SIZE DIFFERENCES OF NATTERJACK TOADS BREEDING IN THE NORTH MERSEYSIDE SAND-DUNES

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ABSTRACT

Snout-vent lengths of large samples of natterjacks were measured at four relatively isolated sand-dune breeding sites in two successive years. It was hoped that the size distributions would indicate whether satisfactory recruitment into the breeding cohort was taking place. Significant differences were found between males and females, between the four sites and between years. It is inferred that one group consists mainly of young individuals, reflecting high toadlet production, while the other three groups have a large proportion of older adults as a consequence of poorer breeding success. The possible reasons for these differences are discussed.

INTRODUCTION

The natterjack toad *Bufo calamita* Laur. is restricted to about forty, mainly coastal, localities in Britain (Cooke, Banks and Langton, 1984) and is specially protected under the Wildlife and Countryside Act 1981.

The north Merseyside sand-dune system supports one of the large populations of this species in the country (Smith and Payne, 1980). Since the 1970's, efforts have been made to conserve this population by statutory protection and positive management of its habitats. At the same time, almost annual monitoring of distribution and breeding success has been attempted in many parts of the dune system.

In 1978, Smith and Payne (1980) reported that the toads had enjoyed a sequence of successful breeding seasons, assisted by a rise in the water-table since 1974, the excavation of about fifty new breeding sites and licensed rescue operations to save tadpoles from desiccation. The adult female population was estimated to contain over 2000 individuals, while many immature toads were observed in the dunes and adjacent urban areas.

Continued monitoring during the 1980s suggests that breeding has been successful in some parts of the dune system but relatively poor in other areas. However, it has proved difficult to count the numbers of toadlets leaving the water and, despite recent research into natterjack population dynamics (e.g. Davis, 1985), it is not known what level of recruitment is necessary to sustain a breeding population (Banks and Beebee, 1988).

An indirect way of determining whether satisfactory recruitment is occurring is to examine the size range of individuals in the breeding groups (Cooke, 1981, 1982). Although growth rates are likely to be variable and related to environmental conditions (Hemmer and Kadel, 1972), a general relationship between size and age may be anticipated. Thus, Davis (1985) found significant positive correlations between snout-vent length and age for both males and females in a Merseyside breeding colony.

On the Merseyside coast, *B. calamita* breeds in discrete groups of dune slacks and excavated scapes which are up to 3km from the next nearest breeding site. Although natterjacks are noted for their ability to 'migrate', especially if their breeding pools dry up (Beebee, 1983), most of the adults are probably relatively site faithful. Thus, Smith and Bownes (1978) found that 70 per cent of Merseyside toads marked in one breeding season and recovered in the next had moved a maximum of only 200m. The largest distance covered was 2.2km by one individual. Movements within a breeding season are likely to be less than this and it was therefore justified, for the purposes of this study, to treat the main breeding groups as isolated populations.

The aims of the study were to investigate natterjack body lengths at four major breeding sites in two successive years and to establish whether this technique can be used to monitor the success, or otherwise, of recruitment into the breeding populations.

MATERIALS AND METHODS

The four study areas were chosen on the basis of two criteria: they were at least 1km from the nearest known breeding site of *B. calamita* and they supported sufficient numbers of adults to provide a large sample size.

Fig. 1 shows the positions of the study areas which are described briefly as follows:

1. *Ainsdale Hills Local Nature Reserve.* This narrow strip of mobile and embryo dunes, 1.6km long and 0.3km wide, contains 13 semi-natural slacks with a total area of about 2.0ha, in which natterjacks have bred during the present decade. Parts of some slack basins were deepened from 1980 onwards.
2. *The National Trust Estate, Formby Point.* About 3km south of Ainsdale Hills, this site consists of four small pools (total area about 0.04ha) on the

