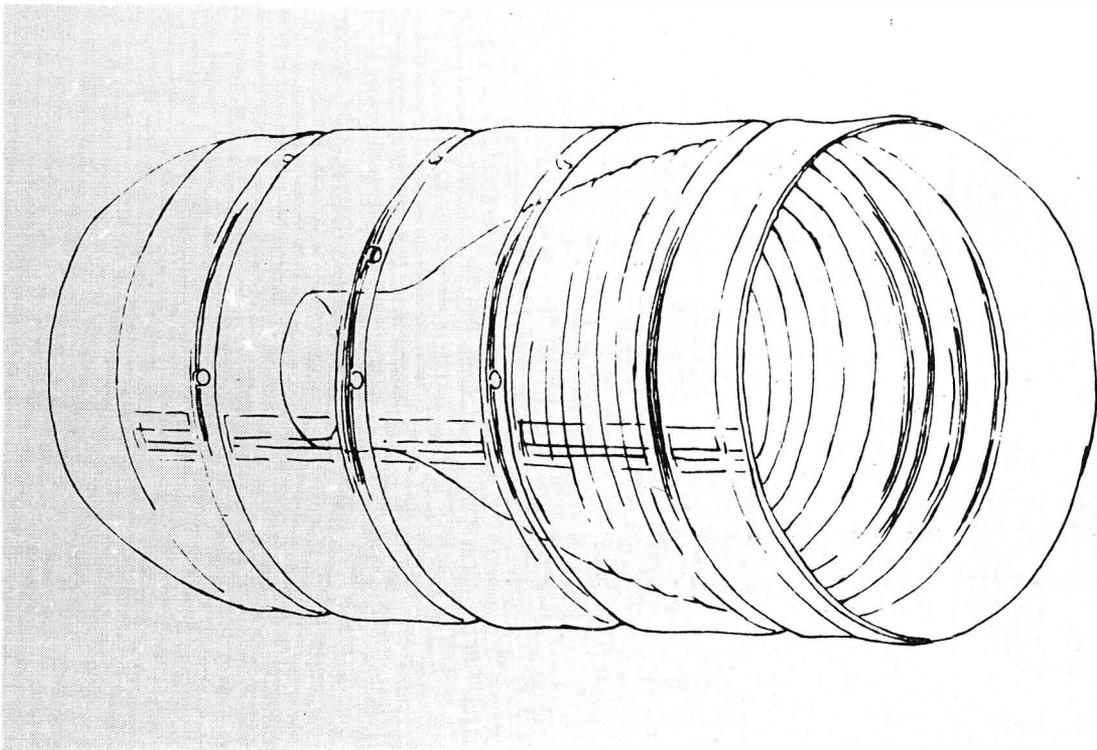


Volume 1, Number 1

December 1985

ISSN 0268-0130

# THE HERPETOLOGICAL JOURNAL



FORMERLY THE *BRITISH JOURNAL OF HERPETOLOGY*

Published by  
THE BRITISH HERPETOLOGICAL SOCIETY

Indexed in  
*Current Contents*

*The Herpetological Journal* is published by the British Herpetological Society and edited on behalf of the Society by Dr. T. J. C. Beebee.

The Journal is published twice a year and is issued free to members. Applications to purchase copies and/or for details of membership should be made to the Hon. Secretary, British Herpetological Society, Zoological Society of London, Regents Park, London NW1 4RY, U.K.

Instructions to authors are printed inside the back cover. Contributions should be addressed to the editor, Dr. T. J. C. Beebee, School of Biology, University of Sussex, Falmer, Brighton BN1 9QG, U.K.

### Copyright

It is a fundamental condition that submitted manuscripts have not been published and will not be simultaneously submitted or published elsewhere. By submitting a manuscript, the authors agree that the copyright for their article is transferred to the publisher if and when the article is accepted for publication. The copyright covers the exclusive rights to reproduce and distribute the article, including reprints and photographic reproductions. Permission for any such activities must be sought in advance from the editor.

## ANNOUNCEMENTS

### OPINIONS FROM THE INTERNATIONAL COMMISSION ON ZOOLOGICAL NOMENCLATURE.

The following opinions of relevance to herpetology were published in the *Bulletin of Zoological Nomenclature*, Vol. 42, Part 2 (June 1985):

- (i) TEIIDAE Gray, 1827, given nomenclatural precedence over AMEIVIDAE Fitzinger, 1826 (Reptilia, Sauria).
- (ii) *Geomyda* Gray, 1834 and *Rhinoclemmys* Fitzinger, 1835 conserved (Reptilia, Testudines).
- (iii) *Testudo Scripta* Schoepff, 1792 and *Emys Cataspila* Günther, 1885 conserved (Reptilia, Testudines).
- (iv) *Lacerta velox* Pallas, 1771 is the type species of *Eremias* Wiegmann, 1834 (Reptilia).
- (v) *Diademon* Seeley, 1894 and *Diademon tetragonus* Seeley, 1894 conserved by the suppression of *Cynochampsia* Owen, 1859 and *Cynochampsia Laniania* Owen, 1859 (Reptilia, Therapsida).

# THE HERPETOLOGICAL JOURNAL

Volume 1, Number 1

December 1985

## CONTENTS

### *Full Papers*

- Palmate newts (*Triturus helveticus*) on the Island of Rhum R. V. COLLIER 1
- A simple funnel trap for studying newt populations and an evaluation of trap behaviour in smooth and palmate newts *Triturus vulgaris* and *T. helveticus* R. A. GRIFFITHS 5
- Diel patterns of movement and aggregation in tadpoles of the common frog, *Rana temporaria* R. A. GRIFFITHS 10
- Salt tolerances of natterjack toad (*Bufo calamita*) eggs and larvae from coastal and inland populations in Britain T. J. C. BEEBEE 14
- An identification key to the geckos of the Seychelles, with brief notes on their distribution A. S. GARDNER 17
- Size increase in the common toad *Bufo Bufo* from Cheshire C. P. WHEATER 20
- Agama gracilimembris* chabanaud, 1918 (Reptilia: Sauria: Agamidae) in Nigeria M. E. GARTSHORE 23
- Herpetofauna of the late pleistocene fissures near Ightham, Kent J. A. HOLMAN 26
- Seasonal changes in metabolism of the lizard *Lacerta vivipara* M. K. AL-SADOON & I. F. SPELLERBERG 32
- Short Notes*
- Optimal temperature for inner-ear performance agrees with field body temperature in *Phelsuma* (Reptilia: Gekkoninae) Y. L. WERNER 36
- The calcium cycle of female day-geckos (*Phelsuma*) A. S. GARDNER 37
- Getting into a pickle with preserved specimens: formalin and distortion in the smooth newt, *Triturus vulgaris* P. A. VERRELL 39

# THE HERPETOLOGICAL JOURNAL

## INSTRUCTIONS TO AUTHORS

1. The *Herpetological Journal* publishes original articles, short notes and mini-reviews on all aspects of herpetology. Faunistic lists and letters are not published. Short notes should include a single data set. Mini-reviews will in general be solicited by the editor, who should in any case be consulted before such a review is written.
2. Two copies of papers and illustrations should be sent to the Editor.
3. Papers should be concise with the minimum number of tables and illustrations. They should be written in English and spelling should be that of the *Oxford English Dictionary*. Papers should be typed or produced on a good-quality word processor, and double-spaced with wide margins all round. Good quality paper is essential for the top copy. Except for short notes, papers should be divided into sections. The first sub-head will be centred in capitals, the second shouldered in lower case, and the third run on in italics. Footnotes are not permitted.
4. For all papers the title should be followed by the name(s) of the author(s) and the address or name of the Institution in which the work was done. For major papers a short abstract is required before the body of the paper. Acknowledgements should be included before the list of references.
5. The usual rules of zoological nomenclature apply.
6. Tables are numbered in arabic numerals, e.g. Table 1; they should be typed on separate sheets and divided by horizontal lines.
7. Line drawings and half-tones are numbered in sequence in arabic numerals, e.g. Fig. 1. If an illustration has more than one part each should be identified as (a), (b), etc. The orientation and name of the first author should be indicated on the back. They should be supplied for uniform reduction by one-half on A4 size paper to fully occupy the width of the paper. Drawings should be in Indian ink on good quality tracing material, Bristol board or faintly *blue*-lined graph paper; photographic prints may be submitted. For half-tones high quality glossy prints are required. All labelling should be applied to illustrations using stencils or transfers. A metric scale must be inserted in micrographs, etc.: a figure for magnification in the legend is not acceptable. Legends for illustrations should be typed on separate sheets.
8. References in the text should be given as in the following examples: Smith (1964) stated . . . , observed by Smith (1964s, b). Smith & Ones (1963). For three or more authors, the complete reference should be given at the first mention, e.g. (Smith, Jones & Brown, 1972), and *et al.* used thereafter (Smith *et al.*, 1972). For the list of references *the full title or standard abbreviations of the journal must be given*. The following examples will serve to illustrate the style and presentation used by the Journal.
  - Bellairs, A. d'A. (1957). *Reptiles*. London: Hutchinson.
  - Boycott, B. B. & Robins, M. W. (1961). The care of young red-eared terrapins (*Pseudemys scripta elegans*) in the laboratory. *British Journal of Herpetology* **2**, 206-210.
  - Dunson, W. A. (1969a). Reptilian salt glands. In *Exocrine glands*, 83-101. Botelho, S. Y., Brooks, F. P. and Shelley, W. B. (Eds). Philadelphia: University of Pennsylvania Press.
  - Dunson, W. A. (1969b). Electrolyte excretion by the salt gland of the Galapagos marine iguana. *American J. Physiol.* **216**, 995-1002.
9. Final acceptance of a paper will depend upon the production by the author of a typescript and illustrations ready for the press. However, every assistance will be given to amateur herpetologists to prepare papers for publication.
10. Proofs should be returned to the Editor by return post. Alterations must be kept to the correction of errors; more extensive alterations will be charged to the author.
11. 25 offprints are provided free of charge. Further copies (minimum of twenty-five) may be purchased provided that they are ordered at the time the proofs are returned.

## PALMATE NEWTS (*TRITURUS HELVETICUS*) ON THE ISLAND OF RHUM

R. V. COLLIER

*Nature Conservancy Council, Inverness IV2 4AG, UK*

*(Accepted 23.8.84)*

### ABSTRACT

Two populations of palmate newts were studied on the Island of Rhum in terms of biometrics, colour form, behaviour, predation and site characteristics. Measurements were compared with data from other workers in different parts of Britain.

### INTRODUCTION

The Island of Rhum is one of the larger islands (10,684 hectares) of the Inner Hebrides and lies fifteen miles due west of Mallaig in Invernessshire (Grid. Ref. NM 365980). It was recommended as a Nature Conservation Area by the Scottish Wildlife Conservation Committee in 1949 under Command 7814 which stated "isolated, yet within easy reach of the mainland, it would make an outstanding station for research and indeed is the most suitable island for this purpose in Scotland".

Rhum was acquired by the Nature Conservancy by purchase and declared a National Nature Reserve in 1957. Since then a considerable amount of habitat management, research and interpretation has taken place. On the research side many groups have been studied such as birds (Love 1980), Lepidoptera (Wormell 1962) and red deer (Clutton-Brock 1981). However very few observations have been carried out on newts (*Triturus* sp) and the Nature Conservancy Council's Handbook (1974) states:

"Palmate Newt (*Triturus helveticus*). Abundant, particularly in the northern half of the island. Very common in the breeding season in lochans and pools which do not contain trout. Found up to 2,200 ft on Hallival. Although the smooth newt (*T. vulgaris*) was reported on one occasion there has been no sign of its occurrence since, despite special search; a mis-identification is suspected."

The comment concerning the occurrence of smooth newts has been supported by further observation since 1974. The broad statement concerning the distribution of palmate newts and trout must be treated with caution. At Loch Sgaorishal, one of the sites covered by the present study, both brown trout (*Salmo trutta*) and palmate newts are common.

The island is ideal for newts with numerous water bodies exhibiting a wide range of characteristics. It is likely that most water bodies contain palmate newts and relative to the mainland there are few predators of even fewer species.

### METHODS

In the week beginning 12th July 1982 observations were carried out on two population of palmate newts, one at Loch Sgaorishal (Grid Ref. NG 349022) and the other at Harris Pool (Grid Ref. NM 340955). The sites were 7 kilometres apart and differed in altitude by 200 metres.

At the Harris Pool sampling of adults was carried out by surveying silt and/or macrophytes using a pond net. Others were caught by hand when individuals could be seen resting in the open. Larvae were taken solely by netting in silt or macrophytes. At Loch Sgaorishal most adults were sampled by catching individuals in the hand when stones were slowly overturned. A small sample were caught by hand when seeing newts resting on top of stones or by sweeping the sparse macrophytes with a net.

Lengths of the body and the tail were taken in adults and the weight recorded using a digital balance accurate to  $\pm 0.1$  g. Before weighing, each individual was placed on the grass for a short time to dispel body moisture. The belly pattern of each individual was recorded under three categories, namely without markings, with dots or blotches.

Particular site characteristics were noted including size of water body, pH, and altitude. Notes and observations were made of the behaviour patterns of the two populations.

### SITE CHARACTERISTICS

Loch Sgaorishal is set in a hollow on open moorland with some shelter from the surrounding topography. It lies at an altitude of 225 m and is 1,300 metres from the sea.

Maximum length:	400 metres
Maximum width:	210 metres
Maximum depth of water:	unknown, exceeds 2 metres
Maximum depth of silt:	unknown, at margins less than 15 cms

pH: 5.5

Most margins are stony with small angular stones <15.0 cm across overlain by larger stones generally <35.0 cm across. Occasional margins of silt are present with very few of the smaller type angular stones.

Vegetation: macrophytes are infrequent with large areas devoid of plants.

<i>Lobelia dortmana</i>	— occasional
<i>Sparganium angustifolium</i>	— rare
<i>Myriophyllum alterniflorum</i>	— occasional
<i>Potamogeton natans</i>	— rare

A very small inlet at one end of the loch has an abundance of *Potamogeton natans* and *Nymphaea alba*.

Harris Pool is set in grassland immediately behind a storm beach at the lower end of Glen Harris. It lies at an altitude of 75 ft and is 200 metres from the sea.

Maximum length:	96 metres
Maximum width:	15.5 metres
Maximum depth of water:	24 cms
Maximum depth of silt:	39 cms
pH:	5.5

Silt is dominant but in a few areas well rounded stones less than 30.0 cms in diameter are scattered. The pool is frequently used by Highland cattle to drink from and wade out into to avoid flies.

There is no doubt that at certain periods and times of the year the site is subjected to a certain amount of salinity. The author has seen westerly gales sending spray that drenches the site. However during the period of this study titration tests revealed no salinity. It would seem that water run off and precipitation counteracts salinity for most of the year.

Vegetation: macrophytes are frequent with scattered emergents covering about 50 per cent of the water surface. These include:

<i>Juncus articulatus</i>	— frequent
<i>Juncus effusus</i>	— frequent
<i>Sparganium</i> sp	— rare
<i>Eleocharis acicularis</i>	— dominant

Occasional floating and submergent species include *Ranunculus aquatilis*, *Menyanthes trifoliata*, *Carex acuta* and rare species are *Potamogeton acutifolius* and *Utricularia minor*.

## RESULTS

### SIZE AND COLOUR

Data on body length and tail length of males and females were compared between the two sites using the Mann-Whitney U test. There was no significant differences between the two data sets at the 95 per cent confidence limit. (See Table 1). Therefore the data were combined.

Data for total length of males and females were compared for each site, again using the Mann-Whitney U test. Males were significantly shorter in both cases at the 99.99 per cent confidence limit. In the case of Harris Pool, males weighed significantly less than females again at the 99.99 per cent confidence limit. (See Table 1)

	Loch Sgaorishal		Harris Pool	
	Males	Females	Males	Females
Total length				
Mean	66.82	73.68	64.43	74.22
S.D.	±3.93	±3.93	±4.92	±7.25
Body Length				
Mean	36.23	39.57	36.64	40.11
S.D.	±1.79	±3.4	±1.93	±2.71
Tail Length				
Mean	30.64	34.04	27.86	34.80
S.D.	±2.23	±3.67	±3.81	±3.62

TABLE 1: Newt sizes

Table 2 indicates the number of individuals under the three categories of belly pattern. Use of the  $\chi^2$  statistic revealed that there was no significant difference at the 95 per cent confidence level between the presence and absence of markings at the two sites. However, a similar analysis showed that the form of marking, i.e. whether dots or blotches was significantly different at the 98 per cent confidence level. The population at Loch Sgaorishal had a predominance of individuals with dots.

	Pool	
	Sgaorishal	Harris
Without marking	10	16
With dots	31	18
With blotches	9	16
Without markings	10	16
With marking	40	34

TABLE 2: Newt markings

### BEHAVIOUR PATTERNS

The two populations showed differing behaviour patterns that are probably related to differing habitats and predation levels.

#### (1) Adults

Loch Sgaorishal: Adult newts generally hid under larger stones overlying smaller stones. On disturbance they either swam quickly to the underside of other large stones or dived between smaller stones. Reaction was generally instantaneous and purposeful. A few individuals were seen in the open on top of larger stones but on disturbance these swam quickly under stones. Most individuals were solitary with two newts rarely found under the same stone.

Harris Pool: Far more adults seen in the open — up to 50 per cent of adults caught. Visible adults were normally resting on top of the fine silt, sometimes associated with macrophytes sometimes not. On disturbance they would dive into the silt and disappear from view. Generally this rapid movement was into silt at the base of macrophytes such as *Eleocharis acicularis* to seek shelter. If away from macrophytes however the newts would dive into the silt.

(2) Larvae

Loch Sgaorishal: Very few larvae were seen and all were under large or small stones.

Harris Pool: All the larvae were caught from silt and/or macrophytes by netting. Considerable numbers were seen and in optimum areas up to twenty individuals were taken with one sweep of the net.

On disturbance or handling the larva curled its body round in a similar behaviour pattern to *Zygoptera* nymphs and lay motionless for a short period.

PREDATION

Predators of palmate newts are generally numerous. Smith (1951) lists aquatic birds, snakes, fish, hedgehogs, stoats, weasels and rats. However, relatively few of these predators are present on Rhum. There are no snakes, hedgehogs, stoats or weasels. Brown rats (*Rattus norvegicus*) are present and birds include heron (*Ardea cinerea*) and red-throated diver (*Gavia stellata*). The brown trout (*Salmo trutta*) is common throughout the lochs on the island whilst the three-spined stickleback (*Gasterosteus aculeatus*) is very localised. The differing behaviour between the two populations may be related to the level and type of predation. Adult newts are much more obvious in the Harris Pool as they lie on the top of the silt. In this water body there are no brown trout or sticklebacks and no red-throated divers. At Loch Sgaorishal the

DISCUSSION

Boulenger (1894) gives the measurements of the palmate newts he found in Cornwall. Evans (1894) gives similar data for specimens collected around Edinburgh and Bell (1966) from Leicestershire sites. These data are compared with Rhum as shown in Table 3.

Creed (1964) considered that in adult newts, body length exceeds tail length, however Smith (1954) thought the opposite. Bell (1966) stated that for most adult newts in his Leicestershire sample the length of the body exceeded the length of the tail. From a sample of 38 females and 11 males the percentages were 98 per cent and 100 per cent respectively. This study found from the sample of 36 males and 64 females that all except one female had body length longer than tail. One individual had body and tail measurement the same.

Creed (1964) gives a short series of weights for palmate newts in the New Forest, males 1.5-2.1g and females 2.1-2.4g. Bell (1966) gives data from a larger sample (16 females and 20 males). The lightness of individuals and the percentage water problem is difficult to overcome accurately. However, Bell's figures are compared with Rhum (sample of 13 males and seven females) in Table 4.

	Cornwall (Boulenger 1894)		Edinburgh* (Evans 1894)		Leicestershire (Bell 1966)		Rhum	
	Male	Female	Male	Female	Male	Female	Male	Female
Total length (mm)								
Maximum	80	85	83	88	140	90	76	87
Mean	—	—	75.2	79.7	69.3	76.1	66	71
Head and body length (mm)								
Maximum	36	42	38	43	—	—	41	46
Mean	—	—	35	38	—	—	36	39.8
Tail length (mm)								
Maximum	44	43	45	45	—	—	41	34
Mean			40	41	—	—	30	33

\*Evans included caudal filament that can vary from 2-7 mm in adult males (Bell 1966).

TABLE 3: Newt Size Comparison

brown trout is frequent (at least up to 1 kg in weight) and red-throated divers are common. Herons occasionally visit both sites and brown rats are present.

*Odonata*, whose nymphs will feed on newt larvae, are present at both sites but to varying degrees of numbers and species. At Loch Sgaorishal the numbers and species are low with only two species of *Zygoptera*, namely *Enallagma cyathigerum* and *Pyrrosoma nymphula*. In contrast, at Harris Pool there are four species of *Zygoptera*, *Enallagma cyathigerum*, *Pyrrosoma nymphula*, *Lestes sponsa* and *Ishmura elegans* and also, three species of *Anisoptera*, *Sympetrum danae*, *Sympetrum nigrescens* and *Libellula quadrimaculata*.

At Loch Sgaorishal six adult newts were found dead under stones but no reason for death was established. The only limb/tail damage from the specimens handled was a small end section of a tail of one adult and similar damage of one larva.

		Leicestershire	Rhum
Females	Mean	3.7	2.0
	Max	5.5	2.5
	Min	2.0	1.5
Males	Mean	2.2	1.4
	Max	3.5	1.7
	Min	1.0	1.1

Weights are in grammes

TABLE 4: Newt Weight Comparisons

## CONCLUSIONS

Comparable data on biometrics between populations of palmate newts in different parts of Britain indicate that the island populations of Rhum have a shorter mean total length than those found in Cornwall by Evans (1894) or in Leicestershire by Bell (1966). Males were shorter than females in the Rhum populations which is supported by Evans (1894) but the converse is true in Bell (1966). In 98 per cent of the total sample on Rhum the head and body length was longer than the tail length. This is supported by Creed (1964) and Bell (1966) but not by Smith (1954).

Bell's (1966) data indicate that males are heavier than females. The converse is true for those newts sampled on Rhum. However, values lie in the same range as those given by Creed (1964).

Colour and pattern of belly markings varied between the two sites on Rhum. Although the presence or absence of markings did not differ significantly the form of pattern was distinctive with three dominant groups.

The behaviour of newts differed between the two Rhum colonies and can be related to varying site characteristics and also possibly to predation levels. Predation is lower on Rhum than on mainland Britain in terms of numbers of predators and species.

## ACKNOWLEDGEMENTS

I would like to record my thanks to Lee Collier for his invaluable assistance with the fieldwork, Dr. A. S. Cooke for his comments and criticism on the first draft of this paper and to Norwich College for assistance in weighing newts.

## REFERENCES

- Bell, G. A. C. (1966). The size of a series of Leicestershire Newts. *British Journal of Herpetology* **3**, 279-284.
- Boulenger, G. A. (1894). Size of British Newts. *Zoologist* **52**, 145-47.
- Clutton-Brock, T. H., Guinness, F. E. and Albon, S. A. (1982). Red Deer: The Behaviour and Ecology of 2 Sexes. *Chicago University Press*.
- Creed, K. (1964). A Study of Newts in the New Forest. *British Journal of Herpetology* **3**, 170-81.
- Evans, W. (1894). On the Reptiles and Batrachians of the Edinburgh District. *Proceedings of the Physiological Society of Edinburgh* **12**, 490-526.
- Love, J. A. (1980). Bird Watching on Rhum. *Scottish Birds* **71(2)**, 48-51.
- Nature Conservancy Council (1974). Isle of Rhum. Reserve Handbook. *N.C.C. Internal Document*.
- Smith, M. (1964). The British Amphibians and Reptiles. Collins. *New Naturalist*.
- Wormell, P. (1982). Entomology of the Isle of Rhum. *Journal of the Linnean Society* **18**, 291-401.

