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THE SUN and the TURTLE

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Basking habits of some of the *Pseudemys* turtles have aroused the curiosity of the authors. Here they present some speculations and comments which they hope will elicit response from other investigators as to the possible reasons for development of this interesting habit by some species but not by all. Is sun exposure needed for heat or growth or for its value in combatting diseases?

By PETER C. H. PRITCHARD AND WILLIAM F. GREENHOOD

Our readers will remember Peter C. H. Pritchard from his first interesting article in the Journal, "To Find the Ridley . . ." (May-June, 1967). In presenting the following article, Mr. Pritchard admits that many of the conclusions reached by the co-authors are based on somewhat tenuous reasoning.

It is curious that the basking habit of turtles should have received so little scientific investigation or discussion, as this habit is surely the most conspicuous one, of freshwater turtles at least, throughout the world. Our field studies were based almost entirely on the rather special situation of the turtle populations of the clear, thermally stable Florida springs, but we feel we have perhaps gained some insights into the habit which are worth recording.

Apparently the only detailed study of the basking habit of turtles in the literature is that of Boyer (1965), who concluded from his studies of the single form, *Pseudemys scripta elegans,* that the principal function of basking was to raise the body temperature. Boyer managed to show a reasonable correlation between the number of turtles seen basking with the ambient temperature, and in particular with the black-bulb temperature; however, his use of only one species prevented him from obtaining the sort of comparative results which we shall describe in this paper. Other functions of basking which have been suggested include: drying up fungus, algae, leeches and other ectoparasites on the skin; enabling the turtle to respire in a relaxed fashion; and allowing the turtle to synthesize Vitamin D from skin sterols such as Ergosterol, under the influence of solar ultraviolet light. Our observations suggest that the last-named may be the primary function of turtle basking, while the overall heating effect is a side effect, frequently an undesirable one.

In field measurements of temperature, captive turtles were transported to the spring runs and forced to bask while cloacal temperatures were monitored continuously by means of a Yellow Springs telethermometer and thermistor probes. Cooling curves in spring water were obtained in the same manner. The site for the most important aspect of this study was on the Rainbow River near Dunellon, Florida, where a large log, about twenty feet long, situated amid a patch of dense aquatic vegetation was used daily by large numbers of basking turtles (up to 45 adult *Pseudemys* were observed on the log at one time). The work reported herein centers around a single day's observation, from shortly after sunrise to shortly before sunset, of wild and experimental turtles, black-bulb temperatures, and air temperatures in the shade. (Spring run temperature was found to be virtually constant at between 22.5 and 22.8° C.). Observations were supplemented by other experiments to determine the rates at which turtles heat up in the sun and cool down when returned to the water.

Turtles of three distinct, though closely related, species were represented on the basking log mentioned above: *Pseudemys nelsoni* Carr (Florida red-bellied turtle); *Pseudemys concinna suwanniensis* Carr (Suwannee River turtle); and *Pseudemys floridana peninsularis* Carr (Peninsula turtle). Hybridization between these forms is very rare or non-existent in the Rainbow River, though it has been recorded occasionally elsewhere between *P. c. suwanniensis* and *P. f. peninsularis* (Carr 1952), between *P. nelsoni* and *P. f. peninsularis* and between *P. nelsoni* and *P. c. suwanniensis* (Crenshaw, unpublished). Only well-marked individuals of the three forms could be identified with certainty through binoculars. Consequently it was only occasionally possible to make species counts of the turtles on the log at any one time.

