

Factors Determining Biodiversity in Sierra Nevada Cold Spring Systems

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Abstract. The downstream extension of caddisflies (Trichoptera) was studied throughout the length of two cold spring systems (designated SH 4 and SH 6) in the Sagehen Creek basin, eastern Sierra Nevada, California. The study was part of a larger study on factors affecting species distribution and richness in cold springs [Erman and Erman, 1990]. Emergence traps were placed at the spring sources and at measured distances downstream to compare differences in species present and numbers emerging. Traps were operated continuously for a year in the SH 4 system and for a 19-week period through summer and fall in the SH 6 system. Seventeen species of caddisfly were collected in SH 4, and 20 species were collected in SH 6. Similarity between the two systems was low; they shared 8 species in common. Similarity from source to lowest station within both systems was even lower and nearly identical—20 percent and 22 percent. Most species were replaced with other species from the sources to the lowest stations. Abundances of emerging caddisflies increased downstream in both systems. Cold-spring sources are habitats for rare and unique species confined to constant conditions. They contribute significantly to the biodiversity of Sierra Nevada aquatic habitats and, yet, are rarely considered for protection in land management practices. Logging, road building, livestock grazing, water development, wildfire, and other activities in the vicinity of springs can affect water volume, riparian vegetation, timing of flow, chemical concentrations, solar radiation, sedimentation, and temperature regimes making springs uninhabitable to the species restricted to them.

INTRODUCTION

This study was part of a larger study on factors affecting invertebrate communities of Sierra Nevada cold springs [Erman, 1989; Erman and Erman, 1990]. The objective of the present study was to determine the downstream extension of caddisflies (Trichoptera) living in the near-constant habitats of spring sources.

Springs in the Sierra Nevada have been almost ignored as areas for study and, more importantly, for protection or consideration in land management

practices. Logging, road building, livestock grazing, water development, wildfire, and other impacts in the vicinity of springs can affect water volume, riparian vegetation, timing of flow, chemical concentrations, solar radiation, sedimentation, and temperature regimes making springs uninhabitable to species restricted to them.

Small seeps and trickles, if they are permanent, may contain rare and unusual species [Erman and Erman, 1990]. And, it is permanence and constancy, primarily, that lead to greater species richness and the associated diversity of habitats in these spring sources. The current drought (which began in the winter of 1986/87 and continues to the present, 1991) has provided a test of permanence and constancy in the springs of the original study conducted from 1982 to 1987. The springs of that study were reexamined in 1990, several years after the onset of the current drought [see Erman and Erman, 1992].

Springs were highly individualistic even within a stream basin and differed widely in species richness and composition. Twenty-one springs were studied in three stream basins. Little similarity of Trichoptera assemblages was present among springs (average similarity=23 percent). A total of 36 caddisfly species were collected with as many as 18 species present in a single spring. Nine species were restricted to the constant temperature of spring sources. Trichoptera richness was positively correlated with an intercorrelated complex of calcium, magnesium, specific conductance, alkalinity, and pH. In multiple regression, calcium accounted for 42 percent of the variation in numbers of Trichoptera species, discharge for another 19 percent, and solar radiation for a further 6 percent. The first two variables were positively correlated, and solar radiation was negatively correlated. High concentrations of dissolved ions, a function of deeper springs or longer contact with underlying soil and rock, was an indication of more permanent springs [Erman and Erman, 1990].

The follow-up survey after four years of drought showed that three springs had dried completely. They were three of the most depauperate springs with only five, four, and two caddisfly species present during the original study in 1990. All other springs but one had greatly reduced discharges [see Erman and Erman, 1992].

In addition to Trichoptera, several other invertebrate groups contain species that are restricted to Sierra Nevada cold springs. Amphipods [Holsinger, 1974], triclads [Kenk, 1970; Kenk and Hampton, 1982; Hampton, 1988], and stoneflies [Surdick, 1981; Szczytko and Stewart, 1984] have been studied in Sierra Nevada springs. Springsnails have been surveyed extensively in springs of the Death Valley system [Hershler and Sada, 1987; Hershler, 1989]. That springs are habitats for unusual species has long been known in both the U.S. and Europe [*e.g.*, Nielsen, 1950].

