to zero at 1.20 m from the rockface (approx. 0.60 m from the outflow's junction with Hot Creek)(Fig. 20a). On 14 November 1997, temperature measurements were made simultaneously with snail counts. Conducted twice to ensure precision, the temperature began at 34.6°C at the rockface, declined to 33.1°C at 0.10 m from the rockface in the outflow/stream, increased again to 34.5°C at 0.40 m, and declined again to 33.4°C at 0.80 m (Fig. 20b). Temperatures over the rest of the tributary were relatively constant (33.8°C $\pm$ 0.10). The range in these temperature readings was only 1.5°C and may reflect precision limits of the thermometer.

Controlled fish-feeding experiment in Hot Creek.

Tilapia in the "Springsnail plus additional food sources" treatment did not prey on live Springsnails, although one fish did contain a bleached shell of an unidentified gastropod (Fig. 21) The bulk of the remaining stomach contents for this treatment was dead organic matter (detritus) and living vegetative matter (fragments of macrophytes). One *Tilapia* in the "Springsnails only" treatment had a small (1.1 mm) *P. bruneauensis* in its stomach (Fig. 21). The composition of the remaining stomach contents in this treatment was very similar to the other *Tilapia* treatment. *Gambusia* in the "Springsnail plus additional food sources" treatment did not prey on live Springsnails (Fig. 21). Most of the remaining stomach contents for this treatment was detritus. One elmid beetle (*Cleptelmis sp.*) larvae was found in a *Gambusia* from this treatment. The composition of the remaining stomach contents in the "Springsnail plus additional food" treatment was primarily detritus, but also included vegetative matter and one elmid beetle (*Cleptelmis sp.*) larvae (Fig. 21).

Movement rates of P. bruneauensis under different food resource availability conditions.

Low chlorophyll a abundance on the tiles in the experimental enclosures appeared to induce a considerable amount of dispersal of Springsnails in the "zero-algae" (0 mg chlorophyll a/m^2) treatment relative to the "half-algae" (35.1 mg chl a/m^2)

