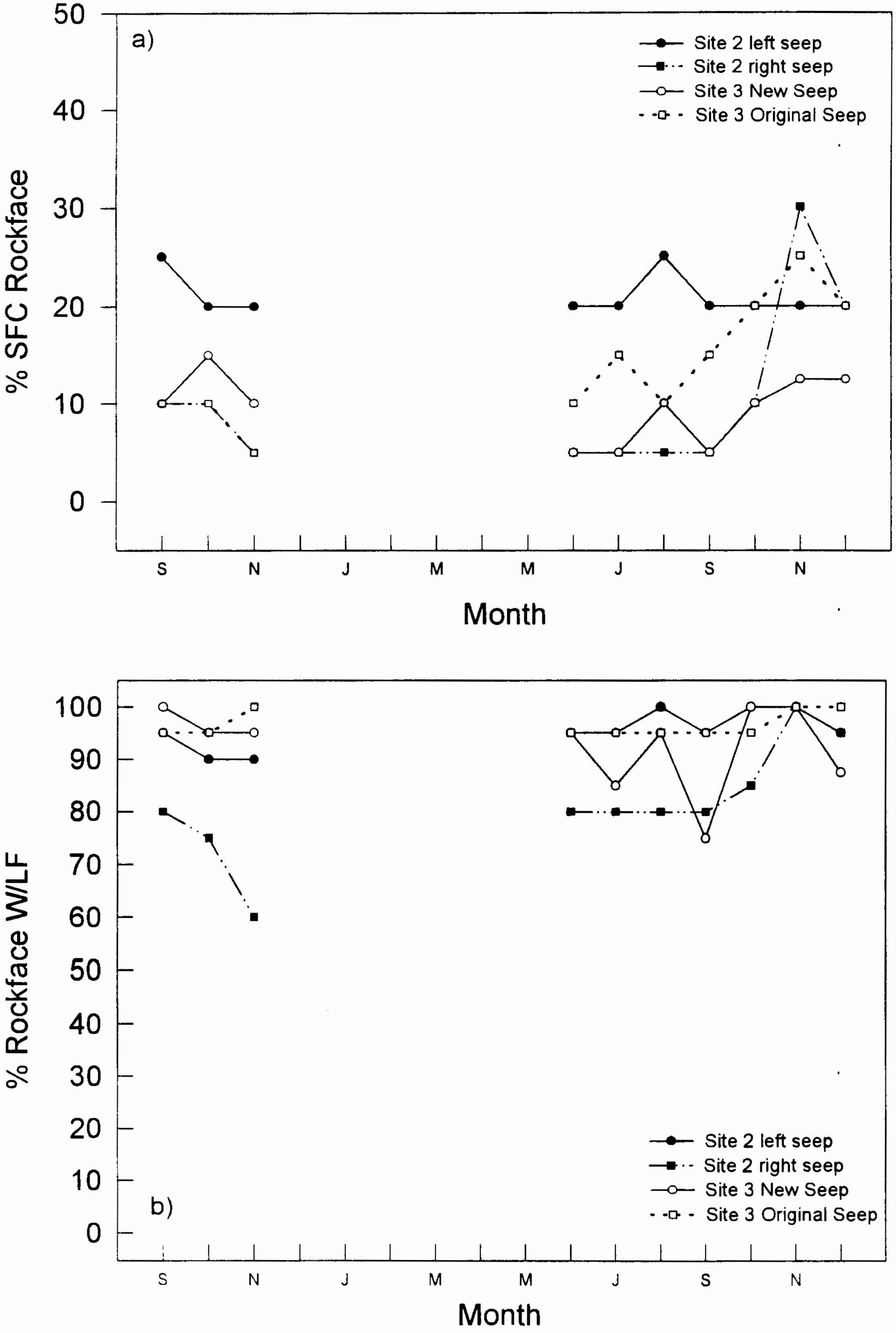

Figure 9. Percent springflow-covered rockface (SFC rockface) (a) and percent rockface, wetted, but lacking flow (rockface W/LF) (b) for the Bruneau Springsnail study sites.

