

Weight loss during artificial incubation vs. Eggshell thinning of California Pergrine Falcon *Falco peregrinus* Eggs brought from the Wild

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ABSTRACT

Our data on water loss from Peregrine Falcon eggs brought from the wild for artificial incubation at facilities of the Santa Cruz Predatory Bird Research Group appear to be inconsistent with several published reports that water loss is depressed in thin-shelled eggs, whether the thinning has been induced experimentally by DDE or is associated with DDE in the eggs of wild birds. Water loss increased with decreasing thickness in our samples, but variance in the rate of water loss was much higher in the thinner-shelled eggs. Although we have not resolved the discrepancies we suggest that patterns of water loss may be different in eggs with living, developing embryos and eggs with dead embryos or eggs preserved in museums. A contaminant effect on the metabolism of embryos and the possible presence of structural abnormalities in eggs with higher rates of water loss are other factors that might explain, in part, these observations.

INTRODUCTION

Among the unresolved problems mentioned at the Third World Conference (Risebrough 1989) was an apparent discrepancy between observations at the Predatory Bird Research Group of the University of California, Santa Cruz (SCPBRG), and the data of several published papers. Peakall *et al.* (1973) reported that dietary DDE thinned the shells, decreased breaking strength and unexpectedly, decreased water loss in three species of birds, white Peking ducks, *Anas platyrhynchos*, American Kestrels, *Falco sparverius*, and Ringed Turtle-Doves, *Streptopelia risoria*. This was attributed to a reduction in the number of pores through the eggshell that are the pathways of exchange of water vapor and other gases. Eggs of Common Terns, *Sterna hirundo*, that failed to hatch after natural incubation in an Alberta colony also showed a lower rate of water loss that was correlated with abnormalities of shell structure, including a reduction in the number of pores and of mammillae (Fox 1976). Cooke (1979) measured water loss from museum eggs of Peregrine

Falcons, *Falco peregrinus*, and found that the functional pore area was decreased in the modern, thinner-shelled eggs. In contrast, we measured higher rates of water loss in thinner-shelled Peregrine eggs. We present our data in an initial attempt to resolve this apparent discrepancy.

MATERIAL AND METHODS

Collection and incubation

The eggs in this study ($N = 136$) were collected from wild eyries between 1985 and 1990 for artificial incubation by the SCPBRG as part of a long-term Peregrine Falcon recovery program in California. In most cases, wild eggs were collected from nest sites deemed unlikely to fledge young on their own, based upon a prior history of failure, in order to prevent breakage and egg loss. Eggs were transported from the field in portable incubators held at a temperature of 37°C.

The incubation technique used at the SCPBRG follows closely that of Burnham (1983). After candling to determine approximate age of the embryo, the eggs are weighed and measured. Because none of the eggs in this study were collected fresh, the theoretical fresh weight was calculated from the egg dimensions (Burnham 1983). We assumed a natural total weight loss of 15% during incubation until pipping (Rahn & Ar 1974, Rahn *et al.* 1979, Burnham 1983). This loss in weight is attributable to a loss of water vapor through the pores of the eggshell as the embryo develops (Rahn *et al.* 1979). The eggs were then placed in an incubator at 35% humidity, and the weight loss was monitored for 48 hours. Eggs weighing more than expected, - on the basis of their estimated weights when fresh and of their predicted water loss during early incubation, - and that showed a low rate of loss during the 48-hour incubation at 35% humidity, were transferred to a „dry“ incubator (roughly 20% humidity, with no water added to the incubator; Figure 1A). Eggs weighing less than expected and that had high rates of water loss were transferred to a higher-humidity incubator (60 or 75%) in an attempt to minimize the excessive water loss (Figure 1B). Weight loss was then monitored daily and the egg was treated accordingly. The contents of eggs that do not hatch were placed in solvent-washed jars for future chemical analysis; eggshells were sent to the Western Foundation of Vertebrate Zoology (WVZ) for thickness measurements and archiving.

In an attempt to standardize our samples as much as possible, only eggs that were alive during the initial 48 hour period, and only those that were showing development (*i.e.*, had at least five days of incubation prior to arrival) were included in this analysis. Not included were eggs with obvious structural damage such as dents or cracks. Nor were eggs included that contained visible pock marks that are routinely covered with glue to retard excessive rates of water loss.

