HERPETOLOGICAL JOURNAL, Vol. 10, pp. 137-142 (2000)

THE TERRESTRIAL SUMMER HABITAT OF RADIO-TRACKED GREAT CRESTED NEWTS (*TRITURUS CRISTATUS*) AND MARBLED NEWTS (*T. MARMORATUS*)

ROBERT JEHLE

Institute of Zoology, University of Vienna, Vienna, Austria

Thirty great crested newts (*Triturus cristatus*) and 25 marbled newts (*T. marmoratus*) were radio tracked for up to 31 days after leaving breeding ponds in western France. Around the pond where most newts were radio-tracked, 95% of all summer refuges fell within a radius from the pond of 63.0 m for *T. cristatus* and 59.5 m for *T. marmoratus*. The most frequently used habitats were directly adjacent to the pond shoreline. For the other two ponds, all summer refuges fell within radii of between 26.2 m and 32.3 m from the ponds respectively. No significant differences among species or ponds were observed in the mean distance that newts moved away from the breeding site. Five radio-tracked *T. cristatus* and two radio-tracked *T. marmoratus* that were moved back into their ponds migrated during the following night in almost identical directions to their initial emigrations, but did not return to the original refuges. In eight cases, several (up to ten) untracked newts were found in the refuges of radio-tracked individuals.

Key words: radio-tracking, terrestrial summer habitat, site fidelity, *Triturus cristatus*, *T. marmoratus*

INTRODUCTION

European newts (genus *Triturus*) exhibit the biphasic life history pattern typical of amphibians and require both aquatic and terrestrial habitats (Griffiths, 1996). In Britain, there is currently a special concern about the conservation status of the great crested newt *Triturus cristatus* (Gent & Bray, 1994; Beebee, 1997), which has become an important "umbrella species" whose protection serves to conserve a multitude of lesser-known, coexisting taxa. Nevertheless, protection measures for *T. cristatus* sites often concentrate on their breeding ponds only; this is mainly because empirical data on their terrestrial ecology and behaviour are scarce, owing to the difficulty of locating newts on land.

Lower fitness parameters for amphibians living in fragmented landscapes corroborate the prediction of the metapopulation concept that isolated populations are exposed to an increased risk of extinction (Hanski & Gilpin, 1997; Hitchings & Beebee, 1997; 1998), and demonstrate that studies on movement patterns are of vital importance for conservation issues. The recent application of radio-tracking to adult *T. cristatus* and *T. marmoratus* enabled Jehle & Arntzen (2000) to follow the movements of these newts over a period of approximately one month after leaving a shared breeding site in western France. In this paper, I extend the study and incorporate data from a second year and two additional ponds. The distance that radio-tracked adult *T. cristatus* and *T. marmoratus* move away from their ponds serves to determine a terrestrial zone around breeding sites which is used for summer refuges. Additionally, this paper reports translocation experiments which tested the hypothesis that *T. cristatus* and *T. marmoratus* return to particular terrestrial shelters.

MATERIALS AND METHODS

The three study ponds are located in the Département de Mayenne, Western France. Pond 1 (approx. 50 m² area, at the edge of pastures with hedgerows) and Pond 2 (approx. 20 m² area, an abandoned sand quarry) lie near the village of Jublains; Pond 3 (approx. 150 m² area) lies in a pasture near the village of Marcillé-la-Ville. In 1997 a radio-tracking study was conducted at Pond 1 only, focusing on a comparison of migration and habitat utilization patterns between adult *T. cristatus* and *T. marmoratus* (Jehle & Arntzen, 2000). In the present paper some data from 1997 are reanalysed alongside data collected in 1998 at all three ponds. At Pond 3 only *T. cristatus* were radio-tracked, despite the presence of a small population of *T. marmoratus*.

