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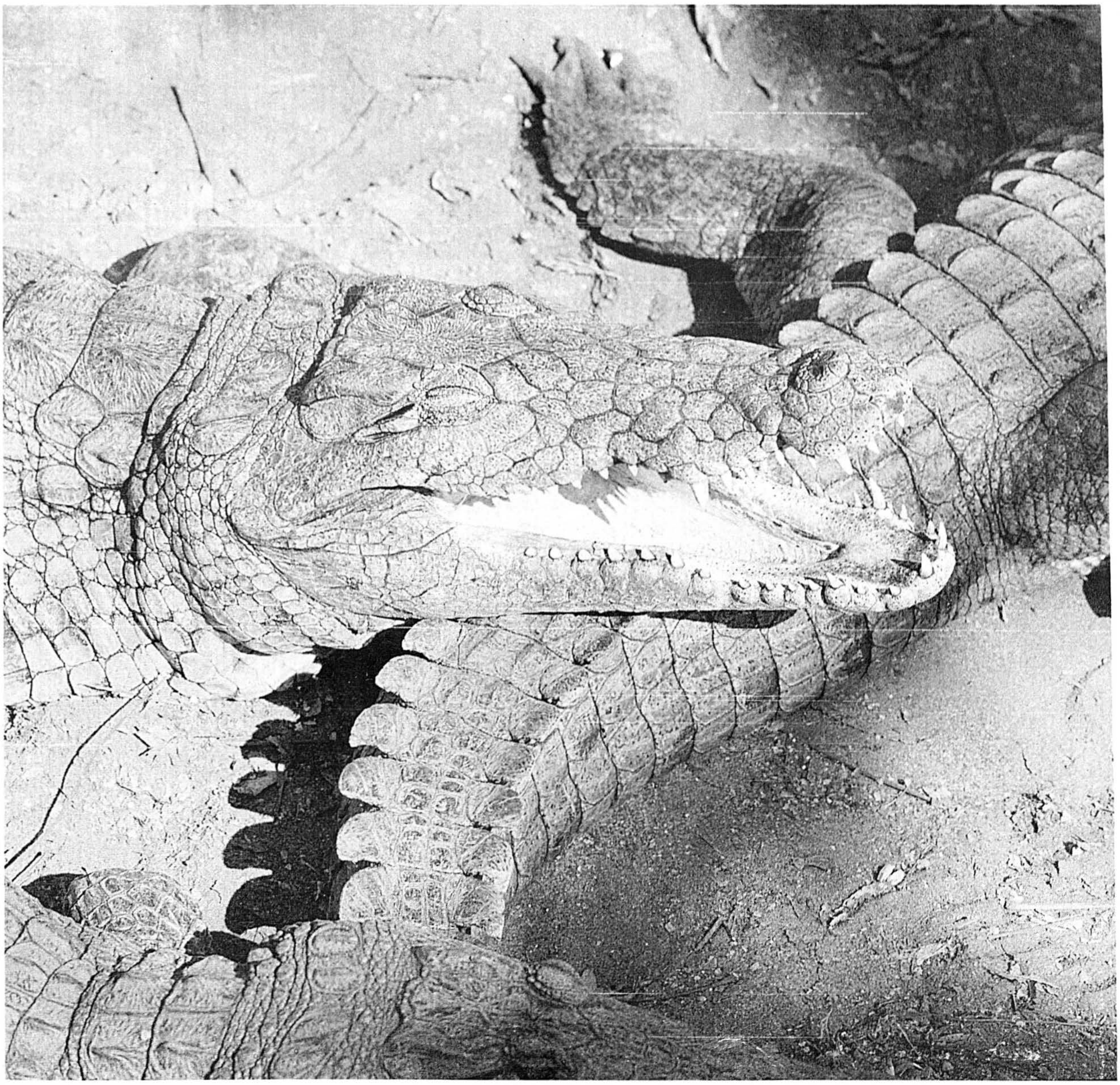

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THE EFFECT OF STOCKING DENSITY, ORIGIN OF EGGS AND WATER FLOW ON GROWTH, SURVIVAL AND BODY CONDITION OF NILE CROCODILES (*CROCODILUS NILOTICUS*)

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ABSTRACT

The effect of stocking density, origin of eggs and water flow regime on growth, survival and body condition of young Nile crocodiles was studied. No adverse effects of high densities, up to 15 animals/m^2 was found. Animals hatched from eggs collected in nature had a slight advantage in growth. All tested parameters had no effect on survival, apart from increased mortality of 4-8 month old crocodiles kept at high density during their first cold season. Continuous water flow did not improve growth. Practical implications of these results are discussed.

