House Wren Nestling Age Can Be Determined Accurately From a Guide of Digital Images

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ABSTRACT

Photographic guides to nestling development are intended to produce age estimates of nestlings with unknown hatching dates, but the accuracy of such guides is largely unstudied. We developed an aging guide for the first 16 days of post-hatch House Wren (Troglodytes aedon) *development. The guide included digital images, with scale bars, from a dorsal and lateral perspective for each day of development. Based on the guide, participants provided age estimates for 52 images randomly selected from 546 images collected from 75 known-age nestlings. Images were from either a dorsal or lateral perspective and may or may not have contained a scale bar. We determined 1) the proportion of age estimates within one day of actual age, 2) if image perspective or the scale bar influenced accuracy, and 3) if photographic guide aging estimates were more accurate than previous estimates based on body measurements. Overall, 88.4% of age estimates were within one day of actual nestling age. Based on mixed models, lateral or dorsal image perspectives did not influence aging accuracy and the presence of a scale bar influenced accuracy, but in an inconsistent manner. Nestling age estimates produced from the photographic aging guide were more accurate than those produced from body measurements.*

INTRODUCTION

Accurate estimates of nestling ages are important in studies of growth and development (Starck and Ricklefs 1998, Brown et al. 2007), nest success and chronology (Mayfield 1975, Paxton and Owen 2002), life history (Moritsch 1985), and avian management and conservation (Paxton and Owen 2002, Penteriani et al. 2005, Jongsomjit et al. 2007). Continual nest monitoring will yield accurate records of nestling age, but not all nests are located early enough for such monitoring and continual disturbance may influence nest success negatively. Due to the variability in development among young, even morphological measurements may not be useful in estimating ages of unknown nestlings (Brown et al. 2011). Several studies have produced photographic guides of nestling development for the purpose of estimating nestling age (e.g., Moritsch 1985, Boal 1994, Penteriani et al. 2005, Jongsomjit et al. 2007). Use of such guides might reduce the number of nest intrusions, nestling handling, and potential mortality at the nest, and also might save time and increase the accuracy of age estimates by observers.

Cautions about using photographic guides to estimate nestling age include growth discrepancies due to gender, nutrition, position in brood, brood size, and variability in growth within and among nests and across the species' range (Paxton and Owen 2002, Gossett and Makela 2005). Additionally, the subjectivity (Bechard et al. 1985), quality, perspective, and scale of the image as well as the experience level of the guide user might influence age estimates.

Despite these concerns, we could find no study that examined the accuracy of their photographic aging guide, nor any study that tested the accuracy of an aging guide produced by other authors. Thus, we do not know how well photographic aging guides work for any species. Here, we determined the proportion of nestling House Wren (*Troglodytes aedon*) age estimates, produced from a guide of digital images of known-age individuals, which were within one day of actual nestling age. We also examined whether the accuracy of age estimates was influenced by the perspective of the image–the dorsal or lateral view of the nestling–and the presence of a scale bar in the image. Finally, age estimates based on use of the digital image aging guide were compared to results of a previous study in which age estimates of individuals in the same population were produced using body mass and wing chord measurements of known-age individuals (Brown et al. 2011).

METHODS

Sixty Peterson-style nest boxes (Davis 1995) were established on Kutztown University property near Kutztown, Berks County, PA (approximately 40°32' 24" N, 75°48'0"W) in Mar 2008 (Brown et al. 2011). Thirty of the boxes were wooden and 30 were constructed of aluminum; interior dimensions of all boxes were similar (Kern et al. 2009). From Apr through Aug 2008 and 2009, boxes were checked nearly every day until eggs hatched and each nestling, on its hatch day, had its toenails uniquely marked with a paint marker. Digital images from a lateral perspective and a dorsal perspective were collected from individual House Wren nestlings during the 2009 breeding season. Some images contained a scale reference (a wing chord ruler), others did not. Only images of nestlings from successful nests, which included images of 75 different nestlings among 13 different nests, were used in this study. Attempts were made to collect images from nestlings on alternate days, or sometimes for several days in a row, weather permitting. Fewer images were collected for nestlings greater than 12 days of age because fledging began at this time. The ages of nestlings in each image ($n = 546$) ranged from one to 16 days of age, with the day of hatching considered as day one.

