A SIMPLE PHOTOGRAMMETRIC TECHNIQUE FOR ESTIMATING EGG VOLUME FROM FIELD MEASUREMENTS

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We compared direct and indirect methods for estimating egg volume in the Northern Fulmar Fulmarus glacialis *and developed a simple photogrammetric technique. We found that more variability in measured egg volume was explained by a photogrammetric estimate of cross-sectional area (78%), in comparison to an ellipsoidal formula derived from field measurements of egg length and breadth (61%), or a published formula (53%) that had been used in previous studies of this species. In future, this photogrammetric technique could also allow measurements of complex shape indices and reduce handling and disturbance at the nest.*

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Egg quality and size are highly variable between and within species, and are often expressed in terms of volume (Davis 1975; Furness 1983; Ollason & Dunnet 1988; Petersen 1992; Kern & Cowie 1996; Weidinger 1996; Jager *et al.* 2000; Bradzinki *et al.* 2002). Egg volume can be measured directly by water displacement (Preston 1974; Székely *et al.* 1994; Kern & Cowie 1996), but this technique can be time consuming and cause additional disturbance in the field. Empirical studies have therefore tended to use a variety of formulae to estimate egg volume (V) from simpler field measurements such as length (L) and breadth (B). Hoyt's (1979) formula, where k_v is a constant that varies between species and within populations (Preston 1974; Kern & Cowie 1996), has been the most widely used of these (Weidinger 1996; Narushin 1997; Potti 1999; Jager *et al.* 2000; Bradzinki *et al.* 2002). However, such ellipsoidal formulae tend to simplify the shape of the egg to only two parameters (Preston 1974; Székely *et al.* 1994; Kern & Cowie 1996); further field methods can be developed to provide more accurate estimates of egg volume that take account of variations in egg shape.

As part of a study on variation in egg size of the Northern Fulmar *Fulmarus glacialis* we compared previously published formulae for estimating egg volume, and developed a simple photogrammetric technique for obtaining more accurate estimates of egg volume from field measurements. During July 2002, the volumes of 19 eggs were estimated directly by water displacement. Each egg was placed in an empty graduated flask, and filled to 250 ml with water, using a second graduated flask. Egg length and breadth were also measured to the nearest 0.01 mm using callipers, and photographs were taken at right angles to the long axis of the egg using a digital camera (Canon D30), with 100-300 mm lens. All photographs were taken with the zoom lens set at approximately 100 mm. The cross-sectional area of each egg was calculated from photographs, using the UTHSCSA ImageTool ver. 3.0, (available free from the University of Texas Health Science Centre at http://ddsdx.uthscsa.edu/dig/itdesc.html). The software's measurement scale was calibrated to the egg length obtained from field measurement. Ten repeat measurements of the same photograph indicate that the CV on these measurements was <1%. Similarly, repeat estimates of cross-sectional area based upon five photographs of the same egg taken from different distances and heights had a CV of <1%.

Direct estimates of volume were then used to derive formulae for predicting volume, first, from field measurements of length (L) and breadth (B) and, second, from photographic estimates of cross-sectional area (CSA). Regression analyses were used to compare estimates of volume based upon these and previously published formulae, with those measured directly by water displacement.

The strongest relationship found was between measured volume and the cross-sectional area obtained from the image analysis. Variability in this photogrammetric estimate of cross-sectional area explained 78% of the variation in measured egg volumes (Table 1). The relationship we derived based upon field measurements of length and breadth explained less (61%) of the variability in measured egg volume, but still proved a better predictor of volume in this species than the general equations proposed by Romanoff & Romanoff (1949) and Hoyt (1979) (Table 1).

Previous studies of egg size variation in this population of fulmars have used Romanoff & Romanoff's (1949) generalised equation (Ollason & Dunnet 1988). Although this and Hoyt's (1979) methods provided a reasonable estimate of egg volume, more variability could be explained by deriving new equations specifically for this species. In future, additional eggs could be measured to improve this estimate for application in further studies. However, the most accurate estimates of egg volume were obtained by using photographs of the egg with field measurements of egg length. Consequently, this technique

Table 1. Results of the regression analyses comparing the performance of the different formulae used to predict egg volume (V) from measurements of egg length (L), egg breadth (B) and cross-sectional area (CSA).
Tabel 1. Resultaten van de regressie-analyses die de zeggingskracht vergelijken van verschillende formules om het eivolume (V) te voorspellen aan de hand van eilengte (L), eibreedte (B) en oppervlak van een dwarsdoorsnede (CSA).