The radio-tracking was conducted between June 21 and July 30, 1997 and between July 1 and August 3, 1998. For a description of the radio-tracking procedure in 1997, see Jehle & Arntzen (2000). In 1998 newts were captured in the ponds between June 30 and July 2 with dip nets and kept in semi-terrestrial enclosures made from 220-litre metal barrels, cut lengthwise and covered with netting to prevent escape. Water in the enclosures was taken from the ponds where the newts were captured. Newts that had moved out of the water were assumed to have started their terrestrial phase, and were equipped with a transmitter and released at approximately 2100 hrs in the pond of their capture. In 1998, Holohil Systems transmitters BD-2A (mass: 0.69 g - 0.78 g; battery life: 25-35 days) were used exclusively, with the external antenna twisted around the

Correspondence: R. Jehle, Institute of Zoology, University of Vienna, Althanstr. 14, A-1090 Vienna, Austria. *E-mail:* Robert.Jehle@univie.ac.at

TABLE 1. Summary of movement data of the radio-tracked adult newts at the three study sites. *T. c.*: crested newt (*Triturus cristatus*), *T. m.*: marbled newt (*Triturus marmoratus*).

	Pond 1		Pond 2		Pond 3
	T. c.	*T. m.*	*T. c.*	*T. m.*	*T. c.*
No. newts released	15	19	5	6	10
No. observed localisations	45	53	8	6	16
Tracking duration (days):					
minimum	3	3	4	4	5
maximum	28	31	13	6	10
median	16	15	5	6	8
Distance to pond (m):					
minimum	1.4	1.8	2.1	1.8	13
maximum	95.7	146.0	26.2	30.0	32.3
median	9.3	12.2	14.8	13.7	15.9

transmitter and fixed with "super glue". Prior to transmitter implantation, the newts were anaesthetised with MS 222 (Sandoz), until the muscular system was relaxed and the animals stopped moving (10-20 mins). The body cavity was opened at the ventro-lateral side for 8-10 mm with a scalpel, and the transmitter was inserted using forceps. The wound was closed with four sutures using an iris cutting needle (a C-shaped needle 7 mm long) and surgical silk supplied for human medicine. Bleeding rarely occurred, and no other complications were observed during the implantation procedure. All animals recovered from anaesthesia after approximately 30 mins with no apparent ill effects. At the end of the tracking period, newts had their transmitters removed and were then released in the pond, as recovering the newts would have damaged the

