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TEMPERATURE AND WATER TOLERANCES OF INCUBATING CROCODILE EGGS

By

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(*Received* 14/4/70)

Introduction

The desiccation work on green turtle eggs described in the paper immediately preceding this (Bustard, 1971) together with studies on water requirements of lizard and snake eggs (Bustard, 1966; Dm'iel, 1967) suggested an investigation of incubation in additional types of reptile eggs. This paper presents data on crocodile eggs. Previous work on lizards and snakes (see Discussion) had shown that although very large amounts of water may be imbibed during incubation by squamate eggs, this was not essential for normal hatching to occur.

METHODS

A clutch of eggs of the New Guinea freshwater crocodile (*Crocodylus novaeguineae*) was collected on the Keram River (Sepik District), just after laying. The eggs were packed in damp newspaper in a foam cooler and sent to Canberra by air. Eggs were placed in the laboratory incubators about [illegible] days after laying. Considering the conditions of transportation it seems unlikely that the water content of the eggs at the commencement of the experiment differed significantly from that at time of laying. Eggs were incubated in silica sand at temperatures of 23, 26, 32 and 38°C with a water content of 7.8% using the same methods as for the turtle eggs. At least ten eggs were used in each experiment. Some eggs were incubated at 32°C but with a moisture content of 3.9 or 2.0%.

RESULTS

(1) Temperature Tolerance

No eggs hatched at 23 or 26°C. At this temperature the developing embryos died. Incubation success was high at 32°C. At 38°C three young (from 10 eggs) developed to full term but had to be helped out of the eggs. All had deformed tails.

(2) Water Uptake in Sand with 7.8% Water Content

The results for incubation of 12 eggs which produced hatchlings are given in Table 1. Although there is a considerable variation in the amount of water taken up it should be noted that no eggs lost water. They either remained at their initial weight or took up varying amounts of water during incubation.

(3) Desiccation

The results of a small desiccation experiment are given in Table 2. It should be noted that all eggs lost a considerable amount of weight in the first week of the experiment. The eggs maintained at 3.9% water content were opened after 1 month (when the water content was the same as after 2 weeks) (Table 2) and found to contain healthy live embryos. Those at 2% water content were allowed to go on developing and hatched. Percentage water loss after 5 weeks (1 week before hatching) was 17.6 and 24.7% respectively for the 2 eggs. The hatchlings were normal in every way.

[illegible]	Incubation time (days) 16	24	32	38	45	% wt change after 45 days
[illegible]	75	77	78.5	80	82	+11.0
[illegible]	73.5	75	74.5	74.5	74.5	+ 2.7
[illegible]	70.5	72	73.5	75	75.5	+ 7.9
[illegible]	67	67.5	68	69	74	+ 7.8
[illegible]	75.5	76	76	76	78.5	+ 4.7
[illegible]	66.5	66.5	65	65	60	no change
[illegible]	76.5	79	81	85	86.5	+13.8
[illegible]	81	81	81.5	83	86	+ 6.2
[illegible]	74.5	75	75	76	76.5	no change
[illegible]	66.5	67	67	68	68.5	+ 0.7
[illegible]	[illegible]	76	78.5	84	93.5	+23.0
[illegible]	[illegible]	73	75	76.5	76	+ 4.1
						mean + 6.8

Table 1. Weights (gm) of individual *Crocodylus novaeguineae* eggs during laboratory incubation in sand containing 7.8% water by weight.

Moisture content	% age weight change after 1 week	after 2 weeks
7.8%	no change	+1.2
3.[illegible]	−14.2 (−11.1; −17.2)	−14.8 (−12.4; −17.2)
2.[illegible]	−14.8 (−11.7; −17.8)	−15.9 (−12.5; −19.2)

Table 2. Weight changes in *Crocodylus novaeguineae* eggs incubated in the laboratory in sand of varying moisture content at 32°C.

Only two eggs were used in each of these groups. The actual % age weight changes are bracketed after the means.

DISCUSSION

The finding that 32°C is a good incubation temperature for *C. novaeguineae* eggs agrees with the data of Deraniyagala (1939) who reported 32°C as the nest temperature of *C. porosus* in Ceylon. The lower incubation temperature at which *C. novaeguineae* eggs will hatch, which is above 26°C, is not yet known. The upper limit is just below 38°C. The deformed tails in those hatching at 38°C, as in other reptiles, appear to indicate high temperature stress (Bustard, 1969).

The crocodile egg desiccation experiment, which must be considered as preliminary in view of the small numbers of eggs involved, like the turtle egg experiment (Bustard, 1971), indicates that eggs which are not able to absorb water from their external medium still hatch. Furthermore, in both classes, eggs, which due to water stress lost a net amount of water during incubation (up to 25% in the crocodile eggs), were able to survive.

These results are of considerable interest in the understanding of the role of water in the development of reptile eggs. Many squamate eggs absorb large amounts of water, increasing by up to 300% of their initial weight during incubation, but will hatch without access to this additional water (Bustard, 1966; Dm'iel, 1967). I suggest that this water uptake is a form of insurance against lethal levels of water stress at a subsequent stage of incubation should environmental conditions result in a sustained net loss of water from the eggs. Chelonian and crocodilian eggs possess albumen (lacking or virtually lacking in squamate eggs, Bellairs, 1957) which may explain why eggs of these Orders of reptiles do not show the phenomenal water uptake associated with many squamate eggs. The albumen is likely to reduce the rate of water loss under adverse conditions since albumen is hydrophilic. This factor was probably overlooked by Rand (1968) when trying to explain the slower rate of water loss of *Crocodylus acutus* eggs from which a section of the shell had been removed compared to intact eggs of *Iguana iguana*. It should be noted, however, that Rand's three intact *C. acutus* eggs lost appreciably less water over a period of 1 week (an average of about 2% than the *C. novaeguineae* eggs incubated in sand of low moisture content over the same time interval (Table 2). While this may result from differences between the eggs the unduly low incubation temperatures used by Rand could perhaps be responsible.

There is considerable qualitative literature on incubation conditions of reptile eggs but a need exists for more controlled experimentation leading to quantitative results. It is known that parchment-shelled reptile eggs maintained at high relative humidity desiccate unless at least part of the egg is in contact with a moist surface (Clark, 1946). It is interesting that even when buried in sand with a water content of 3.9% crocodile eggs lost substantial weight (Table 2). This result indicates that at this water content "available" water was no longer present in the sand medium. On this basis one would expect the results at 3.9% and 2.0% moisture content by weight to be the same. In fact they are very similar. Similarly turtle eggs in sand which had fallen to a water content of 2.5% had already lost about 8% of their weight (Bustard, 1971). These data indicate the importance of substantial "available" water for both the parchment-shelled eggs of sea turtles and the porous but calcified eggs of crocodiles if they are to maintain their initial weight.

Although water loss was high during the first week in the crocodile egg desiccation experiments little further loss occurred in the second week or during the remainder of the incubation period. Albumen may have prevented water loss beyond this level.

SUMMARY

Crocodylus novaeguineae eggs absorbed water when this was available in the external medium. When water was not available they desiccated rapidly. However, eggs which had lost about 20% of their weight through desiccation produced normal hatchlings.

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