## A SIMPLE FUNNEL TRAP FOR STUDYING NEWT POPULATIONS AND AN EVALUATION OF TRAP BEHAVIOUR IN SMOOTH AND PALMATE NEWTS, *TRITURUS VULGARIS* AND *T. HELVETICUS*

R. A. GRIFFITHS

*Department of Applied Biology, UWIST, Llysdyman Field Centre, Newbridge-on-Wye, Llandrindod Wells, Powys, Wales*

(Accepted 4.9.84)

### ABSTRACT

A simple funnel trap constructed from a plastic squash bottle is described. The efficiency of trapping compared to netting and torch-surveying was investigated in *Triturus vulgaris* and *T. helveticus*. In terms of newts detected per man-hour, trapping and torch-surveying were about twice as effective as netting, but produced male biases in both species. Male smooth newts were more trap-prone than male palmates. Traps containing a newt were no more or less attractive to other newts than empty traps. Newts with previous experience of a trap were no more or less trappable than those without trap experience.

### INTRODUCTION

Methods for studying populations of aquatic newts (*Triturus* spp) have, in the main, employed netting, torch-survey or trapping techniques. Dip-netting from the pond bank is probably the most widely used method and can be standardized if carried out for a set period of time or using a set number of sweeps (e.g. Cooke and Frazer, 1976; Cooke, Scorgie and Brown, 1980). It suffers from the disadvantage, however, of causing disturbance to both animals and vegetation and is of little use in attempting to assess distribution patterns within the water column. Searching pond edges after dark by torch-light is often a reliable method for revealing the presence or absence of newts (e.g. Frazer, 1978; Beebee, 1979; Griffiths, 1984), and may be semi-quantitative if search effort per stretch of pond bank is standardized. However, identification in poor light of newt species and sex, often at a distance of a metre or so, generally requires some expertise on the part of the observer. Moreover, this method is of little use in ponds which are steep-sided, turbid or with luxuriant stands of marginal vegetation.

Funnel traps have been used by a number of authors in previous studies of newt ecology (e.g. van Gelder, 1973; Bell, 1977; Dolmen, 1983). A number of different designs have been employed, including bownets (van Gelder, 1973) and fry traps (Dolmen, 1983). Inasmuch as the method requires newts to enter traps of their own accord, trapping is more dependent upon newt behaviour than either netting or torch-survey methods. Animals may become trap-shy or trap-prone, and differences in behaviour at both sex and species levels may therefore result in catch biases which can complicate studies of population ecology.

This paper describes a cheap, simple funnel trap which has been used extensively in ecological studies of newts (*T. vulgaris* and *T. helveticus*) in mid-Wales. Natural trappability in smooth and palmate newts and the effects of previous trap experience on trap behaviour were investigated experimentally under field and laboratory conditions.

### THE TRAP

Each trap was constructed from a 1 litre plastic squash bottle. The bottle was cut into two halves by a circular incision at the point where it begins to taper towards the neck. The screw-top was then cut off and the top (funnel) half inverted into the bottom half to form the trap (Fig. 1). Paper clips may be used to hold the funnel in place. A series of holes were punched into the trap to allow expulsion of air when sinking it into water. When placed in the pond, each trap was tied to a stick to prevent drifting and to mark its position.

### FIELD EXPERIMENTS

#### COMPARISON OF TRAPPING, NETTING AND TORCH-SURVEY TECHNIQUES

*Methods.* A comparison of the efficiency of these three methods in detecting newts was conducted in Llysdyman pond, Powys, in April and May 1984. A description of this site is provided by Harrison, Gittins and Slater (1983).

Commencing on the 4th April 1984, 48 funnel traps were placed in the pond at 2100 hr and emptied at 0900 hr the following morning. The traps were positioned so that all areas and depths of the pond were sampled. Around the pond margin traps were positioned so that the funnel entrance faced towards the pond centre. Areas of 0.5 m depth or over were monitored by using two or three traps suspended on a string. These were arranged so that the top trap lay just below the pond surface with the bottom trap, which was weighted, resting on the pond floor. Each 12 hr trapping programme was conducted at weekly intervals until 30th May. Due to parts of the pond drying out, the number of traps used was reduced to 36 from 16th-30th May. The total time spent placing traps out, and emptying and collecting traps, was about 45 min per week.

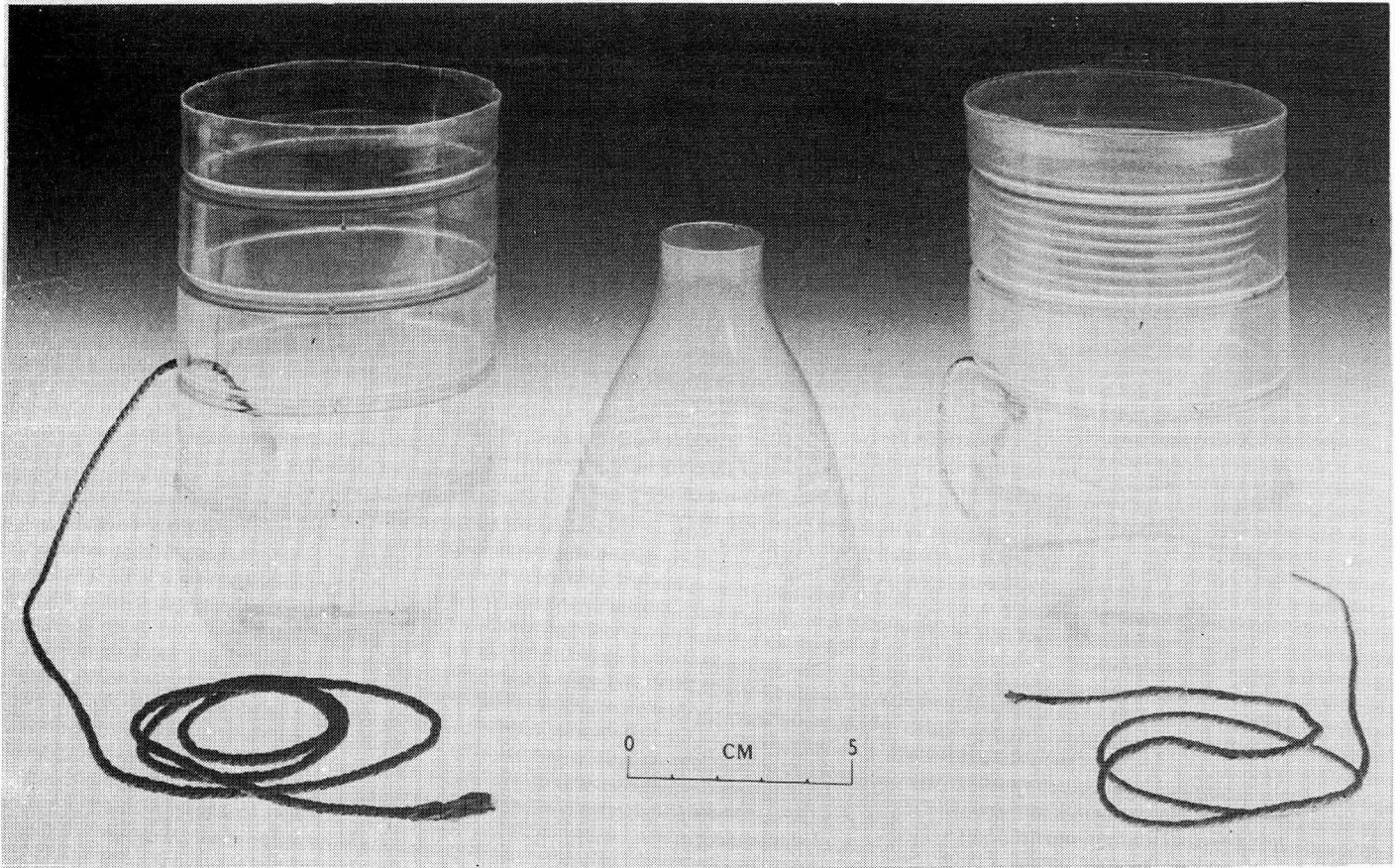


Fig. 1 The squash bottle funnel trap. Trap with funnel removed (left), and trap with funnel in place (right).

Daytime netting sessions were also carried out at weekly intervals during the two-month study period. These were usually conducted 1-2 days after trapping. Each area of the pond where traps had previously been placed was surveyed with three sweeps of a dip-net (approx. 1 mm mesh). Total netting time was about 15 min.

As a result of seasonal changes in turbidity and vegetation cover, it was not possible to carry out a reliable torch-survey on a regular basis. Data for only one evening, 24th April, is therefore included. On this date the water was clear and 30 per cent of the available shoreline was relatively free of emergent vegetation. With the aid of a powerful torch, the newts observed along this shoreline between 2030 and 2100 hr were counted and identified without removing them from water.

*Results.* With 36-48 traps, overnight trapping in April and May produced a total newt catch which was over four times as high as that obtained by netting during the same period (Table 1). A total of 2.25 hr of netting, however, produced only twice as many newts as a single 30 min torch-survey. The proportions of each species and sex captured also varied according to the method used. Thus female *T. helveticus* constituted almost 50 per cent of the newt sample captured by netting, but only about 13 per cent by trapping or torch-surveying. Likewise male *T. vulgaris* made up 30-40 per cent of the newts counted by trapping and torch-surveying, but only about 12 per cent by netting. Both trapping and torch-surveying produced more males than females in both species.

	Male <i>T. vulgaris</i>	Female <i>T. vulgaris</i>	Male <i>T. helveticus</i>	Female <i>T. helveticus</i>	Total	Newts/ Man-Hr
Trapping	184 (40.4%)	38 (8.4%)	173 (38.0%)	60 (13.2%)	455	67.4
Netting	10 (11.5%)	7 (8.0%)	28 (33.2%)	42 (48.3%)	87	38.7
Torch-Survey	12 (32.5%)	3 (8.1%)	17 (45.9%)	5 (13.5%)	37	74.0

TABLE 1. Comparison of numbers of *T. vulgaris* and *T. helveticus* detected in Llysdinam pond using three different techniques. The numbers represent total newts detected by overnight trapping (36-48 traps, 45 min to place and empty traps) and daytime netting (15 min) over nine weeks commencing first week in April 1984, and during a single 30 min torch-survey on 24th April. Figures in parentheses represent percentage of total catch using that method.

EFFECT OF TRAPPED NEWTS ON TRAP RESPONSE

*Methods.* These experiments set out to test the hypothesis that a newt already captured attracts other newts towards that trap. Two traps, one empty and one baited with 'a newt, were placed side-by-side in the pond at 2100 hr and emptied at 0900 hr the following morning. The experiment was repeated with the positions of baited and unbaited traps reversed to avoid complications arising from natural directional preferences. Four pairs of traps were used in each experiment. Four sets of experiments were conducted in two ponds, during April and May 1984, as follows: *Llysdinam Pond* (Contains both *T. vulgaris* and *T. helveticus*):

mid-Wales. In the laboratory newts were subject to natural light-dark cycles via a large window. All newts were in breeding condition and kept at a water temperature of  $14 \pm 2^\circ\text{C}$ . Experiments were conducted between April and June 1984.

EFFECT OF PREVIOUS TRAP EXPERIENCE ON TRAP RESPONSE

*Methods.* Newts were placed singly in plastic aquarium tanks (30 cm long, 22 cm wide, 20 cm deep) two-thirds filled with water. A funnel trap was then placed in each tank and the newts left for 12 hr from 0900 to 2100 hr. Those animals which entered traps during this period of time (i.e. trap-conditioned newts) were released and

	Traps baited with male	<i>T.h.</i>	Traps unbaited	Traps baited with female	<i>T.h.</i>	Traps unbaited
No. <i>T. helveticus</i> captured	10 (5:5)		24 (16:8)	29 (21:8)		20 (16:4)
$\chi^2$		5.76		1.65		
<i>P</i>		<0.025		>0.1		

TABLE 2. The influence of trapped newts on trap attractivity in Bufton's pond (*T. helveticus* only). Figures in parentheses represent *no. males: no. females*. Total no. newts in baited traps: total no. newts in unbaited traps was tested for deviation from a 1:1 result using  $\chi^2$  assuming 1 d.f. The original newt used as bait was not included in the totals.

	Traps baited with male	<i>T.v.</i>	Traps unbaited	Traps baited with female	<i>T.v.</i>	Traps unbaited
No. <i>T. vulgaris</i> captured	8 (7:1)		9 (8:1)	11 (8:3)		7 (4:3)
$\chi^2$		0.06		0.89		
<i>P</i>		>0.5		>0.1		
No. <i>T. helveticus</i> captured	22 (19:3)		18 (14:4)	10 (6:4)		6 (4:2)
$\chi^2$		0.4		1.0		
<i>P</i>		>0.5		>0.1		
Total <i>T. vulgaris</i> + <i>T. helveticus</i>	30 (26:4)		27 (22:5)	21 (14:7)		13 (8:5)
$\chi^2$		0.16		1.89		
<i>P</i>		>0.5		>0.1		

TABLE 3. The influence of trapped newts on trap attractivity in Llysdinam pond (*T. vulgaris*+*T. helveticus*). Legend as Table 2.

- (1) Trap baited with one male *T. vulgaris*.
  - (2) Trap baited with one female *T. vulgaris*.
- Bufton's Pond* (Contains *T. helveticus* only):
- (3) Trap baited with one male *T. helveticus*.
  - (4) Trap baited with one female *T. helveticus*.

*Results.* There was no evidence that a trap already containing a newt was any more attractive to other newts than an empty trap (Tables 2-3). This was the case in both smooth and palmate newts and with traps baited with males or females. In fact, in one experiment at Bufton's pond the empty trap appeared to be more attractive to palmate newts than the trap baited with a male palmate.

LABORATORY EXPERIMENTS

All smooth and palmate newts used in the following laboratory experiments were obtained from sites in

retested for a second 12 hr period from 2100 to 0900 hr. Control experiments were conducted by placing a second group of newts in tanks without traps for 12 hr (trap-unconditioned newts), and then testing their response to traps during a second 12 hr period in the same way as trap-conditioned animals. To avoid complications arising from diel changes in trap behaviour, the experiment was repeated with the conditioning period from 2100-0900 hr, and the testing period from 0900-2100 hr. A total of 32 newts were used in each experimental and control group. This number was made up of 16 *T. vulgaris* and 16 *T. helveticus*, with equal numbers of each sex.

*Results.* Newts with previous trap experience did not differ from newts lacking previous trap experience in their subsequent behaviour towards traps. In neither smooth nor palmate newts was there any significant

association between previous experience and subsequent trap behaviour (Table 4). Moreover, re-organising the data by sex rather than species also failed to reveal any such association, as did pooling data from both species and both sexes.

#### SPECIES AND SEX DIFFERENCES IN TRAP RESPONSE

*Methods.* This experiment set out to investigate differences in trap response using controlled numbers of animals in a laboratory "pond". This consisted of an opaque plastic tank (70 cm long, 50 cm wide, 23 cm deep) filled with water to a depth of 10 cm. Newts were introduced to the tank at least 12 hr before experiments commenced. Three experiments were conducted using the following combinations of animals:

- (1) 10 male + 10 female *T. vulgaris* (experiment conducted three times).
- (2) 10 male + 10 female *T. helveticus* (experiment

conducted three times).

(3) 5 male + 5 female *T. vulgaris* + 5 male + 5 female *T. helveticus* (experiment conducted 6 times).

At 1800 hr 4 traps were placed in the tank, one in each corner, all facing towards the centre. Two hours later the contents of the traps were checked. The dusk test period of 1800-2000 hr was used because both species appear to display a crepuscular activity pattern (Griffiths, unpublished).

*Results.* In both single species and mixed species experiments there were no significant differences in trappability between the sexes in either smooth or palmate newts (Table 5). Moreover, there were also no significant differences in trappability between males of the two species, or between females of the two species. The presence of the other species did not affect the trap response of either smooth or palmate newts (smooth:  $\chi^2 = 0.002$ ,  $P > 0.5$ ; palmate:  $\chi^2 = 0.94$ ,  $P > 0.1$ ).

	SMOOTH		PALMATE		MALE		FEMALE	
	prev. trapped	prev. not trapped						
No. newts in trap	11	8	11	11	9	10	13	9
No. newts out trap	5	8	5	5	7	6	3	7
$\chi^2$	1.17		0.0		0.13		2.33	
$P$	>0.1		>0.9		>0.5		>0.1	

TABLE 4. Effect of previous trap experience on trap response.  $\chi^2$  values refer to each 2x2 contingency table. Equal numbers of each sex were used in the "smooth" and "palmate" tables, and equal numbers of each species in the "male" and "female" tables. Pooling the data from both species and both sexes also failed to reveal any significant association between previous experience and subsequent behaviour ( $\chi^2 = 0.61$ ,  $P > 0.1$ ).

	<i>T. vulgaris</i>		<i>T. helveticus</i>		<i>T. vulgaris</i> + <i>T. helveticus</i>			
	male	female	male	female	male <i>T.v.</i>	female <i>T.v.</i>	male <i>T.h.</i>	female <i>T.h.</i>
Total No. newts used	30	30	30	30	30	30	30	30
Total No. newts in traps	20	18	13	12	17	15	10	16
$\chi^2$	0.11		0.04		0.12		1.38	
$P$	>0.5		>0.5		>0.5		>0.1	

TABLE 5. Species and sex differences in trap behaviour in the laboratory "pond". Scores were tested for deviation from a 1:1 result using  $\chi^2$  assuming 1 d.f. Comparing trappability of the two species: males,  $\chi^2 = 1.8$ ,  $P > 0.1$ ; females,  $\chi^2 = 0.03$ ,  $P > 0.5$  (mixed species experiment).

## DISCUSSION

In terms of newts detected per man-hour, both trapping and torch-surveying were about twice as efficient as netting in Llysdynam pond. In both *T. vulgaris* and *T. helveticus*, however, a male bias was observed using trap and torch-survey methods. Female newts may prefer well-weeded areas of the pond (Frazer, 1978; Cooke *et al.*, 1980) and consequently be under-recorded by torch-surveying. Moreover, in searching for mates, male newts may be more active than females during the breeding period and consequently enter traps more frequently. In the laboratory "pond", however, no such male bias was observed. This discrepancy may be explained by the fact that in the laboratory "pond" (which lacked vegetation and contained equal numbers of each sex) male newts did not have to search so actively to find females, and consequently a lower proportion entered traps than under natural conditions.

Bell (1977) also observed that trapping produces a male biased sex ratio in *T. vulgaris*. Assuming that netting produces an unbiased sex ratio, he proposed that trap ratios (i.e. males/total) be multiplied by 0.63 to obtain the true sex ratio. Applying this correction factor to the present trap data obtained for both *T. vulgaris* and *T. helveticus* resulted in sex ratios very close to those obtained by netting (Table 6). When only trapping is carried out, applying this correction factor to trap ratios therefore seems a reliable method of estimating the true sex ratio when the latter is unknown.

	<i>T. vulgaris</i>	<i>T. helveticus</i>
Trap Ratio	0.83	0.74
Trap Ratio x 0.63	0.52	0.47
Netting Ratio	0.59	0.40

TABLE 6. Sex ratio of newts in Llysdynam pond. Sex ratio is expressed as males/total. Adjusting trap ratios using Bell's (1977) conversion factor of 0.63 yields sex ratios close to those obtained by netting.

Palmate newts captured in pit-fall traps during the inward migration to Llysdynam pond outnumber smooths by about 2:1 (Harrison *et al.*, 1983). Likewise, netting produces a larger number of palmates than smooths in the pond. The disproportionately large number of male smooth newts captured in the pond by trapping therefore suggests that these animals are more trap-prone than others. As female smooth newts appear to be less abundant than other newts in Llysdynam pond, male smooths may search more actively for mates than male palmates and consequently be captured more frequently.

Within a pond there may be large differences between closely adjacent traps in the numbers of newts captured. However, this does not appear to be a result of captured newts attracting others. Newts are rarely evenly distributed within a pond and large catches in a

single trap may be a result of this "clumped" distribution, with newts in a group following one another into the trap.

As the traps prevent ascents to the surface for air, newts could become conditioned into avoiding them on subsequent occasions. Alternatively, a trap may provide a relatively safe microhabitat which newts find attractive. Neither of these hypotheses was borne out in the laboratory. Although there may be species and sex differences in trap response, laboratory experiments suggested that trappability is not accentuated or diminished by previous experience of a trap. However, the present data do not permit predictions as to how repeated trapping of a newt may affect its subsequently behaviour.

The funnel trap described here has also proved to be an effective method of capturing newt larvae; tadpoles of the common frog *Rana temporaria* and common toad *Bufo bufo*, and adult crested newts *Triurus cristatus* (under Nature Conservancy Council Licence). However, some precautions should be observed when conducting a trapping programme. As trapped newts cannot make breathing ascents, the 12 hr trapping period described here should be regarded as the *maximum* length of time that traps are left in position. Leaving traps out for longer periods will almost certainly result in fatalities. Moreover, newts captured in traps placed in sunny positions or during hot weather may expire in under 12 hr so the trapping period on such occasions should be reduced accordingly. For similar reasons, it is essential that every trap can be easily relocated by the observer and secure attachment to some form of marker is therefore strongly recommended. The bownets described by van Gelder (1973) overcome the problem of prevention of breathing by having an extension to the water surface.

Clearly, the efficiency of any method of studying newt populations will be dependent on both intrinsic factors associated with newt behaviour (e.g. diel and seasonal activity patterns, courtship, feeding and egg-laying behaviour), and extrinsic factors associated with site characteristics (e.g. pond accessibility, size, depth, vegetation cover the turbidity). There is therefore no one method which is universally "best". The potential field worker should therefore carefully consider the aims of his survey, in addition to intrinsic and extrinsic factors, before deciding upon a methodology.

## ACKNOWLEDGEMENTS

The newt traps used in this study were kindly donated by Lyons Soft Drinks Ltd. and Spar (U.K.) Ltd. I am also grateful to Mr. S. Mickleburgh and Mr. J. D. Harrison for assistance with the field work and for comments on an earlier draft of the manuscript, and to J. D. H. for allowing me to use his unpublished data on netting. Dr. F. M. Slater and Dr. S. P. Gittins also commented on earlier drafts of the manuscript. I am also indebted to the Manpower Services Commission, the University of Wales and the Llysdynam Charitable Trust for funds and facilities.

## REFERENCES

- Beebee, T. J. C. (1979). Habitats of the British amphibians (2): suburban parks and gardens. *Biological Conservation* **15**, 241-257.
- Bell, G. (1977). The life of the smooth newt (*Triturus vulgaris*) after metamorphosis. *Ecological Monographs* **47**, 279-299.
- Cooke, A. S. and Frazer, J. F. D. (1976). Characteristics of newt breeding sites. *Journal of Zoology* **178**, 223-236.
- Cooke, A. S., Scorgie, H. R. A. and Brown, M. C. (1980). An assessment of changes in populations of the warty newt (*Triturus cristatus*) and smooth newt (*T. vulgaris*) in twenty ponds in Woodwalton Fen National Nature Reserve, 1974-1979. *British Journal of Herpetology* **6**, 45-47.
- Dolmen, D. (1983). Diel rhythms of *Triturus vulgaris* (L.) and *T. cristatus* (Laurenti) (Amphibia) in central Norway. *Gunneria* **42**, 1-34.
- Frazer, J. F. D. (1978). Newts in the New Forest. *British Journal of Herpetology* **5**, 695-699.
- van Gelder, J. J. (1973). Ecological observations on amphibia in the Netherlands II. *Triturus helveticus* Razoumowski: migration, hibernation and neoteny. *Netherlands Journal of Zoology* **23**, 86-108.
- Griffiths, R. A. (1984). Seasonal behaviour and intrahabitat movements in an urban population of Smooth newts, *Triturus vulgaris* (Amphibia: Salamandridae). *Journal of Zoology* **203**, 241-251.
- Harrison, J. D., Gittins, S. P. and Slater, F. M. (1983). The breeding migrations of Smooth and Palmate newts (*Triturus vulgaris* and *T. helveticus*) at a pond in mid-Wales. *Journal of Zoology* **199**, 249-258.