We created an aging guide that contained two representative images, one from a dorsal perspective and one from a lateral perspective, for each day of development through 16 days of age (Appendix). Each image in the guide contained a scale reference (a wing chord ruler). Participants testing the guide ($n = 36$) were provided with a set of 52 images of unknown age nestlings that were randomly selected from the total of 546 images of House Wren nestlings (a different set for each participant), and with the aging guide. Most participants (89 %) had no experience of any kind with birds or aging guides. Participants visually compared random images to those in the guide to provide one age estimate for each unknown-age nestling. Any age estimates that differed from actual nestling age by more than six days ($n = 6$ of 1,872) were considered outliers and removed from analyses.

Statistical methodology - Overall accuracy of estimated ages, as well as accuracy of ages estimated for each day of development, was represented as the proportion of nestlings correctly estimated to within one day of each nestling's actual age.

Differences in age estimates produced from images of dorsal and lateral perspectives were evaluated with a mixed model (van de Pol and Verhulst 2006). Dorsal and lateral perspectives and interactions between nestling age and dorsal and lateral image perspectives were specified as fixed effects and participants as a random effect. This approach uses maximum likelihood for estimating effects (PROC MIXED, SAS Institute, Inc. 2008).

Similarly, the effect of a scale bar in the images was evaluated with a mixed model that included the presence or absence of a scale bar as a fixed effect and participants as a random effect. Differences in estimates produced at each day of development from images with and without a scale bar were assessed with Bonferroni corrected *t*-tests. Based on this conservative correction, P-values ≤ 0.003 were assumed to be significant.

Daily age estimates produced from digital images were compared to those previously produced from mass and wing chord measurement observations (Brown et al. 2011) using a modified Bonferroni correction for chi-square tests (Keppel and Wickens 2004). Based on this correction, significance between pair-wise comparisons was established at the $P \leq 0.027$ level.

RESULTS

Using the digital image aging guide, participants estimated the age of 88.4% of unknown House Wren nestlings to within one day of actual nestling age (Fig. 1). The accuracy of estimates generally decreased for the oldest nestlings.

