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OBSERVATIONS ON THE NATURAL HISTORY OF THE PAINTED FROG *DISCOGLOSSUS PICTUS PICTUS* (AMPHIBIA: ANURA: DISCOGLOSSIDAE) IN THE MALTESE ISLANDS (CENTRAL MEDITERRANEAN)

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Introduction

The painted frog, *Discoglossus pictus* Otth, is the only amphibian presently inhabiting the Maltese Islands. This species is native, fossilized remains having been found in local deposits of Pleistocene age (Bate, 1935; Boessneck & Küver, 1970). Currently, the painted frog is found on Malta and Gozo, the two largest inhabited islands, but it has not been reported from Comino, the third main island, or from any of the smaller islets (Schembri, 1983). The nominate subspecies is known only from Sicily and the Maltese Islands (Lanza *et al.*, 1986) and in the latter is considered to be threatened (Lanfranco & Schembri, 1989).

Apart from references to the occurrence of *D. pictus* in the Maltese Islands (Adams, 1870; Gulia *pater*, 1873; Gulia *fils*, 1909, 1913; Despott, 1915; Capula *et al.*, 1985; Lanza, 1972, Lanza *et al.*, 1986) and to some aspects of its natural history (Lanfranco, 1955, 1957; Savona Ventura, 1979; Schembri, 1983), there is no information on the biology of local populations. Even on a broader geographical scale little information about the biology of this frog actually exists. Many older studies on *'D. pictus'* were carried out on populations now recognized as belonging to other species of this genus (for a recent review of the taxonomy of *Discoglossus* see Lanza *et al.*, 1986). The most detailed observations on the biology of *Discoglossus* are those of Knoepffler (1962) based on individuals from Banyuls-sur-Mer [shwon by Lanza *et al.* (1986) to be *D. pictus auritus*, most likely imported from Algeria] and on others from the island of Port Cros in the Hyères group [currently *D. sardus* (Lanza *et al.*, 1986)].

Field and laboratory studies were undertaken to collect preliminary information on the ecology of *D. pictus pictus* in the Maltese Islands. This study aims to find how this frog has adapted its life cycle to the local environment, which poses problems for any organism with aquatic larval stages: there are very few permanent open bodies of freshwater and the climate alternates between a hot period with very little rain (April to September: average precipitation c. 160 mm, average temperature range 18.1-26.3° C) and a cool wet period (October to March: average precipitaton c. 370 mm, average temperature range 11.0-18.0° C) (Mitchell, 1961; Chetcuti, 1988).

Material and methods

Field observations were made over the period October 1984 to November 1986 at nine sites: Chadwick Lakes, Bidnija, Buskett, Kennedy Grove, Mistra, Wied Speranza and Wied il-Ghasel on the island of Malta, and Wied ix-Xlendi and Wied il-Lunzjata on the island of Gozo, chosen because of their different environmental conditions. The site at Buskett is a valley with relatively steep sides and a sheltered watercourse in which rainwater collects during the wet season. Chadwick Lakes and Kennedy Grove are more exposed and here rainwater collects in small pools, whereas at Mistra, Wied ix-Xlendi and Wied il-Lunzjata water is present during the wet season as a narrow, shallow, slow moving stream. Bidnija and Wied Speranza are also exposed but water here collects in larger volumes than at any of the other sites.

Tadpoles were observed in the field and samples were collected at two-week intervals from Chadwich Lakes and at monthly intervals from the other eight sites. Sites were visited also during the dry season when all water had dried up and no tadpoles were present, to check for the presence of adult frogs. Chadwick Lakes, part of a valley system draining on the northeast coast of Malta, was chosen as the main study area as water is present there from September to July and both adult frogs and tadpoles are relatively abundant.

To investigate larval development in the field, tadpoles were collected at the surface and in mid-water column by fishing with a hand-net for a standard period of 2 mins and were fixed immediately in 70% ethanol. All adults encountered at Chadwick Lakes during a standard 20 min search in a defined area measuring 70 m^2 bordering the watercourse

banks, were collected. Immediately after collection, individuals were weighed to the nearest gram using a spring balance (Salter Ltd.) and the snout-vent lengths and head widths were measured to the nearest 0.1 cm using vernier calipers. Frogs were sexed, scoring as males those individuals having nuptial pads, and were then released.

In the laboratory, the total length (anterior border of head to tip of tail), trunk length (anterior border of head to vent) and tail length (vent to tip of tail) of each tadpole were measured to the nearest 0.1 cm using vernier calipers. Tadpoles were blotted dry on absorbent tissue paper and wet weight was measured to the nearest 0.1 mg using an electronic balance. Tadpoles from two samples were dried to constant weight and weighed individually. To avoid dry-weighing tadpoles, the relationship between body length and dry and wet weights was investigated using Pearson's product-moment correlation (Zar, 1974). As this analysis showed strong positive correlations between trunk length (TRL) and both wet (WW) and dry weight (DW) ($TRL = 0.097\ WW - 0.028$, $r = 0.803$, $d.f. = 23$, $P < 0.001$; $TRL = 0.007\ DW - 0.002$, $r = 0.666$, $d.f. = 23$, $P < 0.001$), only wet weight was determined for subsequent samples.

