M. Kare and O. Maller (eds.) Academic Press, Inc., New York.

———, H. W. Greene and A. S. Rand. 1977. Social behavior in hatchling green iguanas: Life at a reptile rookery. Science 195:689–691.

De Fazio, A., C. A. Simon, G. Middendorf and D. Romano. 1977. Substrate licking in an iguanid lizard: A response to novel situations in *Sceloporus jarrovi*. Copeia 1977:706–709.

Evans, L. 1959. A motion picture study of maternal behavior of the lizard, *Eumeces obsoletus* Baird and Baird. Copeia 1959:103–110.

———. 1961. Structure as related to behavior in the organization of populations in reptiles, p. 148–178. *In:* Vertebrate speciation. W. F. Blair (ed.). Univ. of Texas Press, Austin.

Goldberg, S. 1971. Reproductive cycle of the ovoviviparous iguanid lizard *Sceloporus jarrovi* Cope. Herpetologica 27:123–131.

Gove, D. 1975. A comparison of tongue-flicking in the Squamata. Abst. 55th Annual Meeting, American Society of Ichthyologists and Herpetologists, 42–43.

Greenberg, B. 1943. Social behavior of the western banded gecko, *Coleonyx variegatus* Baird. Physiol. Zool. 16:110–122.

Hunsaker, D. 1962. Ethological isolating mechanisms in the *Sceloporus torquatus* group of lizards. Evolution 16:62–74.

Noble, G., and K. Kumpf. 1936. The function of Jacobson's organ in lizards. J. Genet. Psychol. 48:371–382.

Porter, K. 1972. Herpetology. W. B. Saunders Co., Philadelphia.

Pratt, C. W. 1948. The morphology of the ethmoidal region of *Sphenodon* and lizards. Proc. Zool. Soc. Lond. 118:171–201.

Simon, C. A. 1975. The influence of food abundance on territory size in the iguanid lizard *Sceloporus jarrovi*. Ecology 56:993–998.

Tinkle, D. 1967. The life and demography of the side-blotched lizard, *Uta stansburiana*. Misc. Publ. Mus. Zool. Univ. Mich. 132.

Karen Gravelle, *Biopsychology Program of Hunter College and the Graduate Center of the City University of New York, New York, New York* and Carol A. Simon, *Department of Biology, The City College of the City University of New York, New York, New York, New York and Department of Animal Behavior, The American Museum of Natural History, New York, New York.* Accepted 28 Feb. 1979.

HATCHING AND CRECHE FORMATION BY *CROCODYLUS POROSUS*.—Many species of crocodilians attend and probably protect their nests during incubation, and adults of several species remain with their young for several months after they hatch (*Crocodylus palustris*, Darmakumarsinhji, 1947; *C. niloticus*, Cott. 1971; *Caiman crocodilus*, Staton and Dixon, 1977; *C. moreleti*, Hunt, 1975; *C. porosus*, Webb et al., 1977). However, the role of adults at nests and the significance of juvenile vocalization are unclear. Lee (1968) who worked on *Alligator mississippiensis*, and Hall and Lake (reported in Blake, 1974) working with *C. niloticus*, suggested that calling by juveniles synchronized hatching. Campbell (1973) and Staton and Dixon (1977) felt that the primary purpose of calling was to induce the female to open the nest prior to hatching and to maintain hatchling creches (groups of hatchlings often accompanied by an adult). These interpretations have not been tested experimentally.

This note reports observations on four aspects of hatching and creche formation by *C. porosus*: 1) the effect of vocalization on time of hatching; 2) behavior of adults at nests; 3) the relationship between nest opening and hatching; 4) the effectiveness of hatchling vocalization in maintaining creches in the field. The study was undertaken on the Liverpool and Tomkinson rivers, northern Australia. Descriptions of the area, climate and other studies being undertaken under the auspices of the joint University of Sydney, Department of the Northern Territory Crocodile Research Facility have been given by Messel and Butler (1977).