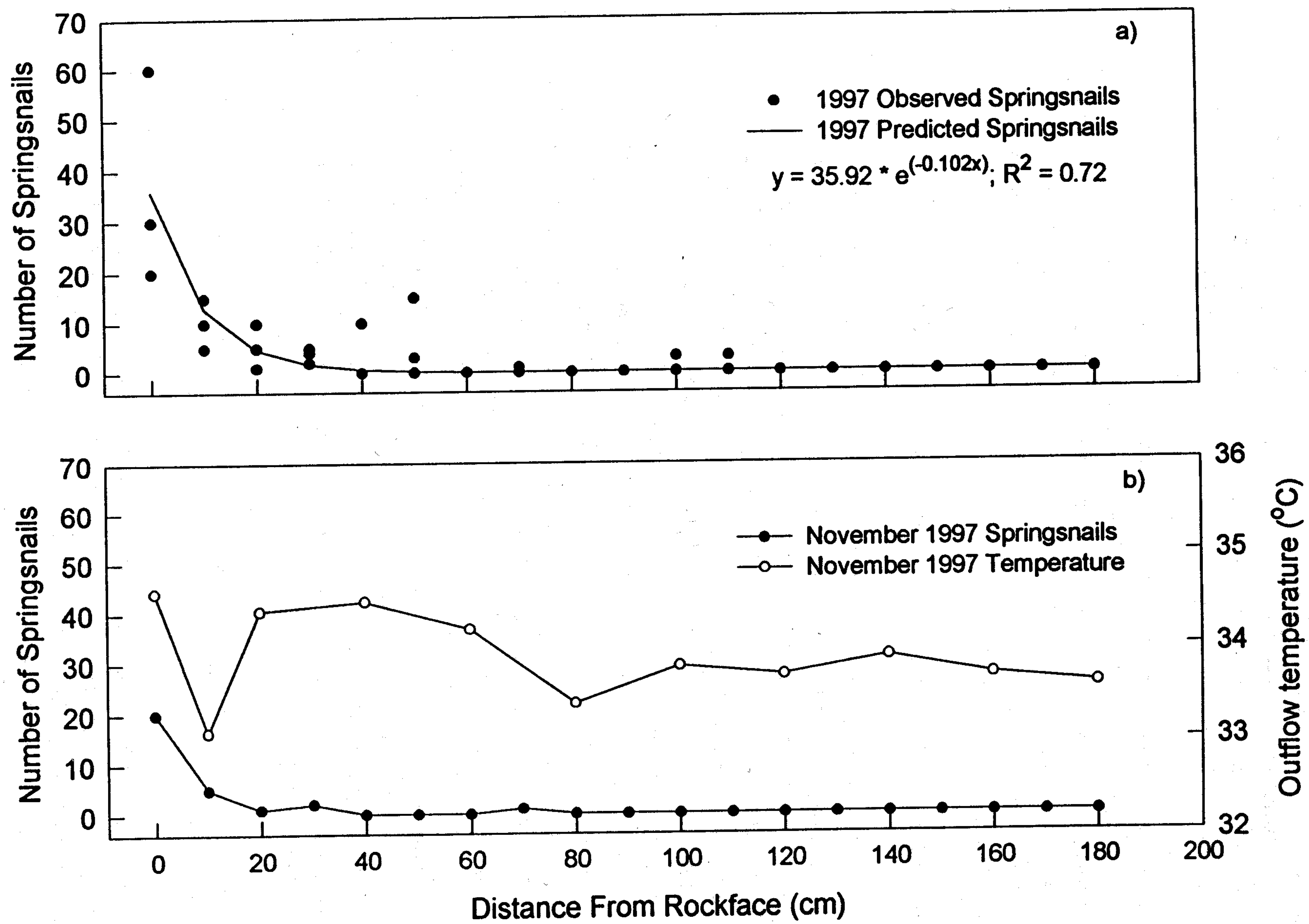

Figure 20. Relict Springsnail distribution data for rockface seep outflow near Site 1 at Hot Creek. (A) Observed and predicted distribution of Springsnails from combined August, September, and November 1997 data. (B) Distribution of Springsnails and water temperature at same location on 15 November 1997. Observations at 0 m were taken directly from the rockface while the remaining observations were made in the deeper (approx. 10 cm) outflow. The area for each observation was approximately 10 cm^2.