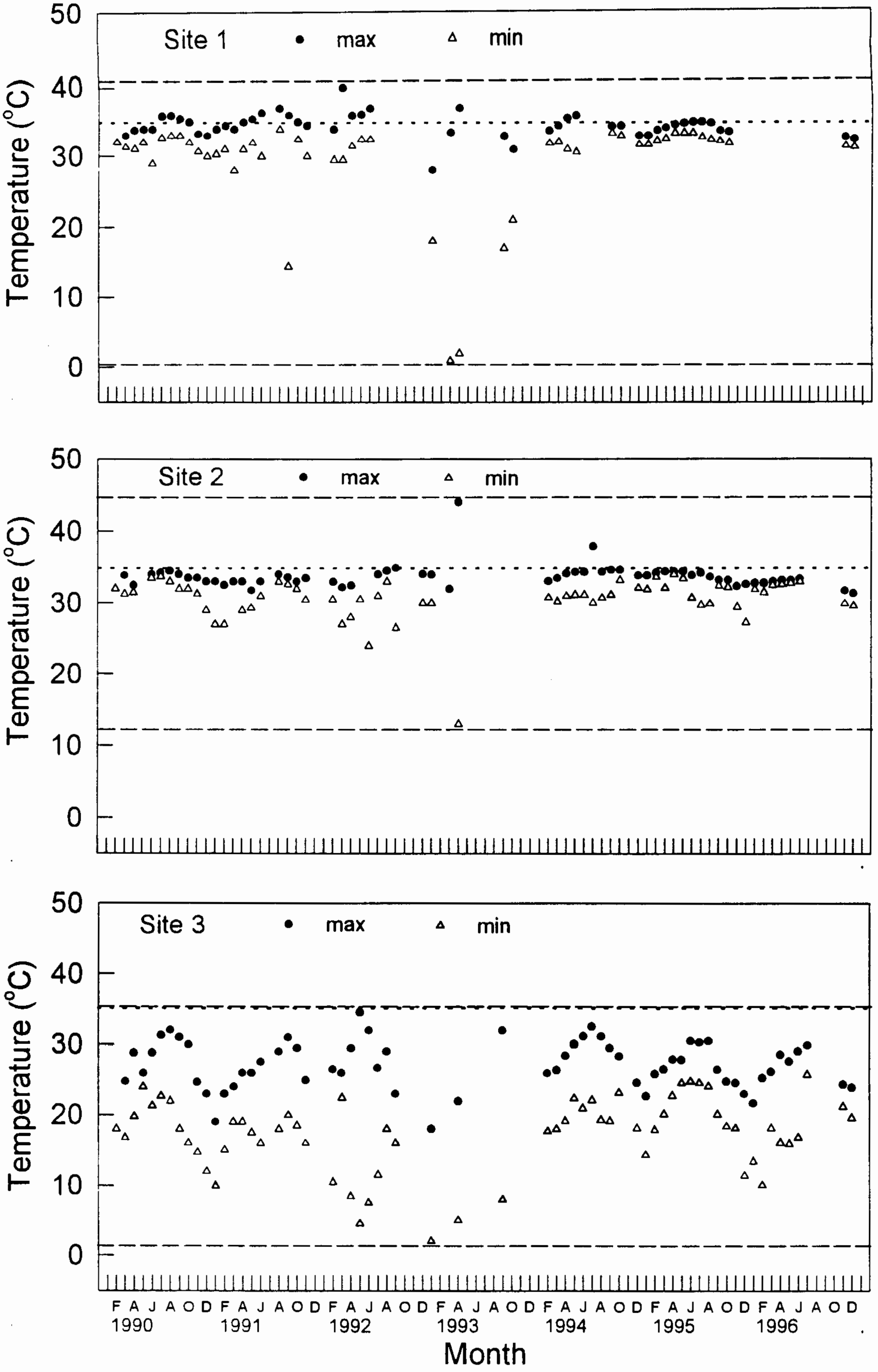

Figure 10. Maximum and minimum water temperatures for the Bruneau Springsnail study sites. Dashed horizontal lines indicate maximum and minimum temperatures. Dotted horizontal lines indicate thermal maximum temperature for *P. bruneauensis*. See text for information on Site 3 New Seep temperature data.

