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Effect of Yohimbine on the Reproductive Behavior of the Male Nile Crocodile *Crocodylus niloticus*

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MORPURGO, B., I. ROZENBOIM AND B. ROBINZON. *Effect of yohimbine on the reproductive behavior of the male Nile crocodile* Crocodylus niloticus. PHARMACOL BIOCHEM BEHAV 43(2) 449–452, 1992.—The effect of yohimbine, an α_2-adrenergic blocker, on the reproductive activity of 12-year-old male, captive Nile crocodiles was tested on 18 animals equally divided into 3 ponds. In each pond, there were 6 males and 30 females. In the first group, six of six males received yohimbine capsules of 30 mg, twice a day, for 1 week. In the second group, two males of a group of six were administered a similar dose of yohimbine. Another group of six males in a separate pond were used as a control group. The yohimbine treatment had a significant ($p < 0.05$) effect on the frequency of headslap display (the main behavioral pattern of reproductive activity) in all treated animals but did not result in a significant increase in copulation frequency. In the two treated groups, the reproductive period was prolonged by 3 weeks, 8–11 weeks. We found a significant increase in the fertility percentage of eggs laid by females in the male-treated groups (30.5% in control group females, 34.1% in the partly treated, and 39.0% in the pond where all six males were treated), even though no increase in mating frequencies was noted. This might be due to more successful copulations. During the treatment period, the daily activity peak, when the male's headslap performance was the most frequent, was shifted from 5:00–6:00 p.m. in the control to 4:00–5:00 p.m. in the treated group. This effect caused females to enter the water earlier than in the control group.

Crocodilia Nile crocodile Social signals Headslap display Fertility Yohimbine Reproduction Behavior

SOCIAL displays in Crocodilia spp., and its relation to courtship and mating behavior, were described in several species (10). A detailed description is presented by Vliet (12), who described the nature and process of the social displays of the American alligator, *Alligator mississippiensis*, in Florida. In these alligators, two major patterns are found—bellowing and headslap.

Bellowing, a vocal display, is a common act in alligator males (6) and may be an adaptation to living in a marsh habitat, where dense vegetation restricts the importance of visual signals (4). In the Nile crocodiles in the Gan-Shmuel crocodile farm (personal observations), bellowing display was not observed; however, the headslap display is very common in captivity and nature (2,5) and serves as a courtship advertising display in the present study. The headslap display in the American alligator has the same posture and movement characteristics as those of the crocodile but bears a small sexual component (12). The relative importance of the headslap display in the Nile crocodile is emphasized by its ability to elicit the approach of females to the performer (4).

Yohimbine, an α_2-adrenergic blocker, was found to elevate reproductive activity in male mammals (1) and fowl (11). Its activity in reptiles has not been investigated.

In this study, the influence of yohimbine on reproductive behavior in male crocodiles was studied.

METHOD

Animals

Eighteen male Nile crocodiles, 12 years old, were divided into three groups, each group in a separate pond. In each pond, there were 30 sexually mature females, 2.40–2.70 m total length, 8 years old.

In group A, all six males were treated. To assess the effect of stimulation of untreated males by treated males, a second group (B) was studied in which only two of six animals were

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TABLE 1

EFFECTS OF YOHIMBINE TREATMENT ON 2 (15,16) OF 6 MALES ON THE NUMBER OF MATINGS AND HEADSLAP DISPLAY PERFORMANCES, EXPRESSED AS MEAN ± SEM PER DAY OF OBSERVATION

	First Week		Second Week		
Male No.	Headslaps	Matings	Treatment	Headslaps	Matings
16	3.5 ± 0.2*	1.7 ± 0.1	Yes	12.3 ± 1.9†	2.3 ± 0.5
15	4.1 ± 0.7*	2.1 ± 0.3	Yes	11.9 ± 2.2†	2.2 ± 0.2
11	9.1 ± 0.9	4.3 ± 0.4	No	10.1 ± 1.0	4.5 ± 0.6
3	3.9 ± 1.0	2.0 ± 0.3	No	4.1 ± 0.9	2.1 ± 0.3
0	4.0 ± 1.2	1.8 ± 0.2	No	3.7 ± 0.0	1.7 ± 0.7
17	0	0	No	−‡	−

The first week is control; the second week treatment.

*†Significant differences ($p < 0.05$) between the treatment and control after Duncan's new multiple-range test.

