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2000 ANNUAL MONITORING REPORT BRUNEAU HOT-SPRING SPRINGSNAIL (*PYRGULOPSIS BRUNEAUENSIS*)

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Bruneau Hot-spring Springsnail (*Pyrgulopsis bruneauensis*)

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SUMMARY

This report presents the 2000 monitoring results from four sites near the Indian Bathtub in southwestern Idaho 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), in 1994, 1995, 1997 by Varricchione and Minshall (1995a, 1996, 1997), Varricchione et al. (1998), and in 1998 and 1999 by Myler and Minshall (1999). An additional seep at Site 3 (New Seep) was included in the 1994, 1995, and 1997-2000 springsnail monitoring efforts. Monitoring was conducted monthly throughout the year from 1990-1999. Starting in 2000, monitoring was conducted June through October.

Springsnails continue to be absent from Hot Creek proper since a flood in July 1991. A relict population of springsnails was found within a 1.80 m seep that drained into Hot Creek (Site 1). Experiments conducted in 1997 and 1998 indicated that springsnail movement rate could not account for the lack of recolonization in Hot Creek. In 1998, field measurements showed a thermal barrier, potentially preventing the springsnails from reaching Hot Creek. Experiments conducted in 1999 by Cary Myler bypassed the thermal barrier with a segment of pipe which acted as a bridge for snail movement (Myler and Minshall 1999).

In 1998, a controlled fish-feeding experiment showed that *Tilapia zilli* were able to recognize *P. bruneauensis* as a food resource both when the fish were starved and when other food was present A fish exclosure was constructed to eliminate possible predation from *Tilapia* (Myler and Minshall 1999). As of November 1999, springsnails were found upstream and downstream of the confluence of the small seep but within the fish exclosure. During the 2000 survey the fish exclosure was removed and springsnails were no longer found in Hot Creek.

Estimates of springsnail populations at Sites 2 and 3 (including Original Seep and New Seep) are within the range of past years, but are some of the lowest densities of the past decade.

The rockface at Site 2 dried up completely in the month of September and was wetted again in the month of October, but springsnails failed to recolonize.

INTRODUCTION

Pyrgulopsis bruneauensis is an endemic snail inhabiting a complex of related hot springs near the Bruneau River south of Mountain Home, Idaho. 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 the most important factor affecting the distribution of *P. bruneauensis*. Experiments showed the thermal tolerance range for the snails to be 11°C-35°C. Reproduction occurred between 20°C and 35°C. Snail growth and reproduction were retarded at temperatures < 24°C. The study also found that under suitable conditions, recruitment and growth may occur at all times of the year, sexual maturity could occur within two months of hatching, maximum size could be reached within four months (both under suitable temperature conditions), and the sex ratio of spring snails was 1:1. In laboratory experiments, springsnails were found to survive on all types of substrate, although higher numbers were found on gravel and silt than on sand (Mladenka 1992). 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).

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). The springsnail's habitat throughout it's known range along the Bruneau River has diminished considerably in recent years because of agriculture-related groundwater mining in the area (Berenbrock 1993). The Indian Bathtub population apparently has been reduced to zero (Mladenka 1992) as a result of reduction of hot water inputs and other habitat alterations.

Springsnail populations apparently were eliminated in Hot Creek (Site 1) by a major runoff event in July 1992 (Royer and Minshall 1993), and have not been found in the creek except for a brief period in 1999. Observations made in 1998 identified a thermal barrier to potential recolonists that exceeded the thermal maximum of the springsnail (Myler and Minshall 1999). Myler and Minshall (1999) postulated that temperatures (> 35°C) reduced springsnail survival in Hot Creek. Addition of protruding substrate, bypass of the thermal barrier, and a fish exclosure enabled the springsnail to recolonize Hot Creek proper (Myler and Minshall 1999). The exclosure was removed June of 2000 and no springsnails were found in Hot Creek during the observations made in June through October 2000.

Gut analyses performed on two Hot Creek fish, *Gambusia* and *Tilapia,* showed that their diets consisted of organic matter and insects, but not of *P. bruneauensis*. However, these analyses were performed in 1995, a year when springsnails were not observed in Hot Creek (Varricchione and Minshall 1995b). In 1998, a fish-feeding experiment was performed, using *Tilapia zilli* taken from Hot Creek and *P. bruneauensis* taken from Site 2. The fish were shown to ingest the springsnail, both when the fish were starved and when they were fed generously. Other experiments indicate that *Tilapia* do negatively impact springsnail populations in Hot Creek including the exclosure experiment mentioned above (Myler and Minshall 1999).

This report presents the results from continued biomonitoring of four springsnail sites near Indian Bathtub for June through October 2000.

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). These sites have been monitored each month during eleven months (January-November) from 1990-1999, with the exception of January-May 1996. Starting in 2000, monitoring will only be conducted June-October.

Royer and Minshall (1993) recommended that Site 3 be divided into two sub-sites: the Original Seep (right side) and a New Seep (left side) (Fig. 2c). These two seeps are approximately 4 m apart from each other and each has a distinct spring-f1ow. Their populations have been monitored separately from 1994 through 2000. In 1994, springsnail size distributions, densities, and eventually temperatures (beginning November 1996) at Site 3-New Seep began to be monitored. These data were kept separate from Site 3-Original Seep, so that it could be determined if the snail population was under different constraints and behaving differently than the population at Site 3-OS.

Size distribution data, life history patterns, densities, and habitat conditions have since been found to be noticeably different between the two sites. Therefore, the data continue to be kept separate. Site 2 also is comprised of two "seeps", but their population data have been combined since the first monitoring year. The purpose of the division of Site 3 was to allow the 1994-2000 Original Seep data to remain consistent with data from previous years and to allow for the incorporation of the New Seep springsnail population and habitat into monitoring efforts. The remainder of this report will refer to Site 3 (Original Seep) as Site 3-OS and Site 3 (New Seep) as Site 3-NS.

Both spring-rockface and stream habitats were examined for *P. bruneauensis* at Site 1. Spring-rockface habitats were monitored at Sites 2, 3-OS and 3-NS. "Spring-

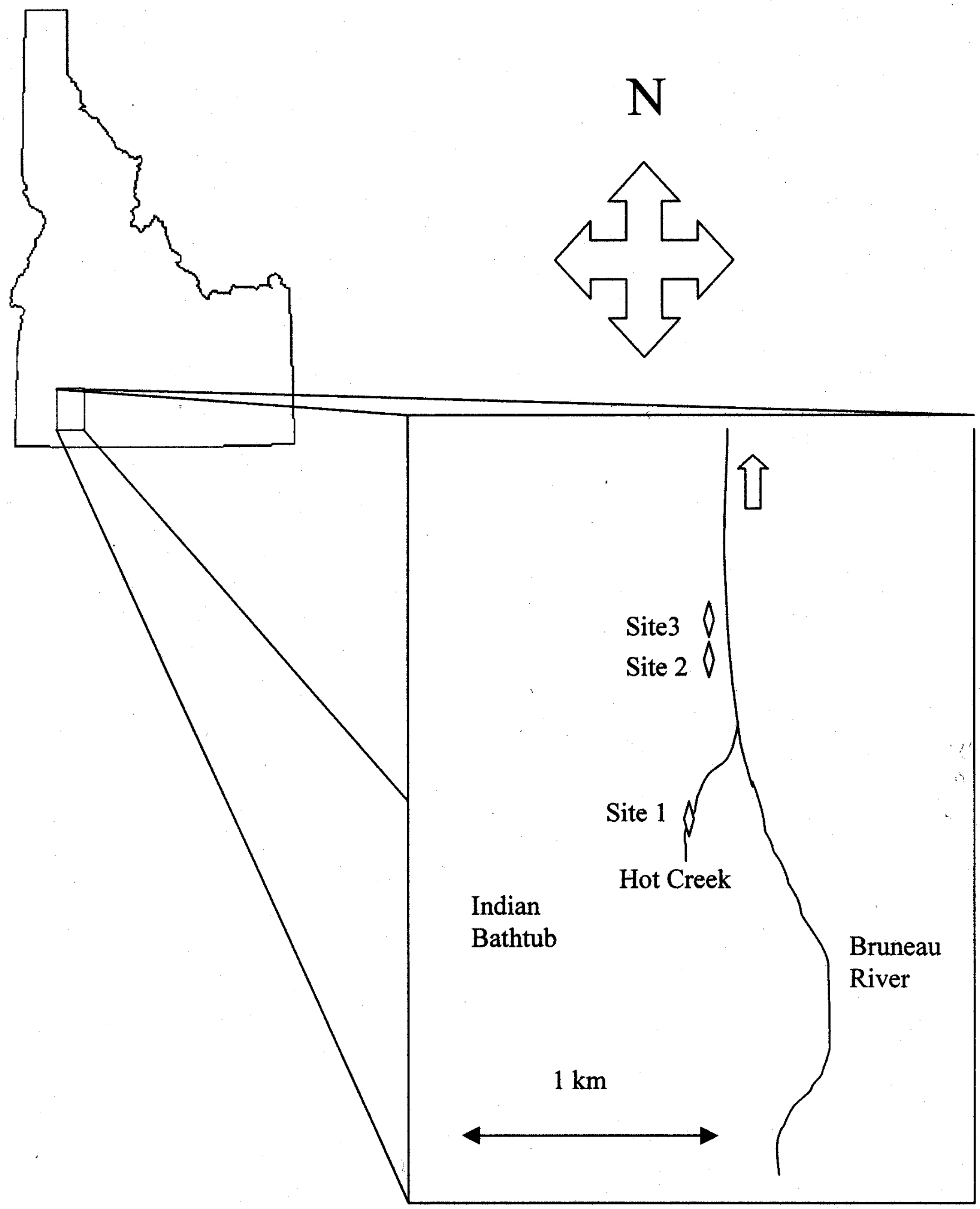


Figure 1. Map showing the locations of the Bruneau Hot-spring Springsnail study sites. Hot Creek is shown as it existed in 2000, emerging over 400 m downstream of Indian Bathtub.