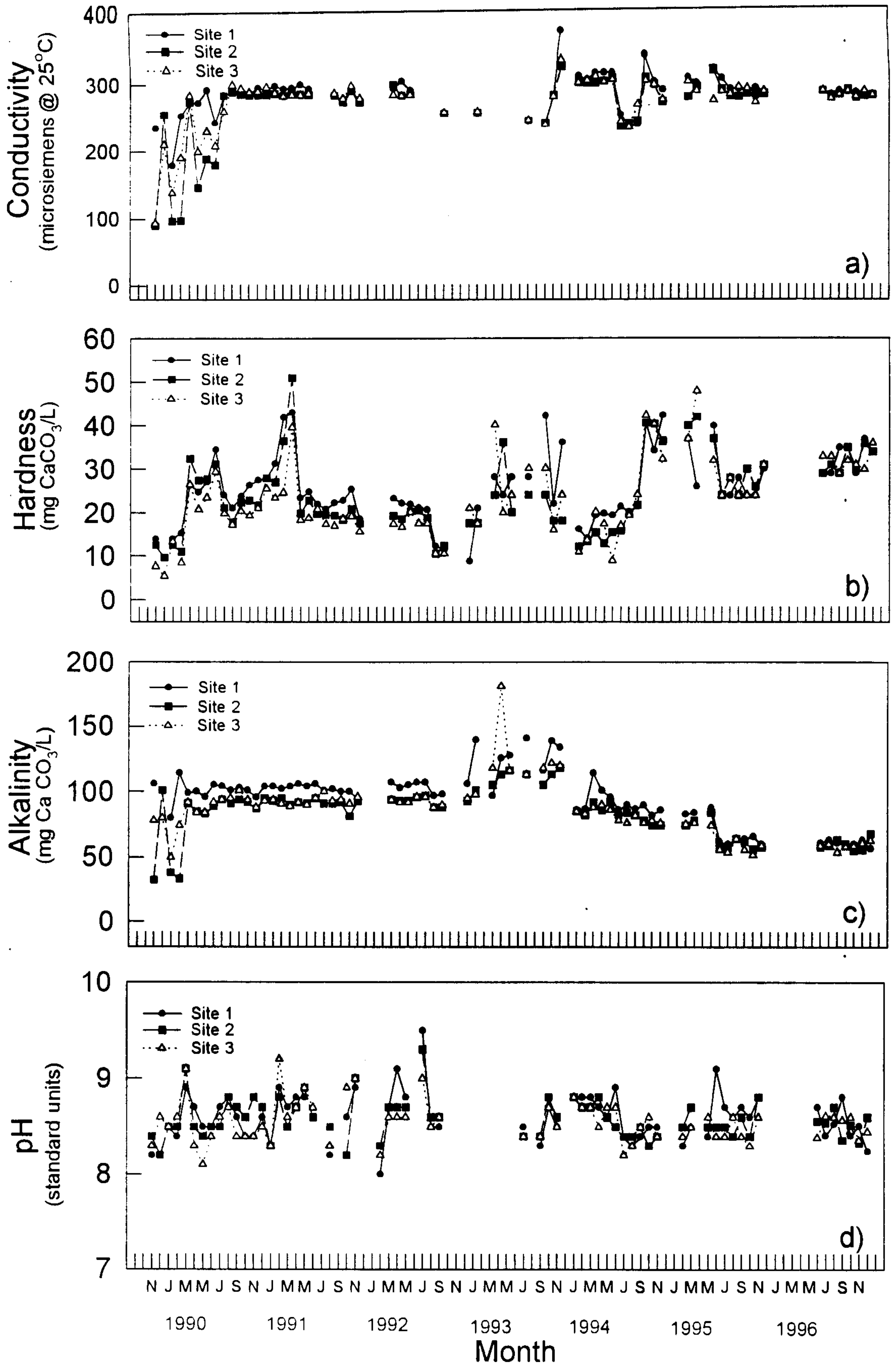

Figure 11. Conductivity (a), hardness (b), alkalinity (c), and pH (d) for the Bruneau Springsnail study sites.

(Fig. 9a). The percent rockface wetted, but lacking flow (W/LF), ranged from 90 to 100% (Fig. 9b). At the right seep, the percent SFC rockface fluctuated between 5 and 10% from September 1995 until October 1996 (Fig. 9a). In November and December 1996, these values were 25 and 20%, respectively, which probably resulted from concurrent rain events. The percent rockface W/LF ranged from a low of 60% in November 1995 to 100% in November 1996 (Fig. 9b). Again, precipitation probably induced the high values. Very low temperatures at Site 2 in 1993 were probably the result of exposure to air (Royer and Minshall 1993). Site 2 maintained relatively constant temperatures during 1996 (Fig. 10). For 1996, minimum temperatures (30°C) were recorded in December and maximum temperatures (33°C) were recorded in June (Fig. 10). Water chemistry for 1996 was similar to values from other years (Fig. 11).

Site 3

The percent SFC rockface for Site 3 Original Seep ranged between a low of 5% in November 1995 to a high of 25% in November 1996 (which probably resulted from a concurrent precipiptation event) (Fig. 9a). The percent rockface W/LF ranged between 95 and 100% (Fig. 9b). Very low temperatures at Site 3 in 1993 were probably the result of exposure to air (Royer and Minshall 1993). In 1996, temperatures varied widely, as in other years, ranging between 10°C in February and 30°C in July (Fig. 10). Water chemistry for 1996 was similar to values from other years (Fig. 11).

Site 3 New Seep

The percent SFC rockface for Site 3 New Seep ranged from 5 to 15% during 1995 and 1996 (Fig. 9a). The percent rockface W/LF ranged from a maximum of 100% (September 1995, October and November 1996) to a minimum of 75% in September 1996 (Fig. 9b). In November and December 1996, Site 3 (New Seep) had the greatest gaps between maximum and minimum temperatures, besides having the lowest overall maximum (23°C) and minimum (15°C) water temperatures (not presented as a figure).

Periphyton Levels

Site 1 (Hot Creek)

In 1996, chlorophyll a and periphyton ash-free dry mass (AFDM) values were greatest during the late summer months (Figs. 12, 13). The highest value for chlorophyll a, 258.3 mg/m^2, was found in July, and the lowest value, 47.6 mg/m^2, was found in November. The highest value for AFDM, 38.8 g/m^2, was found in July, and the lowest value, 9.7 g/m^2 was found in October. This trend is consistent with the seasonal changes in Hot Creek's periphyton community observed during previous years. Except for

