BODY-WEIGHT CHANGES OF EGG-LAYING CURLEWS *Numenius arquata*, AS MONITORED BY AN AUTOMATIC WEIGHING SYSTEM

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ABSTRACT The fluctuating body-weight of free-living female Curlews during egg-laying is described. Weight data were collected using an automatic weighing system. Nests were placed on top of an electronic balance and the data were processed in a computer placed at a distance. The equipment is commercially available, thus permitting its use without a technical staff.

INTRODUCTION

Weighing free living birds during daily activities has been used increasingly as a research method in recent years. In most cases the nest provided the opportunity to weigh the birds, by placing it on top of a balance (Sibly & McCleery 1980, Westerterp *et al.* 1982, Fry *et al.* 1984, Prince & Walton 1984, Wijnandts 1984, Jones 1987). In other instances perches mounted on balances have been used to weigh both captive and free living birds (Newberry *et al.* 1985, Crick & Fry 1986, Reid 1986, Moreno 1989). Especially if combined with a study of behaviour, this method may yield valuable information on various aspects of a species' ecology during the breeding season. In systems used to date either remote readings are made by an observer, or periodical readings are collected by a data logger. The first method is especially worthwhile if several balances can be used at the same place, e.g., with colonial birds, but is very time-consuming for solitary breeding species.

Here we present a weighing method, as well as some results obtained with it, which has certain advantages over methods used by most other authors:

(a) The system monitors weight continuously and can be programmed by the researcher, for instance to react to sudden weight changes. It can therefore record situations of very short duration, such as when a nest is vacated for a few seconds during an incubation relief. Moreover, the amount of data to be stored can be kept at a minimum, if data storage is limited to the interesting moments only.

(b) The accuracy of the system is high, thus allowing its application with small species.

(c) The system can be applied by researchers who do not have the back up of technical staff, because the main equipment can be bought ready for use.

This automatic weighing system enabled us to monitor the body-weight of the shy ground-nesting Curlew (*Numenius arquata*) during the breeding season, because disturbance could be kept minimal.

MATERIALS AND METHODS

Hardware

Our basic weighing system consists of an electronic balance (Sartorius 1500 MP8 or E 12000S, accuracy 0.1 g, capacity 11 kg, RS 232 serial interface) connected via two cables with a small computer (Epson HX20 with microcassette-drive and 16 or 32 Kbyte RAM) and some form of power supply, both located at a distance. In principle any combination of a balance with a RS 232 serial interface and a (field) computer will do. Data collection is governed by a program written in Basic. The principles of the program as we wrote it are explained in the Software section. A supplementary device (Interface IFH S1/3) enables the linkage of the computer to two balances at the same time; C. Swennen applied such a configuration to monitor body-weight of nesting Eiders (*Somateria mollissima*) (pers.comm.).

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Under normal outdoor conditions, without interference from electro-magnetic fields, a simple 6 core cable without shielding will do, to bridge a distance of up to 300 meters between balance and computer. The balance required a power supply of 220 V AC; if the system was used far out in the field, the current supply was provided from a 12 V DC battery, by way of an inexpensive DC to AC converter (Mascot Inverter 8350/12 V, Fredrikstad, Norway). The weighing system would work 48 hrs on 1 completely charged 90 AHr battery. The Epson HX20 computer has a built-in rechargeable Ni-Cd battery, but is usually connected (with an AC adapter) to the same power supply as the balance. As soon as the voltage of the power supply drops below a certain value, the computer turns itself off; with the remaining current the contents of the memory are protected for a long time.

Software

The computer program for use with the Curlew was designed to collect the weight data at the interesting moments only, such as when a bird left the nest. Only the data just before and directly after a major weight change were stored. The advantage of this design is that an accumulation of unnecessary data, from a stable balance, is prevented. The difference between two adjacent measurements (one of the nest plus bird (Figs 1A & D) and one of the empty nest (B and C)) yields the net body-weight of the bird (i.e. A minus B, and D minus C).

