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THE DISTRIBUTION AND BREEDING SITE CHARACTERISTICS OF NEWTS IN CUMBRIA, ENGLAND

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ABSTRACT

The distribution and breeding site characteristics of the smooth newt, *Triturus vulgaris*, the palmate newt, *T. helveticus* and the warty newt, *T. cristatus* were investigated in Cumbria. *T. helveticus* was the commonest species on the acidic rocks in the Lake District, but was not found in limestone areas. *T. cristatus* was seldom found without the commoner *T. vulgaris*, and there was no evidence of the former preferring larger, deeper ponds than the latter.

T. vulgaris and *T. cristatus*, unlike *T. helveticus* were rarely found in water with pH<6. *T. vulgaris* was usually found in water relatively rich in metal ions, while the reverse was true for *T. helveticus.*

Newts were found in ponds in a wide variety of terrestrial habitats, but most often in rough pasture land.

INTRODUCTION

Three species of newt occur in Britain, the smooth newt (*Triturus vulgaris*) the palmate newt (*T. helveticus*) and warty newt (*T. cristatus*). Studies of newt breeding site characteristics have indicated certain differences in the ponds chosen by the different species. Cooke and Frazer (1976) found that the smooth newt tended to be found in water with relatively high concentrations of metals, while the reverse was true for the palmate newt. Yalden (1986) noted that in the Peak district newts showed a distinct geographical separation between the species. *T. vulgaris* and *T. cristatus* occurred mainly on the carboniferous limestone in ponds of pH>7.0, while *T. helveticus* was mainly found on the millstone grit and shales in more acid ponds of pH<7.0. Other studies (Beebee, 1977, 1981, Green, 1984) have indicated the importance of certain terrestrial habitat types around newt ponds, notably the presence of dense vegetation.

The county of Cumbria provides an ideal area in which to examine these ideas. The varied geology and diversity of land use provide study ponds on acid and basic rocks in a variety of habitat types. Such a survey also provided an opportunity to assess the status and prospects of amphibians in an area with relatively few records (Arnold, 1973).

METHODS

During the summer of 1986 a survey of 235 ponds in the county of Cumbria was undertaken. All previously recorded *T. cristatus* sites were visited. Other ponds noted on 1:25000 scale Ordnance survey maps were chosen in an attempt to find sites on many different habitat types and geological substrates in order to determine any associations between them and use by newts. However the survey cover above 350m was limited because of the difficulties of access.

Each of these selected sites was sampled to determine which species were present. All sites were netted and the length of time devoted to each site was related to its size, so larger sites took longer to investigate satisfactorily. Any amphibians seen in and around the ponds were noted. The surface area, maximum depth, and amount of shading were noted. The presence of fish and other likely predator species was also recorded. All the sites containing newts were subject to further analysis. The elevation of each pond was taken from Ordnance Survey maps. The geology of the pond site was also ascribed using 1:50000 drift geology maps with local in-field differences noted.

The terrestrial habitat types found within 100m of the ponds containing newts were identified and the areas taken up by each type estimated using 1:25000 maps and infield observations. Any habitat type occupying >50 per cent of the total was considered to be dominant.

49 of the 166 sites containing amphibians were investigated in more detail. Newts were sampled by 15-minute pond netting; the percentage of open water (i.e. that not covered by algae or weed) was also estimated. Water samples were taken from each pond, pH was measured with a PYE UNICAM PW 9418 metre and the samples were also analysed for Sodium, Potassium and Calcium content using a Corning 400 flame photometer. Water hardness was also measured, 50ml of the water sample were titrated with 0.01m hydrochloric acid, using methyl orange and phenolphthalein indicators. Alkalinity and hardness was expressed as mg/l $CaCO3$.

RESULTS

Fig. 1A-1C show the distribution of the three newt species, *Triturus vulgaris* was the most widespread newt species. The common frog (*Rana temporaria*) was however the commonest amphibian, occurring in 57 per cent of all sites (see Table 1).