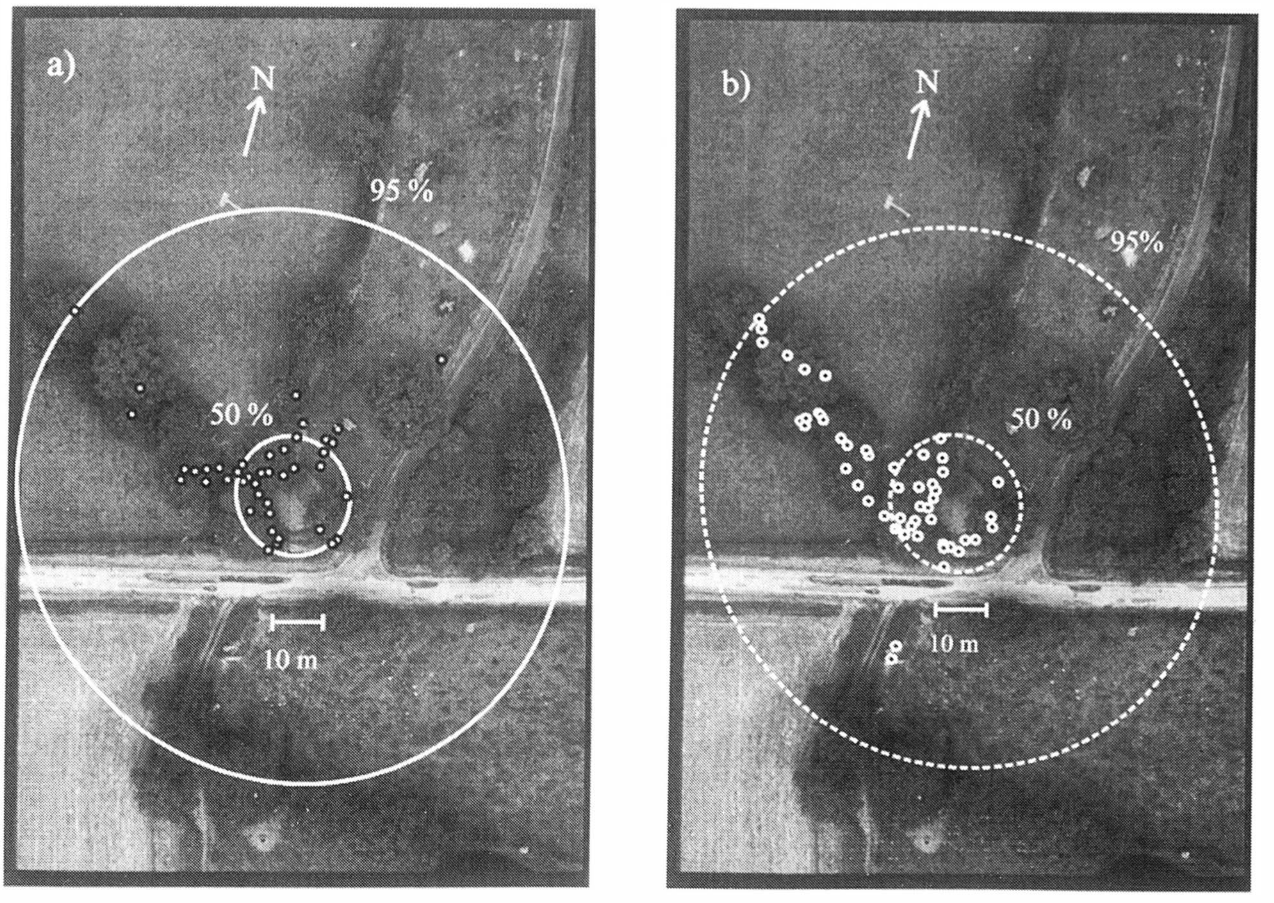

FIG. 1. Aerial photographs of Pond 1 and its surrounding area. The circles around the pond (corrected using ground reference points as the picture is not taken exactly above the pond) encompass the areas where 50% and 95% of the radio-tracked newts were observed. (a) *Triturus cristatus*, two localisations are outside the image; (b) *T. marmoratus*, three localisations are outside the image.

microhabitat in which they were found. Some transmitters were re-used.

The 1997 season showed that the vast majority of migratory activity took place during the first night after the newts were released (Jehle & Arntzen, 2000). The distance travelled from the pond edge after three days was not significantly different from that at the end of the tracking period, when the transmitter battery was due to expire (paired *t*-test with log-transformed data: $P>0.05$). The collection of data in 1998 was therefore restricted to one record per day over a period of up to 13 days, in some cases including a translocation of the newt back to the pond. Localisations of newts are defined as refuges where they were resident for at least 24 hrs, and were marked with a numbered flag. For animals that were recovered dead, and for transmitters found without the animal, data were included up to the last recorded movement. Distance measures were taken to the nearest edge of the pond and to spatial reference points selected on the basis of good visibility and spacing (White & Garrott, 1990). Localisations were plotted on aerial photographs. For Pond 1, circles around the pond were drawn on the photograph to plot the area where 50% and 95% of all summer refuges were observed, as refuges were not expected to be evenly distributed in space. In line with the smaller sample sizes, only circles circumscribing 100% of refuges were plotted around Ponds 2 and 3. Ponds 1 and 2 were considered to be approximately circular and the circles were centred on the middle of the pond. For Pond 3 the circles were centred on the point of release of the newts. Because the aerial photographs were not taken exactly above each pond, the circles were corrected using the reference points and plotted as ellipses. Distances of refuges from the pond centre (Ponds 1 and 2) or point of release (Pond 3) were compared between ponds and between species (simple factorial ANOVA with all ponds) and between sexes within species (*t*-tests for Pond 1) using log-transformed data.

