ARE OSTRICH *STRUTHIO CAMELUS* EGGS THE WRONG COLOUR?

Birds which lay their eggs in unprotected nests on the ground in the open generally have well camouflaged eggs (Lack 1968) which are less conspicuous to predators than white eggs. The Ostrich *Struthio camelus* is a striking exception to this general rule. Ostrich eggs have shells which are shiny creamy white in colour. They are usually not near, and apparently never under, a tree. The nest is usually left unattended during the first week or thereabouts of the laying period (unpubl. obs.), and the adult birds do not cover the eggs when they leave them. As a result the white eggs are easily detected from airplanes (Hurxthal 1979, and pers. obs.) as well as by aerial predators by whom they are often destroyed.

This note describes experiments carried out to investigate why Ostrich eggs are apparently the wrong colour. Most were performed in the course of a study by B.C.R.B. of the communal nesting system of Ostriches in Tsavo West National Park, Kenya, during the months of July to October in 1977 and 1978 (Bertram 1979a, b, 1980). Additional information was obtained by B.C.R.B. and A.E.B. at Ostrich farms at Oudtshoorn, Cape Province, South Africa in January 1979 (Bertram & Burger, in prep.). The aim was to quantify the consequences to Ostriches of having conspicuous rather than camouflaged eggs.

By far the most important aerial predator of Ostrich eggs is the Egyptian Vulture *Neophron percnopterus* which is well known to break them by throwing stones at them (Alexander, quoted by Andersson 1856, van Lawick-Goodall 1970, Boswall 1977, Brooke 1979). No other vulture or raptor species is able to destroy Ostrich eggs. Egyptian Vultures can succeed only if there is no Ostrich at or near the nest, and therefore their predation takes place at the early laying stage.

We present the data in the form of answers to four main questions.

(1) HOW VULNERABLE ARE OSTRICH EGGS?

The predation risk by Egyptian Vultures can be quantified. Of 13 nests in Tsavo which were discovered by the observer early enough that they contained fewer than five eggs, four (31%) were destroyed by Egyptian Vultures. This is a minimum figure, because by observing Ostriches we would be more likely to discover surviving nests than destroyed ones. The destruction rate might be higher still but for the fact that the adult birds increasingly with time attend and guard their nests.

To measure the risks run by unattended nests, 18 artificial nests were constructed and observed in Tsavo. These contained a mean of eight (range 3–23) eggs, some of which were real, some empty shells, and some realistic fibreglass dummies. These artificial nests were scattered in their distribution in space (over *c.* 200 sq km) and in the time of setting them up (over two periods of three months each). Of these 18 nests, eight (44%) were destroyed within seven days. Of the total of 12 artificial nests which were destroyed within the criterion period of 30 days, ten (83%) were destroyed by Egyptian Vultures

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and only two by jackals, a reflection of their effective concealment from earthbound predators. Thus the predation risk to unattended nests is high.

(2) WOULD OSTRICH EGGS BE LESS VULNERABLE IF THEY WERE A DIFFERENT COLOUR?

Twelve Ostrich eggs were dyed a medium brown colour and their vulnerability to predation compared with that of 12 normal white eggs. Because of the shortage of whole eggs, all except six were empty shells (but containing a hen's egg to compensate the predator for its efforts). The eggs were placed singly on the bare ground more than 500 m apart and the different colours alternately. They were observed usually every other day, and the time elapsing until their destruction was recorded. In addition, two eggs dyed bright orange were also put out, designed to be as conspicuous as white eggs but as unfamiliar as brown ones. The difference in conspicuousness between brown and white eggs was striking to the human eye.

Three eggs (one of each colour) were known to have been removed by mammals and so are omitted from further consideration. Of the camouflaged brown eggs, six out of 11 (55%) survived for more than ten days, while only two (17%) of the 12 conspicuous eggs did. The differences in survival time are statistically significant ($P < 0{\cdot}05$, Mann-Whitney test, $n_1 = 11$, $n_2 = 12$). Camouflaged eggs had roughly three times as long a median survival time as normal eggs (3·5 *v.* 10 days). The two orange eggs were destroyed as quickly as the white; despite the small sample, this suggests that the brown colour protected eggs by concealing them rather than by making them unfamiliar.

(3) DO WHITE EGGS GAIN ANY OTHER ADVANTAGES?

The Ostrich is adapted in several ways to living in hot arid environments (Louw *et al.* 1969), and it appeared possible that the white colour of its eggs might be another such adaptation. One of the problems faced by desert birds is that of preventing their eggs from getting too hot, because an egg exposed to full sunlight in combination with high air temperatures is liable to reach a lethally high internal temperature (Bertram & Burger, in prep.). In general a shiny white surface reflects more radiant heat than other colours, and so we might expect that a white shell might help to protect ostrich eggs against overheating. Experiments were carried out at Oudtshoorn to determine whether this was the case.