Collections have been made in Sierra Nevada springs by investigators looking for rare or undescribed species, but no study prior to ours [Erman and Erman, 1990] had been conducted to determine how or why springs

differ in species composition and richness. Hampton [1988], however, studied the downstream extension of triclads in the Lake Tahoe Basin and found that some species were restricted to the upper, coldest areas.

If some species are confined to spring sources, the protection of source areas as separate habitats becomes critical to overall diversity of certain groups of invertebrates. The question of downstream extension of species into a more variable habitat, therefore, is central to understanding the requirements of source species. The high number of caddisfly species present in some springs made these areas ideal natural laboratories for exploring species similarity in environmental gradients over short distances.

STUDY AREAS

Two spring systems were selected for this study, Sagehen 4 (SH 4) and Sagehen 6 (SH 6), from 14 springs studied earlier in the Sagehen Creek basin, Nevada County, California (eastern edge of the Sierra Nevada, westernmost edge of the Great Basin) [Erman and Erman, 1990]. They are located near each other, 1.4 km (0.9 mi) apart, and emerge from a north-facing slope. Elevation for the SH 4 spring source is 1,987 m (6,519 ft) and the lower stream is 1,963 m (6,440 ft); SH 6 spring source emerges slightly higher (2,140 m [7,021 ft] elevation) and the stream drops to approximately 1,969 m (6,460 ft). Both springs emerge in heavily shaded areas and were the two darkest springs of the earlier study. SH 4 has a large permanent moss mat at the source and is open all winter, even in deep snow. SH 6, conversely, emerges as a mere trickle though with some permanent moss development.

The physical characteristics of the two streams are much different. The stream of SH 4 enters an exposed peatland with little change in discharge. Temperature warms rapidly downstream in the summer during the daytime but returns to spring source temperature at night. The stream of SH 6 remains shaded throughout its length, flow increases downstream, and temperatures rise only slightly and gradually during daytime in summer. Therefore, although SH 4 originates as a much larger spring than SH 6, the resultant stream is far smaller than SH 6 when it ends by dispersing into the lower part of a peatland. SH 6, on the other hand, becomes one of the larger tributaries of Sagehen Creek.

METHODS

All sampling at the spring sources was done within the same temperature zone, no more than 10 m (33 ft) from the point where water emerged from the ground. Throughout this paper “spring” refers to spring source. Spring stream is used herein to designate areas downstream that vary in temperature by 2°C (3.6°F) or more from the spring source. This distance varies greatly from spring to spring because it depends on water volume, aspect, and cover. Spring system refers to spring source and spring stream combined.

To determine how far from the spring source species extend, I sampled with emergence traps at measured distances downstream. Traps were pyramids, 1 m x 1 m (3.3 ft x 3.3 ft) at the base, with 80 percent alcohol in the collecting jar at the top. They were emptied weekly.