To study the effects of population density on development, a laboratory culture of tadpoles hatched from a single egg-mass collected from the field was set up at a density of 96 individuals per litre (96 l^{-1} culture). Observations on tadpole development and behaviour were made daily and development was followed by determination of mean trunk length and tail length of 10 individuals picked at random. For tadpoles up to 3 days old, measurements were made using a stereomicroscope fitted with a graduated eyepiece; for older tadpoles vernier calipers were used. On day 7, a 15 l^{-1} culture was set up by taking 30 tadpoles from the 96 l^{-1} culture and placing them in an aerated container of volume 2000 cm^3. On day 35, four other cultures were set up from the 96 l^{-1} culture as follows: 8.5 l^{-1} (10 tadpoles in 1180 cm^3), 40 l^{-8} (10 tadpoles in 250 cm^3) and 84 l^{-1} (21 tadpoles in 250 cm^3). For all cultures, water temperature was $18.5 \pm 1.5°$ C and tadpoles were fed daily on dried algae (*Spirulina*). A protein rich food (powdered beef bouillon cubes) was given after tadpoles had formed hindlimbs. The water was changed regularly. All cultures were provided with a surface for tadpole attachment. All newly metamorphosed juveniles (i.e. those in which the tail was fully resorbed) were weighed to the nearest 0.1 mg using an electronic balance.

Meteorological data were obtained from the Meteorological Office of the Department of Civil Aviation, Luqa, Malta and used to investigate any correlation between climatic factors and spawning time. Statistical analyses follow the methods in Zar (1974).

Results

Field observations on adults

Sexually mature adults were present at Chadwick Lakes from October 1984 to May 1985, and from March 1986 to May 1986, i.e. during the wet season. However adults were absent on 12.01.85, 30.03.85, 28.09.85, 21.10.85, 09.11.85, 19.02.86, 23.05.86, 11.09.86, and 19.10.86, when tadpoles were either absent or were close to metamorphosis. Adults were never abundant in the search area; the maximum density found was 0.16 m^{-1}. At this site there was a supremacy of males (62%) and the sex ratio was 1.6:1.

No significant differences were found in mean head width, snout-vent length or wet weight between adult male and female frogs collected from Chadwick Lakes (Student's t: head width, $t = 0.45$; snout-vent length, $t = 0.12$; wet weight, $t = 0.43$, d.f. $= 24$ and $0.5 < P$ in all cases).

Field observations on larvae

Based on the laboratory observations of variation in tadpole size with increasing age, an approximate spawning date could be calculated for the field populations. At Chadwick Lakes, spawning occurred in February 1985 and in February 1986 respectively, while at Kennedy Grove a spawning occurred in April 1986.

Tadpole abundance varied between October 1984 and November 1986 at all nine sites studied. Tadpoles were absent between May and September (i.e. during the dry season) at all nine sites except at Wied Speranza where sampling was done in a man-made oper reservoir which is kept full of water all the year round. At most sites, no tadpoles were found during certain sampling trips from September to May, even though breeding pools contained sufficient water. At all nine sites investigated tadpoles in any one sample were more or less of the same size (mean coefficient of variation = 8.9%, s.d. = 7.6, n = 27)

which suggests that samples represented approximately the same developmental stage.

Laboratory observations

We followed development of Maltese *D. p. pictus* from the egg

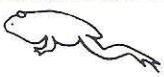
Age (days)	Total length ± S.D. (cm)	
1	0.290 ± 0.273	
2	0.408 ± 0.223	
3	0.487 ± 0.204	
4	0.606 ± 0.158	
5	0.748 ± 0.416	
6	0.818 ± 0.251	
7	0.900 ± 0.335	
33	2.555 ± 0.168	
36	2.690 ± 0.150	
39	2.852 ± 0.581	
42	2.900 ± 0.100	
45	1.977 ± 0.107	
47	1.010 ± 0.141	

FIG. 1 - Stages in the development of *D. pictus* from day one to day 47, based on observations made on a single egg-mass collected at Wied is-Sarg and cultured in the laboratory at a population density of 15 individuals per litre at 18.5 °C. Lengths are means for 10 individuals selected at random. The diagrams are schematic and are only meant to illustrate the developmental sequence.

stage to completion of metamorphosis, at 18.5 ± 1.5 °C (Fig. 1). The following descriptions refer to tadpoles from the 15 l^{-1} culture. Tadpoles cultured at other densities differed in the time spent at each stage.

