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Distribution and Habitat of the Southern Two-Lined Salamander, *Eurycea cirrigera*, in Will County, Illinois: Implications For Population Management and Monitoring

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The southern two-lined salamander (*Eurycea cirrigera*) was found to occur at numerous localities within the Kankakee River State Park in Will County, Illinois. The species is restricted to small drainages within the Kankakee River valley that have flow consisting of groundwater that discharges at seeps or springs at or within the valley bluff. Cooler water temperatures and possibly other conditions that are associated with water derived from seep or spring sources may be important factors in determining salamander abundance. This is particularly relevant to larval habitat. These observations suggest that the spring or seep-fed larval habitat may be the primary limiting factor that may explain why the distribution of *E. cirrigera* is restricted in northern Illinois. It is proposed, that from a conservation management perspective, individual drainages or "spring runs" may best be considered as subpopulations of a metapopulation that are vulnerable to both deterministic and stochastic extinction. Educational field trips conducted by faculty of Chicago State University in 1996 and 1997 have provided preliminary data of relative population size and environmental conditions at some sites. With further refinement and standardization, these census techniques may have high potential for long-term monitoring to assess population status or detect decline. The inventory and census strategies that were used may also be adapted for use with other streamside salamander species that have similar life history traits and habitat requirements.

INDEX DESCRIPTORS: *Eurycea cirrigera*, habitat, distribution, amphibian inventory, amphibian monitoring

The ability to protect, manage and maintain populations of rare or endangered species requires a detailed understanding of an organism's relationship to its environment and the status of its populations (Primack 1993). A thorough knowledge of the natural history and autecology of the species can allow land managers to identify factors that increase risk of extinction and permit effective efforts to maintain viable populations (Primack 1993). Thus, basic information including life history, behavior, distribution and habitat are the foundation from which sound management and conservation practices are built upon. Also, the key to determine status is to census species and monitor populations over time. Such long-term records are vital to distinguish short-term fluctuations from actual change in population numbers due to environmental change or human disturbance (Primack 1993).

The two-lined salamander (*Eurycea cirrigera*) is a forest-dependent species that is widely distributed throughout the eastern United States. The western edge of its range truncates abruptly at the margin of the tallgrass prairie, just inside the eastern border of Illinois (Mierzwa 1989). The species is presently known to occur in Illinois in three areas that are isolated from the main range. These areas are extreme southern Illinois in or near Pope county, east-central Illinois within tributary watersheds of the upper Wabash River, and northeastern Illinois along the Kankakee River in Will and Kankakee Counties (Mierzwa 1989).

Prior to 1989, only three records of *E. cirrigera* were known from northeastern Illinois along the Kankakee River. The first dated from 1932, and was cited as Custer Park in Will County (Mierzwa 1989). The second dated from 1953 along Rock Creek in the Kankakee County portion of Kankakee River State Park (KRSP, Mierzwa 1989). In 1988, the species was found along Rayns Creek in the Will County portion of KRSP on the north side of the Kankakee River (Mierzwa 1989). The Custer Park record originally found by Norman Bergendahl was subsequently determined by Mierzwa in 1988–89 to have occurred near the west boundary of the KRSP along the south side of the Kankakee River (Mierzwa, pers. comm.).

In 1994 and 1995, the primary author conducted field surveys for *E. cirrigera* within the Will County portion of KRSP. This paper presents new localities of *E. cirrigera,* together with additional description of habitat which are especially relevant to larvae. We also provide results of census and pilot monitoring research that was gathered during two Chicago State University student educational field trips held in 1996 and 1997. This information may help to explain why the species distribution is so restricted in Illinois and may provide a baseline from which future monitoring efforts may be compared.

METHODS

Population Inventories

Inventory fieldwork to identify and map specific locations of *E. cirrigera* populations was conducted by the primary author between 12 and 20 September 1994 and on 01 July 1995. U.S. Geological survey maps were used to identify drainages that dissected the valley bluff within the immediate vicinity of the Will County portions of KRSP. Selected drainage or creek channels were also inventoried west of KRSP to slightly northwest of the City of Wilmington to determine if *E. cirrigera* occurred in other areas outside the KRSP.