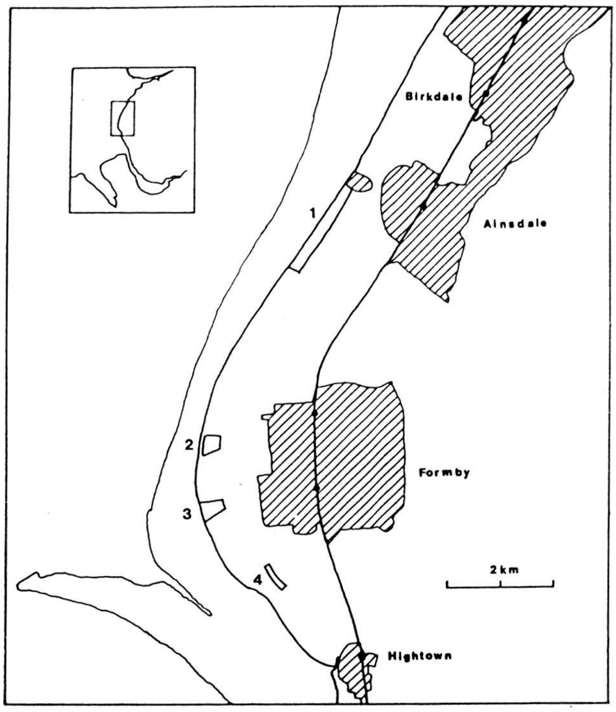

Fig. 1 Locations of study areas in the north Merseyside sand-dune system. 1 = Ainsdale Hills; 2 = National Trust tobacco dump; 3 = Lifeboat Road; 4 = Cabin Hill. Built-up areas are hatched.

so-called 'tobacco dump', a waste tip of denatured tobacco leaves which closed down in the mid-1970s. The high water-holding capacity of the waste maintains a perched water-table in an area of dunes lacking natural slacks. The pools, which date back to the early 1970s, have been deepened on several occasions.

3. *Lifeboat Road, Formby Point.* In a zone of heavy recreational pressure, this site is an area of degraded mobile dunes restored since 1978 under the auspices of the Sefton Coast Management Scheme. Four small scrapes (total area about 0.04ha) were excavated from 1981 onwards; they lie about 1km south of the tobacco dump.
4. *Cabin Hill National Nature Reserve.* The breeding pools are situated in an area of fixed dunes 2km south of Lifeboat Road. Most were formed as borrow pits during the construction of a flood defence bank in 1970. The largest of these shallow pits, covering about 1.6ha, was the sample site.

Visits were made to the study areas after dark during April and May when peak natterjack activity was expected. Pools were systematically searched with a torch; each unpaired animal found was caught with a pond net and sexed by reference to the nuptual pigmentation on the fore digits of the male (Beebee, 1983). Snout-vent length on the dorsal surface was measured to the nearest 1mm by cupping the animal in the palm of the hand and gently compressing it under a transparent plastic ruler. Mating pairs were not disturbed. Measured individuals were immediately returned to the site of capture.

It has been suggested that larger individuals predominate early in the season, while smaller natterjacks breed later (Flindt and Hemmer, 1968). As this could bias the samples, it was decided to take an early and late breeding season sample from each study area in 1988. In the event, only one sample was obtained at the National Trust site, but two were taken from the other three areas at intervals of 18-48 days. The results (see below) did not justify a second sample in 1989, so each area was sampled once in that season.

The data were analysed on a Dec-20 computer using the statistical package 'Minitab'.

RESULTS

Differences Between Males and Females

Snout-vent lengths of males ranged from 42mm to 79mm and of females, 51mm to 82mm. The largest female was 2mm longer than the largest British Isles specimen known to Smith (1951) or Beebee (1983) and equalled the longest individual reported by Banks and Beebee (1986).

Frequency distributions of body lengths for each sample (Fig. 2, Fig. 3) are approximately normal and justify the use of parametric statistics.

A total of 622 males and 90 females was sampled in 1988, while 268 males and 57 females were measured