Eggshell thickness measurements

The eggshell fragments were measured at the WVZ using a model 35 PS Federal bench comparator thickness gauge. If no membranes were attached to the shell a compensation factor of 0.063 mm was added, the mean thickness of the eggshell membranes of 20 pre-1947 Peregrine eggs. Eggshell thickness was then compared to the estimated thickness of the pre-1947 Peregrine eggs from California, previously determined to be 0.369 mm, to calculate the percent thinning.

Statistics

Statistical operations were performed with the software “Minitab” (Ryan *et al.* 1985).

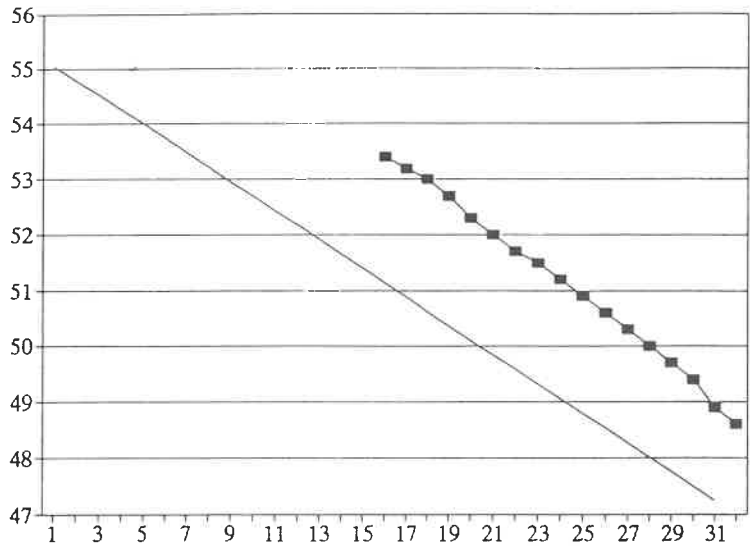
RESULTS AND DISCUSSION

Water loss in our sample ($N = 136$) increased with thinning: Spearman's rank correlation coefficient = -0.401, ($P < 0.01$). The relationship, however, does not appear to be linear; eggs with shell thickness less than 0.32 mm, about 13% thin, showed a much higher variance of water loss during the first two days of incubation at 35% relative humidity (Figure 2).

One consistent difference between our sample and those described above in the cited papers

Figure 1. Egg weight loss during artificial incubation at the Santa Cruz Predatory Bird Research Group facilities. The solid lines show the predicted weight loss (15%) during incubation, beginning at the calculated initial fresh weight. Weight loss during the first 48 hours of incubation at 35% humidity determines the humidity of the next stage of incubation. 1A: Site SC-2, egg 87-15. Transferred to a “dry” incubator at approximately 20 % humidity. 6.5% thin; 1B: Site MC-6, egg 90-127. Transferred to 75% humidity. 18.4% thin. Both eggs hatched.

A



B

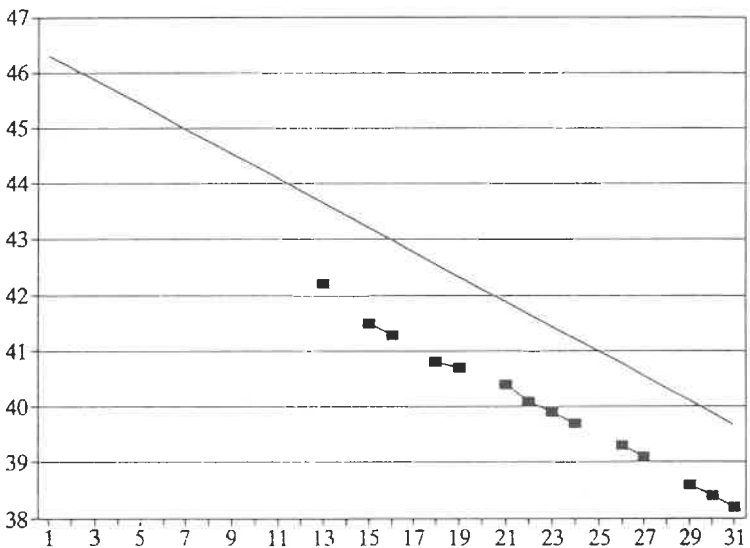
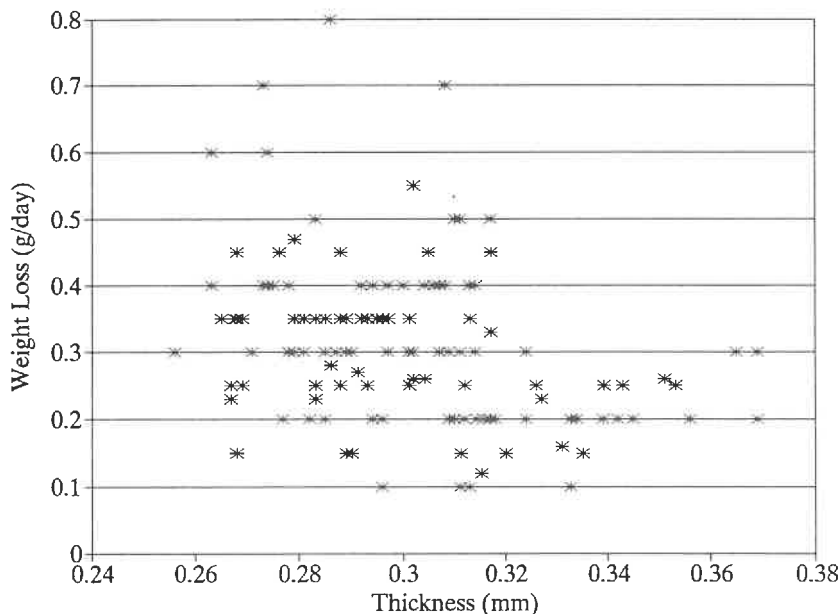


