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Breeding dynamics of Triturus carnifex at a pond in northwestern Italy (Amphibia, Urodela, Salamandridae)

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A population of the Italian crested newt (*Triturus carnifex*) was studied in 1984 at a pond near Druento (Turin, Piedmont, northwestern Italy). Animals entering and leaving the pond fell into paired pit-fall traps during both spring and autumn migrations. A positive correlation found between rainfall and migration, a shortening of migration periods and summer inactivity suggest that, in the Mediterranean region, air moisture may be a limiting factor for newt activity. During their aquatic period adults showed strong individual differences in weight changes that cannot be explained on the basis of initial body weight or length. High variability in crested newt life history traits may be the result of repeated bottlenecks caused by environmental stress and high population isolation.

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Introduction

The *Triturus cristatus* complex is a group of four species: *T.cristatus* (Northern and Central Europe), *T.karelinii* (Greece to Iran), *T. dobrogicus* (Austria to Romania) and *T. carnifex* (Italy), with a broad geographic range (Bucci-Innocenti et al. 1983, Frost 1985). Knowledge of their population structure and dynamics is based mainly on studies done in regions with cold, humid climates (Walther and Lieth 1960), such as England (Bell 1979, Verrell and Halliday 1985), Sweden (Hagström 1979) and West Germany (Glandt 1978, Blab and Blab 1981). These studies suggested that breeding dynamics in this species are highly variable, both between populations and years. Adults may stay in the water all summer to breed and/or to feed, and they can also migrate to the pond a second time in the autumn.

The relevance of temperature in controlling reproductive pattern (cycle and physiology), migration and gametogenesis of newts has been shown previously (Verrell and Halliday 1985, Mazzi 1970, Malacarne et al. 1982), but no evidence has yet been obtained on humidity affecting newt reproductive activity. However, it is likely that if cold is the major factor causing discontinuity in activity at northern latitudes, periods of dry and hot weather might play an important role in the Mediterranean region. Apart from having an influence on the seasonal activity cycle, climate may affect various life-history traits, such as developmental time and larval body size (Berven and Gill 1983), survivorship of amphibian larvae, age at sexual maturity, reproductive effort (Duellman and Trueb 1986) and longevity (Caetano et al. 1985). To analyse these aspects of crested newt population structure and dynamics, we studied a population of *T. carnifex* at Druento (Turin, northwestern Italy) which is characterized by a warmer climate than northern Europe.

Materials and Methods

Study site

The local climate is classified as mediterranean with winter rains (IV(6)1 by Walther and Lieth 1960), with rainfall maxima in May (mean = 113 mm) and Novem-

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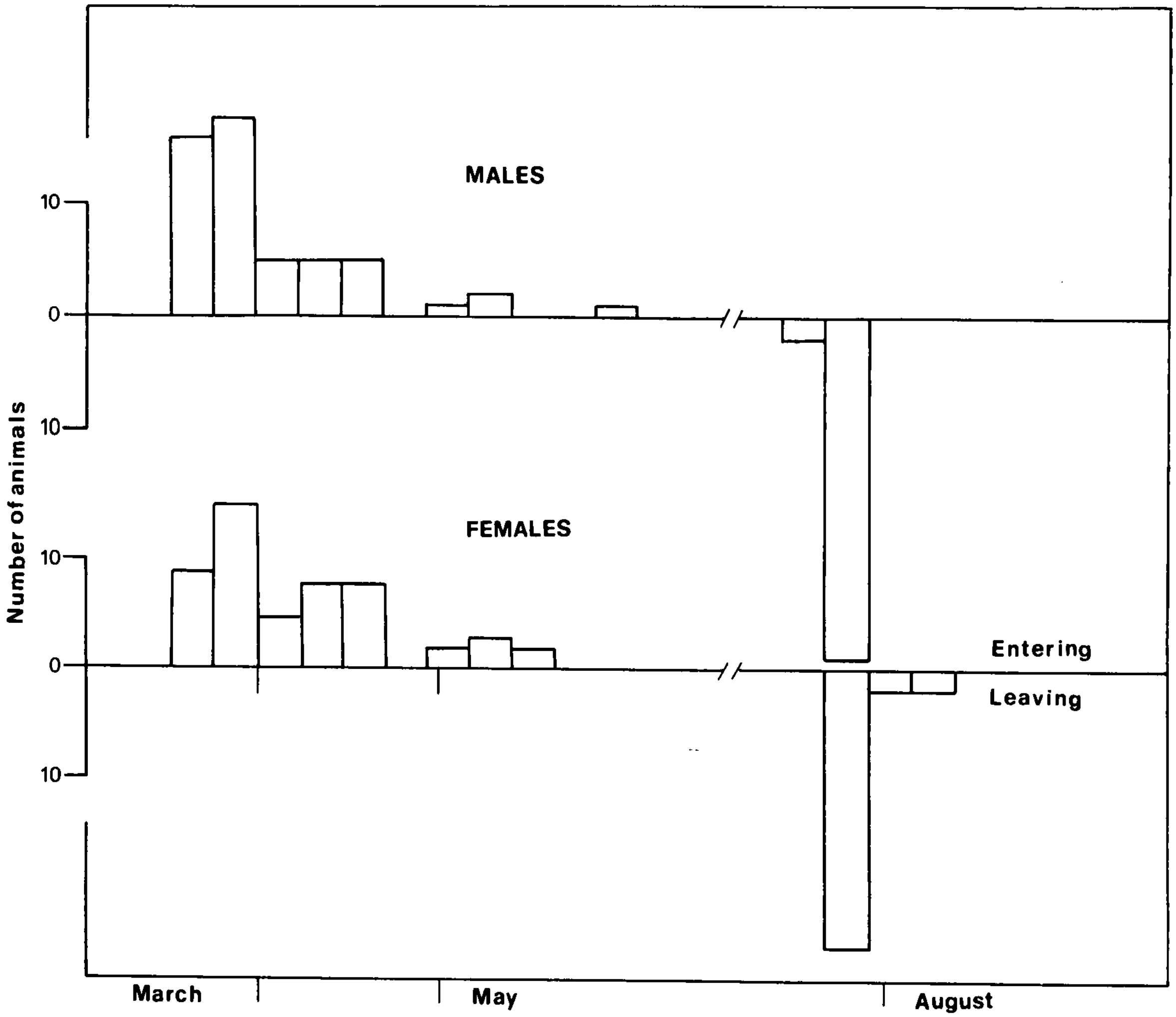