The temperatures reached by eggs in an unattended artificial nest were measured. The nest contained 12 eggs, ten being normal white and two coloured a medium brown colour by means of brown, black and green crayons. Thermistors were inserted from below into the centres of one white and one similar-sized (1365 g) brown egg, and the temperatures attained were recorded at 10 minute intervals over a 24 h period. Figure 1 shows the result of this experiment. Two other less complete experiments in Tsavo on different days yielded comparable results, namely that the maximum central temperatures reached by the eggs averaged 3·5 °C higher for brown eggs (43·3 °C) than for white eggs (39·8 °C).

A temperature of 42·2 °C has been determined as the lethal upper limit for developing hens' eggs (Lundy 1969). Ostrich eggs and embryos might well be adapted to withstanding somewhat higher temperatures than hens' eggs, but for biochemical reasons not vastly higher. Depending on the weather, on some days eggs got hotter than on others, the maximum central temperature measured in a white egg being 43·7 °C; on that day a brown egg would have been hotter still. In addition, there is a marked temperature gradient between the centre of the egg and inside the top surface where the blastoderm floats (Drent 1975, and pers. obs.). In two further experiments with normal white eggs the inside surface reached 45·0 °C whereas the highest central temperature was 41·1 °C. Similar temperature gradients are almost certainly present in brown eggs too.

(4) ARE THE TEMPERATURE RESULTS BIASSED BY THE ARTIFICIAL COLOURING PROCESS?

Clean ostrich egg shell has a shiny surface texture, and colouring with a crayon

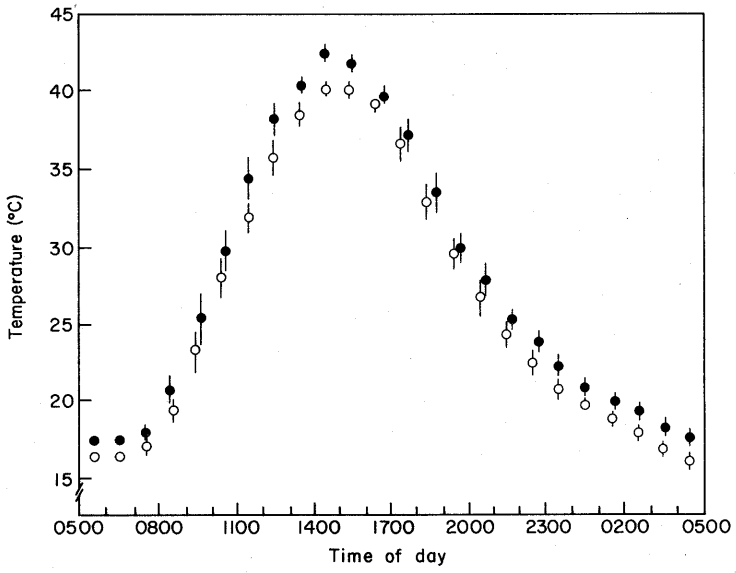

FIGURE 1. Central temperatures of white and brown Ostrich eggs exposed to full sunlight. ○, Normal white egg; ●, brown egg.

obviously reduces the shininess. In addition some crayon may get into the pores of the shell and influence the absorption and conduction of heat. Experiments were conducted to examine these possible biasses.

Five pieces of shell from an Ostrich egg, each about 5 cm in diameter, were treated in the ways described below, and placed on an expanded polystyrene board under full midday sun. The air temperature was 34 °C and there was no detectable wind. After ten minutes for equilibration, the surface temperature of each was measured with a Barnes PRT-10L infra-red field thermometer. The shell pieces were turned around between each of the five series of temperature measurements at three minute intervals.

The treatments of the shell pieces were as follows:

(a) Normal clean shiny creamy-white shell surface.
(b) Shell surface sanded so as not to be shiny.
(c) Shell surface coloured creamy yellow with crayons, leaving it approximately normal coloured but less shiny than the untreated surface.
(d) Shell surface coloured brown with crayon but the crayon then rubbed off, leaving a normal clean shiny creamy-white surface but with a little crayon in the pores.
(e) Shell surface coloured brown with crayons.

Table 1 shows the mean temperatures recorded from each shell piece.

It can be seen that the brown shell became significantly hotter than all the other pieces, but that no other treatment produced a significant difference in temperature. Therefore, it is the brown coloration *per se* which results in the temperature rise. It was not only an outer surface temperature rise, for a series of measurements of the undersides of the shell pieces showed a 6 °C higher temperature of the underside of the brown piece than of the others.

Thus we conclude that the white coloration of Ostrich eggs causes a higher predation rate on them than if they were camouflaged, but it protects the eggs against overheating when left unattended. In very hot conditions, despite a shiny white surface and their very large size, even normal Ostrich eggs can be damaged by overheating, if they are not

TABLE 1

Mean surface temperatures of Ostrich egg shell pieces of different colours

Shell treatment	Temperature °C (s.d.)
Normal shiny white	43·6 ± 1·1
Normal white sanded	43·0 ± 1·9
Creamy crayon	43·0 ± 1·0
Cleaned after colouring brown	43·4 ± 1·7
Brown crayon	52·0 ± 2·3

shaded by the adult birds for part of the day. Nonetheless the colour gives the bird much greater flexibility as to when and for how long it can leave its nest. Shading the eggs would require the bird to be fixed at the nest, while guarding it against Egyptian Vultures can be achieved while the Ostrich is feeding nearby.

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