HERPETOLOGICAL JOURNAL, Vol. 1, pp. 10-13 (1985)

## DIEL PATTERN OF MOVEMENT AND AGGREGATION IN TADPOLES OF THE COMMON FROG, *RANA TEMPORARIA*

R. A. GRIFFITHS

\*Department of Zoology, Birkbeck College (University of London), London WC1E 7HX.

\*Present Address:

Department of Applied Biology, UWIST, Llysdyman Field Centre, Newbridge-on-Wye, Llandrindod Wells, Powys, Wales.

(Accepted 6.10.84)

### ABSTRACT

In a garden pond in London, tadpoles of the common frog, *Rana temporaria*, displayed a clear diel pattern of movement and aggregation. During the morning, tadpoles moved from the deeper area in the middle of the pond to the pond edges. The number of tadpoles around the edges peaked in the afternoon. At night tadpoles tended to disperse and move back to the deeper area. This cycle was closely related to the diel cycles of illumination and temperature. Tadpoles were not evenly distributed around the pond edges, and a stationary feeding aggregation was formed each day on the west to south-west edge. As there was no thermal gradients along the pond edges, the formation of this aggregation was probably due to factors other than temperature.

### INTRODUCTION

Anuran tadpoles are rarely evenly distributed in a pond and frequently form dense aggregations consisting of several hundred individuals. The structure and function of such aggregations has been studied by a number of authors, but the mechanisms which bring tadpoles together are complex (e.g. Bragg, 1954; Brattstrom, 1962; Wassersug and Hessler, 1971; Beiswenger, 1975). One classification system distinguishes between social aggregates which are formed by "biosocial mutual attraction" and simple (or asocial) aggregates formed by tactic responses to environmental stimuli such as light, temperature or food (Bragg, 1954; Wassersug, 1973). Under natural conditions, however, both social and asocial factors are probably operant in tadpole aggregations.

In comparison with studies of aggregation, diel activity in amphibian larvae has been little studied. Several species, however, have been shown to display diel movement patterns related to microhabitat selection (e.g. Mullally, 1953; Beiswenger, 1977; Heath, 1975; Dolmen, 1983; Holomuzki and Collins, 1983). In common with the vast majority of vertebrates, it is likely that such activity patterns are regulated primarily by daily fluctuations in illumination and temperature, possibly in conjunction with an endogenous time-keeping system.

Clearly then, illumination and temperature are involved in the modulation of both aggregative behaviour and diel movement patterns in larval amphibians. The present study set out to investigate diel movements and aggregations in relation to these environmental factors in tadpoles of the common frog

*Rana temporaria*. Aggregations of tadpoles of this species have been described by Savage (1952), and Ashby (1969) describes common frog tadpoles aggregating in patches of sunlight falling on a garden pond. There is, however, little other quantitative information relating to the behaviour of tadpoles of this species.

MATERIALS AND METHODS

The diel behaviour of common frog tadpoles was observed in a pond in the grounds of Westfield College, North London, in April 1982 (Fig. 1). The pond was constructed from concrete and had a surface area of about 4 sq.m. Apart from encrustations of algae, the pond edges were bare and shelved at an angle of about 45° to a flat bottom covered by a layer of leaf litter. Pond depth was about 20 cm. Submerged vegetation consisted mainly of filamentous algae. Smooth newts *Triturus vulgaris* were also found in the pond. A description of the surrounding habitat is provided by Griffiths (1984).

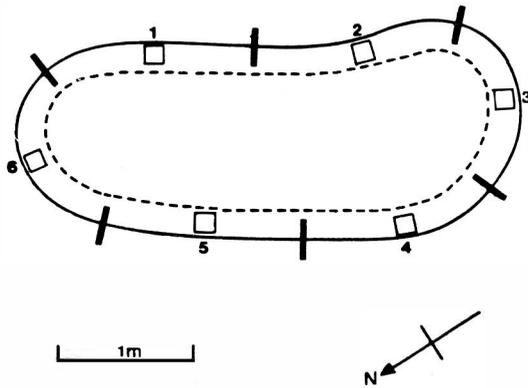


Fig. 1 The study pond. The shelving pond edge is the area between the outer solid line and the inner dotted line. A square indicates the position of each quadrat in each 1.5 m section of shoreline.

The total length of pond shoreline was 9 m, and this was divided into six 1.5 m sections. At least 8 hr before observations commenced, a 15 cm x 15 cm quadrat was placed in the middle of each 1.5 m section, such that it lay submerged on the shelving pond edge (Fig. 1). The position of each quadrat was secured with string tied to a stick on land. Observations commenced at 0500 hr and were repeated at intervals of 1-2 hr until 0200 hr the following day. During each observation period the number of frog tadpoles in each quadrat along the pond edge was counted. Water temperatures at the pond edges and in the pond centre at 15 cm depth were taken with a mercury thermometer graduated at intervals of 0.1°C, and illumination at the pond surface was measured with a EEL photoelectric photometer. At night observations were made using dim, red torchlight.

Observations of tadpole aggregations were made over 18-19th, 20-21st and 28-29th April 1982 (These dates will be subsequently referred to as days 1, 2 and 3). The tadpoles were all free-swimming, feeding independently, and had internal gills (Gosner (1960) stages 25-30).

RESULTS

Frog tadpoles displayed a clear diel pattern of movement and aggregation. During the morning tadpoles moved shoreward from the centre of the pond, and numbers of tadpoles around the pond edges peaked in the afternoon (Fig. 2). During this period, tadpoles were observed grazing on the algae at the pond edges. At night the tadpoles tended to disperse from the edges and move back into deeper water. On day 1 this diel distribution pattern closely followed the illumination cycle. On days 2 and 3, however, the

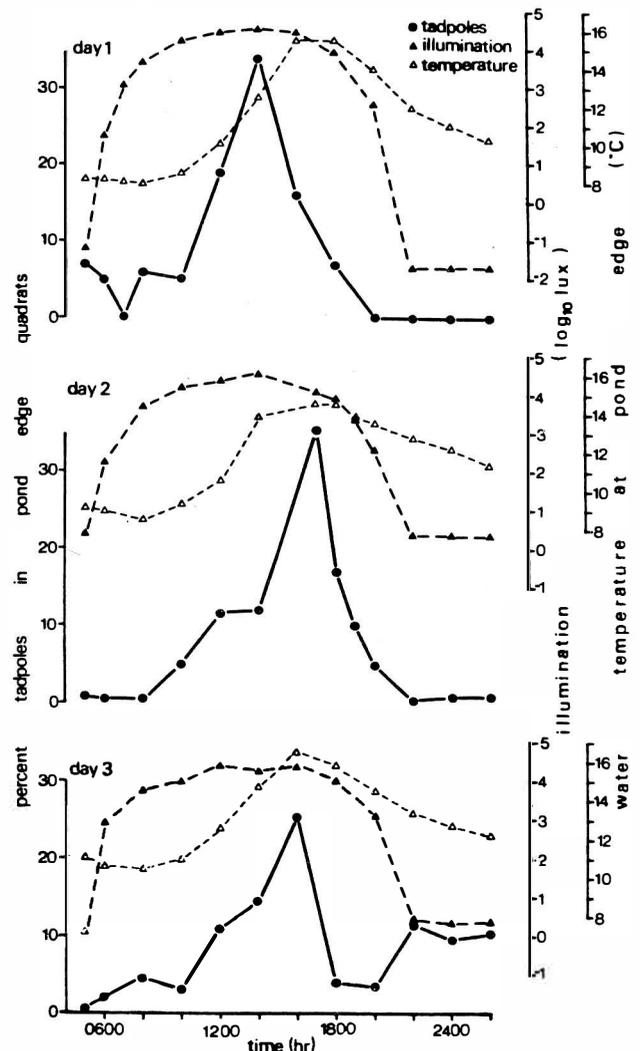


Fig. 2 Diel movement of common frog tadpoles in relation to illumination and pond edge water temperature. Tadpole numbers are expressed as percentages (no. counted/total counted on that day x 100) for easier comparison of results.

numbers of tadpoles around the pond edges showed a closer correspondence with temperature than illumination. During the daytime (i.e. 0600-1800 hr) the pond edges were significantly warmer than deeper water in the middle of the pond (Wilcoxon matched-pairs signed-ranks test (one-tailed):  $N = 15$ ,  $T = 25.5$ ,  $P < 0.05$ ). At night (i.e. 0200-0500 hr) this relationship was reversed and the deep water was warmest ( $N = 11$ ,  $T = 11$ ,  $P = 0.025$ ). However, the temperature difference between the pond edges and the deeper water never exceeded  $1.5^{\circ}\text{C}$ .

During the daytime tadpoles were not evenly distributed around the pond edge (Fig. 3). As tadpoles moved shoreward in the morning, numbers became more closely aggregated towards one end of the pond, and were densest in area 4. The densest aggregation was observed at 1700 hr on day 2, when 75 tadpoles were counted in quadrat 4. Overall, over 40 per cent of all tadpoles counted were observed in quadrat 4. Moreover, this aggregation was stationary and did not change in position over the diel cycle. To assess whether this non-uniform distribution of tadpoles was related to a temperature gradient along the pond edges, on day 1 the water temperature was taken in each quadrat during each observation period from 0500-1800 hr. However, pond edge temperatures did not differ significantly between the six areas (Friedman two-way analysis of variance,  $\chi^2 r = 10.3$ ,  $P > 0.05$ ). Although inactive and unaggregated tadpoles frequently oriented perpendicularly to the shoreline, with the head pointing away from the pond, tadpole aggregations were unpolarized.

## DISCUSSION

The diel cycle of shoreward movement in tadpoles of *Rana temporaria* follows closely the pattern observed in two species of toad tadpoles (Mullally, 1953; Beiswenger, 1977). Moreover, similar diel movement patterns have been observed in salamander larvae (e.g. Heath, 1975; Holomuzki and Collins, 1983). Beiswenger (1977) observed that the increase in American toad (*Bufo americanus*) tadpole activity in the morning was more closely related to light than temperature, and suggested that this allows tadpoles to anticipate the heating of the shallow areas and to move into them accordingly. Certainly, behavioural thermoregulation is well-developed in larval amphibians (e.g. Lucas and Reynolds, 1967; de Vlaming and Bury, 1970) and even in the shallow Westfield pond there was a slight (but significant) temperature difference between the pond edges and the deeper water during both the day and the night. Although the diel movements of frog tadpoles were therefore probably thermoregulatory in function, responses to changes in illumination may assist in the orientation to warmer waters.

Although there existed a slight thermal stratification in the Westfield pond, there did not appear to be any thermal gradients along the pond shoreline. The daily aggregation of frog tadpoles on the west to south-west edge was therefore probably due to factors other than temperature. Daytime aggregations of frog tadpoles

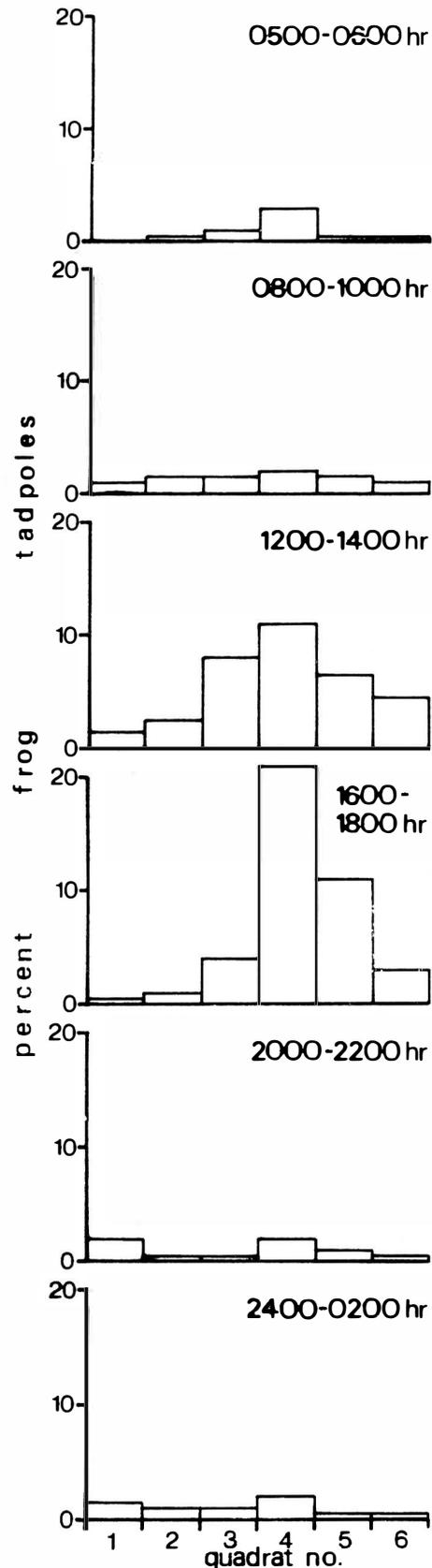


Fig. 3. Diel pattern of aggregation of tadpoles along the pond edge. Tadpole numbers are expressed as percentages (no. counted/total counted  $\times 100$ ) using data from all three days of observations.

along the same shoreline were also observed in 1981 (unpublished observation). The growth of algae along this edge may have been more luxuriant than in other areas (although this was not visually apparent). Alternatively, the tadpoles may have had an innate directional preference for this area. Beiswenger (1977) also reports of two aggregations of *Bufo americanus* tadpoles which were observed to form in the same places each day. The reasons for such behaviour, however, remain unclear.

Beiswenger (1975) classifies the aggregations formed by *Bufo americanus* tadpoles into stationary and moving types. Stationary aggregations are sub-divided into necrophagous groups, feeding groups and metamorphic groups. The aggregations of *Rana temporaria* tadpoles reported here correspond to Beiswenger's feeding groups. These groups are usually confined to shallow areas with little or no vegetation, and are characterized by tadpoles which are primarily engaged in feeding behaviour. Feeding is interspersed by short swims, during which tadpoles may "butt" each other. Such aggregations constantly stir the substrate and thus make the food supply more readily available. No moving aggregations were observed in *Rana temporaria*, but this may have been related to the small size of the pond.

As Beiswenger (1977) points out, it is more meaningful to interpret the formation of tadpole aggregations in terms of a complex of several variables (both social and asocial) operating simultaneously or sequentially, rather than in terms of a single environmental variable. As a result of the close relationship between the daily cycle of light and temperature it is often tenuous to attempt to distinguish between a phototactic and a thermotactic response under field conditions. Moreover, factors such as light and temperature should not be assumed to be directly causative in the regulation of diel behaviour patterns when their role as synchronizers of endogenous biological clocks has not been fully evaluated.

#### ACKNOWLEDGEMENTS

I am grateful to Dr. S. P. Gittins and Mr. J. D. Harrison for their comments on earlier drafts of the manuscript. I am also indebted to Westfield College for permission to work on the College ponds. The work was undertaken whilst in receipt of a SERC research studentship.

#### REFERENCES

- Ashby, K. R. (1969). The population ecology of a self-maintaining colony of the Common frog (*Rana temporaria*). *Journal of Zoology* **158**, 453-474.
- Beiswenger, R. E. (1975). Structure and function in aggregations of tadpoles of the American toad, *Bufo americanus*. *Herpetologica* **31**, 222-233.
- Beiswenger, R. E. (1977). Diel patterns of aggregative behavior in tadpoles of *Bufo americanus*, in relation to light and temperature. *Ecology* **58**, 98-108.
- Bragg, A. N. (1954). Aggregational behaviour and feeding reactions in tadpoles of the Savannah Spadefoot. *Herpetologica* **10**, 97-102.
- Brattstrom, B. H. (1962). Thermal control of aggregation behavior in tadpoles. *Herpetologica* **18**, 38-46.
- Dolmen, D. (1983). Diel rhythms and microhabitat preference of the newts *Triturus vulgaris* and *T. cristatus* at the northern border of their distribution area. *Journal of Herpetology* **17**, 23-31.
- Gosner, K. L. (1960). A simplified table for staging anuran embryos and larvae with notes on identification. *Herpetologica* **16**, 183-190.
- Griffiths, R. A. (1984). Seasonal behaviour and intrahabitat movements in an urban population of Smooth newts, *Triturus vulgaris* (Amphibia: Salamandridae). *Journal of Zoology* **203**, 241-251.
- Heath, A. G. (1975). Behavioral thermoregulation in high altitude tiger salamanders, *Ambystoma tigrinum*. *Herpetologica* **31**, 84-93.
- Holomuzki, J. R. and Collins, J. P. (1983). Diel movement of larvae of the tiger salamander, *Ambystoma tigrinum nebulosum*. *Journal of Herpetology* **17**, 276-278.
- Lucas, E. A. and Reynolds, W. A. (1967). Temperature selection by amphibian larvae. *Physiological Zoology* **40**, 159-171.
- Mullally, D. P. (1953). Observations on the ecology of the toad *Bufo canorus*. *Copeia* **1953**, 182-183.
- Savage, R. M. (1952). Ecological, physiological and anatomical observations on some species of anuran tadpoles. *Proceedings of the Zoological Society of London* **122**, 467-514.
- de Vlaming, V. L. and Bury, R. B. (1970). Thermal selection in tadpoles of the tailed-frog, *Ascaphus truei*. *Journal of Herpetology* **4**, 179-189.
- Wassersug, R. and Hessler, C. M. (1971). Tadpole behaviour: aggregation in larval *Xenopus laevis*. *Animal Behaviour* **19**, 386-389.
- Wassersug, R. (1973). Aspects of social behavior in anuran larvae. In: Vial, J.L. (ed.), *Evolutionary biology of the anurans. Contemporary research on major problems*, pp. 273-297. Univ. of Missouri Press, Columbia.

## SALT TOLERANCES OF NATTERJACK TOAD (*BUFO CALAMITA*) EGGS AND LARVAE FROM COASTAL AND INLAND POPULATIONS IN BRITAIN

TREVOR J. C. BEEBEE

*School of Biology, University of Sussex, Falmer, Brighton BN1 9QG, U.K.*

*(Accepted: 6.10.84)*

### ABSTRACT

- (1) Eggs and larvae taken from coastal and inland natterjack populations were found to be similar in their sensitivities to salt water.
- (2) Spawn was more susceptible than tadpoles to salt damage.
- (3) The effects of salinities comparable with those experienced during a tidal inundation were rapid, mortality occurring within the first 1-2 hours of exposure.

### INTRODUCTION

Survival rates during embryonic and larval development are commonly thought to be crucial factors governing overall sizes and age structures of amphibian populations. In the case of the natterjack toad *Bufo calamita*, two aspects of breeding site chemistry have so far been identified as having significant impacts on the reproductive success of wild populations. These are: (i) pH, which can fall low enough at some heathland sites to cause catastrophic spawn mortality (Beebee and Griffin, 1977); and (ii) total salinity, which can rise to lethal levels following tidal surges into exposed coastal pools and marshes. I have investigated the tolerances of spawn and tadpoles from two widely separated natterjack populations to various degrees of seawater contamination; one site was coastal in north-west England, with a small natterjack population breeding in a single, large pool close to the high-water mark and regularly subjected to salt spray as well as (winter) tidal inundation. The second was on heathland in southern England and separated from the sea by nearly 30 km. Two main aims of the work were: (i) to ascertain whether selection pressures had led to genetic differences between the two populations in the salt tolerances of their developmental stages. Such differences, or lack of them, could be relevant to future natterjack translocations. (ii) To establish whether it is possible to rescue spawn following tidal inundation, and how quickly this needs to be done for a high proportion of the embryos to survive.

### MATERIALS AND METHODS

Spawn was collected from each of the two sites within 24 hours of deposition, and experiments started within a further 24 hours. Short (100 egg) sections were clipped from the ends of at least 4 separate strings at each site in each of the two study years, to ensure as good a genetic mix of material as reasonably possible. Both colonies are thought to contain fewer than 50

females. Seawater was collected from Brighton beach, filtered through a glass sinter and stored at 4° (for no longer than 1 month) prior to use. Conductivity measurements indicated that the salinity of undiluted seawater was equivalent to about 2.75 per cent (w/v) NaCl.

Natterjack spawn was cut into sections of 10 eggs, and batches from all strings sampled from a particular population mixed together. 10 eggs were then selected randomly, placed in plastic tanks containing 2 litres of various dilutions of seawater, and left to develop at ambient temperatures. Any particular tank therefore contained one section of spawn (10 ova) from one particular female. Controls were carried out allowing development in tapwater. Numbers of eggs or tadpoles surviving to particular stages of development, or for predefined times, were then noted together with the occurrence of physical or behavioural abnormalities. Tadpoles were fed on rabbit pellets *ad libitum* (Beebee, 1983). At the end of the experiments, tadpoles or toadlets were released at their sites origin. In some cases, spawn was allowed to develop for fixed periods in water of particular salinities and then transferred to tanks with 2 litres of tapwater to monitor subsequent development.

### RESULTS

In the first year of study, tolerance limits of spawn, small (12 mm) and large (20 mm) tadpoles from the two populations to various degrees of salinity were determined (Table 1). Differences between the two populations show no particular trend and are probably trivial. Spawn was killed by 15-20 per cent seawater (0.4-0.55 per cent NaCl), though often not until around the hatching stage. 25 per cent seawater (0.7 per cent NaCl) prevented all development of the embryos. Tadpoles were more resistant, some even surviving for a week in 30 per cent seawater (>0.8 per cent NaCl); there did not appear to be any major difference between small and large tadpoles in this regard, though the latter may have been marginally more tolerant of the salt.

Conditions	Population Locality					
	ova	Coastal 12 mm Larvae	20 mm Larvae	ova	Inland 12 mm Larvae	20 mm Larvae
Tapwater (control)	10	10	10	10	10	10
Seawater (as percentage of undiluted)						
5%	10	10	10	10	10	10
10%	8	10	10	8	10	10
15%	10	9	10	10	10	10
20%	0	9	10	0	10	10
25%	0	1	10	0	10	10
30%	0	0	5	0	0	0
35%	0	0	0	0	0	0
40%	0	0	0	0	0	0

TABLE 1. Effects of increasing salinity on egg and tadpole survival

10 ova or tadpoles were placed in each tank at the start of the experiments. Figures given are the numbers surviving 7 days later.

In the second year of the study, two salt concentrations known to be ultimately lethal to spawn (25 per cent and 75 per cent seawater) were used to probe further any possible differences between the two populations. Spawn was exposed for various periods before being removed and placed in tapwater to assess recovery during the remainder of development. 25 per cent salinity might result in a pond from a period of heavy storm spray; 75 per cent levels, or higher, can be reached following high tide inundation. Results of these experiments are shown in Fig. 1. Again, differences between populations appeared to be small and insignificant. Low-level salinity could be tolerated for at least 8 hours with no loss of spawn viability, though this had begun to drop by 24 hours. The effects of 75 per cent seawater were much more rapid. Only for the first 15 minutes or so was the spawn completely

recoverable; within an hour it had been damaged to the extent that later hatch rates were reduced slightly (to 70-100 per cent normal) and subsequent development showed further reduced viability to 40-90 per cent. By 2 hours the hatch rate was down to 0-50 per cent and ultimate survival 0-30 per cent.

