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EFFECTS OF THE WATER-OFFLOADING TECHNIQUE ON ADÉLIE PENGUINS

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Abstract.—Experiments were conducted on Adélie Penguins (*Pygoscelis adeliae*) to examine the effect of the water-offloading technique to collect stomach samples on adult foraging cycle duration and mass gain in chicks deprived of a meal. No difference in foraging cycle duration between control and treated adults was measured. Deprivation of a single meal had no effect on mass gain to fledging of 2-wk-old chicks in two colonies, nor did it affect their growth. Survival rate of chicks of stomach-flushed adults and of those fed normally was similar for both colonies. The findings support the acceptance of the water-offloading technique as the most humane method of procuring stomach samples from Adélie Penguins.

EFECTOS DE LA TÉCNICA DE ANEGAR EL ESTÓMAGO CON AGUA EN *PYGOSCELIS ADELIAE*

Sinopsis.—Se condujeron experimentos en *Pygoscelis adeliae* para examinar el efecto de la técnica de anegar el estómago con agua para coleccionar muestras estomacales durante los ciclos de forrajeo de los adultos y en el aumento en masa de pichones desprovistos de una comida. No se midió ninguna diferencia en la duración del ciclo de forrajeo entre los controles y los adultos tratados. En dos colonias, el privar a los pichones de dos semanas de edad de una sola comida no tuvo ningún efecto sobre el aumento en masa o el crecimiento. Las tasas de supervivencia de pichones a los que se le administró agua y las de pichones alimentados normalmente fueron similares en dos colonias. Estos hallazgos apoyan la aceptación de la técnica de anegar el estómago con agua como el método más humano para obtener muestras estomacales en *Pygoscelis adeliae*.

Diet studies of penguins provide Antarctic ecologists with an understanding of the energy flow through the various components of the Antarctic marine food web, and enable an assessment of the impact of penguins on harvested resources. Several methods exist for sampling the stomach contents of penguins (e.g., Duffy and Jackson 1986), but the simplest and most efficient is the water-offloading technique of Wilson (1984). Wilson's technique involves flooding the penguin's stomach with warm water via a tube and pump, and inverting the penguin over a bucket while applying pressure to the stomach to induce regurgitation. Penguins are usually pumped several times until clear water is expelled. Since its inception the technique has received wide acceptance by seabird researchers (e.g., Ryan and Jackson 1986) and is favored by the Commission for the Conservation of Antarctic Marine Living Resources for monitoring dietary trends in Southern Ocean penguins (CCAMLR 1992).

In spite of the popularity and efficacy of the water-offloading method, the trauma to adults during stomach flushing and the possible impact of meal deprivation on chicks of stomach-flushed parents, has raised concern with the Antarctic Animal Care and Ionising Radiation Usage Ethics Committee, Hobart, Australia, which is responsible for overseeing the ethical treatment and husbandry of Antarctic wildlife. Concern pertains to the subsequent behavior of stomach-flushed adults, the effect on chick attendance patterns, and the fate of chicks of stomach-flushed parents. We tested the following hypotheses about the effect of the water-offloading technique on Adélie Penguins (*Pygoscelis adeliae*): (1) Stomach flushing affects foraging cycle duration of Adélie Penguins attending chicks, and (2) meal deprivation affects chick mass gain.

We chose Adélie Penguins for the experiments because of their abundance in the high Antarctic (Wilson 1983), their popularity as a species on which to conduct research, and their importance as an indicator species for the CCAMLR Ecosystem Monitoring Program (CCAMLR 1992). Also, the Adélie Penguin may serve as a useful indicator of possible effects of water-offloading on other species of penguin that exhibit similar nest site fidelity during chick rearing.

To support the interpretation of the results of our experiments we collected data on reproductive performance of experimental adults and the survival of sibling chicks deprived, collectively, of a single meal. We chose deprivation of a single meal, as opposed to several meals, as a factor in the experiments because we assumed researchers seeking penguin stomach samples would study large colonies to minimize the risk of chicks of sampled adults being affected by more than one bout of stomach flushing.

METHODS

Field work was conducted at Shirley Island, near Australia's Casey station (66°17′S, 110°32′E), Antarctica, between 25 Dec. 1991 and 25 Feb. 1992. The island supports about 8000 pairs of Adélie Penguins breeding in 52 colonies (Woehler et al. 1991). To test for differences between colonies we chose two colonies 100 m apart, equidistant from the sea and exposed to identical weather regimes. Colony A comprised 226 breeding pairs and colony B contained 1374 breeding pairs. Eight days after the commencement of hatching, when chicks weighed 605–693 g, 46 nests each containing two adults and two chicks were selected from the periphery of each colony. Both members of a breeding pair were captured during nest changeover, weighed and painted with a unique number on the breast using Nyanzol-D feather dye (Belmar Inc., North Andover, Massachusetts USA) to allow experimental adults to be recognized later in the breeding cycle. Chicks from these nests were weighed and marked on both flippers with numbered Velcro® bands, colored separately for each colony. Chick numbers matched the number of one parent to enable chicks and adults to be matched once chicks formed creches. To enable normal flipper growth, the bands were adjusted on all chicks, irrespective of their role in the experiments, at regular intervals throughout the 55-d nestling period. To ensure consistency in the handling of experimental adults we practiced the water-offloading technique on six penguins before commencing the experiments.

The 46 nests in each colony were assigned to treatment (adults stomach flushed) and control (adults not stomach flushed) groups. Twelve days after hatching, when chicks were estimated (see Green and Gales 1990) to weigh 1000–1090 g, one adult from each nest in the treatment group was captured as it returned from the sea to feed its chick, and its stomach flushed 4–5 times (until clear water was expelled) using Wilson's technique. In this way each nest of two chicks in the treatment group of each colony was deprived of a single meal. Ten days before fledging commenced, banded chicks were counted to assess survival rates, weighed to estimate their mass change, and relieved of their bands.