Eggs had a mean diameter (not including the albumen layer) of 0.10 ± 0.01 mm (n = 10). From a clutch of about 500 eggs, 267 tadpoles (53.4%) hatched within 24 hrs from deposition; remaining eggs did not hatch. From hatching to day 7, development was as described by Gallien & Houillon (1951). On day 33, the forelimbs became just visible under the skin, about 5.3 mm posterior to the mouth. Six days later (day 39) the dorsal side began to darken and in subsequent days patches of pigmentation similar in pattern to those of adults were formed. On day 40, tadpoles became frog-eyed and the hindlimbs were

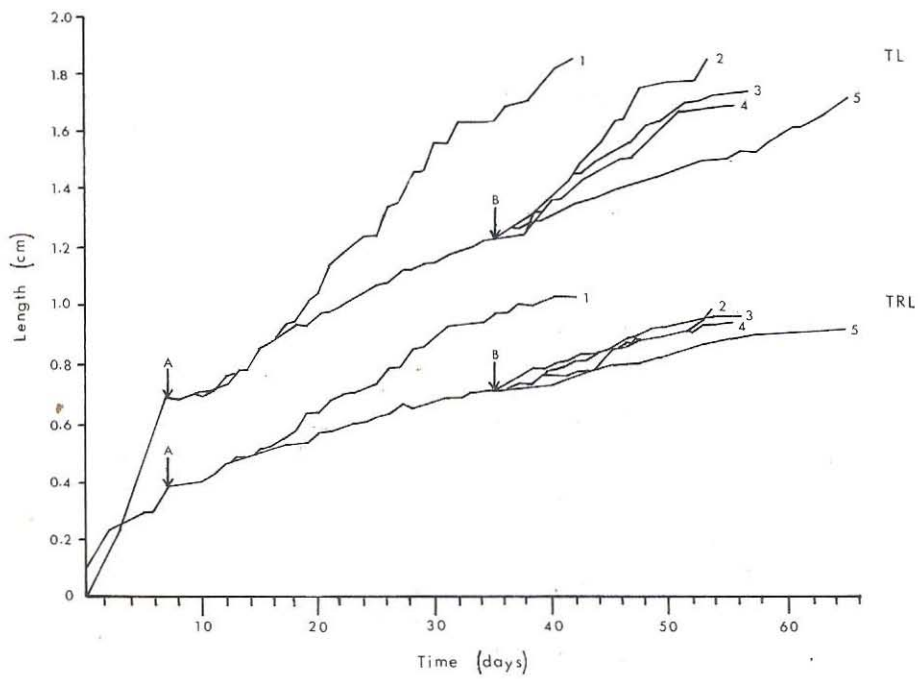


FIG. 2 - Changes in *D. pictus* tadpole trunk and tail lengths (TRL and TL, respectively) during development in laboratory cultures at various population densities; measurements were made until forelimbs emerged in the first tadpole in each culture. Lengths are means of 10 measurements. Arrow A indicates when the 15 l^{-1} culture was set up, and arrow B indicates when the 8.5 l^{-1}, 40 l^{-1} and 84 l^{-1} cultures were set up. 1 indicates 8.5 l^{-1} culture; 2 indicates 15 l^{-1} culture; 3 indicates 40 l^{-1} culture; 4 indicates 84 l^{-1} culture; 5 indicates 96 l^{-1} culture.

fully formed. The left forelimb emerged through the spiracle on day 42 and, within six hours, the right limb had also emerged. Tadpoles ceased to feed on algae about this time. On day 43 the tail began to be resorbed, the mouth lost the horny jaws and widened, and tadpoles started to crawl onto or cling to stones to keep the head out of the water. The tails was fully resorbed and metamorphosis was completed on day 47.