Translocation experiments were conducted with two *T. cristatus* and two *T. marmoratus* at Pond 2 and three *T. cristatus* at Pond 3. Newts that had already been radio-tracked to their terrestrial refuges were recovered during daytime and released back into their ponds at 2100 hrs on the same day. Their migrations were subsequently followed without changing the data collection procedure. The relationship between the direction (in azimuth) of initial emigration from the pond and emigration direction after translocation was determined using linear regression (after Batschelet, 1981). Owing to the limited sample size, data from both species were combined.

RESULTS

In 1997, 30 newts were radio-tracked at Pond 1. In 1998, four, eleven, and ten newts were radio-tracked at Ponds 1, 2, and 3, respectively (Table 1). Thirty-three (60%) newts were recovered alive; for seven newts (13%) the transmitter was found without the study individual, six transmitters (11%) were detected but could not be recovered as they were inaccessible, three newts (6%) were found dead, three newts (6%) were eaten by snakes, and in three cases (6%) the signal was lost. All individuals but one left the pond on the night of release and moved between 2 m and 146 m away from the pond. Newts were tracked for periods ranging from three days to 31 days. Owing to a longer median tracking period in 1997, the number of localisations per individual was higher at Pond 1 than at Ponds 2 and 3 (Table 1).

Sixty-nine localisations of *T. cristatus* and 59 localisations of *T. marmoratus* were analysed (Table 1). The distance of the localisations from the pond/point of release did not vary significantly between *T. cristatus* and *T. marmoratus* ($F=0.04$, $P>0.05$), or between ponds ($F=2.05$, $P>0.05$). At Pond 1, no significant differences between the sexes were detected within species (*T. cristatus*: $t=0.93$, *T. marmoratus*: $t=1.73$, $P>0.05$ in both cases). At Pond 1, the circles encompassing 50% of all *T. cristatus* and *T. marmoratus*

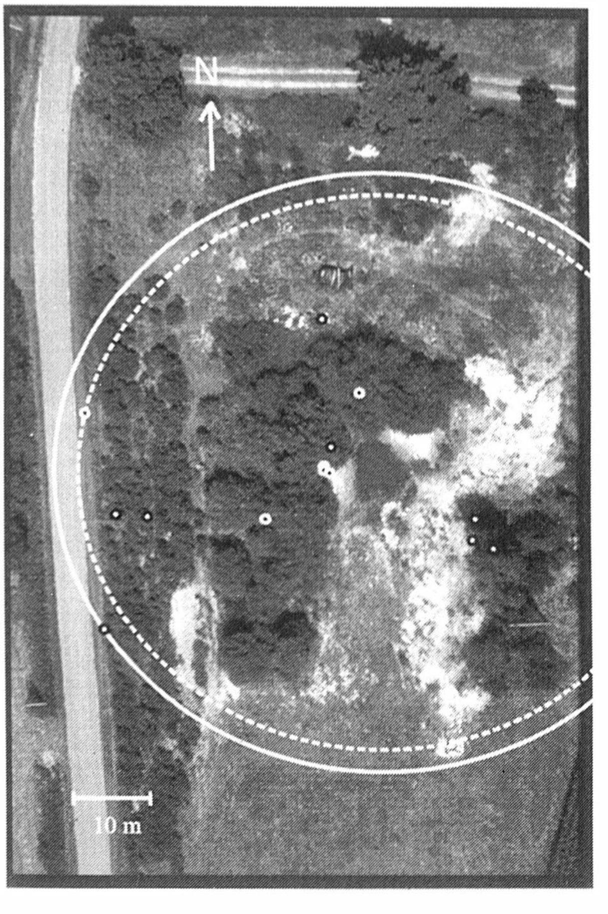

FIG. 2. Aerial photograph of Pond 2 and its surrounding area. The circles around the pond (corrected using ground reference points as the picture is not taken exactly above the pond) encompass the areas where 100% of the radio-tracked newts were observed. Solid line: *Triturus cristatus*; broken line: *T. marmoratus*.

