Influence of Solute Concentration in Albumen on
Water Loss from Avian Eggs

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Shells of avian eggs are penetrated by numerous pores (Tyler 1969) that provide for a diffusive exchange of gases between embryos and the surrounding atmosphere (Wangensteen 1972, Wangensteen and Rahn 1970/71). The number and dimensions of pores through an eggshell are established when the shell forms in the maternal oviduct (Tullett 1975), and are believed to represent an evolutionary compromise between the need to admit oxygen to sustain embryonic metabolism and the need to restrict water loss from the albumen (Packard et al. 1977, Wangensteen and Rahn 1970/71).

In several recent studies, conductance of eggs to water vapor (mg water loss$\cdot$day$^{-1}\cdot$torr^{-1}) was used to assess interspecific (Ar et al. 1974, Rahn et al. 1976) and intraspecific (Packard et al. 1977, Wangensteen et al. 1974) variation in porosity of eggshells. Conductance was determined by measuring daily water loss from eggs maintained under controlled conditions of ambient temperature and vapor pressure, and by dividing values for daily water loss by the presumed gradient in vapor pressure across the eggshells. A basic assumption in these determinations was that vapor pressure at the inner surface of eggshells is approximately equal to the saturation vapor pressure of pure water at the experimental temperature. However, it is known that the osmotic concentration of liquids in contact with the inner egg membrane increases during incubation (Tullett and Board 1976), and so the vapor pressure at the inside of the eggshell must be lower in eggs at advanced stages of incubation than in freshly-laid eggs (Daniels and Alberty 1975). Thus, estimates of porosity of eggshells deduced from conductances of eggs to water vapor may be too low if eggs containing advanced embryos were used in these studies. Although this possible source of error probably is negligible in interspecific comparisons, it may be of considerable importance in studies of adaptive variation in porosity of eggshells within a single species, where small differences may distinguish various populations (Packard et al. 1977).

In the present study, we determined water loss from infertile hens' eggs under controlled conditions of ambient temperature and vapor pressure. Although rates of water loss were reduced in eggs containing liquid with relatively high osmotic activity, we found that the changes in vapor pressure inside eggshells attending increases in solute concentration were too small to elicit changes in rates of water loss that can be detected by the usual experimental procedures.

Thirty-four infertile and unwashed eggs of white leghorn chickens were obtained from a commercial hatchery within 24 h of laying. The eggs were randomly assigned to three treatment groups, placed in desiccators over flakes of KOH, and allowed to equilibrate for 24 h in a constant temperature cabinet at 25°C. The desiccators were vented to the atmosphere through drying tubes filled with "Drierite" ($CaSO_4$). All eggs were weighed on a Mettler analytical balance at approximately 24-h intervals for 5 days (i.e. for a total of six weighings), and the rate of water loss from each egg subsequently was calculated by a linear regression procedure.

After weighing the eggs on the fifth day, two holes were drilled through the shell of each egg at the equator. In one group of eggs (controls), the holes were promptly sealed with epoxy cement. In the other two groups, the contents of the eggs were blown out and replaced with either distilled water or a solution of sucrose (0.8 M), and the holes were then sealed with the epoxy. All eggs were replaced in the desiccators, and weight losses were monitored for another period of 5 days. After the final weighings, rates of water loss again were determined by linear regression, and volumes of the eggs were measured by displacement of water. Barometric pressure during the 12 days of this study averaged 640·7 torr (range 635·7–644·4 torr).

The data on rates of water loss from eggs before and after experimental manipulation are summarized in Table 1, together with results of paired *t*-tests used to assess changes in rates of water loss elicited by experimentation. Eggs in the control group exhibited no detectable change in rates of water loss, indicating that drilling holes in eggshells had no appreciable effect and that water loss during the first interval of study did not affect water loss during the second interval of study. Moreover, eggs that were filled with distilled water had rates of water loss indistinguishable from those of the same eggs prior to experimental manipulation, indicating that vapor pressures inside freshly-laid eggs approximate the vapor pressure of pure water. Finally, eggs containing the 0.8 M sucrose solution exhibited a statistically significant decline (3%) in rates of water loss, which presumably stems from a reduction in the vapor pressure inside eggshells

TABLE 1. Daily water loss ($\overline{X} \pm$ SD) of chicken eggs maintained in a dry atmosphere at a temperature of 25°C. Units are mg H_2O/day

Experimental group	Pre-treatment	Post-treatment	Difference	Paired t
Control	270.8 ± 33.8	268.4 ± 29.8	-2.4 ± 19.9	$t_{10} = 0.39$ $P > 0.5$
Distilled water	255.1 ± 39.1	260.1 ± 46.9	5.0 ± 20.9	$t_{11} = 0.83$ $P > 0.4$
Sucrose solution (0.8 M)'	244.8 ± 32.3	237.4 ± 36.4	-7.4 ± 7.0	$t_{10} = 3.55$ $P < 0.01$

and the consequent decline in vapor pressure gradient across eggshells that drives outward movements of water molecules.

