Incubation period of Moorhens *Gallinula chloropus* in southern Europe

S. Ignacio Encabo

Incubation period is a trait commonly employed in studies of breeding ecology to estimate laying and/or hatching dates of clutches. Several studies at northern latitudes have reported incubation periods of 25–26 days for the Moorhen *Gallinula chloropus*. However, in North Africa incubation in this species only lasts 22 days and so there may be some geographical variation in the length of the incubation period. Here, the incubation period of 42 clutches from a population in eastern Spain was estimated. The mean length of incubation was 23.7 days (SD = 1.3; range = 21–26). Despite decreasing as the season progressed, clutch size had no effect on the length of the incubation period. It is likely that Spanish populations have shorter incubation times than northern European populations and that knowledge of laying dates can be used to obtain more accurate estimate of these times.

Key words: Moorhen, *Gallinula chloropus*, backdating, incubation period, laying date, L'Albufera Natural Park.

S. Ignacio Encabo, *c/Melissa 17-6, 46980 Paterna, Valencia (Spain), e-mail: encabo@uv.es*

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Studies of the breeding ecology of birds are usually based on repeated visits to nests. However, finding natural nests is often difficult because birds conceal them to avoid predation. This implies that some nests are discovered when the clutch has already been completed and incubated for an unknown period of time. Given that the laying date is an important parameter with implications for fitness (Verhulst & Tinbergen 1991, Brinkhof *et al.* 1993, Barba *et al.* 1995), its precise determination is important in studies of avian ecology.

Laying dates can be estimated in a number of ways using the progressive water loss that occurs in eggs during incubation (Furness & Furness 1981, Nol & Blokpoel 1983, van Paassen *et al.* 1984, Cempulik 1993). However, such techniques imply clutch manipulation (recording sizes and masses of eggs) and previous knowledge of the rate of water loss. Furthermore, this rate probably varies in terms of air temperature, egg size and the micro-climatic features in the immediate area around the nest, which thus reduces the usefulness of this technique. In fact, differences in rates of water loss between populations have been found (Galbraith & Green 1985).

Another method involves visiting nests frequently until eggs hatch and then determining the laying date by backdating, a method that requires knowledge of the duration of the species' incubation period.

Available information on the incubation period of the Moorhen *Gallinula chloropus* is uneven. Some studies use fixed periods between the laying of the first egg and hatching, which in North Africa was 22 days (Samraoui *et al.* 2013, Meniaia *et al.* 2014) but 26 days in northern latitudes in North America (Krauth 1972, Brackney & Bookhout 1982, Helm *et al.* 1987). Other studies, however, consider that the incubation period increases positively in relation to clutch size (Huxley & Wood 1976, Gibbons 1986). Gibbons (1986) estimated that one extra egg was equivalent to an extra 0.4 days of incubation. Thus, if clutch sizes vary in the range 5–9 eggs (Cramp 1998), the incubation period will be in the range 23–25 days (using Gibbons' estimation). However, other reproductive traits are also susceptible to affect the length of incubation and, in fact, some studies have shown that incubation periods decrease in length as the breeding season

progresses (MacRoberts & MacRoberts 1972, Hötker 1998, Brown & Brown 1999). Therefore, the effect of laying date on the incubation period should also be considered.

The aims of the present study are to (1) estimate the incubation period of moorhens in southern European populations given that geographical variation seems to exist (Martin 2002, Chalfoun & Martin 2007, Martin *et al.* 2007) and currently available information comes mainly from northern populations, and (2) evaluate the influence of clutch size and laying date on the incubation period to facilitate the choice of a more precise backdating method.

Material and methods

Fieldwork was carried out in a small coastal pond, Estany de La Plana, L'Albufera Natural Park (Valencia, E Spain, 39°16'N, 0°17'W), which lies in an area of rice paddies and has fringing vegetation largely dominated by reeds *Phragmites* spp. and reedmace *Typha* spp.