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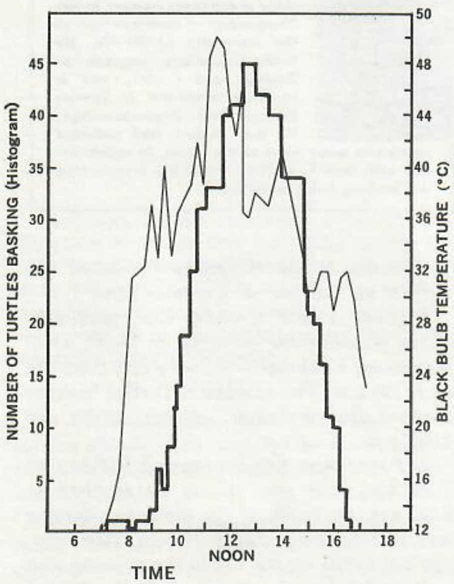
Figures 1 and 2 show that maximum shade temperature occurred at 10:45 a.m.; maximum black-bulb temperature occurred at 11:30 a.m. The number of turtles basking reached its maximum between 12:30 and 1:00 p.m.

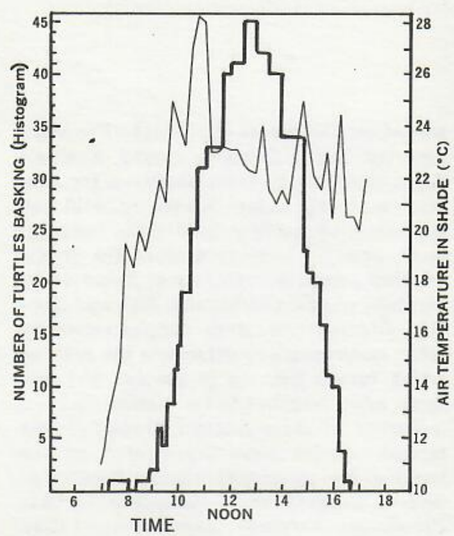
A *Pseudemys nelsoni* started basking at 7:20 a.m. and was joined by another at 8:50 a.m. No turtle of the other two species was seen basking until 9:15 a.m. Moreover, the last turtle on the log in the evening was a *P. nelsoni,* and after it left the log at around 4:40 p.m., four more *nelsoni* were the only turtles found still basking in a nearby backwater of the river — three at 5:00 p.m. and one at 5:20 p.m. Nevertheless, *P. nelsoni* is no more abundant than the other two species. Although no quantitative data were obtained, individuals of *P. nelsoni* seem also to bask for longer periods than the other two species. In fact, three *suwanniensis* tethered in the sun after a particular *nelsoni* had started basking showed signs of distress — indeed the smallest had died — while the *nelsoni* under observation were still basking voluntarily. Even though metabolic heat production is probably increased in turtles which are forced to bask and are struggling for part of the time, it seems that *P. nelsoni* is much more resistant to solar radiation than *P. c. suwanniensis*. *Pseudemys concinna suwanniensis* heated up when placed in the sun as is shown in Figure 3.

As expected, the smallest individual heated up at the greatest rate. All became increasingly active with increasing temperature. Reactions to overheating (above 30° C.) included opening the mouth, panting and eye secretion. Thermoregulation *in extremis* was carried out in the male by extruding the large, black and highly vascular penis, which was curled under the tail, possibly to avoid picking up radiant heat. Body temperature of the turtle at that point was 41.8°; that of the penis was 30.2° C. The turtle, showing obvious signs of distress, was removed from the sun when the body temperature was 43°. In cool water it recovered but did not regain complete control of the hind limbs. The observed lethal temperature of 43-44° corresponds closely with that for *Pseudemys scripta elegans* (Boyer 1965). Near the maximum temperature the turtle became irascible and tried to bite — a striking change in disposition of this normally very pacific species.

The distribution of *Pseudemys nelsoni* corresponds closely with that of the alligator *(Alligator mississippiensis)*, both historically and contemporaneously. This is particularly so in extreme South Florida, where *nelsoni* and its predator, the alligator, are both abundant, while *peninsularis* and *suwanniensis* are both absent. *P. nelsoni* has responded to this danger by evolving an extremely thick, strong carapace, the efficacy of which is attested by practically every adult *nelsoni* from parts of Florida where the alligator is still found. Scratch marks on the turtles' shells attest to the vain efforts of the predators to crack them. A big alligator could presumably crack any *nelsoni* it found, but in marginal cases the adaptation has been well worth while.