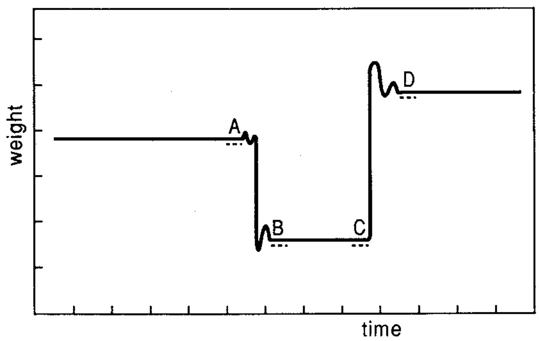

Fig. 1. Schematic path of the weight of the nestbox during an incubation relief of the Curlew, with sexual body-weight dimorphism, the female being heavier than the male. A: male on the nest. B, C: nest empty. D: female on the nest.

The program is continuously collecting data from the balance. The balance-readings enter the computer in a rate of about three per second. Every reading is compared with the previous one. As long as the balance is stable within predefined limits the new reading is added to a list (in temporary memory) of the last 20 readings, while the oldest reading is dropped from this list. A slow increase or decrease of weight, as for instance caused by the steady drying out of the turf beneath the nest, does not hamper this process. Only if the newest reading differs more than a predefined amount (the threshold value, e.g., 15 g) from the previous one (at point A), the mean and standard deviation of the last 20 readings are written into a sequential file in RAM, together with the time of day.

The program then tries to build up a new list of 20 steady readings. Any movement of the balance, however, will disrupt this process, causing the build up of the list to start again. As soon as the list is complete (at point B), the mean and standard deviation of these first 20 readings after a weight disturbance are written to the sequential file in RAM, together with the time of day. Then the program starts again, waiting for another movement of the balance.

The data, stored in RAM, can be written to tape with the microcassette-drive to be processed later, or can be printed on paper with the built-in micro-printer. If the RAM reaches capacity, the computer program will write the contents of the memory to tape, and start itself again, overwriting the old data in RAM.

A listing of the computer program is available on request.

Application in the field

The automatic weighing system has mainly been applied in a research project on the Curlew in three different areas: a sanddune area on the North Sea coast of The Netherlands (during three breeding seasons), an agricultural grassland area in the east of The Netherlands (one breeding season) and a bog area in boreal Sweden (one breeding season).

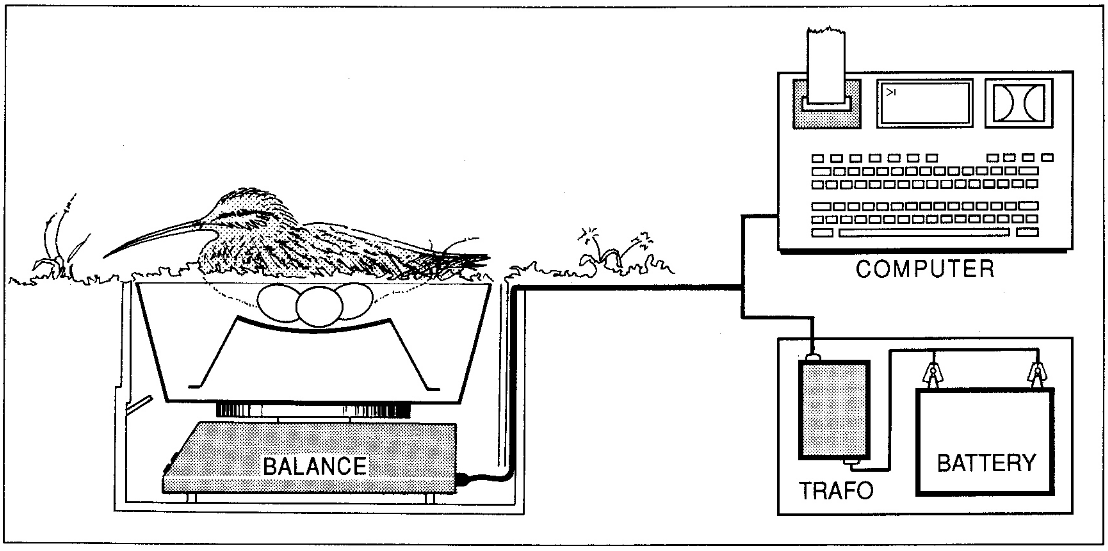

Fig. 2. Situation of the Curlew nest after installation of the weighing equipment (drawing by H. Schekkerman).

