The count at 200 m was 3 000 bacteria cm^{-3}. It was impossible to read the plates giving total coliform counts as these were completely overgrown, except for the cultures made at very high dilutions of the sample taken 200 m from the mouth. The count obtained, 5×10^4 organisms $(100\ cm^3)^{-1}$ is extremely high. The presumptive *E. coli* counts confirmed the very high coliform concentrations in the river water, being 3×10^5, 400 and 200 organisms $(100\ cm^3)^{-1}$ at the mouth, 100 and 200 m north, respectively.

The results indicate that, although the river was carrying an extremely high bacterial load, the presumptive *E. coli* organisms died off rapidly in the saline environment. This would support the view that coliforms have a low salt tolerance. Nevertheless, a count of 200 presumptive *E. coli* per 100 cm^3 indicated substantial sewage pollution with its attendant dangers.

Conclusions

The main conclusions which can be drawn from these limited surveys are:

1) The Salt River carries high nutrient and organic loads which were observed up to 2 km north of the river mouth.

2) The trace metal concentrations in the surface sediments around the discharge were not elevated above normal levels. This does not, however, rule out the possibility of metal pollution higher upstream, and polluted sediments may enter the sea during floods.

3) A disturbed meiofaunal population distribution existed up to 4 km from the mouth, with the absence of harpacticoid copepods for the first 2 km indicative of low oxygen caused by organic pollution, and extremely high numbers of nematodes and harpacticoids in the next 2 km being the most notable features.

4) Very high faecal bacterial counts were obtained during the single bacteriological survey. Numbers fell off rapidly in the saline environment but were still high 200 m north of the mouth.

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Ostrich Eggs in Artificial Incubators: Could their Hatching Success be Improved?

Eggs of ostriches, *Struthio camelus*, are incubated artificially for commercial purposes using techniques adapted from those used for poultry. Although no rigorous comparisons have been made, most farmers concur that eggs in incubators have a lower hatching success and produce a greater proportion of weak chicks than those incubated under birds.[1] Swart[2] found that in eggs incubated artificially, after a storage period of less than 15 days, only 55% of those 71 eggs which were found to have developing embryos actually hatched chicks. Some incubator owners routinely assist the chicks to hatch; chicks which have spent a long time struggling to hatch are often weak with their 'hatching' neck muscles (*M. complexus*) swollen. As part of a study of natural incubation in ostriches,[3] we compared temperatures and humidities in incubators with those of nests. We propose a hypothesis that present artificial incubation techniques might not be appropriate for optimal hatching success of ostrich eggs and we suggest areas for future research.

We measured temperatures, using a mercury thermometer, and humidities, using a Shaw minihygrometer or a Dräger gas-analyser, of the air within 12 incubators operated by five people at Oudtshoorn, southern Cape Province. The incubators were all forced-draught machines, and contained eggs from free-ranging domestic ostriches: the eggs were turned by hand at least once a day. The results obtained by the two methods of measuring humidity were not significantly different, and the temperatures and humidities in the various machines were similar. Air temperature, humidity and water vapour pressure were all significantly higher in incubators than in nests (Table 1, $P < 0.01$, t-test). These different conditions could be a cause of low hatching success.

During incubation, birds' eggs lose weight, which is almost entirely due to unavoidable loss of water vapour through the pores in the shell.[6] This loss results in an air space within the egg, which at hatching is 10 – 20% of the egg volume. Prior to hatching, the chick breaks the membranes at the air space and breathes air. Rahn *et al.*[7] have suggested that the air space should be large enough to accommodate the initial filling of the lung and air sac system and also to provide a reasonably large volume for the rebreathing activities which follow. During incubation the membranes undergo a drying process which increases their permeability for oxygen.[8,9]

Water loss from eggs is independent of the air flow across their surfaces,[10] but is dependent on the water vapour conductance, G_{H_2O}, and on the water vapour pressure difference between the centre of the egg and the microhabitat surrounding the egg,

Table 1. Means (± s.d.) and ranges of temperatures and humidities in and around ostrich eggs during natural and artificial incubation.