INTRODUCTION

The farming of crocodilians has gained interest during the last few decades. However, very little information has been published on rearing conditions. The few papers available deal mostly with alligators (e.g., Webb *et al.*, 1987).

Although Blake and Loveridge (1975), Chabreck and Joanen (1979) and Joanen *et al.* (1981) related growth and survival of crocodilians to temperature and diets, practically no solid data exist in the literature about the effect of other factors such as stocking densities and illumination.

The aim of the present study is to report results of experiments on the effect of stocking densities, sources of eggs and water flow on growth of young Nile crocodiles (*Crocodilus niloticus*).

MATERIALS AND METHODS

The study was carried out at the commercial farm of Clal Crocodile Farms Ltd., Mombasa, Kenya, during 1988 to 1990.

Two thousand three hundred and sixty-eight two month old crocodiles were incubated and hatched in the farm. The eggs were obtained from two sources: about half were collected from nests along the banks of the Tana River (250 km north of Mombasa) and the rest from nests of captive stock on the farm. The hatchlings were held in circular concrete ponds at a density of 10 individuals/m^2 until the start of the experiment.

The experiments were conducted in circular concrete ponds of 6 m radius. The pond walls were 1.2 m high and were covered by sloping conical asbestos roofs. Some sunlight entered the ponds through glass windows of 0.6 x 0.9 m located near the top. The floor of the ponds sloped gently (3%) towards a central drain and the water level was kept so that a radius of 5 m was water covered. Well water of 26°-34°C was supplied through taps at the centre and sprinklers at the water perimeter. Air temperature ranged from between 24° and 38°C and was equal in all treatments of the experiment. Each pond was divided by concrete walls to the level of the pond rim into eight equal sections of 14.2 m^2.

Food, a fresh mixture of fish, chicken and red meat, supplemented by fish concentrate (50% protein), vitamins and minerals was provided once daily *ad libitum* at sunset. The ponds were drained, washed and disinfected (Lisol solution) and refilled every morning.

The study included two consecutive experiments: one with 2-12 months old crocodiles (experiment 1), and the second with 12-22 months old animals (experiment 2).

EXPERIMENT 1

Two ponds were stocked, one with hatchlings obtained from eggs collected from nature ("wild") and the other with hatchlings from eggs of captive brood-stock ("farm") which hatched two weeks before the "wild" crocodiles. Four sections in each pond had continuous water flow and four received water only when daily refilled. The experiment included four density treatments with two replicates for each pond. Initial densities were 6, 9, 12 and 15 animals/m^2. The numbers were reduced by 10% at the end of each two month interval. The experiment lasted 10 months and the final densities were 3.94, 5.91, 7.86 and 9.78 animals/m^2.

EXPERIMENT 2

One pond was stocked with the 1-year old crocodiles taken at the end of experiment 1. This experiment, too, included four initial densities of 7.5, 10, 12.5 and 15 animals/m^2. The numbers were again reduced by 10% at the end of each two month interval. The final densities after 10 months were 4.94, 6.57, 8.21 and 9.85 animals/m^2 respectively. This experiment had two repetitions for each density. During the experiment continuous water flow 1 m^3/hr was provided in all treatments.

Sampling

In both experiments, the animals of each replicate were sampled bi-monthly. The sampling procedure was as follows. The water level was raised to a level which forced the animals to swim in order to prevent them from piling up due to stress. Twenty-five animals were randomly taken, weighed to the nearest gram, and measured for total length to the nearest centimetre. Dead animals were removed and recorded daily during the experiment, and replaced with similar size crocodiles held in a reserve pond.

RESULTS

Experiment 1

Weight and length were highly correlated (Ln weight = 0.0665 x length + 2.4569; r = 0.9815; P <0.001; n = 96), with no significant differences between the replicates and treatments (Fig. 1).