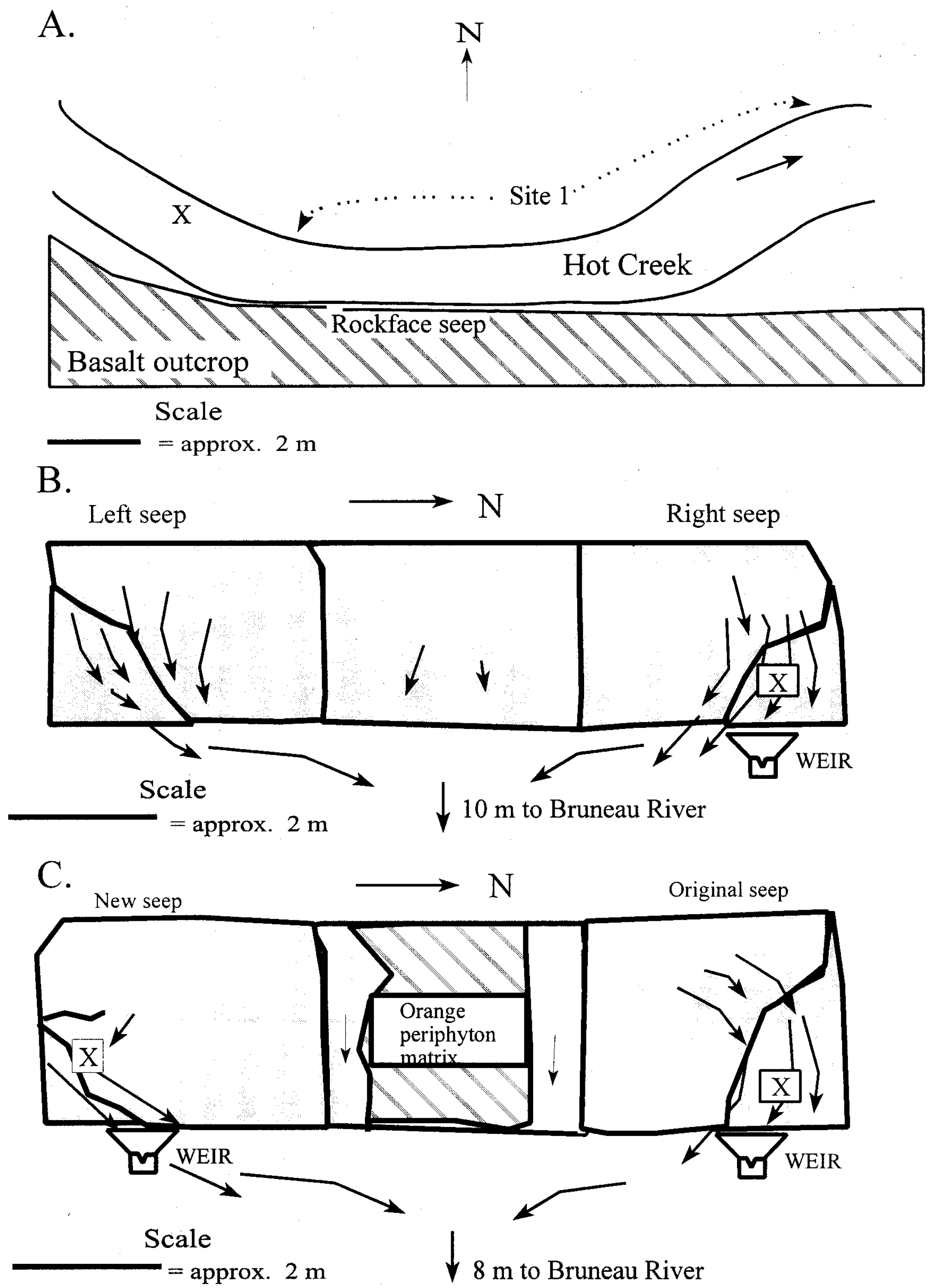


Figure 2. Temperature data logger locations for each of the study sites. Data loggers are represented by "x". A. Map view of Site 1 (Hot Creek). B. Front view of Site 2 rockface. C. Front view of Site 3 rockface (Original and New Seeps).

flow-covered rockface", or "SFC rockface", was defined as madicolous habitat (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. Springsnails occur in both types of habitats.

Study quadrats (Appendix A) 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 the 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 rockface-sampling locations for springsnail size and density monitoring. The random numbers were used to determine the distance across a transect to locate each sample.

Environmental conditions were monitored at the study quadrat (± m) of each site on a monthly basis from June through October. These factors included discharge and stream habitat at Hot Creek (Site 1), amount of flow-covered- and wetted-rockface (Sites 2, 3-OS, and 3-NS), water chemistry , water temperature, and food availability (periphyton abundance).

Springsnail 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-OS, and 3-NS, springsnails were washed from random locations into a standard 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, population monitoring at Site 3 was divided between the Original Seep (n=50) and the New Seep (n=50).

Springsnail Population Fluctuations

Although springsnails recolonized Hot Creek in November 1999, density was not measured routinely at Site 1 because the snail occurred in low numbers (300-400). Springsnail density was measured at the rockface sites (Sites 2, 3-OS, and 3-NS). Densities were estimated as the number of springsnails present within the circumference of a petri dish (8.5 cm diameter) at 10 random locations within the sampling quadrat. Densities were reported as the number of snails per m^2.

Discharge, Temperature, and Water Chemistry Fluctuations

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

In 1994, maximum/minimum recording thermometers were replaced with miniature temperature data loggers at all sites. Internal sensor loggers (Onset Hobo-Temp HTI-05+37) were used from 18 February 1994 to 26 September 1994, and then replaced with external sensor data loggers (Onset StowAway-Temp STEB02-05+37) on 26 September 1994 at Sites 1, 2, and 3-OS. Beginning in November 1996, an additional logger was installed at Site 3-NS. In 2000, data loggers were launched in June and downloaded at the end of the monitoring season (October), in the laboratory, using Boxcar Pro for Windows v. 4.0 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 the regularly-examined section at Site 1. Figures 2b and 2c show the locations of the temperature data loggers at Site 2 and Site 3, respectively. 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 temperature loggers in hot-spring water. The recorders were covered by cobble substrate or hillside talus. Data from temperature loggers in 1997-2000 were used to calculate average daily temperatures for each site (Fig. 10). 1997 was used as a starting point since it was the first year that temperature loggers monitored Site 3-NS.

Water chemistry parameters were measured for all the study sites. Specific conductance (µS/cm) standardized to 25°C was measured in the field using an Orion conductivity meter (Model 126) and YSI 30. 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 and warmed to room temperature and then shaken by hand (approximately 30 sec) to redissolve any solids. Alkalinity and hardness were determined using procedures described in Standard Methods for the Examination of Water and Wastewater (APHA 1992).

Periphyton

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 sample.

Approximately 5 ml of spring or creek water was added to the tube. A modified toothbrush was used to dislodge periphyton from the rock and a dropper was used to 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 three 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) 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 algae was expressed as mg chlorophyll-a per m.

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

From March 1995 to November 1996, 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 B; Robinson and Minshall 1995). In 1997-2000, habitat features were censused once a year. The parameters assessed include 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. Values are given for each parameter measured and a total score is assigned for the year.

Discharge monitoring at the rockface seeps

The water emerging from these seeps is diffuse, making it difficult to monitor flow. Small 90° V-notch weirs were installed approximately 1 m from the rockface seeps on 17 October 1997. The weirs collected diffuse runoff coming from the rockface to permit estimation of spring-flow discharge. The approximate location of the weirs is shown in Figure 2. In 2000, volume (liters) per minute was determined for each of the weirs on a monthly basis from June through October. Stage height (cm) also was recorded monthly from a metal staff gauge permanently attached to the side of each weir.

Intensive search for relict populations of P. bruneauensis in and around Hot Creek

Since *P. bruneauensis* has not been found at the Hot Creek study site for the past several years (Myler and Minshall 1999; Varricchione and Minshall 1997, 1996, 1995a; Royer and Minshall 1993), it is important to determine if potential recolonists for Site 1 occur anywhere in, or adjacent to, the stream between Indian Bathtub and the Bruneau River. Robinson and others (1992) had described a small stream-side refugium that had retained < 10 springsnails after flooding and scouring events in the same year. As grazing pressure was lifted from the Hot Creek area, the growth of thick riparian vegetation near the creek and the seep made observation of this population difficult (Royer and Minshall 1993, Varricchione and Minshall 1997). An intensive search for relict populations of *P. bruneauensis* was conducted June 1998, May 1999, and June 2000 in and immediately adjacent to Hot Creek (between Indian Bathtub and the Bruneau River). The search was completed by examining (without magnification) Hot Creek sediments, emergent vegetation, and nearby rockface seeps for *P. bruneauensis*. Where springsnails were found, temperature were recorded using a Reotemp digital thermometer (model TM 99A).

RESULTS

Springsnail Size Distribution

<u>Site 1 (Hot Creek)</u>

Site 1 (Hot Creek) population density was reduced to zero from a flood in July 1991 (Robinson et al. 1992). Snails were not found in Hot Creek from June 1993 until June 1999. Observations made in 1999 revealed a thermal barrier that blocked movement into Hot Creek. A bypass for the thermal barrier, large protruding substrate, and a fish exclosure has enabled colonization in Hot Creek proper as well as recruitment (Myler and Minshall 1999). Snails recolonized the stream in June 1999 and populations increased each month during 1999. In November 1999, total springsnail population was estimated at 300-400 individuals. Size distribution was not determined in 1999 due to low population densities. The exclosure did not make it through the winter and was removed in June 2000. Since the removal of the exclosure no springsnails have been found in Hot Creek. The flood in July 1991 probably resulted in the death of younger snails and skewed the size distributions in July and September 1992 (Fig. 3c). Mean size distribution data suggest that when the springsnails were present (1990-1992), life histories were correlated with season and a single cohort of individuals moved from juvenile classes in the winter to mature classes in the summer (Fig. 5a).

<u>Site 2 (Upper Rock Face)</u>

The springsnail population at Site 2 maintained a size distribution that was relatively even across size classes between June and September 2000 (Fig 3k). There was no clear trend,