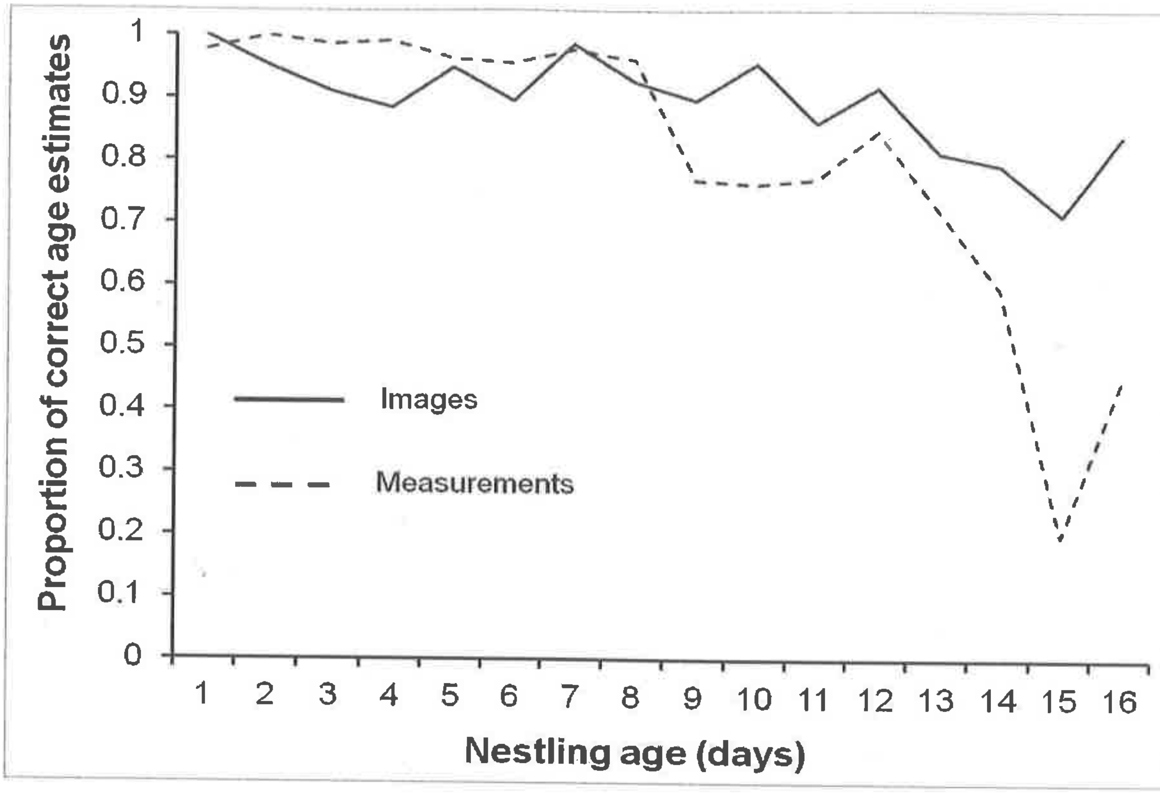

Fig. 1. The proportion of correct House Wren nestling age estimates produced by using an aging guide of digital images (solid line) and by using mass and wing chord measurements (broken line; Brown et al. 2011).

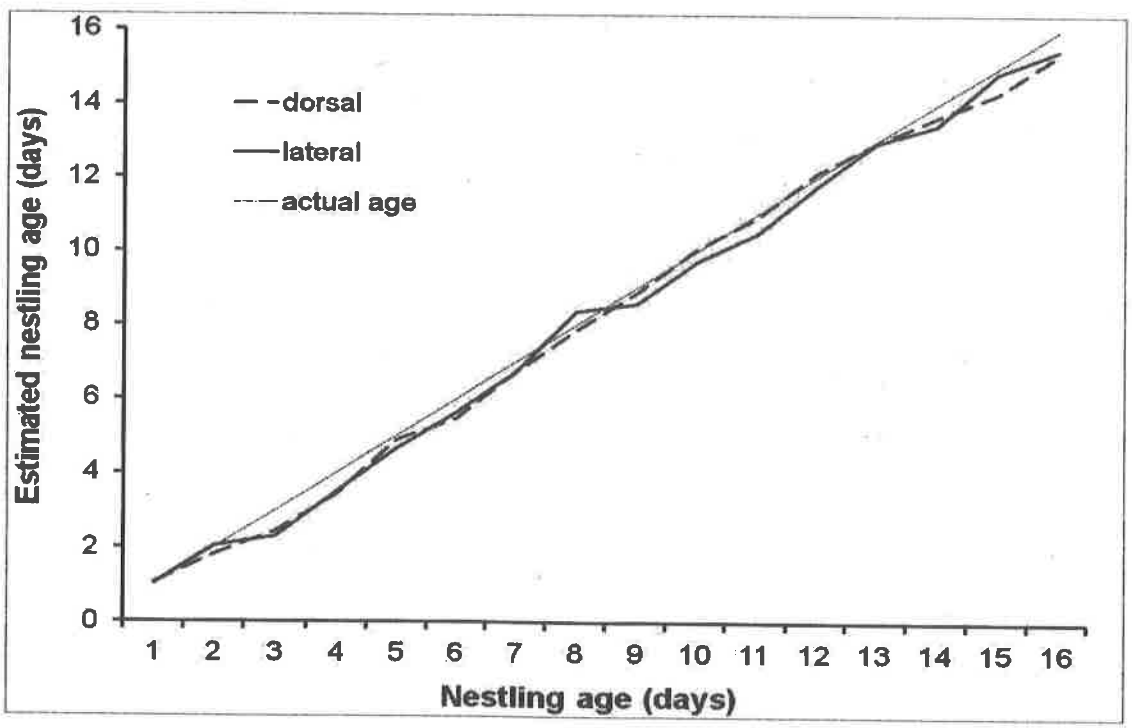

Fig. 2. The differences in House Wren nestling age estimates produced using either the dorsal (dashed line) or lateral (solid line) perspective of the image of unknown-age nestlings compared to actual nestling age (dotted line).