Effect of vocalization on time of hatching.—Two groups of ten eggs from the same nest were incubated in polystyrene boxes. Two weeks before the estimated time of hatching a tape recorder was placed in one box (treatment) and recordings of hatchling calls from a wild nest were played for one hour in every six. Mechanical stimulation of eggs was kept to a minimum. Whenever the tape recorder was turned on in the treatment box the lid had to be opened. Similarly the lid was taken off the other box (control) and replaced so that both boxes received the same slight mechanical stimulation. Rotting vegetation packed around the eggs in both boxes maintained the temperature of the eggs between 30 and 32 C. This is within the normal range of nest temperatures in the wild. Each box was kept in the same room, but the tape recorder could not be heard by me outside the "treatment" box when the lid was in place.

The boxes were checked regularly and eggs were removed when the hatchling's snout broke through the shell. The embryos called in response to the taped calls in the "treatment" box but no calls were heard from the "control" box during checks.

Hatching of eggs in both treatment and control was protracted compared with nests that were excavated. The interval between the first and last eggs hatching was 458 hours in the box subjected to hatchling calls and 397 hours in the box without a tape recorder. There was no significant difference between the mean time of hatching of the two groups ($t_{14 \text{ d.f.}} = 0.66, P > 0.5$).

Calls synchronize development in some species of birds (Vince, 1969) but as young *C. porosus* call only when the nest is disturbed it is unlikely that calling acts similarly for *C. porosus*. Hall and Lake (reported in Blake, 1974) noticed that hatching of *C. niloticus* eggs in nests they opened often caused adjacent nests to hatch prematurely. They suggested that calls from the first nest stimulated the surrounding nests to hatch. It is probable that eggs of *C. niloticus*, like eggs of *C. porosus* do not hatch in response to calls from other eggs, and that eggs hatched in response to mechanical stimulation caused by excavation of adjoining nests.

Behavior of adults at nests.—Fifty two nests were checked at weekly intervals to see if an adult was present and to see whether the eggs were alive. A "Minolta" 8 mm movie camera with intervalometer (Telonics Pty Ltd) was used to photograph seven nests and surrounding areas automatically at three minute intervals for periods of up to 16 days. On most days, lighting limited interpretation of photographs to those taken between 0830 and 1740 hours.

Crocodiles attended nests long after the eggs had been killed by flood waters, and one crocodile was photographed at the nest for the four days during which the nest was covered by between one and three m of water. Some crocodiles attended nests for up to two months after the embryos had been killed, but no nest containing only dead embryos was opened by a crocodile.

Some nests containing live, full term embryos were torn apart and the eggs were removed. Tracks around nests indicated the presence of large crocodiles. There were no tracks of other large animals that might have been nest predators.

At one nest the time lapse camera recorded a large crocodile (estimated to be 3 m long) moving back and forth between a nest and a lagoon 5 m away. In several frames egg shells could be seen strewn around the nest but these had disappeared by the time the crocodile ceased coming to the nest. No other animals were recorded by the camera. The nest was checked the next day. There were no eggs or egg shells left in or near the nest. Seven hatchlings were captured in the lagoon near the nest and at least 20 others were seen further out in the lagoon. *C. niloticus* opens its nest to free its young, then eats the empty egg shells (Pooley, 1977). The fragmentary observations given above suggest that *C. porosus* may show similar behavior.

Hatching of juveniles in the absence of an adult.—Nests at which no adult crocodiles were present were opened by me within two days of the young commencing to call. To test whether opening the nest affected survival of hatchlings one nest was left unopened until the young ceased to call.

Four nests were opened within two days of the young commencing to call. All live embryos in these nests hatched within 40 min of the nest being opened and most fully developed embryos hatched successfully. In the nest left for 14 days the majority of fully developed embryos were dead. Hatching success differed significantly between the nest opened after 14 days and the nests opened after less than two days ($F_{1,3} = 18.18, P < 0.025$).

Eight of the embryos that died in the nest left for 14 days had their snouts protruding from the eggs. The nest was loosely packed and it therefore was unlikely that they were physically incapable of releasing themselves from the eggs. Of the two eggs that hatched successfully one was at the top of the egg cavity and one was in the center. The hatchlings escaped from the nest by digging holes (3 cm diameter) to the surface.

The nest had been inspected regularly throughout the incubation period and the temperature of the egg cavity measured with a mercury thermometer. The temperature of the egg cavity varied between 31 and 33 C and the nest material was always moist. Therefore the hatchlings probably had not been subjected to low temperatures or low humidities which would make them abnormally weak. This suggests that excavation of the nest by an adult

may be necessary for successful hatching of some eggs.