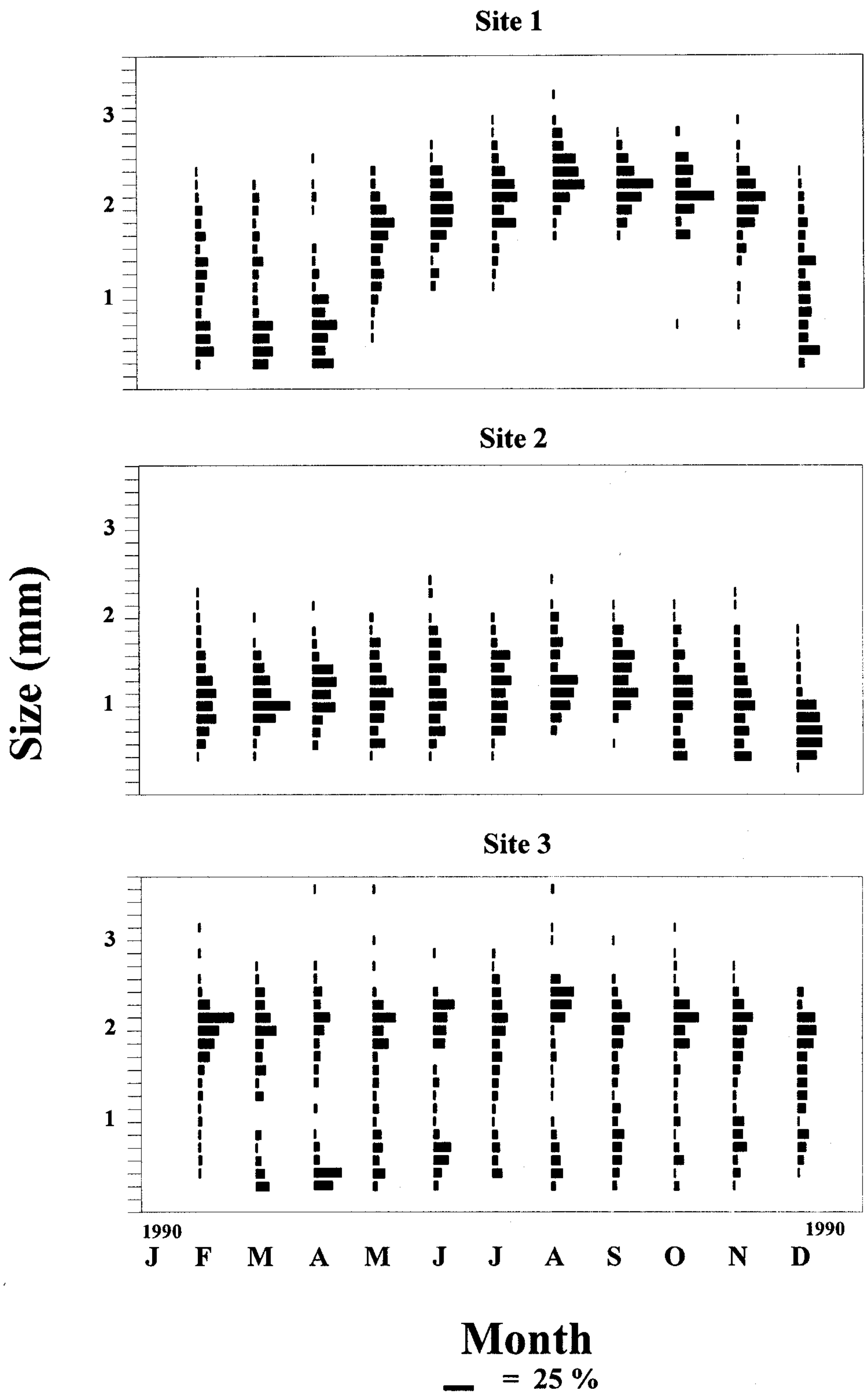


Figure 3a. Size histograms for the Bruneau Springsnail study sites for 1990. Horizontal tick marks represent 0.14mm size classes. Solid bars represent relative abundance of snails for a particular size class (n=100 for each sample).

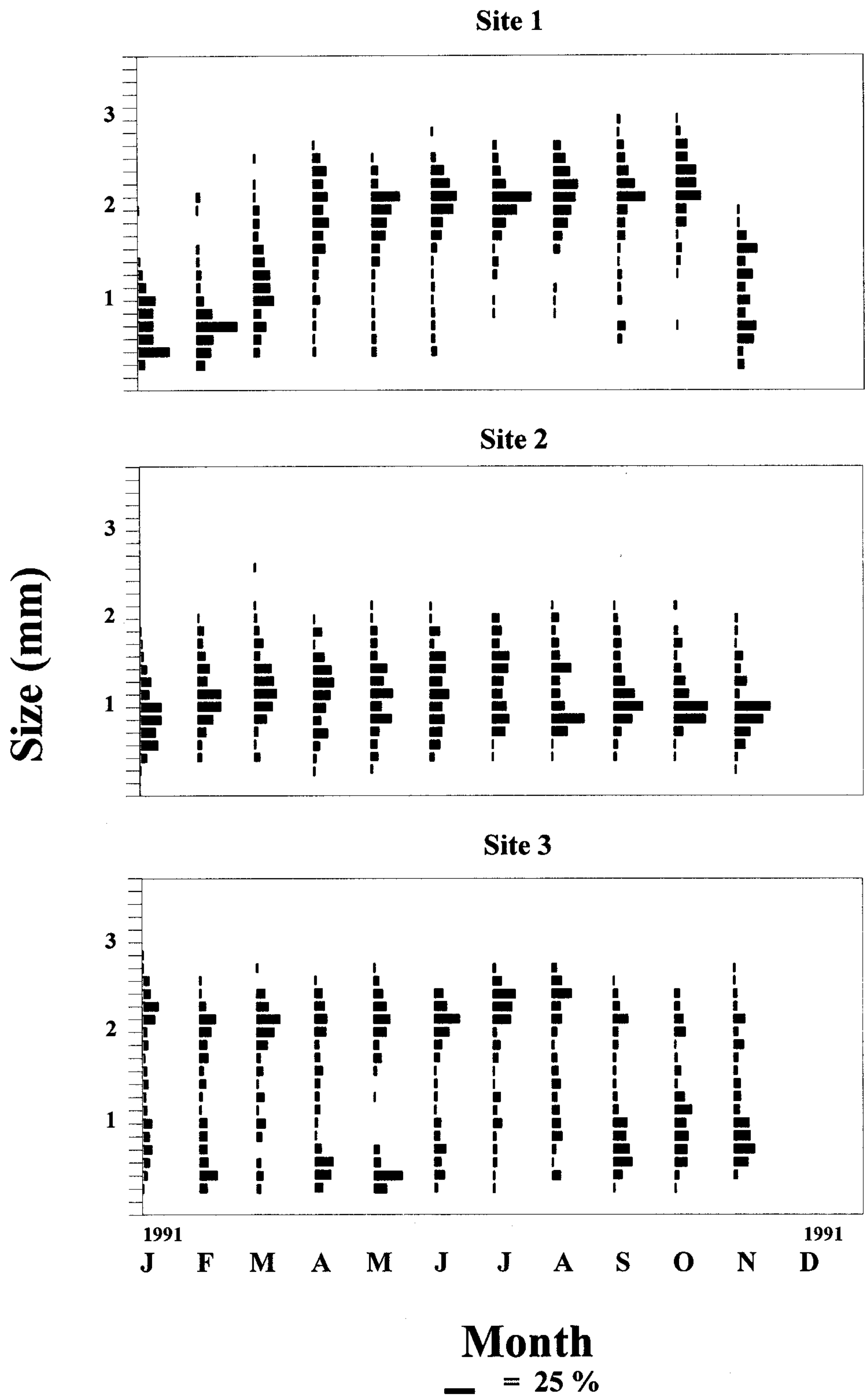


Figure 3b. Size histograms for the Bruneau Springsnail study sites for 1991. Horizontal tick marks represent 0.14mm size classes. Solid bars represent relative abundance of snails for a particular size class (n=100 for each sample).

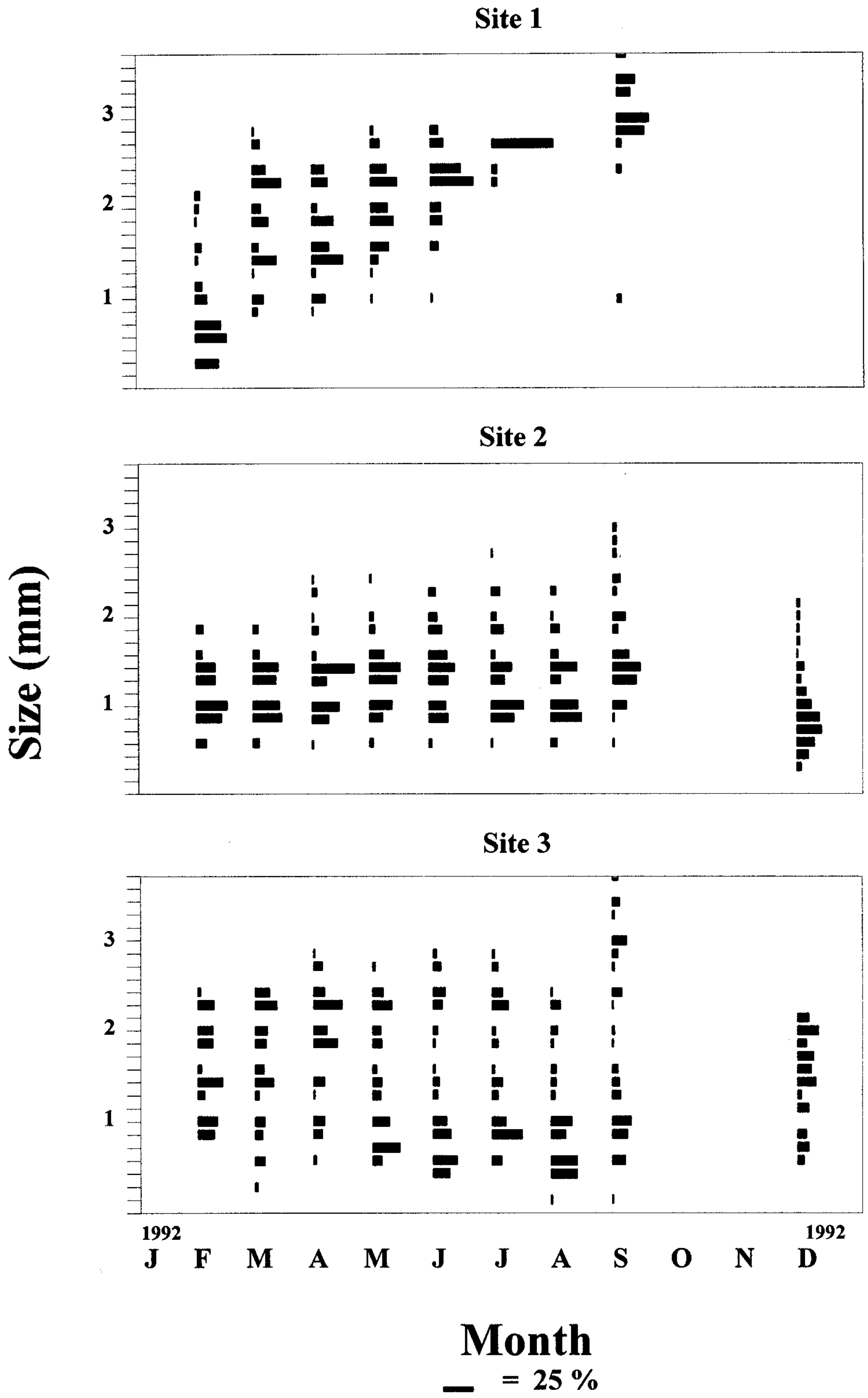


Figure 3c. Size histograms for the Bruneau Springsnail study sites for 1992. Horizontal tick marks represent 0.14mm size classes. Solid bars represent relative abundance of snails for a particular size class (n=100 for each sample). In July, 92% of the snails at Site 1 were found in the 2.66 mm size class (an out of range value for this figure).

