Transactions of the Illinois State Academy of Science
(1997), Volume 90, 1 and 2, pp. 79-88
received 6/17/96
accepted 9/26/96

Ecological Lessons from Two-Lined Salamander Translocations

Gordon R. Thurow
Western Illinois University
Macomb, IL 61455

ABSTRACT

Semiaquatic, stream breeding two-lined salamanders, *Eurycea cirrigera* (formerly *E. bislineata*), were translocated from western Indiana to west-central Illinois, outside the present range. In spite of general habitat degradation in an unfavorable Prairie Peninsula region, microhabitat was found in three areas where *E. cirrigera* colonies were subsequently established. Information was gained about the biology of the salamander, and how it is affected by changes in hydrology, stream flow regimen, and drainage basin vegetation. Recommendations are made concerning management of *E. cirrigera* preserves, conservation and improvement of habitat, and translocation methods.

INTRODUCTION

In previous studies this author made minor range extensions of terrestrial forest dwelling amphibians (wood frogs and *Plethodon*) to west-central Illinois via translocation (Thurow, 1994 and in progress). The drier macroclimate of the Prairie Peninsula (Transeau, 1935) is unfavorable to many amphibians, as their ranges indicate. But the above translocation studies showed some could survive in local forested areas with better microclimates, particularly if habitat improvements were made.

Another amphibian whose Illinois range has diminished is the semiaquatic southern two-lined salamander (*Eurycea cirrigera*, once called *E. bislineata* in Illinois). It still can be found in forest fragments along the eastern Illinois border in tributaries of the Wabash and Ohio rivers, and also in the Vermillion and Kankakee river valleys, which lie in the Prairie Peninsula. Deforestation and resulting increased water temperatures, historical drops in the water table (Bowman 1991, and Visocky 1993, Figs. 3, 6, and Table 3), and decreased water quality probably relate to the Illinois range contraction. These changes are discussed in many ecology texts, and in books on forestry such as by Shepard (1975).

Mierzwa (1989) confirms that isolated *E. cirrigera* populations exist in the Prairie Peninsula (in the Kankakee River area), and this discontinuity proves that the postglacial Illinois range was once more extensive. The salamander's present range extends N, S, E, and even W of this study's translocation area (in Mississippi and Louisiana, Conant and Collins, 1991). There would seem to be no reason why *E. cirrigera* could not exist in western Illinois if suitable habitat could be reached.

Typically, the two-lined salamander lays eggs in riffle areas of clear well oxygenated streams with a rocky bottom. Egg hatching occurs in late May in the Indiana donor area (Minton, 1972, and my observations). Bishop (1941), citing others, says that *E. bislineata* metamorphosis usually occurs in the next year (in summer). This is confirmed by McDowell (1995) for southern Illinois *E. cirrigera*. So permanent moisture in a good quality stream environment appears necessary for successful reproduction (Minton, 1972). This differs completely from the requirements for the terrestrial breeding *Plethodon* or vernal pool breeding wood frogs.

Again, the purpose of this study was to see if translocations could succeed further west in the Prairie Peninsula, and thus to learn more about habitat restrictions and possible conservation methods. Any successful populations could be used for further studies.

MATERIALS AND METHODS

General

Donor salamanders were collected by hand from the Sugar Creek valley in Fountain, Montgomery and Parke counties of west-central Indiana. Transport was in moss filled .946 l canning jars, kept at about 5-20° C. Animals were usually released within a day or two, at one of three study areas, whose exact locations are omitted for their protection. Two were pre-picked areas of more suitable habitat in Brown and central McDonough counties, Illinois. The third was by a less suitable and subsequently deteriorating stream habitat on a farm in NE-central McDonough County. Habitat improvements were made in this latter area.

The improvements to the surrounding redeveloping oak-hickory forest involved tree planting, leaf litter and surface shelter additions, and rock shelter construction as described earlier (Thurow, 1994). Direct aquatic habitat improvements included limestone rock bridges and dams, which improved stream aeration and presumably raised the pH (since ground limestone is used for this purpose in agriculture). Rock piles and flat rocks were added to provide shelter. On land, more shelter objects (flat rocks and boards) were added by a slope seep area, and a few seepage collecting pools were dug. One small watering tank and a wash tub were also emplaced so as to form seepage pools. Some of these went dry when seep and spring drainage followed a different path, and lower pools were sometimes scoured by stream floods. Indirect attempts were made to increase and stabilize stream flow by increasing forest growth on some adjacent areas from 1970 or later, and by converting some crop land to grassland.