Visual encounter survey (VES, Crump and Scott 1994) was used to identify presence-absence of both adult and larva *E. cirrigera.* Natural cover objects were lifted gently and the undersides visually checked for salamanders or larvae. These included limestone cobbles and flagstones within stream or drainage channels, leaf debris, bark,

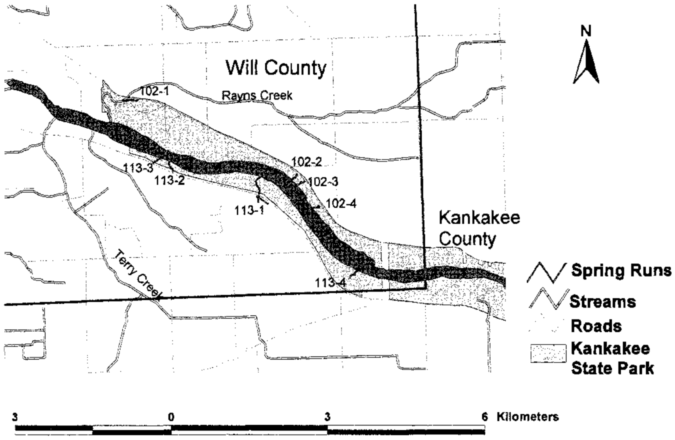

Fig. 1. Locations of spring run study sites within Kanakakee River State Park, Will County, Illinois. The light shading delimits the area of the State Park. Dark shading indicates the channel of the Kanakakee River. The bold line shows the Will/Kanakakee County boundary. Numbers indicate locations of individual spring run study sites. Spring runs are small drainage tributaries that begin at the river valley bluff and are fed by groundwater discharge from seeps or springs. The number 102 indicates those sites that are on the north side of the Kanakakee River and accessible from Route 102, whereas 113 indicates spring runs on the south side of the river accessible from Route 113. Only the Will County portion of Kanakakee State Park was included in the study.

small logs and other debris left by high-water along the bank. Time was recorded for VES conducted at some sites and results calculated as the total number of adults or larvae observed per search unit per observer. Quantified results were expressed in number/minute/observer to compare abundance among sites, but no statistical inferences were made because replicated samples were not obtained.

In 1994 at the Rayns Creek site (102–1; Fig. 1) VES included a combination of area and time-constrained techniques (Fellers 1997). This was believed to be the best approach to survey this site because the main channel of Rayns Creek (102–1C) was a six to nine meter wide, low-gradient, perennial creek. Cover objects within the creek were discontinuous and concentrated at widely separated sediment/cobble bars. VES was conducted and time recorded until all accessible cover objects were lifted (area constrained). When this was accomplished, time was stopped and total number of adults and larvae recorded. Then, the entire process would be repeated after locating the next cobble bar in a downstream direction. Since cobble bars varied in size, search time at each cobble bar varied from three to thirty minutes (unconstrained time recorded). This combination area/recorded time VES technique was also used to inventory the spring-fed tributary or "run" at the Rayns Creek site (102–1S). This small spring-fed drainage was less than one meter wide and the total length of channel providing suitable cover was only about 50 m.

In 1995, typical time-constrained VES (Crump and Scott 1994, Fellers 1997) was used at four other spring-fed tributaries; three on the north side of the Kankakee River 3.66–4.27 km southeast of the Rayns Creek Site (102–2, 102–3, 102–4; Fig. 1) and one 5.49 km southeast on the south side of the river (113–4). Twenty minute time-constrained search periods were conducted at each of these sites. This approach was preferred because all of these spring-fed tributaries were relatively narrow (<4 m) and limestone cover objects were continuous throughout the channel. Thus, the easiest means to inventory the site was to begin at the upstream groundwater discharge point, and search under available cover objects (limestone slabs and cobbles) moving in a downstream direction until the pre-determined period of time had elapsed. The number of adults and larvae observed were recorded and the results were quantified as described above.

Educational Field Trips

Two of us (TB and ELP) led educational fieldtrips in 1996 and 1997. The overall goal of the Chicago State University fieldtrips was to provide students with hands-on experience in field ecology. We also planned to use the fieldtrips to begin to census populations at selected sites, gather environmental data that could be used to further describe and assess habitat, develop and refine census techniques, and explore the potential for these techniques to be used for future population monitoring.

The educational fieldtrips used the same basic VES techniques described above to census adults and larvae at each study site. However, census data were gathered and quantified differently from that used for population inventories in 1994–95. At each study site, student teams were formed, channel sections marked off, and time-constrained searches conducted. The preferred sampling protocol included a team of three student observers, a 10-m long channel segment, and a 20-min census period. Each team recorded the number of larvae and adults found in their section. The mean number of adults and larva observed were calculated for each study site.

Not all samples met the preferred sampling protocol because student numbers varied and it was not always possible to create teams of three observers, and all fieldwork needed to be completed within the time constraints of a 1-d field trip. When a team included two observers, channel sections were shortened to five meters in length. Also, as the day progressed, some census periods were shortened to 10 min so that fieldwork could be completed at all study sites that were originally planned to be visited. In either case, 1996 and 1997 counts were adjusted or standardized as total number of adults or larvae per 20 min/10 m per three observers.

Environmental conditions were also measured at each channel section. These included water temperature (°C), pH, light (lux) and conductivity (ppm). Portable pocket testers were used to measure pH, conductivity and light level.