A tadpole abnormality associated with exposure of spawn to immediately sub-lethal salt conditions was also observed. It occurred in 10 individuals, only 1 of which later recovered and seemed to develop normally (Table 2). The condition involved a prolonged post-hatch phase in which the tadpoles grew broader than usual but remained essentially immobile, followed by more normal morphogenesis but with a severe (>90°) horizontal kink at the base of the tail. Afflicted tadpoles could not swim properly but nevertheless grew normally in terms of total bulk and body proportions, though in the wild they would no doubt have difficulty obtaining food and be highly vulnerable to predation.

## DISCUSSION

The sensitivities of natterjack tadpoles to saline conditions observed in the two populations examined here was broadly similar to those found by others. Mathias (1971) used tadpoles from another coastal colony in north-west England and found malformation at 20 per cent seawater and complete kill at 25 per cent. Andren and Nilson (1979) investigated a Swedish island population and determined that larvae were killed by between 7-11 per cent salinity (25-39 per cent seawater). Neither of these studies compared the sensitivities of spawn and tadpoles, and evidently the former is the more vulnerable constituting the limiting factor for reproductive success in a brackish environment. It looks, however, as if selection has not operated to increase the salt tolerance of coastal populations relative to those inland. There are at least two possible explanations for this: (i) coastal natterjack populations usually have a variety of

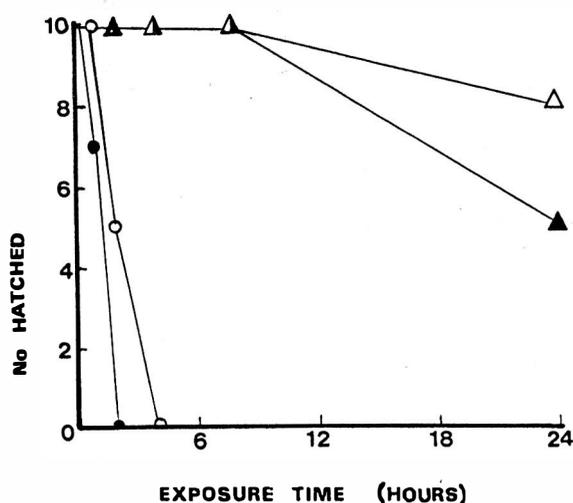


Fig. 1. Effects of salt exposure time on spawn hatch rates. Spawn sections were placed in either 25 per cent or 75 per cent (v/v) seawater, allowed to stand for various times, and transferred to tapwater tanks for subsequent development ▲, Coastal site spawn in 25 per cent seawater; ●, coastal site spawn in 75 per cent seawater; △, inland site spawn in 25 per cent seawater; ○, inland site spawn in 75 per cent seawater.

Time of Spawn Exposure (hours)	Population Locality					
	Coastal			Inland		
	Hatch	Abnormal	Large Tadpole	Hatch	Abnormal	Large Tadpole
25% Seawater:						
0 Exposure	10	0	10	10	0	10
8 Hours	10	0	8	10	0	10
24 Hours	8	5	1	5	1	5
75% Seawater:						
0.25 Hours	10	0	10	10	0	10
1 Hour	7	3	4	10	0	9
2 Hours	0	—	—	5	2	3

TABLE 2. Survival of larvae after various spawn exposure times in saline media.

Experiments used batches of 10 ova, and figures refer to numbers of these surviving to hatch and to large (25 mm) tadpole stages. Numbers of tadpoles showing obvious signs of abnormal development are also given.

breeding pools at their disposal, many or most of which (in the case of dune slacks) are never inundated by the sea and remain completely fresh at all times. The colony selected for this study does not now have such a choice, but its restriction to one exposed breeding pond may be relatively recent following urban development in the surrounding area. Some other coastal colonies, notably in Cumbria, frequently experience inundation and total loss of spawn in particular ponds but these are only one or a few sites out of several or many used by the population as a whole, so selection is unlikely to be intense. (ii) Inundations are often followed by a rapid refreshing of the pools, within a day or two of the high tide, due to the continuous run-off of freshwater from higher land. This effect must be even more marked when only salt spray is involved, probably explaining the observations of Hardy (1974) of both *Bufo calamita* and *B. bufo* tadpoles apparently thriving at 1 per cent salinity in the coastal pond of the present study. Such salt concentrations would be lethal if maintained for many days or weeks, but tolerable for shorter periods. Mathias (1971) found common toad tadpoles to be only slightly less tolerant of salt than those of the natterjack, and Hagstrom (1981) noted *B. bufo* tadpoles thriving at 0.35 per cent NaCl in Norway.

Not only can temporary salination be accompanied by natterjacks, but such events may even be advantageous in some circumstances. The scouring of a pond by saltwater not only puts natterjack spawn at risk, but is also likely to kill off invertebrates (potential tadpole predators) and the tadpoles of other early-spawning anurans (potential competitors). The protracted breeding season of *B. calamita* means that if some spawn of this species is lost at the same time, there is every opportunity for more to be laid in a refreshed pond empty of predators and competitors. This kind of sequence of events certainly happens at some coastal natterjack sites in Cumbria.

It is doubtful whether other natterjack populations, at least in Britain, have been separated for longer (probably >1000 generations) or subjected to greater selective pressures than those compared here. On the basis of this particular parameter there would seem to

be no reason why natterjacks could not be translocated from coastal to inland sites or vice-versa, though of course there could be other as yet unrecognised differences between populations on dunes and heaths. For more immediate conservation purposes, the rapid destruction of embryos caused by concentrated salt solutions comparable with seawater means that any rescue of spawn from inundated sites would need to be carried out more or less at the time of the event for it to be worthwhile. In some cases this may be possible, but there would clearly be little point in, for example, moving spawn in the morning following a tidal surge sometime the previous night.

#### ACKNOWLEDGEMENTS

I am grateful to the Cheshire Trust for Nature Conservation for permission to take spawn from one of their nature reserves, and especially to Peter Healey for his assistance and hospitality. The work was carried out under license from the Nature Conservancy Council and on behalf of the British Herpetological Society Conservation Committee.

#### REFERENCES

- Andren, C. and Nilson, G. (1979). Om stinkpaddans *Bufo calamita* utbredning och ekologi pa den svenska vastkusten. Fauna och Flora **74**, 121-132.
- Beebee, T. J. C. (1983). Factors influencing the growth and survival of natterjack toad *Bufo calamita* tadpoles in captivity. British Journal of Herpetology **6**, 294-299.
- Beebee, T. J. C. and Griffin, J. R. (1977). A preliminary investigation into natterjack toad *Bufo calamita* breeding site characteristics in Britain. Journal of Zoology (London) **181**, 341-350.
- Hagstrom, T. (1981). Tadpoles of the common toad *Bufo bufo* found in brackish water. Amphibia-Reptilia **2**, 187-188.
- Hardy, E. (1974). Naturalists notebook. Aquarist **39**, 136-137.
- Mathias, J. H. (1971). The comparative ecologies of two species of amphibia (*Bufo bufo* and *Bufo calamita*) on the Ainsdale sand dunes national nature reserve. PhD Thesis. University of Manchester.

## AN IDENTIFICATION KEY TO THE GECKOS OF THE SEYCHELLES, WITH BRIEF NOTES ON THEIR DISTRIBUTIONS AND HABITS

ANDREW S. GARDNER

*Department of Zoology, University of Aberdeen, Tillydrone Avenue, Aberdeen AB9 2TN, U.K.*

*Present addresses:*

*The Galton Laboratory, Department of Genetics and Biometry, University College London, Wolfson House, 4 Stephenson Way, London NW1 2HE, U.K.*

*(Accepted 24.10.84)*

### INTRODUCTION

The Republic of Seychelles, lying in the western Indian Ocean consists of a group of mountainous, granitic islands, and a large number of outlying coral atolls and sand cays, distributed over 400,000 km<sup>2</sup> of sea. There are over a hundred islands, ranging in size from Mahé, at 148 km<sup>2</sup> to islands little more than emergent rocks. A total of eighteen species of lizard, from three families are recorded from the Seychelles (Gardner, 1984). The best represented family is the Gekkonidae with eleven species, four of which are endemic to the islands. The identification key presented here should enable interested naturalists to identify any gecko encountered in the Seychelles to the species level, and where there are clearly defined races, to the subspecies level.

In the past there has been frequent confusion of the forms, particularly amongst the "house geckos" and between the races of green day-geckos (*Phelsuma* species) (e.g. Gaymer, 1968; High, 1976; Temple, 1977). The classification of the *Phelsuma* forms presented here is that of Gardner (1984) and differs in several aspects from the classifications given by Cheke (1982) and Meier (1983). That of Gardner (1984) is based on a multivariate morphometric analysis of many body proportion, scalation and colour pattern characters, using large samples taken over the complete range of the taxa. The species *Urocotyledon inexpectata* was transferred to that genus from *Phyllodactylus* by Kluge (1983).

### THE KEY

- |  |   |
|--|---|
| <p>1. Digits gradually dilated distally, with more than 2 adhesive lamellae on the undersurface. 2.</p> <p style="padding-left: 2em;">Digits only dilated at apex, with only a single pair of adhesive lamellae on the undersurface (Fig. 1a). <i>Urocotyledon inexpectata</i> Stejneger.</p>          | <p>4. Scales on chest and at least anterior of belly keeled. Underside white. <i>Phelsuma astriata</i> Tornier. 5.</p>  |
| <p>2. Subdigital lamellae straight and undivided medially. 3.</p> <p style="padding-left: 2em;">Subdigital lamellae obliquely set and medially divided. 11.</p>  | <p>5. Scales on chest and belly not keeled. 6.</p>  |
| <p>3. Digits clawed; all digits with a dilated apex. Pupil vertical. <i>Ailuronyx sechellensis</i> Dumeril and Bibron.</p> <p style="padding-left: 2em;">Digits clawless; thumb and inner toe vestigial. Remaining digits each with a dilated apex. Pupil circular. Genus <i>Phelsuma</i> Gray. 4.</p> | <p>5. Subcaudal scales keeled and not transversely enlarged in original tails. Ground colour of rump and tail usually bright blue, and of flanks, green. Tail unmarked or spotted with red. Red transverse neck bars of ten reduced or absent. <i>Phelsuma astriata astriata</i> Tornier 1901.</p> <p style="padding-left: 2em;">Subcaudal scales unkeeled and transversely enlarged in original tails. Ground colour of rump and tail usually green, and of flanks, grey-brown. Tail usually with a narrow transverse red band on each segment. Usually two distinct red, transverse bars across neck. <i>Phelsuma astriata semicarinata</i> Cheke 1982.</p>                               |
|  | <p>6. Eye ring bright blue. Three red bars across snout and back of head. Otherwise red marking restricted to a pattern of 3 large red spots anterior to a number of small red speckles on the lower back. Underside of chin white. Yellow scales dusting neck and upper back. <i>Phelsuma laticauda</i> Boettger.</p> <p style="padding-left: 2em;">Not as above. A dark chevron or chevrons under the chin, at least in preserved specimens and geckos in dark phase. 7.</p>  |
|  | <p>7. Ground colour of live geckos a dull grey-blue, with mottled flanks and legs. Head marking usually consists of a median red spot behind the internasals, red spots above the eye rings, and a rather variable pattern on the forehead and in the interocular region. Eye ring whitish. Basal tail segments with 5 rows of scales on the dorsal surface. <i>Phelsuma abbotti</i> Stejneger. 8.</p> <p style="padding-left: 2em;">Ground colour of live geckos bright green. Usually a red chevron mark on the head, at least in young geckos. Eye ring green or yellow. Basal tail segments with 7 or 8 rows of scales on the dorsal surface. <i>Phelsuma sundbergi</i> Rendahl. 9.</p> |
|  | <p>8. Snout to vent length to 58 mm. Slender build. Ground colour of back usually a dull grey-green, with heavy flank and leg mottling. Continuous, red, vertebral line up back.</p>  |

Underside white, other than a few yellow scale rows anterior to the preano-femoral row. *Phelsuma abbotti abbotti* Stejneger 1893.

Snout to vent length to 73 mm. Heavy build. Ground colour of back bright grey-blue, with a broken, red vertebral line. Underside orange-yellow with a reddish gular chevron. *Phelsuma abbotti sumptio* Cheke 1982.

9. Adult snout to vent length from 55 to 68 mm. Eye ring yellow or yellow-green. Back pattern highly variable, but often comprises three longitudinal rows of red spots, with the median ones sometimes coalescing into a sinuous vertebral line. Tail often barred with red. No orange or yellow on underside. Some populations have very reduced red markings. Chin shields flat, and white or grey. *Phelsuma sundbergi longinsulae* Rendahl 1939 *n. comb.*  
Adult snout to vent length from 60 to 95 mm. Back pattern consists of a fine vermiculation of red spots. Tails rarely barred. Chin shields raised and tend to be greenish. Often yellow or orange on throat and around vent.
10. Adult snout to vent length from 75 to 95 mm. Keeling on throat scales extending from the chin shields to the level of the forelimbs, and extending down the sides of the belly. Gular scales and chin shields well raised. Edges of mental scale strongly angled. Fourth toe lamellae numbering 18 to 21 on the hind foot. Preano-femoral pores numbering 32 to 37 in males. Eye ring always green. *Phelsuma sundbergi sundbergi* Rendahl 1939.  
Adult snout to vent length from 60 to 78 mm. Keeling on throat scales restricted to a band across the posterior throat region. Gular scales and chin shields slightly raised. Edges of mental scale usually straight. Fourth toe lamellae numbering 16 to 18 on the hind foot. 28 to 34 preano-femoral pores in males. Eye ring often yellow or green-yellow. *Phelsuma sundbergi ladiguensis* Bohme and Meier 1982.
11. Postmentals well developed, standing out sharply from the small gular scales.  
Postmentals not distinct, but a number of polygonal scales merging gradually into the smaller gular scales. Tail with sharp lateral edges. *Lepidodactylus lugubris* Dumeril and Bibron.
12. First digit without free terminal phalange and only minutely clawed. Subdigital lamellae only present on the distal half of the digit (Fig. 1b). Mental much shorter than the inner postmentals (Fig. 1e). No tubercles on tail. *Gehyra mutilata* Wiegmann.  
First digit with free, clawed terminal phalange. Subdigital lamellae run the whole length of the digit (Fig. 1c,d). Mental and inner postmentals nearly equal in length (Fig. 1f). Original tails with rings of tubercles. Genus *Hemidactylus* Oken.
13. Inner digit with short phalanx, whose tip does not extend far beyond the tip of the lamellae (Fig. 1c). Back not tuberculate, or very feebly so, and uniformly grey, sometimes with small black speckles. *Hemidactylus frenatus* Dumeril and Bibron.  
Inner digit with phalanx well developed, extending far beyond the tip of the lamellae (Fig. 1d). Back distinctly tuberculate, often conspicuously marked with black.
14. Body tubercles very large and strongly keeled. Back with dark blotches, but without transverse stripes. Tail barred on every second segment. 8 to 10 upper labial scales on each side. *Hemidactylus brookii* Gray.  
Body tubercles small, only slightly keeled. Back with distinct transverse stripes. Tail barred on every 3rd or 4th segment. 10 to 14 upper labial scales on each side. *Hemidactylus mercatorius* Gray.

#### NOTES ON THE DISTRIBUTIONS AND HABITS OF THE SPECIES

1. *Urocotyledon inexpectata*. Endemic. Nocturnal. Widely distributed in the granitic islands, where it may be found under loose bark or stones. The eggs are laid communally under flakes of granite. The smallest gecko species in the Seychelles.

2. *Ailuronyx sechellensis*. Endemic. Nocturnal. Widely distributed in the granitic Seychelles, but most abundant on the seabird islands of Cousin, Cousine, Aride and Frigate. A very large species, it is found both in buildings and on trees on the seabird islands, but is restricted to forest and coconut plantations on the other islands. Rare on Mahé, but frequently seen in the Vallée de Mai on Praslin.

3. *Phelsuma astriata astriata*. Endemic. Diurnal. Occurs on Silhouette, and Mahé and its associated islets in the granitic group and on Astove in the outer islands. Abundant on forest trees, coconut plantations and bananas.

4. *Phelsuma astriata semicarinata*. Endemic. Diurnal. Occurs on Praslin, La Digue and all the wooded islands associated with them. On the non-granitic islands, it is found on Denis, D'Arros and St. Joseph. Abundant on trees, rocks and in houses.

5. *Phelsuma laticauda*. Indigenous. Diurnal. Found only in the Farquhar Group of Farquhar, Providence and Cerf in the outer islands, where it is abundant on coconut and banana trees.

6. *Phelsuma abbotti abbotti*. Endemic subspecies restricted to Aldabra. Diurnal. Abundant in all wooded habitats.

7. *Phelsuma abbotti sumptio*. Endemic subspecies restricted to Assumption Island. Diurnal and abundant in the coconut plantation.

8. *Phelsuma sundbergi longinsulae*. Endemic. Diurnal. Occurs on Mahé, Silhouette, North and Frigate, and the smaller islands in the Mahé group, and on Cosmoledo, Remire and Bird Island in the non-granitic islands. Abundant on trees. Often enters houses on Mahé.

9. *Phelsuma sundbergi sundbergi*. Endemic. Diurnal. Occurs on Praslin, Curieuse and Chauve Souris in the north-west granitic islands, and on Denis, Marie-Louise, Poivre and Platte in the outer islands. Abundant on forest trees and in coconut plantations.

10. *Phelsuma sundbergi ladiguensis*. Endemic. Diurnal. Occurs on La Digue, Felicité, The Sisters, Coco and Marianne in the north eastern granitic islands. Abundant on forest trees and in coconut plantation.

11. *Lepidodactylus lugubris*. Indigenous. Nocturnal. Occurs only on Coëtivy in the Seychelles, where it is apparently parthenogenetic, the population consisting of females only.

12. *Gehyra mutilata*. Introduced. Nocturnal. Occurs on most of the inhabited granitic islands, and on Denis, Bird Island, Farquhar and Coëtivy in the outer islands. This common gecko is usually associated with houses.

13. *Hemidactylus frenatus*. Probably indigenous. Nocturnal. Occurs on most islands in the Amirantes Group and on Platte and Bird Island, living both in houses and in trees and rocks.

14. *Hemidactylus brookii*. Introduced. Nocturnal. A single population of the Asian subspecies, *H. b. brookii*, exists on Desroches Island in the Amirantes, where it coexists with *Hemidactylus frenatus*.

15. *Hemidactylus mercatorius*. Probably indigenous. Nocturnal. Distribution is non-overlapping with *H. frenatus*, occurring on the islands of the Aldabra and Farquhar Groups. Lives both in houses and in rocks and trees.

#### ACKNOWLEDGEMENTS

I would like to thank Mr. Serge Savy and Mr. L. Chong Seng of the Ministry of Agriculture, Republic of Seychelles, for permission to collect the specimens and for assisting my work in many ways. I am grateful to Dr. R. S. Thorpe for helpful comments on the

manuscript. This work was carried out while I held a research studentship from the Science Research Council at the University of Aberdeen.

#### REFERENCES

- Bohme, W. and Meier, H. (1982). Eine neue Form der *madagascariensis*-Gruppe der Gattung *Phelsuma* von den Seychellen. *Salamandra* **17**, 12-19.
- Cheke, A. S. (1982). *Phelsuma* Gray 1825 in the Seychelles and neighbouring islands: a reappraisal of their taxonomy, and description of two new forms. *Senckenbergiana biologica* **62**, 181-198.
- Cheke, A. S. (1984). Lizards of the Seychelles. In *Biogeography and ecology of the Seychelles Islands*, 331-360. Stoddart, D.R. (Ed.). Dr. W. Junk Publishers, The Hague.
- Gardner, A. S. (1984). The evolutionary ecology and population systematics of day geckos *Phelsuma* in the Seychelles. Ph.D. thesis, University of Aberdeen.
- Gaymer, R. (1968). Amphibians and reptiles of the Seychelles. *British Journal of Herpetology* **4**, 24-28.
- High, J. (1976). *Natural history of the Seychelles*. Port Victoria, Seychelles. Government Printer.
- Kluge, A. G. (1983). Cladistic relationships among Gekkonid lizards. *Copeia* **1983**, 465-475.
- Meier, H. (1983). Zur Taxonomie und Ökologie der Gattung *Phelsuma* auf den Seychellen mit Nachträgen zu dieser Gattung auf den Komoren. *Salamandra* **18**, 49-55.
- Rendahl, H. (1939). Zur Herpetologie der Seychellen. I. Reptilien. *Zoologische Jahrbucher, Abteilungen Systematik Ökologie und Geographie der Tiere*. **72**, 157-328.
- Stejneger, L. (1893). On some collections of reptiles and batrachians from East Africa and adjacent islands, recently received from Dr. W. L. Abbott and Mr. William Astor Chanler, with descriptions of new species. *Proceedings of the United States National Museum* **16**, 711-741.
- Temple, S. (1977). Castaway reptiles of the Indian Ocean. *Animal Kingdom* **80**, 19-26.
- Tornier, G. (1901). Die Reptilien und Amphibien der deutschen Tiefseexpedition 1898/99. *Zoologischer Anzeiger* **24**, 61-66.

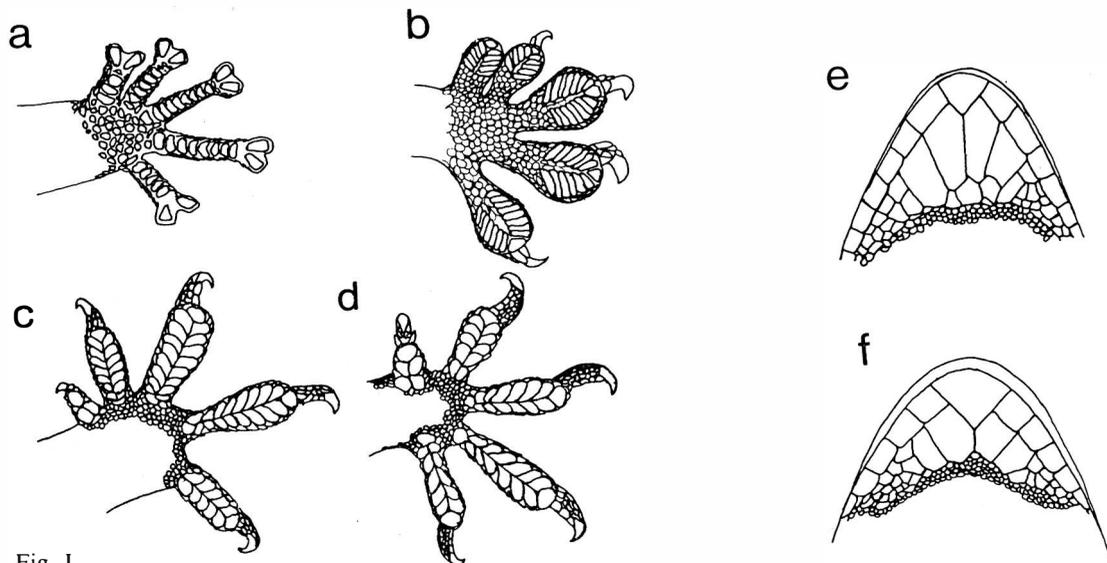


Fig. 1.  
a-d. Left forefoot, ventral views of: (a) *Urocotyledon inexpectata*; (b) *Gehyra mutilata*; (c) *Hemidactylus frenatus*; (d) *Hemidactylus mercatorius*.

e-f. Ventral view of chin of: (e) *Gehyra mutilata*; (f) *Hemidactylus frenatus*.

## SIZE INCREASE IN THE COMMON TOAD *BUFO BUFO* FROM CHESHIRE

C. P. WHEATER

*Department of Zoology, University of Manchester, Manchester, U.K.*

(Accepted 19.11.84)

### ABSTRACT

Toads were collected from two sites in Cheshire from March to November. Body length (snout to vent), jaw width, hind leg length and weight were measured. Three size ranges were observed and compared. Body length was found to be positively correlated to jaw width, hind leg length and weight and was used to calculate the growth rates over the year. It was determined that the percentage increase in size decreased with age.