Species	*No. of ponds used*	*% of ponds used*
Rana temporaria	133	57
Bufo bufo	40	17
Triturus vulgaris	56	24
Triturus helveticus	31	14
Triturus cristatus	32	15

TABLE 1: The number and percentage of ponds occupied by amphibians in a survey of 235 ponds.

The percentage of sites containing *T. cristatus* is likely to be overestimated, mainly because previously recorded sites were visited. The comparative figure for the random search phase revealed the species in 7 per cent of all ponds. *T. helveticus* was less common than *T. vulgaris*, but this may be due to the small number of ponds sampled on high fells.

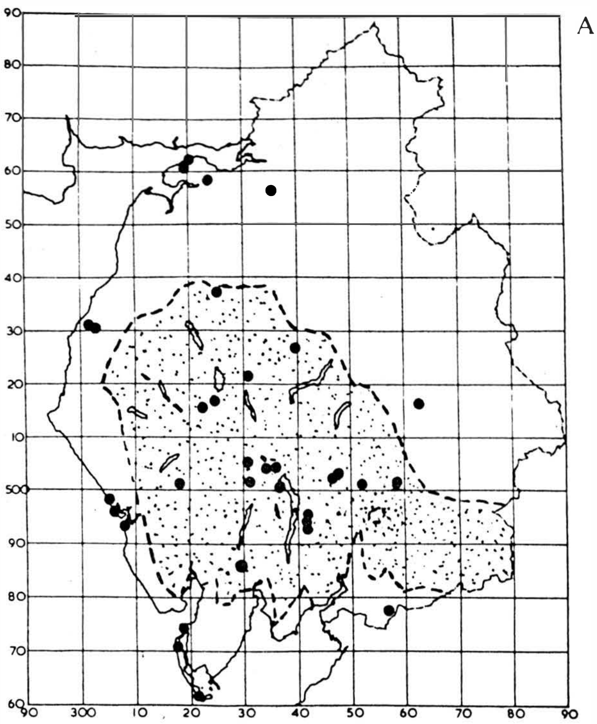
Only 8 sites contained all three newt species, but all the *T. cristatus* sites contained at least one other newt species. It was found with *T. vulgaris* in 30 of 32 ponds, confirming the similarity in their national distribution (Arnold, 1973).

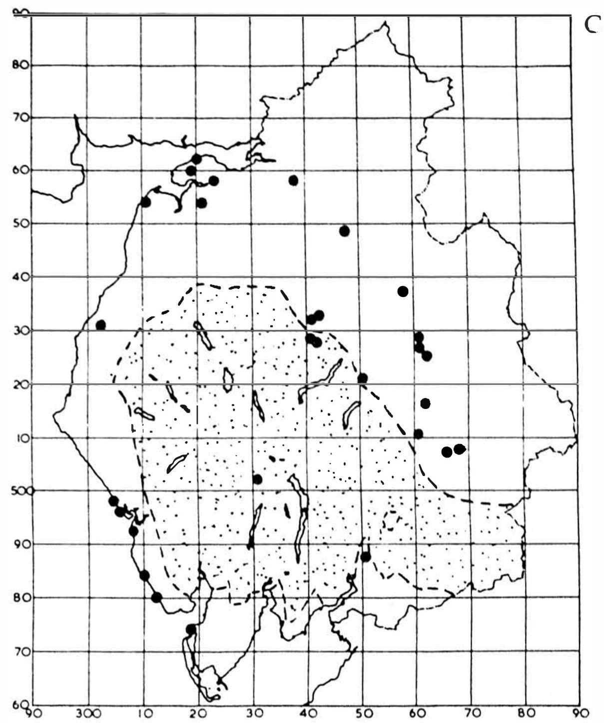
Only two sites were found to contain both *T. cristatus* and *T. helveticus* without *T. vulgaris*, a species combination which appears to be rare nationally. Only two sites were found to contain all five species of amphibian.