Incubation conditions	Internal egg temperature (°C)	Nest air temperature (°C)	Relative humidity (%)	Water vapour pressure (Torr)	No. records	Water loss (g d^{-1})	Source
Natural nest	35.9 ± 0.6	31.8 ± 0.2	—	—	288	—	Ref. 4
Natural nest	32.9 ± 0.7 (30.3 – 33.8)	33.6 ± 0.7 (31.9 – 34.6)	41 ± 5 (32 – 52)	16.0 ± 2,1 (11.7 – 20.8)	144	3.8 ± 0.8[a] (2.4 – 5.1)	Ref. 3
Natural nest	—	32.2 ± 0.8 (31.7 – 33.8)	43 ± 3 (39 – 49)	15.6 ± 1.1 (14.1 – 17.9)	120	—	Ref. 3
Artificial incubators	~ 36.3[b]	36.3 ± 0.2 (36.0 – 36.6)	63 ± 10 (57 – 68)	28.5 ± 4.4 (21.4 – 35.4)	12	— 2.8 ± 0.4[c] (2.1 – 3.5)	This study

[a] n = 58 eggs in seven nests. [b] Egg temperatures were probably near equilibrium with incubator air temperature (see text) [c] n = 19 eggs (from A. P. Koen[5] and pers. comm.).

ΔP_{H_2O}(Torr), according to the following formula[6]:

Water loss (mg d^{-1}) = $G_{H_2O} \cdot \Delta P_{H_2O}$.

G_{H_2O} is relatively constant within a species[6] and has been calculated to be 135 – 187 mg d^{-1} $Torr^{-1}$ for ostrich eggs.[3,11] This is close to the value predicted from the weight of the egg and the duration of the incubation period.[11] The mean daily weight loss of naturally incubated ostrich eggs (Table 1) is also very close to the value predicted from the size of the eggs, relative to those of other species.[3,12] Ostriches do not therefore have eggshells which are less permeable than those of other birds, despite their other adaptations to hot, arid conditions.[4,13–16] The necessity for oxygen and carbon dioxide exchange is the constraint which precludes the reduction of porosity of eggs.[6]

Water loss from an ostrich egg is thus affected by ΔP_{H_2O}, which is dependent on the egg temperature and the temperature and humidity of the microenvironment. Although the air temperature in incubators was significantly higher than in nests, the internal egg temperature could be similar in both situations since eggs in incubators gain heat only by convection from the warm air, whereas those in nests gain heat by convection and by conduction from the warm skin of the brooding bird. The higher water vapour pressure in incubators, a product of temperature and humidity, resulted in reduced water loss from the eggs relative to those in nests. The daily weight loss of eggs in incubators was significantly less than that of eggs in nests (Table 1, $P < 0.01$, t-test). The eggs of wild ostriches have a 0 – 21 day pre-incubation period followed by 42 days of incubation, and the total water loss at hatching amounts to 11 – 15% of the total (approximately 1500 g) egg mass.[3] Farmers generally place eggs in incubators within two days of laying and such eggs would lose only 8% (about 120 g) of their mass at hatching.

We suggest that high humidities in incubators may be a factor contributing to low hatching success. The air space available to the pre-hatching chick would be significantly less than in natural nests. High humidity prior to pipping depresses the rate of diffusion of O_2 through the shell and membranes of chicken eggs[6,17] and this could be expected in ostrich eggs too. Ostrich egg incubators are usually fitted with sensitive thermostats but humidity is rarely measured nor accurately regulated.

We urge investigation into the effects of humidity on the hatchability of ostrich eggs and into other potential causes of failure such as handling procedures and the lack of cooling periods during incubation. Tens of thousands of ostrich eggs are incubated artificially each year. The production of healthy chicks, worth about R25 each, appears to be a bottleneck in the productivity of the multi-million rand industry. Our studies of incubation physiology in ostriches were prompted by an academic interest in the largest living bird, but a detailed study of ostrich incubation, both natural and artificial, could prove to be beneficial to the industry.

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