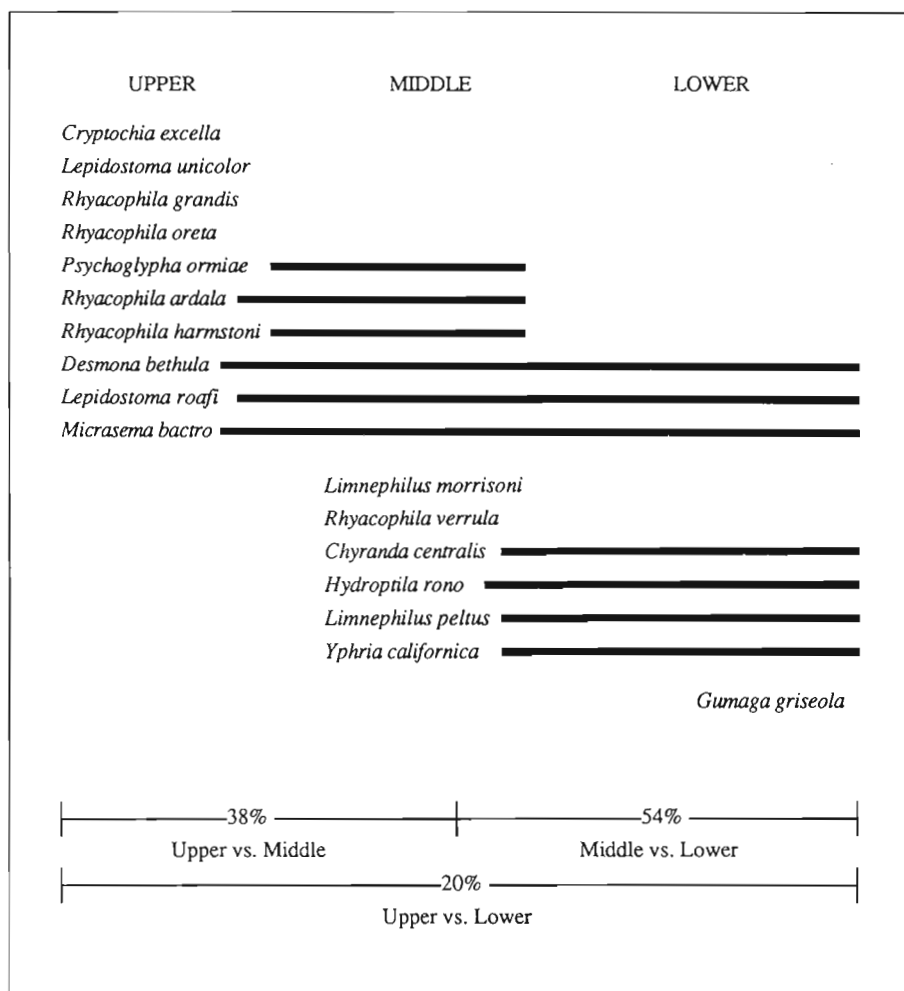
One trap was placed at each of the spring sources. Temperature at SH 4 source was a near-constant 4.6°C (40.3°F) and at SH 6 source, a near-constant 3.6°C (38.5°F). On SH 4 stream, a second trap was placed 270 m (886 ft) downstream (summer temperature range 5° to 9°C [41° to 48.2°F]) and a third, 450 m (1,476 ft) downstream from the source (summer temperature range 5° to 24°C [41° to 75.2°F]). On the SH 6 stream, a second trap was placed 1 km (0.6 mi) downstream and a third was 1.8 km (1.1 mi) downstream (summer temperature maximum 8.5°C [47.3°F]). The three SH 4 traps were operated for one year; the SH 6 traps were operated for a 19-week period in the summer and fall. An earlier study on all Trichoptera in the Sagehen Creek basin [Erman, 1989] had shown that most species would be caught in that 19-week period.

To make similarity comparisons between locations based on species composition, I used Jaccard's index, $a/a+b+c$, where a is the number of species in common between any two sites, b is the number of species in site b only, and c is the number of species in site c only [Pielou, 1984]. The lower the number, the lower the similarity between two sites.

RESULTS AND DISCUSSION

The downstream extensions of Trichoptera species present in the spring sources are shown in Figures 1 and 2. Seventeen species were collected in the SH 4 system over a year; 20 species were collected in the SH 6 system over the 19 weeks of greatest caddisfly emergence. Similarities were low and nearly identical between the sources and the lowest stations in the two systems, with a 20 percent similarity between SH 4 spring source and its lower stream and a 22 percent similarity between SH 6 spring source and its lower stream. Of the 17 species in the SH 4 system, only 3 were found at all three stations

Figure 1. Trichoptera species similarities among three emergence traps on Sagehen 4 cold-spring system—the source (Upper), 270 m (886 ft) downstream (Middle), and 450 m (1,476 ft) downstream (Lower)—from 13 July 1980 to 3 July 1981. Extended lines indicate species present at more than one station.



