SHORT COMMUNICATIONS

The Volume of Stomach Oils Increases during Prefledging Weight Loss in Leach's Storm-Petrel (*Oceanodroma leucorhoa*) Chicks

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We have investigated the physiological mechanisms responsible for stomach oil accumulation unique to the Procellariiformes (Duke et al. 1989; Roby et al. 1986, 1989; Place et al. 1986, 1989; Jackson and Place 1990). An earlier study with Leach's Storm-Petrel (*Oceanodroma leucorhoa*) reported that chicks near fledging (55 days and older) accumulate greater volumes of stomach oil than younger chicks (Place et al. 1989). To better document the age of onset of oil accumulation, we measured the volume of stomach oil in 38 chicks of known hatching date throughout the 1989 breeding season on Little Duck Island, Maine (44°10'N, 68°15'W). The volume of stomach oil in 20 chicks was measured once at ages varying from 14 to 69 days. The volume in 15 chicks was measured at ages 25.3 days (SE = 1.5), 42.0 days (SE = 1.4), and 58.5 days (SE = 1.5). Three additional chicks fledged before a third sampling could be performed.

We determined stomach oil volume by dilution of a tritium-labeled glycerol triether ([^{3}H]-GTE), a nonabsorbable, nonmetabolizable lipid-phase marker (Place et al. 1989). Chicks were fed 0.5 cc of olive oil that contained 1.3 μCi/ml of ^{3}H-GTE. We sampled the proventricular lipids, after periods of 1-3 h. Stomach oils were separated from aqueous and particulate phases by centrifugation at 10,000 × g for 10 min before samples were removed for scintillation counting and lipid analysis (Place et al. 1989). A minimum of 2 h was needed to ensure complete equilibration of the tracer (i.e. constant specific activity) with endogenous lipids.

To validate the volume estimation technique, we prepared a set of artificial stomach oils by adding increasing quantities of olive oil (0-9 ml) to 1 ml of avian Ringer's in 15 ml conical centrifuge tubes. The oil-Ringer's mixture was vortexed to produce an unstable milky emulsion. Labeled olive oil (0.5 ml) was delivered to each tube by the same procedure as performed in the field. The artificial stomach oils were mixed by hand agitation and sampled 2 h later as described for authentic stomach oils. The volume of the lipid phase can be estimated by this technique with a high degree of precision (Fig. 1).

Our study covered >90% of the nestling growth period in Leach's Storm-Petrel chicks (Fig. 2: A and B), and includes the last 15 days before fledging when chick mass decreases (Ricklefs et al. 1980a, 1980b). Stomach oils were found in all chicks sampled, and the volume of stomach oil was highly variable within any age group (Fig. 2C). A repeated-measure ANOVA showed no significant between-bird variation in the 15 chicks sampled repeatedly ($F_{14,44} = 731.4, P = 0.728$), but there was a highly significant ($F_{2,44} = 11.94, P < 0.0002$) age effect on the volume of stomach oil. When the data from all 38 chicks were grouped into 5-day age intervals, a one-factor ANOVA revealed a significant effect ($F_{10,78} = 6.64, P < 0.0001$) when contrasting the volume of oil in each group. In pairwise comparisons, there was a significant difference ($P \leq 0.05$) between the volume of oil in chicks of age groups 60-64 days and 65-69 days, and chicks of all other age groups. After 60 days of age, the mean volume of oil (6.3 ± 2.9, $n = 25$) increased nearly threefold when compared with the mean volume of oil in the previous 54 days (2.3 ± 1.8, $n = 52$). Earlier stomach oil volume estimates for Leach's Storm-Petrel chicks (1.2 ± 0.9 ml, 39.4 ± 0.5 days, $n = 12$ [Place and Roby 1986]; 8.3 ± 1.6, $n = 12$, 65-70 day old chicks [Place et al. 1989]) are consistent with the present estimates.

