days after hatching while body mass does not. Reference to Figure 2 suggests that bills lengthen about 2 mm over four days, while body mass barely increases at all. It also appears that, having fledged at around 40 g (Figure 1), their bills continue to grow to adult length ($\bar{x}$ 24.8; Prater *et al.* 1977) but little or no weight is gained for a further 10 days after fledging. At fledging their wings are still very short ($\bar{x}$ 92.9, S.D. 5.17, range 83–100 mm, n = 23) compared with those of adults (male $\bar{x}$ 111.5, range 105–117, female $\bar{x}$ 115.7, range 111–122; Holland *et al.* 1982), and we presume that further growth over the 10 days post-fledging goes into increases in length rather than into mass.

Discussion

Visser & Beintema (1988) suggest that waders vary between slow-growing but energetically conservative species (e.g. Lapwing *Vanellus vanellus*) and fast-growing but energetically extravagant species (e.g. Black-tailed Godwit *Limosa limosa*). In growing at 1.65 g day^{-1} (3% of adult weight per day) and fledging in 19 days, Common Sandpipers seem to belong in the second group. This is also consistent with field observations that very little brooding is done after the first four days (Yalden 1986).

Green (1984) suggested that bill-length could provide a good estimate of age and that it might also allow the relative condition of a wader chick to be assessed. It certainly appears that bill-length is a better indicator of age over the first four days of life than is mass and this is probably true after fledging as well. Figure 3 indicates that in the middle period of chick growth, when bills measure between 12 mm and 20 mm (equivalent to ages around four to 20 days – Figure 2), the bill-length and mass are well correlated and so their relative values should give a useful indication of the chick's condition. Over this range of bill-lengths, the (reduced major axis) regression is y = 3.88x – 37.98 (Pearson's r – 0.97; t = 21.0; $p < 0.001$).

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Predicting the hatching dates of Curlew *Numenius arquata* clutches

MURRAY C. GRANT

RSPB, The Lodge, Sandy, Bedfordshire SGI9 2DL, UK

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The number of days to hatching was highly correlated with an index of egg density in four study populations, the index of egg density being obtained from measurements of egg length, breadth and weight. Regression equations of days to hatching against the index of egg density did not differ significantly between study areas, whilst the overall equation predicted days to hatching with a mean error of approximately two days.

Introduction

During studies of breeding waders it is useful to be able to predict the hatching dates of nests under study since the chicks of many species leave the nest within a day or two of hatching and thereafter become extremely difficult to find and therefore ring or fit with radio-tags. The option of visiting nests throughout the incubation period with sufficient frequency to ensure that successful hatching is confirmed is often impossible (due to time constraints) and may not be desirable since such frequent visiting may increase the possibility that observer activities will influence the outcome of the nesting attempts. Since egg density decreases during incubation (Rahn & Ar 1974) it is possible to produce regressions between days to hatching and an index of egg density based upon measurements of egg length (L), breadth (B) and weight (W) – i.e. W/LB^2. Such equations have been produced for several wader species, including Redshank *Tringa totanus,* Snipe *Galllnago galllnago,* Lapwing *Vanellus vanellus* and Black-tailed Godwit *Limosa lapponica,* and these allow prediction of hatching dates from the relevant egg measurements (Green 1984; Galbraith & Green 1985). Equations have been obtained from different study populations of Lapwing and Redshank which have demonstrated inter-population variation in patterns of egg weight loss with time to hatching for Lapwing (Galbraith & Green 1985) but not for Redshank (Green 1984). In this note data are presented on the relationship between days to hatching and the egg density index (W/LB^2) for Curlew *Numenius arquata* from four different study populations.

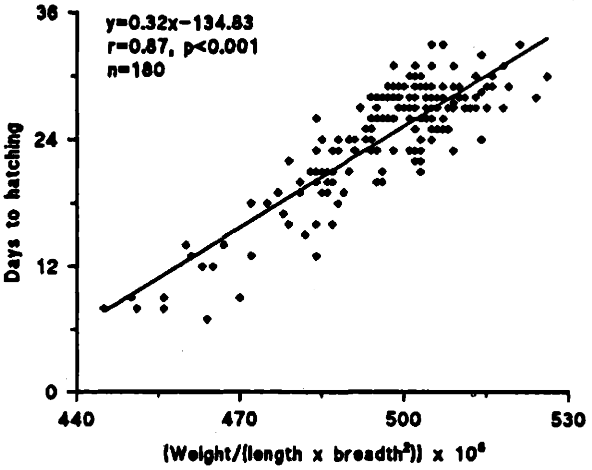

Fig. 1. Days to hatching for Curlew clutches in relation to the mean egg density index of clutches. Data are taken from four different study populations.

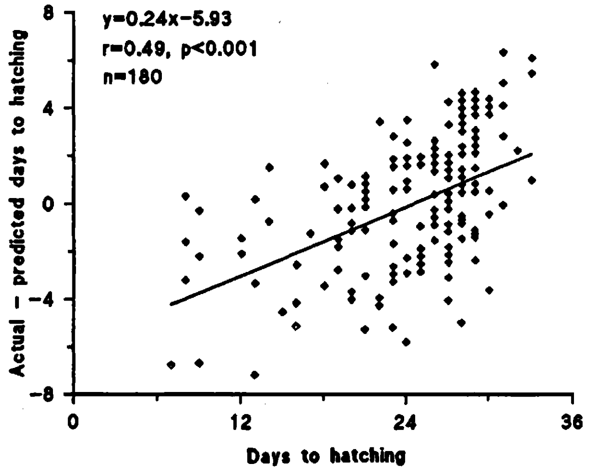

Fig. 2. The difference between actual days to hatching and those predicted from the relationship in Fig. 1, in relation to the actual days to hatching.