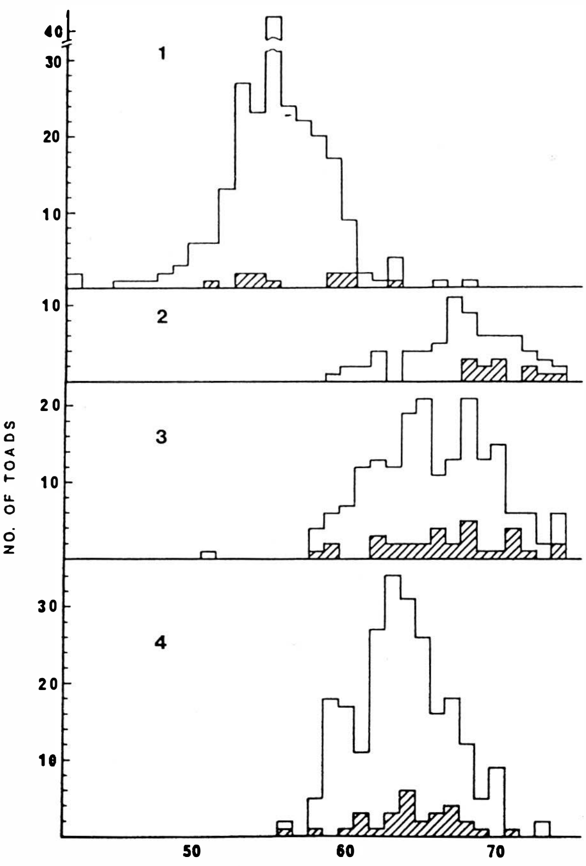

Fig. 2 Distributions of snout-vent lengths in samples of breeding natterjack toads measured in 1988 at:
1. Ainsdale Hills; 2. National Trust; 3. Lifeboat Road; 4. Cabin Hill. Open Columns = males; hatched = females.

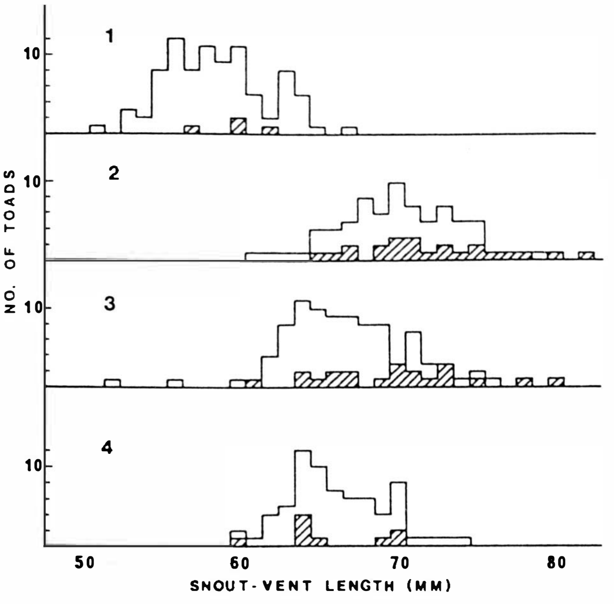

Fig. 3 Distributions of snout-vent lengths in samples of breeding natterjack toads measured in 1989 at:
1. Ainsdale Hills; 2. National Trust; 3. Lifeboat Road; 4. Cabin Hill. Open columns = males; hatched = females.

the following year. Apparent sex ratios of 6.9:1 and 4.7:1 in the two seasons reflect the fact that male natterjacks spend much more time at the breeding site than females (Arak, 1983) and therefore have a higher probability of capture. Davis (1985) reported sex ratios ranging from 12.1:1 to 5.5:1 in samples of natterjacks breeding at Cabin Hill between 1981 and 1983.

Table 1 compares the body lengths of males and females in the two seasons. Females were significantly larger than males ($p < 0.001$), being on average 3.7mm longer in 1988 and 4.9mm longer in 1989. Also, there was a significant ($p < 0.001$) increase in the lengths of both sexes between years, males averaging 3.0mm longer and females 4.2mm longer in 1989.

Differences Between Early and Late Samples in 1988

Table 2 compares early and late breeding season samples of males at three sites. Female sample sizes were too small for a satisfactory test. At Ainsdale, the second sample has a significantly higher mean ($p = 0.03$), while, at Cabin Hill, the mean of the second sample is significantly lower than the first ($p = 0.01$). The mean of the second Lifeboat Road sample is higher than the first but not significantly so ($p = 0.1$). It seems reasonable to conclude that there is no systematic trend towards larger animals in the later samples. Therefore, a second sample was not taken in 1989. For subsequent comparisons, the two 1988 samples were pooled for each site.

Differences Between Sites and Between Years

There are considerable differences in mean body lengths between the four sites, Ainsdale toads being the smallest, National Trust the largest and Cabin Hill and Lifeboat Road animals intermediate in size. These trends are shown in both males and females and are consistent between seasons (Table 3). One-way analysis of variance (Table 3) shows that the differences between sites are significant in both years for both sexes ($p < 0.01$).

	1988		*1989*	
	males	*females*	*males*	*females*
No. sampled	622	90	268	57
Mean body length (mm)	61.5	65.2	64.5	69.4
S.D.	5.9	5.1	5.4	5.5
Two sample t	6.3		6.1	
p	<0.001		<0.001	

TABLE 1: Differences between male and female body lengths in 1988 and 1989.

	Ainsdale		*Lifeboat Road*		*Cabin Hill*	
	early	*late*	*early*	*late*	*early*	*late*
No. sampled	113	104	89	54	121	84
Mean body length (mm)	54.7	55.8	65.2	66.3	64.1	63
S.D.	3.2	3.6	4.3	4.0	3.1	3.2
Two sample t	2.24		1.51		2.53	
p	0.03		0.13		0.01	

TABLE 2: Differences between body lengths of males in early and late season samples, 1988.