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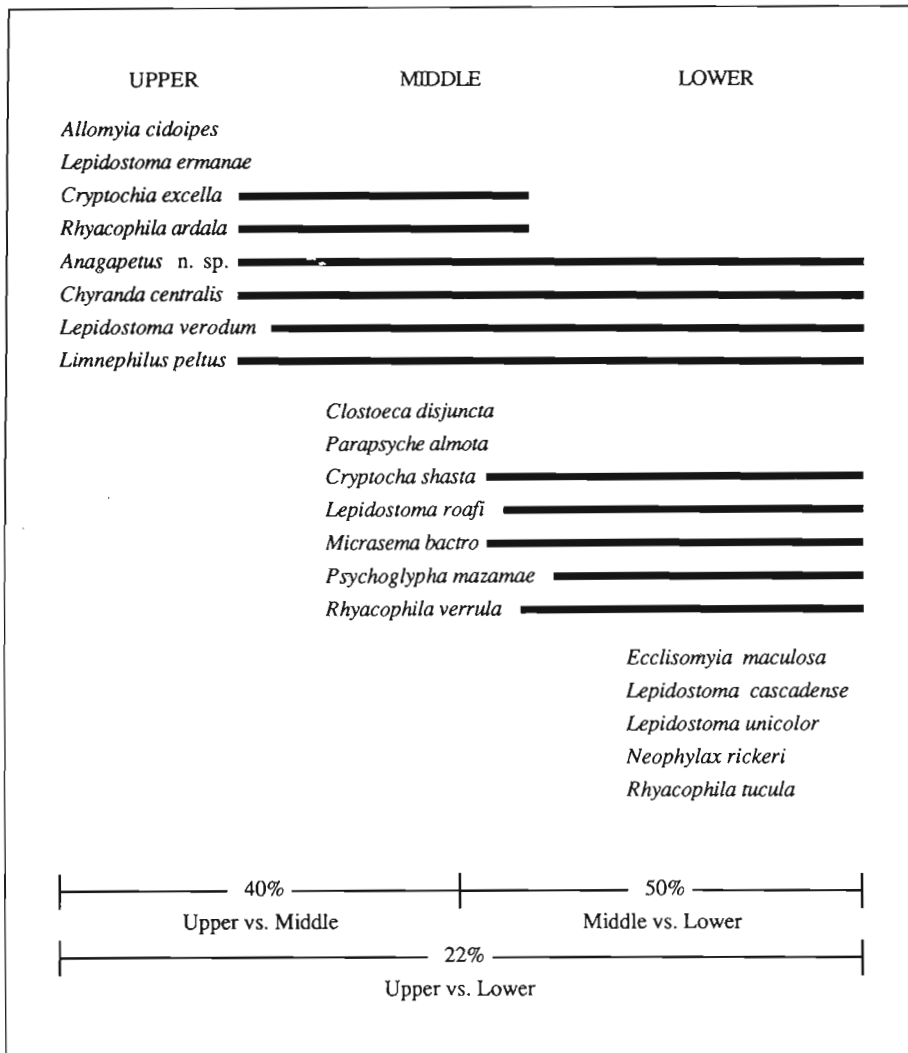


Figure 2. Trichoptera species similarities among three emergence traps on Sagehen 6 cold-spring system—the source (Upper), 1 km (0.6 mi) downstream (Middle), and 1.8 km (1.1 mi) downstream (Lower)—from 26 June 1984 to 30 October 1984. Extended lines indicate species present at more than one station.

year period, these assumptions were considered valid. However, the longer the period a trap is operated, the more likely it is to collect an occasional, incidental species. For example, 5 additional species (13 total) were eventually collected at the SH 6 source (designated SH 6 Upper in Figure 2) over several years. Further, as the habitat becomes more diverse (e.g., the stream becomes larger), the less well a single trap can describe species present (N. A. Erman, unpub. data). In the previous larger study, other sampling and collecting techniques were used to corroborate emergence trap data.