Four sites were initially studied during the educational field trip on 14 September 1996 (102–1C, 102–1S, 102–2, 102–3; Fig. 1). The habitat of these sites were quite varied and included a moderate-size, permanently flowing stream known as Rayns Creek (102–1C), a small seepage-fed drainage with dolomite cobbles overlying a sand substrate that drains into the main channel of Rayns Creek (102–1S), and two seepage-fed tributaries that dissect dolomite bedrock near the Kankakee River Valley bluff east of Rayns Creek (102–2 and 102–3; Fig. 1). Sites 102–2 and 102–3 were most similar to one another and consisted of small seepage-fed channels within "mini canyons" of dolomite bedrock. The channel bottoms at these two sites were covered with extensive amount of dolomite cobbles. Thus, the primary educational objective for the 1996 field trip was to have students determine if salamander numbers were significantly different among the four sites. We also desired them to independently assess if environmental conditions were significantly different among the sites.

Single classification analysis of variance (1-way ANOVA) was used to separately test whether adult number, larva number, water temperature, light level and conductivity were significantly different among sites. Newman-Keuls multiple comparisons were made to indicate which of the four sites were significantly different from one another at a 0.05 significance level. A nonparametric Kruskal-Wallis test (Siegel 1956) was used to test for significant difference in pH among sites. The Kruskal-Wallis test is a nonparametric test used

Table 1. Visual Encounter Survey results for 1994 and 1995 inventories of *Eurycea cirrigera* at Sites 102-1, 102-2, 102-3, 102-4 and 113-4 at Kankakee River State Park, Will County, Illinois.

		Adults		Larvae	
Date	Site	Total	#/min	Total	#/min
09/15/94	102-1C	25	0.13	0	0
	102-1S	0	0	29	0.52
07/01/95	102-2	8	0.40	24	1.20
	102-3	2	0.10	5	0.25
	102-4	5	0.25	1	0.05
	113-4	11	0.55	7	0.35

to decide whether k independent samples are from different populations (Siegel 1956).

The following year the educational field trip was held on 27 September 1997 and research interest was focused on the two most similar sites, 102–2 and 102–3. This time, we desired for the students to consider the effects of two factors simultaneously (site and year) by comparing data on salamander numbers and environmental conditions collected during the 1997 field trip with that obtained by students in 1996. Therefore, a two-way classification analysis of variance (2-way ANOVA) was used to test if adult number, larva number, water temperature, light level and conductivity were significantly different considering site (102–2 vs. 102–3) and year (1996 vs. 1997) as variables. Comparison between years for pH was not made, as the extensive presence of dolomite and subsequent buffering of pH afforded were no longer expected to yield significant results between years. It was still desirable, however, to have students measure and analyze this variable to gain practical field experience. Therefore, the nonparametric Mann-Whitney U test was used to test for difference in pH between sites 102–2 and 102–3 for 1997 only. The Mann-Whitney test is used to decide whether two independent groups are from the same population (Siegel 1956).

RESULTS

Population Inventories

The results of the 1994 and 1995 inventories revealed that with the exception of Rayns Creek, *E cirrigera* are restricted to small, seepage or spring fed drainages that dissect the river valley bluff throughout the KRSP (Mauger 1995, 1996; Fig. 1). Both adults and larvae were documented at eight sites, four on the north and four on the south side of the Kankakee River (Mauger 1995, 1996; Fig. 1). *E. cirrigera* were not found at other drainages or creeks such as Terry Creek, Horse Creek or other un-named tributaries to the west of the KRSP.

On 15 September 1994, VES counts were conducted at the Rayns Creek site, including the main channel section (102–1 C, Fig. 1) and a small spring and seepage fed drainage that emptied into the main channel of Rayns Creek in close proximity to Route 102 (102–1S, Mauger 1995). Seven cobble bars within the main channel were surveyed for a total search time of 191 min (95.5 min for each of two observers). About 50 m of the spring run channel were surveyed and total search time was 56 min (28 min for each of two observers). The entire spring run channel with water flow was included. On 15 September 1994, many adults were found within the main channel of Rayns Creek (102–1C; Fig. 1), but no larvae were found (Table 1). Conversely, many larvae were observed within the spring run (102–1S), but no adults were found (Table 1).

This apparent disparity should be viewed relative to the availability of cover objects. Most cover objects in the spring-fed drainage were submerged and there were few terrestrial cover objects present to search for adults. However, five adults were found on a return visit on 16 September 1994 under leaf litter or scattered cobbles in a non-flowing section of the spring run channel a few meters upstream of the groundwater discharge point. In contrast, no larvae were found within the main channel of Rayns Creek during the 15 September VES count, nor on the 16 September return visit.