The effect of water-offloading on adult foraging cycle duration was examined only at colony A because it was impossible to observe the movements of marked adults at both colonies simultaneously. We recorded the departure and return times of 22 control and 19 treatment birds on their second foraging trip after being stomach-flushed (the time taken to complete the stomach flushing precluded measurement of birds on their first trip). We standardized procedures for capture and handling of adults and chicks, and behavior of observers around the colonies to minimize the confounding effect inconsistencies in these activities could have had on the results.

RESULTS

There was no difference in mass of adults at marking between colonies (ANOVA: $F_{1,180} = 0.7$, $P > 0.5$) and treatment groups ($F_{1,180} = 1.5$, $P > 0.2$), nor was there a colony-by-treatment interaction ($F_{1,180} = 1.0$, $P > 0.5$). Similarly, there were no differences in the initial mass of chicks between colonies ($F_{1,96} = 0.2$, $P > 0.5$) and treatments ($F_{1,96} = 0.2$, $P > 0.5$), and the colony-by-treatment effect was not significant ($F_{1,96} = 1.8$, $P > 0.2$). Bill length at fledging varied between colonies ($F_{1,96} = 6.4$, $P < 0.05$) with bills of chicks in colony A (31.0 ± 2.1 mm [SD]) being slightly larger on average than those in colony B (29.8 ± 2.4 mm). There was no difference between treatments, however, ($F_{1,96} = 1.1$, $P > 0.2$; C × T: $F_{1,96} = 1.9$, $P > 0.2$). Adults on their second foraging trip after being stomach-flushed spent 31.2 ± 16.7 h ($n = 19$) at sea compared with 29.5 ± 15.5 h (SD) ($n = 22$) for control birds ($F_{1,40} = 0.12$, $P > 0.5$). Stomach-flushed adults yielded an average of 411 ± 151 g (range: 128–737 g) of krill (*Euphausia* sp.) and fish (*Pleuragramma antarcticum*) which, assuming adults fed chicks their entire stomach contents, constitutes the mass of food their offspring were collectively deprived of during the experiments.

There were no differences in chick mass gain due to either colony or treatment, suggesting that mass gains for birds in colonies (irrespective of treatment) and treatment (irrespective of colony) were similar. There was a colony-by-treatment interaction ($F_{1,96} = 5.3$, $P < 0.05$) indicating that mass gain by chicks with a stomach-flushed parent was similar for both colonies, and mass gain by chicks with parents not stomach-flushed differed between colonies (see Table 1). The interaction term, however, barely reached acceptable levels of significance ($F_{1,100(0.05)} = 5.2$) and presumably reflects between-colony variation in chick mass gains. There was

TABLE 1. Mean mass gain of Adélie Penguin chicks from two-chick nests at Shirley Island, Antarctica, 1991–1992. Treatment refers to whether or not one parent of a nest of two chicks was stomach flushed, thus depriving the chicks of a single meal.

			Chick mass (g)	
Colony	Treatment	*n*	Mean	SD
A	No flush	26	2949.0	572.1
A	Flush	25	2738.0	503.3
B	No flush	28	2518.7	473.9
B	Flush	21	2767.8	405.8

no difference between mass gain of chicks of parents stomach-flushed, and those of parents not stomach-flushed, *within* colonies.

A total of eight pairs of siblings, or 14.8% of pairs, were raised to fledging in the control nests (three and five pairs in colonies A and B, respectively) and six pairs of siblings, divided evenly between colonies and representing 13.0% of pairs, were raised by stomach-flushed parents. The survival rate of chicks of treated and control adults was similar for both colonies (Table 2).

DISCUSSION

In the analyses above both "colony" and "treatment" are fixed effects. It was impossible to sample birds in more than two colonies simultaneously and two colonies do not exhaust all possibilities for this effect. The results, therefore, are only weakly inferential about the effects of the water-offloading technique on birds in other Adélie Penguin colonies.

Sibling 10-d-old chicks were collectively deprived of 128–737 g of food, which corresponds (assuming one chick consumed the lot) to 0.5–3.0% of the 26 kg of food estimated by Green and Gales (1990) to fledge an Adélie Penguin chick. This is a trivial amount of food and would not be expected to affect seriously the growth and survival of a healthy chick. Expressed another way, however, the missed meal amounted to 13–74% of the 1000-g mass of chicks when adults were stomach flushed. Relative

TABLE 2. Survival rate of Adélie penguin chicks deprived of a single meal compared with survival of chicks fed normally. All nests contained two chicks at the beginning of the experiment. Treatment refers to whether or not one parent of a nest of two chicks was stomach flushed.

Colony	Treatment	# banded	# alive	# dead	% lost[a]	% survived
A	No flush	46	26	11	9	56.5
A	Flush	46	25	14	7	54.3
B	No flush	48	28	11	9	58.3
B	Flush	37	21	9	7	56.7

[a] Number of chicks not accounted for, presumably captured by Skuas (*Catharacta maccormicki*).

to their stage of development, the upper end of this range represents a substantial cost to young chicks, yet the effect on their growth and mass gain was negligible. Clearly, in the breeding season in which the experiments took place there was sufficient plasticity in the feeding regime of chicks to overcome this shortfall in their food intake.

Adults on their second foraging trip after being stomach-flushed spent a similar length of time at sea as did control birds. Presumably the nest-site fidelity of the stomach-flushed penguins took ascendancy over any effect the technique may have had on their foraging behavior. The results support the acceptance of the water-offloading technique as the most humane method of procuring stomach samples from Adélie Penguins.

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