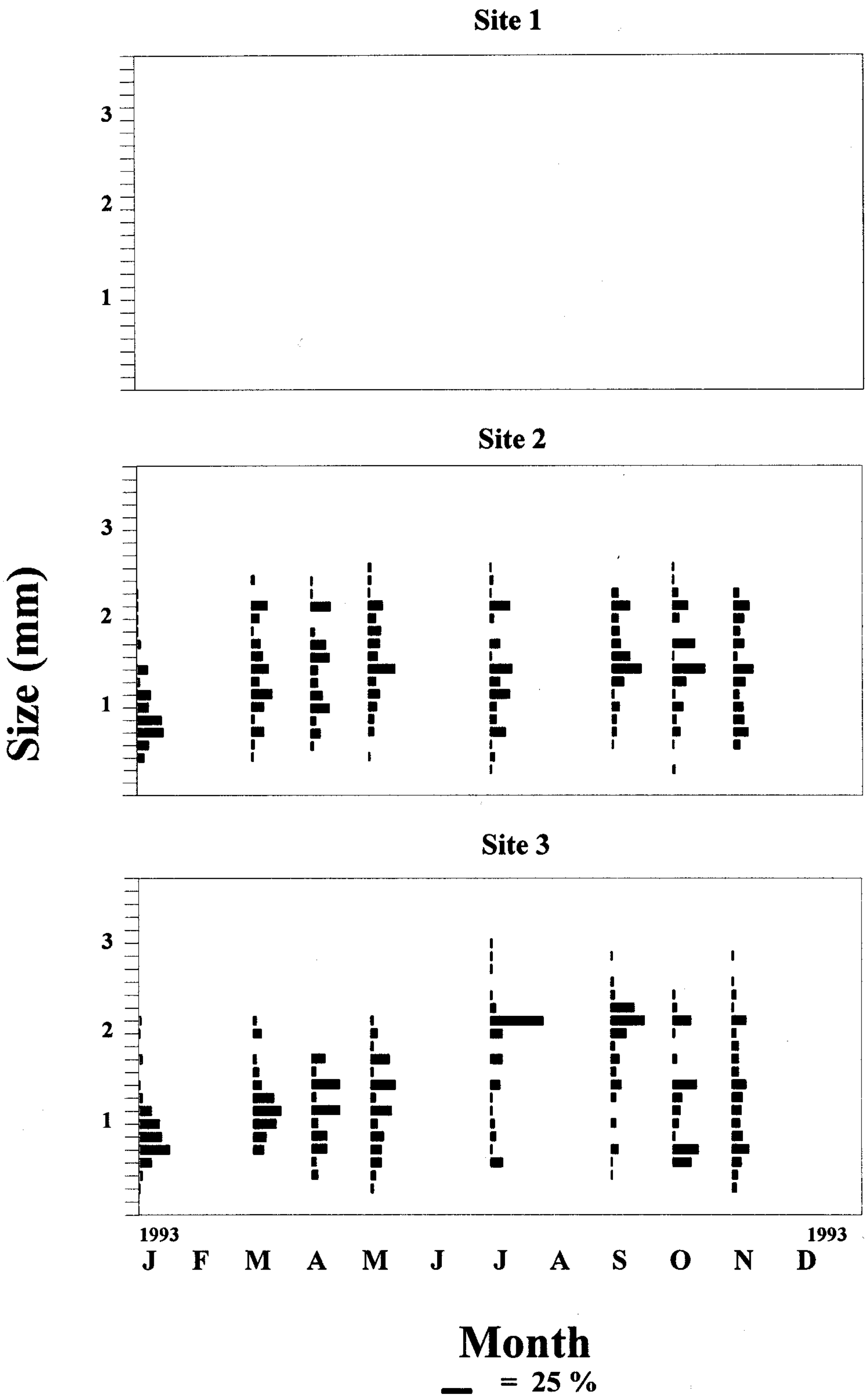


Figure 3d. Size histograms for the Bruneau Springsnail study sites for 1993. Horizontal tick marks represent 0.14mm size classes. Solid bars represent relative abundance of snails for a particular size class (n=100 for each sample).

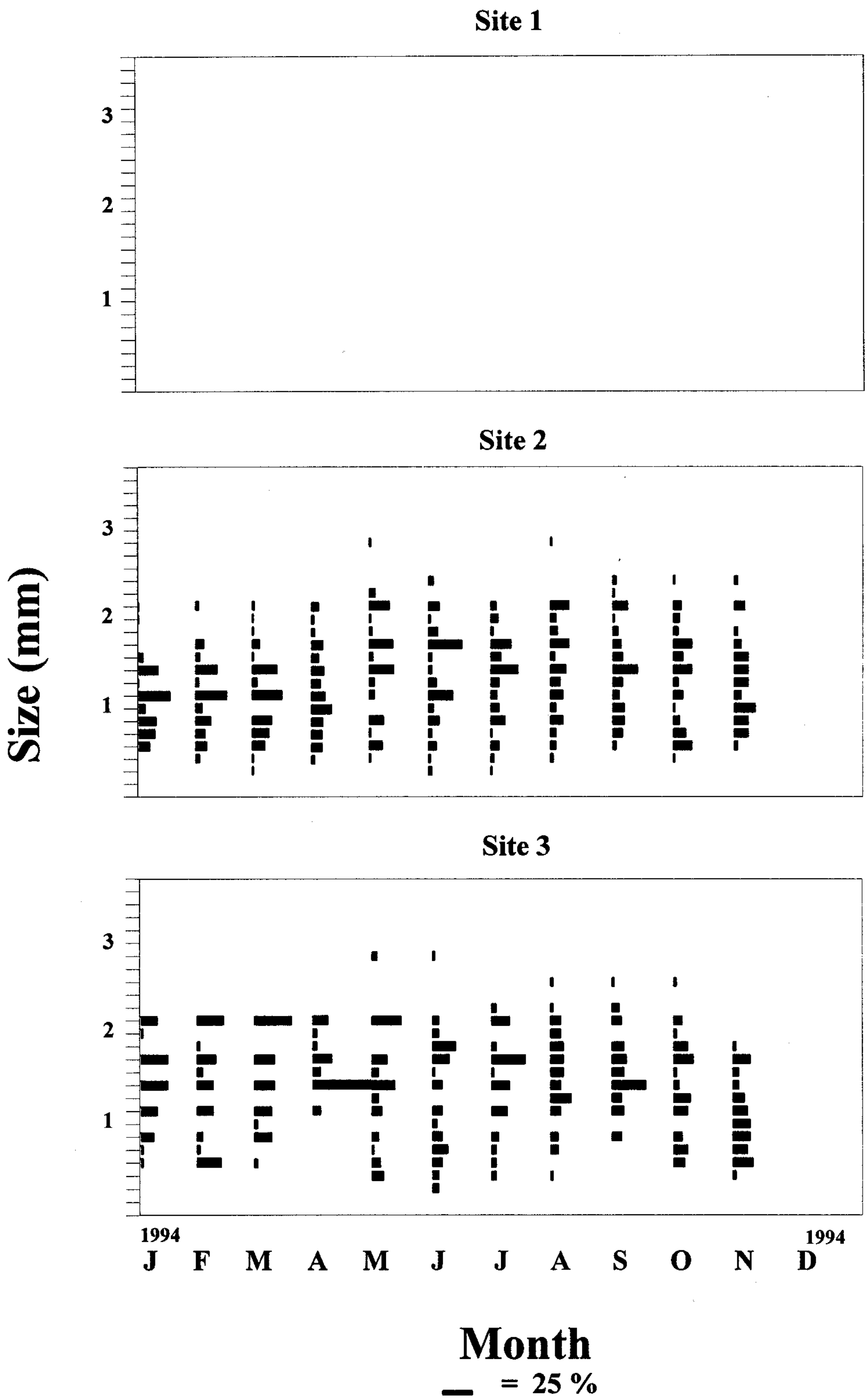


Figure 3e. Size histograms for the Bruneau Springsnail study sites for 1994. Horizontal tick marks represent 0.14mm size classes. Solid bars represent relative abundance of snails for a particular class (n=100 for Site 2; n=50 for Site 3).

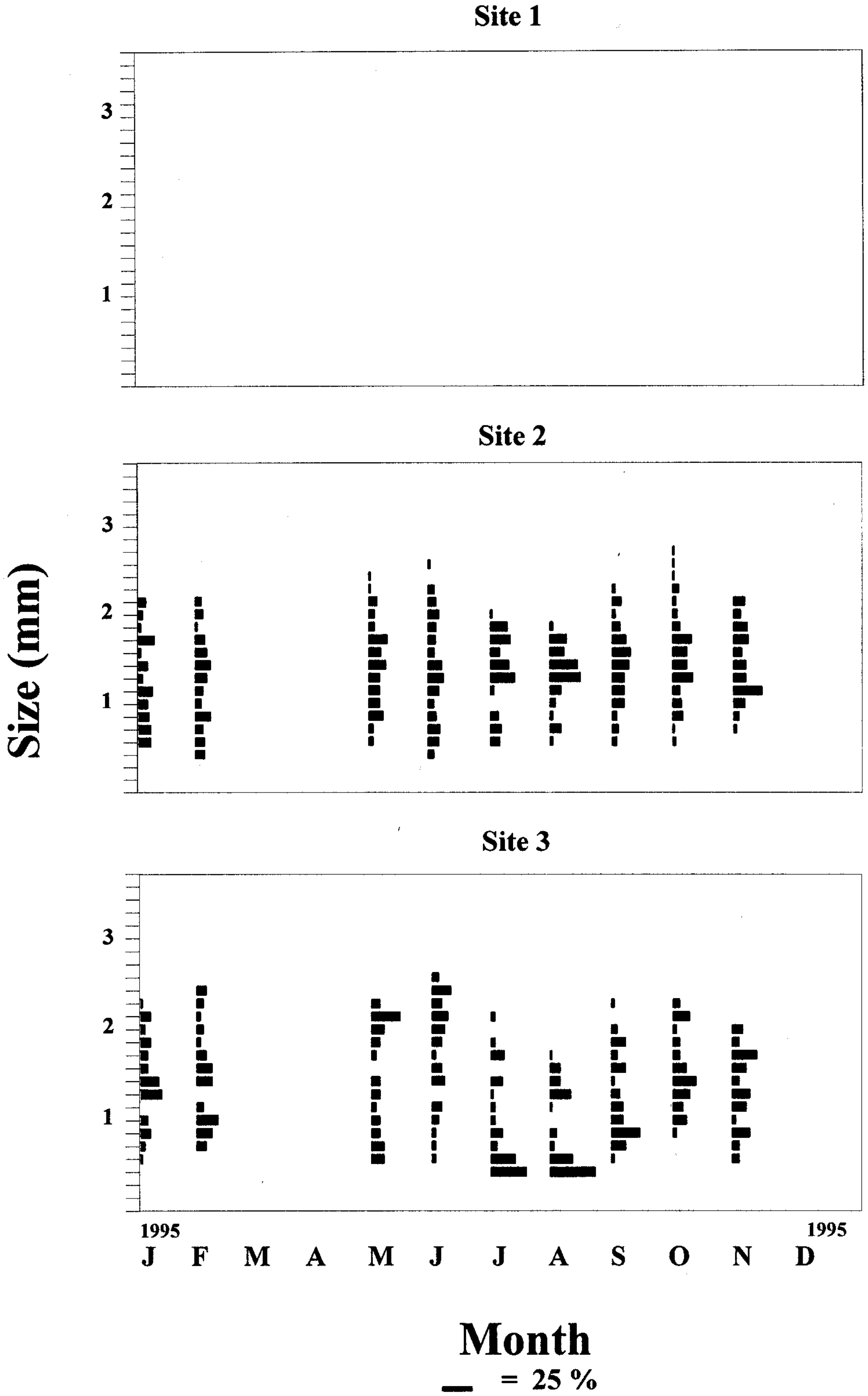


Figure 3f. Size histograms for the Bruneau Springsnail study sites for 1995. Horizontal tick marks represent 0.14mm size classes. Solid bars represent relative abundance of snails for a particular size class (n=100 for Site 2; n=50 for Site 3).