• **Figure 1**



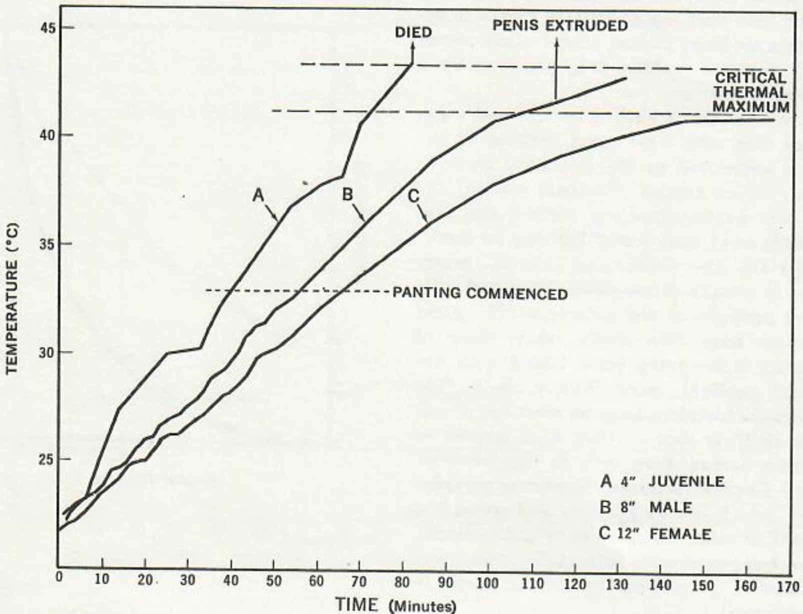
• **Figure 2**

It seems reasonable to assume that *Pseudemys nelsoni* can tolerate long periods of hot sunshine because of its thick shell, which delays conduction of heat to the viscera. There is no marked tolerance to high body temperature in this form, and in fact the critical thermal maximum is slightly lower than that of the other two species (Hutchison 1966). The fact that *P. nelsoni* can not only tolerate this exposure, but, judging by its behavior, actually requires it, may be explained as follows:

Adult *Pseudemys* of the three species found in Rainbow River have a purely herbivorous diet, as can be observed or determined by analysis of stomach contents (Carr 1952). Young *Pseudemys* are known to be mainly carnivorous; they are also not seen to bask nearly as frequently as adults (nor, for that matter, are the carnivorous mud and musk turtles). It is probable that *Pseudemys* in Rainbow River become herbivorous when about five inches long, and weighing about one pound. Big adults, on the other hand, are perhaps fifteen inches long and may weigh twenty pounds. Consequently, about 95% of the total weight, and over 95% of the total bone, of the adult turtle is accreted after the change to a purely herbivorous diet (Figure 4).

The vegetable food of these animals is very low in Vitamin D, and it is known that this vitamin is essential for calcium phosphate uptake. Young turtles in captivity deprived of Vitamin D develop soft shells and die; larger turtles cease to grow. However, even if Vitamin D is absent from the diet, it can be synthesized by the action of ultraviolet light on skin sterols. Thus, soft-shell in baby turtles can be avoided either by exposing them to direct sunlight or by feeding them substances rich in Vitamin D, such as cod liver oil, in conjunction with the necessary calcium source. Adult, herbivorous, *Pseudemys* in the wild, then, must synthesize their Vitamin D by basking in the sun, and the more bone accumulated, the more exposure required. Turtles have most of the body covered by the shell, and the integument is horny and tough, so that rather protracted exposure is necessary for sufficient Vitamin D to be synthesized.

The upper size limit of turtles in temperate zones may be fixed by the necessity to pick up heat fairly rapidly in the daytime, for turtles which live in the thermally stable Florida Springs or move into them during the winter are substantially larger than most of the other freshwater species in temperate zones. In general, it is probably advantageous for turtles to be as large as thermal considerations allow, to grow rapidly, and to have a lot of bone in the shell. Large size enables the females to carry more eggs, and the three factors together help protect the animal from predation.



