TOTAL BODY WATER AND ITS TURNOVER IN NORMAL AND SALT-LOADED NESTLING LEACH'S STORM-PETRELS, OCEANODROMA LEUCORHOA

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Ever since the discovery of the function of the avian nasal salt gland by Schmidt-Nielsen et al. (Amer. J. Physiol 193:101-107, 1958) most research on osmoregulation in birds has been concerned with the structure, function and physiological control of the gland. The costs (metabolic, water turnover, etc.) associated with osmoregulation, especially in growing chicks, have not been addressed. In the case of a small pelagic seabird, the problem of high salt (sodium) intake is exacerbated by the need to satisfy high mass-specific energy requirements. This study provides an account of total body water content and water fluxes in growing chicks of Leach's storm-petrel from Little Duck Island, ME.

Total body water and water turnover rates were measured using tritiated water (Nagy and Costa, Amer. J. Physiol 238:R454-R465, 1980). Turnover rates in the lab were measured using both a captive hand-reared colony and wild birds brought into the lab for two-day experiments. Nasal gland secretions were collected from restrained birds by placing their bills into specially designed funnels which emptied into microcentrifuge tubes. Regurgitated meals were collected from adults as they flew into the colony at night to feed their chicks.

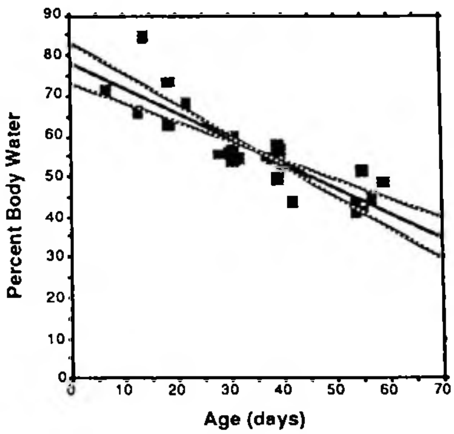

Figure 1. Body water content as a function of age in Leach's storm petrel chicks. Total body water was calculated by comparing equilibrated (1-3 hours post injection) blood samples with standard dilutions of injected tritiated avian ringers. The equation Percent body water = -0.62 (SE = 0.073) X Age + 78.0 % (R^2 = 0.752) decribes the line drawn. The dotted lines represent the 95% confidence limits for the fitted equation.

Total body water decreases with increasing age of the chick (Fig. 1). Water turnover rates in unfed chicks are extremely low and are similar in both field and lab environments (Table 1). These values are lower than the rate (480 ml $kg^{-1}day^{-1}$) measured for foraging Leach's storm-petrel adults but comparable to values (67 ml $kg^{-1}day^{-1}$) for incubating adults (Ricklefs et al. Physiol. Zool. 59: 649-660, 1986). Chicks fed seawater have higher rates of water turnover than unfed or fed chicks.

Table 1
Tritiated water space and flux in Leach's storm petrel chicks under different feeding regimes. Mean values ± one standard deviation are presented.

Treatment (n = 6)	Mass (g)	Tritiated Water Space (ml kg^{-1})	Water Flux (ml $kg^{-1}day^{-1}$)
Laboratory (Unfed)	44.0 ± 4.5	566 ± 32	60 ± 12.2
Laboratory (Fed)	44.0 ± 4.5	566 ± 32	136 ± 6.0
Field (Unfed)	60.3 ± 16.2	582 ± 138	97 ± 39.1
Field (Fed)	69.5 ± 7.1	552 ± 21.0	230 ± 176
Salt Challenged	56.5 ± 14.2	517 ± 134	396 ± 108

Secretion from the nasal glands could only be induced by a hypertonic stimulus. Handling did not produce spontaneous secretion. Nasal secretion began 14 ± 8.3 minutes following saltwater feeding and continued for up to 8 hr. Maximal secretion was reached by 30 minutes followed by a gradual decrease for the next 3-4 hours (Figure 2). The secretion was a highly concentrated fluid (1100-1600 mOsmol/kg) containing primarily Na, K and Cl (Figure 2). The ion composition remained constant throughout the secretion. The water in the secretion was in equilibrium with total body water as assessed by identical specific activity of injected tritiated water. Only 44.3 ± 7.33 % (n =4) of the ingested salt was secreted by the nasal gland. The high osmolarity values are in agreement with those reported by Schmidt-Nielsen for Leach's storm petrel adults (1961).

Table 2
Plasma composition of samples before and after oral challenge. Mean values ± one standard deviation are presented.

Treatment	N	Concentration			
		Osmotic (mOsmol/l)	Na (mEq/l)	K (mEq/l)	Cl (mEq/l)
Control	6	306 ± 2.9	154 ± 1.9	1.05 ± 0.13	117 ± 3.6
Isotonic	6	312 ± 5.2	153 ± 4.6	1.57 ± 0.56	117 ± 3.8
100% Seawater	5	333 ± 2.6	160 ± 2.4	2.94 ± 0.20	124 ± 1.9

Dosing with seawater (948 ± 8.7 (n =12) mOsmol/kg) resulted in statistically significant increases in plasma osmolarity, sodium, chloride and especially potassium (Table 2).