Methods

Data were collected during studies of breeding Curlew undertaken in the Orkney Isles, north-east Scotland (from 1990–1992), Co. Antrim, Northern Ireland (1993–1995), Lough Erne, Co. Fermanagh, Northern Ireland (1994–1995), and the Northern Pennines, north England (1995). Study areas in Orkney and Lough Erne were at low altitudes (10–70 m a.s.l.), whilst the Antrim and Pennines study areas were at altitudes of 200–400 m, and 300–400 m a.s.l., respectively. Habitats comprised mixtures of Heather *Calluna vulgaris* moorland with wetland and wet grasslands on the Orkney study areas, wet grasslands on the Lough Erne study areas, and rough, marginal grasslands on the Antrim and Pennines study areas.

Maximum lengths and breadths of each egg in each clutch were measured to the nearest 0.1 mm using vernier calipers and weight was measured to the nearest 0.5 g using a 100 g Salter, or a 300 g Pesola spring balance. The egg density index was then calculated as $(W/LB^2) \times 10^6$, and the mean value taken for each clutch. Hatching was determined in most cases by visiting nests whilst the chicks were still in the nest, or by finding recently hatched chicks close to the nest. Where this was not possible (12 nests) successful hatching was determined from the facts that, eggs were last observed in an advanced stage of chipping, remains indicative of hatching (e.g. shell membranes) were found later in the nest, and alarm calling adults were nearby. Thus, for almost all successful nests hatching dates were known precisely, whilst for the remaining few they were known to within one to two days. Egg measurements were taken from each clutch once only (usually on locating the nest) and no eggs were measured after eggs in the clutch had started chipping.

Results

As expected, days to hatching was highly correlated with the index of egg density (Fig. 1). Within each study area there were no significant differences between years in either the slopes or the elevations of the regression of days to hatching against egg density, i.e. for:

a. Orkney; slope, $F_{2.87} = 0.43$, $p > 0.05$, elevation, $F_{2.89} = 0.55$, $p > 0.05$;
b. Co. Antrim; slope, $F_{2.14} = 0.14$, $p > 0.05$, elevation, $F_{2.16} = 0.39$, $p > 0.05$; and
c. Lough Erne; slope, $F_{1.43} = 0.95$, $p > 0.05$, elevation, $F_{1.44} = 0.47$, $p > 0.05$.

Thus, data from different years on each study area were combined to test for between study area differences. Between the study areas no significant differences occurred in either regression slopes ($F_{3.172} = 0.27$, $p > 0.05$), or elevations, though the differences were close to significance for the elevations ($F_{3.175} = 2.45$, $p = 0.07$).

The overall regression equation tended to underestimate days to hatching when eggs were measured in recently laid clutches, and progressively overestimated days to hatching when eggs were measured from approximately 20 days to hatching onwards. This tendency was sufficiently pronounced as to produce a significant correlation between the residuals from the original regression and days to hatching (Fig. 2). As in previous studies (Green 1984; Galbraith & Green 1985) it was possible to remove this bias in the prediction of days to hatching by producing a predictive equation from the regression of egg density against days to hatching (as opposed to regressing days to hatching against egg density). However, from the practical point of view of using these data to predict hatching dates, two factors were considered to make this approach less satisfactory than that of using the original regression equation. First, the overall difference between the predicted and actual days to hatching was greater when the equation was derived by regressing egg density against days to hatching (the mean value of the magnitude of differences being 2.61 ± 0.12 s.e., as opposed to 2.16 ± 0.12 s.e.). Second, when using this equation in any future studies it will be possible to determine from the estimated days to hatching whether it is likely to be an underestimate or over-estimate, and thus make allowances for this in deciding when next to visit a nest.

The performance of the regression equation as a predictor of days to hatching was tested by constructing the regression using data from three of the four study areas, calculating predicted values for the fourth study area and comparing these with the actual values. This was carried out for each of the four study areas in turn, demonstrating that estimates from the regression tend to have a mean error of approximately two days (Table 1).

Discussion

Results presented in this note demonstrate that it is possible to estimate hatching dates of Curlew nests with reasonable precision using regressions of days to hatching against W/LB^2. The relationship between days to hatching and the egg density index did not differ significantly between the four study populations. Also, the levels of error in the predictions of days to hatching for each of the four study populations were similar when using equations derived from data which excluded that particular population. Thus, it is likely that the equation obtained from the present studies will be applicable to study populations elsewhere, at least within the British Isles (bearing in mind the biased predictions likely to be obtained for clutches measured relatively close to hatching).

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Table 1. Magnitude of differences between predicted and actual days to hatching for four study populations. Predicted values for each study population are calculated from a regression based upon data from the remaining three study populations.

Study area	Mean (±s.e.)	Maximum	n
Orkney	2.19 (±0.18)	6.79	93
Antrim	2.21 (±0.40)	6.67	20
Lough Erne	2.29 (±0.23)	5.69	47
Pennines	2.30 (±0.35)	6.64	20

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