Crocodiles ready to hatch rarely called spontaneously. Calls could be elicited from a nest by bumping the surface, by a loud noise such as a low flying aircraft or the playing of a tape recording of hatchling calls close to the nest. In the field the agent most likely to bump the nest would be a parent. Not calling except when the nest is bumped may reduce the chances of calls of the young attracting predators when an adult is not present.

Hatchling vocalizations and maintenance of creches.—This experiment tested whether hatchling calls kept hatchlings together in the field. In an initial experiment 11 hatchlings were released into the upper reaches of the Liverpool River. They immediately swam to the bank. After ten minutes a tape recording of hatchling calls was played from a boat 9 m upstream and 7 m from the bank. A current estimated as 2 km/hour was flowing from the boat towards the site of release.

In a second experiment seven hatchlings were released in the same section of the river but on the opposite bank. After ten minutes a tape recording of hatchling calls was played from the bank 9 m from the site of release. There was a current estimated as 1 km/hour flowing from the site of release towards the tape recorder.

Of the hatchlings from the two releases, all but one moved to within 0.5 m of the tape recorder within 20 min of its being turned on. They remained there until it was switched off two hours later. The one hatchling that ignored the call swam off vigorously when released and was not seen again. During the second experiment one hatchling released during the first experiment, seven days previously, responded to the tape recording by swimming diagonally across the river (30 m wide) from 30 m downstream, crawling up the bank and sitting on the tape recorder.

Although hatchlings did not form creches during this study, previous studies have shown that *C. porosus* hatchlings sometimes form creches accompanied by an adult crocodile (Webb et al., 1977). Hatchling creches have been described for other species of crocodilians *A. mississippiensis*, McIlhenny, 1935; *C. niloticus*, Modha, 1967; Cott, 1971). This study has shown that vocalization is an effective means of maintaining hatchlings in groups. Vocal com-

munication is almost certainly the primary means of keeping creches and adults in contact. Why juveniles do not form creches in the absence of an attendant adult when they have the means of keeping in contact is not known, but dispersing may be an advantage when an adult is not present to protect the creche from predators.

LITERATURE CITED

BLAKE, D. K. 1974. The rearing of crocodiles for commercial and conservation purposes in Rhodesia. Rhod. Sci. News 8:315–324.

CAMPBELL, H. W. 1973. Observations on the acoustic behavior of crocodilians. Zoologica 58:1–11.

COTT, H. B. 1971. Parental care in the crocodylia, with special reference to *Crocodylus niloticus*, p. 166–180. *In*: Crocodiles, Proc. 1st Work. Meet. Crocodile Spec., New York, March 1971. I.U.C.N. Public. New ser.

DARMAKUMARSINHJI, K. S. 1947. Mating and parental instinct of the marsh crocodile (*Crocodylus palustris* Lesson). J. Bombay Nat. Hist. Soc. 42:445–446.

HUNT, R. H. 1975. Maternal behavior in the Morelet's crocodile *Crocodylus moreleti*. Copeia 1975:763–764.

LEE, D. S. 1968. Possible communication between eggs of the American alligator. Herpetologica 24:88.

MCILHENNY, E. A. 1935. The alligator's life history. Christopher Publishing House, Boston.

MESSEL, H., AND S. T. BUTLER. 1977. Australian animals and their environment. Shakespeare Head Press, Sydney.

MODHA, M. L. 1967. The ecology of the Nile crocodile (*Crocodylus niloticus* Laurenti) on Central Island, Lake Rudolf. E. Afr. Wild. J. 5:74–95.

POOLEY, A. C. 1977. Nest opening response of the Nile crocodile *Crocodylus niloticus*. J. Zool. 182:17–27.

STATON, M. A., AND J. R. DIXON. 1977. Breeding biology of the spectacled caiman, *Caiman crocodilus crocodilus* in the Venezuelan Llanos. U.S. Fish Wildl. Serv. Wildl. Res. Rep. 5.