Species present in the two spring systems were substantially different. Eight species were common to both systems. Similarity between the two was only 28 percent. Such low similarity would be expected in spring streams as different as these, and the primary objective of this study was not to compare the two streams, nor was sampling effort equal. However, given the close proximity of the sites, comparisons are logically made. The large differences in light and temperature downstream are reflected in species present. Two species highly tolerant of, and restricted to, areas

of SH 4; and of the 20 species in the SH 6 system, 4 were found at all three stations (Figures 1 and 2). Most species, then, were replaced from the source to the end of the spring stream.

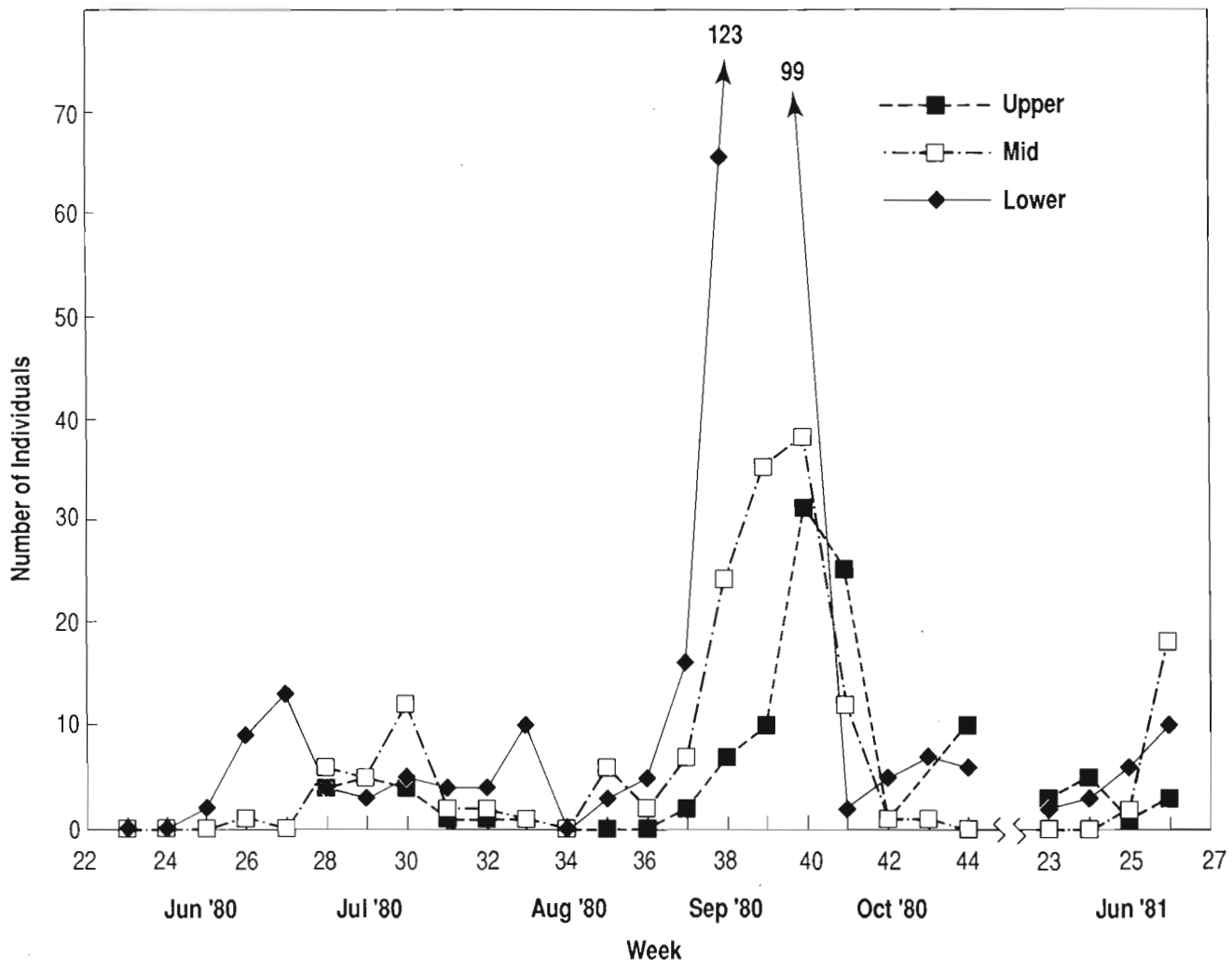
The number of Trichoptera species increased downstream on SH 4 from 10 at the source to 12 at the middle station and then decreased to 8 species at the lowest station where summer temperature fluctuation was large. On SH 6, where maximum temperatures were never very high, species numbers increased steadily downstream from 8 to 13 to 14.