The installation of the balance underneath a Curlew nest took two to three hours, and was usually done during the last hours of the night. Curlews in the dune research area, when disturbed from their nests during the night, tend to stay away until first light. The nest was replaced by an artificial cup of the same size, the original nest lining was put back and great care was taken in reconstructing the vegetation around the nest. The artificial nest and the surrounding vegetation were placed in a box, measuring 34 x 34 cm and 14 cm deep, which was placed on top of the balance. The balance in turn was placed in a watertight case, dug into the ground at the nest site (Fig. 2). The nest box fitted rather tightly into this case, leaving a square gap of two to four mm width: this was the only alteration visible to the birds. The balance was placed somewhat elevated in its case, to prevent it from getting wet by water trickling in through the slit during rainfall.

In the dune area the cables between nest-balance and other equipment were dug into the ground for their entire length, to prevent detection of the equipment by people; for the Curlews it sufficed to conceal only the first few meters. The computer, battery and converter were placed in a case at a distance of 50 to 100 meters from the nest, out of sight behind a ridge or bush, thus enabling visits without disturbing the birds. To minimize the chance of disturbance most visits to the equipment were made during the night. The nest itself was visited for inspection two to four times only during the incubation period of 29 days. Dirt and overgrowing vegetation were removed from the slit around the nest, and, if necessary, accumulated rainwater was drained from the nest box.

The computer was sealed in a transparent polythene bag, with a narrow slit for the paper emerging from the microprinter. Every night or every 36 hours the battery was changed and the data in the memory were printed on paper. The computer program was then restarted with an appropriate threshold value, depending on the amount of wind, i.e. expected movement of the balance. In normal weather conditions a threshold value of 10 or 15 g was used for the Curlews, which themselves weighed 600 to 900 g.

RESULTS

Twenty-two Curlew nests were tested with the system, three of which were deserted as a result of the installation: two in the laying phase and one with a recently completed clutch. Of the nineteen nests which were accepted by the birds, nine contained incomplete clutches, whilst ten were complete, having been incubated for a period ranging from 0 to 22 days. Most of the weighing results will be published separately.

For seven females, five from the Dutch dune region, one from the grassland area and one from the swedish bog area, weighing data were available from the laying period. Curlews generally produce clutches of four eggs. Since the exact site of the nest, a scrape in the ground, cannot be predicted, the balance can only be installed after the first egg has been laid. Body-weight data from the seven egg-laying females are presented in figure 3.

Although the number of cases is still low, we may tentatively derive a general pattern of body-weight change during egg-laying in Curlews, with the following features (results given in mean ± *SD*):

(a) Eggs are being laid with an interval of about 36 hours, often alternately in early morning and late afternoon (length of all seven intervals from figure 3, plus interval A 1-2 as established by observation: 36.3 ± 4.9 hours, $n = 8$).

(b) In the intervals between eggs the female gains weight rapidly, often reaching the same body-weight level as before the last egg laid. Maximum rate of weight increase during each laying interval varies from 3.7 to 19.3 g per hour, and is on average 8.9 g per hour (only measuring intervals of more than 100 minutes taken into account; $n = 9$). Female C shows an extreme weight gain of 25 g in only 19 minutes, in dry weather, during the interval between egg 3 and 4.

Total weight increase in each interval (difference between lowest and highest weight during an interval) is 78.0 ± 17.7 g ($n = 5$). Because the fresh egg-weight (in the dune research area) is 75.2 ± 5.7 g (own obs., $n = 29$), the female can generally regain its lost body-weight completely.

(c) Although the female curlew clearly has the capacity to regain all of its lost body-weight during a laying interval, it does not do so in most cases. Especially in the last laying interval the body-weight of most females starts to decrease after