Monitoring involved turning and replacing cover objects, recording sightings, and also recording evidences of reproduction (eggs, larvae, and immature metamorphosed animals). Repeated visits were made most years through 1993, but my required long absences in 1994 and 1995 limited observations then. Release area habitats were all so small in McDonough County that no transects or quadrats were needed. Visits were limited to reduce habitat disturbance. In most years the Brown County stream was only examined near the release area, for the same reason. Previous absence of *E. cirrigera* from the translocation areas was confirmed by other herpetologists (Conant and Collins, 1991), and by my own field work since 1966.

Brown County Unimproved Area (Site 1)
Nearly all of west-central Illinois is covered by glacial till or loess deposits. However, as the Illinois and Mississippi Rivers converge to the south more glacial deposits have been eroded away in the intervening area. The main river (McKee Creek) draining through Adams and Brown counties to the Illinois River has more rock outcroppings along its tributaries than the LaMoine River does in McDonough County. Cooler clearer waters for the upper McKee Creek basin were observed, and evidenced by the presence of *Rana clamitans*, which is missing from much or all of the upper LaMoine River drainage basin.

A north flowing tributary of McKee Creek was chosen, south of Mt. Sterling. The area is forested, with oak, hickory, and hard maple. The main disturbance is limited to occasional selective lumbering. There are sandstone outcrops on the slopes, and sandstone and limestone flat rocks in the stream bed. A rocky stream bottom 2-3 m wide extends for over 1 km. In October 1976, 56 salamanders were released near the juncture of two of the tributary's branches. In 1977, 219 more animals were released. In 1978 releases totaled 102, plus some eggs. In 1979, 127 more salamanders were released, for a total of 504. One monitoring visit was usually made per year.

Central McDonough County Unimproved Area (Site 2)
Most McDonough County streams have mud bottoms, with only scattered glacial erratic rocks. The streams are usually surrounded by pasture or eroding crop fields. However, there is one north flowing tributary to the LaMoine River which cuts down through bluffs, and has rocky banks and about a 3 m wide rocky bottom for over 110 m near its terminus. Most of the drainage basin occurs on one farm, and the land adjacent to the stream is pastured savannah or woods rather than crops, which reduces stream turbidity. This restricted area of habitat is semi-protected by the management policies on this family farm.

On 9/27/87, 196 *E. cirrigera* were released here. On 6/2/88, 19 more were released, plus about 40 larvae, and on 8/27/91, 49 more salamanders were released, for a total of approximately 304 animals. Brief monitoring visits were made about once a year, usually taking less than one hour.

NE-Central McDonough County Improved Area (Sites 3-7)
This farm has about 36 ha (90 acres) of wooded or semi-wooded area, most around another north flowing tributary to the LaMoine River. However this stream does not have a rocky bottom, and extends upstream beyond the farm into crop areas. From 1970 to 1975, when the translocations started, this stream was permanent, and even its side branches persisted most of the summer. After the droughts of the 1980s, parts of the main stream went dry in several years, and its tributaries stopped flowing nearly every year.

Stream flow regimens reflect drainage basin conditions, and drainage basin experiments have confirmed that more devegetation caused more surface runoff and erosion (Hibbert, 1967, Horwitz, 1974). This faster runoff, or more extreme flooding, can cause difficulties for organisms adjusted to less changeable conditions (Bowles and Apfelbaum, 1989). Less vegetation leads to more surface evaporation, and this plus more runoff leads to drier

conditions between rains. If more precipitation evaporates or runs off, then less soaks into the ground, and springs dry up and water tables drop. This of course is hastened by withdrawal of groundwater, as in McDonough County. This gradual surface xerification in agricultural areas of the U.S. is indicated by place names for springs that have since gone dry, by measurements of declining water tables (Ehrlich, et al., 1977, p. 263), and by relative increases in plant species which are more resistant to dryness (1979 M.S. thesis of D.B. Fisher Jansen, Western Illinois University, pp. 59-60). In 1975 the NE-central McDonough County farm had five spring areas and about five additional seepage areas. In 1992 only three definite spring areas were left, with reduced flow, and one of these is below the surface of the stream.