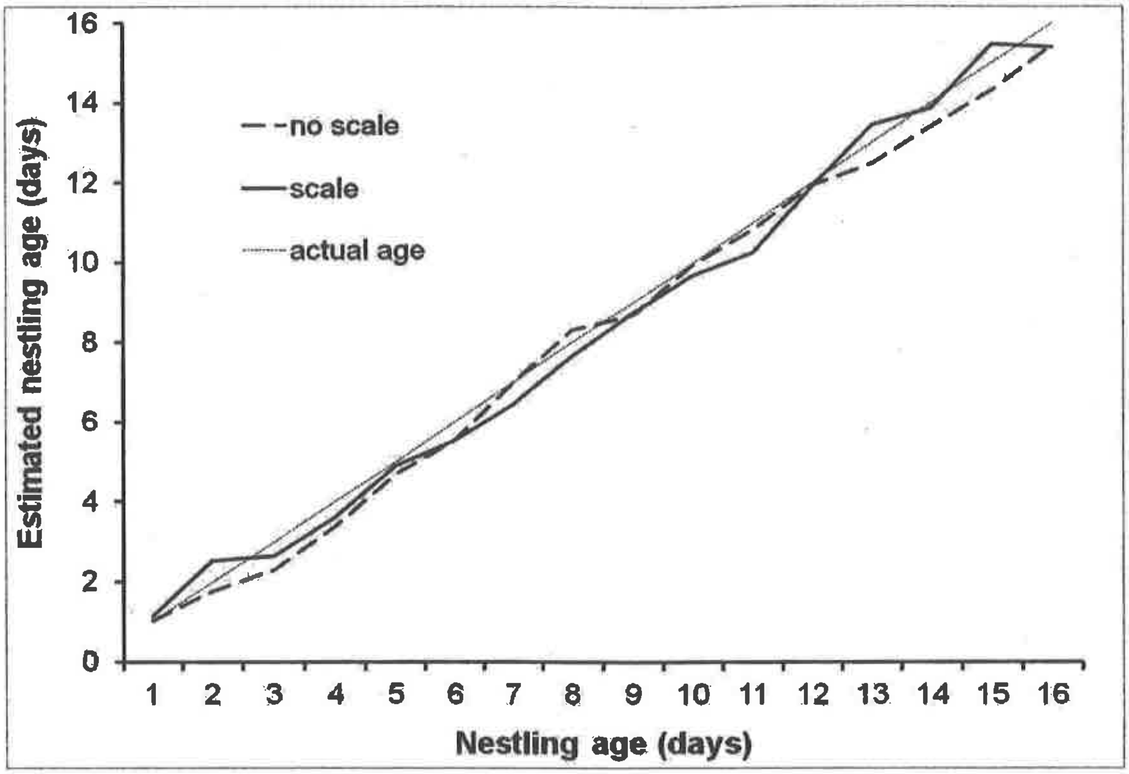

Fig. 3. The differences in House Wren nestling age estimates produced using an image of unknown-age nestlings that either included a scale bar (solid line) or did not include a scale bar (dashed line) compared to actual nestling age (dotted line).

Using images to produce age estimates was more accurate overall than using mass and wing chord measurements (X^2 = 28.9, df = 1, P <0.0001), which was 85% accurate (Brown et al. 2011). Based on Keppel and Wicken's (2004) modified Bonferroni correction for chi-square tests, nestling age estimates produced with the photographic guide and those produced based on body measurements differed significantly at 4, 10, 14, 15, and 16 days of age (all P <0.027). The increase in accuracy of age estimates from the photographic guide relative to morphometric measurements was largely due to improved age estimates for older nestlings (Fig. 1).

Age estimates based on a dorsal or lateral image perspective did not differ overall ($F_{1,1827}$ = 0.33, P = 0.56), but there was an interaction of image perspective and nestling age ($F_{30,1822}$ = 1430.3, P < 0.0001). However, no daily comparisons between age estimates determined from dorsal and lateral image perspectives were significant at the conservative P < 0.003 level (Fig. 2). Additionally, nominal differences in average age estimates due to image perspectives for a given age were smaller than the scale at which accuracy was determined (one day), and, therefore, any differences have little practical meaning.