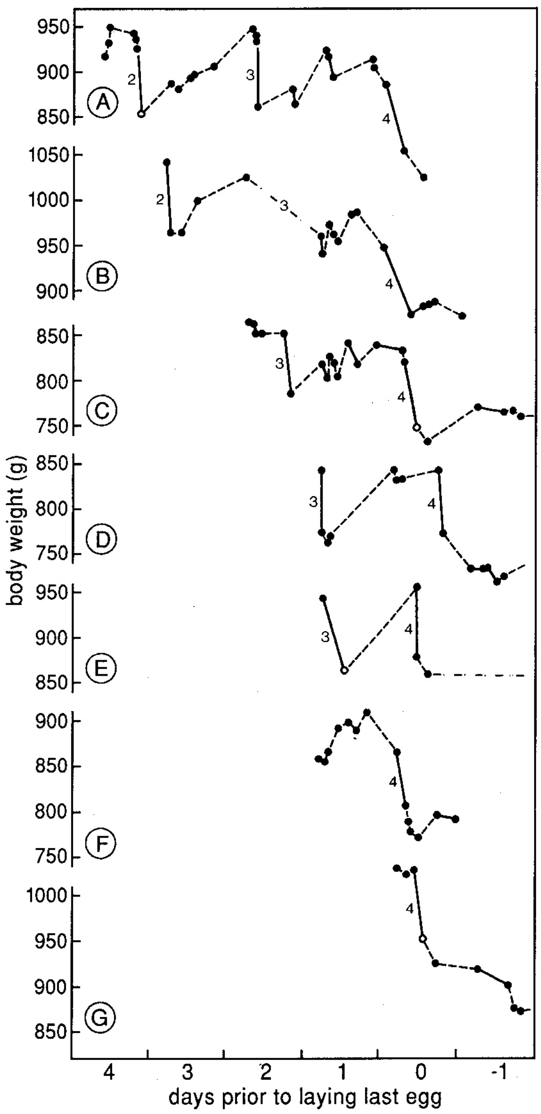

Fig. 3. Data on body-weight of egg-laying female Curlews (individuals A to G). Solid lines: female on the nest; dotted lines: female off the nest (at least part of the time); widely broken: missing data. A sudden decline in body-weight denotes the laying of an egg, indicated by its ranking number. Measurements started before laying the second egg in two females (A and B), the third egg in three females (C to E) and the fourth and last egg in two females (F and G). Open circles: female body-weight not directly measured, but reconstructed from egg weight.

having reached a maximum 9 to 19 hours before the laying of the last egg. This is of course visible only when enough measurements are available, in five of the seven females. In four of these five females, the decrease in the last interval between maximum weight and weight just before egg-laying is 34.9 ± 9.5 g, with a maximum of 42.6 g; the body-weight of female D stays at the same level during the last 14 hours.

In the three cases were measurements are available in the period before laying the second or third egg (eggs A2, A3 and C3), the maximum weight decrease is only 12.1 g (mean 11.6 ± 0.7 g).

(d) Whereas the body-weight invariably starts to increase immediately after the laying of the second and third egg (n = 6; a slight initial decrease of 11.6 g only after egg D3), the body-weight generally decreases during the first hours after the laying of the last egg (6 out of 7 cases). This decrease is 25.1 ± 9.5 g (n = 6), with a maximum of 39.1 g (female D). Some birds subsequently loose more weight (D,G), others gain weight (C,F) in the next few days, but no female regains the high body-weight of the egg-laying period.

(e) The combined weight decrease just before (c) and just after (d) the laying of the last egg (excepting the egg-weight itself) is on average 50.0 ± 12.1 g (n = 5, data available for females A, B, C, D and F). The overall difference in body-weight level between the egg-laying phase and the incubation-phase (difference between maximum body-weight before the last egg and the average early morning body-weight during the first two to five days of incubation, substracting egg-weight) varies considerably between birds, and is on average 25 ± 31 g (n = 5, data available for females B, C, D, E and G). It is negative in female E only, which means that its total weight loss is less than egg-weight. This may have been caused by the lack of measurements between egg 3 and 4.

DISCUSSION

Automated weight registration of free living birds on their nest yields a variety of information, the simplest of which is the nest attentiveness. If the species under study shows sexual body-weight dimorphism, the respective contributions of male and female in the nest attentiveness can be established as well. This kind of registration may also produce data on disturbances of the normal pattern, for instance by people or predators. In our research we could, for instance, record how a predator (most likely a corvid) took the opportunity to steal a Curlew egg immediately after an inspection visit by us to the nest, and how a Spotted Flycatcher (*Muscicapa striata*) nest with fledglings was eventually robbed by a Magpie (*Pica pica*), as judged from its recorded body-weight.