This sampling regime assumes that there is little difference in species present at a site from year to year and that one trap will adequately describe the most prominent species present. Based on nearly continuous sampling at a few spring stream sites over a five-

of warm temperatures, *Hydroptila rono* and *Gumaga griseola*, were abundant in the SH 4 downstream areas. The presence of these two species can also be an indicator of temporary water. One species, *Lepidostoma unicolor*, was present at both the uppermost SH 4 station and the lowest SH 6 station. This result has no special significance because this species has wide tolerance and was found during the larger study over a range of temperatures.

Total adult emergence peaked at different times in different locations depending on life cycles of species present (Figures 3 and 4). Emergence peaks in SH 4, in weeks 39 to 40, are due to different species composition in the upper station and the two lower stations. The autumn emergence of *Rhyacophila ardala* accounts for the maximum peak of 31 individuals in the upper spring source station in week 40 (Figure 3); the emergence of *Desmona bethula* explains the highs at the middle (38 individuals, week 40) and lower (123 individuals, week 39; 99 individuals, week 40) stations. Maximum numbers of emerging caddisflies, therefore, were

Figure 3. Number of Trichoptera adults emerging weekly in a 1 m x 1 m (3.3 ft x 3.3 ft) pyramid trap during the summer and fall in Sagehen 4 cold-spring system at the source (Upper), 270 m (886 ft) downstream (Middle), and 450 m (1,476 ft) downstream (Lower), 1980, 1981.



