

Sandwich Terns *Sterna sandvicensis* feeding on shell fractions

During four evenings at the onset of egg laying, in late April and early May 1995, at least five Sandwich Terns *Sterna sandvicensis* were observed eating shell fragments on the island of Griend in the Dutch Wadden Sea. This behaviour was not observed before or after the egg-laying period. One observation concerned a female on the brink of egg laying, as could be seen from the swollen abdomen.

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Table 1. Body mass, skeleton mass, egg volume, egg mass and shell mass (mean \pm s.d.) for Sandwich, Common and Arctic Terns breeding 011 ilte is/and of Griend between 1991 and 1994 (sample sizes are given in parentheses). Egg volumes were derived from data collected on

	Sandwich Tern	Common Tern	Arctic Tern
<i>Griend between 1991 and 1994</i>			
Body mass (g)	252 \pm 18 (173)	123 \pm 8 (114)	115 \pm 13 (69)
Skeleton mass* (g)	14.9	7.3	6.8
Egg volume* (ml)	34.71 \pm 2.59 (2123)	19.72 \pm 1.51 (199)	18.93 \pm 1.23 (73)
Egg masse (g)	35.78	20.34	19.52
Shell mass* (g)	2.00	1.19	1.14

- Calculated using the average skeleton mass of 5.9% of the body mass, obtained from six tern species (Graveland *et al.* 1995).
- calculated using the formula of egg volume = k X length X width', where ks.nd.chTttt = 0.5087 \pm 0.0102 (n = 24), kcommonTern = 0.5115 \pm 0.0107 (n = 21), kAmk T'trn = 0.5102 \pm 0.0109 (n = 22).
- < Calculated using the average egg mass as 103.8% of the egg volume (van Klinken 1992).
- Calculated using the average shell mass of 5.85 % of the egg mass, obtained from six tern species (Graveland *et al.* 1995).

Our observations on shell-eating Sandwich Terns may indicate that this assumption does not always hold.

We estimated the amount of calcium needed by the Sandwich Tern to produce its usual two-egg clutch. The mass of an average Sandwich Tern egg is 35.8 g (Table 1). The average eggshell mass is 2.00 g (Table 1), of which 35% or 0.70 g is calcium (Table 2). Thus, in order to produce a two-egg clutch, a Sandwich Tern needs 1.40 g calcium, which has to be drawn from internal sources or obtained by ingestion.

Females of wild bird species mobilize up to a maximum of 15% of their skeletal calcium for eggshell formation (Hurwitz 1964, Simkiss 1967, March & Sadleir 1975, Graveland & van Gijzen 1994). The mass of the skeleton of the Sandwich Tern is estimated at 14.9 g (Table 1), 25% calcium (Table 2). Thus, for eggshell formation, a maximum of 0.56 g (14.9 g * 25% * 15%) calcium may be mobilized from the skeleton. The remaining 0.84 g (1.40 g - 0.56 g) calcium must be obtained from food. The diet of Sandwich Terns on Griend consists mainly (96-99%) of Sprat *Sprattus sprattus*, Herring *Clupea harengus*, Sandeel *Ammodytes tobianus* and Greater Sandeel *Ammodytes lanceolatus* (veen 1977, Brunninkmeijer & Stienen

1994, Stienen & Brunninkmeijer 1994). The calcium content of Herring is approximately 0.8% of the fresh mass and is assumed representative for the Sandwich Tern diet (Table 2). The digestion efficiency of calcium typically ranges between 50% and 70% (Graveland & van Gijzen 1994). We estimated the daily food intake from the predicted field metabolic rate (FMR), the energy content of fish and the digestion efficiency. The expected FMR of a 252-g breeding Sandwich Tern is 361 kJ per day (16 h/day at nest, using 10.2 kJ/h, 8 h/day at sea, using 24.8 kJ/h; Birt-Friesen *et al.* 1989). Herring contains approximately 78 kJ per g (Montevicchi *et al.* 1984, Barrett *et al.* 1987), and 82% is digested by terns (Klaassen *et al.* 1992). So an adult female Sandwich Tern needs 63 g (361/(7 * 82%)) herring per day. At this rate of intake, a total of 0.30 g (63 g * 60% * 0.8%) calcium can be absorbed daily. Conceivably, however, the FMR is lower during egg laying than during chick rearing, and, accordingly, calcium intake is lower.

In many bird species, such as the Great Tit *Parus major*, the Domestic Fowl *Gallus domesticus* and the Red-cockaded Woodpecker *Picoides borealis*, eggshell formation occurs in the last 10-20 h before egg laying, mostly during the night (Mongin & Sauveur 1974,

Table 2. Average calcium contents (in %) of skeleton and eggshell of Sandwich Tern, Common Tern and Arctic Tern and of their prey species

Source of calcium	% calcium	Reference
Skeleton	25	Graveland & van Gijzen 1994
Eggshell	35	Graveland & van Gijzen 1994
Snail shell*	33.1	Graveland & van Gijzen 1994
Crab**	7.8	L. Zwartz, unpubl. data
Herring.h.<	0.8	Jung 1965, Kling & Wöhlbier 1977
Common Shrimpl>	0.2	Jung 1965, Kling & Wöhlbier 1977

* Taken by Sandwich Tern.

** Taken by Common Tern.

† Taken by Arctic Tern.

Schifferli 1979, Gilbert 1983, Repasky *et al.* 1991, Graveland & Berentse 1995, Perrins 1996). Probably eggshell formation in Sandwich Terns also occurs mostly at night, because they were seen eating shell fragments only in the evening. So two eggshells need to be formed in two days, for which at most 0.60 g (2 g x 0.30) calcium can be obtained from the regular diet (assuming the expected FMR of chick-rearing Sandwich Terns, see above). Since the calcium demand is 0.84 g, at least 0.24 g calcium has to be obtained by the intake of shell fragments or other calcium-rich material. The calcium content of shells is about 33% (Table 2). With an average digestion efficiency of calcium of 60% (Graveland & van Gijzen 1994), each female tern would need to ingest at least 1.2 g (0.24 g/(33% x 60%)) of shell fragments.

Common Terns *Sterna hirundo* and Arctic Terns *Sterna paradisaea* breeding on Griend have never been observed eating additional calcium sources, such as shell particles, during egg laying. For the formation of two eggs, Arctic and Common Terns need 0.80 g (2 x 1.14 g x 35%) and 0.83 g (2 x 1.19 g x 35%) calcium, respectively (Table 1). They can mobilize 0.26 g (15% x 6.8 g > 25°C) and 0.27 g (15% x 7.3 g x 25%) calcium from their skeletons, respectively. The remaining part, 0.54 g and 0.56 g, respectively, has to be obtained from the food. In most European marine areas, fish is the staple food of terns (Pearson 1968, Cramp 1985). Yet on Griend between 1987 and 1990, Arctic and Common Tern chicks were fed, in addition to Clupeidae (21% and 50%, respectively), mainly Common Shrimp *Crangon crangon* (33% and 30%, respectively), small Shore Crab *Carcinus maenas* (21% and 5%, respectively) and flatfish (14% and 7%, respectively), particularly Flounder *Platichthys flesus* (Veen & Faber 1989, Stienen & van Tienen 1991), a diet comparable with that of some German Wadden Sea colonies (Becker *et al.* 1987). Very likely, parents feed on the same diet. From these species, Crab is relatively calcium rich (Table 2) and may very well act as a main calcium source for eggshell production in Common and Arctic Terns.

We suggest that the intake of shell fragments by female Sandwich Terns reflects the need to supplement their normal diet with calcium-rich material for eggshell formation.

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