### INTRODUCTION

The size ranges of the common toad (*Bufo bufo*) have been examined by a number of workers (Mathias, 1971; Gittins *et al.*, 1980; Frazer, 1983). However, little has been published on the growth rates during the year, and most of the information available is concerned with breeding adults rather than juveniles. The present study is an attempt to fill this gap and examines the increase in size over the year of recently emerged toads in comparison with second years and older.

### METHODS

Toads were collected from two sites in Cheshire. These were Abbots Moss Hall (Grid Ref. SJ 593 681), a privately owned estate near Delamere and Tabley Hall (Grid Ref. SJ 727 769), owned by the University of Manchester and situated near Knutsford. In the former site captures were made from a marshy area. The trapping grid was situated 15 m away from a pond. The vegetation consisted mainly of Yorkshire fog (*Holcus lanatus*-50 per cent) and marsh horsetail (*Equisetum palustre*-30 per cent) with *Juncus* species (5 per cent) and small clumps of marsh thistle (*Cirsium palustre*-1 per cent). Small quantities of *Ranunculus* species were also present. The height of the vegetation was never below 0.5 m during the trapping season, which lasted from late March until mid-November. The ground was uneven, showing tussock-like formations.

At Tabley Hall the sampling site was situated on a mat of bulrushes effectively floating on the north east edge of Tabley Mere. The site was 25 m from the open water to the south west. The vegetation reached heights of up to 2 m and consisted of bulrushes (*Scirpus lacustris*-50 per cent) and great hairy willow-herb (*Epilobium hirsutum*-50 per cent). The ground cover consisted of nettles (*Urtica dioica*-10 per cent) and horsetails (10 per cent).

The animals were collected in large plastic pitfall traps (90 mm in diameter and 135 mm deep). These captures occurred whilst trapping for surface-active Coleoptera (Wheater, 1984). It was noticeable that

larger adults were infrequent in the traps. This may have been a result of the trap size, preventing the entry of animals over a certain size (about 60 mm). Smaller specimens, however, were common and in total 1025 animals of all sizes were obtained over the trapping period.

A sample from each site was examined for each trapping occasion (the traps were examined at fortnightly intervals). In those catches where large numbers of very small toads were present, samples of 10 were taken. All large toads captured were examined.

Measurements of weight, body length (from snout to vent), jaw width (at the widest point) and hind limb length were taken for 188 specimens.

### RESULTS

Weight is a measurement of particular ecological interest. This, however, tends to vary with the fullness of the gut. It was decided, therefore that the variability of this measurement negated its use as an estimate of annual growth rate. Since body length was found to be easy to measure and is of obvious value as an indicator of size, the rate of growth was calculated as the increase of body length with date. Three size groups are evident (I, II, III on Fig. 1). It can be seen from Table 1 that in all cases (except leg length) there is a decrease in the percentage increase of size with increased age. The data for the size ranges were separated and regression analyses performed on them. For the small size range (I), increase in size was positively related to time ( $Y = 1.97X - 6.31$ , significance of b:  $p > 0.0001$ ). Similar results were obtained for size II animals ( $Y = 1.699X + 16.221$ , significance of b:  $p > 0.0001$ ). These figures show an average size increase of 1.97 mm and 1.699 mm per fortnight respectively. This may also be expressed as 0.14 mm and 0.12 mm per day. Presumably size I animals are "this year's" animals and size II consists of "last year's" animals. Size range III showed no significant relationship between length and time and is more diverse in distribution. These animals are presumed to come from a range of ages over two years old and do not show a distinct pattern of growth. The regression lines calculated for the two smaller size

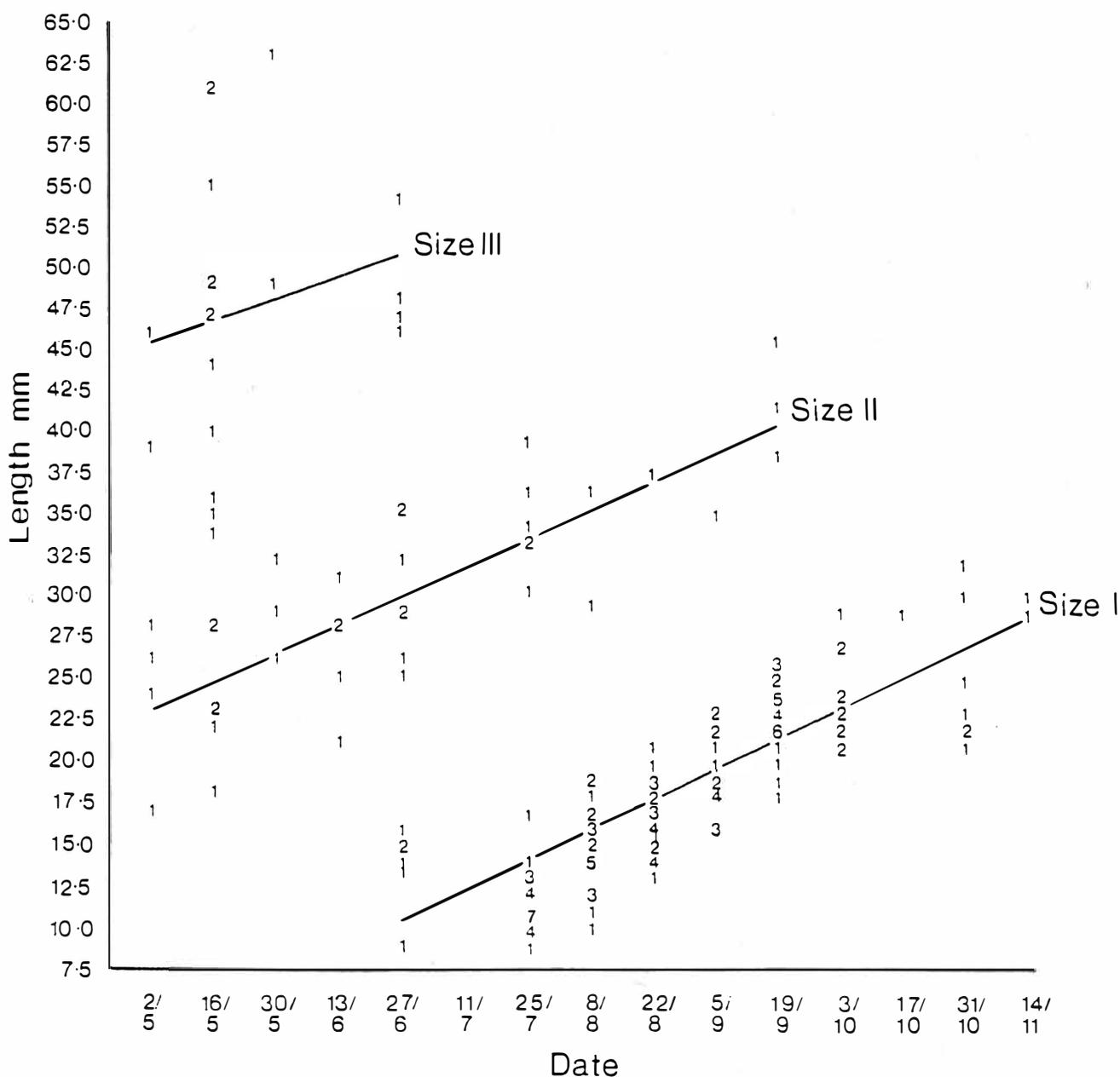


Fig. 1. Graph of body length plotted against date showing the regression lines calculated for each size range. The numbers indicate the number of points plotted. The equations and regressions of the lines are listed below.

Size I  $R = 0.844$   $Y = 1.97 X - 6.31$   $p < 0.001$   
 Size II  $R = 0.81$   $Y = 1.699 X + 16.22$   $p < 0.0001$   
 Size III  $R = 0.201$   $Y = 1.28 X + 40.33$   $p = 0.395$

ranges were compared using a t-test and were found to have significantly different slopes ( $t = 3.189$ , degrees of freedom = 164,  $p > 0.01$ ). The increase in size in group I is, therefore, more rapid than in group II and is presumably a result of the animals emerging in late June and early July and requiring to build up food reserves prior to hibernation in the Autumn. Peak emergence (peak numbers of small specimens caught) was from 27th June to 25th July at both sites.

Size, as measured by snout to vent length, was found to be significantly correlated with jaw width ( $R = 0.986$ ,  $p > 0.001$ ), leg length ( $R = 0.980$ ,  $p > 0.001$ ) and weight ( $R = 0.871$ ,  $p > 0.001$ ). The mean measurements of size range III animals are comparable to (if slightly lower than) those found by Collier (1970) and Mathias (1971). Both authors were primarily examining adult toads and this seems to confirm that animals in this size range are breeding adults.

	Size I (n = 130)			Size II (n = 38)			Size III (n = 20)		
	$\bar{x}$	S <sup>2</sup>	increase during the year	$\bar{x}$	S <sup>2</sup>	increase during the year	$\bar{x}$	S <sup>2</sup>	increase during the year
Snout/vent length mm	18.2	5.28	110%	29.8	6.14	74%	47.5	8.36	15%
Jaw width mm	6.1	2.08	120%	10.3	2.16	47%	17.7	3.17	14%
Leg length mm	21.5	5.08	40%	34.0	6.83	72%	56.8	10.87	21%
Weight g	0.75	0.68	742%	3.2	2.01	399%	14.3	8.14	106%

TABLE 1

The means ( $\bar{x}$ ) and variances (S<sup>2</sup>) of each measurement were calculated for each size range over the capture period. The percentage increase in size during the year was calculated as the difference between the mean size at the beginning of the year ( $\bar{x}_0$ ) and the mean at the end ( $\bar{x}_1$ ), expressed as a percentage of the mean at the beginning, i.e.  $\frac{(\bar{x}_1 - \bar{x}_0) \times 100}{\bar{x}_0}$

## DISCUSSION

It appears from this study that growth in first year toads is rapid (an average of 0.14 mm per day) and that this is followed by a smaller rate of increase (0.12 mm per day) in the second year of life. Gittins *et al.* (1982) found no significant relationship between length and age for either male or female toads; however his specimens were all breeding adults, collected during their breeding migration. Similar animals examined during this study also showed no significant relationship of length with time. This confirms Gittins' suggestion that "linear growth is insufficient after a toad has reached sexual maturity". Breeding adults are commonly judged to be those over two years old. During this study these showed a wide range of sizes and were only captured until the end of June after which the breeding migration had presumably ceased. It is interesting to note that first year animals were caught later in the year than were the other two size ranges. This probably reflects a difference in the behaviour of the age groups. It seems likely that more young toads stay close to the breeding ponds in their first year than do older animals, and, in view of the captures of group I animals in October and November, they may hibernate here. Haapanen (1974) found no marked differences in site tenacity between young and older toads, but he did not study first year animals.

## ACKNOWLEDGEMENTS

I would like to thank Professor D. M. Guthrie for granting facilities in the Zoology Department at Manchester, Manchester University Estates Department and Mr. and Mrs. Hamilton for permission to collect on their land, Dr. D. W. Yalden for reading and commenting on the manuscript and Miss H. J. Reed for her assistance.

## REFERENCES

- Collier, R. V. (1970). Notes on the toad (*Bufo bufo*) at Castor Hanglands *British Journal of Herpetology* **4**, 144-151.
- Frazer, J. F. D. (1983). *Reptiles and Amphibians in Britain* Collins, London.
- Gittins, S. P., Parker, A. G. and Slater, F. M. (1980). Population characteristics of the common toad (*Bufo bufo*) visiting a breeding site in mid-Wales. *Journal of Animal Ecology* **49**, 161-173.
- Gittins, S. P., Steeds, J. E. and Williams, R. (1982). Population age structure of the common toad (*Bufo bufo*) at a lake in mid-Wales determined from annual growth rings in the phalanges. *British Journal of Herpetology* **6**, 249-252.
- Haapanen, A. (1974). Site tenacity of the common toad, *Bufo bufo* (L.). *Annales Zoologica Fennici* **11**, 251-252.
- Mathias, J. H. (1971). *The comparative ecologies of two species of Amphibia (Bufo bufo and B. calamita) on the Ainsdale Sand Dunes National Reserve*. Ph.D. Thesis, Manchester.
- Wheater, C. P. (1984). *The ecology of some surface active Coleoptera from Cheshire*. M.Sc. Thesis, Manchester.

## **AGAMA GRACILIMEMBRIS CHABANAUD, 1918 (REPTILIA: SAURIA: AGAMIDAE) IN NIGERIA**

M. E. GARTSHORE

*RR#3 Dundas, Ontario L9H 5E3, Canada.*

*(Accepted 18.1.85)*

### INTRODUCTION

Due to its diminutive size and sparse distribution, *Agama gracilimembris* is seldom encountered in the field by the collector. Its range, diagnosis, description and colour in life have been reported by Grandison (1968), and later she discussed its taxonomic affinities to *A. weidholzi* (Grandison, 1969). Little else is available in the literature on this species. In this paper, new information is reported on *A. gracilimembris* in Nigeria where it is not uncommon in wooded savannas.

### DESCRIPTION

In life, adults of both sexes vary in colour from pale sandy brown to almost black, but during the breeding season become markedly dichromic. Males develop a more vivid dorsal pattern, with pink undersides and blue sides to the tail; and sometimes pink and blue scales scattered over the whole body. Gravid females become much duller and develop 2-3 orange patches on either side of the dorsum. The head, posterior to the tympanum, becomes bluish-black with the single conical spines standing out as pale blue (Fig. 1). This colour transformation in gravid females is very similar to that observed in *A. doriae* and *A. sankaranica* (Gartshore, unpublished data). Juveniles tend to be much duller than adults, usually a pale sandy brown with only faint scrawls suggesting the adult pattern.

During the breeding season females average larger than males (snout-vent length for females ( $n = 4$ ) is 48-53 mm; for males ( $n = 5$ ) 40-42 mm). Grandison (1968) reported 44.0-47.0 mm for males and 49.0-56.7 mm for gravid females. Juveniles captured between October and December averaged 26.7 mm ( $n = 7$ ). These may have hatched as early as the previous June.

Unlike other Nigerian members of the genus this species has a marked lateral fold. Males also have a pronounced swelling at the base of the tail caused by enlarged hemipenes. The only other Nigerian agama to have this is *A. sankaranica*.

### RANGE

*A. gracilimembris* occurs in Sudan and Guinea savanna woodlands from the Republic of Benin in the west to Central African Republic in the east (Grandison, 1968). In Nigeria, it was also observed to occur in wooded savannas. Fig. 3 gives localities from

my records and those reported by Grandison (1968). Bohme (1975) collected two males and a female at Boki in northern Cameroon and Joger (1982) collected a single specimen at Benue National Park in Cameroon. Joger (personal communication) found this lizard at Koumbala camp in Central African Republic. Stephen Spawls (personal communication) recorded it at Wa, northern Ghana a range extension to the west.

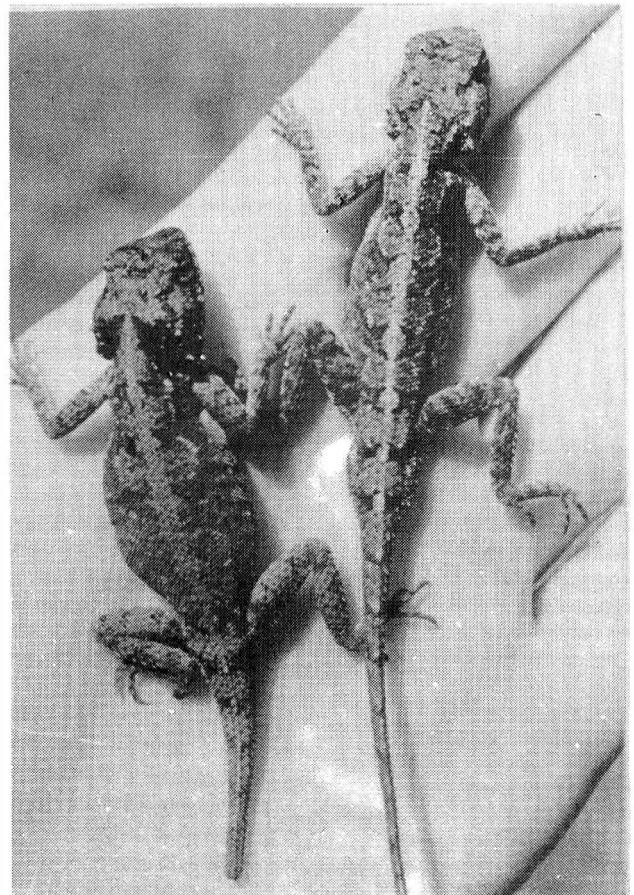


Fig. 1. Two adult *Agama gracilimembris* (female on left, male on right) at the beginning of the breeding season. Note differences in dorsal pattern: the female is duller with dark areas posterior to the tympanum; the male is vividly marked and has enlarged hemipenes.

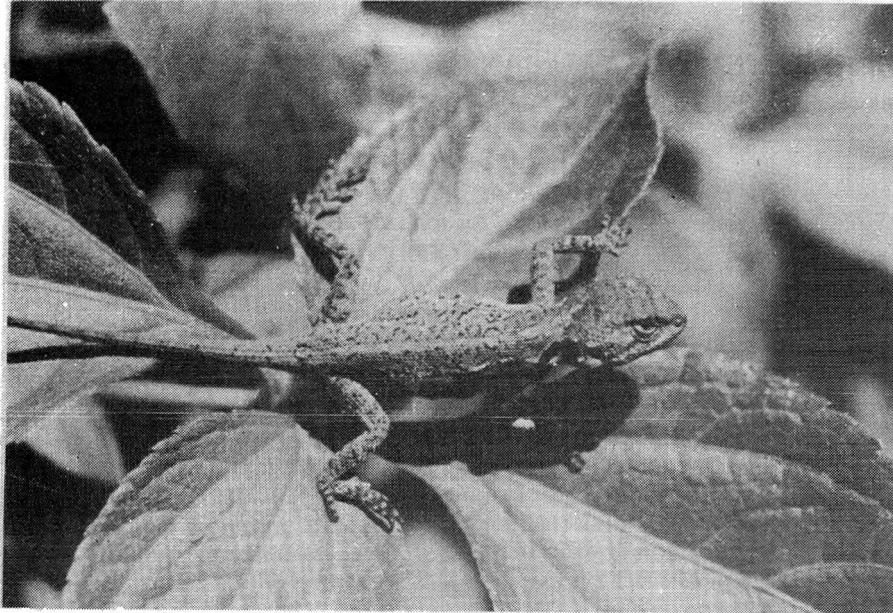


Fig. 2. Juvenile *Agama gracilimembris* captured in October. Only faint scrawls mark the adult dorsal pattern.

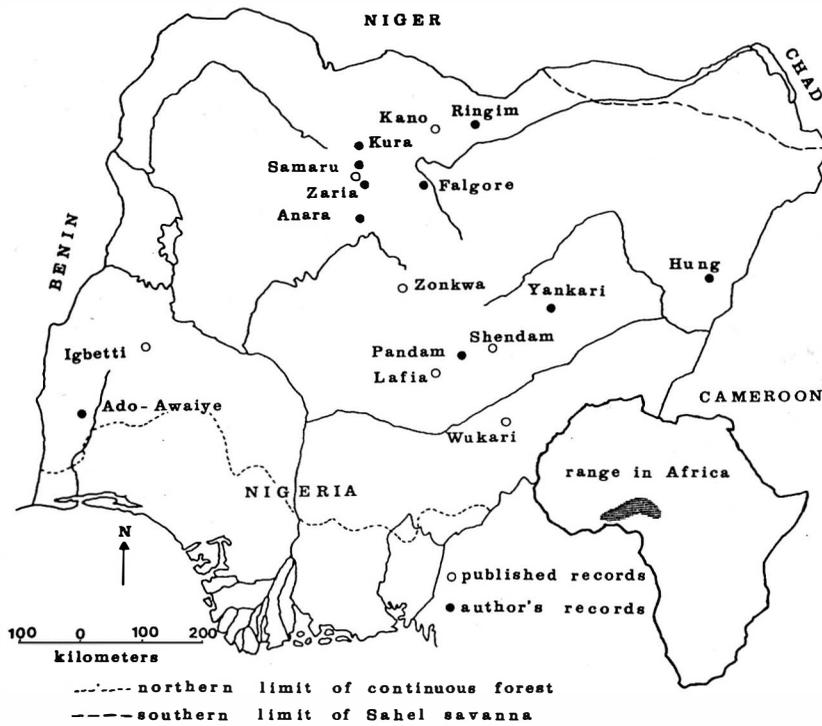


Fig. 3. Map of Nigeria showing localities where *Agama gracilimembris* has been observed or collected. Insert shows known range of the species.

HABITAT

*A. gracilimembris* was most often seen in open lightly wooded savanna where vegetation was confined to isolated clumps. The following brief habitat descriptions serve to demonstrate the kinds of areas where this species was observed in the present study: (a) open, degraded, sloping ground of ironstone gravel

and quartzite, sparsely grassed and with isolated shrubs (n = 11 observations); (b) degraded, fallow farmland with lateritic soil and isolated clumps of *Dichrostachys*, *Bauhinia* and *Guiera* shrubs (n = 5); (c) open, relatively undisturbed, combretaceous woodland (n = 3); (d) fragmented gneiss and quartzite ridges in mature *Anogeissus* woodland (n = 2); (e) open cultivated field or vehicle tracks in river floodplain

with 2 m high grass and *Mimosa pygra* thickets (n = 2); (f) closed canopy *Isobertinia doka* woodland near gallery forest with dense ground cover of grass (n = 1); (g) open doka woodland on smooth granitic outcrop and ironstone (n = 1); (h) edge of gallery forest on large inselberg under exfoliated slabs of granite (n = 1); (i) sandy soil in cultivated field of sorghum (n = 1). Thus, it appears that this species occurs in a wide variety of habitats in wooded savannas.

#### BEHAVIOURAL ECOLOGY AND SOCIAL ORGANIZATION

*A. gracilimembris* were often seen sunning on small termite mounds or other vantage points. When approached they fled down small holes or into grass tussocks (Fig. 4). The latter behaviour is peculiar to this agama and was an effective means of escape.



Fig. 4. Subadult *Agama gracilimembris* taking refuge in grass tussock when faced with a potential predator.

This is a solitary species. No social interactions were observed in the field but it is likely that the sexes consort only when a female is receptive. Males occupy home ranges but do not apparently defend territories or attempt to secure sole access to females. This is in marked contrast to some other species of agamas such as *A. agama* and *A. doriae* which are very conspicuous in their defense of territories and control of access to females (Gartshore, unpublished data). This difference in social organization may account for the male's smaller size relative to the female's. From March to June males tend to occupy elevated perches 0.5-1.5 m high in leafless shrubs where possibly they gain a better vantage point for surveillance of potential mates. Gravid females were observed from 2nd April to 30th May, thus, as in other agamas breeding commences with the onset of the first rains in April. Few adults were observed after June, the last record being on 22nd August. Thereafter, only juveniles were observed which mature over the dry season to breed the following year. It is clear, that here we are dealing with an annual species. *A. weidholzi* the western vicariant of *A. gracilimembris* is solitary and probably also an annual species (Joger, 1979).

It is of interest to note that in the case of *A. gracilimembris* and *A. sankaranica* males share the following characteristics: solitary, reduced nuptial colours, size smaller than females, conspicuous hemipenes and use of surveillance posts. These similarities are more likely to be due to concurring social organizations than any real taxonomic affinities.