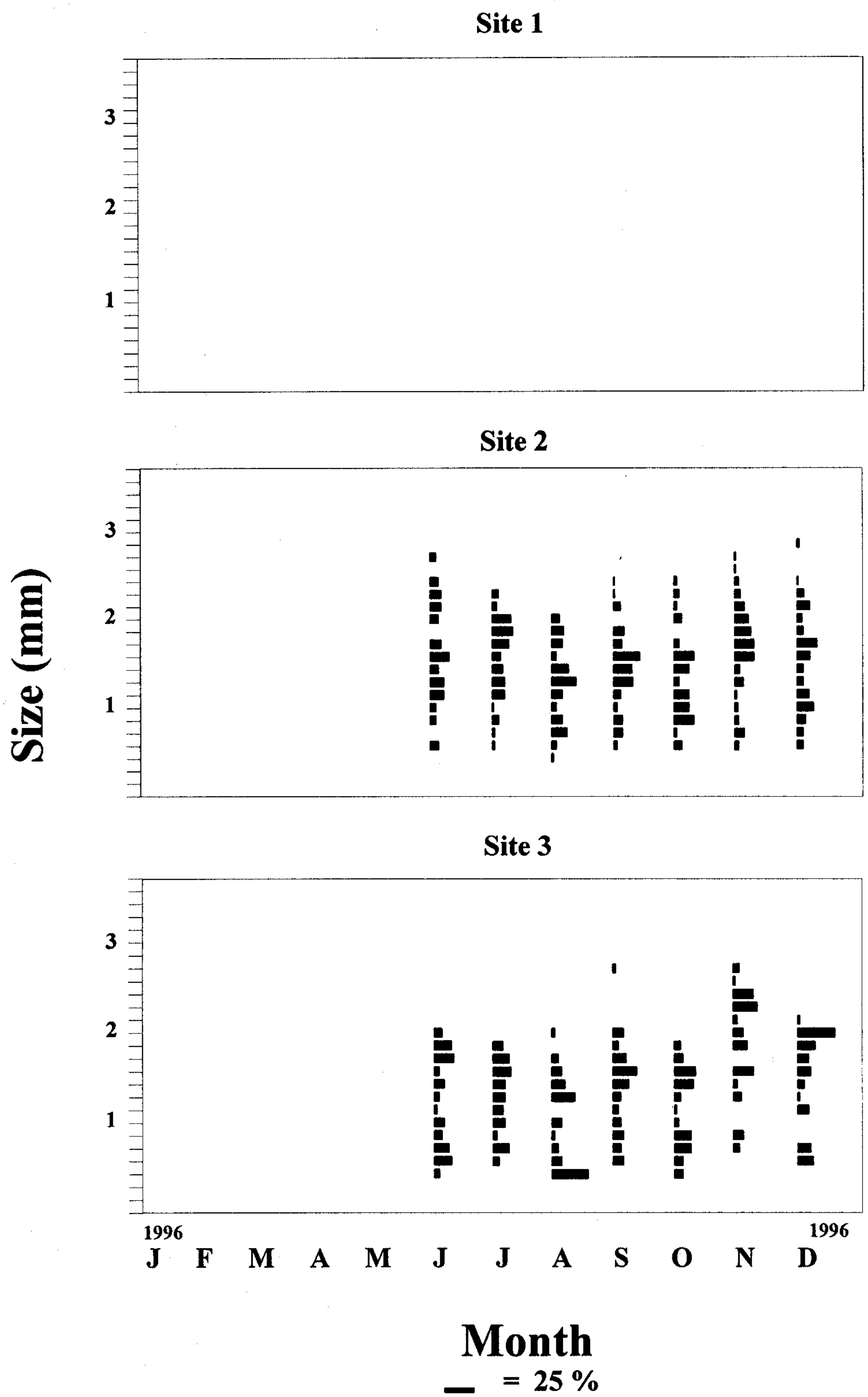


Figure 3g. Size histograms for the Bruneau Springsnail study sites 1996. Horizontal tick marks represent 0.14mm size classes. Solid bars represent relative abundance of snails for a particular size class (n=100 for Site 2; n=50 for Site 3).

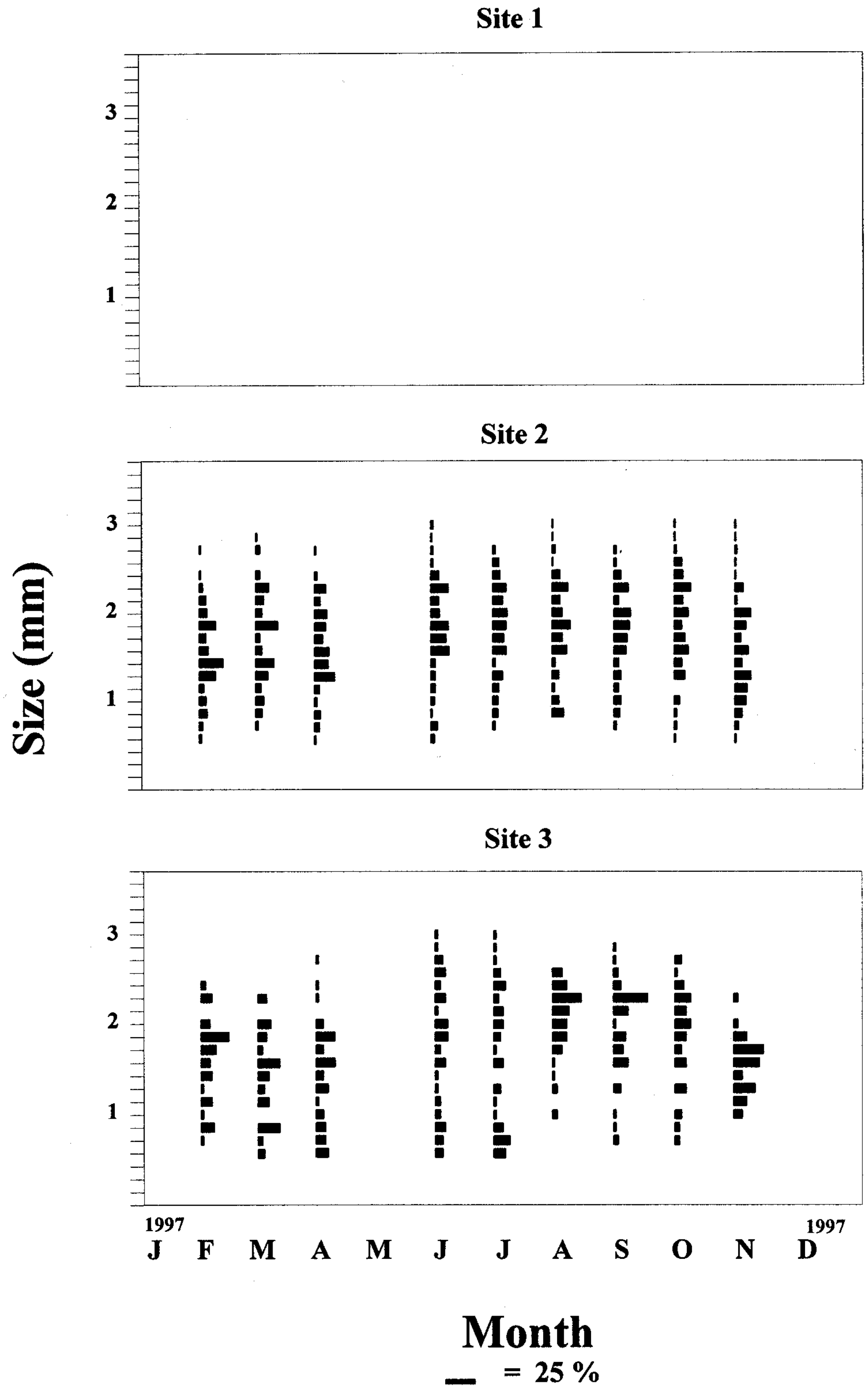


Figure 3h. Size histograms for the Bruneau Springsnail study sites for 1997. Horizontal tick marks represent 0.14mm size classes. Solid bars represent relative abundance of snails for a particular size class (n=100 for Site 2; n=50 for Site 3).