For seven years (1997–2000 and 2014–2016) periodical inspections of the lagoon shores from mid-March to late August were carried out to locate Moorhen nests. When a nest was found it was checked weekly to determine basic breeding parameters. The laying date (of the first egg) was calculated only in incomplete clutches based on the assumption that female moorhens lay one egg daily (Wood 1974, McRae 1996a). The hatching date was initially taken to be the day of the visit when chicks and eggs were observed in the nest simultaneously. However, Moorhen clutches hatch asynchronously (Gibbons 1985, McRae 1996b), often over a period of 48 hours (Anderson 1965, Wood 1974), and so the hatching date was considered to be that of the day of the visit if less than half of the clutch had hatched, or the previous day if more than half of the clutch had hatched. Clutches thought to have suffered intraspecific brood parasitism (i.e. eggs of different size and tonality, additional eggs in complete clutches or more than one egg laid in a nest on a single day; but see Gibbons (1986) for more details) were ruled out. In the end, 42 broods with known laying and hatching dates were used. Although most were first breeding attempts, second and reposition clutches were also employed. All clutches belonged to different pairs and so data can be assumed to be statistically independent.

Data analyses were performed using the Statistica 7.0 statistical package (StatSoft 2004). In order to evaluate the effect of clutch size and laying date on the incubation period, a multiple regression model was used with the period between laying and hatching as the response variable, and egg-laying date and clutch size as predictors.

Results

The mean time (±SD) elapsed between laying and hatching was 23.7±1.3 days (median 24 days, 95% confidence limit: 23.3–24.1 days, $n=42$) in a range of 21–26 days (Figure 1). When the laying date and clutch size were taken into account, the whole regression model was statistically significant ($F_{2,39}=3.74$, $P=0.033$); however, only laying date showed a significant relationship with incubation period (Laying date: $F_{1,39}=5.42$, $P=0.025$; Clutch size: $F_{1,39}=1.38$, $P=0.246$). Thus, the length of incubation tended to decrease as the season progresses (Figure 2; regression line: $y=-0.014x+24.933$, $R^2=0.131$).

Discussion

Laying date is an important trait that is frequently used in studies on reproduction (e.g. Krebs *et al.* 2002, Both *et al.* 2005) and, given that it may affect several fitness parameters, it should be estimated as accurately as possible. Determining the hatching date is also important, for instance, in bird ringing, above all because it has been recently suggested that the hatching date is a more accurate parameter than the laying date when studying the optimal timing of reproduction in birds (Tomás 2015). Even so, knowledge of the length of the incubation period permits the calculation of the laying date for broods in which only the hatching date is known; as well, it is a way of determining the hatching date for broods that have been discovered early in the laying period.

Several studies at northern latitudes of the Moorhen have employed a constant incubation period of 26 days (Krauth 1972, Brackney & Bookhout 1982, Helm *et al.* 1987), although

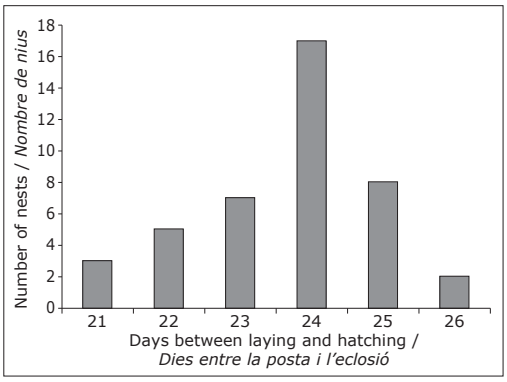

Figure 1 Frequency distribution of the incubation period (days between laying and hatching).
Distribució de freqüències del període d'incubació (dies entre l'inici de la posta i l'eclosió).

Huxley & Wood (1976) related this period to clutch size. These authors estimated incubation adding 22 days to the half the total number of eggs. In their study, the mean clutch size was 6.6 eggs and so the mean incubation period was calculated at close to 25 days.

Unlike the 25–26 days in northern populations, in North Africa laying dates have been inferred from hatching dates to give a length of incubation of 22 days (Samraoui *et al*. 2013, Meniaia *et al*. 2014). However, for moorhens breeding in eastern Spain the length of incubation is nearer to 24 days (this study). Thus, there seems to be geographical variation in the length of the incubation period. The increase in environmental temperature along the latitudinal gradient (warmer towards the south) would account for progressively shorter incubation periods in southern populations since warmer temperatures tend to reduce the length of incubation (Ardia *et al.* 2006, Hepp *et al.* 2006). However, this difference might also be due to reasons that are not exclusively related to geographical variation. For instance, eggs in southern populations are smaller than those in northern ones (Cramp & Simmons 1980, Samraoui *et al*. 2013), probably due to smaller adult body sizes (Cucco *et al.* 1999), and it is known that larger eggs take longer to incubate (Rahn & Ar 1974, Ricklefs & Starck 1998). Whatever the reason for these latitudinal differences, 24 days would seem to be a more accurate length of time for southern European populations. Other factors also affect the length of incubation (e.g. Murphy 1995; Yogev *et al.* 1996, Engstrand & Bryant 2002) and should be used for more accurate estimations. In the present study, the incubation period decreased as the season progressed, as has been reported in other species (e.g. Galbraith 1988, Murphy 1995, Brown & Brown 1999). Warmer temperatures during the breeding season probably shorten the incubation period (Ardia *et al.* 2006, Hepp *et al.* 2006). However, the relationship between incubation and laying date show considerable dispersion (low regression coefficient), which might limit the use of laying date as an accurate covariate.