	1988						1989					
	Males			Females			Males			Females		
	n	*x*	*SD*	*n*	*x*	*SD*	*n*	*x*	*SD*	*n*	*x*	*SD*
Ainsdale	217	55.2	3.44	11	56.5	3.86	83	58.6	3.26	4	59.8	2.06
Cabin Hill	205	63.7	3.17	29	64.3	3.29	60	66.2	3.02	9	65.6	3.40
Lifeboat Road	143	65.6	4.16	38	66.8	3.94	72	66.2	3.86	21	69.8	4.74
National Trust	57	66.9	3.55	12	70.3	2.05	53	69.6	3.65	23	72.2	4.43
ANOVA f ratio		362.3			33.8			130.6			12.4	
p		<0.01			<0.01			<0.01			<0.01	

TABLE 3: Analysis of body length differences between sites in the two seasons.

Site	*Year*								
	1980	*1981*	*1982*	*1983*	*1984*	*1985*	*1986*	*1987*	*Mean Score*
Ainsdale Hills	1	3	1	2	3	3	3	3	2.4
National Trust	2	2	1	3	0	1	1	—	1.4
Lifeboat Road	—	2	1	2	2	2	3	3	2.1
Cabin Hill	2	2-3	2	2	—	1	1	2	1.8

TABLE 4: Natterjack breeding success from 1980 to 1987 at the four study area based on estimates of toadlet production during routine monitoring. (0 = no toadlets, 1 = small numbers, 2 = moderate numbers, 3 = large numbers, – = no count).

DISCUSSION

It would be surprising if natterjack toads living only a few kilometres apart in the same dune system showed marked variations in growth rates. Therefore, it is likely that the differences observed reflect different age structures in the four breeding groups.

Davis (1985) measured natterjacks at Cabin Hill, ageing individuals of known sex by reference to growth rings in the phalanges. Comparisons with his data suggest that, in 1988, most males at Ainsdale were 3-4 years old, while most females were aged 4-5 years. The oldest group was at the National Trust Site where, in 1988, most males were at least 6 years old and most females about 7. At the other two sites, it seems that the majority of males were aged 5-6 years and most females 7. The difference in ages between the sexes is explained by Davis's (1985) finding that females mature one year later than males.

The 3-4mm increase in mean body length between years corresponds closely to the expected increment from one year's growth in older animals derived from Davis's (1985) regression equations. This suggests that there was little or no recruitment to the breeding cohorts in 1989.

Merseyside natterjacks can begin breeding at 2 years (males) or 3 years (females), although they may not be fully active until 1-2 years later (Davis, 1985). Therefore, in the 1988 breeding season, the first appearance of toads which metamorphosed in 1986 (males) or 1985 (females) could be anticipated. However, the Ainsdale adults seem to have been a year older than this while those at the National Trust site probably derive from the 1981 and 1982 spawnings, implying a sequence of four years' poor recruitment at the latter site.

Low apparent recruitment could be due to a number of factors, including:

1. Emigration of juveniles or young adults to other parts of the dune system;
2. Young adults not appearing at the breeding sites;
3. Poor breeding success in earlier years;
4. High mortality of immature toads.

Although natterjacks are known to abandon breeding sites and move elsewhere (Beebee, 1983), there is no evidence that this has happened recently in the Merseyside dunes. Indeed, the colonisation of new scrapes dug in the last few years has been relatively slow.

Arak (1983) showed that large males can displace smaller males by antagonistic behavioural interactions at calling sites. This could lead to fewer small males being sampled, especially at the smaller pools, such as those at Lifeboat Road and the tobacco dump where high densities of males can occur. However, this should not affect the size distribution of females arriving to spawn. As has been shown in this study, the trend of female body size follows that of the males (Fig. 2, Fig. 3).

Breeding success has been routinely monitored by estimating the number of toadlets emerging from the pools. The results for the 1980s are summarised in Table 4. This shows that large numbers metamorphosed at Ainsdale, especially from 1984 onwards, but fewer toadlets appeared at other sites, the National Trust area having the worst record overall. However, it is important to note that some metamorphosis occurred at the less successful sites in most years, giving the impression that satisfactory breeding was taking place, although with declining performance at Cabin Hill and the National Trust site.