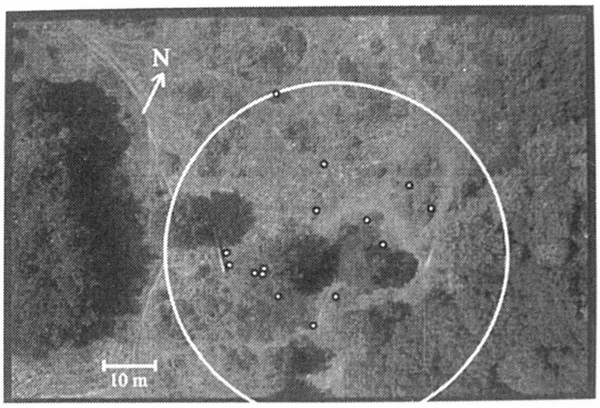

FIG. 3. Aerial photograph of Pond 3 and its surrounding area. The circle around the pond (corrected using ground reference points as the picture is not taken exactly above the pond) encompass the areas where 100% of the radio-tracked *Triturus cristatus* were observed.

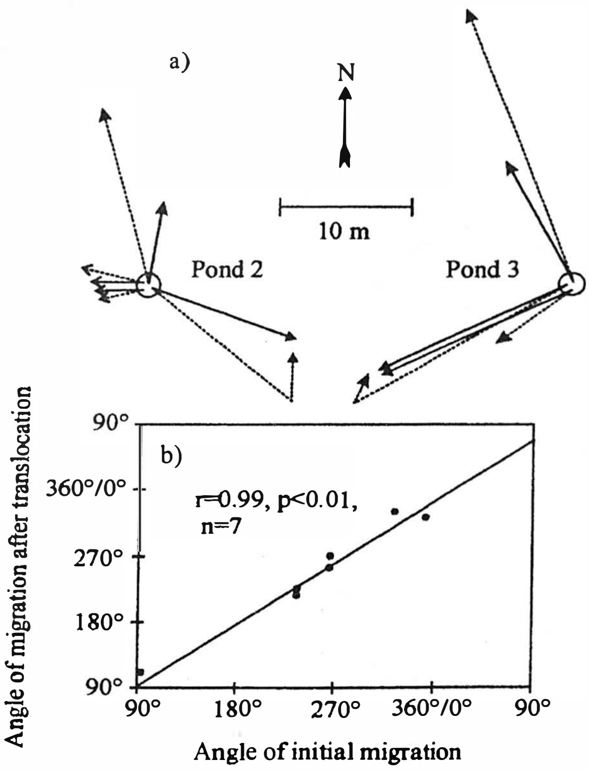

FIG. 4. Translocation experiments of radio-tracked newts. (a) Migrations of five *Triturus cristatus* (filled arrowhead) and two *T. marmoratus* (open arrowhead) which were released in Ponds 2 and 3, recovered, and put back into the ponds. Arrows with the same origin represent one individual. Solid line: initial emigration from the pond; broken line: emigration after translocation back into the pond. (b) Relationship between the initial direction of migration and the direction of migration after re-release in the ponds.

localisations had radii of 12.2 m and 14.8 m, respectively; the circles encompassing 95% of localisations had radii of 63.0 m (*T. cristatus*) and 59.5 m (*T. marmoratus*) (Fig. 1). The circles encompassing all localisations around Pond 2 had radii of 30.0 m (*T. cristatus*) and 26.2 m (*T. marmoratus*, Fig. 2). At Pond 3 a circle of radius 32.3 m encompassed all localisations of *T. cristatus* (Fig. 3).