Formula	R^2	$F_{1,16}$	P
$V = 0.0002(CSA)^{1.6433}$	0.78	58.87	<0.001
$V = 0.0063\ (LB)^{1.1753}$	0.61	25.14	<0.001
$V = 0.85\ (pLB^2)/6$	0.53	18.61	<0.001
$V = 0.51(LB^2)$	0.53	18.61	<0.001

should provide greater power for exploring the causes and consequences of egg size variation both in this and other species. It also provides a useful alternative to direct measurements of egg volume that would require more handling and consequent disturbance to the birds. In future, images could also be analysed to obtain more complex indices of shape. For example, there has been recent interest in the influence of egg shape on incubation efficiency (e.g. Liker *et al.* 2001), but measuring complex properties such as sphericity and ovoidness has previously proved difficult to achieve in the field (Mänd *et al.* 1986; Petersen 1992; Narushin 2001). Finally, the technique could be further developed by attaching two laser pointers to the camera, so that parallel laser beams at known distance apart can be seen on the photograph and used to calibrate the measurement scale in ImageTool. Eggs could thus be photographed in the nest, and egg-volume or shape estimated with minimal disturbance at the nest site.

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EEN EENVOUDIGE FOTOGRAMMETRISCHE METHODE VOOR DE BEPALING VAN HET EIVOLUME AAN DE HAND VAN METINGEN IN HET VELD

De auteurs hebben een vergelijking gemaakt van directe en indirecte methoden om het eivolume bij Noordse Stormvogels *Fulmarus glacialis* te bepalen. Ze hebben een eenvoudige fotogrammetrische methode ontwikkeld om het eivolume aan de hand van een foto van de dwarsdoorsnede te bepalen. Ze vonden dat de variatie in gemeten eivolume beter werd verklaard met deze fotogrammetrische schatting van de dwarsdoorsnede van een ei (78%) dan door twee andere methoden: 1) een ellipsoïdale formule die is afgeleid van metingen van lengte en breedte van een ei (61%) en 2) gepubliceerde algemene formules die zijn gebruikt bij eerdere studies naar de Noordse Stormvogel (53%). De fotogrammetrische methode zou in de toekomst metingen van complexe vormen mogelijk moeten maken. De methode leidt bovendien tot minder verstoring bij het nest.

REFERENCES

Bradzinski S.S., Ankney C.D., Leafloor J.O. & Abraham B.F. 2002. Egg size as a predictor of nutrient composition of eggs and neonates of Canada Geese (*Branta canadensis interior*) and Lesser Snowgeese (*Chen caerulescens caerulescens*). Canadian Journal of Zoology 80: 333-341.

Davis J.W.F. 1975. Age, egg-size and breeding success in the Herring Gull *Larus argentatus*. Ibis 117: 460-473.

Furness R.W. 1983. Variation in size and growth of Great Skua *Catharacta skua* chicks in relation to adult age, hatching date, egg volume, brood size and hatching sequence. Journal of Zoology, London 199: 101-116.

Hoyt D. F. 1979. Practical methods of estimating volume and fresh weight of bird eggs. Auk 96: 73-77.

Jager T.D., Hulscher J.B. & Kersten M. 2000. Egg size, egg composition and reproductive success in the Oystercatcher *Haematopus ostralegus*. Ibis 142: 603-613.

Kern M.D. & Cowie R.J. 1996. The size and shape of eggs from a Welsh population of Pied Flycatchers - Testing Hoyt's use of egg dimensions to ascertain egg volume. Journal of Field Ornithology 67: 72-81.

Liker A., Reynolds J.D. & Székely T. 2001. The evolution of egg size in socially polyandrous shorebirds. Oikos 95:3-14

Mänd R., Nugul A. & Sein A. 1986. Oomorphology: a new method. Auk 103: 613-617.

Narushin V.G. 1997. The avian egg : geometrical description and calculation of parameters. Journal of Agricultural Engineering Research. 68: 201-205.

Narushin V.G. 2001. Shape geometry of the avian egg. Journal of Agricultural Engineering Research. 79: 441-448.

Ollason J.C. & Dunnet G.M. 1988. Variation in breeding success in Fulmars. In: Clutton-Brock T.H. (ed). Reproductive success; studies of individual variation in contrasting breeding systems: 263-278. University of Chicago Press, Chicago.

Petersen M.R. 1992. Intraspecific variation in egg shape among individual Emperor Geese. Journal of Field Ornithology 63: 344-354.

Potti J. 1999. Maternal effects and the pervasive impact of nestling history on egg size in a passerine bird. Evolution 53: 279-285.

Preston F.W. 1974. The volume of an egg. Auk 91: 132-138.

Romanoff A.L. & Romanoff A. J. (eds) 1949. The avian egg. John Wiley, New York.

Székely T., Karsai I. & Williams T.D. 1994. Determination of clutch-size in the Kentish Plover, *Charadrius alrexandrinus*. Ibis 136: 341-348.

Weidinger K. 1996. Egg variability and hatching success in the Cape Petrel *Daption capense* at Nelson Island, South Shetland Islands, Antarctica. Journal of Zoology, London 239: 755-768.