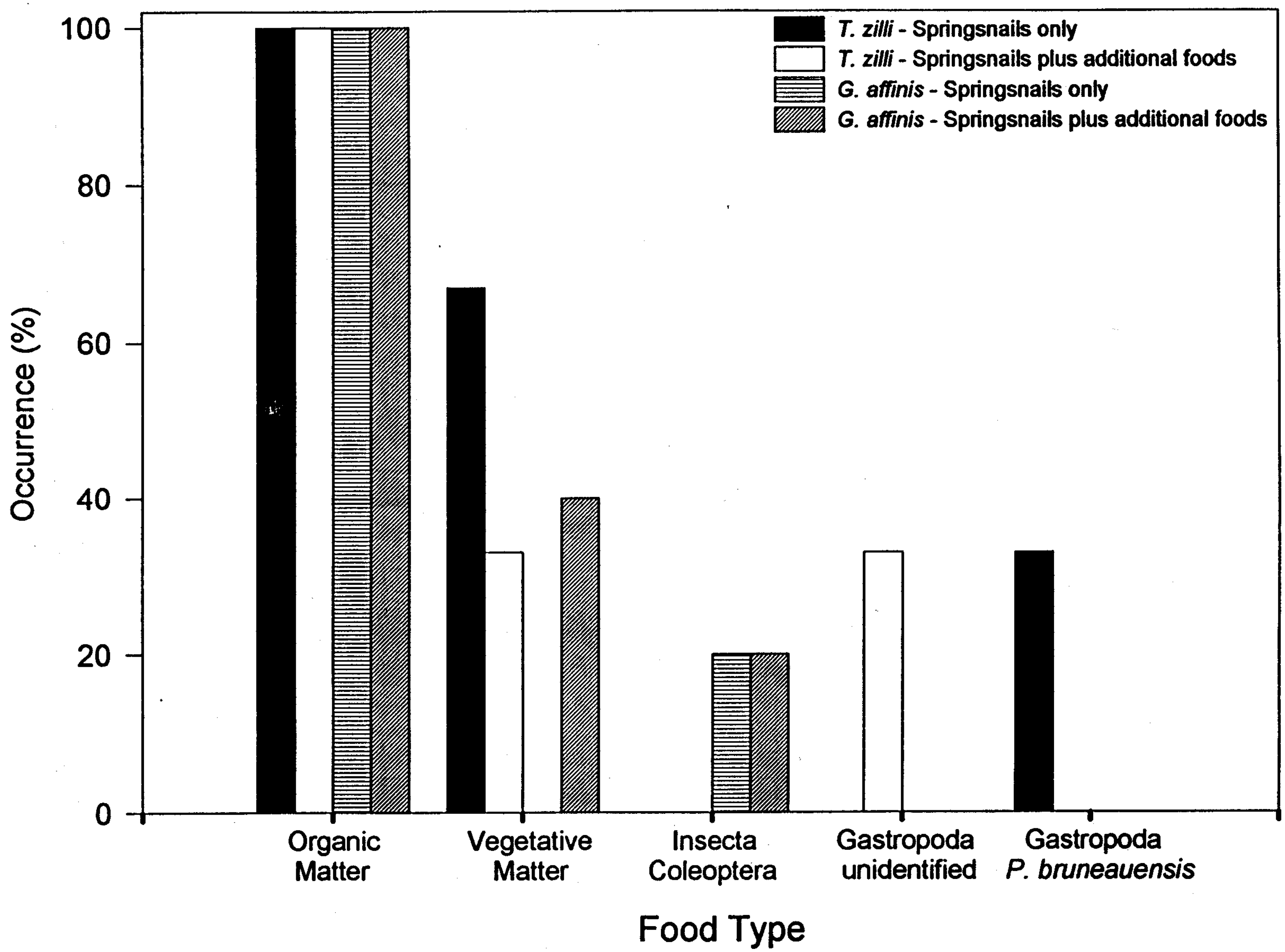

Figure 21. Occurrence of food types in the guts of *Tilapia zilli* (n = 3 for each treatment) and *Gambusia affinis* (n = 5 for each treatment) under Sprinsnail-only and Springsnail-plus-additional-food availability treatments in the controlled fish-feeding experiment in Hot Creek, Bruneau, Idaho.

treatment and "full-algae" (63.7 mg chl a/m^2) treatment within the first 1.5 hours after the experiment had begun (Fig. 22a). Springsnails in both algae-colonized tile treatments appeared to be more prone to stay in their initial location because of greater food availability. After 21.5 hours (Fig. 22b) and 27.5 hours (Fig. 22c), the amount of Springsnail dispersal within the experimental enclosures appeared to increase greatly in the "half-algae" and "full-algae" treatments. In all cases, the median distances traveled by Springsnails were similar ($\pm$ 4 cm) within each sampling period (Fig. 22). Also, in all cases, some Springsnails had traveled 21.8 cm (the greatest distance possible in the enclosures) by the 21.5 hour sampling.