On 01 July 1995 VES was conducted at four different sites (102–2, 102–3, 102–4 and 113–4; Fig. 1, Mauger 1996). All of these sites are smaller drainages with their perennial source of flow derived from seep and/or spring discharge. Twenty-minute time-constrained VES (one observer only) was used at all four sites. Both adults and larvae were found at all of these sites (Mauger 1996). However, encounter rates varied widely, suggesting that population numbers may vary among the sites (Mauger 1996). Sites 102–2 and 113–4 showed the highest encounter rates for both adults and larvae (Table 1). In contrast, sites 102–3 and 102–4 showed the lowest numbers of both adults and larva (Table 1). Site 102–4 had the lowest larval encounter rate, in contrast to substantially higher adult rate (Table 1).

Observation of larval sizes suggested that different aged cohorts may be present. For example, many larvae had relatively small body size, usually less than 20 mm in total length. However, larger larvae far in excess of 20 mm were encountered, and some of these were in pre- or near metamorphic state. These pre-metamorphic specimens showed body morphology and coloration that closely resembled the adults. External gills were still present, but were greatly reduced. These observations suggest the presence of different cohorts indicative of a prolonged or delayed period of larval development that may span 2 or 3 yrs. A prolonged period of larval development over several years has been noted in other published accounts of larval life history of *Eurycea* species (Ryan 1998, Bruce 1982a, Bruce 1982b).

1996 Chicago State University Educational Field Trip

There was a significant difference in adult abundance in 1996 (Table 2, $P = 0.0206$). No adults were found at either Rayns Creek sites 102–1C or 102-S. A significantly higher number of adults were found at site 102–3 compared to the remaining three sites (Newman-Keuls multiple comparisons, $P < 0.05$). Although there was a much lower number of adults found at site 102–2 compared to 102–3, the means were not significantly different (Newman-Keuls, $P > 0.05$).

In contrast, no significant difference was observed in abundance of larvae (Table 2, $P = 0.3398$). Site 102–3 had the highest mean number of larvae compared to somewhat lower, but more equitable numbers for sites 102–1S and 102–2. However, only one larva was found at site 102–1C, which was within the main channel of Rayns Creek.

It is important to note that only one larva was found out of a total of two samples taken at the Rayns Creek main channel site. The inclusion of this larva in this data set reflects a bias in sampling technique because census counts conducted by the students did not distinguish between two distinct flows at the confluence zone of the seep and main channels. For example, at the confluence zone, the seep channel enters and flows along the east side of a cobble bar within the main channel of Rayns Creek before merging with main channel flow slightly downstream. The one larva occurred in the seep flow within this confluence zone.

There was a significant difference in water temperature (Table 2, $P < 0.001$). The highest water temperature occurred within the main channel of Rayns Creek (102–1C), and the mean was significantly different from all other sites (Newman-Keuls, $P < 0.05$). Conversely, the seep channel (102–1S) had the lowest water temper-

Table 2. Statistical comparisons of *Eurycea cirrigera* numbers and environmental conditions between sites 102-1C, 102-1S, 102-2, and 102-3 at Kankakee River State Park, Will County, Illinois. Presented here are the results of 1996 Chicago State University educational field trip. Listed are means, P-, and F-values, and degrees of freedom (df) of 1-way ANOVAs and (for pH comparisons only) medians, P-, and H-values, and degrees of freedom for a nonparametric Kruskal-Wallis test. Significant comparisons at the level of P ≤ 0.05 are indicated by asterisks (*).

	102-1C	102-1S	102-2	102-3	P	F/H	df
Adults	0.00	0.00	3.68	7.15	0.0206*	5.84	8
Larvae	0.50	3.00	1.83	5.40	0.3398	1.30	8
H_2O Temperature	17.2	12.5	14.0	14.3	<0.001*	59.03	8
Light Level	2850	2050	11025	1675	0.6824	0.52	8
Conductivity	700	600	745	705	0.3733	1.19	8
pH	8.30	7.70	7.80	7.95	0.0860	6.60	3

Table 3. Statistical comparisons of *Eurycea cirrigera* numbers and environmental conditions between sites 102-2 and 102-3 for 1996 and 1997 at Kankakee River State Park, Will County, Illinois. Presented here are the results of 1997 Chicago State University educational field trip. Listed are means and P-values for site comparisons, year comparisons, and site and year comparisons of 2-way ANOVAs and (for pH comparisons only) Mann-Whitney U statistics. Significant comparisons at the level of P ≤ 0.05 are indicated by asterisks (*).

	96 102-2	97 102-2	96 102-3	97 102-3	Site P	Year P	Site/ Year P
Adults	3.68	3.33	7.15	7.20	0.0518	0.9335	0.9108
Larva	1.84	4.33	5.40	14.67	0.0118*	0.0277*	0.1784
H_2O Temperature	14.0	16.3	14.3	15.9	0.9923	0.0036*	0.5403
Light Level	11025	3184	1675	3184	0.0454*	0.1413	0.1486
Conductivity	745.0	562.8	705.0	605.7	0.9607	0.0001*	0.1592
pH	—	7.50	—	7.70	0.0850	NA	NA

ature, and the mean was significantly different from all other sites (Newman-Keuls, P < 0.05). Both sites 102–2 and 102–3 were significantly cooler than the main channel of Rayns Creek (102–1C, Newman-Keuls, P < 0.05). However, sites 102–2 and 102–3 were not significantly different from one another (Newman-Keuls, P > 0.05). All three sites with the coolest water temperature have flow derived from discharge of groundwater at spring or seep heads.

