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CONDUCTANCE, PORE GEOMETRY, AND WATER LOSS OF EGGS OF CASSIN'S AUKLET

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The ratios of egg mass to body mass in the Alcidae are relatively large (Sealy 1975) when compared with those of most other groups of birds (Rahn et al. 1975). Cassin's Auklet (*Ptychoramphus aleuticus*) weighs about 165 g (Manuwal 1974b, Sealy 1975), and its single egg of about 29 g is twice that predicted from the egg mass-body mass relationship of birds in general (Rahn et al. 1975). The auklets nest in burrows and rock crevices, and during incubation the single egg is held between the lateral incubation patch and the wing (Manuwal 1974a, b). The incubation time of 38 days is considerably longer than the 25 days predicted for eggs of this size. It is of particular interest as it has been suggested that the functional egg characteristics such as conductance, water loss (Rahn and Ar 1974), and metabolism (Rahn et al. 1974) increase not only in proportion to their mass but are inversely related to incubation time. To see whether these generalizations apply also to Cassin's Auklet eggs, we measured the conductance and incubation water loss of these eggs and described the physical dimensions of the egg and the shell as well as the pore geometry responsible for the egg conductance.

Eggs were collected in April 1977 and May 1978 on the Farallon Islands, west of San Francisco, California. The water vapor conductance was measured by the method of Ar et al. (1974). Egg volumes were measured by water displacement, and surface area and shell thickness by the method of Paganelli et al. (1974). Initial egg mass was obtained by weighing eggs after the air cell had been displaced with water, using a hypodermic syringe. In order to learn the number of pores the shells were boiled in 2.5% NaOH to remove protein fibers, then briefly etched in concentrated nitric acid. After drying, an aqueous solution of methylene blue was applied to the inner surface of the shell to render the pores more visible (Tyler 1953). Each egg was examined under a compound microscope and twenty fields (0.25 cm²) were counted and averaged.

TABLE 2. Conductance and pore geometry.

	G	L	A_p	N
	mg / day·torr	mm	mm²	
$\bar{x}$	4.08	0.23	0.419	3,295
S.E.	0.16	0.01	0.034	152
n	21	8	8	8

G = conductance, L = pore length, A_p = total pore area, N = number of pores per egg, and r = radius of pore, where $A_p = .447\ G \cdot L$ (Rahn et al. 1974) and $r = [A_p/N\pi]^{0.5} = 6.4\ \mu m$.

TABLE 1. Physical dimensions of Cassin's Auklet eggs and shells.

		Egg						Shell			
		Mass g	Vol. cm³	Density g·cm⁻³	Area cm²	Length cm	Width cm	Mass g	Thickness mm	Vol. cm³	Density g·cm⁻³
	$\bar{x}$	29.74	27.87	1.067	45.7	4.69	3.39	1.88	0.23	1.05	1.79
	S.E.	0.6	0.6	.001	0.6	.03	.03	.08	0.01	—	—
	n	14	14	14	14	14	14	8	8	8	8
Schönwetter (1963)	n = 80	28.0				4.67	3.37	1.88	0.22		
Manuwal (1974a)	n = 75	27.4				4.62	3.35				

TABLE 3. Observed values and those predicted as a function of egg mass (Prediction I) and as a function of egg mass and incubation time (Prediction II). See text.

	Conductance $mg \cdot day^{-1} \cdot torr^{-1}$	Water loss $mg \cdot day^{-1}$	Number of pores
Observed	4.08	101	3,295
Prediction I	6.08	186	6,020
Prediction II	4.01	118	—

The total effective pore area was calculated from the conductance and shell thickness values as previously described (Rahn et al. 1976); by dividing this value by the number of pores in each egg, we calculated the mean radius of the average pore. To establish the rate of incubation water loss three eggs were weighed on two occasions, 12, 11, and 9 days apart.

Table 1 gives the physical characteristics of the eggs and shells and compares some of these with values reported by Schönwetter (1963) and Manuwal (1974a). Table 2 provides the data for conductance and pore geometry. The water loss for the three eggs was 105, 107, and 90 $mg \cdot day^{-1}$ and averaged 101 $mg \cdot day^{-1}$.

As shown in Table 3, the values predicted as a function of egg mass (Prediction I) for the conductance (Ar and Rahn 1978), the daily water loss (Drent 1970), and pore number per egg (Tullett and Board 1977) are all significantly higher than the measured values. The values predicted as a function of the mass/incubation time ratio (Prediction II; Ar and Rahn 1978) agree well with those observed, supporting the general concept that incubation time is an important determinant of the functional characteristics of avian eggs.

Since the conductance, according to Fick's law of diffusion, is proportional to total pore area (number of pores times the individual pore area) and inversely proportional to the pore length or shell thickness, it is not surprising that the number of pores in Cassin's Auklet eggs is less than their predicted number since their shell thickness is the same as that predicted for eggs of their size (Ar et al. 1974). The product of daily water loss and incubation time predicts the total water loss during incubation, which for Cassin's Auklet is 13% of the initial egg mass and compares well with the average loss of 16% (Drent 1975) and 15% (Ar and Rahn, unpubl. data) established for more than 65 species.

In summary, structural and functional aspects of eggs of Cassin's Auklet are reduced commensurate with their 50% longer incubation period when compared with eggs of the same mass but more typical incubation times.

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