Twenty-three untracked newts were found sharing the refuges of eight radio-tracked newts, with up to ten newts in one refuge. The five *T. cristatus* and the two *T. marmoratus* that were translocated back to their respective ponds left the pond on the day of translocation. They did not migrate to the refuge in which they were recovered the day before (Fig. 4a), but showed a significant tendency to depart in the same direction as before (Fig. 4b). Two *T. cristatus* spent four and seven days, respectively, in a transient refuge before moving closer to their initial site of recapture (Fig. 4a).

DISCUSSION

The radio-tracking methodology is a direct monitoring technique which is suitable for collecting data on the secretive terrestrial life of adult newts. The observed losses were within the range of other telemetric studies on urodeles (Madison, 1997; Madison & Farrand, 1998), and the frequent observations of radio-tracked newts sharing refuges with untracked newts is in line with the assumption that the migration behaviour of radio-tracked individuals was not abnormal. The time when the study individuals moved to the terrestrial part of their enclosures, prior to being implanted with transmitters, coincided with a decreasing number of newts in the ponds; this supports the view that the study animals were ready to leave the water. Nevertheless, the procedures of implanting and removing a transmitter are invasive and their full consequences are unknown; for example, no data are available on possible adverse consequences for the newts after the study period. One of the major limitations of radio-tracking newts is the short lifetime of transmitters, precluding the collection of data over entire seasons. The transmitters' mass was between 7.0% and 14.3% (median: 8.7%) of the newts' body mass, and more powerful batteries would raise the transmitter mass:body mass ratio to an unacceptable level. Future tracking studies, also with regards to juveniles, may be possible using remotely detectable tags without internal energy sources (Lovei, Stringer, Devine & Cartellieri, 1997).

Spatial movement patterns were very similar between breeding sites. During the period of study, 50% of all newts moved only a few metres away from the shore of Pond 1, which suggests that the most important area was directly adjacent to the breeding site. As only a few individuals performed the large-distance movements, the smaller apparent summer habitat range in Ponds 2 and 3 might be a consequence of the smaller sample size. For the purpose of defining a protected area of terrestrial habitat around a breeding site, a simple prescribed radius might not be satisfactory as a general guideline, as newts are likely to prefer certain directions and habitat types. However, quantifying habitat use is time-consuming, and radio-tracking data as well as drift fence studies have shown that, although movements are non-random in orientation, narrow migration corridors do not necessarily exist (Jehle, Pauli-Thonke, Tamnig & Hödl, 1997; Dodd & Cade, 1998).

The radius encompassing 95% of all *T. cristatus* and *T. marmoratus* refuges in this study was considerably smaller than the 164.3 m buffer zone estimated for North American ambystomatid salamanders on the basis of 95% of recaptures (Semlitsch, 1998). Two factors might account for this difference. First, *T. cristatus* and *T. marmoratus* have an aquatic phase which lasts approximately 5 and 3 months, respectively (Bouton, 1986; Griffiths & Mylotte, 1987), whereas ambystomatids are more terrestrial, spending 86-99% of the year on land (Semlitsch, 1998). Second, ambystomatids exhibit bimodal migratory activity with peaks in April/May and October/November, and when radio-tracked over the entire year move up to 286.5 m away from their ponds (Madison, 1997; Madison & Farrand, 1998). Drift-fence studies on *T. cristatus* also suggested an increase of migration activity in autumn (Verrell & Halliday, 1985), and mark-recapture data showed that within about one year single *T. cristatus* can migrate over much larger distances than those observed in this study (Kupfer, 1998). With the present limitation of battery life, the task of collecting radio-tracking data of large-bodied newts after summer would require that animals be caught and tagged during their terrestrial phase. The data from the present study are not sufficient for the designation of a general terrestrial buffer zone encompassing the space required over all life stages (cf. Semlitsch, 1998).