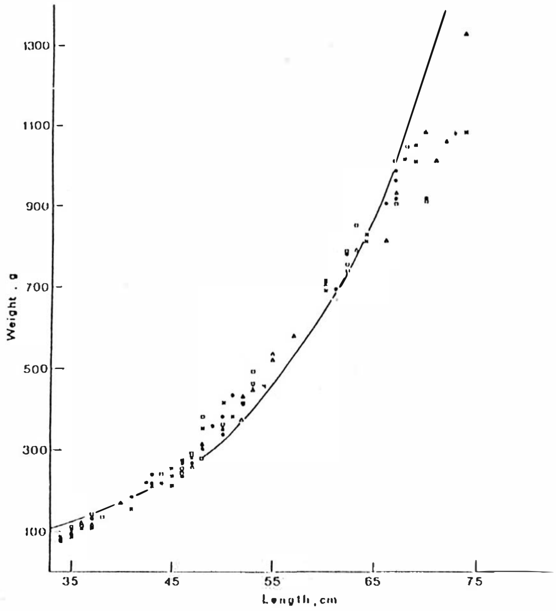

Fig. 1 The relationship between weight and length of captive young crocodiles 2-12 months old. Data are means for samples of 25 animals taken from each experimental groups at 2-month intervals. The markings are for densities at the following declining order: dots (highest density), crosses, squares and triangles (lowest density).

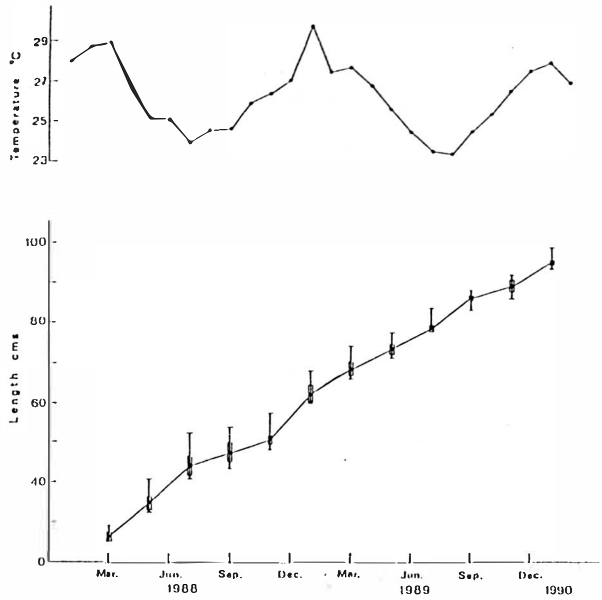

Fig. 2 Growth curve of 2-22 months old captive crocodiles. Means, standard deviations and ranges are all for the samples of the experimental groups. Ambient mean monthly temperature is given. Note the inhibited growth during the cold months of July-November.

Comparison of growth and survival of crocodiles originating from eggs laid in nature ("wild") and those obtained from captive broodstock ("farm") yielded the results in Table 1. Although the respective "farm" animals were significantly heavier (means were 132 and 97 g; t-test, P <0.01) and longer (38 and 35 cm, respectively; t-test, P <0.01) than "wild" animals at the beginning of the experiment, their final weight and length were not significantly different. Total mean survival of "farm" and "wild" animals was equal (83 and 84%, respectively) for the entire 10 months.

Comparison of growth and survival between crocodiles reared in sections with continuously flowing ("flowing") water and once daily changed ("standing") water is shown in Table 2. There was no difference between the groups in either initial or final body weight and length. Mean survival rate was also similar — 86 and 83% in "flowing" and "standing" water groups, respectively.

	Two Month Old Crocodiles				One Year Old Crocodiles				Growth Rate		
Hatched from eggs laid by	Average Length cm	S.E.	Average Weight g	S.E.	Average Length cm	S.E.	Average Weight g	S.E.	Change in Length cm	Change in Weight g	Mean Survival %
Farm Females	38	1.1	132	23.0	68	1.6	978	47.3	30	846	83
Wild Females	35	1.1	97	13.3	70	2.4	1031	122.6	35	934	84
t-tests	5.4	—	3.8	—	1.96	—	1.2	—	—	—	—
P	0.01	—	0.01	—	N.S.	—	N.S.	-	—	—	—

TABLE 1. Growth rate and survival of crocodiles that hatched from eggs laid by farm and wild (Tana River) females between the ages of 2-12 months. Means (±S.E.) are for 8 sections.

