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Author(s): H. Robert Bustard

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THE ADAPTIVE SIGNIFICANCE OF COLORATION IN HATCHLING GREEN SEA TURTLES

H. ROBERT BUSTARD

ABSTRACT: The color pattern of hatchling green turtles is an example of countershading. However, the black dorsal coloration has the disadvantage of making the hatchlings conspicuous to predators when crossing pale-colored sand to the sea. Furthermore, those hatchlings which emerge during the day rapidly reach lethal body temperatures through radiation effects (potentiated by the black carapace). It is suggested that the black carapace plays an important role in elevating the hatchling turtles' body temperatures when they are floating at the surface of the sea. Experimental data are given to demonstrate this effect. Increased body temperature will result in faster growth due to the stimulatory effect on metabolism. A more rapid growth rate during an extremely vulnerable stage of the life history will have survival value. Presumably the black dorsal coloration is retained because this increased survival more than offsets the loss from terrestrial disadvantages.

HATCHLING green turtles, *Chelonia mydas* (L.), are black on the dorsal surfaces and immaculate white below, an example of countershading. Many fish have developed countershading and are almost invisible when viewed from the side (Cott, 1940). Hatchling turtles occupy a similar environment with surface-swimming fish like the mackerel which are dark blue on the back and silvery-white on the belly. The black upper surfaces of the turtles when viewed from above match the sea and camouflage them from sea birds. The white lower surfaces blend in with the sky when viewed from below and camouflage the turtles from deeper swimming fish.

Most hatchlings emerge from their nests after dark (Moorhouse, 1933; Bustard, 1967) when they may be preyed upon by land crabs such as *Ocypode*. Even at night the black upper surfaces are a distinct disadvantage on pale-colored sand making the hatchlings clearly visible as they make their way to the sea. (Although some important green turtle rookeries are on dark sand beaches the majority occur on pale sand. Many major rookeries are on coral cays or reef-fringed islands where the sand is virtually white.) This undoubtedly increases predation by crabs which depend on visual cues (Bustard, unpubl.). Similarly it makes them more readily visible to gulls which patrol the beaches on clear nights when the moon is nearly full.

Some hatchlings emerge during the day (Moorhouse, 1933; Bustard, 1967) when their black upper surfaces again make them clearly visible to seabird predators on pale sand beaches. Furthermore, during the heat of the day temperatures may be lethal for hatchlings. Field studies have indicated that radiation is critical in causing heat death in the field. The black dorsal surfaces potentiate this by absorbing heat rapidly. Often hatchlings emerging during the heat of the day and orienting towards the sea are unable

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to reach the beach before being overcome by heat stress. A shade-seeking behavioral mechanism, which occurs when their body temperatures exceed about 36 C, has recently been discovered (Bustard, unpubl.).

In the laboratory 10 hatchling turtles with an internal body temperature of 36 C survived surface sand temperatures of 50–56 C for 15 min in the absence of a radiation source. The air temperature 2.5 cm above sand at 51 C was 35 C. At the end of this period the turtles' rectal temperatures were between 36 and 40 C, suggesting that they gained little heat by conduction. This result was borne out by a similar experiment in which 10 hatchlings with body temperatures of 33 C were placed on sand at 40 C with an air temperature 3.5 cm above the sand of 30 C and left there for 30 min. At the end of the experiment their rectal temperatures averaged 34 C (range 33.0–34.8, $SD \pm 0.54$). These experiments demonstrate that an exceptionally hot substrate by itself does not cause lethal body temperatures, even when the exposure to it is many times longer than would occur naturally. The color of the undersurfaces does not affect the rate of temperature gain by conduction from the substrate.

The effects of radiant heat are, of course, dependent on the color of the upper surfaces. In a laboratory experiment, the rectal temperatures of 10 turtles with the upper surfaces whitewashed were monitored and compared with 10 untreated hatchlings. The two groups were kept in identical conditions before the experiment and subjected to the same radiant heat environment. The experiment was conducted on coral sand with a surface temperature (shaded while measured) of 40–42 C. The time taken for a turtle to show locomotory loss from heat exhaustion, which in nature would have resulted in death, was recorded. This averaged 45% longer for "white" compared with normal turtles. Presumably the black dorsal coloration occurs despite terrestrial disadvantages because its advantages at sea far outweigh these disadvantages.

The hatchlings are extremely buoyant and at rest float at the surface of the sea with a considerable portion of the carapace out of the water. Parts of the head and front flippers are usually also exposed (Fig. 1). The figure illustrates one of two typical front flipper resting positions; in the other the flippers are folded back on top of the edges of the carapace. Under these conditions it seems feasible that the black dorsal surfaces promote an increased body temperature by absorption of radiant heat.