‡Male 17 was depressed by other males and during the second week of the experiment was killed by males 11 and 16.

treated. In group C (control), the six male crocodiles were not treated.

Observations

Mating activity in the farm commenced in March and continued for 4 weeks before the experiment began.

During the 14 days of the experiment, observations were carried out from 6:00 a.m.–5:00 p.m. (as daylight afforded). Each headslap display and mating act was recorded. The males were all tagged and could be identified individually.

Yohimbine Administration

Yohimbine, from Sigma Ltd. (St. Louis, MO), was weighted and placed in a gelatin capsule, each capsule containing 30 mg. Twice a day, all males were fed a whole, 30- to 50-g fish (*Cyprinus cypris*). During the second week, the eight treated males were provided with a capsule of 30 mg yohimbine, which was placed inside a fish. Each animal received 30 mg twice a day for 7 days.

Following the end of the treatment, the behavioral observations went on for another 5 weeks. The observations were conducted to determine the reproductive activity period. The females layed eggs during May–June and in mid-July the fertility of eggs was examined (13).

Statistical Analysis

Results are presented as the mean and SD. Significant differences between groups were determined by using one-factor analysis of variance (ANOVA) and Duncan's new multiple-range test. Correlation was determined using Spearman's rank correlation coefficient.

RESULTS

The use of the headslap display as the main behavioral pattern of reproductive behavior in the experimental crocodiles was verified by finding a significant correlation ($r = 0.857$, $p < 0.05$) between the display frequency and number of matings using untreated male crocodiles data, as shown in Table 1.

Effect of Yohimbine in the "All Treated" Group, Group A

Group A had two control treatments: Group A before the treatment and Group C as a control for the treatment week to exclude the effect of other parameters, such as photoperiod

TABLE 2

EFFECT OF YOHIMBINE TREATMENT ON 6 OF 6 MALES FROM GROUP A

	Group A, Before Treatment	Group A, During Treatment	Group C, First Week	Group C, Second Week
No. of headslaps/day	18.9 ± 2.1*	27.3 ± 3.2†	22.5 ± 1.8*	20.9 ± 3.3*
No. of matings	8.4 ± 1.9	9.3 ± 2.2	10.9 ± 3.2	9.8 ± 2.0

The number of headslap displays and matings per day were compared between Group A 1 week before treatment to A in the treatment week. The number of headslap displays and matings per day were compared between the control (Group C, six untreated males) during the 2 weeks before treatment session and the treated Group A. Numbers are expressed as mean ± SEM per day of observation. The headslap display frequency was not different in the control group during the first and second week and the level was significant lower than group A during treatment.

*†Significant differences ($p < 0.05$) between the treatment and control after Duncan's new multiple-range test.

TABLE 3

EFFECT OF YOHIMBINE (30 MG*2/DAY FOR 7 DAYS) ON COURTSHIP AND MATING PERIOD AND ON LAID EGGS' FERTILITY PERCENTAGE IN THE THREE EXPERIMENTAL GROUPS

	Treatment		
	Group A (6 of 6)	Group B (2 of 6)	Control (Group C)
Reproduction period (weeks)	11	11	8
No. of nests	9	7	9
No. of eggs	182	203	220
Egg fertility (%)	39.4 ± 1.9	33.2 ± 3.2	30.5 ± 1.7

and change in water temperature, which might cause changes in activity not related to the treatment (8).

There was a significant effect of yohimbine treatment on the headslap display frequency: a total of 18.4 performances per day in the group before and a total of 27.3 in the group during the yohimbine administration period. No effect was found on mating act frequency, (Table 2) between treated and control males.

Effect of Yohimbine in Group B

Yohimbine had a significant effect on the frequency of the headslap display in the two treated crocodiles (4.1 and 3.5 before, 11.9 and 12.3 during the treatment). No significant difference was found in these parameters between the untreated males in this group and those of the control group, C, during the experiment (Table 1).

The fertility percentage of eggs was the highest in the pond in which all males received yohimbine (Table 3).

In the two treated groups, A + B, the reproductive period was prolonged: 11 weeks in the treated and 8 weeks in the control (Table 3).

The treatment also had an effect on the daily "activity peak." Repeated-measures ANOVA followed by pairwise multiple comparison tests showed that activity peaked at 5:00–6:00 p.m. in the control group and 4:00–5:00 p.m. in the treatment group. Before the experiment, in Groups A and C the hour in which the frequency of the headslap display was highest was 5:00–6:00 p.m. It was also the peak hour of Group C on the second week, but shifted to 4:00–5:00 p.m. during the treatment period in Group A (Fig. 1). This shift was not very clear in Group B, where two of six males were treated.