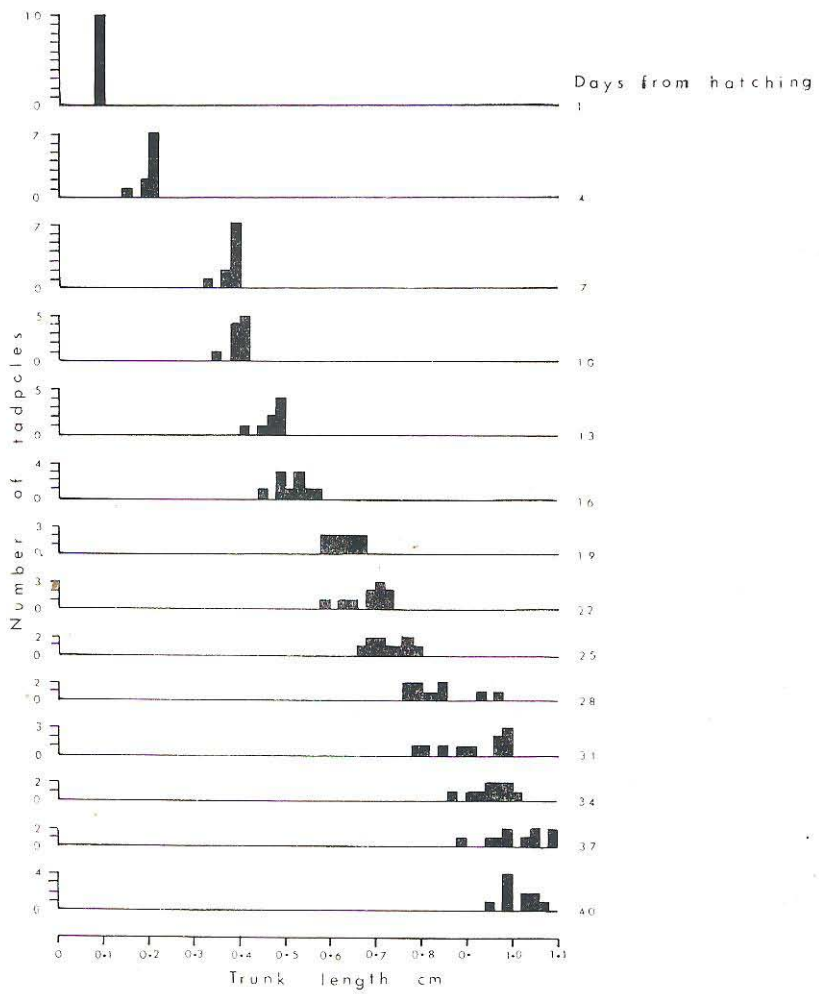


FIG. 3 - Size frequency histograms for tadpoles of *D. pictus* cultured in the laboratory at a density of 15 l^{-1} up to day 40. Development was synchronized up to day 40, but then showed considerable variation.

TABLE 1 - Regression equations and correlation coefficients describing relationships between time (t) and trunk length (TRL), and time (t) and tail length (TL) for different population densities. All calculations were carried out on logarithmically transformed data, n. = number of tadpoles; r = correlation coefficient; P = level of significance of correlation coefficient.

Population density (tadpoles/l)	Correlated variables	n	Regression equation	r	P
8,5	t/TRL	17	logTRL = 0.96 logt −0.65	0.985	<0.001
	t/TL	17	logTL = 1.17 logt −0.75	0.975	<0.001
15,0	t/TRL	38	logTRL = 0.63 logt −0.01	0.990	<0.001
	t/TL	38	logTL = 0.64 logt +0.21	0.985	<0.001
40,0	t/TRL	18	logTRL = 0.63 logt −0.12	0.992	<0.001
	t/TL	18	logTL = 0.82 log −0.18	0.980	<0.001
84,0	t/TRL	22	logTRL = 0.54 logt +0.03	0.982	<0.001
	t/TL	22	logtTL = 0.65 logt +0.01	0.968	<0.001
96,0	t/TRL	51	logTRL = 0.44 logt +0.18	0.996	<0.001
	t/TL	51	logTL = 0.41 logt +0.46	0.970	<0.001

Rate of development, measured as increase in trunk length and tail length, decreased with increasing population density (Fig. 2). Tadpoles from the same clutch cultured under identical conditions were the same size at hatching, but grew at different rates as development proceeded (Fig. 3). The time-trunk length equations for the 8.5 l^{-1} and

TABLE 2 - Pairwise comparison of the time/trunk length, and time/tail length regression equations (see Table 1) for the different population densities using Student's t, Figures are t values for the time/tail length comparisons (above diagonal) and for the time/trunk length comparisons (below diagonal); * = significant at P = 0,05.

Population density (tadpoles/l)	8.5	15.0	40.0	84.0	96.0
8.5	—	4.192	4.011*	2.980	3.643
15.0	1.079*	—	1.760*	0.041*	6.620
40.0	3.900	1.010*	—	3.976	2.391
84.0	9.401	6.418	2.840	—	1.760*
96.0	2.793	19.000	4.735	3.713	—

TABLE 3 - Age (in days from hatching) when forelimbs break the skin and of completion of metamorphosis, and the mortality, at each population density.

Population density (tadpoles/l)	No. of tadpoles in culture	Day forelimbs first emerge	Day forelimbs last emerge	Last day of metamorphosis	No. dead with hind limbs	No. dead with all limbs	% of total dead
8.5	10	53	60	65	0	3	30.0
15.0	30	42	61	66	1	3	13.3
40.0	10	58	70	75	0	7	70.0
84.0	21	57	92	97	0	4	19.0
96.0	64	65	125	130	2	9	17.2

TABLE 4 - Mean trunk length (TRL), standard deviation (s.d.), and coefficient of variation for tadpoles with emergent forelimbs at various population densities.