The presence of a scale bar significantly influenced the accuracy of age estimates ($F_{1,1825}$ = 7.5, P = 0.0063), particularly for older nestlings due to an interaction of the presence of a scale bar with nestling age ($F_{30,1824}$ = 1497, P < 0.0001; Fig. 3.). Based on *post hoc* examinations of least squares means, differences existed at 2, 8, 11, 13, 14, and 15 days of age (all P < 0.003). Because nearly all of the differences in age estimates were less than one day, the presence of the scale bar is also not likely to practically influence aging accuracy results.

DISCUSSION

This is the first study we are aware of that evaluated the accuracy of a photographic or digital image development guide on nestling age estimation. The ages of most House Wren nestlings were successfully estimated to within one day of their actual age by novice participants using an aging guide of digital images. Generally, the ages of older nestlings were not estimated as accurately as younger nestlings. The perspective of the image of the unknown nestling (dorsal or lateral) and the presence of a scale bar in the image of the unknown nestling did not have any practical bearing on the outcome. We acknowledge that the scale bar— a wing chord ruler—may be easier to use if it started at zero when aligned with the bill of the nestling, but this arrangement presented logistical difficulties: one hand was needed to hold the (usually uncooperative) nestling and support the ruler, while the other hand operated the camera. Such alignment was therefore not possible. The accuracy of age estimates achieved by visually comparing images of unknown-age nestlings to those in the aging guide was greater than the accuracy of estimates produced using only mass and wing chord measurements (see Fig. 1).This difference in accuracy was likely due to mass recession in older nestlings and variability in measurements collected from individual nestlings (Brown et al. 2007, Brown et al. 2011).

A few studies have examined the effectiveness of photographic aging guides, but did not quantitatively assess accuracy of age estimates. For example, Hanson and Kossack (1957) reported "little trouble" in determining the ages of nestling Mourning Doves (*Zenaida macroura*) through the seventh or eighth day of development based on photographs and written descriptive notes. Age estimates for older nestlings were more difficult because some characters were obscured in the photographs. Conversely, Bechard et al. (1985) were not satisfied that nestling Red-tailed Hawks (*Buteo jamaicensis*) could be changed accurately to within a few days of their actual age due to the subjectivity of photographic comparisons and local variability among young. Neither study, however, provided an actual accuracy assessment. Many of the published photographic development guides describe phenotypic changes in raptors (e.g., Moritsch 1985) and it remains unclear if the positive findings for the House Wren aging guide apply to other orders or species of birds with a different pattern of development where daily changes may not be as evident or meaningful as for House Wrens. Assessing accuracy on a different time scale may be appropriate, as warranted by the life history of the species in question.

The 88% level of accuracy in estimating the daily ages of House Wren nestlings was noteworthy given the large proportion of complete novices among participants. Furthermore, the motivation of novice participants was not high in all cases because some participants were students who completed this exercise for extra credit. Likely, greater levels of aging accuracy could be achieved if participants had more experience (Weinberg and Roth 1994) or, as field ornithologists, were more invested in the effort of estimating nestling ages. For example, experienced observers produced more accurate estimates of nestling age based on morphological measurements than did novices (Brown et al. 2011).

Concerns about the use of photographic guides for estimating nestling age remain, including the potential growth differences between the sexes (e.g., Holcomb and Twiest 1971), and local or range-wide variability among young for reasons related to diet, environment, and conditions in the nest, including the number and ordering of young (Bechard et al. 1985, Paxton and Owen 2002, Gossett and Makela 2005). Some photographic guides were developed based only on one brood and authors suggest caution generalizing age estimates derived from these guides (e.g., Griggs and Steenhoff 1993). Currently, photographic aging guides may be easier to develop due to increased access to digital imaging technology. Potentially, they can provide an accurate estimate of nestling age and reduce the number of visits to the nest and the handling of nestlings. We encourage researchers to test the effectiveness of photographic aging guides in other species and groups of birds. Future research should also consider the influence of observer experience on the accuracy of age estimation.

