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THE VOLUME OF SNOWY PLOVER EGGS

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Abstract.—The volume of Snowy Plover *Charadrius alexandrinus alexandrinus* eggs was measured using an egg volumeter. The volumeter was tested both indoors and outdoors using steel balls and real eggs, respectively. Both measurements showed that the volumeter is accurate. The volume of Snowy Plover eggs was 8.4 ± 0.4 cm^3. It is suggested that a simple device be used to measure volume because the error of the volumeter is small (0.06 cm^3) and the device is easy to use in the field.

EL VOLUMEN DE LOS HUEVOS DE *CHARADRIUS ALEXANDRINUS*

Sinopsis.—El volumen de los huevos del playero *Charadrius alexandrinus* se midió utilizando un metro de volumen. El metro de volumen fue puesto a pruebas dentro y fuera del laboratorio utilizando esferas de acero y huevos, respectivamente. Ambas medidas mostraron que el metro de volumen es preciso. El volumen de los huevos del playero resultó ser de 8.4 ± 0.4 cm^3. Se sugiere que se utilice un solo instrumento para medir el volumen de huevos, debido a que el error del metro de volumen es pequeño (0.06 cm^3) y el aparato es fácil de utilizar en el campo.

Knowledge of egg volume is important to all researchers of avian ecology. Egg size may relate to neonatal mass (Ricklefs et al. 1978), and to the survival chance of chicks (Bolton 1991, Galbraith 1988), whereas density of egg relates to incubation stage (Rahn and Ar 1974, Yalden and Yalden 1989). Although the length and weight of eggs are easy to measure in the field, the volume of an egg is also dependent on shape. Hoyt (1979) recommended using linear estimates for egg volume, but calculating egg volume from linear measurements introduces significant inaccuracy (Preston 1974). The aim of this paper is to report on the egg volume of Snowy Plover (*Charadrius alexandrinus*) as measured by a volumeter.

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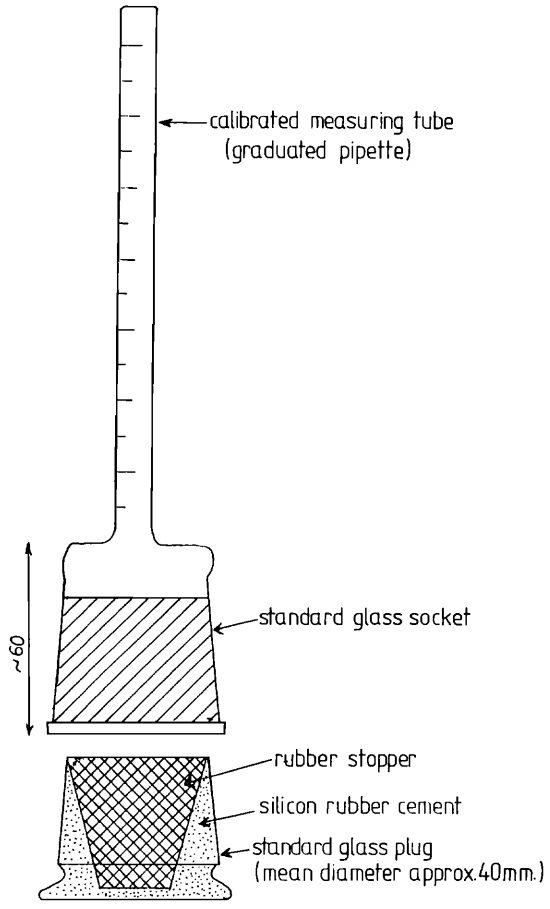

FIGURE 1. Schematic representation of the volumetric device.

METHODS

The Volumeter

We built a simple device to measure the volume of eggs (Fig. 1), similar to the one invented by Hanson (1954). The volumeter consists of a 15-cm^3 graduated pipette melted to the honed neck of a glass bottle, while the upper end was closed by melting. A removable glass stopper was fitted into the neck of the bottle. The inside of the stopper was filled by a rubber plug and glue was used to fix the plug in the stopper.

Zeroing.—The empty device was turned upside down, held in one hand, and after removal of the stopper approximately 55 cm^3 water was injected into the neck. Then the device was plugged and inverted, and after 5–10 s the base level of the meniscus was read.

Measurement.—The device was turned upside down and the stopper was removed. All drops remaining on the inside of stopper were carefully shaken back into the neck. The objects to be measured were put into water on a wire holder with fixed loop at the end. After removing the holder, the device was plugged and slowly inverted, and the mensicus was read. The difference between the zeroed and measured values gave the volume of the object.