Population density (tadpoles/l)	Sample size	Mean TRL (cm)	s.d. (cm)	Coefficient of variation
8.5	10	0.958	0.022	2.30
15.0	29	1.020	0.033	3.24
40.0	10	0.903	0.024	2.66
84.0	20	0.873	0.041	4.70
96.0	54	0.855	0.046	0.20

15 l^{-1} cultures and for the 15 l^{-1} and 40 l^{-1} cultures (Table 1) are not significantly different at $P = 0.05$ (Table 2), which suggests a comparable rate of trunk development at the lower culture densities. No similar pattern was however apparent for tail development. The higher the culture density, the longer it took the forelimbs to emerge and the longer it took for tadpoles to metamorphose (Table 3). Mortality was affected by culture density $\chi^2 = 15.614$, d.f. $= 4$, $0.001 < P < 0.005$; Table 3). However, on omitting the mortality value for the 40 l^{-1} culture, mortality was no longer dependant on culture density ($\chi^2 = 1.468$, d.f. $= 3$, $0.99 < P$; Table 3); no explanation for this result can be offered. Of 267 hatchlings, 238 individuals (89%) successfully completed development to the juvenile frog stage.

TABLE 5 - Number of individuals completing metamorphosis at various population densities; TRL = mean trunk length, WW = mean wet weight, s.d. = standard deviation.

Population density (tadpoles/l)	Initial population size	No. completing metamorphosis	Mean TRL (cm)	s.d. (cm)	Mean WW (cm)	s.d. (cm)
8.5	10	6	0.958	0.038	0.124	0.033
15.0	30	23	0.998	0.023	0.138	0.017
40.0	10	2	0.860	0.057	0.076	0.017
84.0	21	7	0.859	0.033	0.079	0.005
96.0	56	37	0.881	0.040	0.080	0.140

Intraculture variation of trunk length at the time forelimbs emerged, estimated by calculating the coefficient of variation (Table 4), was found to be positively correlated with culture density (Pearson product-moment correlation: $r = 0.900$, d.f. $= 3$, $0.02 < P < 0.05$). The trunk lengths at which the forelimbs emerged were different at the various culture densities (Kruskal-Wallis test: $\chi^2 = 18.975$, d.f. $= 4$, $P < 0.001$). This is probably due to the 15 l^{-1} culture where tadpoles with emergent forelimbs had a substantially larger mean trunk length than in the other cultures (Table 4). At the lower densities (8.5 l^{-1}, 15 l^{-1}, 40 l^{-1}) all individuals metamorphosed within 19 days of the first emergence of forelimbs. The cohort at 84 l^{-1} took 35 days, while that a 96 l^{-1} took 60 days to complete metamorphosis from the time the first individual of that particular culture developed the forelimbs. Culture density was not correlated with the mean trunk length at which the tadpoles metamorphosed (Pearson product-moment correlation: $r = -0.759$, d.f. $= 3$, $0.1 < P < 0.20$). The trunk length at which tadpoles metamorphose varies with culture density (Kruskal-Wallis test: $\chi^2 = 3036.301$, d.f. $= 4$, $P < 0.001$). Those tadpoles metamorphosing from the 8.5 l^{-1} and the 15 l^{-1} cultures were heavier than the rest, weighing between 0.07 g and 0.14 g more.

Discussion

In the Maltese Islands, the main factor limiting reproduction of *D. pictus* is the availability of freshwater in quantities and situations that permit the frogs to spawn and the larvae to develop successfully. Here *D. pictus* breeds in any available freshwater: reservoirs, cisterns, watercourses, temporary pools and roadside ditches, and in the deeper rainwater puddles and cart ruts (Schembri, 1983). This ability to make use of any available freshwater is one reason this frog is successful under local conditions. Another reason is the very rapid development of the larvae. In the laboratory, tadpoles cultured at a density of 8.5 l^{-1}, comparable to the field densities measured in this study, metamorphosed 65 days after hatching with some individuals completing metamorphosis in as little as 46 days. At high cullure densities (96 l^{-1}) however, development time was much longer (130 days). At Chadwick Lakes, *D. pictus* tadpoles took about two months to complete metamorphosis, similar to laboratory development times for the low

density cultures. Accelerated development times are a well known adaptation of anurans to evanescent water (Salthe & Mecham, 1974).