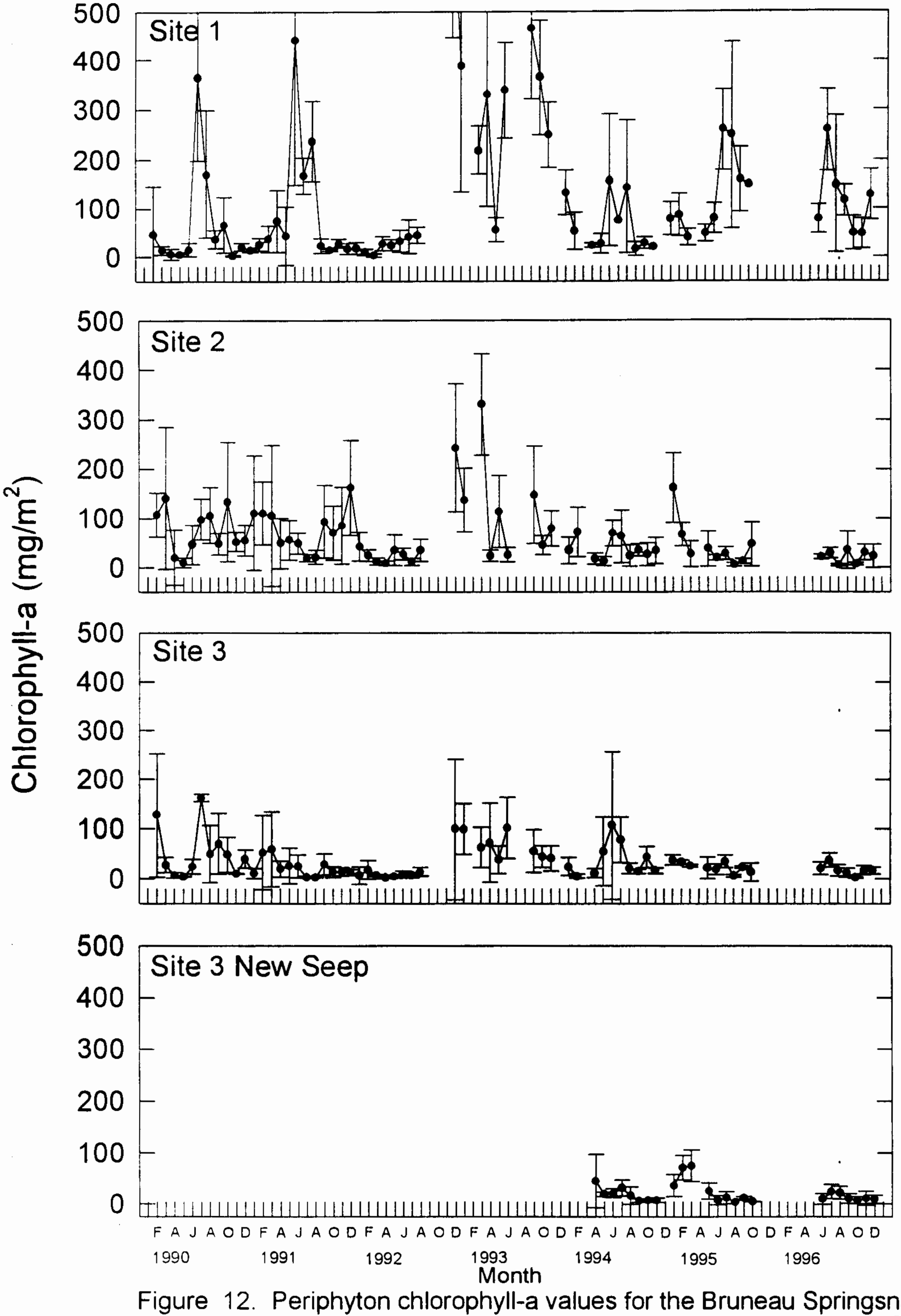

Figure 12. Periphyton chlorophyll-a values for the Bruneau Springsnail study sites. The value for Site 1 in December 1992 was 742.7 mg/m^2. Error bars represent one standard deviation from the mean. (n = 5 for Sites 1 and 2; n = 3 for Site 3 and 3 New Seep).

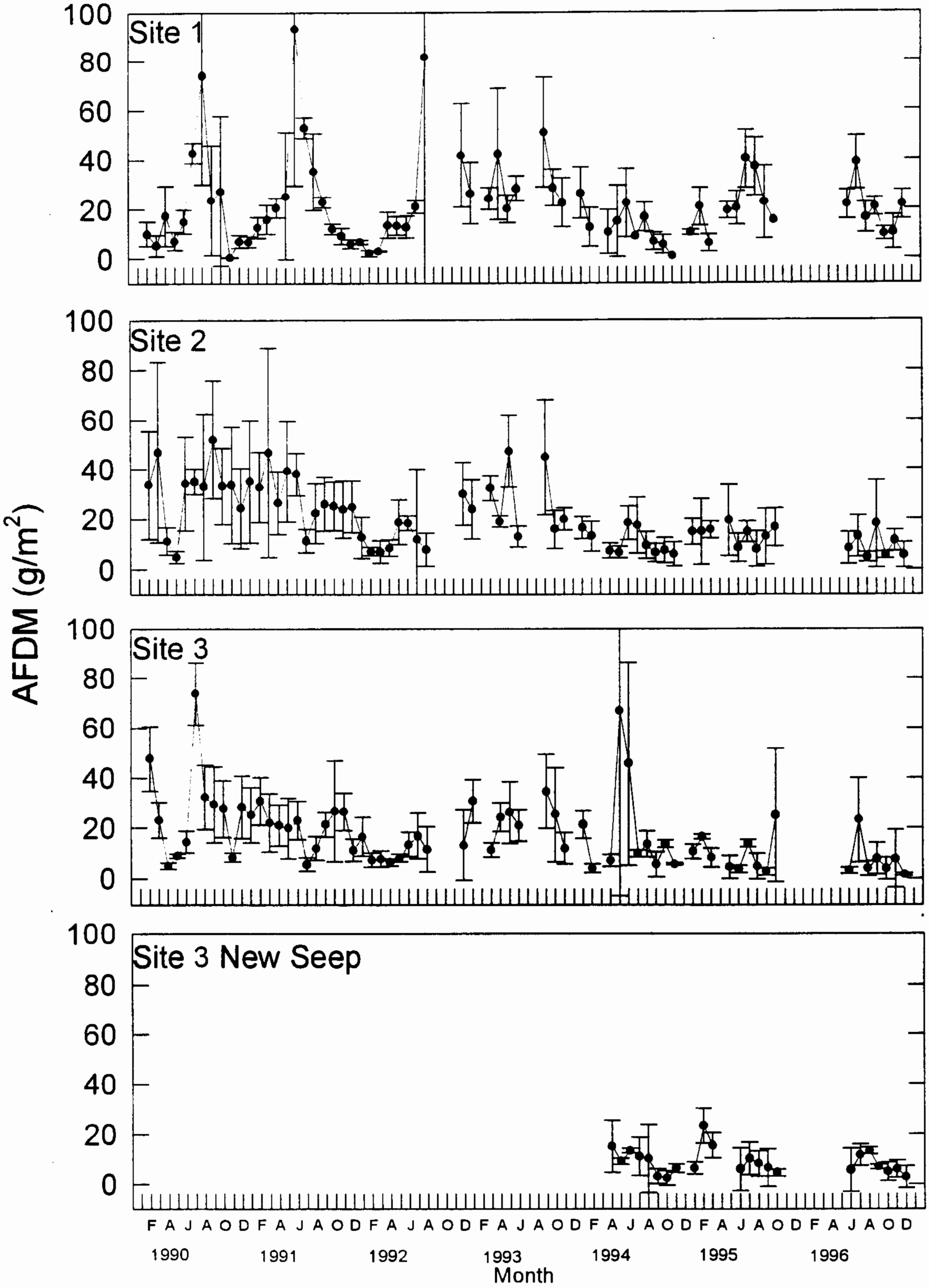

Figure 13. Periphyton ash-free dry mass (AFDM) values for the Bruneau Springsnail study sites. Error bars represent one standard deviation from the mean. (n=5 for Sites 1 and 2; n=3 for Site 3 and Site 3 New Seep).

some high chlorophyll a and AFDM values between mid-1992 and mid-1993, periphyton communities did not appear to be greatly affected by the presence or absence of *P. bruneauensis* in Hot Creek.