VINCE, M. A. 1969. Embryonic communication, respiration and synchronisation of hatching, p. 233–

260. *In*: Bird vocalizations—their relations to current problems in biology and psychology. R. A. Hinde (ed.). Cambridge University Press, London.

WEBB, G. J. W., H. MESSEL AND W. E. MAGNUSSON 1977. The nesting of *Crocodylus porosus* in Arnhem Land, northern Australia. Copeia 1977:238–249.

W. E. MAGNUSSON, *Department of Zoology, School of Biological Sciences, University of Sydney, Sydney, Australia 2006.* Accepted 30 March 1979.

OBSERVATIONS ON THE BODY TEMPERATURE AND ACTIVITY IN THE RED SPOTTED TOAD, *BUFO PUNCTATUS*.—

Several studies have shown that anurans are capable of regulating their body temperature through behavior (Lillywhite, 1970; Lillywhite et al., 1973; Seymour, 1972; Pearson and Bradford, 1976; Carey, 1978). The purpose of this study was to determine the effect of behavior on the body temperature of the toad, *Bufo punctatus*.

Materials and methods.—This study was conducted at the Philip L. Boyd Deep Canyon Desert Research Center in Palm Desert, Riverside County, California during August 1974 and August 1978. Toads were collected from a small (1.5 × 4 m) man-made pond at the research center were they have been established for several years. Miniature (6 × 16 mm) temperature-sensitive radio transmitters were used to continuously monitor toad body temperatures, with an accuracy to 0.1 C (McGinnis, 1967). The transmitter was inserted into the coelomic cavity through a 2 cm incision on the ventral surface of the toad anterior to the seat patch. The incision was closed with 000 surgical suture, and the toad was released the next eve-
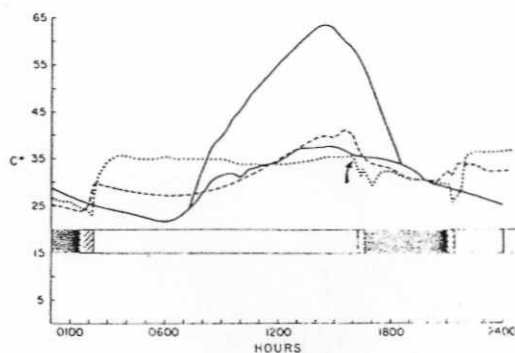

Fig 1. Body temperature and activity of *B. punctatus* (toad A) on 9 August 1974. The lines depict surface temperature in sunlight (upper solid) and in shade (lower solid), toad body temperature (dotted) and ambient temperature at approximate location of toad (dashed). Note drop in body temperature (arrow) prior to emergence from burrow retreat. The lower bar indicates the location of toad in pond (solid black), away from pond (diagonal hatching) or in burrow (clear).

ning. After release, the body temperature of each toad was recorded continuously for a period of 2–3 days at ½ to 1 hour intervals. Signals were received by an AM radio via a loop antenna placed in the general vicinity of the toad. Air temperature, ground-surface temperature in the sun and shade, and ambient temperature in the immediate vicinity of the toad were recorded with thermistor leads and a Model 44 YSI Telethermometer. If environmental temperatures exceeded 50 C, they were measured with a mercury thermometer (−20 to 110 C).

Results and discussion.—A total of five toads (516 temperature recordings) were monitored over a period of 11 days. A summary of body temperatures is given in Table 1. The average over-

TABLE 1. SUMMARY OF BODY TEMPERATURES RECORDED FROM *B. punctatus* AT DEEP CANYON IN 1974 (TOADS A–C) AND 1978 (TOADS D–E).

Toad	Time period	Active body temp.				Overall body temp.			
		$\bar{x}$	SD	Range	N	$\bar{x}$	SD	Range	N
A	8/9–8/10	28.7	3.5	23.0–33.8	34	32.6	3.7	23.0–37.0	90
B	8/16–8/19	22.9	1.7	20.8–25.0	67	29.5	3.8	20.8–34.1	164
C	8/19–8/21	22.2	1.5	19.8–25.8	30	27.5	3.9	19.8–32.7	78
D	8/14–8/15	21.9	1.3	20.0–26.5	35	29.5	4.2	20.0–33.2	90
E	8/16–8/17	23.0	2.0	19.0–26.9	37	30.8	3.5	19.0–35.2	94