There was no significant difference in light level (Table 2, P = 0.6824). The higher mean at site 102–2 was due to a few gaps in the canopy that resulted in a few extremely high light level readings that biased the mean upward.

There was also no significant difference in mean conductivity or pH (Table 2, P = 0.3733 and P = 0.081, respectively). All sites with flow derived from springs or seeps (102–1S, 102–2, 102–3) showed very similar pH. The highest pH observed was in the main channel of Rayns Creek (102–1C).

1997 Chicago State University Educational Field Trip

There was no significant difference in abundance of adults between sites 102–2 and 102–3 (Table 3, P = 0.0518). Also, there was no significant difference across years or in site-year interaction. However, the mean numbers of adults at Site 102–3 were more than twice that of site 102–2 in both 1996 and 1997.

There was a significant difference in the abundance of larvae between sites 102–2 and 102–3 (Table 3, P = 0.0118). Site 102–3 had significantly greater numbers of larvae in both 1996 and 1997. There was also a significant difference between years with both sites showing substantial increase from 1996 to 1997 (Table 3, P = 0.0277). There was no significant site-year interaction (Table 3, P = 0.1784).

No significant difference in water temperature was found between sites 102–2 and 102–3 (Table 3, P = 0.9923). There was a significant difference between years with both sites showing warmer water temperature in 1997 (Table 3, P = 0.0036). The actual mean difference was a few degrees warmer in 1997 (ca. 16°C) compared to 1996 (ca. 14°C). These differences were not unusual and could easily result year to year depending upon the weather patterns that prevail prior to and during the period that measurements are taken.

A significant difference in light level was found between the two sites (Table 3, P = 0.0454). The difference is considered a statistical artifact and attributed to the extreme variability in light level readings that occurred at site 102–2 in 1996 when some readings were influenced by highly localized "canopy gaps" (see 1996 results section). Note that in 1997, mean light level at site 102–2 is substantially lower and much more comparable to those for site 102–3.

There was no significant difference in conductivity of water between sites 102–2 and 102–3 (Table 3, P = 0.9607). However, there was a highly significant difference between years (Table 3, P = 0.0001). There was a substantial decrease in conductivity at both sites in 1997. There was no significant site-year interaction (Table 3, P = 0.1592).

As expected, there was no significant difference in pH between sites 102–2 and 102–3 (Table 3, P = 0.085). A significant difference in pH would not be expected, because both sites have flow derived from groundwater discharge and exposed dolomite is a prominent feature at both sites.

DISCUSSION

Population Occurrences and Habitat Conditions

Nearly all of the drainages at which *E. cirrigera* populations occur are fed by groundwater discharge from seeps or springs that occur at or within the valley bluff (herein referred to as "seep runs"). The valley bluff is comprised of shallow sand deposits overlying dolomite bedrock. Seep runs result from water that percolates downward through sand deposits and flows laterally when it reaches underlying bedrock. Discharge occurs in areas where this interface is exposed along the valley bluff, often flowing through small ravines and canyons that dissect the valley bluff.

Flow in seep runs consist of clear, cool water flowing over dolomite cobbles embedded in or resting upon a fine, sandy substrate. In areas where drainages dissect dolomite bedrock, miniature canyons have formed and the channel bottom is heavily strewn with cobbles and flagstones. At a few sites, water is sometimes reduced to a partial surface flow that is mostly confined beneath the layer of cobbles. At times, the flow is not evident at the surface, and larvae are found only within scattered pools and puddles. These observations suggest substantial variability in groundwater hydrology and flow may exist among sites, over the course of the season, or from year to year.

At the Rayns Creek site, adults were fairly easy to find under cobbles within the channel, or under leaf litter, small logs or other debris that is stranded along the banks. Adults were found within or in close proximity to the main channel at distances up to 0.4 mile (0.64 km) south of Route 102. However, larvae at the Rayns Creek site were only found in the narrow seep run that parallels a sand dune ridge close to Route 102 (102–1S). Larvae are readily found within this seep run up to and within the confluence zone within the main channel of Rayns Creek. All other sites within the KRSP where adults and larvae have been found consist of seep runs.