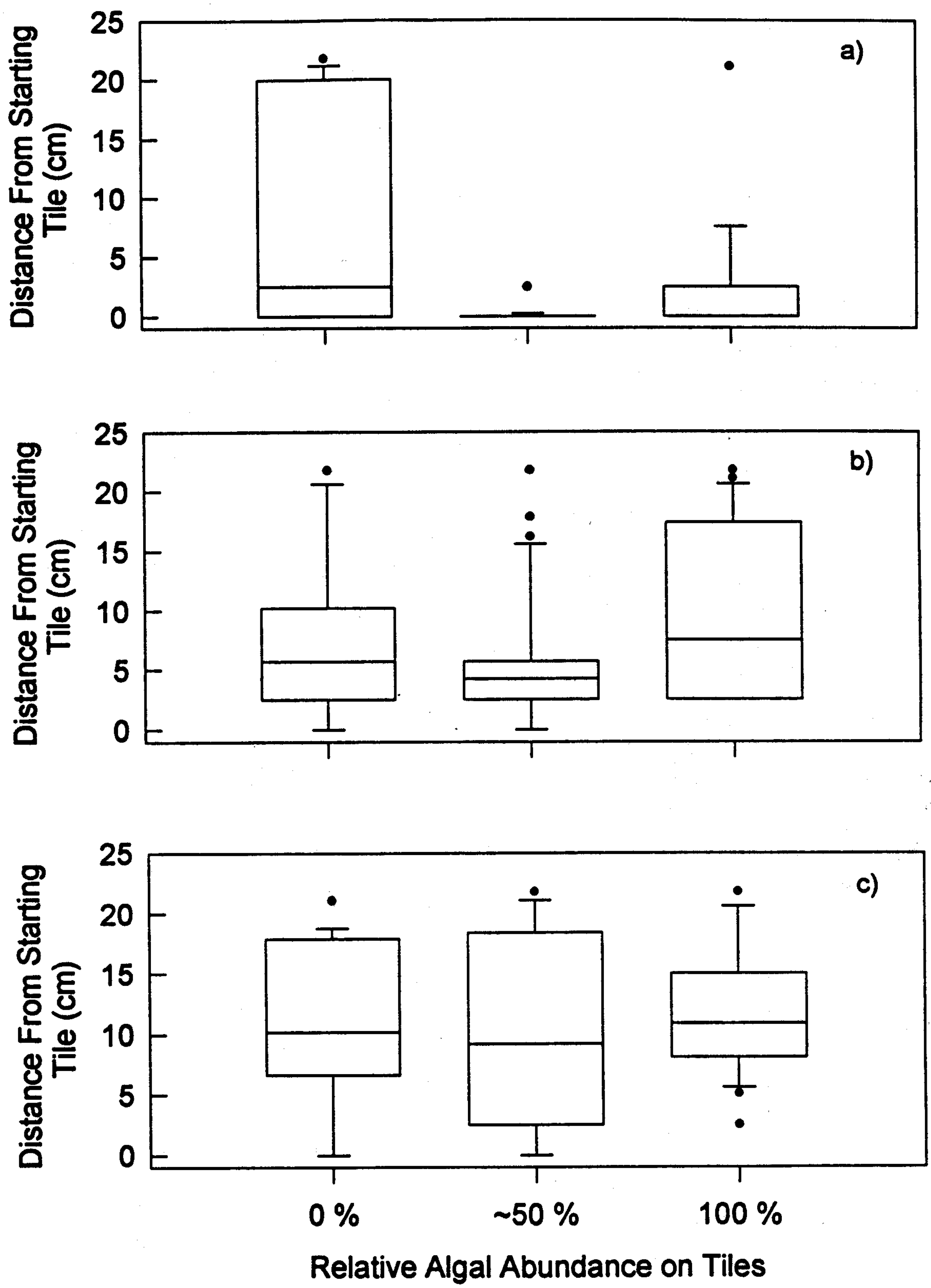

Figure 22. Box plots of Springsnail distance from the starting tiles in each of the three algae-colonized tile treatments at Hot Creek in Bruneau, Idaho. The experiment began at 14:30 on 14 November 1997. Springsnail locations on tiles were noted at 16:00 on 14 November 1997, b) 12:00, and c) 18:00 on 15 November 1997. Horizontal lines represent the 25%ile, median, and 75%ile. The "error bars" are the 10%ile and 90%ile. Solid circles are outliers.

DISCUSSION

Conditions at Indian Bathtub and Hot Creek

The only place that Springsnails were found in or near Hot Creek was on a rockface 1.80 m from the creek. The population at the rockface was small (36.7 $\pm$ 20.8 cm per 10 cm^2) and declined exponentially to zero 0.60 m before the outflow joined with Hot Creek. A number of factors may be responsible for the lack of Springsnail recolonization. These factors may include poor substrate quality, predation (most likely by fish), an inability to move long distances, and unsuitable temperature regimes. Experiments and field measurements were done in 1997 to assess the relative importance of these factors.

The Indian Bathtub and Hot Creek areas have been greatly impacted by sedimentation in recent years. 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). Additionally, the Springsnail's habitat has diminished considerably in recent years because of agricultural-related groundwater mining in the area (Berenbrock 1993). The Indian Bathtub population has apparently been reduced to zero (Mladenka 1992). 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 November 1997, there is no evidence to suggest that Springsnails have recolonized Hot Creek since July 1992.

Hot Creek does not have a cobble-dominated substrate layer near the surface of the streambed. Most of the materials are sands and small gravels. Although Mladenka's (1992) study showed that Springsnails are able to survive on all sizes of substrate, large substrate is important because it provides a stable surface for egg-laying. The area near Mladenka's (1992) study area does have a substrate layer composed primarily of gravels, but that layer is at least 15 cm below the streambed surface.