Volume Measurements

Indoors.—To determine the accuracy of the volumeter, the diameters of seven steel balls were measured to the nearest 0.05 mm (range of balls' diameter: 9.60–24.18 mm). Then the volume was calculated according to the formula $\pi d^3/6$. Two observers measured diameter of each ball five times, then measured the volume using the volumeter following the methods above. The order of measures was randomized. Five control measures were also performed by both observers, but only the empty holder was immersed into the volumeter.

Outdoors.—Breadth, length and volume of eight randomly selected eggs (one from each of eight clutches of three) were measured on 16 Jun. 1990 in Csaj-tó, near the village of Csanytelek, southern Hungary (46°30′N, 20°00′E). The measurement took 20–30 s for each egg, and each egg was measured three times by the same two observers. After measuring, all eggs were put back into the nestscrape. The volume coefficient (K_v) was calculated from volume = $K_v{}^x LB^2$, where L and B are the length and breadth of the egg, respectively (Hoyt 1979).

Statistical Procedure

Univariate regression analyses (SPSS-PC) with the mean of replicated measures were used (Norusis 1990). Outdoor measures were compared by a three-way nested ANOVA with the factors of method of measurement, observers and egg size, and the replications were nested within the egg size. No interaction term was significant between the factors ($P > 0.16$). Means ± 1 SD, two tailed probabilities, and coefficients of variation (CV) are given.

RESULTS

Accuracy of the Device

Indoors.—The correlation between the two methods of volume measurement was highly significant (Observer 1: $r = 1.0$, $P < 0.001$, $n = 7$; observer 2: $r = 0.995$, $P < 0.001$, $n = 7$). The variance of the smallest and the largest balls' measured volume was not significantly different (F-tests, $n_1 = 5$ and $n_2 = 5$, observer 1: $F = 1.46$, $P > 0.3$; observer 2: $F = 1.10$, $P > 0.4$). The control measures with empty holders gave 0.06 ± 0.04 cm^3 error (observer 1) and 0.06 ± 0.03 cm^3 (observer 2).

Outdoors.—The measured and calculated egg-volumes were significantly correlated in both observers (observer 1: $r = 0.958$, $P < 0.001$, n

= 8; observer 2: $r = 0.975$, $P < 0.001$, $n = 8$). The measured and calculated volumes were not significantly different (three-way ANOVA, $F = 0.10$, $P > 0.75$, $n = 96$), nor were the observers ($F = 3.51$, $P > 0.06$), although egg size had a significant effect ($F = 207.95$, $P < 0.001$).

Volume of Eggs

The volume of eight eggs was 8.38 ± 0.39 cm^3 measured by volumeter (CV = 4.62), whereas the breadth was 23.17 ± 0.43 mm (CV = 1.84) and the length was 32.13 ± 0.64 mm (CV = 1.99). The egg-index (LB^2) was 17.25 ± 0.76 cm^3 (CV = 4.38), so the volume-index was calculated as $K_v = 0.486 \pm 0.006$ (CV = 1.24).

DISCUSSION

The results of this study showed that the volumeter is accurate and reliable, and that the readouts do not differ significantly between observers. The control measures of empty holders showed a small error, which is less than 1% of the volume of a Snowy Plover's egg. If a linear estimate of egg-volume were used with $K_v = 0.51$ (Hoyt 1979), it would result in 0.42 cm^3 error between the measured volume and linear estimate (5% of Snowy Plover eggs). The small error of the volumeter probably came from leakage between the stopper and neck, which could be avoided by using fine grease. This error is less than those of other volumeters (Loftin and Bowman 1978, Morris and Chardine 1986). The device is simple to make, a skilled technician can prepare it in less than 2 h, and use is also straightforward, although it is important to turn the device up and down carefully to avoid egg damage.

The volume-index (K_v) of Snowy Plover is lower than that of most birds reported by Hoyt (1979:Fig. 1). In Hoyt's (1979) paper, four species out of 115 (3%) fall below the "normal" range of K_v, and three of these outliers are shorebirds *Charadrii*. We think the reason for this result is that the eggs of shorebirds are relatively more pointed. The exact evolutionary benefit of having a pointed egg is unknown, although it may be the efficient use of space (Andersson 1978). Most shorebirds lay clutches of four, and when an extra egg was added to the clutch the development of the embryo was slowed (Hills 1983).

Hoyt (1979) suggested that egg volume should be determined empirically for species such as shorebirds that have very asymmetrical eggs. As we showed in this study, it is more accurate to measure volume than to estimate it from linear measurements. To determine volume we recommend a device like ours in the field.

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