#### ACKNOWLEDGEMENTS

Many thanks to A. G. C. Grandison for her enthusiasm, encouragement, help and patience. Thanks also to W. Bohme, M. Dyer and U. Joger who made helpful comments on an earlier draft.

- Bohme, W. (1975). Zur Herpetofaunistik Kameruns, mit Beschreibung eines neuen Scinciden. *Bonner Zoologische Beitrage* 26, 2-48.
- Grandison, A. G. C. (1968). Nigerian lizards of the genus *Agama* (Sauria: Agamidae). *Bulletin of the British Museum of Natural History (Zoology)* 17, 67-90.
- Grandison, A. G. C. (1969). *Agama weidholzi* (Sauria: Agamidae) of West Africa and its relationship to *Agama gracilimembris*. *Bulletin de l'Institut Francais Afrique Noire*. T 31 serie A 2, 666-675.
- Joger, U. (1979). Zur Okologie und Verbreitung wenig bekannter Agamen Westafrikas (Reptilia: Sauria: Agamidae). *Salamandra* 15, 31-52.
- Joger, U. (1982). Zur Herpetofaunistik Kameruns (II). *Bonner Zoologische Beitrage*. 33, 313-342.

## HERPETOFAUNA OF THE LATE PLEISTOCENE FISSURES NEAR IGHTHAM, KENT

J. ALAN HOLMAN<sup>1</sup>

*The Museum, Michigan State University, East Lansing, Michigan 48824 U.S.A.*

<sup>1</sup> This research was done whilst the author was a visiting professor at the University Museum, Oxford, Summer, 1984

(Accepted 1.12.84)

### ABSTRACT

The late Pleistocene fissure deposits near Ightham, Kent, have yielded the remains of *Triturus* sp., *Bufo bufo*, *Bufo calamita*, *Rana temporaria*, *Anguis fragilis*, *Natrix natrix*, *Coronella austriaca*, and *Vipera berus*. These are the first British fossil records of the British endangered species *Bufo calamita* and *Coronella austriaca*, and the first record of any kind of *Coronella austriaca* from Kent. *Rana temporaria* comprises 87 per cent of the minimum number of individuals of the fossil fauna. It is postulated that the fossil amphibians and reptiles accumulated during the early Flandrian Stage when the temperature first became as warm as it is in southern England today.

### INTRODUCTION

The fossiliferous fissures near Ightham, Sevenoaks Area, Kent, have yielded the largest Pleistocene herpetofauna thus far recorded from the British Isles. This paper details that fauna which provides the first British fossil records of *Bufo calamita* and *Coronella austriaca*.

E. T. Newton (1894) published on the vertebrate fauna collected by Lewis Abbott from the Ightham fissures. Among these vertebrate remains were quantities of anuran bones and some reptile elements. Newton (1894, pp. 189-190 and Plate 10) provided a short annotated list of the herpetological remains, and figured a few specimens. Abbott (1894) provided a detailed account of the fissures of SE England, a history of the Shode Valley where the Ightham fissures occur, and a specific geological description of the fissures that yielded the fossils. He also discussed the fossil plants and invertebrates found at the site. Stuart (1982) indicates concisely the status of the Ightham fissure deposits in his discussion of British cave and fissure Pleistocene vertebrate faunas as follows. "Few British examples have been described but the Ightham Fissures, near Sevenoaks, Kent, in Upper Greensand (Cretaceous), have yielded a rich late-Pleistocene fauna (Newton, 1894). It is now generally recognized that these deposits represent a considerable period of Devensian and Flandrian time". I shall comment on the possible age of the deposit based upon the herpetofauna in the discussion section of the present paper.

With the kind help of Dr. Angela Milner and Ms Sandra Graham of the Department of Palaeontology of the British Museum (Natural History), I was given the privilege of studying the Ightham Fissures herpetological fossils. These fossils came from three sources: (1) materials presented by Mr. Lewis Abbott, (2) materials from the Lewis Abbott collection presented by Sir H. H. Howorth in 1920, and (3)

collections acquired from Mr. F. Corner in 1916.

It became immediately clear that these collections were in need of re-study as certain species were unidentified and certain misidentifications had been made. Characters supplementing those given by E. T. Newton (1894) for the identification of British Pleistocene amphibians and reptiles are given in the present paper, and presence in the fauna of *Bufo calamita* and *Coronella austriaca*, previously unrecognized is documented.

### SYSTEMATIC PALAEOLOGY

In the following section, minimum numbers of individuals of each species are based either on the largest number of either non-paired elements or of right or left elements. For instance, if a species was represented by six skulls, and by four left and three right humeri, the minimum number of individuals would be six. If a species was represented by six skulls, and seven left and six right humeri, the minimum number of individuals would be seven. When fossils were in distinctly separate lots, as in *Triturus* below, each lot was counted as at least one individual.

Class Amphibia

Order Caudata

Family Salamandridae

*Triturus* sp.

*Identifiable material* — Lewis Abbott Collection: BM(NH) R-4735, a skull and an attached string of vertebrae; R-4736, 18 vertebrate and two fragmentary limbs. F. Corner Collection: BM(NH) R-10164, three vertebrae.

These three lots represent a minimum number of three individuals.

*Remarks* — This genus was reported by E. T. Newton (1894). The genus is osteologically different from other European caudates, but unfortunately there is not enough comparative material available at

the present time to determine what species is represented. Since specimen R-4735 has a nearly complete skull, it is possible that a specific determination may be made in the future. All three species of British newts, *Triturus cristatus*, *T. helveticus*, and *T. vulgaris* have been reported from the general area in modern times (Frazer, 1983, Figs. 27, 31, and 32).

#### Order Salientia

Since 1955 I have been impressed with the value of the ilium as the single best element upon which to base identifications when only disarticulated individual bones are available in the fossil record. The osteological structure of the ilium, and to a lesser extent the structure of the sacrum, reflects the mode of locomotion of the animals. Long-leaping anurans, hopping anurans, running or dashing anurans, walking anurans, climbing anurans, and burrowing ones all have different ilial structure, especially in the posterior part of the bone where the great ligaments attach. Convergence of these characters in different anuran families is not only of great interest, but might cause serious problems in the identification of early Tertiary anurans, but in late Pleistocene faunas, this has not been the case.

There are several thousand anuran bones from the Ightham Fissures, most of which are isolated postcranial elements. Among these postcranial

*Remarks* — The ilia of *Bufo bufo* and *Bufo calamita* are readily distinguishable (Fig. 1). As indicated by Frazer (1983) *Bufo bufo* is a hopping toad, whereas *Bufo calamita* is a running toad capable of making mouse-like dashes. This apparently is reflected in the ilia of the two species, especially in the posterior portion of the bone. *Bufo bufo* has a low, rounded ilial prominence that develops a roughened protuberance on it in older individuals (Fig. 1a, b). *Bufo calamita* on the other hand has a distinctive triangular ilial prominence that never develops a protuberance (Fig. 1c). *Bufo bufo* is a relatively common species in the general area today (Frazer, 1983, Fig. 18).

#### *Bufo calamita* Laurenti

*Identifiable material* — Lewis Abbott Collection: BM(NH) R-4730, one left ilium; R-10173, four left and six right ilia; R-10176, five left and six right ilia.

This is a minimum number of 12 *Bufo calamita* from the Ightham Fissures.

*Remarks* — Specimen R-4730 was figured and discussed by E. T. Newton (1894, Plate 10, Fig. 4) as *Bufo bufo*. The figure inadequately shows the triangular ilial prominence that distinguishes *B. calamita* readily from *Bufo bufo* which has a rounded, sometimes somewhat roughened ilial prominence as discussed in the previous section. The natterjack has not been recorded in Kent since 1960

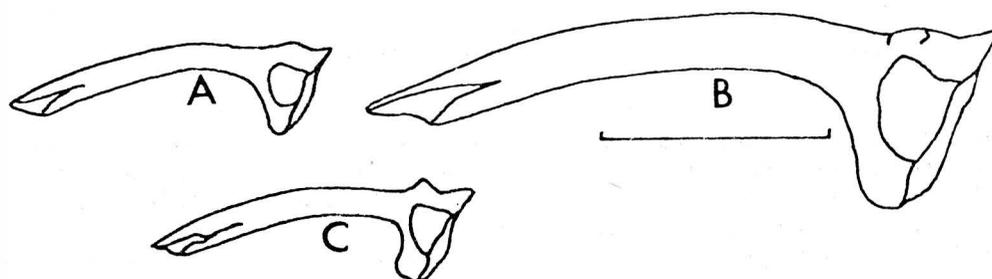


Fig. 1 Left ilia of A, young *Bufo bufo*, B, large adult *Bufo bufo*, C, adult *Bufo calamita* in lateral view. The line equals 20 mm.

elements are several hundred ilia that I believe may be identified to species with confidence in most cases. Other elements are so difficult to identify that they have been left in the category to which they were originally referred which was "*Rana-Bufo*".

#### Family Bufonidae

##### *Bufo bufo* Laurenti

*Identifiable material* — Lewis Abbott Collection: BM(NH) R-10170, one right ilium; R-10174, five left and four right ilia; R-10175, two left and four right ilia. F. Corner Collection: BM(NH) R-10171, four left and two right ilia.

This is a total minimum number of 12 individuals of *Bufo bufo* from the Ightham Fissures collections.

(Frazer, 1983, Fig. 22) and there are only two of these pre-1960 records.

#### Family Ranidae

##### *Rana temporaria* Linnaeus

*Identifiable material* — Lewis Abbott Collection: BM(NH) R-2920, three left and one right ilia; R-4731, one left ilium; R-10177, two left ilia; R-10178, 350 left and 383 right ilia. F. Corner Collection: BM(NH) R-10179, seven left and seven right ilia.

This is a minimum number of 391 individuals of *Rana temporaria* from the Ightham Fissures.

*Remarks* — Specimen R-4731, a left ilium, was correctly figured as *Rana temporaria* by E. T. Newton (1894, Plate 10, Fig. 1a, 2, and 3). The genus *Rana* may

be separated from the genus *Bufo* on the basis of the presence of an ilial blade (vexillum of Böhme, 1982) in *Rana* and its absence in *Bufo* (compare Figs. 1 and 2 of the present paper). The ilial blade in *Rana temporaria* appears to differ from European and American *Rana* in having an ilial blade that is depressed anteriorly

osteoderms, some with ribs attached; R-8931, an almost complete individual fine enough for a museum exhibit specimen; R-8932, four skull fragments, one left dentary, one pectoral girdle fragment, 38 vertebrae, a mass of osteoderms, and 27 single osteoderms, R-10163, 17 vertebrae and one rib, R-

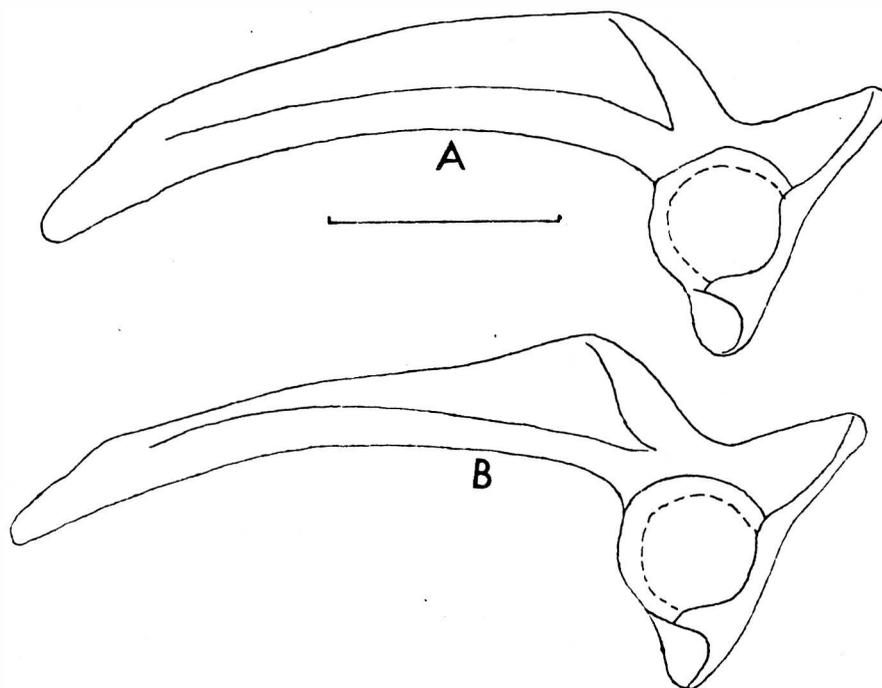


Fig. 2. Left ilia of A, *Rana esculenta*, B, *Rana temporaria* in lateral view. The line equals 10 mm.

(Fig. 2). Based on this character, all of the Ightham ilia appear to represent the common British frog *Rana temporaria*. *Rana temporaria* is quite easily distinguished from *Rana esculenta* which has a fully-developed ilial blade (Fig. 2). *Rana temporaria* occurs in the area today (Frazer, 1983, Fig. 12).

Class Reptilia

Order Squamata

Family Anguidae

*Anguis fragilis* Linnaeus

*Identifiable material* — Lewis Abbott Collection: BM(NH) R-10169, one left compound bone (posterior mandible), two left dentaries, eight vertebrae, five ribs, and a mass of osteoderms; R-4728, one body whorl of fused osteoderms and two single osteoderms; R-4734, two skull fragments, seven frontoparietals, 10 left and eight right compound bones, seven left and seven right dentaries, 429 vertebrae, 44 ribs, and five single osteoderms; R-10166, 2 caudal vertebrae; R-10167, six vertebrae and three ribs; R-10168, posterior section of skull. This is a minimum number of 11 slow worms in the L. Abbott Collection. F. Corner Collection: BM(NH) R-8929, fused mass of vertebrae, ribs, and osteoderms, R-8930, one posterior skull fragment, 59 vertebrae, and 10 masses of fused

10165, a mass of fused material consisting of at least three individuals based on three discernible left dentaries in the mass. This appears to be a minimum number of eight individuals in the F. Corner Collection.

A total minimum number of 19 slow worms is then represented in the Ightham Fissures material.

*Remarks* — *Anguis fragilis* skeletal elements, including skull bones, lower jaw bones, vertebrae, osteoderms, and even ribs are easily distinguishable from other British and European reptiles, mainly due to modifications for a limbless, fossorial condition. Smith (1973, Fig. 58) provides an illustration of an *Anguis fragilis* skull in three views, and another illustration (Fig. 57) of *Anguis fragilis* mid-caudal vertebrae compared to those of *Lacerta vivipara*.

Comparison of the Ightham fossils with four specimens from the Oxford University Museum and one from the Michigan State University Museum showed no trenchant differences. Nevertheless, one large lower jaw from BM(NH) R-4734 had a total length of 22.9 mm. This represents a much larger jaw than the largest Oxford specimen which had this measurement 17.0 mm, and came from an animal that was 290 mm in total length. Smith (1973) provides a measurement of a specimen of a slow worm from Kent which was the second largest he had seen in Britain,

and this specimen had a total length of 400 mm. Thus, by projection of relative proportions, the fossil probably was as large or larger than Smith's Kent animal.

Of possible taphonomic interest, I believe, is the fact that skeletal elements of *Coronella austriaca* were found associated with *Anguis fragilis* R-10166 and 10167 in the Abbott Collection and with R-8929 in the Corner Collection. Frazer (1983) states that *Coronella austriaca* feeds upon *A. fragilis* and provides an illustration of a smooth snake constricting a slow worm. Could the mass condition of much of the slow worm material at the Ightham Fissures be related to their having been stomach contents of smooth snakes?

#### Family Colubridae

##### *Coronella austriaca* Laurenti

*Identifiable material* — Lewis Abbott Collection: BM(NH) R-10159, one trunk vertebra; R-10160, 11 trunk vertebrae; R-10161, 11 trunk vertebrae; R-10162, two trunk vertebrae. F. Corner Collection: BM(NH) R-10158, right dentary; R-10156, one vertebra; R-10157, one vertebra. A minimum number of at least two individuals of smooth snake are represented at the Ightham Fissures.

*Remarks* — These vertebrae were found in boxes labelled *Anguis fragilis*, *Natrix natrix*, and *Vipera berus*. The trunk vertebrae of *Coronella austriaca* are quite

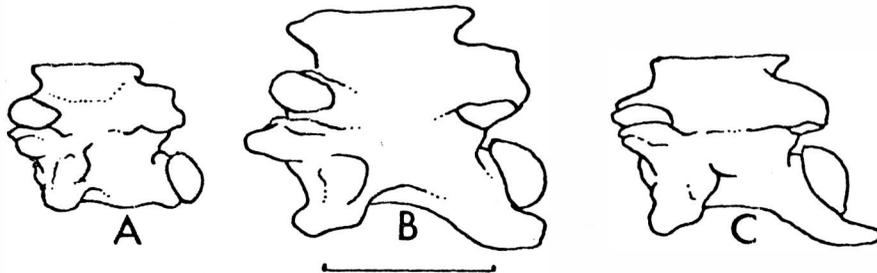


Fig. 3. Trunk vertebrae of A. *Coronella austriaca*, B. *Natrix natrix*, C. *Vipera berus* in lateral view. Modified from Szyndlar (1984). The line equals 4 mm.

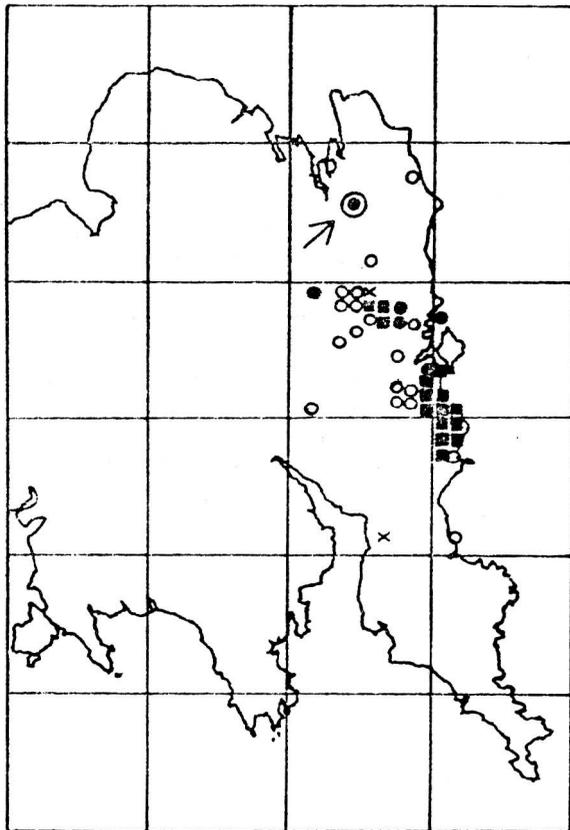


Fig. 4. Modern distribution of *Coronella austriaca* redrawn from Frazer (1983) and fossil distribution of this species from Ightham, Kent (dot surrounded by circle and indicated by arrow). Modern distribution symbols: open dot, up to and including 1959; closed dot, 1960-69 inclusive; closed squared, 1970 to present; X, introduction.

distinctive, especially from *Natrix natrix* and *Vipera berus* (Fig. 3) and also from snakes that occur on the European Continent today (Szyndlar, 1984). It is notable that *Coronella austriaca* trunk vertebrae have some characters in common with some New World colubrids of the Subfamily Xenodontinae, yet they are included in the colubrid family Colubrinae by Dowling and Duellman (1978). These possibly parallel vertebral characters include the broad haemal keel and depressed neural arch of *Coronella*. A combination of definitive characters for the trunk vertebrae of *Coronella* include (1) the lack of hypapophyses (immediately separating them from *Natrix natrix* and *Vipera berus*, Fig. 3), (2) a non-distinct, broad, haemal keel, (3) a low but not obsolete neural spine, and (4) a depressed neural arch.

The dentary of *C. austriaca* also appears to be distinctive, at least when compared with those of *Natrix natrix* and *Vipera berus* (figures of skulls of *Vipera berus* and *Coronella austriaca* are provided by Smith, 1973, Figs. 67 and 78). The Ightham fossil had a total of 27 tooth and alveolar spaces, with the posterior teeth being shorter and stouter than the anterior teeth. *Natrix natrix* appears to have fewer teeth and alveolar spaces (19 in an uncatalogued Oxford University Museum specimen), and all of the teeth almost equally long and slender.

The smooth snake, as far as I can determine, has never been recorded as a fossil in Britain, and has never been reported from Kent during prehistoric or historic times (Frazer, 1983, Fig. 44). If *Coronella austriaca* bones are present in other British Pleistocene fossil collections, it will be interesting to discover whether the species ever occurred outside of southern England, especially during interglacial stages.

The nearest modern records of *Coronella austriaca* to Ightham, Kent, are from Sussex and Surrey (Fig. 4). Data for this figure are from Frazer (1983).

*Natrix natrix* (Linnaeus)

*Identifiable material* — Lewis Abbott Collection: BM(NH) R-4732, posterior part of skull, one occipital complex, three fragmentary skull pieces, two pterygoids, six left and two right compound bones (posterior mandibles), one left and three right dentaries, 126 vertebrae, and one rib; R-2919, six vertebrae. F. Corner Collection: BM(NH) R-10153, 26 vertebrae; R-10155, one right dentary, and 145 vertebrae, two of which are pathologically fused.

There is a minimum number of two grass snakes from the Ightham Fissures.

*Remarks* — Most vertebrae of *Natrix natrix* may be distinguished from most vertebrae of *Vipera berus*. *Natrix natrix* has higher neural spines that are more concave anteriorly (in lateral view) than in *Vipera berus*; and *N. natrix* usually has a much less pointed hypapophysis than in *Vipera berus* (Fig. 3). *Natrix natrix* appears vertebrally separable from *Natrix tessellata* on the basis of the rounded rather than the truncated hypapophysis in *N. natrix* and on the much less gracile parapophyseal processes in *N. natrix* (Szyndlar, 1984). It has previously been pointed out that *Natrix natrix* trunk vertebrae may be separated from those of *Coronella austriaca* on the basis of the lack of hypapophyses in *C. austriaca*.

The compound bone (posterior mandible) of *Natrix natrix* appears to be readily distinguishable from that of *Vipera berus*. E. T. Newton (1894) gives these characters so clearly that I quote them here. "The hinder two-thirds of a mandibular ramus is referred to this species (*Vipera berus*), it agrees with the corresponding part of the viper in being anteriorly slender and rounded, deep in the coronoid region, and strongly curved from end to end. The common snake (*Natrix natrix*) has the ramus of the lower jaw less curved, stouter throughout, and not especially deep in the coronoid region".

*Natrix natrix* occurs in the general area today (Frazer, 1983, Fig. 43).

Family Viperidae

*Vipera berus* (Linnaeus)

*Identifiable material* — Lewis Abbott Collection: BM(NH) R-4729, left compound bone (posterior mandible) figured by E. T. Newton (1894, Plate 10, Fig. 18), R-4733, 53 vertebrae and one dentary bone. This is a minimum of two individuals based on the fact that the two above lots appear distinctive.

*Remarks* — Characters for distinguishing the vertebrae and compound bones of *Vipera berus* from other British snakes have been given in previous sections. Based on a single specimen of *Vipera ursini* (Michigan State University H432), it would appear that *V. berus* may have a somewhat higher neural spine. Szyndlar (1984) discusses further useful osteological characters of *Vipera berus*.

*Vipera berus* occurs in the general vicinity of the fossil site today (Frazer, 1983, Fig. 41).