This accumulation of stomach oils occurs when chick body mass decreases, primarily from reductions in

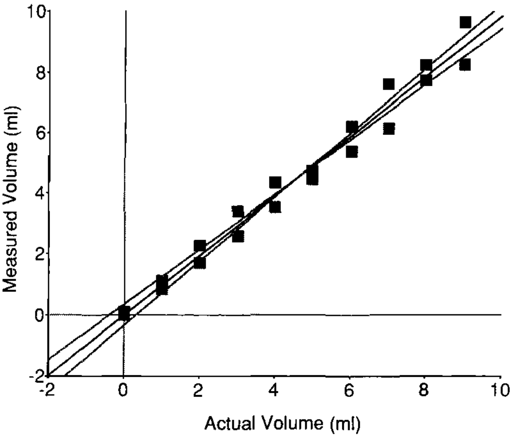

Fig. 1. Calibration curves for stomach oil volume estimation. The volume of lipid was determined from the dilution of a tritium labeled glycerol triether ([^{3}H]-GTE) added to an olive oil meal. The linear regression is defined by the equation: measured volume (ml) = (0.984 ± 0.035) × actual volume (ml) − 0.019 (ml); $F_{(1,19)} = 770.4, P < 0.001, r^2 = 0.977$). The curves represent the 95% confidence limits for the regression.

lipid stores of adipose tissue (Ricklefs et al. 1980a). Stomach oils accumulate in chicks at this age even if fed more frequently (i.e. nightly meals in the laboratory) (Place et al. 1989). The volume of stomach oil in these older chicks was apparently regulated. However, the lipid composition of the oil was dynamic and changed in response to subsequent dietary lipid intake (Place et al. 1989). Because the tracer was diluted to near background detection levels by subsequent meals delivered by the parents, we believe the accumulation of greater quantities of oil results from an overall slowing of gastric emptying in older chicks (Place et al. 1989).

The ability to concentrate dietary constituents into a high-energy meal that occupies smaller volume with lower osmotic load provides an advantage for both adults and chicks. Warham et al. (1976) hypothesized that production of stomach oil by adults involves a 5–35-fold concentration of the energy in the prey at the time of capture. Simmons and Whittow (1984) similarly estimated that the energy density of food delivered to Dark-rumped Petrel (*Pterodroma phaeopygia*) chicks must be 3–5 times higher than that of whole prey to meet nestling energy requirements. Ricklefs et al. (1986) deduced from the ratios of energy expenditure to water turnover that adult Leach's Storm-Petrels assimilate diets that are less energy-dense than those they feed their chicks. Bech et al. (1986) arrived at a similar conclusion from a comparison of the mass delivered to nestling Antarctic Petrels (*Thalassoica antarctica*). In Wilson's Storm-Petrels (*Oceanites oceanicus*), the lipids in stomach oil accounted for 78% of the energy delivered to the chick, although lipids accounted for only 27% of the total mass (Obst, 1988). Obst suggested that without stomach oils, the potential foraging area of adult Wilson's Storm-Petrels would be reduced by 75%.

We suggest that stomach oils also serve as energy and water stores for fledglings while they learn to forage. Although it is difficult to document that fledglings leave the nest with a full "tank" of stomach oils, the advantages of doing so are easily demonstrated. The weight savings over similar lipid stores in adipose tissue are substantial. Carcass (10.2 ± 1.6% wet weight), abdominal (80.5 ± 8.6%), and skin (58.7 ± 8.8%) fat are the three major lipid stores in Leach's Storm-Petrel chicks ($n = 12$; Roby et al. 1986, unpubl. data). The average percent wet weight of lipid in stomach oils is 96 ± 2% ($n = 12$) (Place et al. 1989). Even if we restrict our comparison to abdominal adipose tissue, stomach oils have a higher energy density than body stores. In addition, stomach oils do not incur the energetic and temporal cost of remobilization (Ricklefs 1974, Roby et al. 1989), and they can be jettisoned instantaneously if needed for weight reduction or protection (Jacob 1982). Whether other procellariiform chicks exhibit prefledging stomach oil accumulation must await future studies. With Leach's Storm-Petrel fledglings, one potential function for

