APPENDIX 1

A photographic and morphometric guide to aging Gyrfalcon nestlings

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A1.1 Introduction: the importance of estimating nesting phenology

Nesting phenology is an important parameter in raptor biology used to quantify territory quality and for understanding factors that affect population productivity and stability, such as weather and food supply (Newton 1991, 1998). The accurate estimation of nestling ages is an easy way to establish nesting phenology, including dates for clutch initiation, hatching, and fledging. Nestling ages are also useful to inform the actions of field researchers, such as planning dates for banding of nestlings and collection of prey remains (Booms and Fuller 2003, Marti et al. 2007, Varland et al. 2007). Photographic aging guides are a useful tool for aging raptor nestlings, and within Falconidae have been written for American Kestrel (*Falco sparverius;* Kluscarits and Rusbuldt 2007), Prairie Falcon (*Falco mexicanus;* Moritsch 1983), and Peregrine Falcon (*Falco peregrinus;* Clum et al. 1996), but not for Gyrfalcon.

The primary aim of this work is to assist researchers in determining the age of Gyrfalcon nestlings from hatch to fledging on the basis of photographic images and morphological measurements, and to establish important dates in nesting phenology. Such a tool provides a quick and easily interpreted reference to aid in aging nestling Gyrfalcons. A photographic aging guide is especially useful for observers who cannot access a nest either for lack of training or applicable research permits, or who through prudence opt to observe a nest from a distance and reduce disturbance to the Gyrfalcons. A photographic guide can also help minimize disturbance times if researchers take photos of nestlings, and then compare these to the aging guide after leaving the nest area. When doing so, placement of a ruler or object of known dimensions in the nest will help approximate the size of the nestlings.

We caution against entering nests with nestlings aged <15 days old. Nestlings at such a young age are susceptible to mortality from cold weather, and young can perish if the female remains absent from the nest long enough due to disturbance. Additionally, a female that is surprised by a human observer and flushed from the nest may accidentally knock small young from the nest. Also note that nestlings ≥ 35 days old may fledge prematurely when disturbed.

We point out that individual variation in nestling development can derive from intrinsic and extrinsic factors such as sex, diet, and level of parental investment. Also, nestlings often hatch asynchronously, and the ages of nestlings in the same nest can differ by multiple days. Therefore, a photographic aging guide should serve as a best approximation for nestling age and for calculating parameters such as nest initiation, hatch date, and fledge date. Nestling ages can also be calculated from morphometric measurements taken by researchers with appropriate permits and scientific justification. We therefore include equations to calculate nestling ages based on morphometrics.

A1.2 Methods: Gyrfalcon natural history

After a monogamous courtship period ending in late March to early April (low Arctic) or late March to mid-May (high Arctic), female Gyrfalcons lay clutches of two to five eggs, with clutch sizes of three to four eggs more common at lower latitudes, and four to five eggs more common in the high Arctic (Burnham 2007). The egg-laying interval is approximately 60 hours (Platt 1977, Tømmeraas 1989), and it takes approximately 7.5 days to lay a clutch of four eggs. Observations on the commencement of incubation and synchrony of hatching are inconsistent and appear to vary with latitude. Platt (1977) in describing nesting behavior from Canada "believed" that incubation commenced with the penultimate (next-to-last) egg, but did not possess observational data in support of this claim. He observed both parents "sitting" on the incomplete clutch, but eggs were also left unattended for hours at temperatures as low as 5°C. K. Burnham (unpubl. data) reports that in Greenland incubation commences with the penultimate egg and lasts 35 days, and hatching is partially synchronous, with three eggs hatching at one time, and the fourth egg hatching two days later. In contrast, Tømmeraas (1989) reported that incubation commences asynchronously in Norway. He observed a female incubating her first egg <50% of the day, increasing incubation to 70% of the day with the second egg. Platt (1976) reported an incubation period of 35 days, although without specifics, and Woodin (1980) reported an incubation period of 35 days for the final egg from a clutch of four eggs in Iceland. We have heard anecdotal evidence of completely synchronous hatching, but published records (Woodin 1980) and photographic evidence from Alaska (B. Robinson, unpubl. data) show asynchronous hatching at intervals of 8 to 24 hours, which corroborates the observation of asynchronous initiation of incubation. In this manual, we follow data supported by observations (Woodin 1980, Tømmeraas 1989, K. Burnham unpubl. data) and assume asynchronous incubation, an incubation period of 35 days for the final egg, and asynchronous hatching. Once hatched, the nestling period lasts approximately 45 days for males and 49 days for females until fledging (Wynne-Edwards 1952, Cade 1960).