57 of the 235 sites contained at least one fish species, but only 23 of the 166 amphibian sites contained fish, a significant difference ($X^2 = 4.8$, df = 1, $p<0.05$). Of these only seven had newts, all of which were *T. vulgaris*.

		T. cristatus	*T. vulgaris*	*T. helveticus*
Elevation	Mean	114m	122m	155m
	range	8-310m	8-310m	10-506m
Surface area	mean	910m^2	1,400m^2	460m^2
	range	12-10000m^2	12-15000m^2	10-5000m^2
Maximum depth	mean	0.68m	0.87m	0.55m
	range	0.2-1.5m	0.2-2.5m	0.2-1.5m
% Open water	mean	47%	53%	49%
	range	2-98%	2-98%	5-90%

TABLE 2: Physical characteristics of all newt breeding sites.





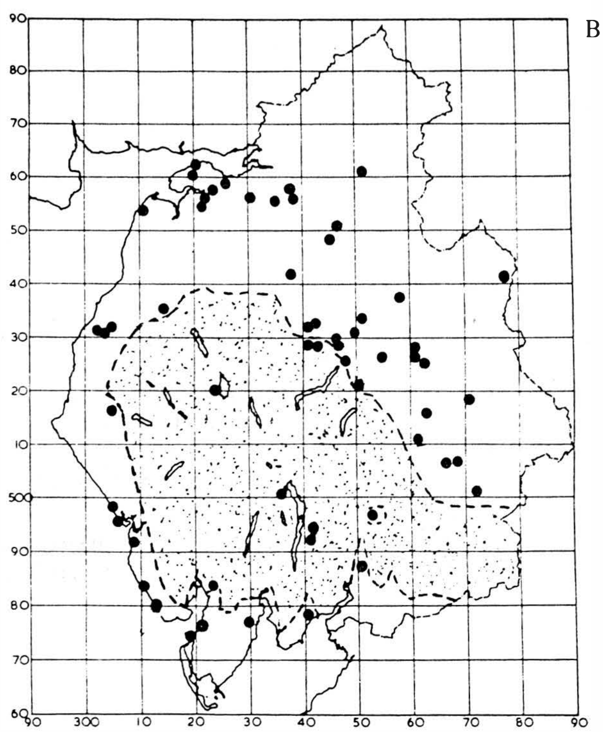


Fig. 1 The distribution of newts in Cumbria.
A. *Triturus helveticus*, B. *Triturus vulgaris*, C. *Triturus cristatus*. Stippled area = Extent of acidic metamorphic and igneous rocks. Scale is shown by 10km squares.

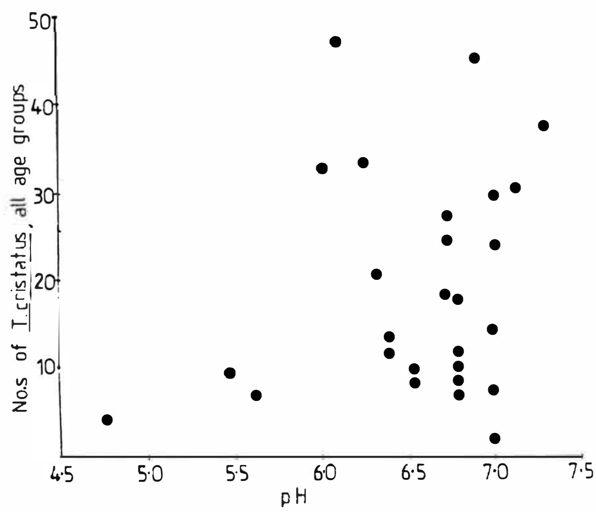


Fig. 2 The relationship between pH and numbers of *T. cristatus* in Cumbrian ponds.

The physical characteristics of the newt breeding sites is summarised in Table 2. There were no significant relationships between newts and elevation. *T. helveticus* had the highest mean for elevation and occurred in the highest site at 506m. The surface area and maximum depth of *T. cristatus* ponds was on average smaller than for *T. vulgaris* sites, but greater than *T. helveticus* ponds.