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LITERATURE CITED

Bechard, M.J., B.W. Zoellick, and M. Nickerson. 1985. Accuracy in determining the age of nestling Red-tailed Hawks. *Journal Wildlife Management* 49:226-228.

Boal, C.W. 1994. A photographic and behavioral guide to aging nestling Northern Goshawks. *Studies Avian Biology* 16:32-40.

Brown, W.P., A.L. Alexander, D.A. Alexander, M.E. Zuefle, and T.J. Underwood. 2011. Estimating ages of House Wren nestlings based on body mass, wing chord length, and feather tract development patterns. *North American Bird Bander* 36:101-110.

Brown, W.P., P. Eggermont, V. LaRiccia, and R.R. Roth. 2007. Are parametric models suitable for estimating avian growth rates? *Journal Avian Biology* 38:495-506.

Davis, W.H. 1995. Testing the features of the Peterson box. *Sialia* 17:135-136.

Gossett, D.N. and P.D. Makela. 2005. Photographic guide for aging nestling Swainson's Hawks. U.S. Department of the Interior, Bureau of Land Management, *Idaho Technical Bulletin* 2005-01. Burley, ID.

Griggs, G.R. and K. Steenhoff. 1993. Photographic guide for aging nestling American Kestrels. U.S. Department of the Interior, Bureau of Land Management, Boise, ID.

Hanson, H.C. and C.W. Kossack. 1957. Methods and criteria for aging incubated eggs and nestlings of the Mourning Dove. *Wilson Bulletin* 69:91-101.

Holcomb, L.C. and G. Twiest. 1971. Growth and calculation of age for Red-winged Blackbird nestlings. *Bird-Banding* 42:1-17.

Jongsomjit, D., S.L. Jones, T. Gardali, G.R. Geupel, and P.J. Gouse. 2007. A guide to nestling development and aging in altricial passerines. US Department of Interior, Fish and Wildlife Service, Biological Technical Publication, FWS/BTP-R6008-2007, Washington, DC.

Keppel, G. and T.D. Wickens. 2004. Design and analysis: a researcher's handbook. Prentice Hall, London.

Kern, T.T., T.J. Underwood, and W.P. Brown. 2009. Field comparisons of insulated metal nest boxes to wood nestboxes: temperature differences and bird preferences. *Bluebird* (winter 2009-2010):6-10.

Mayfield, H.F. 1975. Suggestions for calculating nest success. *Wilson Bulletin* 87:456-466.

Moritsch, M.Q. 1985. Photographic guide for aging nestling Ferruginous Hawks. U.S. Department of the Interior, Bureau of Land Management, Boise, ID.

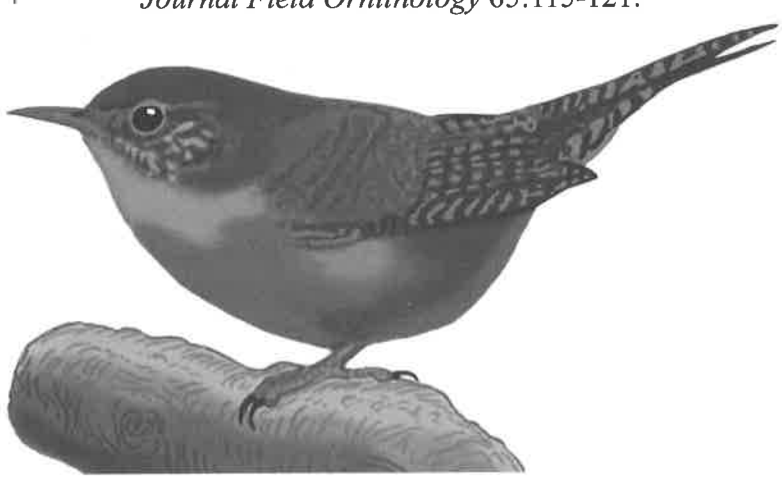
Paxton, E.H. and J.C. Owen. 2002. An aging guide for Willow Flycatcher nestlings. Colorado Plateau Field Station, Flagstaff, AZ.