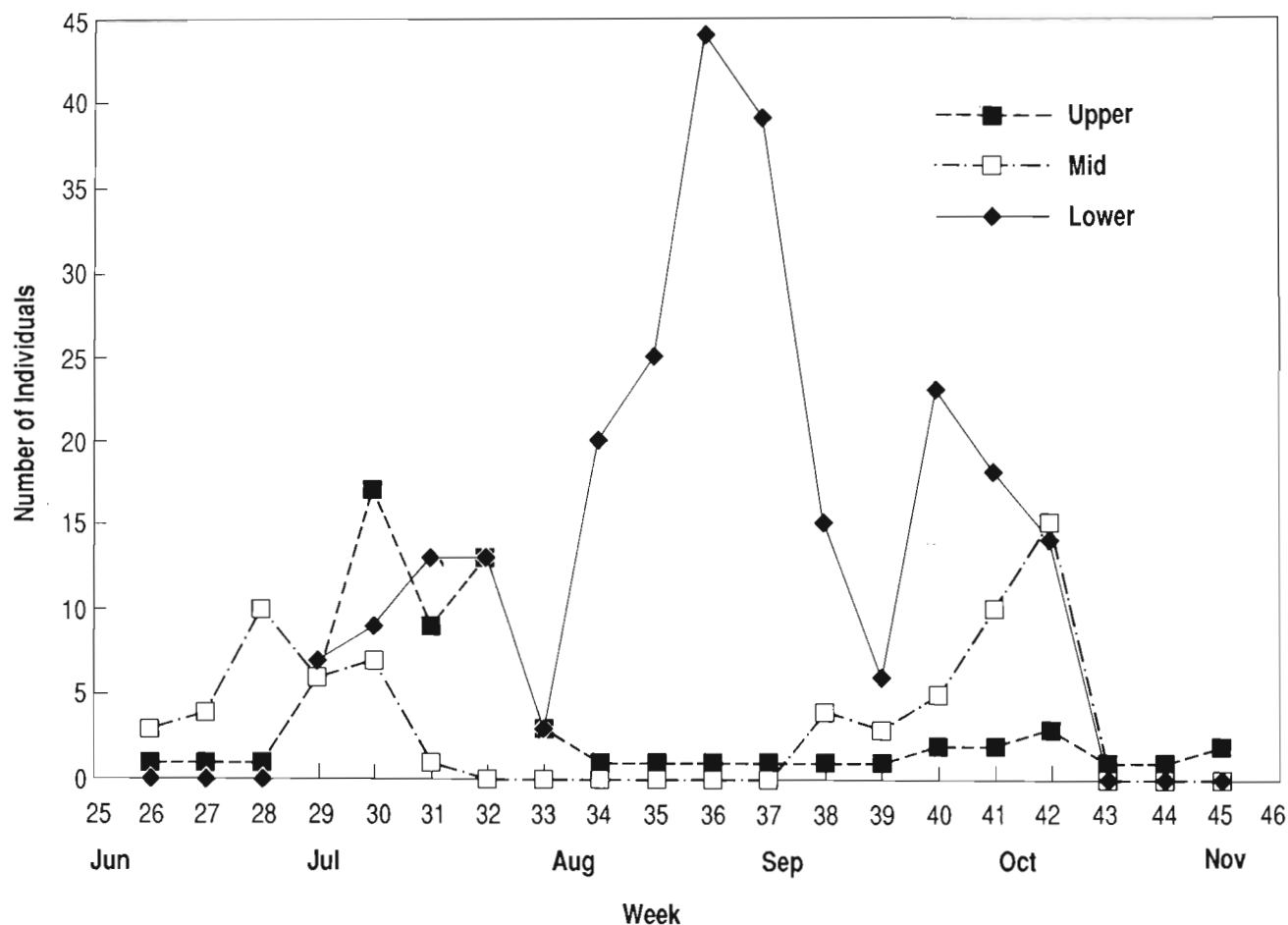


Figure 4. Number of Trichoptera adults emerging weekly in a 1 m X 1m (3.3 ft x 3.3 ft) pyramid trap during the summer and fall in Sagehen 6 cold-spring system at the source (Upper), 1 km (0.6 mi) downstream (Middle), and 1.8 km (1.1 mi) downstream (Lower), 1984.

four times higher at the lowest station than at the source. Further, *D. bethula* is a larger species than *R. ardala*.

At SH 6 the peaks at the lowest station during week 36 (Figure 4) are explained by the combined emergences of several species; the three most abundant were *Lepidostoma roafi*, *Rhyacophila verrula*, and *Rhyacophila tucula* (44 individuals). The small emergence peak at the upper station in July was due to *Lepidostoma ermanae* (17 individuals), a species known only from that spring source and restricted to the upper, coldest seep area. Maximum abundances at the lowest station here were 2.5 times higher than at the source; and, again, the species at the lower station were considerably larger in size. In general, species at cold spring sources were small; larger-sized species, though present, were not abundant.

Spring source species may exhibit different emergence patterns from species farther downstream, emerging throughout the year or during cooler months [Erman and Erman, 1990]. Numbers are not high and emergences may be prolonged in the sources. Farther downstream, species reach far higher abundances and emergence periods are shorter.

Results of this study indicate that as stream size and habitat diversity increase downstream, as in SH 6, species richness and abundance increase. However, if environmental conditions become more extreme as

in lower SH 4 (high maximum temperature and large daily temperature fluctuations), they may limit species richness and yet cause high production of those species adapted to such conditions.