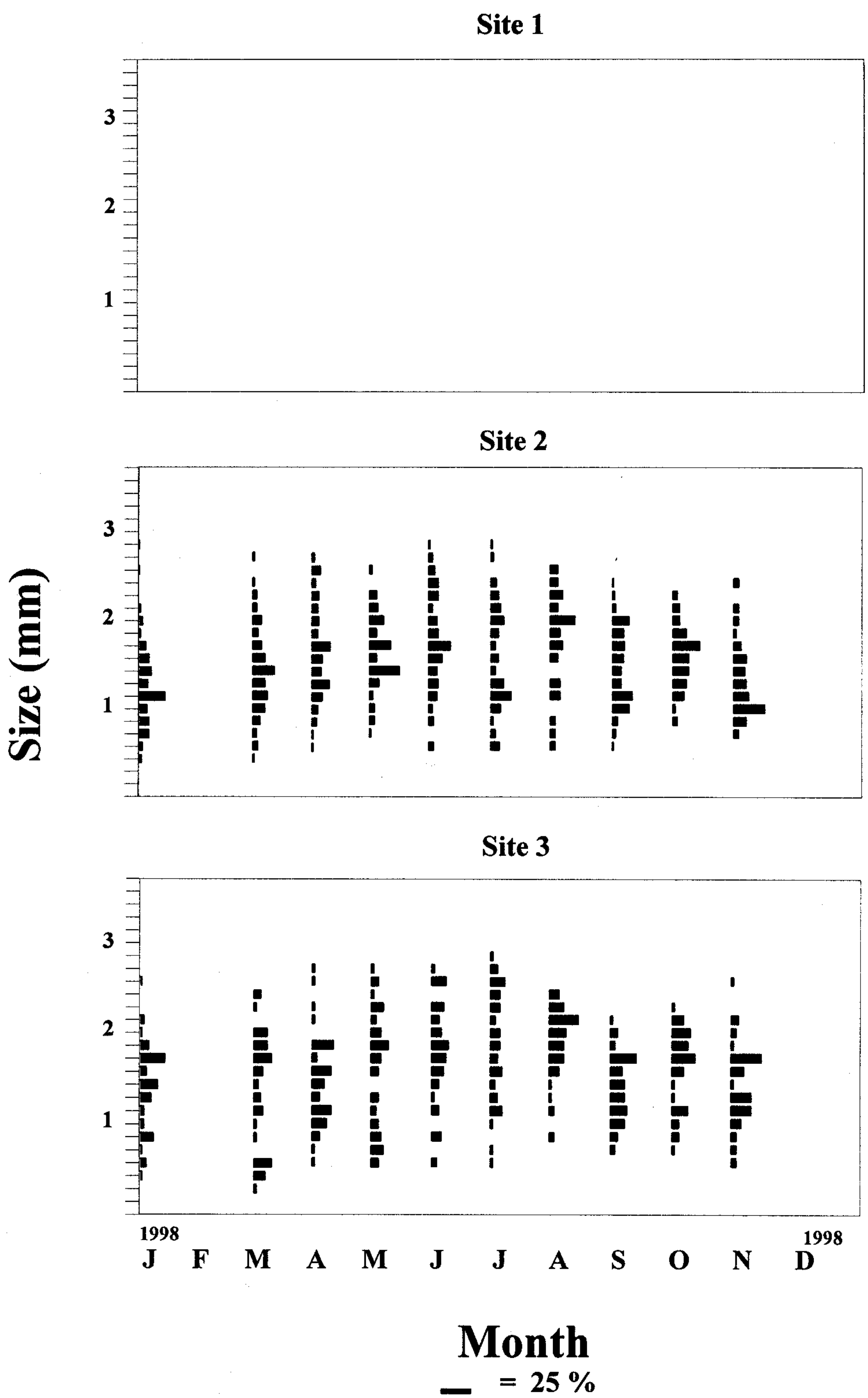


Figure 3i. Size histograms for the Bruneau Springsnail study sites for 1998. Horizontal tick marks represent 0.14mm size classes. Solid bars represent relative abundance of snails for a particular size class (n=100 for Site 2; n=50 for Site 3).

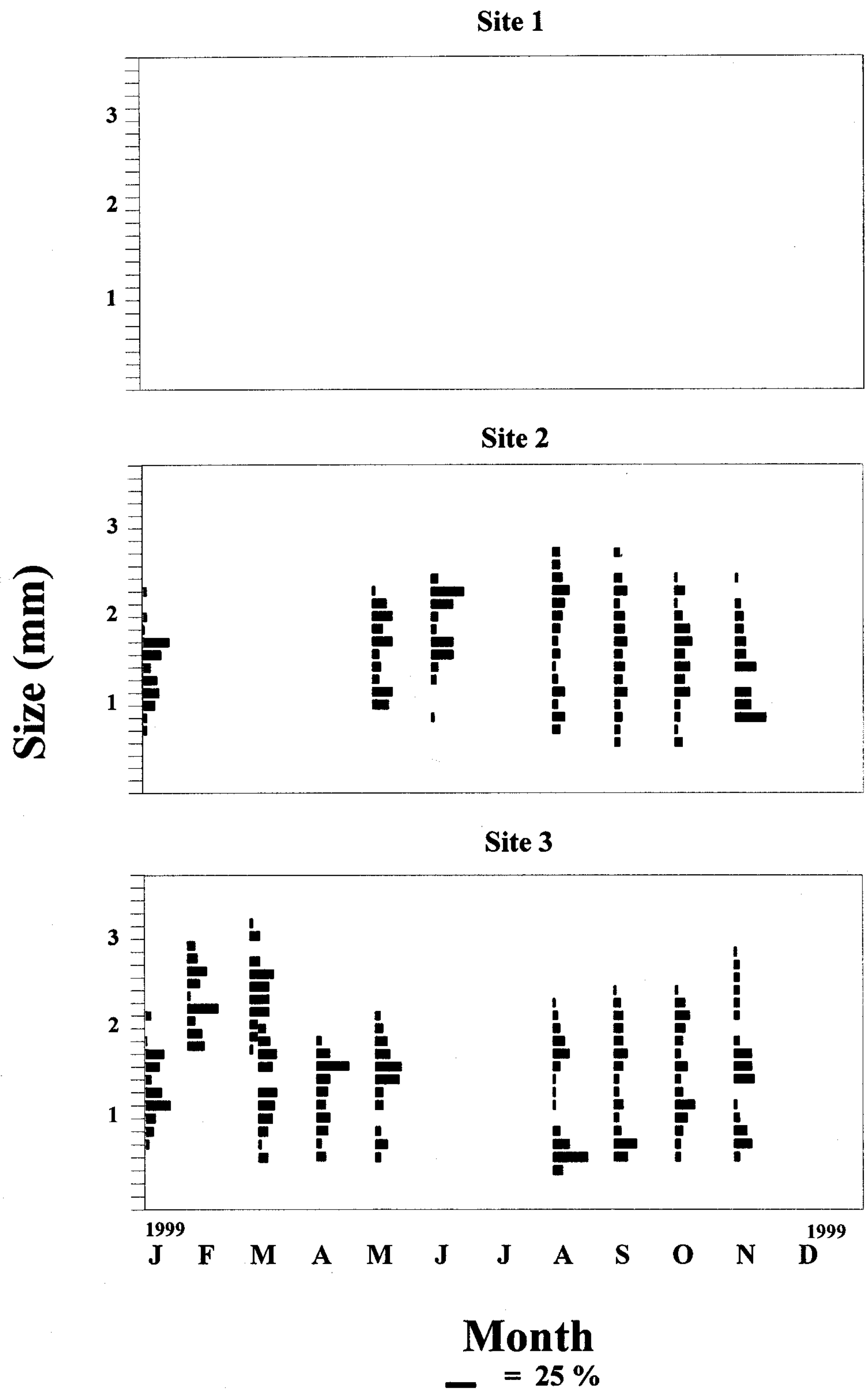


Figure 3j. Size histograms for the Bruneau Springsnail study sites for 1999. Horizontal tick marks represent 0.14mm size classes. Solid bars represent relative abundance of snails for a particular size class (n=100 for Site 2; n=50 for Site 3).

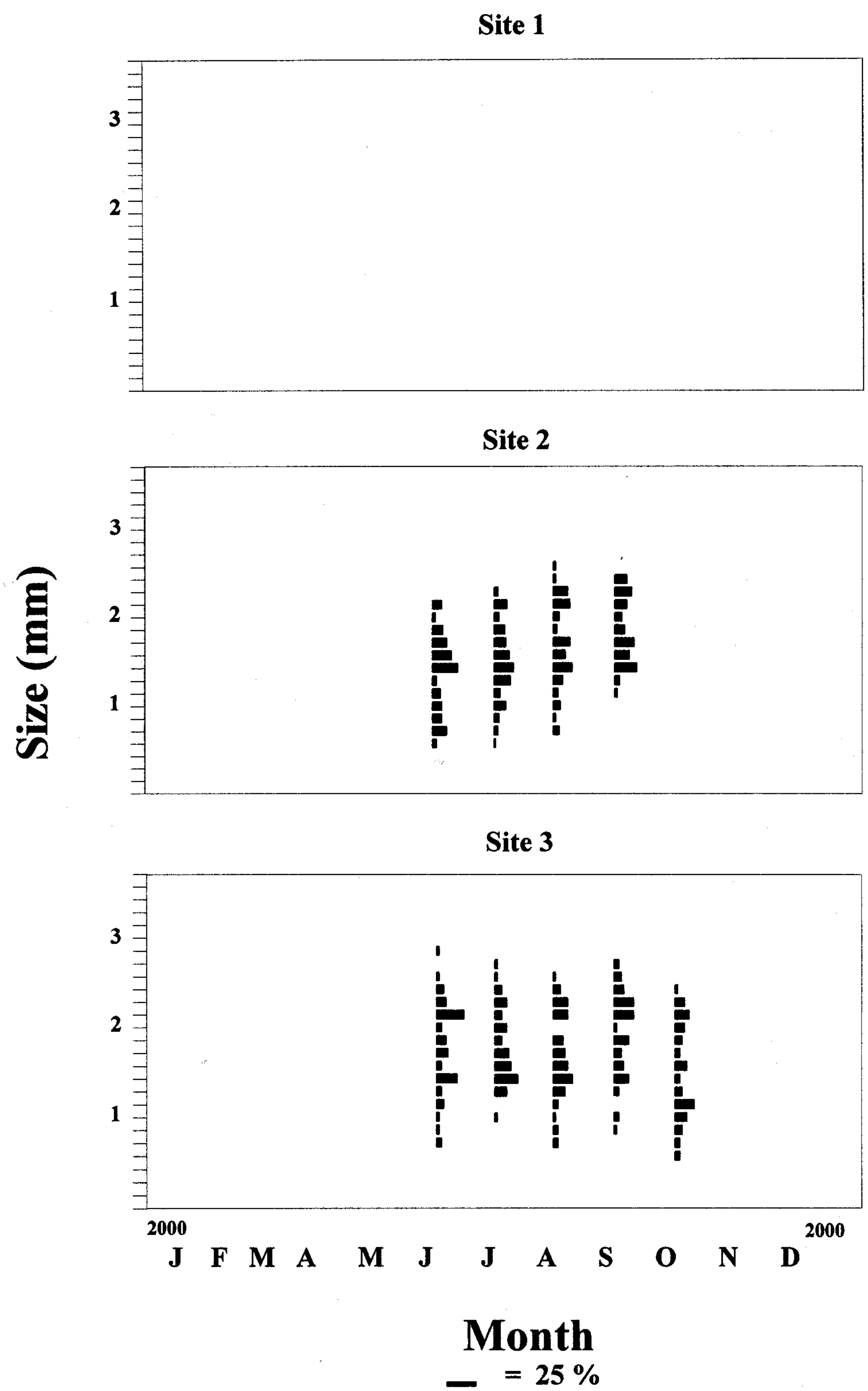


Figure 3k. Size histograms for the Bruneau Springsnail study sites for 2000. Horizontal tick marks represent 0.14mm size classes. Solid bars represent relative abundance of snails for a particular size class (n=100 for Site 2; n=50 for Site 3; n=50 site 2 September 2000)