Owing to successional processes and the relatively small size of typical amphibian ponds, many such ponds are short-lived on an ecological timescale. The colonisation of newly-formed breeding sites, in combination with abandonment of sites that become unsuitable, is a major component of amphibian population dynamics. The importance of hedgerows as corridors in the "bocage" landscape typical of western France is well documented (for example carabid beetles: Burel, 1989), and, being among the preferred habitat types (Jehle & Arntzen, 2000), it is very likely that they also serve as main corridors for dispersal of large-bodied newts. However, a study on *T. cristatus* in England revealed a preference for deciduous woodlands (Latham, Oldham, Stevenson, Duff, Franklin & Head, 1996), whereas in Mayenne a local expansion of the species' distribution was associated with the removal of shrubs and small woodlands (Arntzen & Wallis, 1991); this suggests that habitat preferences may vary across the species' range. The multiple functions and the varying quality of different types of hedgerow as lifelines between populations of mammals has been demonstrated (Bennett, Henein & Merriam, 1994), but the role of hedgerow quality for connecting newt breeding sites is not yet quantified.

That European newts return to their breeding ponds after being translocated has been documented before (Joly & Miaud, 1993), but according to the best of my knowledge this is the first study to show that they also return to particular areas on land. Translocated newts moved away from their ponds in very similar directions to those of their initial emigration. Although none of the newts used exactly the same refuge again, that might have been due in part to disturbance associated with recovering the newt prior to translocation. Separate observations have indicated that when newts were translocated to different terrestrial habitats they subsequently moved only short distances (<5 m) and in no particular direction (unpublished data). Apparently, they were disorientated when translocated to an unknown site, as observed by Madison & Farrand (1998) with translocated, radio-tracked *Ambystoma tigrinum*. The question of whether newts become disorientated through massive alterations of the terrestrial area around established breeding ponds, for example due to urban development, is still open.

Personal observation suggested that ample refuges were available to the newts in my study area; this implies a social behavioural mechanism behind the frequent detection of several newts sharing a refuge. The basis of such behaviour in *T. cristatus* has been addressed by Hayward *et al.* (2000), but its implications have not been investigated in the context of alteration of habitat or translocation of animals to make way for roads or other developments.

ACKNOWLEDGEMENTS

This study was financed by the Austrian Science Foundation (FWF grant P-11852 BIO to W. Hödl), and conducted under the permits 97/204 & 98/226/AUT of the Ministère de l'Environment, Paris. The Austrian Academy of Sciences (KIÖS) provided additional transmitters. Thanks are due to M. Sztatecsny for help in the field, D. Bardou for hospitality, and the landowners for access to their property. Pim Arntzen initiated my work in Mayenne, and his suggestions significantly improved a previous draft of the manuscript. Critical remarks by C. Cummins and three anonymous reviewers helped to avoid unwarranted conclusions.

REFERENCES

Arntzen, J. W. & Wallis, G. (1991). Restricted gene flow in a moving hybrid zone of newts (*Triturus cristatus* and *T. marmoratus*) in western France. *Evolution* **45**, 805-826.

Batschelet, E. (1981). *Circular Statistics in Biology*. London: Academic Press.

Beebee, T. J. C. (1997). Changes in dewpond numbers and amphibian diversity over 20 years on chalk downland in Sussex, England. *Biol. Cons.* **81**, 215-219.

Bennett, A. F., Henein, K. & Merriam, G. (1994). Corridor use and the elements of corridor quality: chipmunks and fencerows in a farmland mosaic. *Biol. Cons.* **68**, 155-156.

Bouton, N. (1986). Données sur la migration de *Triturus cristatus* et *T. marmoratus* (Urodela, Salamandridae) dans le Département de la Mayenne (France). *Bull. Soc. Herp. Fr.* **40**, 43-51.

Burel, F. (1989). Landscape-structure effects on carabid spatial patterns in western France. *Landscape Ecology* **2**, 215-226.