DISCUSSION

The Ightham Fissures near Sevenoaks, Kent, have yielded the largest Pleistocene herpetofauna thus far reported from the British Isles. At least four species of amphibians and four species of reptiles are represented, and as Dr. A. S. Cooke has indicated (personal communication), it would be unusual to find as many forms in a single site anywhere in Britain today. Fig. 5 indicates the minimum number of individuals of each species represented. These numbers may be somewhat misleading as I believe that the absence of lacertids and the rarity of newts may be a reflection of the very small size of the individual bones of these forms. These tiny elements may have escaped detection by the early collectors, or they may have slipped through the collecting screens during the washing process. On the other hand, the large number of *Rana temporaria* bones compared with those of the two *Bufo* species, could be a reflection of their relative abundance at the time.

MINIMUM NUMBER OF INDIVIDUALS OF HERPETOLOGICAL SPECIES OF THE LATE PLEISTOCENE OF IGHTHAM, KENT

<u>Triturus</u> sp.	3
<u>Bufo bufo</u>	12
<u>Bufo calamita</u>	12
<u>Rana temporaria</u>	391
<u>Anguis fragilis</u>	19
<u>Natrix natrix</u>	8
<u>Coronella austriaca</u>	2
<u>Vipera berus</u>	2

Fig. 5. Minimum number of individuals of herpetological species from the late Pleistocene of Ightham Fissures, Kent.

The herpetofauna may bear importantly on the age of the deposit. As previously stated, the Ightham Fissures have been believed to represent a considerable amount of Devensian (last glacial stage) and Flandrian (10,000 year before present onward) time. Since the Ightham Fissures herpetofauna indicates as moderate a climate as would be expected in southeastern England today, one may rule out any full glacial time, at least during the slot represented by the herpetological fossils. However as pointed out by Stuart (1982), the Devensian was a long, complex, multicyclic stage, lasting from 50,000 to 10,000 years ago; hence just calling the Devensian a "cold stage" is probably an oversimplification. It is not beyond possibility that the herpetological fossils could represent some warming trend in the Devensian, but this would seem a less parsimonious choice than the following one.

It is believed that between about 10,600 and 10,100 years ago southern Britain had a Tundra vegetation, a periglacial climate, and an arctic fauna (Pennington, 1977; Coope, 1977). There appears to have been a warming trend after 10,100 years before present, so that by 9500 years ago southern England had a climate at least as warm as today (Coope, 1977; Osborne, 1974). During this warming trend the open Tundra vegetation was replaced by open birch scrub between about 9700 to 8700 years ago (Hibbert *et al.* 1971). After this came hazel scrub (8700-8100 years before present), then a hazel and pine mixture (8100-7100 years before present), and then deciduous forest (oak, elm, alder, hazel) from 7100-5000 years before present.

Based upon the preservation and apparent mineralization of the fossils, and on the basis of the occurrence of several extinct mammals from the same fissures at Ightham (E. T. Newton, 1894), I would venture a guess that the herpetofauna lived in early Flandrian times, probably around 9500 years ago when the temperature was as warm as it is in southern England today (Fig. 6).

BRITISH LATE PLEISTOCENE STAGES		POSTULATED CLIMATE	IGHTHAM, KENT, FISSURE SITE
FLANDRIAN		TEMPERATE	●
DEVENSIAN	LATE		
	MIDDLE	COLD	
	EARLY		
IPSWICHIAN		TEMPERATE	
WOLSTONIAN		COLD	

Fig. 6. Postulated time of occurrence (closed circle) of Ightham, Kent, Pleistocene herpetofauna.

It is certainly beyond the scope of this paper, which is mainly a preliminary faunal listing, to go into a detailed discussion of the palaeoecology of *Bufo calamita* and *Coronella austriaca*. Nevertheless, I have studied the herpetological collections at the British Museum (Natural History) from the temperate early middle Pleistocene Cromerian Stage from West Runton in Norfolk, and neither *Bufo calamita* nor

*Coronella austriaca* were present. *Bufo bufo*, *Rana temporaria*, *Natrix natrix*, and *Vipera berus*, however, were not uncommon. It may be that *Coronella austriaca* has never occurred outside of southern England, but that before the intensive alteration of natural habitats by humans it had a wider distribution in the southern part of the country.

What would the prehistoric habitat of *Bufo calamita* and *Coronella austriaca* have been like at Ightham, Kent? It is difficult to define the exact environment of the area during the time of the deposition of the bones, as the exact age of the site is hypothetical, and thus the composition of the surrounding vegetation can only be guessed. Nevertheless, it seems certain that the topography of the Kentish Rag of the Valley of the Shode where the fossils came from (E. T. Newton, 1894) was quite irregular and with numerous ledges and fissures.

One of the most interesting aspects of the late Pleistocene amphibian and reptile fauna in North America south of the glacial boundaries (Lundelius *et al.* 1983; Fay, 1984; Holman, 1985) is that although there was a widespread extinction of large mammalian species at the end of the Wisconsin Stage about 10,000 years ago; that taxonomically the herpetofauna essentially remained unchanged into the present. It is then noteworthy that in the first large late Pleistocene British herpetofauna documented, that this also appears to be the case. One may speculate then, that whatever biological attributes these poikilothermic animals had, that they allowed them to be more fit than the large mammals to withstand the marked changes (Stuart, 1982, p. 139) that characterized the Flandrian Stage.

#### ACKNOWLEDGEMENTS

Dr. Thomas Kemp graciously allowed me to study at the Oxford University Museum in August and September of 1984. Dr. Angela Milner and Ms Sandra Chapman allowed me access to the Ightham Fissures herpetological fossils and provided me with study space at the British Museum (Natural History). Dr. Michael Benton provided literature, technical help, and many other kindness during the study period. Dr. Gillian King of the Oxford University Museum provided comparative skeletal material. Ms Denise Blagdon of the Oxford University Museum supplied technical assistance. Drs. A. S. Cooke, P. F. A. Maderson, A. R. Milner, G. Underwood, and D. W. Yalden provided useful verbal comments about British amphibians and reptiles. Dr. A. S. Cooke read a manuscript of this paper and provided useful written comments. To all of these people I am very grateful. Michigan State University provided a Research Initiation Grant for the project, and I gratefully acknowledge this help.

#### REFERENCES

- Abbott, W. J. L. (1894). The ossiferous fissures in the Valley of the Shode, near Ightham, Kent. *Quarterly Journal of the Geological Society of London* 50, 171-185.

- Böhme, G. (1982). Biometrische untersuchungen an Skelettle-  
menten von anuran. *Wissenschaftliche Zeitschrift der  
Humboldt-Universität zu Berlin* 31, 209-216.
- Coope, G. R. (1977). Fossil coleopteran assemblages as  
sensitive indicators of climatic changes during the  
Devensian (last) cold stage. *Philosophical Trans-  
actions of the Royal Society of London B* 280, 313-340.
- Dowling, H. G. and Duellman, W. E. (1978). *Systematic  
herpetology: A synopsis of families and higher  
categories*. Hiss Publications, New York.
- Fay, L. P. (1984). Late Appalachian herpetofaunas: stability  
in the midst of change. Doctoral Dissertation, Michigan  
State University, East Lansing.
- Frazer, D. (1983). *Reptiles and amphibians in Britain*.  
Collins, London.
- Hibbert, F. A., Swifter, V. R., and West, R. G. (1971). Radio-  
carbon dating of Flandrian pollen zones at Red Moss,  
Lancashire. *Proceedings of the Royal Society of  
London B* 177, 161-171.
- Holman, J. A. (1985). The known herpetofauna of the late  
Quaternary of Virginia poses a dilemma. *In press in  
Proceedings of the Symposium on the Quaternary of  
Virginia*. Virginia Division of Mineral Resources  
Publications, Charlottesville.
- Lundelius, E. L., Graham, R. W., Anderson, E., Guilday, J.,  
Holman, J. A., Steadman, D. W., and Webb, S. D.  
(1983). *Terrestrial vertebrates: In. Late Quaternary  
Environments of the United States*. University of  
Minnesota Press, Minneapolis.
- Newton, E. T. (1894). The vertebrate fauna collected by Mr.  
Lewis Abbott from the Fissure near Ightham, Kent.  
*Quarterly Journal of the Geological Society of London*  
50, 183-204.
- Osborne, P. J. (1974). An insect assemblage of Early  
Flandrian age from Lea Marston, Warwickshire and its  
bearing on the contemporary climate and ecology.  
*Quaternary Research* 4, 471-486.
- Pennington, W. (1977). The late Devensian flora and  
vegetation of Britain. *Philosophical Transactions of the  
Royal Society of London B* 280, 267-272.
- Smith, M. A. (1973). *British amphibians and reptiles*,  
5th edition. Collins, London.
- Stuart, A. J. (1982). *Pleistocene vertebrates in the British  
Isles*. Longman, London and New York.
- Szyndlar, Z. (1984). Fossil snakes from Poland. *Acta Zoo-  
logica Cracoviensa*, 28, 1-156.

HERPETOLOGICAL JOURNAL, Vol. 1, pp. 32-36 (1985)

## SEASONAL CHANGES IN METABOLISM OF THE LIZARD *LACERTA VIVIPARA*

MOHAMED K. AL-SADOON\* AND IAN F. SPELLERBERG†

\* *Department of Zoology, College of Science, King Saud University, P.O. Box 2455, Riyadh, Saudi Arabia*

† *University of Southampton, Department of Biology, Southampton, England SO9 3NH*

(Accepted 23.1.85)

### ABSTRACT

Acute oxygen consumption determinations for both adults and sub-adults of *L. vivipara* were made over the temperature range 5-30°C during summer and winter. During winter dormancy, both adults and sub-adults were found to have a metabolic rate lower than the metabolic rate of summer animals at each experimental temperature. This reduction of oxygen consumption in winter lizards can be interpreted as an "inverse compensation" (Precht's Type 5 pattern of response). It is concluded that this adjustment can reduce energy costs during the winter period and is a pre-requisite for survival during winter dormancy.

### INTRODUCTION

Some reptiles have evolved a number of ways by which they can tolerate low winter temperatures. For example, some species of reptiles which inhabit cool, temperate zones and high altitudes have low critical minimum temperatures, compared to their summer critical minimum temperature (Spellerberg, 1976). Instantaneous shifts in the metabolic rate-temperature curves (Aleksiuk, 1971; 1976a) of cool-temperature

species has been reported to be an adaptation to winter conditions. Many reptiles raise their metabolic rate after exposure to low temperature acclimation (Bennett and Dawson, 1976). In addition, a depression of body temperature below freezing point without internal ice formation, has been observed in few species (Lowe *et al*, 1971).

Winter dormancy in ectotherms has sometimes been called "brumation" to distinguish it from hibernation in endotherms, but it has not found universal

acceptance (Gregory, 1982). In this research the term winter dormancy has therefore been used. Gilles-Baillien, (1974) has suggested that hibernation in small mammals differs from that of the winter dormancy in reptiles, particularly with regard to two aspects. Firstly, winter dormancy in reptiles does not involve adaptive hypothermia and secondly, reptiles do not regulate the dormancy state by internal means. The latter difference has been questioned since some reptiles do undergo some physiological adjustments in their metabolic rate during the winter dormancy period (Moberly, 1963; Bennett and Dawson, 1976; Gatten, 1978; Patterson and Davies, 1978a and Johansen and Lykkeboe, 1979).

The objective of this investigation was to measure levels of oxygen consumption during winter dormancy (adults and sub-adults) and to compare the results with the metabolic rate of *L. vivipara* during the summer.

## MATERIALS AND METHODS

Six male adult *L. vivipara* (mean weight 3.8 gm) and six sub-adult *L. vivipara* (mean weight 2.6 gm) were used for the measurement of summer oxygen consumption. These two groups of lizards were obtained near the New Forest in Southern England. Metabolic rates ( $0, \text{ml g}^{-1} \text{h}^{-1}$ ) were measured at various temperatures (5–30°C) during early September. These results are referred to as the "summer" levels of oxygen consumption.

A further two groups of six lizards each (adults, 3.9 gm; sub-adults, 2.7 gm) were used for the winter metabolic studies. These lizards were placed in a small tank (40 cm x 25 cm) and on 15th November 1980, the entire tank was buried at 35 cm depth in an outdoor vivarium. The tank was half filled with moist hay to maintain a high humidity. Ground temperatures inside the tank were recorded daily. The lizards were left for four months under these conditions which simulated natural conditions for winter dormancy of *L. vivipara*. The first measurements of oxygen consumption were made on 3rd February 1981, following 80 days winter dormancy. The lizards were removed from the holding tank and placed in the animal chambers and their oxygen consumption was measured at different temperatures between 5–30°C. After taking the oxygen measurements, the lizards were returned to the outdoor vivarium for further measurements of oxygen consumption during winter dormancy. The second determinations of oxygen consumption on the adults only were made on 2nd March 1981 (total of 100 days winter dormancy).

A double chamber volumetric system was used for measurements of oxygen consumption. Animals were not allowed to acclimate to the test temperature i.e. acute M-T curves were obtained. Six to eight small respirometers were used. Each respirometer consisted of two 500 ml flasks joined by a vertical glass manometer filled with manometer fluid. One of the flasks served as the animal chamber and the other as a compensating chamber (thermobarometer). Small bags of soda lime (carbon dioxide absorbent) and silicagel (water absorbent) were placed in each flask. Each respirometer was placed in a water bath to

maintain a constant experimental temperature to +0.5°C. The animals were fasted for two days then placed in the flasks at a given temperature (experimental temperature) for 1–4 hours. During this time no readings were taken in order to ensure that the effects of handling were reduced and that the respiration reached standard levels. After this resting period the animal's resting metabolism (standard metabolism) was measured by closing the animal chamber to the atmosphere and then adjusting the thermobarometer so that it was also closed to the atmosphere. The manometer fluid rises as oxygen is consumed in the animal chamber. A syringe (1 ml) of pure oxygen was attached to the animal chamber and direct readings from the syringes could then be taken indicating the volume of oxygen necessary to re-adjust the manometer fluid to its previous level. This process was repeated and readings were taken every 10–15 minutes for at least two hours. Further readings over shorter intervals (e.g. 5 minutes) were taken at higher temperatures because of the high metabolic rate associated with higher temperatures. Between four and six values of oxygen consumption (at each temperature level for each animal) were selected from the lowest but consistent readings. The procedure was repeated for temperatures ranging from 5–30°C intervals. The oxygen consumption values obtained were converted to standard conditions and expressed in mls oxygen consumed per g body weight per hour. All experiments were made at a time when the lizards would normally be active. Full details of the methods may be found in Al-Sadoon (1983) or Al-Sadoon and Spellerberg (1985b).

Comparisons of mean oxygen consumption between experimental groups were made using two tail t-tests. The rejection level of statistical significance adopted in this research was  $P > 0.05$ . Most of these statistical analyses were made with the aid of computer (ICL 2900) at Southampton University.

## RESULTS

Rates of oxygen consumption of adult and sub-adult *L. vivipara* for both summer and winter groups are given in Table 1. Statistical analysis revealed no significant difference ( $P > 0.05$ ) between the two winter groups of adult lizards at any of the six temperatures. However statistical analysis did show that mean oxygen consumption values for both adults and sub-adults were significantly higher for the summer lizards compared to the winter lizards at all temperatures. Data for the two winter samples for the adult lizards were combined when the summer and winter samples were compared (Table 1). At all temperatures the oxygen consumption of sub-adults was found to be higher than that of adults and this may be explained by using specific metabolism which varies inversely with body weight (Al-Sadoon and Spellerberg, 1985a).

The M-T curves for adults and sub-adults were obtained by plotting (semi-log) the mean oxygen consumption values against the appropriate temperatures. A comparison of the M-T curves for both summer and winter samples is shown in Fig. 1.

Temp. (°C)	Adults				Sub-adults		
	Summer	80 days winter dormancy	100 days winter dormancy	P (Data for winter combined)	Summer	80 days winter dormancy	P
5	.037	.016	.017	<.010	.082	.030	<.002
10	.051	.023	.021	<.005	.150	.051	<.001
15	.068	.045	.049	<.010	.183	.089	<.020
20	.131	.063	.064	<.020	.206	.126	<.050
25	.160	.101	.128	<.001	.263	.164	<.050
30	.292	.145	.141	1.001	.385	.252	<.010

TABLE I. Mean oxygen consumption values ( $O_2$  ml  $g^{-1}$   $hr^{-1}$ ) for adults and sub-adults of *L. vivipara*. Summer and winter samples were examined at various temperatures.

From these data it is possible to calculate  $Q_{10}$  values which are presented in Table 2. The "overall"  $Q_{10}$  values for the winter groups are higher than the "overall"  $Q_{10}$  values for the summer groups.

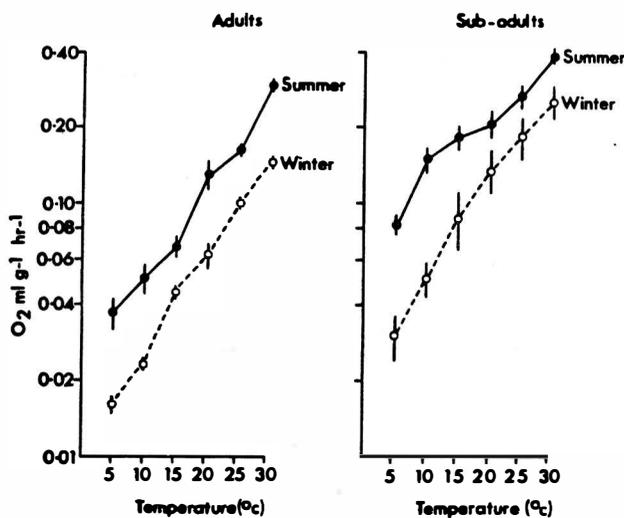


Fig. 1. Acutely measured M-T curves of *L. vivipara* (adults and juveniles) determined at different temperatures in summer and winter seasons. Each point represents the mean oxygen consumption of several lizards. Vertical lines represent  $\pm$  standard errors.

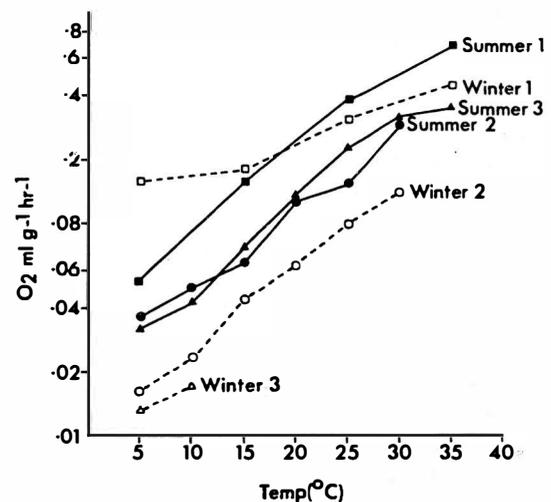


Fig. 2. Comparison between the M-T curves of different populations of *L. vivipara* (adults) during winter and summer seasons. (1) Sveegaard and Hansen (1979); (2) Present study (1983); (3) Patterson and Davies (1978a, 1978b).

In Fig. 2 the oxygen consumption values recorded in this research are compared with the results from two other studies on *L. vivipara*. It is interesting to note that the M-T curves for *L. vivipara* from Denmark are higher than the M-T curves for *L. vivipara* collected in England. Whereas results in the present study showed

Temp. interval (°C)	Adults		Sub-adults	
	Summer	80 days winter dormancy	100 days winter dormancy	80 days winter dormancy
5-10	1.90	2.06	1.52	2.89
10-15	1.77	3.82	5.44	3.04
15-20	3.71	1.96	1.87	2.00
24-25	1.49	2.57	3.59	1.69
25-30	3.33	2.06	1.23	2.36
"Overall" (5-30)	2.28	2.41	2.33	2.34

TABLE 2.  $Q_{10}$  values for oxygen consumption of adults and sub-adults of *L. vivipara*.

that summer levels of oxygen consumption of summer lizards were always higher than those of winter, this is not the case for the *L. vivipara* from Denmark. That is, Sveegaard and Hansen (1979) reported higher levels of oxygen consumption for winter animals at 5°C and 15°C compared with results for the summer animals. At higher temperatures the reverse was true.

## DISCUSSION

The acute M-T curves for the summer and winter groups of adult and sub-adult lizards (Fig. 1) shows that there is a reduction in the metabolic rate of winter lizards. This observed reduced level of resting oxygen consumption in the winter lizards may be regarded as "inverse" or "undercompensation" as suggested by patterns of responses described by Precht (1958). Energy conservation in *L. vivipara* during their dormancy period (early October to early March) is obviously important since at that time food could not be obtained nor could it be digested efficiently at such low body temperatures (Spellerberg, 1982).

That winter oxygen consumption rates at each experimental temperature are lower than might be expected for summer measurements at the same temperature has been reported for many species of reptiles. Moberly (1963) for example observed a reduction in winter metabolism at higher temperatures in the desert lizard, *Dipsosaurus dorsalis*. Acclimation to cold resulted in reduction of active and standard metabolism of *Chelydra serpentina* (Gatten, 1978). Other studies (Mayhew, 1965; Fitzpatrick *et al*, 1971, 1972; Hoskins and Aleksuik, 1973; Fitzpatrick and Brown, 1975; Sveegaard and Hansen, 1979 and Johansen and Lykkeboe, 1979) have also demonstrated a reduction in the oxygen consumption rates following exposure to low temperatures.

The overall  $Q_{10}$  of winter lizards is higher than that of summer lizards for both adults and sub-adults (Table 2). This observation emphasises the comparatively large differences in oxygen consumption between summer and winter animals at low temperatures whereas at higher temperatures the difference diminishes. Previous research has shown that in some other species of reptiles the  $Q_{10}$  is higher in dormant than in non-dormant or active animals (Aleksiuk, 1976a; Aleksiuk, 1976b; Gatten, 1978; Johansen and Lykkeboe, 1979).

The present results are similar to those reported by Patterson and Davies (1978a, 1978b). Comparison of the present results with those obtained by Sveegaard and Hansen (1979) strongly suggest that there may be latitudinal and temperature based adjustment in the M-T curve of *L. vivipara* (from Denmark). That is, those lizards obtained from areas near the New Forest have, during both winter and summer, a lower metabolic rate compared to those lizards studied in Denmark over the same temperature range. This effect seems to indicate that the lizards are adapted to local temperature conditions. Assuming that, an average, daily summer temperature in Denmark is lower than that in England (15°C and 23°C respectively) the following hypothesis could be presented: a comparison between the oxygen consumption rate of an English

*L. vivipara* at an average summer day temperature of 23°C (0.150 O<sub>2</sub> ml g<sup>-1</sup> hr<sup>-1</sup>) and a Danish *L. vivipara* at 15°C an average Danish summer day temperature (0.160 O<sub>2</sub> ml g<sup>-1</sup> hr<sup>-1</sup>) shows a close similarity of the oxygen consumption rates. These results may support evidence of metabolic adjustments to climate and thus provide insights into the capability of reptiles to adapt to cold environments.

The higher levels of oxygen consumption at 5°C and 15°C (results from Sveegaard and Hansen (1979) in Fig. 2) for winter animals, compared to the summer animals are particularly interesting. This elevation in the lower part of the M-T curve in respect to the upper part of the curve for the winter *L. vivipara* from Denmark suggests the presence of a temperature dependent shift which has previously been reported by Tromp and Avery (1977).

## ACKNOWLEDGEMENTS

This research was supported financially by a research studentship from King Saud University, Saudi Arabia. This is gratefully acknowledged by the senior author. We wish to thank both the Nature Conservancy Council and the Forestry Commission for their permission to undertake field work at certain study sites in England. We gratefully acknowledge the technical assistance of the following: N. D. Smith, R. Cornick and B. Lockyer. Sue Coxson typed the manuscript.