It is apparent that a relationship exists between the occurrence of *E. cirrigera* larvae and the presence of a permanent or semi-permanent flow of groundwater that emanates from seep or spring discharge at the valley bluff. Freshwater amphipods (*Gammarus* sp.) also occur at many locations where *E. cirrigera* larvae are found. At some sites, *Gammarus* appears to be the dominant freshwater macroinvertebrate species present. The freshwater Amphipod genus *Gammarus* occurs in a wide variety of unpolluted lakes, ponds, streams, brooks and subterranean waters (Pennak 1978). These organisms are considered cold water dependent, adapted to the benthos and usually require high dissolved oxygen levels (Pennak 1978). *Gammarus* may constitute an important dietary item for both *E. cirrigera* adults and larvae, and their distribution is likewise constrained by the availability of cold, well-oxygenated water.

The dependence of larvae upon groundwater discharge is further supported by water temperature data. No significant differences in water temperature have been found at sites with normal flow of groundwater emanating from seep or springs at the drainage head. Both *E. cirrigera* adults and larvae occur at all of these sites. The only site at which larvae have not been found is within the main channel of Rayns Creek. Normal flow at this site is primarily derived from a much larger watershed and from sources outside of and far upstream of the KRSP. Fig. 2 shows a water temperature profile that was recorded at the spring run at the Rayns Creek site on 16 September 1994. This profile indicates a striking disparity in water temperature between the seep run (102–1S, 11.4–17.6°C) and the main channel (102–1C, 23.4–24.0°C; Mauger 1995). Water temperature gradually increased in the seep run from 11.4°C at the head, to 13.8–16.0°C in the midsection, to a high of 17.0–17.6°C at the confluence zone within the main channel of Rayns Creek (Fig. 2).

The co-occurrence of *E. cirrigera* larva and *Gammarus* in conjunction with apparently lower water temperature of seep runs suggest that cool temperature and possibly other characteristics typical of water derived from seeps or springs is an important requirement for larval habitat (Mauger 1995). A strong dependence upon groundwater derived from springs is known to exist for other *Eurycea* species, especially paedomorphic species that occur in the Edwards Plateau region of central Texas (Bruce 1976, Bruce 1982a, Bowles 1995). Thus, it may be that populations of *E. cirrigera* within individual drainages in the KRSP are dependent upon a suite of larval habitat requirements that must be maintained over a period of 2–3 yrs in order for successful recruitment to occur. A similar scenario for larval habitat has been proposed for *E. junaluska,* a rare salamander species with a distribution restricted to the southern Blue Ridge Mountains (Ryan 1998).

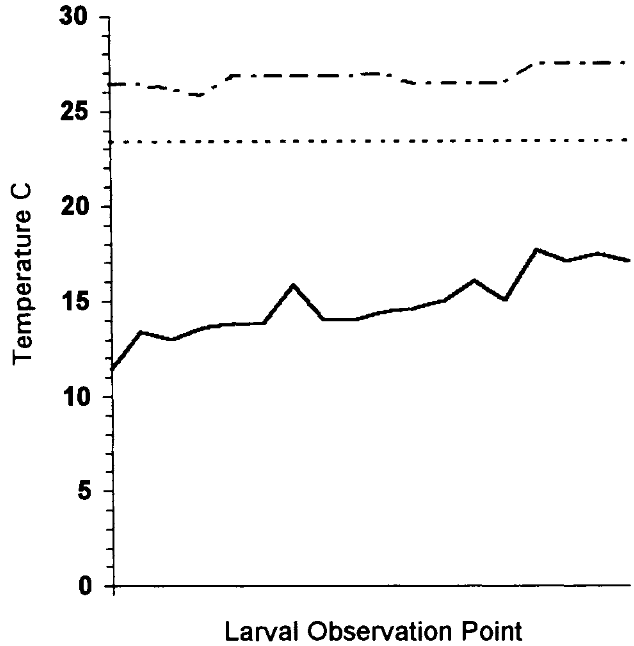

Fig. 2. Air and water temperatures (°C) taken at observation points of larval *Eurycea cirrigera* within spring run at Rayns Creek Site 102–1S on 16 September 1994 at Kankakee River State Park, Will County, Illinois. Units on the x-axis for spring run air and water temperature represent measurements recorded sequentially at each location where larvae were encountered starting at the discharge point and moving downstream to the confluence zone at the main channel of Rayns Creek. Therefore, values on the x-axis are a general representation of temperature trend from the discharge point (0 m) to the confluence zone 50 m distant. A straight reference line is provided for water comparison to the temperature in the main channel of Rayns Creek because no larvae were found and water temperature in the general area of the spring run was relatively constant. The solid line indicates water temperature of a spring run, the dashed line is the reference water temperature in the main channel of Rayns Creek, and the line with unequal dashed indicates air temperature.