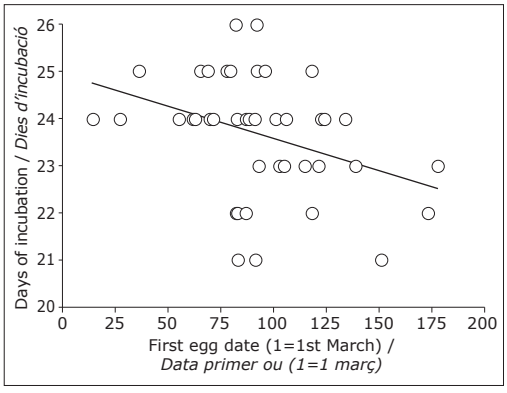

Figure 2 Relationship between the duration of incubation and laying date.
Relació entre la data de l'inici de la posta i la durada de la incubació.

I found no relationship between clutch size and incubation period, despite the fact that the length of incubation increases with clutch size (Gibbons 1986, Hötker 1998, Engstrand & Bryant 2002). The effect of clutch size could be reduced if parents exhibit higher nest attentiveness, lay smaller eggs or modify the onset of incubation; however, none of these factors were taken into account in this study.

In conclusion, 24 days should be considered as the period occurring between laying and hatching dates in Moorhens in southern Europe for backdating purposes, although for more accurate estimates the laying date could also be taken into account.

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Resum

Període d'incubació de la Polla d'aigua Gallinula chloropus *al sud d'Europa*

El període d'incubació és una eina emprada freqüentment als estudis sobre l'ecologia reproductora per estimar la data de posta i/o eclosió de nius. En la Polla d'aigua *Gallinula chloropus* diversos estudis en poblacions septentrionals han considerat períodes d'incubació de 25-26 dies. Al nord d'Àfrica, però, es consideren només 22 dies. Per tant, sembla existir cert grau de variació geogràfica en el període d'incubació. En aquest treball s'ha estimat el període d'incubació de 42 nius localitzats a l'Estany de La Plana (Parc Natural de l'Albufera de València). La mitjana del temps d'incubació fou de 23,7 dies (desviació típica = 1,3 dies; rang = 21-26 dies). Aquest període va disminuir al llarg de l'estació reproductora mentre que el nombre d'ous no va tenir cap efecte. Proposo considerar un temps d'incubació més curt que en poblacions del nord d'Europa, tenint en compte la data de posta per obtenir estimacions més precises.

Resumen

Período de incubación de la Gallineta común Gallinula chloropus *en el sur de Europa*

El periodo de incubación es una herramienta comúnmente empleada en los estudios sobre la ecología reproductora para estimar la fecha de puesta y/o eclosión de los nidos. En la Gallineta común *Gallinula chloropus* diversos estudios en poblaciones de latitudes norteñas han considerado periodos de incubación de 25-26 días. Sin embargo, en el norte de África únicamente consideran 22 días. Por lo tanto, parece existir cierto grado de variación geográfica en la duración de la incubación. En este trabajo, se ha estimado el periodo de incubación de 42 nidos localizados en el Estany de la Plana (Parque Natural de l'Albufera de Valencia). El tiempo promedio de incubación fue de 23,7 días (desviación típica = 1,3 días, rango = 21-26 días). Este periodo se redujo a lo largo de la estación, mientras que el tamaño de puesta no tuvo ningún efecto. Propongo considerar un tiempo de incubación más corto que en poblaciones europeas norteñas, teniendo en cuenta la fecha de puesta para obtener estimaciones más precisas.

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