• Figure 3

Turtles in situations where spring run water temperatures are constant (such as the one under observation and others in

Florida) do not bask to gain heat, as they were seen basking when both air and black-bulb temperature were lower than that of the water; also, they were sometimes seen basking with the bridge and plastron under water, when no overall heating occurs (Boyer 1965); and the turtle is not active when basking, and does not utilize the greater potential for activity caused by the higher temperature. Turtles cool down to the ambient temperature rapidly upon returning to the water; consequently, even though they may spend considerable time basking, they perform all normal activities at temperatures very close to that of the surrounding water. However, basking may assist these turtles at times to digest their cellulose-rich diet. (Figure 5 shows cooling curve for heated turtle replaced in water of the run.)

The curve may be seen to approximate to Newton's Law of Cooling. Furthermore, turtles may take water into the cloaca to accelerate cooling; cloacal temperature sometimes shows a sudden drop followed by a gradual temporary rise.

A correlation of shell thickness and vegetarian diet with time spent basking in the sun is supported by the following facts:

(a.) Green turtles *(Chelonia mydas)* are the only herbivorous sea turtles, and also the only ones ever found basking on land.

(b.) On the Galápagos Islands, where there is usually dense cloud cover and little direct sunlight in the mountains, the giant tortoises have thin shells, while those of Aldabra, a low-lying coral island with unlimited sunlight, have thicker shells. The Galápagos tortoises have no shortage of calcium in their diet — they feed largely on *Opuntia* cactus, very rich in this element.

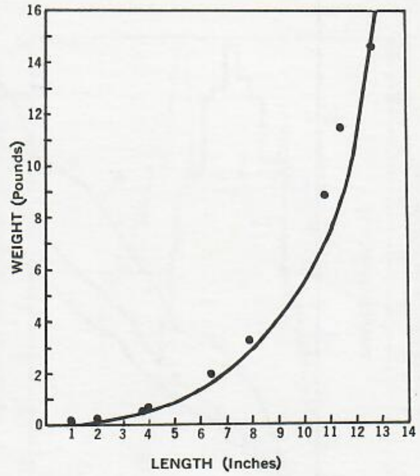
(c.) Gopher tortoises *(Gopherus polyphemus)*, which live in burrows and spend less time than other tortoises in bright sunlight, often have extremely thin shells, with large fontanelles persisting to a late stage in development.

(d.) Fossil tortoises from glacial periods of North America and the West Indies have very thin shells (W. Auffenberg, personal communication).

To summarize: turtles which have thick shells for protection need to bask for long periods or require a carnivorous, Vitamin D rich diet. Vegetarian tortoises whose habitat or mode of life precludes much basking have thin shells, which in such cases constitutes no particular disadvantage.

Emydine turtles basking voluntarily almost invariably extend the palmate surfaces of the hind extremities so that they are fully exposed to the source of radiation. The turtles, when disturbed, are very quick at twisting around and lowering their feet for pushing off into the water, but nevertheless there is a delay in doing so, and this delay constitutes a liability which must be compensated by some overriding advantage. The heat gained by the feet is small compared to that picked up by the shell, but the amount of thin, metabolically active tissue exposed to the source of radiation is greatly increased by placing the feet in this position. It seems possible that this habit is a method of increasing the rate of synthesis of Vitamin D.

It has been stated that one possible purpose of basking is to destroy ectoparasitic leeches, fungi and algae. However, fungi (e.g., *Saprolegnia* spp.) are readily killed by comparatively short exposure to heat, dryness and sunlight (J. T. Mullins, personal communication). They are not usually found on healthy turtles, even on those species which do not bask extensively. Leeches, commonly found on healthy turtles of many species, are not killed by prolonged dryness; moreover, they usually attach be-



• **Figure 4**

low the edges of the carapace where they are not exposed to direct rays of the sun.