	Two Month Old Crocodiles				One Year Old Crocodiles				Growth Rate		
	Average Length cm	S.E.	Average Weight g	S.E.	Average Length cm	S.E.	Average Weight g	S.E.	Change in Length cm	Change in Weight g	Mean Survival %
Flowing	36	2.11	116	29.8	70	2.4	997	68.9	33.9	881.0	86
Standing	36	1.30	104	14.6	69	2.2	1025	129.1	32.82	920.5	83
t-value	0.46	—	1.0	—	1.22	—	0.52	—	—	—	—
P	N.S.	—	N.S.	—	N.S.	—	N.S.	—	—	—	—

TABLE 2. Growth rate and mortality comparison between crocodiles that grew in ponds with flowing water and standing water between the ages of 2-12 months. Means (± S.E.) are for 8 sections.

Density animals/ m²	BL. cm at age 2 mth	BL. cm at age 4 mth	Density animals/ m²	BL. cm at age 6 mth	Density animals/ m²	BL. cm at age 8 mth	Density animals/ m²	BL. cm at age 10 mth	Density animals/ m²	BL. cm at age 12 mth	Total mean growth (CM) from start
6	37±1.6	48±2.4	5.4	50±1.8	4.9	55±1.9	4.4	65±2.4	3.9	71±2.5	34
9	37±1.0	46±1.4	8.1	47±1.6	7.25	52±2	6.5	62±5.4	5.9	68±1.3	31
12	35±1.0	44±1.8	10.7	46±2.3	9.6	51±2	8.7	62±1.8	7.8	70±2.6	35
15	35±1.6	44±2.6	13.4	47±2.9	12.0	51±1	10.9	62±2.1	9.8	68±1.2	33

TABLE 3. The effect of stocking density on growth of 2-12 months old crocodiles, (*Crocodilus niloticus*). Body length (BL). Data are means (± S.E.) in cm for 50 animals in each group.

The above stocking densities had no effect on growth during any of the periods (ANOVA $F_{3,199} = 0.5578$, $P = 0.6435$, N.S.; Table 3 and Fig. 2).

Survival was lower during the first cold season (4 months, July-November, 1988), when the crocodiles were under 8 months old (Fig. 3), and was larger among 7-8 months old crocodiles at high densities, but this difference was not significantly affected by density (ANOVA $F_{3,199} = 0.13$, $P = 0.9422$, N.S.).

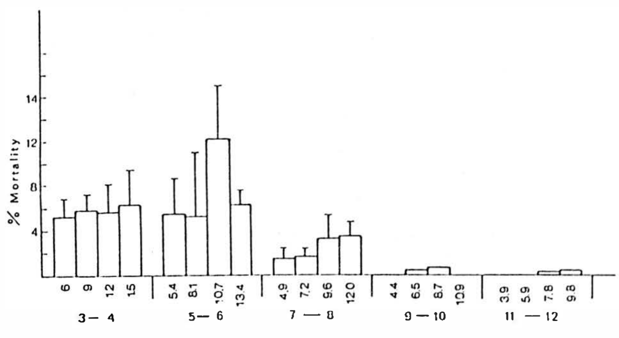

Fig. 3 Bi-monthly mortality percentage (± standard error) of 2-12 months old crocodiles arranged according to stocking density. Upper numbers are densities (animals/m²); lower numbers are the periods of growth (months) from the beginning of the experiments, and correspond to the ages of the animals.