Two-lined salamanders were released into small stream branches; along a rock pile added to the main stream below two spring areas; and by a spring seep on a valley slope. All these areas were forested. One other stream branch that later carried sewage lagoon and swine waste from outside the farm was not used, nor was the main stream below this point.

Site 3 (Table 1) was the upper part of a partly spring fed side-branch to the north. In one fork the former landowner had emplaced a pipe, which still had a continuous flow of spring water in the 1970s. In that decade 187 releases were made near this spring, which later gradually dried up in the 1980s. So later releases were made in the other larger fork.

Site 4 (Table 1) was another stream side-branch, where the same former landowner had a well near the head and increased seepage flow by dynamiting (probably before 1955). The well still overflowed sometimes in early 1980, and releases were made for several years (Table 1). But by 1990 the well overflow had stopped, and downstream flow from surface runoff also ceased in most summers, though small seepage pools persist in a gully further downstream. Forest clearing took place over 100 years ago for a railroad along this streamlet. The railroad track was removed about 100 years ago (Shadwick, 1968, p. 124). So nearby trees are now mostly slippery elm (*Ulmus rubra*), black walnut (*Juglans nigra*), and shingle oak (*Quercus imbricaria*), though large white oak (*Q. alba*) and shagbark hickory (*Carya ovata*) are found farther down the ravine. The gully section of the stream with the rock pile and flat rocks is less than one m wide, and only about 26 m long.

Site 5 (Table 1) received three group releases in 1989, in the main valley stream by a rock pile below two spring areas. There was also a riffle area here, with added flat rocks. This release was attempted because this part of the stream has never gone dry. However, the stream does flood up over its banks every year after heavy rains, and this would reduce egg survival except perhaps in special sheltered locations.

Site 6 (Table 1) is the second oldest farm release. Eighty salamanders were first released in 1976 on this spring-seepage slope, and more later (Table 1). There was no real tributary side-branch stream here, and the nearby main stream was not good habitat, as it was semi-polluted and sometimes muddy and flooded. This part of the main valley was selectively lumbered in 1972 and earlier, but some hickories and white oak remain on and above this west facing slope. The frequently wet part of the slope is less than 200 square m, and does not extend to the stream.

Site 7 (not in Table 1) is in a branch of a second smaller river tributary stream west of the main farm stream. The surrounding oak-hickory-basswood forest is good quality, but rocks on the stream bottom are limited. On 4/25/96, 91 salamanders were released.

RESULTS

Brown County Unimproved Area (Site 1)

Only a very few animals (less than 5) were seen during the release years, and none for years afterward. The stream below the release area completely dried up during droughts such as in 1980, 1983, and 1988. On 10/28/90 one larva and six metamorphosed animals were seen, that had spread downstream and also up both tributary forks. On 10/19/91 one was seen in each fork, and on 9/26/92 and 9/25/93 one was seen up one fork even after major flooding. On 5/2/93 two salamanders and one larva were seen in the main tributary. On 4/8/95 three adults and three larvae were seen in or by the main stream and its larger branch. On 4/22/96 I saw 14 *E. cirrigera* in about one hour's searching, and two large rocks with a total of at least eight separate egg masses. More could have been found, but I wished to limit possible damage. So a colony is surviving here.