Gallien & Houillon (1951) describe egg and larval development of *D. pictus* from Tunis but provide no information on population density in their cultures. Development at two temperatures (20 and 25 °C) was studied from 1.5 h after laying until tadpoles were 138 h old in the 20 °C culture, and 94 h old in the 25 °C culture. Development in Maltese *D. pictus* cultured at a population density of 15 l^{-1} at 18.5 °C was very similar to that described by Gallien & Houillon (1951). Eggs of Tunisian *D. pictus* were very slightly larger (0.13 mm) than those of Maltese *D. p. pictus* (0.10 mm). At all stages, Tunisian tadpoles were larger than those from Malta and completed metamorphosis in a shroter time. Brief descriptions of development of Maltese *D. pictus* beyond day 7 (see 'Results' section) supplement the observation of Gallien & Houillon (1951) which do not extend beyond this time. Tunisian populations of *D. pictus* are now regarded as a distinct subspecies, *D. p. auritus* (Lanza *et al.*, 1986).

Rainfall is known to trigger emergence and spawning in burrowing anurans living in xeric regions (Bentlye, 1966) and may also be the environmental cue for Maltese *D. pictus*. Spawn and tadpoles were present, and adult frogs were active, at Chadwick Lakes only during the wet season. Rain may act directly to cue spawning since frogs appear locally within hours of the first substantial rainfall following a dry period.

Discoglossus reproduces in all months of the year in the Maltese Islands, provided that water is available (Despott, 1913). Spawning occurred in October, January, February, March and April at the nine sites studied. Tadpoles, while still abundant at the end of May 1986 at Wied Speranza where water was readily available in an open irrigation cistern, were absent from all other sites as 'natural' water had by this time of the year dried up. This suggests that locally, *Discoglossus* breeds facultatively, reproductive activity continuing for as long as water is available.

Tadpoles were absent during certain sampling trips when water was plentiful in the breeding pools. One reason may be that all tadpoles from previous clutches had completed their metamorphosis and no new clutches had yet been laid. This, and the observation that at a particular site tadpoles apparently reached the same stage in development synchronously, suggests that tadpoles had been spawned at the

same time; either by a single female, or by different females laying within the same time frame.

In the laboratory, growth and differentiation of tadpoles were retarded at high culture densities. Many species of frogs respond similarly (Wilbur & Collins, 1973; Smith-Gill & Berven, 1979; Dash & Hota, 1980; Selmlitsch & Caldwell, 1982; Sokol, 1984) and explanations for this density effect fall in two broad categories: behaviourally mediated inhibition (e.g. Gromko *et al.*, 1973) and inhibition due to specific particulate or chemical factors (e.g. Rose & Rose, 1961; Akin, 1966; Licht, 1967; Steinwascher, 1978). Whatever the mechanism in Maltese *D. pictus*, one implication of this density effect in nature is that when tadpoles are crowded, their protracted development times may leave them in a pool that dries up before they metamorphose. Under these conditions it would be advantageous for females to avoid spawning under crowded conditions by choosing the largest available bodies of water (in terms of volume), or at least those with few or no tadpoles already in them. This could explain why tadpoles from the same pool were all at the same stage of development: they may represent one female's spawn.

Differential developmental rates within one clutch may also be advantageous. By extending the time period over which juveniles invade the land, the chances that temporary adverse environmental conditions become more favourable are increased, therefore ensuring that at least some representatives from each clutch survive. In this respect, it is significant that, in *D. pictus*, intraculture variability in development increased with increase in culture density.

Our results conform to the Wilbur & Collins (1973) growth-based model of metamorphosis; amphibian larvae must attain a minimum threshold size before metamorphosis can occur. Whether a tadpole metamorphoses at the threshold size or continues to grow depends on its recent growth history: slow-growing tadpoles metamorphose at or near the lower threshold while fast-growing tadpoles continue to grow and transform at a larger size. For *D. pictus*, this model predicts that larvae from high density cultures, where growth rate is slow, metamorphose on reaching the threshold (Table 4; ca. 0.91 mm trunk length). Larvae from lower culture densities continue growing beyond the threshold; newly metamorphosed juveniles from the low culture densities were found to be heavier than those developing at higher densities.

Mortality was independent of density for *D. pictus* tapoles reared

in the laboratory. In nature, predators may play an important role in regulating the density of tadpoles and adults. Known predators of *D. pictus* in the Maltese Islands include adult *Discoglossus* and later tadpole stages (Lanfranco, 1955; Savona Ventura, 1979), dragonfly larvae, adults and larvae of the larger dytiscid beetles and notonectid bugs (S. Schembri, personal communication), the freshwater crab *Potamon fluviatilis* (Savona Ventura, 1979), the weasel *Mustela nivalis* and the hedgehog *Erinaceus algirus* (Lanfranco, 1969) and the snakes *Coluber viridiflavus* and *Telescopus fallax* (Pieris, 1964).