There was a significant negative correlation between the numbers of *T. cristatus* and *T. vulgaris* and the extent of open water, $r = -0.353$ and -0.421 respectively ($p<0.05$ in both cases). There were no significant relationships between newts and maximum depths.

T. helveticus occurred in 20 ponds on the Skiddaw slates/Borrowdale volcanic groups. Only 4 of these sites contained other newts, three with *T. vulgaris* and one with *T. cristatus*. The opposite was the case on Carboniferous strata, where 18 ponds contained *T. vulgaris*, only one of which had *T. helveticus*.

Factor range	Sodium (mg/l) <8.5	Sodium (mg/l) >8.5	Potassium (mg/l) <1	Potassium (mg/l) >1	Calcium (mg/l) <15	Calcium (mg/l) >15	pH <6.7	pH >6.7	CaCO3 (mg/l) <70	CaCO3 (mg/l) >70
No. of sites	24	25	24	25	25	24	24	25	25	24
T. helveticus sites	10	9	13	6	14	5	12	7	16	3
T. vulgaris sites	16	21	13	24	13	24	15	22	13	24
T. cristatus sites	12	15	9	18	12	15	11	16	10	17
T. helveticus only	8	4	11	1	10	2	8	4	11	1
T. vulgaris only	14	16	10	20	10	20	12	18	10	20

TABLE 3: Chemical characteristics of newt ponds

T. cristatus was found in 11 sites on Carboniferous limestone, all of which contained *T. vulgaris*. *T. helveticus* was not found on limestone, but did occur with *T. vulgaris* on sandstones, till and sand dunes.

Data from the 49 chemically-analysed sites are summarised in Table 3. In order to test for any site preferences, the chemical factors were studied one by one and the median value was taken so as to divide the sites into two groups of as near equal size as possible. Thus for sodium the median value was 8.5 mg/l, which divided the sites into two groups of 24 and 25.

There were no significant relationships between newts and sodium levels. However, the mean sodium level for *T. helveticus* was lower than that for the other species.

T. helveticus was associated with <15mg/l Calcium ($X^2 = 6.05$, d.f. = 1, $p<0.05$), and Hardness ($X^2 = 10.1$, d.f. = 1, $p<0.001$), and showed significant negative correlation with hardness ($r = -0.564$, $p<0.05$) which accounted for 32 per cent of the variation in numbers of newts. *T. vulgaris* conversely was associated with >15mg/l Calcium ($X_2 = 6.63$, df = 1, $p>0.05$).

Dominant habitat type	% of newt sites dominated by habitat type: *T. cristatus*	*T. helveticus*	*T. vulgaris*
Pasture farm land	28%	26%	33%
Arable farm land	0	0	0
Conifer woodland	6%	3%	0
Deciduous woodland	3%	0	6%
Mixed wood	0	0	0
Gardens and Buildings	3%	3%	7.4%
Scrub	16%	10%	7.4%
Marsh	13%	10%	17%
Moorland/Heath	9%	20%	11%
Sand dunes (grazed)	19%	23%	9.3%
Bare rock	3%	3%	5.5%

TABLE 4: Terrestrial habitats: dominant type around newt ponds

Habitat type	% of newt sites with habitat type: *T. cristatus*	*T. helveticus*	*T. vulgaris*
Pasture farm land	64%	41%	87%
Arable farm land	3.5%	0	8%
Coniferous woodland	14%	9%	13%
Deciduous woodland	14%	9%	21%
Mixed woodland	14%	0	15.3%
Gardens and buildings	15%	9%	31%
Scrub	39%	27%	51%
Marsh	36%	32%	39%
Moorland/Heath	46%	64%	51%
Sand dunes (grazed)	21%	23%	15%
Bare rock	7.1%	14%	15%

TABLE 5: Terrestrial habitats frequency around newt ponds.

T. helveticus was also associated with <1mg/l Potassium (X^2 = 5.24, d.f. = 1, $p<0.05$). *T. vulgaris* preferred >1mg/l Potassium, (X^2 = 8.4, d.f. = 1, $p<0.05$).