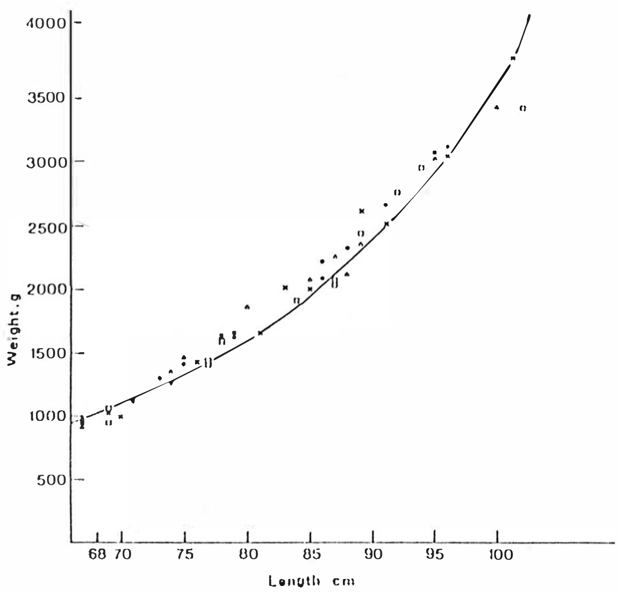

Fig. 4 The relationship between weight and length of captive young crocodiles 12-22 months old. Data are means for samples of 25 animals taken from each experimental groups at 2-month intervals. The markings are for densities at the following declining order: dots (highest density), crosses, squares and triangles (lowest density).

EXPERIMENT 2

Weight and length were highly correlated (Ln weight = 0.040 x Length + 0.990; P <0.001) without any significant differences between the replicates and treatments (Fig. 4). No effect of density on either growth or survival was observed during this experiment (Table 4).

Density animals/ m²	BL, cm at age 12 mth	BL, cm at age 14 mth	Density animals/ m²	BL, cm at age 16 mth	Density animals/ m²	BL, cm at age 18 mth	Density animals/ m²	BL, cm at age 20 mth	Density animals/ m²	BL, cm at age 22 mth	Total mean growth (CM) from start
7.5	67±0.2	74±0.4	6.7	81±0.8	6.1	87±1.3	5.48	88±1.4	4.9	98±2.4	31
10	69±0.2	77±0.2	9	81±2.6	8.1	87±0.1	7.29	90±1.9	6.6	98±4.2	29
12.5	69±0.6	75±1.1	11.2	79±1.1	10.1	84±1	9.12	90±1	8.2	98±2.7	29
15	69±1.7	74±1.2	13.5	79±0.3	12.1	86.±0.4	10.94	89±1.4	9.8	96±0.3	27

TABLE 4. The effect of stocking density on growth of 12-22 months old crocodiles, (*Crocodilus niloticus*). Body length (BL). Data are means (± S.E. in cm for 50 animals in each group.

DISCUSSION

Our results show that crocodiles which hatched from eggs collected in nature had an advantage in terms of growth over crocodiles originating from eggs laid in captivity. The "wild" crocodiles which started significantly smaller than the "farm" ones, reached mean weight and length after 10 months similar to those obtained by "farm" animals. Six of the 7 biggest groups of animals at the end of the experiment, were of groups originating from "wild" eggs. This was surprising since "wild" eggs suffered from rough treatment; they were removed from their nests, transported by boat to an artificial nest where they were kept for another month, and then transferred by car over 250 km of rough road to a room in which incubation conditions were far from ideal. The "farm" eggs remained in their original nests for 70 days and only then taken to the same incubation room. Possible explanations for the better growth of the "wild" crocodiles are, (a) "better" egg quality of "wild" crocodiles due to superior nutrition of the adults, and/or (b) only the "best" embryos survived the rough handling of the transport to the incubation room. We have no data to support or refute either of these explanations, but future experiments are planned to test them.

Although we reared our experimental animals at densities higher than normally practiced by alligator farmers (Chabreck, 1967), our high densities had no effect on growth. This is in contrast to the finding of Elsey *et al.* (1990) that growth of juvenile alligators was negatively affected by densities as low as 3/m² and even lower. Further experiments are needed in order to find what density will negatively affect growth and survival of Nile crocodiles. We suggest that our results are due to better management which minimized stressing the animals. These results may be significant economically for crocodile farming due to savings in area, facilities and labour. However, increased densities may have negative consequences in terms of greater risks per unit.

Even though temperature was not a parameter dealt with in these experiments, we noticed it had dual negative effects; it inhibited growth during both cold seasons (Fig. 1), and increased mortality of 4-8 months old crocodiles during their first cold season. These two adverse effects may be overcome by increasing the temperature of the ponds during the cold seasons as suggested by Blake and Loveridge (1975), but further experiments are needed to test this.

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