Central McDonough County Unimproved Area (Site 2)

A single salamander was seen on 10/8/88, 8/16/89, 11/1/90, 9/25/92, and 4/8/95. None were seen during a very brief visit on 7/29/89. On 8/27/91 (before further releases) two adults were seen, plus one larva which proved local reproduction. A large flood occurred shortly before the 1992 visit, and may have swept some salamanders downstream. None were seen sheltering under bottom rocks like some of the aquatic insects (e.g. *Gerris sp*.), and the one salamander seen here (and also the one in Brown County the next day) was on the ravine slope above the flood level. A one and a half hour visit on 10/15/93 revealed 11 metamorphosed animals, under rocks from down near the stream to high on both slopes near drainage lines. On 5/14/96 four adults, one larva, and one egg clutch were found in one hour's search, in spite of disturbance from two recent floods. The female who left the egg clutch because the rock was lifted, hid between rocks about ten cm away, and was seen to return to the clutch about five minutes after the rock was replaced. It appears that a healthy colony is being established.

NE-Central McDonough County Improved Area (Sites 3-7)

The translocations made on this one farm were less successful than the above two areas, but more instructive. Two-lined salamanders have persisted for years in three of these five places, but only two have shown evidence of reproduction. Releases and most later sightings for four sites are shown in Table 1. Brief summaries of the observations follow.

At Site 3 some salamanders (not shown in Table 1) were seen after releases near the pipe spring in the 1970s. A little downstream in this fork a freshly dead animal was seen in 1983, two live animals in 1989, and another in 1992. Only single animals were found in the other larger fork in 1987 and 1988 (releases were made here from 1983-1990), and this streamlet began to dry up in the summers. No larvae or metamorphosed juveniles were found, and this translocation was deemed unsuccessful. Monitoring will continue, but no animals were seen in 1993-1996.

Site 4 early releases were in the upper side valley, near the well. Some salamanders (not shown in Table 1) were seen here for a short time. Farther downstream, in a gully where moisture remains the longest, one salamander was seen in 1987, and another with an egg clutch in 1992. The streamlet dried up shortly after hatching in early June, resulting in hatchling mortality. In wetter 1993, an egg clutch hatched, and the larvae had a good chance of survival to metamorphosis in 1994. In 1995, two adults were seen before the oviposition season. Three egg clutches were seen in May, and one larva in the fall. In spring 1996 one large larva was seen in April, and one egg clutch with a brooding female in May. In 1996, two recently metamorphosed animals and an almost metamorphosed larva were seen July 5th, and three small 1996 larvae on August 15th. The success of this colony is limited (Table 1), and it could die out also because of the small habitat size.

Site 5 has never yielded any sightings. Stream flooding causes too much erosion and mud deposition, and efforts at this area will be abandoned. However, in fall 1993 one recently metamorphosed animal was found at least 1.2 km downstream and up another branch. Of course this individual could also have originated farther from the main stream, at Site 4 a little below Site 5, or from Site 3 or 6 farther down the valley and about .75 km above the sighting. On 9/14/96, an adult was seen near the same place. Salamanders with this pigment pattern were only released at Site 6 after 1989, so this is the most likely place of origin. This proves that the two-lined salamander can be dispersed down streams, probably aided by floods which were observed.

In Site 6 the first sighting was in 1986, ten years after the first release. It was an immature metamorphosed animal, probably hatched in 1984. So more releases were made, and in 1987 small larvae were found surviving in a film of slope seepage water under flat rocks. Altogether, the size (age) of young animals sighted indicated successful hatchings in 1984, 1986, 1987, 1989, and 1991-1996. Table 1 shows that some of these eggs were not found. A female was seen brooding a 1992 egg clutch, and by June 11th had excavated a little depression to hold slope seepage water for the recent hatchlings (another female at Site 4 did this in 1993). I then tranferred the hatchlings to a dug pool downslope, though subsequent rains would probably have accomplished the same thing.

As Table 1 shows, three to 25 metamorphosed salamanders were seen here annually, from 1986 to 1995, plus larvae and eggs. Salamanders were usually found in an area of less than 100 square m. Some individuals were seen more than once in a given year, but the estimated minimum number of different individuals varied from three to at least eight. These came from age, sex, and pigmentation differences sometimes recorded in the field notes. In 1993 there were 11 sightings of larvae. As many as four different larvae were seen in one visit, but one egg clutch is typically larger than this. There were almost certainly more than four larval *E. cirrigera* living at Site 6 in late 1993, and probably more than eight metamorphosed animals. Only six visits were possible in 1994, but nine salamanders, three larvae, and one egg clutch were seen. A single visit on 4/6/95 revealed seven salamanders, and a May 1995 visit yielded four females and three egg clutches. Five adults and one larva were seen in the fall. In 1996, 13 salamanders were seen through June (six in one day), but no larvae or eggs. Sufficient seepage does not develop immediately after rains, and there were no substantial rains till May. On 7/7/96 five salmanders and three 1996 larvae were found. Color differences showed that only one

of the 1996 sightings possibly was from the ten 1996 releases. Long term survival of this small colony obviously depends on continued spring seepage from this slope. The upland area above this slope is protected forest, and some seepage should continue, barring major climatic change.