Site 2 (Upper Spring Rockface)

During 1996, the highest value for chlorophyll a at Site 2, 34.5 mg/m^2, was found in September, and the lowest value, 4.0 mg/m^2, was found in August (Fig. 12). The highest value for AFDM, 18.1 g/m^2, was found in September, while the lowest value, 4.8 g/m^2 was found in August (Fig. 13). Chlorophyll a and AFDM values in 1996 were consistent with the majority of those measured in 1994 and 1995, but smaller than those measured between 1990 and 1993.

Site 3 (Lower Spring Rockface)

Chlorophyll a values for Site 3 reached its highest value in July (37.2 mg/m^2) and its lowest value in October (2.6 mg/m^2) for 1996 (Fig. 12). The highest value for AFDM, 23.2 g/m^2, was found in July, and the lowest value, 3.1 g/m^2 was found in June (Fig. 13). Chlorophyll a and AFDM values in 1996 were consistent with the majority of those measured in 1994 and 1995 (except for high values in May and June 1994), but smaller than those measured between 1990 and 1993.

Site 3 (New Seep)

The highest value for chlorophyll a, 24.7 mg/m^2, was found in July, and the lowest value, 7.4 mg/m^2, was found in October for Site 3 New Seep (Fig. 12). The highest value for AFDM, 13.4 g/m^2, was found in August, and the lowest value, 5.0 g/m^2 was found in October (Fig. 13). Chlorophyll a and AFDM values have remained consistently low between 1994 and 1996.

Hot Creek Habitat

Using the Idaho Department of Health and Welfare Habitat Assessment Field Data Sheet for lowland streams (Appendix A), habitat assessment scores were obtained on a monthly basis for Hot Creek. Conditions remained fairly constant between 1995 and 1996, with only seasonal changes in vegetation being apparent (Table 1). Overall, scores for the riparian community were intermediate to high, while substrate scores were low (Table 1). Particle size distribution data showed that $\geq$ 70% of Hot Creek's substrate was less than 1 cm in diameter (Fig. 14). Distributions did not vary widely between 1995 and 1996.