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SUMMARY

Field and laboratory observations on *Discoglossus pictus pictus* were made to study aspects of its population ecology in the Maltese Islands. Development of the eggs and the effect of tadpole population density on development were studied in the laboratory by culturing tadpoles from the same spawning at densities of 8.5, 15, 40, 84 and 96 individuals/litre. Just over 50% of eggs laid at a single spawning hatched within 24 hours of deposition. The remaining eggs did not hatch. At a temperature of 18.5 °C and a tadpole culture density of 15 individuals/litre, development took an average of 47 days from hatching to metamorphosis. The rate of development depended on culture density. Tadpoles developed at a slower rate in the high density cultures and metamorphosed at lower body weights than those in the low density cultures. Within each culture, the rate of development varied between individuals, the higher the culture density, the greater the variability. Tadpole mortality was generally independant of culture density. Significant positive correlations were found between tadpole body length and both wet weight and dry weights in laboratory cultures. In the field, both sexually mature adult frogs and developing tadpoles were only present during the wet season, except at one site where an artificial reservoir contained water throughout the year. No significant differences were found between wet weight,

head width and snout-vent length for adult male and female frogs from Chadwick Lakes. At this site there was a preponderance of males (male: female ratio = 1.6:1). Frogs from different localities in the Maltese Islands spawned at different times, but in any one locality, they spawned more or less synchronously. The results of laboratory observations are discussed in relation to field conditions.

Key words: Biology, *Discoglossus pictus pictus*, Anphibia, Anura.

RIASSUNTO

Sono state effettuate ricerche in campo ed in laboratorio su *Discoglossus pictus pictus* per investigare l'ecologia dei popolamenti nelle Isole Maltesi. Lo sviluppo delle uova e l'effetto della densità della popolazione dei girini sul loro sviluppo sono stati investigati in laboratorio sottoponendo dei girini originati della stessa ovata a delle densità di popolamento di 8.5, 15, 40, 84 e 96 individui/litro. Poco più del 50% delle uova deposte in una singola ovata si sono schiuse entro 24 ore della deposizione. Le rimanenti uova non si sono schiuse. Ad una temperatura di 18.5 °C ed una densità di popolamento di 15 individui/litro, la durata media dello sviluppo dalla schiusura fino alla metamorfosi era di 47 giorni. La rata dello sviluppo dipendeva dalla densità del popolamento. Lo sviluppo dei girini è risultato più lento, e la metamorfosi si effettuava a peso minore, nelle colture ad alta densità rispetto a quelle a bassa densità. Entro le colture individuali, la rata di sviluppo variava per individuo, tale variabilità essendo più accentuata nelle colture ad alta densità. La mortalità era generalmente indipendente dalla densità delle colture. Correlazioni di significato positivo si sono notate tra la lunghezza del corpo del girino e sia peso umido che peso secco nelle colture in laboratorio. In campo, la presenza di rane sessualmente mature e di girini in fase di sviluppo era limitata alla stagione umida, eccezione fatta per una stazione associata ad un serbatoio artificiale contenente l'acqua durante tutto l'anno. Non sono state notate differenze significative tra peso umido, larghezza della testa e lunghezza antero-posteriore tra rane adulte maschi e femmine provenienti dalla località di Chadwick Lakes. In questa stessa località si riscontrava una preponderanza di maschi (indice maschi:femmine = 1.6:1). Rane provenienti da località diverse delle isole Maltesi depongono uova in periodi diversi, però per ogni data località, la deposizione risultava più o meno sincronizzata. I risultati ottenuti in laboratorio sono discussi in relazione alle condizioni vigenti in campo.

Parole chiave: Biologia, *Discoglossus pictus pictus*, Anphibia, Anura.

REFERENCES

ADAMS A. L. (1870) *Notes of a naturalist in the Nile Valley and Malta.* Edinburgh, Edmonton & Douglas: i-xvi, 1-295.

AKIN G. C. (1966) *Self-inhibition of growth in* Rana pipiens *tadpoles.* Physiol. Zool., 39: 341-356.

BATE D. M. A. (1935) *Two new mammals from the Pleistocene of Malta, with notes on the associated fauna.* Proc. Zool. Soc. London, 112: 247-264.

BENTLEY P. J. (1966) *Adaptations of Amphibia to arid environments.* Science, N. Y. 152: 619-623.

BOESSNECK J. & KÜVER M. (1970) *Alluviale Tierknochenfunde aus der Ghar Dalam-Höle, Malta.* Senckenbergiana biol., 51: 147-158.

CAPULA M., NASCETTI G., LANZA B., BULLINI L. & CRESPO E. G. (1985) *Morphology and genetic differentiation between the Iberian and the other west Mediterranean* Discoglossus *species (Amphibia Salentia Discoglossidae).* Monitore Zool. Ital., n.ser. 19: 69-90.