A1.3 Photographic record

Our description of Gyrfalcon nestling development is derived from photos taken by KKB of a single female produced and raised in captivity at The Peregrine Fund in Boise, Idaho, USA from hatch to age 35 days. In each photo a ruler aids in the measurement and description of feather development.

We further describe Gyrfalcon nestling development from photographs obtained at a single nest in western Alaska. We used a Reconyx PC-800 camera mounted on a cliff face adjacent to the nest to record the entire nestling period from before hatch to fledging, May to July 2015, one female and two male nestlings. Because we observed the time of hatching for all three nestlings, we provide their exact ages in hours for the first two days of life, and give their ages in round days thereafter.

A1.4 Aging via morphometrics

Gyrfalcon nestlings can be aged from measurements taken of mass, length of the seventh primary, and length of the central rectrix. We obtained Equations 2 and 3 used to age nestlings from measurements of body mass and length of the seventh primary, respectively, from Poole (1989). We (OKN) derive Equation 4 to age nestlings by the length of the central rectrix from measurements of 38 known-age nestlings in northeast Iceland from 1982 to 1996. We measured the central rectrix to the nearest mm with a ruler from the lip of the feather papilla to the feather tip along the straightened rachis when nestlings were 15 to 40 days old. Known age was regressed on central rectrix length to obtain Equation 4. We did not distinguish between males and females in the analysis. Analyses were done using STATISTICA and results were highly significant ($R^2 = 0.953$, $p<0.000$).

A1.5 Discussion: how to interpret the data

The estimation of nestling ages is a means to help us understand the nesting biology of birds, and not an end unto itself. Nestling ages inform us of important events in nesting phenology, chief of which is clutch initiation date. Clutch initiation date is a measure of territory quality (Newton 1991, Sergio and Newton 2003) and can be influenced by weather and prey availability during courtship. Nestling ages can also be used to estimate hatch date, fledge date, and to inform researchers who need to return and band nestlings at the appropriate age. To estimate nest initiation date from nestling ages, use Equation 1.

Equation 1 – Clutch initiation date (CID)
Clutch initiation date can be estimated from the age of the oldest nestling.

$$\text{Eq. 1) CID} = \text{JD} - \text{Age} - 35 - \text{OI}$$

where
CID = date first egg laid;
JD = Julian date of the nest observation;
Age = age of the oldest nestling;
35 = the incubation period starting with the penultimate egg (Woodin 1980); and
OI = Onset of Incubation. Assumptions:

1) Egg laying interval of 60 hours, therefore: 2.5 days are required to lay a clutch of 2 eggs, 5 days for 3 eggs, 7.5 days for 4 eggs, and 9 days for 5 eggs.
2) Asynchronous initiation of incubation begins with first egg, full incubation begins with the penultimate egg. Therefore, OI = egg-laying interval – 2.5 days.

Example: On June 15 (Julian date 166) a nest contains four nestlings, the oldest of which is 20 days old.

$$\text{CID} = 166 - 20 - 35 - (9-2.5) = 104.5 \text{ or} \sim 105$$

The estimated Julian date for clutch initiation is 105, or April 15.

A1.6 Aging nestlings via morphometric measurements

Equation 2 – Body mass

Body mass can be used to estimate ages for small nestlings aged 11 days or younger (Poole 1989).

$$\text{Eq. 2)}\ NA = -0.000069 * WT^2 + 0.057 * WT - 1.2$$

where NA is nestling age and WT is body mass (g).

Equation 3 – Length of seventh primary

Length of seventh primary and Equation 3 can be used to estimate the age of nestlings older than c. 11 days (Poole 1989).

$$\text{Eq. 3)}\ NA = 0.15 * PL + 11.7$$

where NA is the nestling age in days and PL is the length in mm of primary number seven. The seventh primary, counted from the carpal joint outwards, is measured with a ruler from the point of insertion in the body to the feather tip ventrally along the straightened rachis.