Figure 2. Weight loss (grams per day) over the first 48 hours of artificial incubation at 35% humidity versus eggshell thickness of Peregrine Falcon eggs brought from the wild in 1985-1990. N = 136. The normal range of weight loss of Peregrine eggs is 0.20-0.28 g per day, depending on egg size.



is that our data were derived from living eggs whereas the other data derived principally from eggs without living, developing embryos. Peakall *et al.* (1973) determined water loss by placing the eggs in a desiccator and weighing them daily. Although some eggs may initially have been fertile, it is unlikely that there would have been any development before death of the embryos. In Fox's study (1976), water loss was determined by weighing the wild eggs during incubation. Of the 26 eggs in the study that failed to hatch, 61% were addled (no discernable embryonic development), 17% died during the first week, 4% during the second, and 18% during the third week, including 11% that died during pipping; water loss from these eggs was less than in the eggs that hatched (Fox 1976). Cooke (1979) determined water loss in the museum eggs of Peregrines by filling the eggshells with distilled water, sealing any holes, placing them in a desiccator, and weighing them daily. Water loss from the modern eggs was decreased at temperatures of 20°C and 40°C, but the difference in water content was statistically significant only at 20°C. Both Fox (1976) and Peakall *et al.* (1973) had concluded that the number of pores was reduced in their thin-shelled eggs, but Cooke (1979) considered this unlikely. He found no reduction in the numbers of pores in the thinner-shelled eggs, measuring them by dyeing the inside of the shell, and counting the number of red spots that appeared on the outer shell. He did find, however, that the reduction in water vapor conductance was associated with an increase in the ratio of mammillae height to mammillary layer, and suggested that structural disruptions in the inner layer of the eggshell were responsible for the lower rate of water loss. No organochlorine levels were reported in this manuscript.

Lindén *et al.* (1984) measured weight loss during the natural incubation of Peregrine eggs in Finland; three of the four clutches of thinner-shelled eggs disappeared before the second weighing and a slight negative correlation between water loss and thickness was not statistically significant. Unpublished observations were quoted, however, of high rates of water loss during artificial incubation of Peregrine eggs unless humidity was increased.

During the metabolic burning of fat, water is generated, increasing the difference in water vapor pressures between the egg interior and the external environment. Although the passage of gases through the membrane and shell is passive, the net flux is determined by the difference in vapor

pressure (Rahn *et al.* 1979). This factor could therefore account for the higher rates of weight loss in the viable Common Tern eggs measured by Fox (1976), but would not explain the observed differences among the eggs of our study, nor the observations of Peakall *et al.* (1973) and of Cooke (1979).

Organochlorines may increase the rate of basic metabolic processes (Matsumura 1975), and produce an excitatory syndrome in the central nervous system (Cohn *et al.* 1981). Such an effect could account for some of the differences observed in our sample, but its significance awaits experimental verification; an increase in rate-of-loss might be expected as the embryo matures.

Particularly to be explained is why some of the thinnest-shelled eggs, 0.26-0.28 mm or 26-30% thin, have normal rates of water loss, whereas other eggs showing 13-30% thinning have rates of water loss 3-4 times higher under the standard conditions of 35% humidity (Figure 2).

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