12 of the 19 *T. helveticus* sites had pH<6.7 while *T. vulgaris* was found in 15 sites with pH<6.7 and 22 with pH>6.7. The ponds containing only *T. helveticus* showed a greater tendency to have lower levels of metal concentrations and pH than sites with only *T. vulgaris*. Sites with both species had more intermediate levels of metals and pH. The mean pH for *T. helveticus* sites was 6.3, that for the other two species was 6.6. The relationship between pH and numbers of *T. cristatus* is shown in Fig. 2. The three sites with pH<6.0 had relatively small populations. Both *T. vulgaris* and *T. cristatus* were found much less often than expected by chance at pH<6 (X^2 = 68.4, and X^2 = 69 respectively, both df = 1, $p<0.0001$).

Terrestrial Habitat

A wide range of habitat types were encountered around newt breeding ponds. In all, 11 categories were represented, see Tables 4 and 5.

A scrub area was found around 43 per cent of all newt breeding sites and 39 per cent of *T. cristatus* sites had a scrub component. Woodland was found within 100m of 31 per cent of all newt sites, but was rarely the dominant habitat. Only one *T. helveticus* site and three *T. cristatus* sites were dominated by woodland. A marsh habitat was found around 33 per cent of all newt ponds, with a similar percentage for each species.

All three species were found in garden ponds. *T. cristatus* was found at one site with *T. vulgaris*, and *T. helveticus* occurred in a garden pool adjacent to open moorland. This species was not found in sites with an arable land component, and no newt sites were encountered where arable land was dominant. Conversely pasture farmland was the most common habitat type, being dominant around >25 per cent of all newt sites.

64 per cent of *T. helveticus* sites had some heath/moorland habitat and this was dominant around 6 ponds. Less than 11 per cent of the ponds containing the other species were dominated by moorland but ponds with large populations of *T. cristatus* and *T. vulgaris* were encountered on open moorland without any form of scrub or woodland within 1km.

DISCUSSION

The *T. cristatus* data do not support the view that the species prefers larger deeper ponds than does *T. vulgaris* (Cooke and Frazer, 1976). In fact *T. vulgaris* was more often found in larger sites, the largest of which also contained fish. Whether such sites would be suitable for *T. cristatus* if fish were absent is not known, but similar ponds in other studies contained large populations (Green, 1984). The mean surface area of *T. cristatus* ponds in this study was 910m². In Durham, Green (1984) found this species in sites up to 12,000m² in area, and only 7 of 46 sites were <100m². Beebee (1977) and Durkin and Cooke (1984) also thought the importance of deep sites for *T. cristatus* was overstated.

Newt breeding ponds occurred in a wide range of habitats, including gardens. Scrub and woodland components seemed to be important. Beebee (1977) found that *T. cristatus* was only found in significant numbers on Downland in ponds with a large scrub area nearby. Nevertheless in this study, large newt populations were encountered on open moorland several kilometres away from any scrub or woodland. However, frogs and toads were often absent from such sites, possibly indicating a difference in habitat. Rough pasture seems to be more suitable for amphibans than arable fields (Beebee, 1981, Green, 1984) but newts can utilise arable land adjacent to other habitats (Cooke, 1986).

The distribution of newts on the various geological strata in the north of England indicate some preferences which are likely to be associated with water quality. *T. vulgaris* and *T. helveticus* rarely occurred together in Cumbria, but in Northumbria, Durkin and Cooke (1984) found them together in 27 of 31 sites. They suggested this was related to the water being of intermediate quality in terms of pH, hardness and metal content.

T. helveticus can survive in ponds low in nutrients, and such sites are common in the Lake District. This may explain why Smith (1964) thought *T. helveticus* was a montane species. However the absence of *T. helveticus* from the Pennines (an upland area with hard water) supports the view taken by Cooke and Ferguson (1975) that the association was chemical rather than physical.