Fig. 1. The numbers of male and female crested newts (*Triturus carnifex*) entering and leaving the pond during different weeks in 1984. Animals entering are shown by histograms above each line, those leaving below.

ber (mean = 79 mm). Minima occur in January (mean = 32 mm) and July (mean = 60 mm) (Perosino 1987).

The pond has a surface area of just under 700 m^2, a maximum depth of about 1 m, and the only source of water to the pond comes from rainfall. It normal dries up during the summer. From spring 1984 the pond was surrounded by a clear polyethylene fence, with plastic pit-fall traps on both sides of the fence at about 4 m intervals, depending on topography (Gibbons and Semlitsch 1982). The fence was 50 cm high and buried to about 10–15 cm deep. Unfortunately, the conditions at the site prevented a complete encirclement of the pond as part of the perimeter was covered by shrubs and trees. Fence and pitfalls were therefore only intended to sample the population as newts entered and left the pond, and not to achieve total capture. The pitfalls and the ground between the pond edge and the inside of the fence were checked daily from February to November.

After collection, each specimen was anesthaetized by immersion in 0.1% MS 222 Sandoz solution, and marked by toe-clipping. The belly pattern was recorded and/or animals were autotransplanted for individual recognition (Andreone 1986, Ferner 1979, Hagström 1973, Rafiński 1977). The sex of each newt was recorded, together with its snout-vent length (SVL = from the snout to the posterior edge of the cloaca to the nearest mm) and weight (to the nearest 0.5 g).

Maximum and minimum air temperatures were recorded daily, together with general weather conditions (i.e. if it had rained or not, etc.). Animals were then released onto the side of the barrier opposite to that on which they were caught.

Results

Spring immigration

A total of 53 males, 51 females and one juvenile were captured while entering the pond in spring. The first crested newts were caught outside the fence on 18

Tab. 1. Mean lengths and mean weights (± standard deviation) for both sexes at different times of the breeding season. Sample sizes, given in parentheses, refer to all newts caught, both marked and unmarked. Males and females of all periods differ significantly in length and weight (Student's t test: $p \leq 0.05$).

	Immigrating in spring	Emigrating
Male length (mm)	70.3±3.8 (50)	71.4±3.2 (50)
Female length (mm)	73.4±4.8 (51)	73.1±4.5 (39)
Male weight (g)	6.9±1.3 (50)	6.8±1.2 (50)
Female weight (g)	8.9±2.0 (51)	8.0±1.7 (39)

March, 15 days after the fence was put in place. Most newts (64% of immigrants) were caught after a rainy or a mild day, when minimum temperature approached 5°C.

As shown in Fig. 1, most adults (87% of entering animals) went into the pond before the 20 April. Only one juvenile (49 mm SVL) was captured on 5 May. In this population juveniles (recognized by their smaller dimensions and lack of sexual secondary characters) had a bright yellow stripe along the middle of the back.