A laboratory experiment was carried out to test this hypothesis. The experiment was performed on 10 one-week-old hatchlings since newly emerged turtles swim continuously and do not spend long periods resting at the surface. The upper surfaces of 5 hatchlings were painted white 3 days before the experiment. This caused no detectable differences in their behavior compared with untreated

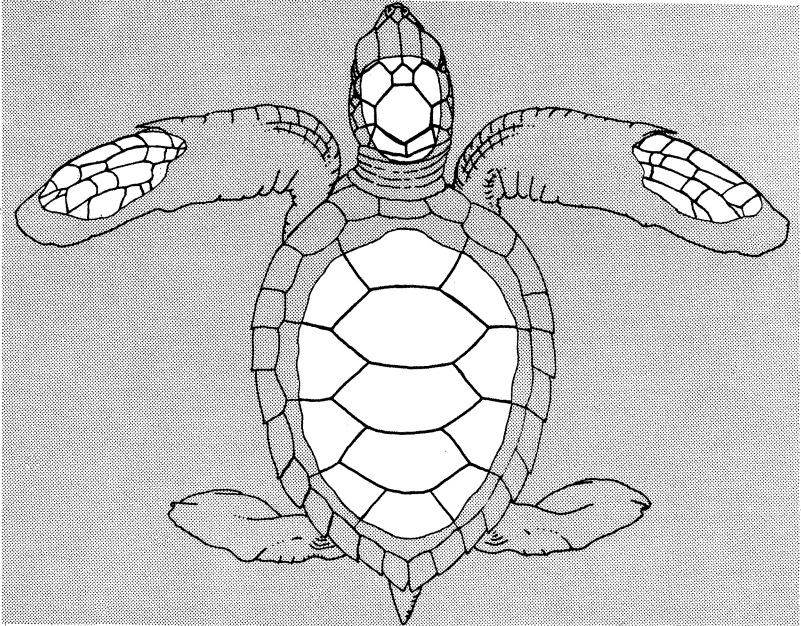


FIG. 1.—Hatchling green turtle floating at the water surface. The pale areas are out of the water.

hatchlings. The experiment was carried out in an aquarium with a radiant heat source which provided shaded air temperatures of 24–25 C, equivalent to a hazy sun in the tropics, and temperature of 22 C near the surface. The water was moved in order to simulate a slight sea swell. Periodic temperature readings of the turtles were taken with a Schultheis rapid-recording thermometer inserted into the cloaca. The mean temperature of normal hatchlings was 1.7 C (range 1.1–2.3, $SD \pm .41$) above water temperature whereas the mean for the white painted hatchlings was only 0.3 C (range 0.0–0.6, $SD \pm .32$) above the water temperature, i.e., the cloacal temperature of the black hatchlings averaged 1.4 C above the mean for the white painted hatchlings. In the absence of a radiation source the temperature of 10 one-week-old unpainted hatchlings was similar to water temperature.

I consider that the heating effect in the open ocean would be at least as great as in the experimental situation where it was reduced by additional turtle activity resulting from the hatchlings banging against the sides of the aquarium.

An increased body temperature will result in more rapid food assimilation because of the stimulatory effect on metabolism. This will lead to a faster growth rate during a vulnerable stage when the hatchling turtles cannot dive well and are subject to aerial as well

as aquatic predation. Hence any factors tending to increase body temperature, such as the dark dorsal coloration, have survival value.

Two other observations lend support to the suggested adaptive value of black coloration while the hatchlings are small and at the water surface. Hatchling green turtles start regular diving at 2-3 months of age when their weight has increased from about 22 g at birth to about 1,200 g. At 6 months of age they have become much lighter in dorsal coloration (Tanis, pers. comm.). The black coloration is lost with increase in size and regular diving.

Hatchlings of the other member of the genus, *Chelonia depressa*, are pale grey in dorsal coloration when hatched. *C. depressa* hatchlings average 40% heavier at birth than hatchling *mydas* (Bustard and Limpus, 1969) which are at the maximum size that gulls can swallow. Since *depressa* hatchlings are above the critical size for bird predation, there would be no survival value in having black upper surfaces for camouflage purposes. Darker upper compared with lower surfaces still provides countershading. The black upper surfaces have presumably either not been developed in this species or have been eliminated because of their terrestrial disadvantages.

The only obvious explanation for the immaculate white undersurfaces of hatchling *mydas* is for camouflage. It is noteworthy, therefore, to find that *depressa* hatchlings also have white lower surfaces. Although they are too large at birth to be eaten by seagulls, *depressa* hatchlings must have many fish predators. Unfortunately the behavior of juvenile *depressa* is unknown.

Not all hatchling sea turtles are dark above and light ventrally. Hatchling loggerheads (*Caretta caretta*) are a similar color on both surfaces or may even be darker ventrally. Since the principle of countershading is widely followed, it seems likely that predation is reduced by other means. Loggerhead hatchlings, for instance, have rough carapaces which become spinose within several months of hatching, a probable deterrent to predators.

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Research School of Biological Sciences, Australian National University, Canberra, A. C. T.