It appears that Springsnails (at least those 0.91 through 2.10 mm in size) are not a preferred food item for the exotic fish in Hot Creek. However, the controlled fish-feeding experiment, conducted in November 1997, did show evidence of Hot Creek fish occasionally consuming gastropods (one *T. zilli* consumed a *P. bruneauensis* and another consumed a bleached and unidentified snail shell). Snails were not found in the gut contents of Hot Creek fish in 1995 (Varricchione and Minshall 1995b), but that finding may have been a result of the (apparent) lack of Springsnails in Hot Creek. Any Springsnails that do migrate to Hot Creek may be immediately preyed upon by fish, preventing any chance of re-establishing a stable population. However, the results of our feeding experiments suggest that the snails are mainly eaten incidental to the ingestion of other foods. Possible preference of the fish for very small Springsnails, veligers, or eggs remains unknown and may warrant additional study.

At the spring seep near Hot Creek (Site 1), temperatures in the outflow may limit Springsnail populations. The temperature in the outflow was at the high end of the temperature tolerance range found by Mladenka (1992). This logic is supported by the fact that the highest densities of the relict population were found on the rockface where exposure to air could cool the snails if they were too hot. However, it seems unlikely that the temperatures downstream of the outflow acted as a barrier to Springsnail movement, even though no snails were found further than 1.1 m from the spring (Fig. 20).

Movement rate studies indicated that *P. bruneauensis* is capable of moving as much as 1 cm per hour. In both food-limited and -unlimited treatments, at least 2 or 3 Springsnails had moved the greatest distance within the experimental enclosures (21.8 cm) by 21.5 hours. The distance from the relict population rockface to Hot Creek (1.80 m) could theoretically be traveled in less that 9 days (and probably a much shorter time) barring any unsuitable conditions. As with temperature, movement rates do not appear to explain the lack of Hot Creek recolonization.

Other habitat parameters measured at Hot Creek (Site 1) (stream temperature, discharge, periphyton chlorophyll-a and biomass, substrate composition, and riparian habitat quality) in 1997 remained fairly consistent with data collected in previous years (at least after sedimentation events in 1991 and 1992). The lack of grazing in the area has led to a rapid recovery in riparian vegetation over the past few years.

Conditions at the Rockface Seeps

Springsnail size-distribution and density measurements, along with rockface habitat parameters (periphyton chlorophyll-a and biomass, water temperature, and chemistry, and rockface flow and moisture conditions) remained relatively consistent with data from previous years. The rockface seeps had water temperatures that were consistently lower than those in Hot Creek (Site 1) and rarely exceeded the thermal tolerance temperature (35°C) (Mladenka 1992). This most likely explains the higher amounts of year-round recruitment at the rockface seep sites (2, 3-OS, and 3-NS) compared with Hot Creek. Temperature ranges clearly affect the *P. bruneauensis* populations. Average size and growth rates were smaller, but densities were greater, at the rockface seeps than in Hot Creek (1990-1992). The rockface sites are probably more suitable for Springsnail success than Hot Creek.

Small, 90° V-notch weirs were installed at the rockface seep sites (2, 3-OS, and 3-NS) to provide a means of monitoring discharge. Although measurements have only been made for 2 months, it appears that there may be large amounts of variability in the flows. Continued monitoring should provide useful insight into the status of the local groundwater situation.

The rockface habitat mapping and total Springsnail population estimates provide a broader understanding of the status of the endangered snail and its environment at the study sites. The areas which have been monitored since 1990 have been approximately 2 m^2 at each of the rockface seep sites. The rockface mapping in 1997 relied on less intensive sampling, but it expanded population estimates and habitat descriptions up to

18.25 m^2 at both Site 2 and Site 3 (including OS and NS). These measurements should provide a base from which longterm trends in population and habitat conditions can be determined.

In 1994 Springsnail size distributions, densities, and eventually temperatures (beginning November 1996) at Site 3-NS began to be monitored. This data was kept separate from Site 3-OS, 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-OS. Size distribution data, life history patterns, densities, and habitat 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.

Some parts of the rockface study sites (Sites 2, 3-OS, and 3-NS) are covered by thick layers of periphyton. At Site 2 and Site 3-NS this periphyton is primarily composed of diatoms, green algae, and, most likely, warm-water-adapted bacteria. At Site 3-OS, 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 a very thick layer of this periphyton matrix so it is not monitored for Springsnails. 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 of periphyton appear to be spreading into damp areas where water is not flowing down the rockface (areas of low disturbance). As groundwater flows decrease, less rockface area will be covered by fast flowing water, and more habitat probably will be covered by this bacterial-algal complex. Given enough reduction in springflow, Springsnail populations could be reduced to abundances that are too small to remain viable.