## REFERENCES

- Aleksiuk, M. (1971). Temperature-dependent shifts in the metabolism of a cool temperate-reptile, *Thamnophis sirtalis parietalis*. *Comparative Biochemistry and Physiology* **39A**, 495-503.
- Aleksiuk, M. (1976a). Reptilian hibernation: Evidence of adaptive strategies in *Thamnophis sirtalis parietalis*. *Copeia*, **1976**, 170-178.
- Aleksiuk, M. (1976b). Metabolic and behavioural adjustments to temperature change in the red-sided garter snake (*Thamnophis sirtalis parietalis*): an integrated approach. *Journal of Thermal Biology* **1**, 153-156.
- Al-Sadoon, M. K. (1983). The role and the nature of the metabolic rate-temperature curves in lizards from different climatic regions. Ph.D. Thesis, Southampton University, pp.264.
- Al-Sadoon, M. K. and Spellerberg, I. F. (1985a). Comparison of thermal acclimation effects on the metabolism of *Chalcides ocellatus* (desert lizard) and *Lacerta vivipara* (cool-temperate lizard). *Comparative Biochemistry and Physiology* **81A**, 939-943.
- Al-Sadoon, M. K. and Spellerberg, I. F. (1985b). Effect of temperature on the oxygen consumption of lizards from different climatic regions. *Amphibia - Reptilia*, in press.
- Bennett, A. F. and Dawson, W. R. (1976). Metabolism. In *Biology of the Reptilia*. Vol. 5, 127-223. Gans, C. and Dawson, W. R. (Eds). Academic Press, London.
- Fitzpatrick, L. C., Bristol, J. R. and Stokes, R. M. (1971). Thermal acclimation and metabolism in the Alleghany Mountain Salamander, *Desmognathus ochrophaeus*. *Comparative Biochemistry and Physiology* **40A**, 681-688.

- Fitzpatrick, L. C., Bristol, J. R. and Stokes, R. M. (1972). Thermal acclimation and metabolic rates in the dusky salamander, *Desmognathus fucus*. *Comparative Biochemistry and Physiology* **41A**, 89-96.
- Fitzpatrick, L. C. and Brown, A. V. (1975). Metabolic compensation to temperature in the salamander *Desmognathus ochrophaeus* from a high elevation population. *Comparative Biochemistry and Physiology* **50A**, 733-737.
- Gatten, R. E. Jr. (1978). Aerobic metabolism in snapping turtles, *Chelydra serpentina*, after thermal acclimation. *Comparative Biochemistry and Physiology* **61A**, 325-337.
- Giles-Baillien, M. (1974). Seasonal variations in reptiles. In *Chemical Zoology, Vol. IX, Amphibia and Reptilia*, 353-376. Florkin, M. and Scheer, B. T. (Eds). Academic Press, New York.
- Gregory, P. T. (1982). Reptilian hibernation. In *Biology of Reptilia Vol. 13, Physiology*, 52-154. Gans, C. and Pough, F. H. (Eds). Academic Press, London.
- Hoskins, M. A. H. and Aleksuk, M. (1973). Effects of temperature, photoperiod and season on *in vitro* metabolic rates of tissues from *Thamnophis sirtalis parietalis*, a cold climate reptile. *Comparative Biochemistry and Physiology* **45A**, 737-756.
- Johansen, K. and Lykkeboe, G. (1979). Thermal acclimation of aerobic metabolism and O<sub>2</sub>-Hb binding in the snake, *Vipera berus*. *Journal Comparative Physiology* **130**, 292-300.
- Lowe, C. H., Lardner, P. J. and Halpern, E. A. (1971). Super cooling in reptiles and other vertebrates. *Comparative Biochemistry and Physiology* **39A**, 125-135.
- Mayhew, W. W. (1965). Hibernation in the horned lizard *Phrynosoma m'calli*. *Comparative Biochemistry and Physiology* **16**, 103-119.
- Moberly, W. R. (1963). Hibernation in the desert iguana, *Dipsosaurus dorsalis*. *Physiological Zoology* **36**, 152-160.
- Patterson, J. W. and Davies, P. M. C. (1978a). Thermal acclimation in temperate lizards. *Nature*, Lond, 275, 646-647.
- Patterson, J. and Davies, P. M. C. (1978b). Energy expenditure and metabolic adaptation during winter dormancy in the lizard *Lacerta vivipara* Jacquin. *Journal of Thermal Biology* **3**, 183-186.
- Precht, H. (1958). Concepts of temperature adaptation of unchanging reaction systems of cold-blooded animals. In *Physiological Adaptations*, 50-77. Prosser, C. L. (Ed). Am. Physiol. Soc., Washington.
- Spellerberg, I. F. (1976). Adaptations of reptiles to cold. In *Morphology and Biology of Reptiles*, 261-285. Bellairs, A. d'A. and Cox, C. (Eds). Linnean Society Symposium Series No. 3. Academic Press, London and New York.
- Spellerberg, I. F. (1982). *Biology of Reptiles*. Glasgow and London: Blackie.
- Sveegaard, B. and Hansen, I. L. (1979). Body temperature, critical minimum temperature and oxygen consumption in lizards, *L. vivipara*, *L. agilis* and *L. pityusensis*. M.Sc. Thesis, Denmark.
- Tromp, W. I. and Avery, R. A. (1977). A temperature-dependent shift in the metabolism of the lizard *Lacerta vivipara*. *Journal of Thermal Biology* **2**, 53-54.

HERPETOLOGICAL JOURNAL, Vol. 1, pp. 36-37 (1985)

### SHORT NOTE:

## OPTIMAL TEMPERATURE FOR INNER-EAR PERFORMANCE AGREES WITH FIELD BODY TEMPERATURE IN *PHELSUMA* (REPTILIA: GEKKONINAE)

YEHUDAH L. WERNER

*Department of Zoology, The Hebrew University of Jerusalem, 91904 Jerusalem, Israel.*

(Accepted 7.1.85)

The performance of the vertebrate inner ear is often assessed by the electrical AC output of the hair cells: the alternating potentials of the cochlear duct, commonly nicknamed "cochlear microphonics", or CM. The shape of the audiogram (displaying sound intensity required for a standard CM response, against a scale of sound frequencies) is affected by temperature. In reptiles, at least, one can define for each species an optimal temperature which yields an optimal audiogram (Werner, 1972, 1976).

In a recent review I showed good overall correlation among lizards between these specific optimal temperatures for cochlear performance, and variously

defined ecological, whole body, optimal or preferred body temperatures (Werner, 1983). This is part of the well-known phenomenon that many physiological processes of reptiles tend to have their temperature optima at or near the ecologically preferred body temperature (Huey, 1982).

For *Phelsuma madagascariensis* my limited data (Werner, 1976, 1983) had suggested a cochlear optimum around 30°C, and an overall preference in captivity of 26-29°C (Fig. 1). Unfortunately, at the time I overlooked the paper by Crawford and Thorpe (1979) who found that in the field (on Praslin, Seychelles, in August) *Phelsuma madagascariensis*

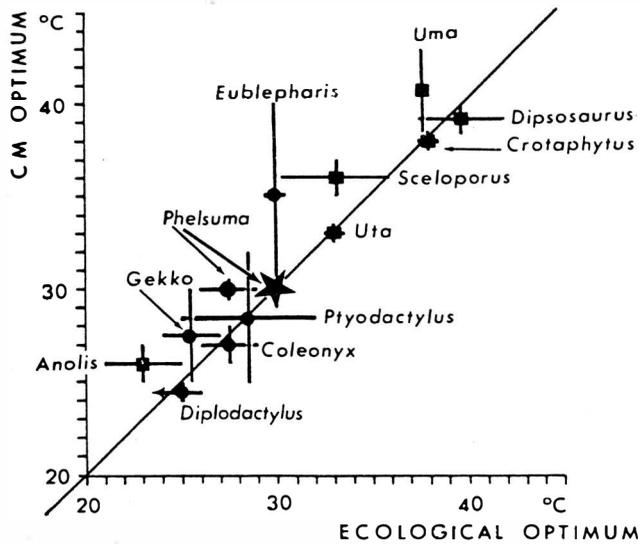


Fig. 1. The relation of the temperature optimum for the CM audiogram, to the ecological temperature optimum of the same species. Symbols (squares, iguanids; circles, gekkonids) are in the middle of respective ranges (bars); all these data from Werner (1983). Star, present correction for *Phelsuma madagascariensis*.

averages ( $\approx$  prefers) a body temperature of 29.9°C. Although admittedly both pieces of evidence are not too compelling, it does seem at present that the agreement between the two kinds of optimal temperature is even better in this case than previously thought (Fig. 1, star).

#### REFERENCES

- Crawford, C. M. and Thorpe, R. S. (1979). Body temperatures of two geckos (*Phelsuma*) and a skink (*Mabuya*) in Praslin, Seychelles. *British Journal of Herpetology* 6, 25-31.
- Huey, R. B. (1982). Temperature, physiology, and the ecology of reptiles. In *Biology of the Reptilia*, Vol. 12, 25-91. Gans, C. and Pough, F. H. (Eds.). New York: Academic Press.
- Werner, Y. L. (1972). Temperature effects on inner ear sensitivity in six species of iguanid lizards. *Journal of Herpetology* 6, 147-177.
- Werner, Y. L. (1976). Optimal temperatures for inner-ear performance in gekkonoid lizards. *The Journal of Experimental Zoology* 195, 319-352.
- Werner, Y. L. (1983). Temperature effects on cochlear function in reptiles: a personal review incorporating new data. In *Hearing and other Senses: Presentations in Honor of E. G. Wever*, 149-174. Fay, R. R. and Gourevitch, G. (Eds.). Groton: Amphora Press.

HERPETOLOGICAL JOURNAL, Vol. 1, pp. 37-39 (1985)

#### SHORT NOTE:

### THE CALCIUM CYCLE OF FEMALE DAY-GECKOS (*PHELSUMA*)

ANDREW S. GARDNER

*Department of Zoology, University of Aberdeen, Tillydrone Avenue, Aberdeen AB9 2TN, U.K.*

*Present Address:*

*The Galton Laboratory, Department of Genetics and Biometry, University College London, Wolfson House, 4 Stephenson Way, London NW1 2HE, U.K.*

*(Accepted 24.10.84)*

#### INTRODUCTION

Day-geckos of the genus *Phelsuma* Gray 1825 are widely distributed on the islands of the western Indian Ocean. Most species are diurnal, arboreal and coloured green or blue with red markings. In the granitic Seychelles, two species occur at high densities on most islands: *P. astriata* and *P. sundbergi* (Thorpe and Crawford, 1979; Gardner, 1984). During a study on *Phelsuma* evolutionary ecology in the Seychelles, several hundred specimens of both these species were

examined, both during 15 months field work and subsequently in the laboratory after preservation in 70 per cent alcohol. It became apparent in the field that individual, reproductively active females pass through a calcium cycle involving the storage of calcium in the endolymphatic sacs (which are visible as whitish swellings on either side of the neck) and its subsequent deposition as egg-shell. Slightly gravid females (i.e. those with small, but externally visible oviducal eggs) almost always had large, well calcified endolymphatic sacs. Very heavily gravid females, with almost full

sized eggs, often had small sacs, as did those non-gravid females with soft, flabby abdomens, which had probably recently laid. The eggs of *Phelsuma*, as of other Gekkonine geckos, have a hard, well calcified shell with considerable ability to withstand desiccation. While the calcium storage capacity of geckos endolymphatic sacs is widely appreciated (e.g. McKeown, 1984), these cyclic events have not been clearly shown in wild geckos. Reproduction of *Phelsuma* in the granitic Seychelles is both asynchronous and aseasonal (Gardner, 1984).

## METHODS

Specimens were killed by thoracic injection of pentobarbitone sodium, and preserved in 70 per cent alcohol for up to two years prior to this study. The condition of the endolymphatic sacs was noted in 162 female *P. astriata* and 187 *P. sundbergi* from a range of 25 islands from the granitic Seychelles, scoring them as small (not externally visible), medium (slightly swollen) and large (considerable swellings on sides of neck). Also noted were the presence and size of externally visible oviducal eggs and the presence of a calcareous crust formed on the skin of the preserved specimen. This crust was a white or yellow deposit found particularly on the dorsal surface of the abdomen and around the vent. In addition, the stomach contents of 65 *P. astriata* and 32 *P. sundbergi*, of both sexes, from Praslin were examined, and the presence of any calcareous material was noted.

## RESULTS

Table 1 gives the data on the condition of the endolymphatic sacs, oviducal eggs and the presence of a calcareous crust in the preserved specimens. The figures are generally similar for both species. In both *P. astriata* and *P. sundbergi* there was a highly significant association ( $p > 0.999$ ) between the condition of the endolymphatic sacs and the presence and size of externally visible oviducal eggs. ( $\chi^2$  4 d.f. = 25.4 *P. astriata*; 36.6 *P. sundbergi*). There was a tendency for females without externally visible oviducal eggs to have small endolymphatic sacs and for slightly gravid females to have large sacs. Heavily gravid females had small, medium or large sacs.

The development of calcareous skin crusts in the preserved specimens was strongly associated with the presence of large oviducal eggs. No non-gravid or slightly gravid females developed this crust whereas 60.7 per cent of heavily gravid *P. astriata* and 59.0 per cent of heavily gravid *P. sundbergi* did so. Moreover, amongst the heavily gravid females, there was a significant association ( $p > 0.999$ ) between the development of a skin crust and the condition of the endolymphatic sacs ( $\chi^2$  = 18.9 2 d.f. for both species pooled). A crust formed on many geckos with small or medium endolymphatic sacs, but on very few specimens with large endolymphatic sacs.

On dissection, the heavily gravid females with small sacs fell into two categories. Most had developed calcareous skin deposits, and proved to have unshelled

### (a) *P. astriata*

	ENDOLYMPHATIC SACS (SKIN CRUST)		
	small	medium	large
non-gravid	65 (0)	24 (0)	23 (0)
slightly gravid	2 (0)	5 (0)	15 (0)
heavily gravid	10 (9)	8 (7)	10 (1)

### (b) *P. sundbergi*

	ENDOLYMPHATIC SACS (SKIN CRUST)		
	small	medium	large
non-gravid	72 (0)	36 (0)	20 (0)
slightly gravid	2 (0)	3 (0)	15 (0)
heavily gravid	24 (16)	7 (5)	8 (2)

TABLE 1. The condition of the endolymphatic sacs in preserved specimens of mature female *Phelsuma astriata* and *Phelsuma sundbergi*, together with the presence of externally visible oviducal eggs. Bracketed figures are the numbers of specimens in each category that developed a calcareous skin deposit on preservation.

oviducal eggs. Some, however had not developed skin deposits, and these were found to be carrying shelled eggs. Indeed some of these females contained a single egg, having already laid one. Heavily gravid females with large endolymphatic sacs did not develop a calcareous deposit and contained unshelled eggs.

Mineral matter was found in eleven of the stomachs examined, consisting of coral sand, land snail shells, fragments of marine mollusc shells and fragments of gecko egg-shell. The two land snails found had been eaten when dead as the shells contained sand and other debris. In ten of these cases, the gecko was an adult female, the exception being one sub-adult male containing some sand grains. All the matter found was calcareous. There was no obvious association between the presence of ingested calcareous material and the reproductive state of the gecko in this small sample.

## DISCUSSION

The simplest interpretation of these observations is that individual reproductively active females pass through a calcium cycle. Females without visible oviducal eggs tend to store calcium in their endolymphatic sacs. As most slightly gravid females had large endolymphatic sacs, and some females with ingested calcareous material were not visibly gravid, most of the storage of calcium probably occurs before the eggs are visible externally. In heavily gravid females this stored calcium is mobilized from the sacs shortly before oviposition. Geckos preserved at this stage develop a calcareous deposit on the skin, and, hence, it is likely that the blood contains a large amount of calcium. The mobilized calcium is laid down as egg-shell, so that geckos with shelled eggs

have small endolymphatic sacs, and do not develop a skin deposit on preservation.

It is likely that the ingestion of calcareous material is intentional and normal in reproductively active females to replace the large amounts of calcium lost in the production of shelled eggs. Captive geckos are regularly fed cuttlefish and dietary supplements to replace their calcium, without which uncalcified, inviable eggs are produced or bone degeneration may occur (Demeter, 1976; Bloxam and Vokins, 1978; Howard, 1980). Deliberate ingestion of calcareous material by female geckos in the wild has not been previously reported, though Vinson (1975) did note the presence of coral fragments in the stomachs of two specimens of *Phelsuma guentheri* on Round Island, Mauritius. One of these was a female, but the sex of the other specimen was not given.

#### ACKNOWLEDGEMENTS

This study was carried out while I was the holder of a studentship from the Science Research Council at the University of Aberdeen. I wish to thank Dr. R. S. Thorpe for valuable advice and the staff of the Royal Scottish Museum for kindly allowing me the use of their research facilities.

#### REFERENCES

- Bloxam, Q. and Vokins, M. (1978). Breeding and maintenance of *Phelsuma guentheri* (Boulenger 1885) at the Jersey Zoological Park. *Dodo. Journal of the Jersey Wildlife Preservation Trust* **15**, 82-91.
- Demeter, B. J. (1976). Observations on the care, breeding and behaviour of the giant day-gecko *Phelsuma madagascariensis* at the National Zoological Park, Washington. *International Zoo Year Book* **16**, 130-133.
- Gardner, A. S. (1984). The evolutionary ecology and population systematics of day-geckos (*Phelsuma*) in the Seychelles. Ph.D. thesis, University of Aberdeen.
- Howard, C. J. (1980). Breeding of the flat tailed day gecko *Phelsuma laticauda* at Twycross Zoo. *International Zoo Year Book* **20**, 93-96.
- McKeown, S. (1984). Captive maintenance and propagation of Indian Ocean day geckos (genus *Phelsuma*). *Bulletin of the Chicago Herpetological Society* **19**, 55-63.
- Thorpe, R. S. and Crawford, C. M. (1979). The comparative abundance and resource partitioning of two green gecko species (*Phelsuma*) on Praslin, Seychelles. *British Journal of Herpetology* **6**, 19-24.
- Vinson, J. M. (1975). Notes on the reptiles of Round Island. *Bulletin of the Mauritius Institute* **7**, 49-67.

HERPETOLOGICAL JOURNAL, Vol. 1, pp. 39-40 (1985)

#### SHORT NOTE:

### GETTING INTO A PICKLE WITH PRESERVED SPECIMENS: FORMALIN AND DISTORTION IN THE SMOOTH NEWT, *TRITURUS VULGARIS*

PAUL A. VERRELL

*Animal Behaviour Research Group, The Open University, Milton Keynes MK7 6AA, U.K.*

(Accepted 19.11.84)

#### INTRODUCTION

In an interesting and highly relevant paper to herpetologists, Lee (1982) cautioned against the unguarded use of morphometric data collected from preserved specimens. In an analysis of 20 characters in the toad *Bufo marinus*, Lee found a number of significant effects of preservation when data from the 'fresh' and 'preserved' states of the same toads were compared using univariate statistics. One important point raised by Lee at the end of his paper concerned the species- and tissue- specificity of responses to a preserving fluid.

In an ongoing study of the reproductive biology of the smooth newt (*Triturus vulgaris*), I have collected and preserved several hundred specimens; but, can I be

sure that the 10 per cent unbuffered formalin solution that I use for preservation does not distort the characters in which I am interested? In this report, I present data on the effects of preservation on several morphological characters which suggest little distortion when compared with the "fresh" state.

#### METHODS

The data presented below were derived from the analysis of 20 male and 20 female smooth newts obtained from ponds in the Oxford and Milton Keynes areas of southern England, between April 1982 and February 1984. Within one or two days of capture, the newts were sacrificed in m-aminobenzoate and scored

for the following characters to the nearest 0.5 mm:

1. Snout-vent length — from the tip of the snout to the posterior angle of the vent.
2. Tail length — from the posterior angle of the vent to the tip of the extended tail.
3. Tail height — measured 10 mm posterior to the posterior angle of the vent.

The newts were then each given an incision in the ventral body wall and placed individually in labelled bottles containing 10 per cent unbuffered formalin solution.

On 1st October 1984, these 40 newts were again scored for the three characters defined above. The mean number of days spent in formalin was 393 for the males and 408 for the females.

In addition, 25 male newts were dissected fresh, one or two days after capture, and the combined weight of the two testes recorded for each individual. After a maximum period of 240 days in formalin, the testes were weighed once again. In all comparisons between "fresh" and "preserved" measures, Student's t-test was used.

## RESULTS

Means, standard deviations, per cent differences between means and the results of t-tests are shown in Table 1 for the three morphological scores recorded for both sexes. For all scores, there was shrinkage after preservation; however, differences between means were not statistically significant for any score. Individual newts showed much variability in their scores' responses to formalin; 50 per cent showed a reduction in tail height, 70 per cent a reduction in snout-vent length and 72.5 per cent a reduction in tail length. No individual scores were increased by preservation.

In fresh specimens, male newts had significantly longer ( $t = 4.2, P < 0.001$ ) and higher ( $t = 4.3, P < 0.001$ ) tails than females. There was no significant sexual dimorphism in snout-vent length ( $t = 1.2, P > 0.05$ ). However, after preservation, snout-vent length was just significantly greater in males ( $t = 2.03, P = 0.05$ ). It thus seems that preservation in formalin "created" a novel sexual dimorphism in this sample of newts.

Before preservation, the mean (+ standard deviation) weight of the males' testes was  $0.055 \pm 0.03$  g. Weight after preservation was  $0.053 \pm 0.029$  g, a decrease of 3.6 per cent which was not significant ( $t = 0.24, P > 0.05$ ).

## DISCUSSION

In all, the data presented above suggest that 10 per cent unbuffered formalin solution is a preservative that causes little distortion in smooth newts; nevertheless, there is a general shrinkage of the tissues. In the case of snout-vent length, this shrinkage was sufficient to result in the appearance of a novel sexual dimorphism. With regard to the testis, formalin probably has little influence on histological appearance due to general shrinkage, although it may have more subtle effects in terms of the microdistortion of various cell types.

For my purposes, formalin is an effective preserving fluid. However, the distortion it causes may have serious consequences in other areas of herpetology, such as the study of sexual dimorphism in amphibians. Several workers have used the extent of sexual dimorphism to predict the occurrence of intermale combat in a species (e.g. Shine, 1979). Whilst such data may result in questionable interpretations (as in Woolbright, 1983 and Sullivan, 1984), I suggest that a more basic flaw may be present. If data are collected from preserved specimens, then spurious cases of sexual dimorphism may appear, as found in the present study and by Lee (1982). I can only agree with Lee (1982, p.280) that "uncritical use of morphological data . . . from preserved specimens could lead to spurious conclusions".

## REFERENCES

- Lee, J. C. (1982). Accuracy and precision in anuran morphometrics: artifacts of preservation. *Systematic Zoology* **31**, 266-281.
- Shine, R. (1979). Sexual selection and sexual dimorphism in the Amphibia. *Copeia* **1979**, 297-306.
- Sullivan, B. K. (1984). Size dimorphism in anurans: a comment. *The American Naturalist* **123**, 721-724.
- Woolbright, L. L. (1983). Sexual selection and size dimorphism in anuran Amphibia. *The American Naturalist* **121**, 110-119.

	Fresh	Preserved	%	t
Male (N = 20)				
Snout-vent length/mm	45.25 ± 2.50	44.57 ± 2.43	-1.5	0.88
Tail length/mm	43.20 ± 3.24	41.75 ± 3.22	-2.9	1.42
Tail height/mm	9.05 ± 2.36	8.55 ± 1.84	-5.5	0.75
Female (N = 20)				
Snout-vent length/mm	44.25 ± 2.75	43.00 ± 2.46	-2.9	0.75
Tail length/mm	38.00 ± 4.50	36.80 ± 4.60	-3.2	0.83
Tail height/mm	6.50 ± 1.22	6.12 ± 1.45	-5.9	1.70

TABLE 1. Results of t-tests and descriptive statistics for 40 specimens of *Triturus vulgaris* measured fresh and after preservation.