In Site 7 one salamander was seen one day after the releases. It will be years before the success of this last small release can be evaluated.

DISCUSSION

As of mid 1996, two translocated colonies of *E. cirrigera* (Sites 6 and 1) have survived 20 and almost 20 years. This would seem to meet the long term success criterion suggested by Dodd and Seigel (1991). A third population (Site 2) is probably doing well after almost nine years. Site 4 continues after 16 years, while Site 3 may have died out 17 years after the first releases. Site 5 in the main farm stream, showed no evidence of survival, and Site 7 is too recent to evaluate.

Some would question shortening the lives of a large number of salamanders from even a common species, just to establish a few additional small marginal colonies. However much useful information has been generated, which should be helpful in the conservation of this and other semiaquatic salamanders: (1) Translocation of about 200 individuals appears sufficient to establish a colony in good habitat. The number could be smaller. (2) Under special circumstances, the wet area occupied by a colony can be less than 200 square m, or even 26 square m of stream bottom. (3) Two-lined salamanders can survive in drier west-central Illinois, when more suitable habitat is found or created. (4) Although the preferred breeding habitat is clear rock-bottomed streams in forested areas, seepage slope films can also be used, particularly if there are seepage pools downslope. (5) Pristine forests are not necessary, and survival can occur in selectively lumbered redeveloping oak-hickory forest. (6) My experience and the species range of both northern and southern two-lined salamanders indicate that glaciated regions can be inhabited if rock outcrop areas are reached, or if enough glacial boulders have been concentrated onto a stream bottom by erosion and downslope movement. (7) Non-outcrop forest streams will also support two-lined salamanders if rocks are added. (8) *Eurycea cirrigera* can disperse at least .75 km downstream. (9) Previously unreported behavior for two-lined salamanders but not *Desmognathus fuscus* (Bishop, 1941, Fig. 60 and page 316) involves excavation of a water filled depression below the eggs by a brooding female in shallow water. The brooding drive was confirmed by one female who returned to her eggs shortly after being disturbed, and by others who stayed in place when the rock was lifted. (10) Devegetation of drainage basins tends to cause xerification and loss and deterioration of surface waters and stream flow regimens, and should be avoided in and around nature preserves for semiaquatic animals like the two-lined salamander.

This last point cannot be overemphasized, both for translocations and to prevent extirpations in the present range. No area is exempt, even so-called protected areas, which I also observed. Agricultural devegetation and house building upstream and outside of Shades State Park, Indiana, have caused great masses of sand to enter one stream from erosion. This sand mass has migrated downstream into the park and partly buried the rock

bottom stream habitat, reducing herptile populations. Such problems could possibly be ameliorated if inflowing streams were monitored at park boundaries.

Fortunately for conservationists of small animals like the two-lined salamander, it is not necessary to purchase hundreds of acres of land to preserve habitat for a colony. If one protects the smaller drainage basin of a terminal end branch of a stream system, there will be no upstream devegetation, erosion, or pollution to ruin the stream. A forested drainage basin area as small as 5 ha (about 12.5 acres) is sufficient to support a colony long term. Three of my colonies survive in smaller wet areas, although these are surrounded by more forest habitat. Of course a still larger area is better for long term survival, and some springs would also be desirable.

ACKNOWLEDGMENTS

This work was partly supported by Illinois Department of Natural Resources non-game wildlife conservation (tax check-off) grants in 1986 and 1987, by two sabbaticals, and by Western Illinois University Research Council Grants in 1977 and 1979. I would like to thank two landowners (who wish to remain anonymous) for permission to use release sites on their land, and the Indiana Department of Natural Resources for collecting permits.