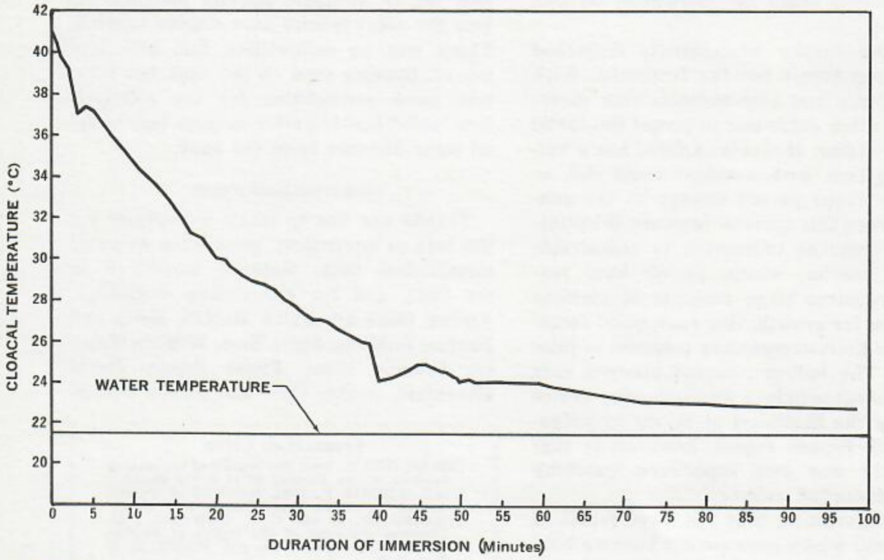
Epizoophytic algae on turtle shells like *Basicladia* (see Edgren *et al.* 1953; Neil and Allen 1954), in addition to their obvious camouflaging function, provide additional surface area for evaporatively cooling the shell when wet, and later insulating it from the sun's rays when dry. *P. c. suwanniensis* with extensive algal growth on the carapace were seen to bask longer than other members of the same species, and even longer than *P. nelsoni*. In non-basking forms, such as *Macroclemys*, such algae often grow on the skin of the limbs and head, whereas in healthy *Pseudemys* they are seldom seen elsewhere than on the carapace and bridge.

The two thick-shelled Floridian *Pseudemys, P. nelsoni* and *P. s. scripta*, have black carapaces as adults, perhaps as an adaptation for keeping warmer when the ambient temperature is very low. Young *nelsoni* have green carapaces with broad yellow bands on the laterals. In the adult the green becomes black and yellow becomes dark red; the latter color is practically as efficient as black at absorbing radiation. Black pigment is in fact already present in the green areas. As Gadow (1901) says: "the green color, often so beautiful in baby specimens of *Chrysemys* (i.e. *Pseudemys*), is optical, produced, according to Agassiz, by a network of black pigment, spread over a layer of yellow oil."

Marked specimens of *P. c. suwanniensis* have been shown to grow significantly only during the months of March to November (Jackson 1964).

During the non-growing months the food supply and the ambient water temperature remain constant. Opportunities for basking, however, are curtailed by the lower air temperatures, and lower intensity and shorter daily periods of sunlight during this time. Although the amount of calcium present in aquatic vegetation is not high, the calcium carbonate content of the water in Rainbow Run is 67 p.p.m. (Collins and Howard 1928). As turtles imbibe large amounts of water, presumably they obtain needed calcium in this manner. This suggests that the availability of Vitamin D, as obtained through basking, may be a significant factor in permitting or limiting growth of the shell.

Shortly after midday the particular basking log under observation housed to capacity forty-five adult turtles. In several places the turtles were two deep, probably



• **Figure 5**

advantageous for the lower turtles, having the carapace shielded from the heat but with the head and limbs exposed to the ultraviolet light of the sun. Occasional jostling and displacement of turtles occurred from a large number of other turtles in the aquatic vegetation around the log.