DISCUSSION

Conditions at Indian Bathtub and Hot Creek

Only a small amount of groundwater is seeping out of the

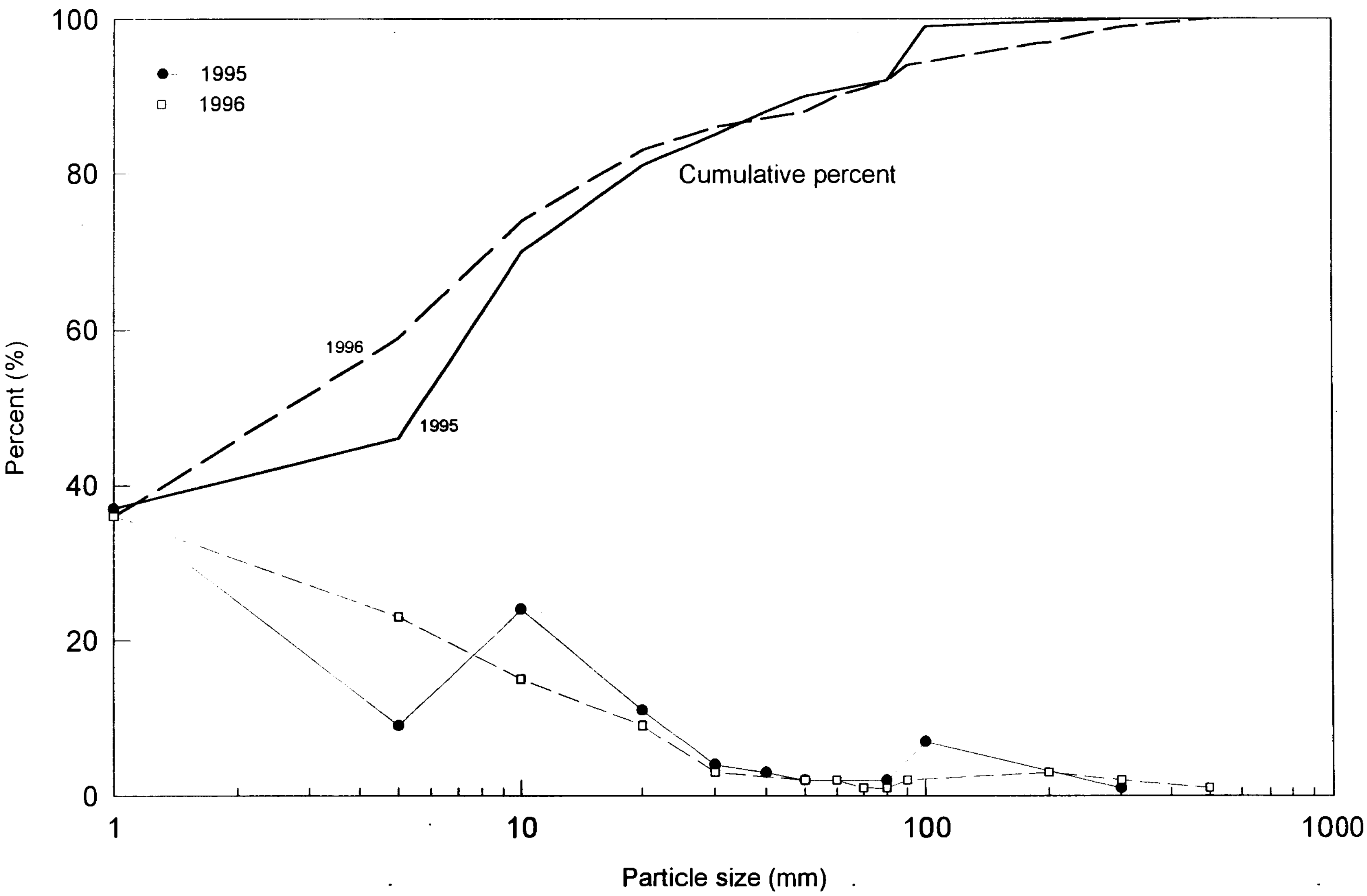

Figure 14. Substrate particle size distributions for Hot Creek (Site 1) for 1995 and 1996.

Table 1. **Habitat assessment scores for Site 1 (Hot Creek).**

Date	Bottom Substrate	Pool Substrate	Pool Variability	Canopy Cover	Channel Alteration	Deposition	Channel Sinuosity	Channel Capacity	Bank Stability	Bank Vegetation	Streamside Cover	Riparian Width	Total Score	Percent of Maximum
Maximum score possible:	20	20	20	20	15	15	15	15	10	10	10	10	180	100
3/95	4	5	5	16	12	2	10	9	8	8	6	5	90	50
5/95	4	5	5	16	12	2	10	9	8	8	8	5	92	51
6/95	4	5	5	15	12	2	10	9	9	9	5	5	90	50
7/95	4	5	5	14	12	2	10	9	9	10	5	5	90	50
8/95	4	5	5	14	12	2	10	9	9	10	5	5	90	50
9/95	4	5	5	14	12	2	10	9	9	10	5	5	90	50
10/95	4	5	5	15	12	2	10	9	9	10	5	5	91	51
11/95	4	5	5	15	12	2	10	9	9	9	6	5	91	51
6/96	4	5	5	15	12	2	10	9	8	9	5	5	89	49
7/96	4	5	5	14	12	2	10	9	8	10	5	5	89	49
8/96	4	5	5	14	12	2	10	9	8	10	5	5	89	49
9/96	4	5	5	14	12	2	10	9	8	10	5	5	89	49
10/96	4	5	5	15	12	2	10	9	8	10	5	5	90	50
11/96	4	5	5	15	12	2	10	9	8	10	6	5	91	51
12/96	4	5	5	16	12	2	10	9	8	9	6	5	91	51

Indian Bathtub portion of Hot Creek. The water from this area sinks below the ground surface and reemerges about 200 m "downstream" (Fig. 1). In 1996, the discharge at Site 1 (approximately 300 m "downstream" of Indian Bathtub) ranged between 0.006 and 0.011 m^3/sec (Fig. 8) Besides a high value in March 1994 (0.024 m^3/sec), Hot Creek discharge between 1993 and 1996 (post-flood years) appears to be slightly lower than values measured prior to the 1992 flood (Fig. 8). The lowest values were recorded in the winter months immediately following the 1992 flood (Fig. 8). This may be a result of increased riparian vegetation cover and evapotranspiration (see below). High discharges may have been missed between January and May 1996. The small rockface/spring outlet adjacent to the creek at Site 1 has a small trickle of water which seeps down the rockface (Fig. 2a). This small spring-flow area was overgrown by dense grasses during 1996 and hindered springsnail observation (none were found, but there may be individuals deep in the dense vegetation).

The riparian community appeared to offer a reasonable amount of shade and streambank stability, but these habitat characteristics were offset by Hot Creek's poor channel morphology and substrate composition (Table 1, Fig. 14). In July 1995, Kelly Sant revisited the monitoring sites. He noted that there had been an increase in vegetative cover at all the sites since he had been monitoring in 1992. The riparian vegetation has been slowly increasing in ground cover since the removal of cattle grazing in the Hot Creek area (c. 1992). The streambank cover does not appear to affect stream periphyton growth and so food resource availability does not appear be a limiting factor to springsnail recolonization of Hot Creek. Chlorophyll a values in 1994, 1995, and 1996 fluctuated within the range of values that was measured between 1990 and 1993 (years when springsnails were present at Site 1). Habitat scoring appears to reflect seasonal changes in habitat, rather than overall improvement (Table 1). Future evaluation would probably only need to occur in the middle of the summer and winter seasons to evaluate the "extreme" conditions.

The primary obstacle to the return of *P. bruneauensis* to Hot Creek appears to be a lack of significant recolonization. If any recolonization has occurred already, it has not yet resulted in a substantial population size based upon examinations of Site 1 stream substrate. A number of factors may be reducing the chances for successful recolonization; these factors may include unsuitable substrate type, weak migration abilities, and a lack of an upstream colonization source.

The stream bottom at Site 1 was described as originally having areas of large cobbles which became embedded as a result of cattle grazing (Mladenka 1992). Runoff events in 1992 deposited additional loads of sediment. Substrate analyses in Hot Creek (Fig. 14) showed that ≥ 70% of the substrate in Hot Creek were ≤ 1 cm in diameter in 1995 and 1996. Laboratory experiments have indicated that springsnails do not prefer large substrate sizes to small substrate sizes (Mladenka 1992). However, *P. bruneauensis* springsnails need hard surfaces for depositing eggs (large cobble and snail shells are two possibilities). Also, different communities of periphyton tend to colonize and thrive on different types of substrate. An altered substrate composition may reduce the chances for springsnail survival by affecting oviposition success and food quality (Mladenka 1992).