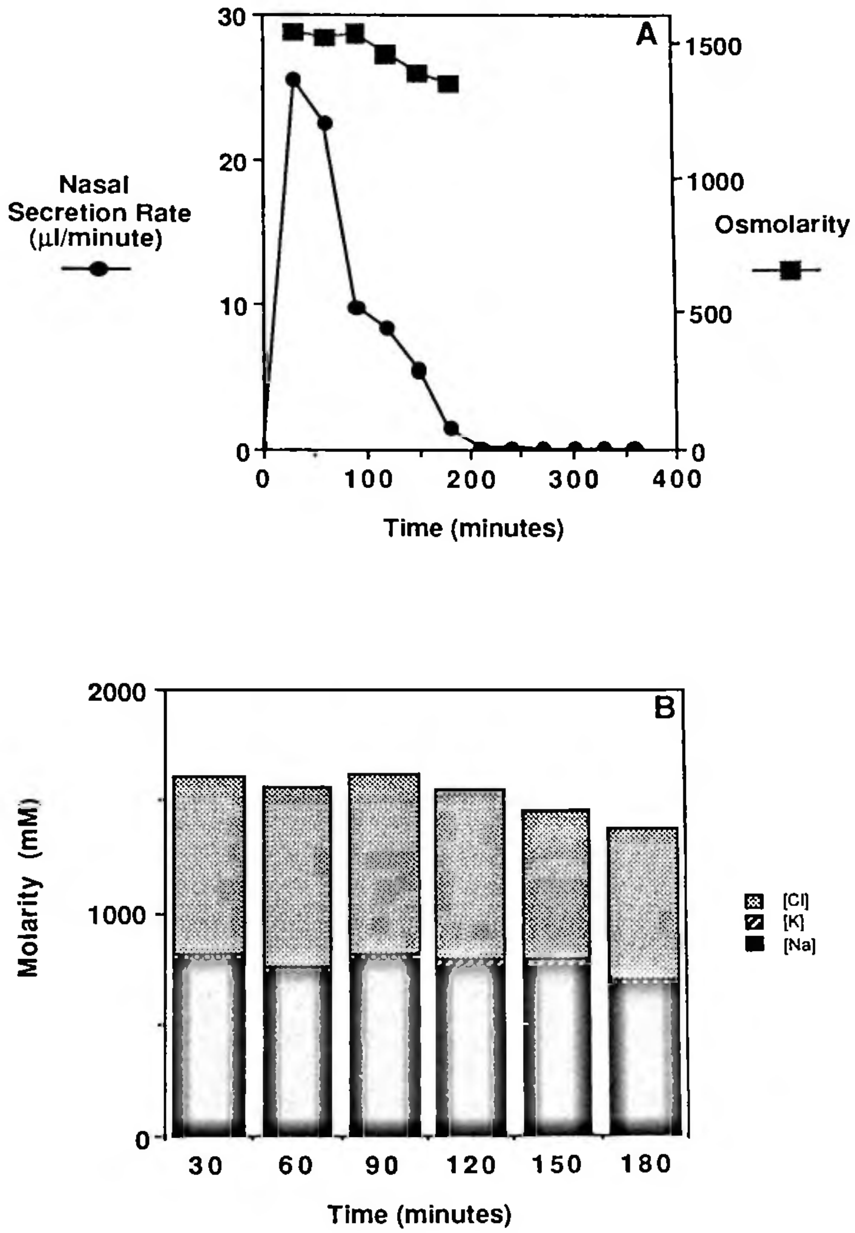

Figure 2. Nasal secretion rates (A) and ion composition (B) from a single chick challenged with 6 cc of orally delivered seawater.

Even though Leach's storm petrel chicks are apparently able to produce a highly concentrated nasal secretion following an acute salt load, the chicks that were artificially reared on a diet of 730 ± 4.0 mOsmol/kg grew slower (Mean wing cord at age 38-40 days: 72 ± 7.9 mm; n = 12 for laboratory reared birds and 92

± 13, n = 5; for field reared birds; $F_{(1,27)} = 19.9$; $P = 0.0001$) than wild chicks and had lower survival rates. We observed accumulations of urates in the kidneys of one chick we necropsied following death. At first consideration this would not seem to be an unusually high salt load for a bird which commonly feeds on crustaceans which have osmolarities near 1000 mOsmol/kg. Surprisingly, however, we found that the osmolarity of meals being carried by adults was only 388 ± 62 (n =6) mOsmol/kg.

In conclusion, we found that chicks of Leach's storm-petrels are capable of producing a highly concentrated nasal secretion and have very low rates of body water turnover. In addition, adults may reduce the osmolarity of a meal or select prey items which are lower in osmolarity for their chicks, thus minimizing the osmotic stress for their growing chicks. When chicks are given a chronic high salt load growth may be slowed. These findings seem to indicate that high salt loads acting through reduced chick growth rates may affect individual fitness. If this finding is supported by further studies then the cost of osmoregulation may have a significant effect on prey selection, feeding behavior, and even distribution of seabirds.

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