As in this study, Cooke and Frazer (1976) and Beebee (1983) found that *T. vulgaris* and *T. cristatus* were less common in ponds with pH<6. Cooke and Frazer (1976) suggested that embryonic *T. vulgaris* may be unable to survive at pH<6. However Dolmen (1980) found *T. vulgaris* breeding ponds in Norway with pH values below 6 (down to 4.5) during the period of egg and larval development.

T. vulgaris occurred in ponds with low potassium (<1mg/l) only when calcium levels exceeded 6mg/l. *T. helveticus* occurred in 6 sites with potassium and calcium concentrations below these levels. Cooke and Frazer (1976) found only two *T. vulgaris*, and 14 *T. helveticus* ponds with <6mg/l calcium. *T. vulgaris* can survive in ponds if either calcium or potassium, or both are present in high concentrations. Conversely *T. helveticus* can breed in ponds deficient in both these metals, and rarely occurs if calcium levels exceed 20mg/l. Research into the effects of different concentrations of metal ions on immature stages of newt development may well reveal the reasons for the differences in survivorship, which ultimately influence species distribution.

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PARTITIONING OF WATER WITHIN THE ALLIGATOR (*ALLIGATOR MISSISSIPPIENSIS*) EGG AFTER 60 DAYS OF INCUBATION

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ABSTRACT

Eggs of *Alligator mississippiensis* were incubated up to day 60 of incubation under either dry conditions (on metal shelves, without a substrate) or wet conditions (on vermiculite). Incubation temperatures were 30°C and 33°C. Eggs on the shelves lost water during incubation; water loss from eggs on vermiculite was small, and in some cases, negligible. On day 60, after incubation at 30°C, eggs incubated on shelves had significantly less amniotic fluid and yolk sac than eggs incubated on vermiculite. In eggs incubated at 33°C, on day 60 amniotic fluid was absent and the mass of the yolk sac was smaller in eggs incubated under dry conditions. Embryo mass and the amount of allantoic fluid were unaffected by the extent of water loss from the eggs at both temperatures. The mass of allantoic fluid was correlated with the mass of the egg on day 60. Yolk sac mass at both temperatures was not correlated with egg mass on day 60 but was correlated with the water lost from the egg. These results suggest that (1) in alligator eggs, loss of water is borne primarily by the yolk sac; and (2) that retention of water in the allantois may be associated with a need to prevent a deleterious build-up of waste metabolites. This contrasts with the situation in avian eggs where water loss is borne primarily by the allantois and embryonic tissues.

INTRODUCTION

Water loss from avian eggs is a normal part of incubation (Ar and Rahn, 1980). This progressive dessication affects differentially the water content of individual compartments within the egg as incubation proceeds. The allantoic fluid shows the first signs of dehydration. When this compartment is exhausted the volume of amniotic fluid declines (Hoyt, 1979; Simkiss, 1980; Tullett and Burton, 1982). When all of these fluid reserves are exhausted, near the end of incubation, it is the embryonic tissues which become dehydrated (Hoyt, 1979; Tullett and Burton, 1982; Davis and Ackerman, 1987; Davis, Shen and Ackerman, 1988). The yolk sac, by contrast, is unaffected by dehydration (Hoyt, 1979; Tullett and Burton, 1982).

The water relations of reptilian eggs are highly variable and are dependent upon species, eggshell structure and hydration of the incubation substrate (Packard and Packard, 1980, 1984; Packard, Packard and Boardman, 1982; Packard, 1991). Soft-shelled eggs of squamates absorb large amounts of water during incubation but where the shell structure is more complex, as in pliable-shelled turtle eggs, the exchange of water with the nesting substrate is reduced. Eggs of other turtles and crocodilians which have rigid eggshells often exhibit no net water exchange during natural incubation (Ferguson, 1985; Packard, 1991). In addition, all reptilian eggs incubated on substrates with low water potentials, which still have humidities greater than 99 per cent (Tracy, Packard and Packard, 1978), can lose water during incubation when compared with substrates with higher water potentials.