The Lifeboat Road results appear anomalous in that, despite at least 'moderate' metamorphic success since 1983, few young adults have appeared in the breeding population. The most likely explanation is that what are perceived as 'moderate' toadlet numbers at these tiny, easily searched ponds are still too few to outweigh the high mortality suffered by immature animals in the years before they enter the breeding cohort.

Factors contributing to low toadlet numbers at some sites were spring/summer droughts in 1982, 1984 and 1985, predation of tadpoles by aquatic invertebrates and growth inhibition of natterjack tadpoles by those of other anurans, especially *B. bufo*.

Catastrophic mortality of developmental stages due to drying out of water bodies is an expected problem for an amphibian which habitually spawns in ephemeral pools (Beebee, 1979; Davis, 1985). However, emergency deepening, by hand, of some sites, particularly at Ainsdale, has undoubtedly aided metamorphosis in some years.

Tadpole predation has been shown to be major mortality factor by Banks and Beebee (1988) and Davis (1985). There is also some evidence that invertebrate predators of natterjack tadpoles are more abundant in deeper pools that are less likely to dry up (Banks and Beebee, 1988). In Merseyside, older scrapes appear to support higher densities of predators than younger ones. Those at Cabin Hill and Lifeboat Road have particularly large numbers of dragonflies (Odonata), especially *Sympetrum striolatum*. Banks and Beebee (1988) list nymphs of this genus as being effective predators of natterjack tadpoles. The two mild winters of 1987-88 and 1988-89 may well have enhanced predator numbers at the Merseyside sites.

It is known that high densities of other anuran tadpoles can inhibit the growth of natterjack tadpoles, making them more susceptible to desiccation and predation (Banks and Beebee, 1987). In Merseyside, *B. bufo* and to a lesser extent, *Rana temporaria*, are associated with older, more permanent water bodies in the fixed dunes, while *B. calamita* favours ephemeral or recently created pools nearer the sea. As yet, few common toads have bred in the Ainsdale frontal dune slacks, although they began to invade this area in the mid-1980s. At other sites, particularly Cabin Hill and the tobacco dump, common toad numbers increased during the 1970s and, by the 1980s, tadpole densities were probably high enough to produce inhibition effects.

Little is known about mortality factors affecting toadlets and immature natterjacks (Davis, 1985). It is possible that toadlets arising from growth-inhibited tadpoles show reduced survival because, for example, they have less time to gain weight before hibernation.

Adult natterjacks are long-lived (Beebee, 1983) and have previously survived several successive years with adverse breeding conditions in Merseyside (Smith and Payne, 1981). Cooke (1981), however, points out that old females (over 70mm long) may lay spawn with reduced viability. He describes 'senile' populations, resulting from minimal recruitment over at least three years, in which males exceed an average of 60mm long, with no individuals less than 55mm. By 1989, this description applied to three of the four breeding groups studied here with the possible exception of Lifeboat Road where one male measured 52mm (Fig. 3). Banks and Beebee (1986) also found that old female natterjacks could produce spawn with reduced viability. Two out of about 20 aged females laid some non-viable eggs, those individuals being 11 and 12 years old.

Routine monitoring during 1988 and 1989 showed that all sites supported large numbers of breeding adults which laid many spawn strings. There was no evidence of reduced spawn viability. However, it seems clear that recruitment to three of the breeding groups in recent years has been insufficient to prevent the size distribution shifting towards a preponderance of larger and older individuals. This trend is most apparent at the tobacco dump and Lifeboat Road (Fig. 2, Fig. 3) where the small size of the pools may make natterjack tadpoles particularly susceptible to predation and inhibition problems.

Conservation measures to increase recruitment at three of the study areas seem justified. These could include removal of completing anurans, predator and scrub control and the excavation of more shallow scrapes, which should be situated in the frontal dunes and have as large an area as possible. Continued monitoring of adult size distribution is also desirable.

The results of this study confirm that recruitment can be monitored by measuring snout-vent lengths of adult natterjacks assembling to breeding sites. The technique is simple and seems to be more sensitive than the inevitably crude and possibly misleading estimation of toadlet production. One disadvantage is that a licence is required to handle the animals, this being unnecessary for counting toadlets. Also, comparisons should be confined to the same general area. Natterjacks from other regions of the country may well have different growth rates. The approach has potential both for alerting site managers to the need for action to promote recruitment and for monitoring the effects of conservation management over a period of years.

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REFERENCES

Arak, A. (1983). Sexual selection by male-male competition in natterjack toad choruses. *Nature, London*. **306**, 261-262.