Dodd, C. K. & Cade, B. S. (1998). Movement patterns and the conservation of amphibians breeding in small, temporary wetlands. *Cons. Biol.* **12**, 331-339.

Gent, A. & Bray, R. (Eds., 1994). *Conservation and management of great crested newts.* English Nature Science Report No. **20**. Peterborough: English Nature.

Griffiths, R. A. (1996). *Newts and Salamanders of Europe.* London: T. & A. D. Poyser.

Griffiths, R. A. & Mylotte, V. J. (1987). Microhabitat selection and feeding relations of smooth and warty newts, *Triturus vulgaris* and *T. cristatus*, at an upland pond in mid-Wales. *Holarct. Ecol.* **10**, 1-7.

Hanski, I. & Gilpin, M. E. (Eds., 1997). *Metapopulation Biology: Ecology, Genetics, and Evolution.* San Diego: Academic Press.

Hayward, R., Oldham, R. S., Watt, P. J. & Head, S. M. (2000). Dispersion patterns of young great crested newts (*Triturus cristatus*). *Herpetol. J.* **10**, 129-136.

Hitchings, S. P. & Beebee, T. J. C. (1997). Genetic substructuring as a result of barriers to gene flow in urban *Rana temporaria* (common frog) populations: implications for biodiversity conservation. *Heredity* **79**, 117-127.

Hitchings, S. P. & Beebee, T. J. C. (1998). Loss of genetic diversity and fitness in common toad (*Bufo bufo*) populations isolated by inimical habitat. *J. Evol. Biol.* **11**, 269-283.

Jehle, R., Pauli-Thonke, A., Tamnig, J. & Hödl, W. (1997). Phänologie und Wanderaktivität des Donaukammmolches (*Triturus dobrogicus*) an einem Gewässer auf der Wiener Donauinsel). In *Populationsbiologie von Amphibien: eine Langzeitstudie auf der Wiener Donauinsel*, 119-132. Hödl, W., Jehle, R., & Gollmann, G. (Eds.) Linz: Stapfia 51.

Jehle, R. & Arntzen, J. W. (2000). Post-breeding migrations of newts with contrasting ecological requirements. *J. Zool., Lond.* **251**, 297-306.

Joly, P. & Miaud, C. (1993). How does a newt find its pond? The role of chemical cues in migrating newts (*Triturus alpestris*). *Ecol. Ethol. Evol.* **5**, 447-455.

Kupfer, A. (1998). Wanderstrecken einzelner Kammolche (*Triturus cristatus*) in einem Agrarlebensraum. *Zeitschrift für Feldherpetologie* **5**, 238-242.

Latham, D. M., Oldham, R. S., Stevenson, M. J., Duff, R., Franklin, P. & Head, S. M. (1996). Woodland management and the conservation of the great crested newt (*Triturus cristatus*). *Aspects of Applied Biology* **44**, 451-459.

Lovei, G. L., Stringer, I. A. N., Devine, C. D. & Cartellieri, M. (1997). Harmonic Radar – a method using inexpensive tags to study invertebrate movement on land. *New Zealand J. Ecol.* **21**, 187-193.

Madison, D. (1997). The emigration of radio-implanted spotted salamanders, *Ambystoma maculatum*. *J. Herpetol.* **31**, 542-551.

Madison, D. M. & Farrand III, L. (1998). Habitat use during breeding and emigration in radio-implanted tiger salamanders, *Ambystoma tigrinum*. *Copeia* **1998**, 402-410.

Semlitsch, R. D. (1998). Biological delineation of terrestrial buffer zones for pond-breeding salamanders. *Cons. Biol.* **12**, 1113-1119.

Verrell, P. A. & Halliday, T. R. (1985). The population dynamics of the crested newt *Triturus cristatus* at a pond in southern England. *Holarct. Ecol.* **8**, 151-156.

White, G. C. & Garrott, R. A. (1990). *Analysis of Wildlife Radio-Tracking Data.* San Diego: Academic Press.

Accepted: 24.8.00