In freshly-laid eggs, the thin (or watery) layer of albumen is in contact with the inner egg membrane (Tullett and Board 1976), and the osmotic activity of this albumen fraction initially determines the vapor pressure at the inner aspect of the eggshell. Although data on the osmotic activity of this solution are not available, osmotic activity probably is low, for the vapor pressure of the solution approaches that of pure water (Table 1). However, the thin albumen disappears by day 5 of incubation and the thick albumen comes into direct contact with the inner egg membrane (Tullett and Board 1976). The osmotic concentration of the thick albumen reaches 500 mOsM by day 6 of incubation (Tullett and Board 1976), and presumably continues to increase with advancing age owing to the further transfer of water from the albumen to the yolk. Indeed, our choice of 0.8 M sucrose for use in the present experiment was based upon the assumption that the osmotic activity of such a solution (ca. 800 mOsM) would approach the upper limit of osmotic activity attained by solutions in contact with the inner egg membrane during later stages of embryogenesis; data presented in Table 1 indicate that the reduction in vapor pressure attending such an increase in solute concentration (from ca. 23.7 torr in freshly laid eggs to 23.4 torr in 0.8 M sucrose) would lead to small decreases in rates of water loss under experimental conditions.

We next compared rates of water loss from eggs following experimental manipulation by one-way analysis of covariance (using volume as the covariate) to determine whether the reduction in rates of water loss manifested by eggs filled with the sucrose solution led to a detectable decline in the mean value relative to either of the other two groups of eggs. Because eggs varied little in size, covariance revealed that individual variation in volume had no appreciable effect on rates of water loss, and so final comparisons among groups were simply by one-way analysis of variance.

Analysis of variance of rates of water loss from eggs after experimental manipulation indicates that statistically significant differences cannot be detected among the various groups ($F_{2,31} = 1.91; P = 0.165$). Thus, the decline in rates of water loss in eggs filled with the sucrose solution was so small that it cannot be detected using statistical procedures of the type likely to be used to assess geographic variation in conductance of eggs to water vapor (see Packard et al. 1977).

We conclude from this experiment that the vapor pressure inside avian eggshells closely approximates that of pure water, regardless of the degree of development of the contained embryo, and that the error associated with this approximation generally is too small to be detected.

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Bald Eagles Nesting in Baja California

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Published records of Bald Eagles (*Haliaeetus leucocephalus*) nesting in Baja California during the last 50 years are nonexistent to our knowledge, and few records exist prior to that time. Friedmann et al. (1950:61, Pac. Coast Avifauna 29) describe the distribution of Bald Eagles in Baja California as "a scattering of pairs on both the Pacific and Gulf Sides." Nesting Bald Eagles were first reported by Bryant (1889, Proc. Calif. Acad. Sci. 2: 237–320), who found a pair on Isla Santa Margarita (24°25'N, 111°50'W; hereafter abbreviated as 2425-11150) and saw an adult on the "estero" north from Magdalena Bay (the region where one pair was seen in 1977). Other records were reviewed by Grinnell (1928, Univ. Calif. Publ. Zool. 32).

In January 1971, C.E.K. observed one flying immature Bald Eagle near Las Tinajas (2540-11204) and two adult and one flying immature eagle in the vicinity of Medano Amarillo (2445-11159) (Magdalena Bay region on the west coast of Baja California), and suspected that the species was nesting nearby. Three adult Bald Eagles were also seen during two other Magdalena Bay surveys in January and July of 1972, one adult near Isla Creciente (2422–11135) and the other two near Medano Amarillo. M. N. Kirven (pers. comm.) observed a pair of adults on a nest in a large cactus on Isla Santa Margarita in December of 1962, but the nest was not checked for contents. C.J.H. and D.W.A. definitely confirmed nesting in Baja California in March of 1977: a pair with two large young in a nest near San Jorge (2534-11206), north of Santo Domingo on 26 March, and a pair with one large young in a nest on Isla Creciente (2422-11139) near Almejas Bay on 27 March. The two pairs were nesting in mangroves, and were approximately 150 km apart. Two of the three young flew from their nests (one from each nest) when approached. Additionally, on 12 June 1977, an adult and a flying young-of-the-year were observed on Isla Santa Margarita; and on 10 June, a subadult Bald Eagle was observed near Puerto Algudin (2437-11149) (D.W.A.).

The eaglets found in 1977 were fledged or nearly ready to fledge, which indicates an early breeding season in the Magdalena Bay region. Assuming the eaglets we observed were fledging, and that the incubation period is 35 days and the period from hatching to fledging around 75 days (Herrick 1924, Auk 41: 213–231), the eggs were probably laid in late November or early December. These dates are similar to those from southern Florida (approximately the same latitude) (Brown and Amadon 1968, Eagles, hawks, and falcons of the world, pt. 1, McGraw-Hill).

All of coastal Baja California, plus the mainland coast of Mexico as far south as Mazatlan, and the adjacent islands were surveyed for nesting Ospreys (*Pandion haliaetus*) between 23 March and 1 April 1977 by C.J.H. and D.W.A.; 84 h of flying time were logged. It is doubtful that many additional nesting Bald Eagles are present in the coastal region surveyed.—*Received 6 July 1977, accepted 22 September 1977.*