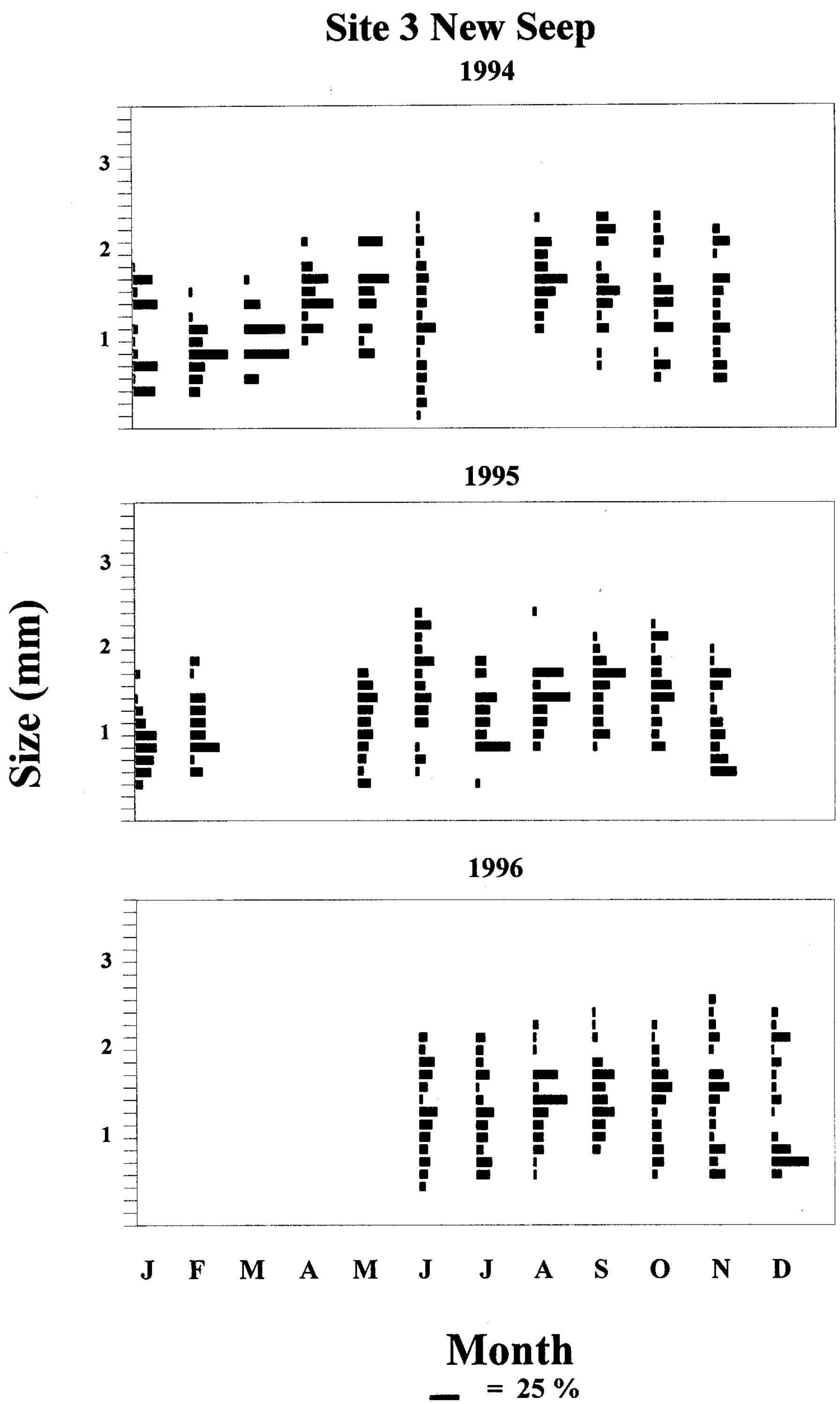


Figure 4a. **Size histograms for the Bruneau Springsnail study site for 1994-1996 3 New Seep. Horizontal tick marks represent 0.14 mm size classes. Solid bars represent relative abundance of snails for a particular size class (n=50 for each sample).**

Site 3 New Seep

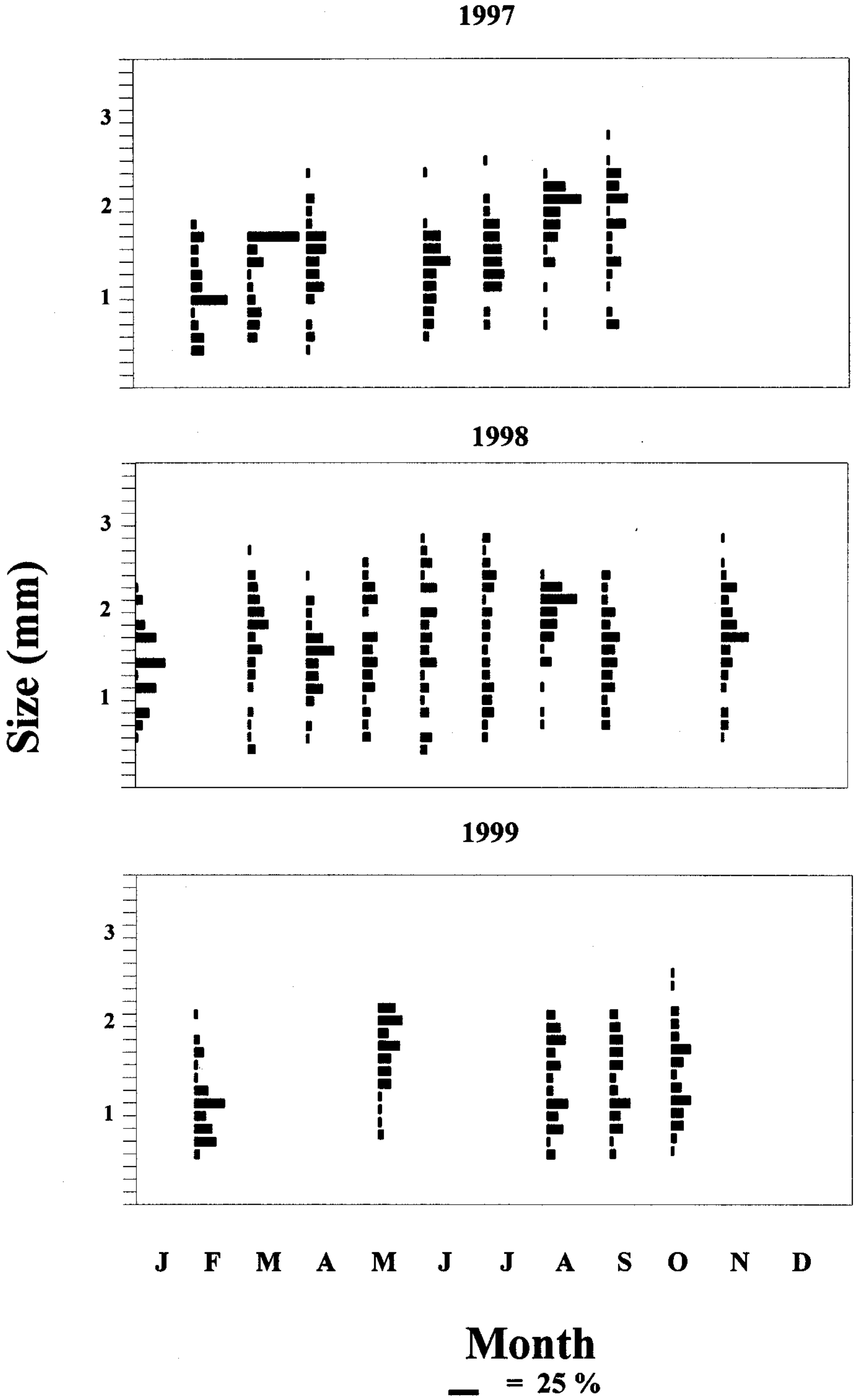
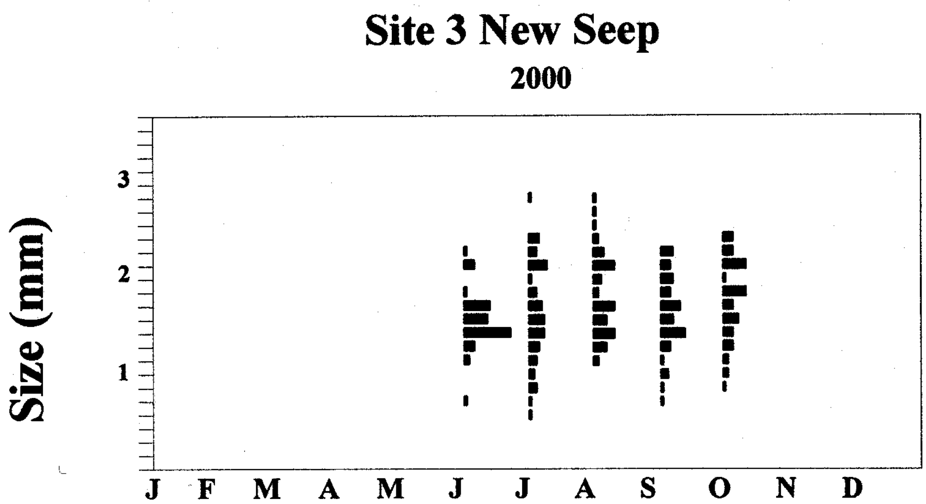


Figure 4b. Size histograms for the Bruneau Springsnail study sites for 1997-1999 3 New Seep. Horizontal tick marks represent 0.14 mm size classes. Solid bars represent relative abundance of snails for a particular asize class (n=50 for each sample).



Month

= 25 %

Figure 4c. Size histograms for the Bruneau Springsnail study site for 2000 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).