LITERATURE CITED

Bishop, S. C. 1941. The salamanders of New York. New York State Museum Bulletin 324: 1-365.

Bowles, M. L. and S. I. Apfelbaum. 1989. Effects of land use and stochastic events on the heart-leaved plantain (*Plantago cordata* Lam.) in an Illinois stream system. Natural Areas Journal 9(2):90-101.

Bowman, J. A. 1991. Groundwater supply and demand in Illinois. Illinois State Water Survey, Champaign, IL 91 pp.

Conant, R., and J. T. Collins. 1991. A field guide to reptiles and amphibians of eastern and central North America. Houghton-Mifflin Co., Boston, MA 450 pp.

Dodd, C. K. Jr. and R. A. Seigel. 1991. Relocation, repatriation, and translocation of amphibians and reptiles: are they conservation strategies that work? Herpetologica 47:336-350.

Ehrlich, P. R., A. H. Ehrlich, and J. P. Holden. 1977. Ecoscience: population, resources, environment. W. H. Freeman and Company, San Francisco. 1051 pp.

Hibbert, A. R. 1967. Forest treatment effects on water yield. In: International Symposium of Forest Hydrology (W. E. Sopper and H. W. Lull, Eds.). Pergamon Press, New York. pp. 527-543.

Horwitz, E. C. J. 1974. Clearcutting. Acropolis Books Ltd., Washington D. C. pp. 149-155 of 179 pp.

Jansen, D. B. Fisher. 1979. A survey of the bryophytes of the southern two-thirds of Fulton County, Illinois. M.S. Thesis, Western Illinois University. 65 pp.

McDowell, W. T. 1995. Larval period and reproductive biology of *Eurycea cirrigera* from Pope County, Illinois. Bull. Chicago Herp. Soc. 30(12):248-250.

Mierzwa, K. S. 1989. Distribution and habitat of the two-lined salamander, *Eurycea cirrigera*, in Illinois and Indiana. Bull. Chicago Herp. Soc. 24(4):61-69.

Minton, S. A. Jr. 1972. Amphibians and reptiles of Indiana. Ind. Acad. Sci., Indianapolis, IN 346 pp.

Shadwick, G.W. Jr. 1968. History of McDonough County, Illinois. Desaulniers, Moline, IL 256 pp.

Shepard, J. 1975. The forest killers. Weybright and Turvey, New York. 423 pp.

Thurow, G. R. 1994. Experimental return of wood frogs to west-central Illinois. Trans. Ill. St. Acad. Sci. 87(1 and 2):83-97.

Transeau, E. N. 1935. The prairie peninsula. Ecology 16: 423-437.

Visocky, A. P. 1993. Water-level trends and pumpage in the deep bedrock aquifers in the Chicago region, 1985-1991. Illinois State Water Survey, Circular 177, Champaign, IL 44 pp.

Table 1. Southern Two-Lined Salamander releases (R) and sightings (S) at four sites on a farm in NE-central McDonough County, Illinois. Releases or sightings of larvae are added in parentheses, and "e" indicated that some eggs were also released or seen. A fifth release in a different stream is not shown here.

Years	Site 3 (N side branch)		Site 4 (middle side branch)		Site 5 (main stream)		Site 6 (slope springs)	
	R	S	R	S	R	S	R	S
1975	9							
1976	74						75 (5)e	
1977	80	1						
1978								
1979	24 e							
1980			98					
1981			91 (2)					
1982			130					
1983	108	1	36 (1)					
1984	75		63					
1985	114		68 (1)					
1986	32						57	3
1987	5 (65)	1	10	1			53	14 (12)
1988		1					18 (4)	9
1989		2			142 (39)		5	8
1990	36						3	8
1991							2	6
1992		1		1 e				10 (10)e
1993				1 e				25 (11)
1994								9 (3)e
1995				2 (1)e				16 (1)e
1996	(partial year)			3 (5)e			10	18 (3)
Totals	557 (65)e	7	496 (4)	8 (6)e	142 (39)	0	223 (9)e	126 (40)e