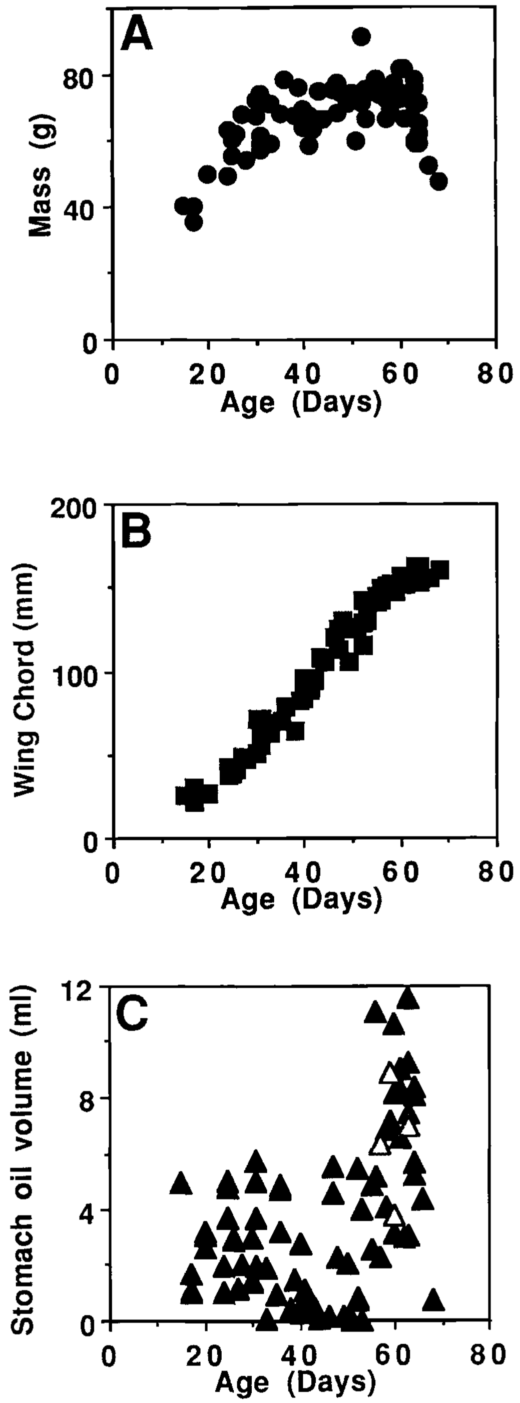

Fig. 2. Relationship between mass and age (A), wing cord and age (B), and stomach oil volume and age (C) in 38 Leach's Storm-Petrel chicks on Little Duck Island, Maine, USA, in 1989. The open triangles in Fig. 2C represent estimates for stomach oil volume obtained by aspiration.

stomach oils is to store energy and water during their first week at sea.

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Thermal Relations of Nestling Red-winged Blackbirds in Southeastern Michigan

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Low ambient temperatures or abnormal rainfall may reduce the nesting success of birds by lowering the body temperatures, and therefore the growth rates, of the nestlings (Case 1978), reducing clutch sizes (see Klomp 1970), or increasing the incidences of starvation or nest abandonment because of an inability of the parents to feed their young (e.g. Brenner 1966, 1968). The neonates and young of many altricial passerines may be especially vulnerable to adverse weather conditions if left alone in the nest because they are relatively small and lack thermoregulatory capabilities. For example, young Red-winged Blackbirds (*Agelaius phoeniceus*) weigh approximately 3-4 g at hatching, and they are largely naked and incapable of effective thermoregulation for roughly the first half of the 10-day nestling period (Holcomb and Twiest 1971, Hill and Beaver 1982, Olson in prep.) By day 4,

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