Females were significantly longer and heavier than males. No correlation was observed for either sex between arrival date and SVL, weight, length/weight ratios (Spearman's r correlation test). During the first two weeks of migration males were more numerous than females. The sex ratio among immigrants and residents within the pond evened out on the third week and became female biased afterwards.

Emigration

A total of 50 males and 39 females was captured while leaving the pond from 19 July to 5 August (Fig. 1). Once more the sex ratio was male-biased at the beginning of migration, and females were significantly larger than males (Tab. 1).

Fourteen males and nine females (43% of the leaving animals) were marked. Four males and two females were recaptured in the autumn (Tabs. 2 and 3). Males recaptured in summer spent from 97 to 126 d (mean stay of 116 d ± 9.4 SD) in water: the sooner they entered, the longer they stayed (Spearman's $r = 0.997$, $p < 0.001$). No correlation was found between body length or weight and the length of the aquatic period. The females spent 79 to 124 d in the pond (mean stay of 99 d ± 17.2 SD). Males thus spent a longer time in the water than females (Student's $t = 3.98$, $p = 0.007$) as found by Hagström (1979). The only juvenile recaptured was caught in the autumn after a period of 168 d.

During the aquatic phase three males and two females gained weight but the majority of individuals maintained the same weight or lost weight (Tabs. 2 and 3). These individual differences were not related to initial body weight, length, or the ratio of body weight to length; no statistically significant correlation was found between these variables.

Tab. 2. Dates of capture, recapture (months indicated by roman numeral) and number of days spent in water for males of *Triturus carnifex*. Each specimen was recognized by individual marking. W1 = Weight (in g) at first capture; W2 = Weight (in g) at recapture; W2–W1 = Weight difference (in g). The dates with "*" refer to animals caught during the period of autumnal migration. The male with "‡" is the same one that was captured on 29 March and recaptured on 24 July.

Entering	W1	Leaving	W2	Days in pond	(W2-W1)
21 III	7	26 VII	8	126	+1
25 III	5	26 VII	5	122	0
26 III	6	26 VII	8	121	+1
26 III	5	26 VII	5	121	0
27 III	8	28 VII	6	122	−2
29 III	8	28 VII	9	120	+1
29 III	7	24 VII	6	116	−1
1 IV	7	25 VII	6	114	−1
13 IV	6	25 VII	6	102	0
18 IV	6	25 VII	6	97	0
21 III	7	30 IX *	7	192	0
28 III	7	2 X *	7	187	0
17 IV	8	1 X *	8	166	0
29 III ‡	7	5 X *	9	170	+2

Autumnal migration

Specimens were found both on the outside and on the inside of the fence between 20 September and 14 November. The 15 males and 10 females caught showed incompletely developed secondary sexual characters. Seven out of thirteen juveniles captured in 1984 were caught during the autumn. Juvenile body length ranged from 31 – 45 mm.

Tab. 3 Dates of capture, recapture and time spent in water for females of *Triturus carnifex*. All the parameters are as reported in Tab. 2.

Entering	W1	Leaving	W2	Permanence	(W2-W1)
21 III	10	25 VII	9	124	−1
29 III	6	26 VII	6	118	0
14 IV	10	26 VII	10	102	0
18 IV	9	24 VII	10	97	+1
19 IV	9	27 VII	9	88	0
3 V	10	26 VII	10	83	0
6 V	8	25 VII	9	79	+1
16 IV	11	20 IX *	10	156	−1
12 IV	9	22 IX *	10	162	+1

Discussion

Migration and sex ratio

In the Druento population most adults entered the pond in one month and left it during a 2-wk period at the end of July. In Northern Europe both the spring immigration and emigration periods last longer: the former from February to May and the latter from July to October (Blab and Blab 1981, Verrell and Halliday 1985).

In this population the earlier the adults entered the pond, the longer they stayed. There was no evidence that individuals shifted between a terrestrial and an aquatic stage during the breeding season, or that the terrestrial habitat was preferred to the aquatic one as has been recorded for a population in Sweden (Hagström 1979).

No newt movements were recorded during the hottest period, between 5 August and 19 September.

Data on *T. cristatus* in northern Europe suggest that a threshold temperature of about 0°C (Harrison et al. 1983) or lower exists, above which the newts are active. Newts have been observed migrating when thick snow is still on the ground. Our data on *T. carnifex* suggest a higher threshold of 4°C, the same temperature reported by Verrell and Halliday (1985) for *T. cristatus*. The only other data concerning the Italian species were reported by Galgano (1944) who observed that Italian crested newts greatly decreased their activity when temperature was below 6°C.