Equation 4 – Length of central rectrix

Length of central rectrix in mm and Equation 4 can be used to estimate the age of nestlings older than c. 13 days (Nielsen unpubl. data).

$$\text{Eq. 4)}\ NA = 0.1886 * CR + 13.649$$

where NA is the nestling age in days and CR is the length in mm of the central rectrix measured with a ruler from the lip of the feather papilla to the feather tip along the straightened rachis.

Hatch to 12 hours
Natal down is moist, matted, and unfluffed when the nestling hatches, but dries within approximately four hours. Chick capable of lifting head, but weakly, and most likely to be observed in a prostrate position unless being fed. Eyes closed, or if open, slit-like. Presence of egg shells and unhatched eggs may indicate recent hatching, but egg shells may be removed from nest by parents within hours of hatching, and infertile or dead eggs can be present for weeks (B. Robinson, unpubl. data).

Ages 0, 10 hours

Ages 6, 38, and 47 hours

Age 2–4 days
Natal down is white and fluffy. Nestling able to sit in upright posture, although unstable and not strong. Eyes are open and less slit-like, but not yet fully open.

Age 7–8 days
Natal down covers most of the back and dorsal surface of the wings, but is sparse on the breast and abdomen. Eyes are now fully open. Posture is increasingly upright.

Age 10–12 days
Second natal down is emerging, giving the overall down covering a lumpy appearance. Down remains relatively sparse with approximately 25% of skin visible and bases of down feathers visible. Unsplit sheaths of rectrices emerge.

Age 15–17 days
Second natal down is increasingly dense and now covering 90% of the nestling with little bare skin visible. Bases of individual down feathers no longer visible. Primary sheaths dark and plainly visible, length 2–3 cm. Primaries and greater primary coverts begin to break the sheath at approximately 17 days. Rectrix sheaths visible, length to 2 cm.

Age 19–21 days
Primaries and greater primary coverts have extended from the sheaths, and barring on feathers is plainly visible. Rectrices extend from sheaths by ≥2 cm. Auricular skin begins to darken, as does the down on crown of the head.

Age 24–26 days
Note the presence of scapular contour feathers. Auricular skin continues to darken in color and is increasingly feathered, and down on head turning increasingly gray. Rectrices to 10 cm in length.

Age 29–31 days

Feather development is rapid and nestlings are increasingly covered with contour feathers. Visible down on the back may be as low as 20% of total coverage, and down coverage on breast and abdomen approximately 50%. Contour feathers on the head are lengthening and feather patterning on head becomes evident. Feathers on the face nearly cover the auricular skin.

Age 34–35 days
By 35 days the majority of the nestling's body is covered in contour feathers, with visible down approximately 25% of total coverage. Primaries, secondaries, and rectrices are still blood-rooted and growing.

Age 40–42 days
Nestlings at this stage are nearly fully feathered, with down visible only in small patches.

Age 46–48 days
Nestlings have attained full juvenal plumage and exercise vigorously prior to fledging.

Glossary

Auricular – The area on the side of the bird's head behind the eye where the ear opening is located.

Coverts – Small contour feathers that cover the bases of flight feathers. Those on the upper (dorsal) surface of the body are called upper wing and upper tail coverts.

Crown – The upper part of the head.

Nape – The back of the neck.

Natal down – The layer of down feathers that is present on a bird when it hatches.

Second natal down – The layer of down feathers that a nestling grows over its first weeks of life.

Primary – The outer flight feathers of the wing that are attached to the carpal and metacarpal bones of the wing tip. On Gyrfalcons there are 10 primaries on each wing.

Rectrix (pl. rectrices) – The flight feathers of the tail. Gyrfalcons have 12 rectrices, six on either side of the tail.

Scapular – The area over the shoulders and along each side of the back.

Secondary – Flight feathers of the wing that are found proximal to the primaries, and which attach to the ulna. In Gyrfalcons there are 16.

Sheath – The wax-like keratinous material that encases and protects newly developing feathers as they emerge from the follicle.

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