Fish predation may be preventing any successful springsnail recolonization of Hot Creek. Gut content analysis found no evidence of springsnails being preyed upon by the Hot Creek fish *Gambusia* and *Tilapia*. The diets of the fish were found to consist of organic detritus, vegetative matter, and a small number of insects (Varricchione and Minshall 1995b). Still, this finding may be explained by very small numbers of springsnails existing in the creek during 1995, and hence the low probability of finding shells in gut analyses. A controlled feeding experiment, using *Gambusia* and *Tilapia*, would test the likelihood that fish predation is hindering *Pyrgulopsis* recolonization in

Hot Creek.

The continued lack of recolonization at Site 1 suggests that the springsnails do not have strong migratory capabilities. Because no springsnails have been observed upstream of Site 1 (including Indian Bathtub), there is probably a lack of an upstream recolonization source. Also, any colonists deposited by visiting waterfowl probably encounter the same unfavorable conditions as mentioned above.

Conditions at the Rockface Seeps

The rockface seeps had water temperatures that were consistently lower (rarely greater than the thermal tolerance temperature 35°C (Mladenka 1992)) than those in Hot Creek (Site 1)(Fig. 10). This most likely explains the higher amounts of year-round recruitment at the rockface seep sites (2, 3, and 3 New Seep) compared with Hot Creek (Figs. 5a-b, 6). Temperature ranges clearly affect the *Pyrgulopsis* populations. Average size and growth rates were smaller, but densities were greater, at the rockface seeps than in Hot Creek. The rockface sites are probably more suitable for springsnail success, given that groundwater flows are consistent.

Periphyton chlorophyll a and biomass (ash-free dry mass) were consistently lower at the rockface sites (often greater than

5 times lower; Figs. 12, 13). Still, they supported springsnail densities that were often 2-3 times greater than those found in Hot Creek (Fig. 7)(high temperature was probably the more important factor influencing density).

In 1994, springsnail size distributions, densities, and eventually temperatures (beginning November 1996) at Site 3 New Seep (Fig. 2) began to be monitored. This data was kept separate from Site 3 Original Seep, at the suggestion of Royer and Minshall (1993), so that it could be determined if its snail population was under different constraints and behaving differently than Site 3 Original Seep. Size distribution data (Figs. 3e-g, 5b), life history patterns (Fig. 6), densities (Fig. 7), and habitat (Figs. 9, 10, 12, 13) are noticeably different between the two sites. More years of monitoring are required to gather enough data to conduct appropriate statistical tests to decide if the Original Seep and New Seep data should be combined. Genetic and growth experiments could be conducted to determine if these populations are actually different from each other and/or from Sites 1 and 2.

Hot Creek conditions are very poor and appear to be the result of poor land management practices on the watershed upstream of Site 1. As recommended previously by Varricchione and Minshall (1995a, 1996), springsnail population and habitat data collected to date indicate that immediate measures should be taken to rehabilitate the Indian Bathtub-Hot Creek area and restore the habitat conditions to at least those found prior to July 1992. This is the minimum effort required to restore the Bruneau Hot-spring Springsnail to Hot Creek. Habitat restoration would show whether the springsnail will repopulate naturally or if transplantation is necessary. However, long-term restoration is dependent on sound land management practices (e.g. continued prevention of grazing on high risk areas within the watershed) and increased thermal flows. A recolonization experiment could also be an important step in the recovery of *P. bruneauensis* in Hot Creek. Factors such as substrate quality and fish predation need to be evaluated further as potential barriers to springsnail recolonization. Springsnail-covered cobbles from a rockface site could be transplanted to Hot Creek and placed under mesh screens to exclude fish predators. Flumes could be placed alongside Hot Creek with different types of substrate to determine if substrate quality in Hot Creek in hindering successful recolonization. In addition to these experiments, Hot Creek discharge could potentially be increased with a reduction in the intensity of groundwater mining on the surrounding agricultural lands.

ACKNOWLEDGMENTS

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Appendix A. Idaho Department of Health and Welfare's habitat assessment field data sheet for lowland streams (taken from Robinson and Minshall 1995).

Habitat Assessment, Glide/Pool Prevalence (modified after Plafkin et al., 1989).

Stream Name: __________ Station: __________ Date: __________ Location Description: __________

Idaho Department of Health and Welfare - Division of Environmental Quality
HABITAT ASSESSMENT FIELD DATA SHEET
GLIDE/POOL PREVALENCE

	CATEGORY			
HABITAT PARAMETER	**OPTIMAL**	**SUB-OPTIMAL**	**MARGINAL**	**POOR**
1. Bottom substrate/ instream cover	Greater than 50% mix of rubble, gravel, submerged logs, undercut banks, or other stable habitat. 16-20 ___	30-50% mix of rubble, gravel, or other stable habitat. Adequate habitat. 11-15 ___	10-30% mix of rubble, gravel, or other stable habitat. Habitat availability less than desirable. 6-10 ___	Less than 10% rubble, gravel or other stable habitat. Lack of habitat is obvious. 0-5 ___
2. Pool substrate characterization	Mixture of substrate materials with gravel and firm sand prevalent, root mats and submerged vegetation common. 16-20 ___	Mixture of soft sand, mud, or clay; mud may be dominant; some root mats and submerged vegetation present. 11-15 ___	All mud or clay or channelized with sand bottom; little or no root mat; no submerged vegetation. 6-10 ___	Hard-pan clay or bedrock; no root mat or vegetation. 0-5 ___
3. Pool variability	Even mix of deep/shallow/ large/small pools present. 16-20 ___	Majority of pools large and deep; very few shallow. 11-15 ___	Shallow pools much more prevalent than deep pools. 6-10 ___	Majority of pools small and shallow or pools absent. 0-5 ___
4. Canopy cover (shading)	A mixture of conditions where some areas of water surface fully exposed to sunlight, and other receiving various degrees of filtered light. 16-20 ___	Covered by sparse canopy; entire water surface receiving filtered light. 11-15 ___	Completely covered by dense canopy; water surface completely shaded. OR nearly full sunlight reaching water surface. Shading limited to < 3 hours per day. 6-10 ___	Lack of canopy, full sunlight reaching water surface. 0-5 ___