Educational Fieldtrips and Population Monitoring

Censuses conducted on fieldtrips by Chicago State University in 1996 and 1997 suggested that differences in population numbers of adults and larvae may occur among individual drainage sites and from year to year. Inventories conducted by Mauger (1995) indicated the presence of both adults and larvae at the Rayns Creek site, but no larvae were found within the main channel habitat and only in the spring run. Census results in 1996 found no adults at the Rayns Creek site, but larvae were found in the spring run. The one reported larva found in the main channel of Rayns Creek actually occurred in spring run flow at the confluence zone of the spring run and main channel.

The differences in census results observed at the Rayns Creek site probably do not indicate an actual change in population status, but reflect sampling bias resulting from weather conditions, differences in density of cover objects at sites, and possibly observer inexperience. For example, warmer weather patterns and subsequently drier substrate conditions can make finding adults difficult, especially when cover objects are scarce. Failure to find adults at the Rayns Creek spring run in 1996 is not unusual, considering that substantially more cover objects (i.e. cobbles) occur within the main channel away from the spring run. The seep channel is only a few hundred feet in total length, and most cobbles are submerged within the channel. Fewer cobbles or other cover objects exist along the edge above the water line where adults would be more likely to be found. Adults can be found in the spring run by concentrating search effort in the upper reaches of the run where surface flow does not occur. In such areas, cobbles are exposed and the substrate is moist; ideal conditions for finding adults.

In contrast, student censuses observed higher numbers of adults and larvae at Site 102–3. This contrasts with results obtained by Mauger (1996) that appeared to indicate higher relative abundance at the 102–2 site. This discrepancy may represent an actual change in population numbers among sites and across years. Sampling bias and observer inexperience are not believed to have contributed to the difference because both sites 102–2 and 102–3 had comparable cover object conditions (i.e. limestone cobbles). Therefore, the likelihood of finding adults and larvae at either site would not have been biased by differences in cover.

Differences in groundwater flow may also have existed between these two sites. Mauger (1996) noted greater surface water flow at site 102–2 in 1995, while greater flow was observed at site 102–3 in 1996 and 1997. Water flow conditions were visually estimated by timing how fast water moved between two fixed points. Observed differences in census results may indicate that population numbers have fluctuated in response to changes in flow or to water quality conditions. For example, reduced flow might lead to lower dissolved oxygen levels which could affect abundance of larvae.

Water temperature is the only environmental condition in which significant differences in population numbers of *E. cirrigera* appear related to. However, this relationship only applies to larvae. Water temperature is significantly cooler in spring runs compared to the main channel of Rayns Creek. Both adults and larvae of *E. cirrigera* occur at all spring run sites. However, larvae have not been found within the main channel of Rayns Creek (site 102–1C), although adults can be quite abundant (Mauger 1995). One advantage to larvae that is attributable to groundwater is a constant and less variable thermal regime. Flow within the main channel in Rayns Creek is derived from sources outside of and far upstream of the KRSP. The thermal environment of water in Rayns Creek would be expected to vary dramatically over the season, with higher extremes most apparent during July and August. Therefore, a cooler, less variable thermal regime is believed to be an important component of *E. cirrigera* larval habitat.

Adult *E. cirrigera* can utilize terrestrial habitat adjacent to the channel. The forest canopy keeps most channel areas shaded, and damp substrate and other moist microclimates are available despite high air or water temperatures. During the day, adults hide under cover such as rocks, logs and leaf litter within or along the bank of the main channel. Cover objects within the main channel or on cobble bars that are not submerged, and on nearby banks often have very saturated or damp soil that sustains high moisture conditions that are favored haunts of adults, especially during hot summer weather. Adults have also been found in small holes or burrows in loamy sand deposits that form the channel banks at Rayns Creek (Mauger 1995, 1996). These observations suggest that the spring or seep-fed larval habitat may be the primary limiting factor that may explain why the distribution of the species is restricted in northern Illinois.

There are certainly many environmental and habitat conditions that could be important in determining salamander population numbers between sites or over years (e.g. dissolved oxygen, velocity or volume of flow, etc.). However, water temperature and a groundwater source are clearly important components of larval habitat, with *E. cirrigera* larvae occurring only in the cooler, more stable thermal regime characteristic of spring or seep fed runs. Not surprisingly, pH did not differ because dolomite bedrock provides an abundant source of calcium and magnesium cations that buffer water. A significant difference in light level in 1997 was attributed to some localized gaps in tree canopy and likely have little or no effect upon occurrence or abundance because both adults and larvae hide underneath limestone cobbles or other cover most of the time. Factors or causes to account for lower conductivity in 1997 remain unknown, and there potential influence upon salamander numbers is unclear.

An important perspective to emphasize is that the goal for Chicago State University educational fieldtrips was to provide students with "hands-on" experience in field ecology study. Conditions that have been measured in these studies were essentially chosen based upon availability and access to equipment. However, addition of a dissolved oxygen meter may be important for future monitoring work. Further, the data from the fieldtrips reported here were not obtained from controlled field experiments and are not as statistically rigorous as scientific study of populations and habitat would demand. However, they minimally provide qualitative and/or relative measures that could be used as a baseline upon which future monitoring can build upon. Also, the results have contributed substantially to knowledge of basic habitat conditions and requirements of *E. cirrigera* in northern Illinois.