Several other researchers studying one spring stream [e.g., Minshall, 1968; Ward and Dufford, 1979] have found that species richness increases downstream. It is important to remember, however, that species downstream commonly are not the same as those living in spring sources.

In conclusion, spring sources are habitats for rare and unique species confined to constant conditions, either because the species are relicts of a different climatic period or because they have more recently evolved. Cold spring sources contribute significantly to the biodiversity of Sierra Nevada aquatic habitats. Effort should be given to the study, protection, and management of cold springs.

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REFERENCES

- Erman, N. A., Species composition, emergence, and habitat preferences of Trichoptera of the Sagehen Creek Basin, California, U.S.A., *Great Basin Nat.*, 49(2), 186-197, 1989.
- Erman, N. A. and D. C. Erman, Biogeography of caddisfly (Trichoptera) assemblages in cold springs of the Sierra Nevada (California, USA), *California Water Resources Center, Contribution 200*, ISSN 0575-4941, 29 pp., 1990.
- Erman, N. A. and D. C. Erman, Physical/chemical profiles of Sierra Nevada cold springs before and during drought, in *The History of Water: Eastern Sierra Nevada, Owens Valley, White-Inyo Mountains*, edited by C. A. Hall, Jr., V. Doyle-Jones, and B. Widawski, pp. 428-439, University of California, White Mountain Research Station, *Symp. Vol. 4*, 1992.
- Hampton, A. M., Altitudinal range and habitat of triclads in streams of the Lake Tahoe Basin, *Am. Mid. Nat.*, 120(2), 302-312, 1988.
- Hershler, R., Springsnails (Gastropoda: Hydrobiidae) of Owens and Amargosa River (exclusive of Ash Meadows drainages, Death Valley System, California-Nevada, *Proc. Biol. Soc. Wash.*, 102(1), 176-248, 1989.
- Hershler, R. and D. W. Sada, Springsnails (Gastropoda: Hydrobiidae) of Ash Meadows, Amargosa basin, California-Nevada, *Proc. Biol. Soc. Wash.*, 100(4), 776-843, 1987.
- Holsinger, J. R., Systematics of the subterranean amphipod genus *Stygobromus* (Gammaridae), Part I: Species of the western United States, *Smithsonian Contributions in Zoology*, 160, 63 pp., 1974.
- Kenk, R., Freshwater triclads (Turbellaria) of North America. II. New or little known species of *Phagocata*, *Proc. Biol. Soc. Wash.*, 83(2), 13-22, 1970.
- Kenk, R. and A. M. Hampton, Freshwater triclads (Turbellaria) of North America XIII. *Polycelis monticola*, new species from the Sierra Nevada Range in California, *Proc. Biol. Soc. Wash.*, 95, 567-570, 1982.
- Minshall, G. W., Community dynamics of the benthic fauna in a woodland springbrook, *Hydrobiologia*, 32, 305-339, 1968.

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Nielsen, A., On the zoogeography of springs, *Hydrobiologia*, 2, 313-320, 1950.

Pielou, E. C., *The interpretation of ecological data: A primer on classification and ordination*, Wiley, New York, 263 pp., 1984.

Surdick, R. F., New Nearctic Chloroperlidae (Plecoptera), *Great Basin Nat.*, 41(3), 349-359, 1981.

Szczytko, S. W. and K. W. Stewart,

Descriptions of *Calliperla* Banks, *Rickera* Jewett, and two new western Nearctic *Isoperla* species (Plecoptera: Perlodidae), *An. Ent. Soc. Am.*, 77(3), 251-263, 1984.

Ward, J. V. and R. G. Dufford, Longitudinal and seasonal distribution of macroinvertebrates and epilithic algae in a Colorado springbrook-pond system, *Archiv für Hydrobiologie*, 86 (3), 284-321, 1979.