From the pattern of body-weight change in the egg-laying female Curlews it is possible to make deductions about the physiological processes taking place. Complete development of the follicles (i.e. the rapid growth stage) in the ovary of larger bird species like chickens and gulls takes seven to ten days (Rickleffs 1974). For the Curlew this period is in accordance with the minimum time required for the production of a replacement clutch, never less than ten days (own observations). Most of the growth of the follicles of all four eggs should therefore have taken place before the first egg is laid. In the 6-day period of actual egg laying the albumen and the shell have to be added to complete the egg; this takes place in the oviduct, during the laying interval. The rapid increase in body-weight during the 36 hour laying interval, sometimes as fast as 25 g in 19 minutes, must largely be due to the intake of water, which constitutes 86-90 % of the albumen (Rickleffs 1974). In precocial species like the Curlew the albumen makes up about 54 % of the total egg weight (Rickleffs 1974), which means that the albumen of a Curlew egg contains about 36 g of water. An intake of 36 g of water only partly explains the average maximum weight increase of 78 g during an egg-laying interval. Most of the remaining weight increase may however also constitute water intake, because:

(a) weight loss during short periods of nest attentiveness in between the laying of eggs is rather high and may only be explained by evaporation of water (Fig. 3, see interval A3-4, B3-4, C3-4 in com-

Table 1. Number of minutes per day spent foraging and resting, by female Curlews in two research areas and in three periods: just before egg-laying, in the egg-laying phase and in the incubation phase. Calculated from direct observations during one to three complete days in each phase.

	fase	pre-breeding	egg-laying	incubation
foraging	Dutch dunes	310	163	328
	Swedish bogs	622	342	485
resting	Dutch dunes	499	558	167
	Swedish bogs	189	325	43

parison with incubation bouts on day 0 and -1 in females C, F and G);

(b) the time spent foraging in the egg-laying phase is much lower than in the pre-laying and in the incubation phase (see below).

According to Rickleffs (1974) the daily energy requirement of the female should be 40 to 60 % higher than normal in order to be able to produce the eggs, each of which is equivalent to about 225 % of the basal metabolic rate of the bird. Observations of the behaviour of the female curlews, however, indicate that they spend a lot of time resting instead of foraging in the egg-laying phase (Table 1, own prelimary observations). This suggests, together with the high foraging intensity in the days before egg-laying, that most of the energy reserves required for the production of eggs has already been accumulated before egg-laying starts, probably partly already in the wintering quarters: the average body-weight of wintering Curlews on the isle of Vlieland rises sharply from March to April (Glutz von Blotzheim *et al.* 1977).

Body-weight decrease just before and directly after the laying of the last egg may be explained by the shrinkage of the ovary and oviduct, which apparently starts as soon as the production of the last egg is finished, many hours before it is laid. In Pheasants (*Phasianus colchicus*) the ovary and oviduct shrink during incubation by 95 and 89 % resp. of the weight they have in the laying period (Rickleffs 1974).

Although the costs of the automatic weighing system, about £ 1800, may be a problem for small research programs, its easy applicability and versatility are great advantages. The main equipment can be bought ready for use. Some dexterity and some acquaintance with BASIC is required to install and operate the system without the help of technical staff. If it is not possible to connect the system to the electrical mains it may be a drawback that the system requires frequent renewal of batteries. Once in operation data collection can proceed with a minimum of disturbance and a maximum of precision and alertness.

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SAMENVATTING

Met behulp van een geautomatiseerd weegsysteem, een combinatie van een kleine computer en een electronische balans, kon het gewichtsverloop van broedende wulpen worden gevolgd met een minimum aan verstoring. Een beschrijving van het weegsysteem en de toepassing ervan in het veld worden gegeven. Daarna worden resultaten gepresenteerd over het fluctuerende lichaamsgewicht van vrouwtjes-wulpen tijdens de eilegperiode. Het bleek dat de eieren werden gelegd met een interval van 36 uur, afwisselend in de ochtend en de avond. Tussen het leggen van de eieren (gewicht 75 g) vond een snelle gewichtstoename plaats, waarschijnlijk vooral veroorzaakt door inname van water, dat bijna 90 % van het albumen in een ei uitmaakt. Hierdoor keerde het lichaamsgewicht vlak voor het leggen van een ei steeds ongeveer op hetzelfde niveau terug. Alleen vlak voor het leggen van het vierde en laatste ei trad in de meeste gevallen een afname van het lichaamsgewicht op. In de eerste uren na de eileg daalde het lichaamsgewicht meestal nog verder. Deze verschijnselen zouden veroorzaakt kunnen worden door het slinken van ovarium en oviduct, dat wellicht reeds begint een aantal uren vóór het laatste ei gelegd wordt.