Finally, observer inexperience in search techniques is also a major factor to consider. Ultimately, the most important result of the Chicago State University fieldtrips to keep in mind are the census techniques that were used. Refinements to sampling design are required and once standardized, these can be used to repeatedly census sites which can be used to detect changes in population numbers of *E. cirrigera* adults and larvae. Despite some of these problems and biases with initial fieldtrip censuses, the techniques reported here have high utility and application to long-term monitoring studies to detect population decline. However, different statistical techniques will likely be needed to explore or test for long-term trends. Also, the census strategies and techniques piloted in this study could be readily adapted for use with other streamside salamander species that have similar life history traits and habitat requirements.

Management Implications

Seep runs within the KRSP are separated from one another by varying distances, as well as varying amounts and configurations of suboptimal or inhospitable terrestrial habitat. For example, many drainages are isolated from one another by substantial areas of dry, sandy, upland forest. These uplands could function as barriers preventing movement of adults between sites, or minimally restricting adult movement between sites to the occasional periods when cool, moist weather conditions prevail. Therefore, seep runs may be naturally isolated from one another and might be considered subpopulations of a metapopulation that are vulnerable to both deterministic and stochastic extinction. Although *E. cirrigera* at KRSP may be more continuously distributed in the traditional sense of a population (i.e. based on genetics), a more functional approach as defined by McCullough (1996) may be appropriate.

For purposes of conservation management, two key points are apparent at the KRSP, (1) individual, groundwater-fed drainages or "spring runs" are spatially discrete, and (2) there is some likelihood of extinction in one or more of these drainages (i.e. patches) because viable populations of larvae are restricted to aquatic habitats that depend upon a relatively stable or permanent source of groundwater-derived flow. Events or processes that eliminate or substantially reduce groundwater discharge, and/or degrade water quality conditions for prolonged periods (i.e., relative to recruitment and adult lifespan) could lead to localized extinction. The degree of re-colonization of these patches would be a function of distance to surviving neighbor patches, and the spatial configuration, connectivity and structural heterogeneity of intervening terrestrial habitats. This would be especially applicable to hostile terrestrial habitat, as well as to the amount of connectivity between drainages by low-lying habitats that provide moister and/or suitable microclimates for dispersal of adults (e.g. forested floodplain along the main channel of the Kankakee River).

The obvious relationship between groundwater discharge and *E. cirrigera* larvae suggests that strategies for management of viable populations need to focus on events or processes that occur within the watershed that may alter or degrade groundwater quality and/or reduce quantity. Such concerns have been cited for three neotenic or paedomorphic *Eurycea* species that are endemic to the Edwards Plateau Region of Central Texas (Cole 1995). Populations of these species are highly vulnerable to extrinsic forces, because the habitat they occupy is restricted to the springhead and downstream spring runs up to 400 m below the springhead (Cole 1995). For example, direct impact to springhead habitat resulting from pool maintenance activities (i.e. chlorine and water-jet cleaning) was observed at the Barton Spring and Eliza Spring and these activities were suspected of causing temporary decrease in salamander abundance (Cole 1995).

More recently, populations of salamanders at both Barton and Eliza Spring appear to have increased since alternative cleaning procedures were developed and instituted (Cole 1995). However, the U.S. Fish and Wildlife Service recently listed the Barton Springs salamander (*Eurycea sosorum*) as an endangered species (Federal Register 1997). The primary threat identified was degradation of the quality and quantity of water that feeds the spring due to urban expansion over the Barton Springs watershed (Federal Register 1997).

Certainly, similar scenarios are possible at the KRSP because discharges of groundwater at seep or spring heads within the preserve are highly dependent upon percolation of water in upland areas outside the KRSP. Many of these areas are under intensive row-crop agriculture, and thus a whole host of potential impacts to salamander habitat within the KRSP are possible including water quality degradation from pesticides, herbicides, fertilizers and sediment. Also, major roads parallel both sides of the Kankakee River. All spring runs within the KRSP are precariously close to these roads, and in some instances seep or spring heads occur on the opposite side of the road outside of the preserve.

Finally, degradation of water quality and excessive siltation from increased surface runoff in uplands outside the KRSP would also be of great concern. For example, episodes of high-volume surface runoff occur at many of the spring runs, as evidenced by high-water stranding of larger logs, garbage and other debris. Monitoring of population numbers relative to water quality and flow conditions at selected spring runs within the KRSP is warranted to provide an early warning of degrading habitat conditions that could cause decline in population numbers. With adequate warning, local extinction could be avoided if aquatic or other habitat conditions are rectified with prompt management attention.

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