CHETCUTI D. (1988) *The climate of the Maltese Islands.* Unpublished B.Ed. (Hons) dissertation, Faculty of Education, University of Malta: i-xiii, 1-301.

DASH M. C. & HOTA A. K. (1980) *Density effects on the survival, growth rate and metamorphosis of* Rana tigrina *tadpoles.* Ecology, 61: 1025-1028.

DESPOTT G. (1913) *I nostri Rettili.* Archivium Melitense, 2 (18/20): 93-96.

DESPOTT G. (1915) *The reptiles of the Maltese Islands.* The Zoologist, 891: 321-327.

GALLIEN L. & HOUILLON C. (1951) *Table chronologique de développement chez* Discoglossus pictus. Bull. Biol., 85: 373-375 + plates VII-IX.

GROMKO M. H., MASON F. S. & SMIT-GIL S. J. (1973) *Analysis of the crowding effect in* Rana pipiens *tadpoles.* J. Exp. Zool., 186: 63-72.

GULIA G. [*pater*] (1873) *Fauna maltese, classis Reptilia.* Il Barth, 2 (15-16): 300.

GULIA G. [*fils*] (1909) *Cenni bibliografici sulla fauna vertebrata maltese.* Boll. Soc. Zool. Italiana, ser. 2, 10 (9/10): 300-318.

GULIA G. [*fils*] (1913) *Uno sguardo alla zoologia delle 'Isole Maltesi'.* IX Congr. Int. Zool., Monaco, sect. 4: 545-555.

KNOEPPFLER L. P. (1962) *Contribution a l'étude du genre* Discoglossus *(Amphibiens, Anoures).* Vie et Milieu, 13: 1-94.

LANFRANCO G. (1955) *Reptiles and amphibians of the Maltese Islands.* Malta Year Book, 1955: 198-209.

LANFRANCO G. (1957) *Reptiles in Malta.* Times of Malta, 8th December, p. 5.

LANFRANCO G. (1969) *Maltese mammals.* Malta, Progress Press: 1-28, plates 1-8.

LANFRANCO G. & SCHEMBRI P. J. (1989) *Vertebrates other than birds.* In: Red data book for the Maltese Islands, 127-139. SCHEMBRI P. J. & SULTANA J. (Eds). Valletta, Malta, Department of Information.

LANZA B. (1972) *Gli anfibi e i Rettili delle isole circumsiciliane.* Lav. Soc. Ital. Biogeogr., n. ser. 3: 755-804.

LANZA B., NASCETTI G., CAPULA M. & BULLINI L. (1986) *Les discoglosses de la région méditerranéenne occidentale (Amphibia; Anura; Discoglossidae).* Bull. Soc. Herp. France, 40: 16-27.

LICHT L. E. (1967) *Growth inhibition in crowded tadpoles: intraspecific and interspecific effects.* Ecology, 48: 736-745.

MITCHELL P. K. (1961) *The Maltese climate and weather.* In: Malta, a background for development, 48-82. BOWEN-JONES H., DEWDNEY J. C. & FISHER W. B. (Eds). Durham, Durham University Press: 1-356.

PIERIS [pen-name] (1964) *The cat snake.* Times of Malta, 11th December, p. 11.

ROSE S. M. & ROSE F. C. (1961) *Growth controlling exudates of tadpoles.* Symposia of the Society for Experimental Biology, 15: 207-218.

SALTHE S. N. & MECHAM J. S. (1974) *Reproductive and courtship patterns.* In: Physiology of the Amphibia, Vol. 2, 310-521. LOFTS B. (Ed.). New York, Academic Press.

SAVONA VENTURA C. (1979) *Reptiles and amphibians in Maltese ecology.* Potamon, N° 2: 14-16.

SCHEMBRI P. J. (1983) *The painted frog 'iz-zring'.* Civilization, 5: 126-127.

SEMLITSCH R. D. & CALDWELL J. P. (1982) *Effects of density on growth, metamorphosis, and survivorship in tadpoles of* Scaphiopus holbrooki. Ecology, 63: 905-911.

SMITH-GILL S. J. & BERVEN K. A. (1979) *Predicting amphibian metamorphosis.* Amer. Nat., 113: 563-585.

SOKOL A. (1984) *Plasticity in the fine timing of metamorphosis in tadpoles of the hylid frog,* Litoria ewingi. Copeia. 1984 (4): 868-873.

STEINWASCHER R. (1978) *Interference and exploitation competition among tadpoles of* Rana utricularia. Ecology, 59: 1039-1046.

WILBUR H. M. & COLLINS J. P. (1973) *Ecological aspects of amphibian metamorphosis.* Science, N. Y., 182: 1305-1314.

ZAR J. H. (1974) *Biostatistical analysis.* Englewood Cliffs, New Jersey, Prentice-Hall: i-xiv, 1-620.

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