Stream Name: ______________ Station: ______________ Date: ______________ Location Description: ______________

Idaho Department of Health and Welfare - Division of Environmental Quality
HABITAT ASSESSMENT FIELD DATA SHEET
GLIDE/POOL PREVALENCE

	CATEGORY			
HABITAT PARAMETER	OPTIMAL	SUB-OPTIMAL	MARGINAL	POOR
5. Channel alteration	Little or no enlargement of islands or point pars, and/or no channelization. 12-15 ___	Some new increase in bar formation, mostly from coarse gravel; and/or some channelization present. 8-11 ___	Moderate deposition of new gravel, coarse sand on old and new bars; and/or embankments on both banks. 6-10 ___	Heavy deposits of fine material, increased bar development; and/or extensive channelization 0-3 ___
6. Deposition	Less than 5 % of bottom affected; minor accumulation of coarse sand and pebbles as snags and submerged vegetation. 12-15 ___	5-30% affected; moderate accumulation of sand at snags and submerged vegetation. 8-11 ___	30-50% affected; major deposition of sand at snags and submerged vegetation; pools shallow, heavily silted. 4-7 ___	Channelized; mud, silt and/or sand in braided or nonbraided channels; pools almost absent due to deposition. 0-3 ___
7. Channel sinuosity	Instream channel length 3 to 4 times straight line distance. 12-15 ___	Instream channel length 2 to 3 times straight line distance. 8-11 ___	Instream channel length 1 to 2 times straight line distance. 4-7 ___	Channel straight; channelized waterway. 0-3 ___
8. Lower bank channel capacity	Overbank (lower) flows rare. Lower bank W/D ratio < 7. (Channel width divided by depth or height of lower bank.) 12-15 ___	Overbank (lower) flows occasional. W/D ratio: 8-15 8-11 ___	Overbank (lower) flows occasional. W/D ratio: 15-25 4-7 ___	Peak flows not contained or contained through channelization. W/D ratio > 25 0-3 ___

Stream Name: ______________________

Station: ______________________

Date: ______________________

Location Description: ______________________

Idaho Department of Health and Welfare - Division of Environmental Quality
HABITAT ASSESSMENT FIELD DATA SHEET
GLIDE/POOL PREVALENCE

	CATEGORY			
HABITAT PARAMETER	**OPTIMAL**	**SUB-OPTIMAL**	**MARGINAL**	**POOR**
9. Upper bank stability	Upper bank stable. No evidence of erosion or bank failures. Side slopes generally < 30°. Little potential for future problems. 9-10 ___	Moderately stable. Infrequent, small areas of erosion mostly healed over. Side slopes up to 40° on one bank. Slight potential in extreme floods. 6-8 ___	Moderately stable. Moderate frequency and size of erosional areas. Side slopes up to 60° on some banks. High erosion potential during extreme high flow. 3-5 ___	Unstable. Many eroded areas. "Raw" areas frequent along straight sections and bends. Side slopes 60° common. 0-2 ___
10. Bank vegetation protection	Over 90% of the streambank surfaces covered by vegetation. 9-10 ___	70-89% of the streambank surfaces covered by vegetation. 6-8 ___	50-79% of the streambank surfaces covered by vegetation. 3-5 ___	Less than 50% of the streambank surfaces covered by vegetation. 0-2 ___
OR Grazing or other disruptive pressure	Vegetative disruption minimal or not efficient. Almost all potential plant biomass at present stage of development remains. 9-10 ___	Disruption evident but not affecting community vigor. Vegetative use is moderate, and at least one-half of the potential plant biomass remains. 6-8 ___	Disruption obvious; some patches of bare soil or closely cropped vegetation present. Less than one half of the potential plant biomass remains. 3-5 ___	Disruption of streambank vegetation is very high. Vegetation has been removed to 2 inches or less in average stubble height. 0-2 ___

Stream Name: ____________ Station: ____________ Date: ____________ Location Description: ____________

Idaho Department of Health and Welfare - Division of Environmental Quality

HABITAT ASSESSMENT FIELD DATA SHEET
GLIDE/POOL PREVALENCE

	CATEGORY			
HABITAT PARAMETER	OPTIMAL	SUB-OPTIMAL	MARGINAL	POOR
11. Streamside cover	Dominant vegetation is shrub. 9-10 ___	Dominant vegetation is of tree form. 6-8 ___	Dominant vegetation is grass or forbes. 3-5 ___	Over 50% of the stream bank has no vegetation and dominant material is soil, rock, bridge materials, culverts, or mine tailings. 0-2 ___
12. Riparian vegetative zone width (least buffered side)	> 18 meters 9-10 ___	Between 12 and 18 meters. 6-8 ___	Between 6 and 12 meters. 3-5 ___	< 6 meters. 0-2 ___
Column Totals	___	___	___	___
Score				

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