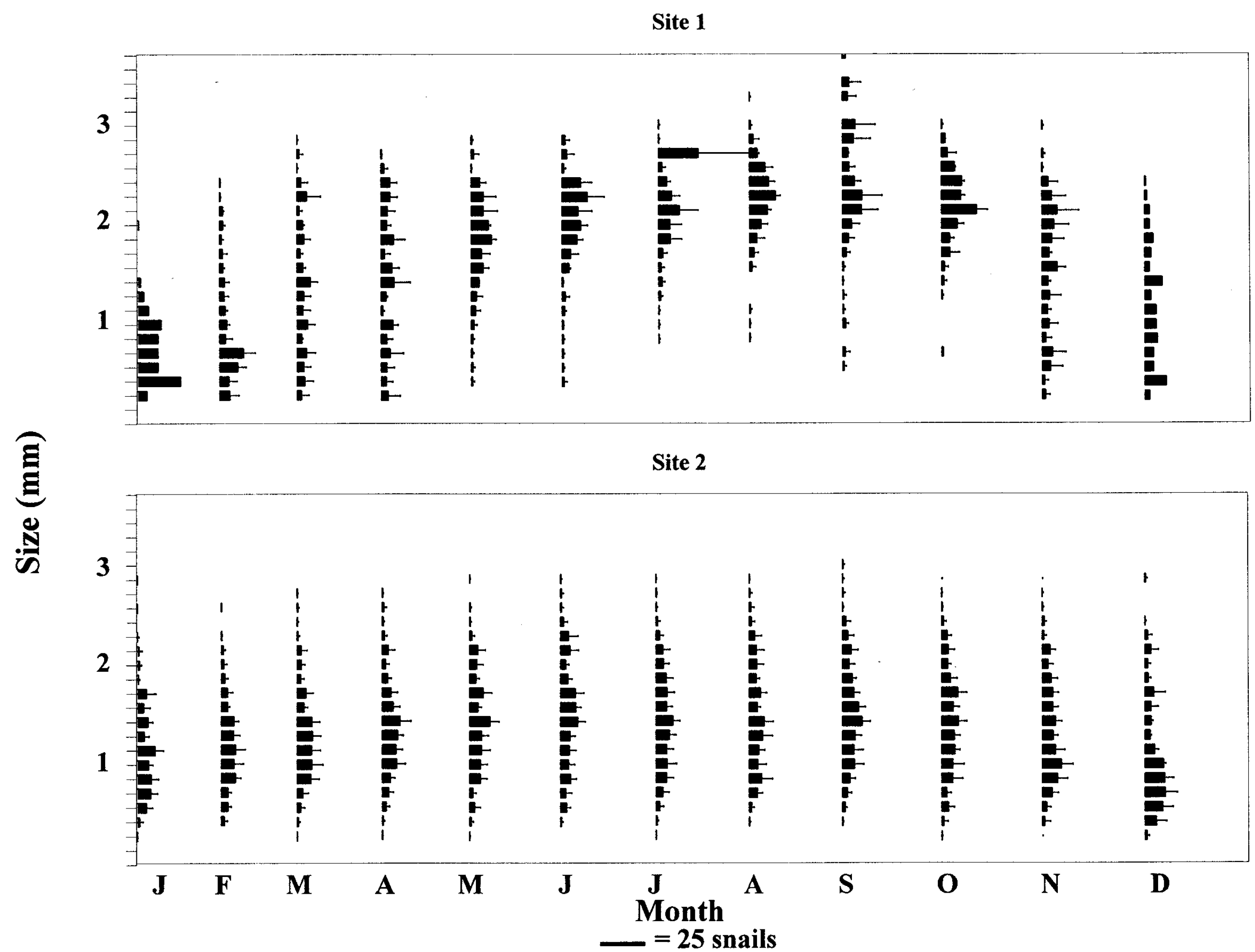


Figure 5a. Size histograms for Bruneau Springsnail study sites 1 and 2 based upon data from 1990-2000. Horizontal tick marks represent 0.14 mm size classes. Error bars represent one standard deviation from the mean. Figures lacking error bars did not have enough sets of data to determine standard deviations.

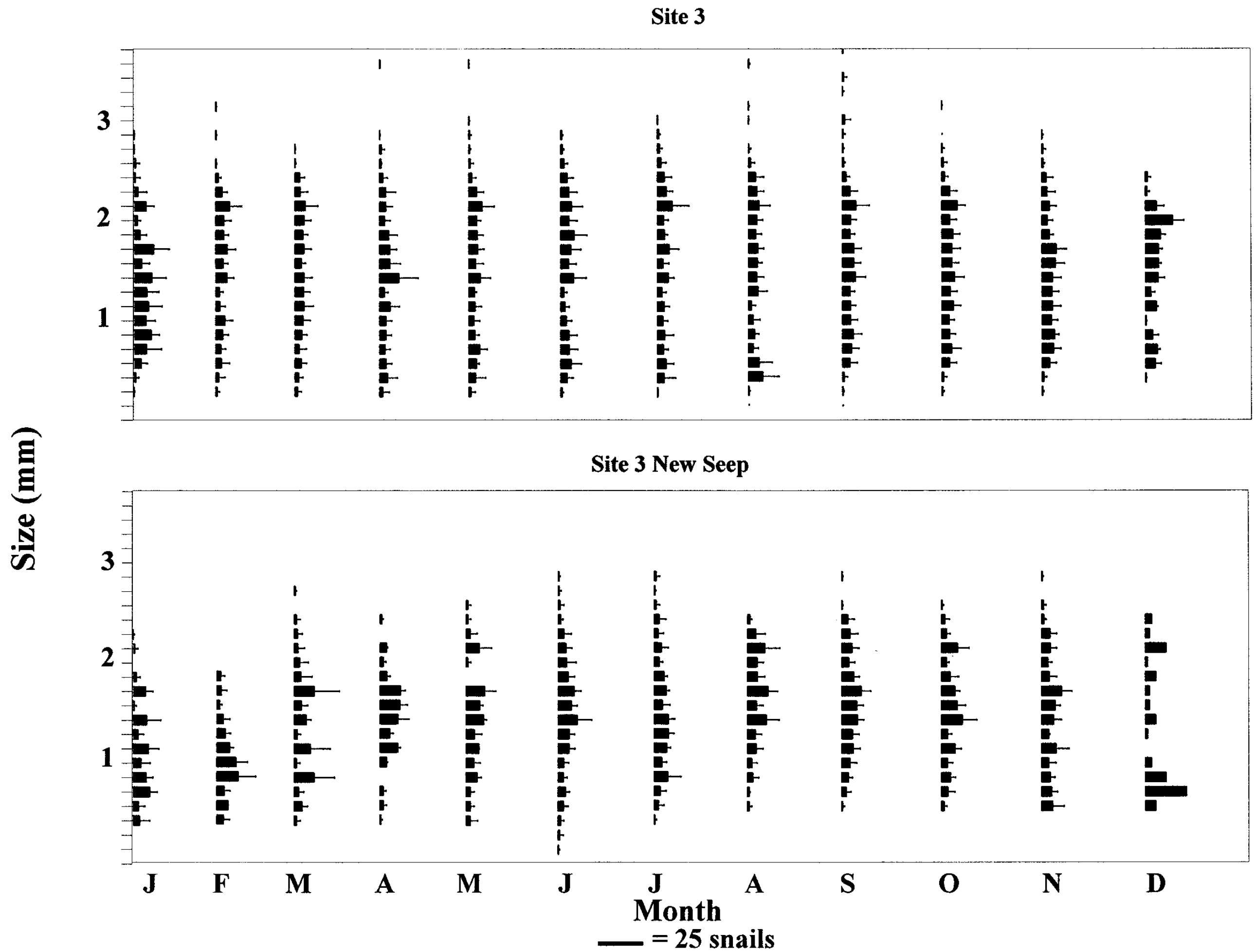


Figure 5b. Size histograms for Bruneau Springsnail study sites 3 and 3 New Seep based upon data from 1990-2000. Horizontal tick marks represent 0.14-mm size classes. Error bars represent one standard deviation from the mean. Figures lacking error bars did not have enough sets of data to determine standard deviations.

although the population appeared to mature in September, which has not been seen in previous years. Size distribution trends for 2000 fall within the range of previous monitoring years. The right seep rock face was dry during the month of September (making n = 50). During the month of October the rock face was wetted but no springsnails had recolonized. No size distribution data were collected for the month of October, due to lack of individuals at this location. Mean size distribution data (Figure 5a) showed juveniles to be prevalent at all times of the year.

In 2000, springsnail density at Site 2 ranged from 4,471 snails/m^2 in June to 1,174 snails/m^2 in September (Fig. 7). These numbers fell within the range set by previous monitoring years; however, 2000 appears to have some of the lowest densities found in the last decade (Figure 7). Densities at Site 2, between 1990 and 1999, have generally been higher than those at the other study sites, although monthly estimates have exhibited great variability (Fig. 7). Typically, lower densities at Site 2 were found during colder months (September through February) (Fig. 7). With the right seep rockface becoming dry in September, densities in 2000 are the lowest recorded. Both the right and left seeps had dead snails present on the rockface, which were not included in the counts.

Site 3-OS (Lower Spring Rockface)

There were no clear size distribution trends between June and October 2000 (Fig. 3k). Mean size distribution data for the springsnail population at Site 3-OS did not show clear trends associated with season over the past eight years (Fig. 5b).

In 2000, Site 3-OS springsnail population maintained fairly constant densities between the months of June and October. With the exception of 1992 and 1996, densities were within the range of data from previous monitoring years (Fig. 7). In 2000, the highest snail density at this site was 3,445 snails/m^2 in July while the lowest density was 1,506 snails/m^2 in June (Fig. 7). Many snails appeared to be hidden in the algae, making them hard to count during the months of September and October, and some may have been missed.

Site 3-NS

Between June and October 2000, the springsnail population at Site 3-NS also lacked any clear trends in size distribution (Fig 4c). Previous mean size distribution data (Fig. 5b) suggested that the New Seep population maintained a fairly even distribution of individuals across the different size classes during all seasons and that the development of cohorts at both Site 3 seeps might not be a frequent occurrence.

Snail densities at Site 3-NS were generally lower than those at Sites 2 and 3-OS (Fig. 7). In 2000, the highest density, 1,982 snails/m^2, was recorded in August and the lowest density, 608 snails/m^2, was recorded in June. Densities in 2000 were slightly higher than those in 1999, which were among the lowest since 1994 (Fig. 7). Currently, Site 3-NS does not provide a habitat suitable for large populations of springsnails because of its small rockface area, large amount of shading, and diffuse groundwater flow. In October, many snails were located in algae making exact counts of snails difficult. Still, this seep does support a viable population.

Comparison of Average Monthly Snail Sizes Among Sites

An analysis of the average monthly snail sizes, based upon data collected between 1990 and 2000 (Fig. 6), revealed distinct differences in population life histories among the study sites. The slopes of the linear regressions calculated in Figure 6 were used as estimates of site-specific population growth rates. Snails at Site 1 grow as a distinct cohort. The water temperatures at Site 1 were the warmest (often above the thermal maximum temperature of 35°C (Fig. 10; Mladenka 1992)). Recruitment probably only occurred in the cooler winter months, based upon the small average snail sizes found between January and March. The slope of the regression line for Site 1 (0.244; $p < 0.005$) (Fig. 6) was strongly positive and appeared to represent 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 average snail size of all the study sites (Fig. 6). The populations at the other sites (2, 3-OS, and 3-NS) did not exhibit trends seen at Site 1 (analyzed between June and August for comparative purposes). Both Site 2 and Site 3-NS had significant regression lines ($p < 0.005$) with slightly positive slopes (0.046 and 0.073, respectively). Site 3-OS data were very scattered and even exhibited a slightly negative trend between January and August (slope = 0.008, $p = 0.972$).

Discharge, Temperature, and Water Chemistry Fluctuations

<u>Site 1 (Hot Creek</u>)

Hot Creek discharge dropped after channel scouring and sediment loading in July 1992 (Fig. 8). 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). Extreme temperatures at Site 1 prior to September 1994 (date when minimum-maximum thermometers were replaced with submersible temperature data loggers) may have been the result of thermometer exposure to air (Figs. 8, 9; Royer and Minshall 1993, Varricchione and Minshall 1997). Water temperatures in 2000 ranged from 32.1°C to 35.4°C, which is consistent with trends after September 1994 (Fig. 9). Mean temperatures appeared to remain constant in 2000 at 34°C (Fig. 10). There was no apparent change in water chemistry at Site 1 during 2000 (Fig. 11). Conductivity and alkalinity values fall with in the range of previous monitoring years. Hardness values were lowest since 1994.