Relationships between humidity and amphibian activity are not as clear. A positive relationship has been reported by Blanchard (1930), Galgano (1944) and Smith (1969). In contrast, Verrell and Halliday (1985) in *T. cristatus* and Harrison et al. (1983) in *Triturus vulgaris* and *Triturus helveticus* found no evidence that humidity influenced newt activity during breeding migrations. In our study we observed a positive correlation between rainfall in the 24 h before we inspected the traps and the number of newts captured. We suggest that humidity may play a different role depending on climate: in Mediterranean countries humidity may be a limiting factor for amphibian movements, and this may explain why rainfall tends to be correlated with amphibian activity (Diaz-Paniagua 1980). In other countries, however, where humidity levels are high enough for amphibian movement to occur at all times, no relationship between humidity and activity level exists (i.e. oceanic and temperate areas).

At Druento pond, males tended to arrive before females, and the autumn sample was also male-biased. The final sex ratio of the breeding population was 1:0.75 (males:females). Sex ratios of breeding populations range from an excess of males (Hagström 1979, Giacoma 1988) to an excess of females (Bell 1979) or to a 1:1 ratio (Feldmann 1975, Glandt 1978, Hagström 1979, Verrell and Halliday 1985).

The migration of juveniles to water has been recorded both for *T. carnifex* (Galgano 1944) and *T. cristatus* (Bell 1979, Glandt 1978, Verrell and Halliday 1985). The frequency of migrating juveniles does not seem to be a species-specific characteristic as it varies widely both among localities and years, from zero to a maximum of 71% of all aquatic individuals (Bell 1979). In our study a higher percentage of juveniles (22%) was found among autumn migrants than among spring immigrants (1%) or aquatic newts (5%), which is the same pattern reported by Galgano (1944).

Size structure

The percentage of recaptures (49%) was high enough to allow further examination of the data. Females were significantly longer and heavier than males: this dimorphism has been shown in some but not all populations studied (Grönlund and Säterberg 1984, Giacoma 1988).

In a population studied in England, autumn *T. cristatus* migrants had an intermediate length, suggesting that they may have been about to breed for the first time (Verrell and Halliday 1985). At Druento pond autumn *T. carnifex* migrants did not differ significantly in length from the spring immigrants.

Juveniles, which ranged from 32–68 mm long, were clearly distinguishable based on morphology. Bell (1979) found that juveniles ranged from 39 mm to approximately 60 mm, while shorter ones (40–50 mm) were recorded at Yrrel pond (Verrell and Halliday 1985).

One of the most interesting aspects of the population concerned weight changes during the breeding season. Previous studies of *T. cristatus* have indicated that the aquatic habitat may provide a rich environment where both juveniles and mature males gain weight whereas females do not as they lay eggs (Verrell and Halliday 1985). In contrast, Grönlund and Säterberg (1984), working on the same species did not observe such an increase. These different results may reflect variations in the biogenic capacity of the environment (Joly 1986).

In our population of *T. carnifex* not all individuals increased in weight during their time in the pond. These individual differences may result from different feeding strategies. In the alpine newt (*T. alpestris*) Chacornac and Joly (1985) observed a plasticity in foraging (depending on availability) and individual specialization. In our case there was no correlation between either length of time spent in water or initial weight, and weight gain, suggesting that individual differences in feeding strategies might result in different weight changes.

Conclusions

Studies of the Italian crested newt (*T. carnifex*) population structure and dynamics carried out at a climatically marginal area of the wide latitudinal and altitudinal range of the *T. cristatus* complex, highlight the complex's strong potential for flexibility. The positive correlation found between rainfall and migration contrasts with findings on a population of *T. cristatus* from southern England (Verrell and Halliday 1985). These data together with the shortening of migration periods and the summer inactivity, suggest that in the Mediterranean region air moisture may be a limiting factor for newt activity.

Moreover, all species of crested newt seem to be characterized by high variability in some aspects of population structure, such as sex-ratio, % of juveniles and presence/absence of sexual dimorphism (weight). This may be the result of repeated bottlenecks caused by periods of predictable ecological stress related to the highly variable and unpredictable aquatic environment. Furthermore, ponds, like lakes or mountaintops, may be viewed as continental islands (Brown 1971, Browne 1981). Isolation among populations resulted in substantial genetic differences among local populations (Kalezić 1985); it may be increased by the strong philopatry shown by adults to a single breeding site (Joly and Miaud, pers. comm.). Adult philopatry is one possible cause of the interaction between newts' high potential for flexibility and predictable periods of environmental stress and may result in a highly variable of lifecycle and population structure traits.

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