The week after yohimbine was discontinued, headslap display frequency declined and was not significantly different than the control group.

DISCUSSION

Of five parameters studied, yohimbine treatment had an effect on four: headslap display frequency, the time of peak activity during the day, length of courtship and mating period, and egg fertility. The only reproductive parameter on which no effect was found was the number of matings per treated male.

In Zimbabwe, the origin of the crocodiles used in the present study, the courtship and mating season lasts about 8 weeks (7); we found a similar period in the control group of the present study. The prolonged period found in the treated groups is a considerable change from the natural period of reproductive activity and was clearly due to yohimbine treatment.

The effect of yohimbine treatment on "activity timing peak" and headslap display frequency, but not on the number of matings performed by a treated male crocodile, might have resulted from an asynchrony of male and female activity patterns. The yohimbine was given to crocodiles at 11:00 a.m.

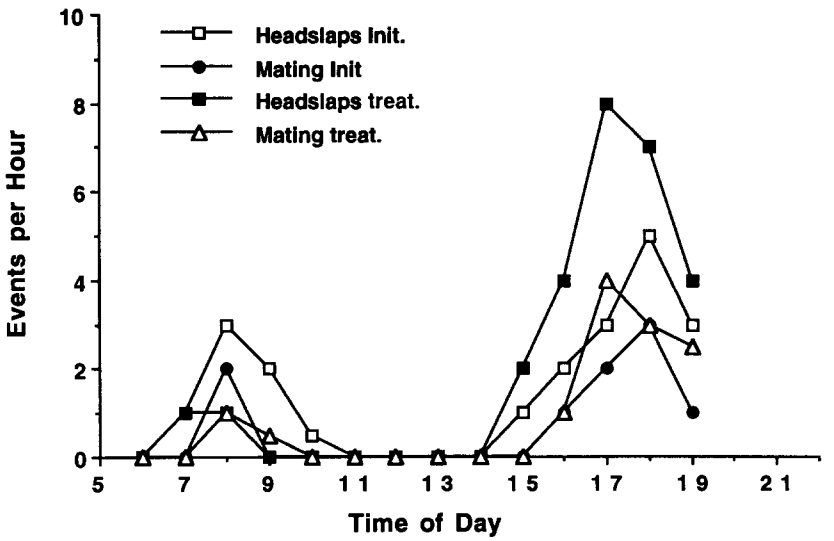

FIG. 1. Effect of yohimbine, 30 mg twice a day for 1 week, on mean headslap display frequency and mating. Average of 7 days of treatment. The treatment had a significant effect on the headslap display frequency (Headslaps Init.) and the reproductive activity timing during the day, from 5:00–6:00 p.m. before (Init.) to 4:00–5:00 p.m. during the treatment (treat.) period.

and 2:00 p.m. and the change in the males' behavior were noted at 4:00 p.m., an hour when most females crocodiles were outside the water—the mating site (9). From 4:00 p.m., males tried to attract females to the water by performing the headslap display (14). It did cause an earlier entrance of the females, as shown by the shifting of the activity peak. The effect of a different, later, yohimbine administration might affect the number of matings as well because later in the afternoon most females are already in the water. This point requires further study. The effect of yohimbine on headslap display frequency declined rapidly once treatment was discontinued. However, matings in the treated ponds continued for an additional 3 weeks when all sexual activity had ceased in the control pond.

All laying females were of the same age and almost the same size, parameters that affect egg fertility and successful hatching (3). The significant effect of yohimbine treatment on fertility might be due to differences in the treated males' ability and quality and not quantity of matings. The yohimbine treatment may cause a larger sperm volume, as found in *Galus domesticus* males (11).

Yohimbine has been shown to affect sexual behavior in mammals by interacting with α_2-adrenergic receptors in the CNS (1). A similar effect was reported in fowl (11), presumably acting by a similar CNS mechanism.

In this study, we have shown that yohimbine also affects sexual behavior in male reptiles. This suggests that the CNS control of sexual behavior in reptiles is also under adrenergic influence.

The similarity of CNS control of sexual behavior in vertebrates indicates that such neural organization is phylogenetically ancient.

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