Highway 484 passes over a bridge within 25 yards of the log. The basking turtles are accustomed to heavy motor traffic and to motor boats passing quite near to them. They are easily frightened by pedestrians, however stealthily they move, possibly because relatively few people walk along this highway. In the Chipola River in the Panhandle of Florida, though, basking *Pseudemys concinna mobiliensis* are frightened even by a rowing boat 150 yards away, perhaps because boats are infrequent on this river.

Basking turtles when mildly disturbed twitch and thrust out the forelimbs. With *peninsularis* and *suwanniensis* this movement is often sufficient to propel the turtle into the water. However, *nelsoni* has a bulbous plastron with a raised front end, so that the limbs do not engage on the substrate when this nervous response is initiated. As frequent immersion is undesirable in this species, which, as we have reasoned, requires large amounts of incident radiation for growth, this anatomical factor will thus limit unnecessary response to false alarms. The bulbous, curved plastron may also be a contributory strengthening device to lessen the likelihood of injury by alligators. The former reason, however, is suggested by our own experience watching mildly disturbed *nelsoni*.

It is interesting that the three forms of *Pseudemys* which have similar basking habits as well as practically identical diets of *Sagittaria, Lemna* and *Naias* and other water plants (Carr 1952) should co-exist in apparent defiance of Gause's Law. However, there is evidence to suggest that the population is not an equilibrium one while Gause's Law applies only to equilibrium populations. Marchand (1942) found the population of turtles in Rainbow Run during the two preceding years to consist of 37.3% *suwanniensis*, 33.3% *peninsularis* and only 2.1% *nelsoni*, based on a probably valid sample of 1022 turtles. The other species were *Sternotherus odoratus, Trionyx ferox, Deirochelys reticularia* and *Chelydra serpentina*. (One *Trionyx*, one *Deirochelys* and many *S. odoratus*, as well as a single *S. minor*, but no *Chelydra* were found on the present survey).

In 1966 the populations of the three *Pseudemys* had apparently become of comparable abundance; certainly a far higher proportion of *nelsoni* than 2.1% was present, even though we cannot substantiate this with accurate figures. We believe that *nelsoni* is gradually becoming preponderant at Rainbow Run, possibly by competing successfully for basking sites, having an advantage over the other species in having a black shell and being able to commandeer the basking sites and still pick up enough radiation for an adequate activity potential before the other species have started basking. There was no competition for, and little use of, basking sites on the bank but there was much competition for the relatively few "safe" basking sites on large logs wedged some distance from the bank.

Acknowledgements

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Literature Cited

BOYER, DON R., 1965. The ecology of the basking habit in turtles. Ecology 46 (1 & 2): 99-118.

CARR, ARCHIE F., 1952. Handbook of Turtles. Cornell University Press, Ithaca; i-xv, 1-542.

COLLINS, W. D. and C. S. HOWARD, 1928. Chemical character of the waters of Florida. Water Supply Pap. 596b. ppl. 177-233. U. S. Geol. Surv.

EDGREN, R. A., M. K. EDGREN and L. H. TIFFANY, 1953. Some North American turtles and their epizoophytic algae. Ecology 34: 733-740.

GADOW, H., 1901. Amphibia and Reptiles (Cambridge Natural History Series).

HUTCHISON, V. H. and R. J. KOSH, 1966. Critical thermal maxima in turtles. Herpetologica 22:32.41.

JACKSON, C. G., 1964. A biometrical study of form and growth in *Pseudemys concinna suwanniensis* Carr (Order: Testudinata). University of Florida doctoral dissertation, pp. i-vii, 1-76.

MARCHAND, L. J., 1942. Contribution to the knowledge of certain freshwater turtles. University of Florida Master's Thesis. 1-83.

NEILL, W. T. and E. R. ALLEN, 1954. Algae on turtles; some additional considerations. Ecology, *35* (4): 581-584.

ROSE, FRANCIS L. and W. G. WEAVER, 1966. Unpublished observations.