Banks, B. and Beebee, T. J. C. (1986). A comparison of the fecundities of two species of toad (*Bufo Bufo* and *B. calamita*) from different habitat types in Britain. *Journal of Zoology, London* (A) **208**, 325-337.

Banks, B. and Beebee, T. J. C. (1987). Spawn predation and larval growth inhibition mechanisms for niche separation in anurans. *Oecologia (Berlin)* **72**, 569-573.

Banks, B. and Beebee, T. J. C. (1988). Reproductive success of natterjack toads *Bufo calamita* in two contrasting habitats. *Journal of Animal Ecology* **57**, 475-492.

Beebee, T. J. C. (1979). A review of the scientific literature pertaining to the Natterjack Toad (*Bufo calamita*) throughout its geographical range. *Biological Conservation* **16**, 107-134.

Beebee, T. J. C. (1983). *The natterjack toad*. Oxford University Press.

Cooke, A. S. (1981). *Natterjacks in Britain, 1980*. Unpublished report, Nature Conservancy Council.

Cooke, A. S. (1982). *Natterjacks in Britain, 1981*. Unpublished report, Nature Conservancy Council.

Cooke, A. S., Banks, B. and Langton, T. (1984). *Natterjacks in Britain, 1983*. Unpublished report, Nature Conservancy Council.

Davis, C. A. (1985). The population dynamics of the natterjack toad (*Bufo calamita* Laur.) in the north Merseyside sand-dune system. Unpublished PhD thesis. Liverpool Polytechnic.

Flindt, R. and Hemmer, H. (1968). Beobachtungen zur Dynamik einer Population von *Bufo Bufo* und *Bufo calamita*. *Zoologische Jahrbücher (Systematik, Ökologie und Geographie der Tiere)* **95**, 469-476.

Hemmer, H. and Kadel, K. (1972). Gewichtszustand und Wachstumsverlauf bei der Kreuzkröte (*Bufo calamita* Laur.). *Forma et Functio* **5**, 113-120.

Smith, M. A. (1951). *The British Amphibians and Reptiles*. London: Collins.

Smith, P. H. and Bownes, C. F. (1978). *The use of artificial breeding pools by adult Natterjack Toads in Ainsdale Sand Dunes National Nature Reserve in 1978*. Unpublished report, Liverpool Polytechnic.

Smith, P. H. and Payne, K. R. (1980). A survey of Natterjack Toad *Bufo calamita* distribution and breeding success in the north Merseyside sand dune system, England. *Biological Conservation* **19**, 27-39.

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TEMPORAL CHANGES IN THE BEHAVIOUR OF FOAM-MAKING *LEPTODACTYLUS FUSCUS* TADPOLES

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ABSTRACT

Recently-hatched *L. fuscus* tadpoles kept out of water make a heap of foam which helps them to survive. At first, isolated tadpoles can make foam (by spitting mucus bubbles), but later, tadpoles can only make foam when in a group of five or more. If tadpoles are separated from one another, out of water, they can aggregate by active, apparently random wriggling movements, but this ability too declines with time since hatching.

INTRODUCTION

I have previously shown (Downie, 1984, 1989) that stage 27-28 tadpoles (Gosner, 1960) of the foam-nesting frog *Leptodactylus fuscus* are able to make a foam which replaces the original nest foam made by the parents. The tadpoles are able to live in this foam for up to several weeks, normally in the original nesting burrow, and to enter any nearby pool that forms, as feeding-stage tadpoles, once heavy rain falls. Foam making is a communal activity: the tadpoles stimulate each other by contact, to wriggle and spit out mucus-rich bubbles, and the wriggling movements themselves produce some bubbles. The 1984 study presented evidence that the ability to make foam diminished the longer the tadpoles remained in the nest. In this note, I report on aspects of this decline—the aggregative ability of tadpoles out of water and the ability of individuals to make foam.

MATERIAL AND METHODS

Collection and Maintenance of Tadpoles

Two foam nests of *L. fuscus* were collected from burrows around the margin of a temporary pool site on the University of West Indies campus at St. Augustine, Trinidad, and from the bank of a ditch at Carmody Road, also in St. Augustine, in June and July 1989. The first nest was collected on 23 June, and the tadpoles were already stage 27-28 and making foam. However, heavy rain had occurred on 17 June, so this must have been a recently-laid nest (it takes 4-5 days to reach stage 27-28: Downie, 1984). The second nest was found on 15 July and the tadpoles were recently hatched, not