Penteriani, V., M.M. Delgado, C. Maggio, A. Aradis, and F. Sergio. 2005. Development of chicks and predispersal behaviour of young in the Eagle Owl *Bubo bubo*. *Ibis* 147:155-168.

Starck, J.M. and R.E. Ricklefs. 1998. Avian growth and development: evolution within the altricial-precocial spectrum. Oxford University Press, New York, NY.

Van de Pol, M. and S. Verhulst. 2006. Age-dependent traits: a new statistical model to separate within- and between individual effects. *American Naturalist* 167:766-773.

Weinberg, H.J. and R.R. Roth. 1994. Rectrix shape as an indicator of age in the Wood Thrush. *Journal Field Ornithology* 65:115-121.



House Wren by George West

Appendix

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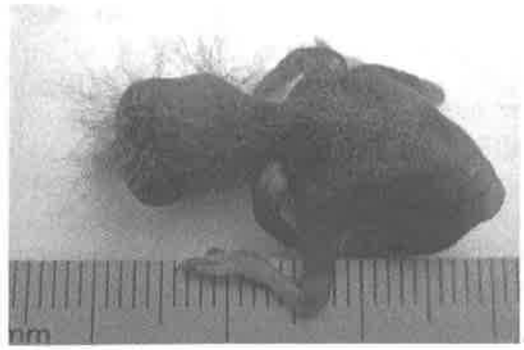

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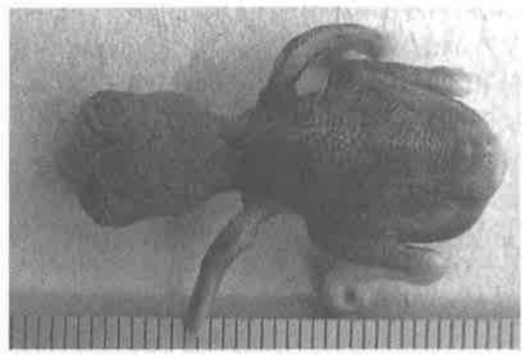

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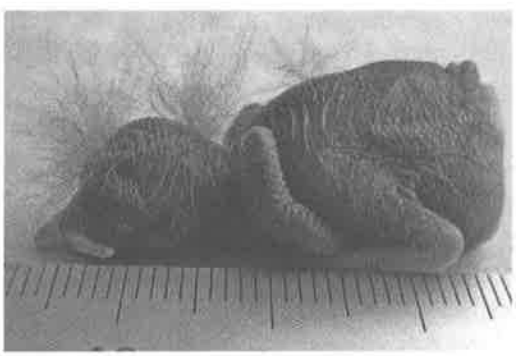

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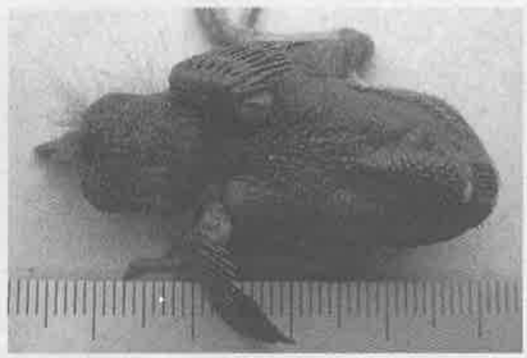
Day6_side



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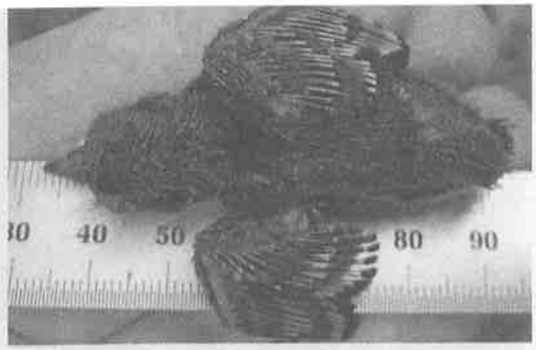
Day9_side



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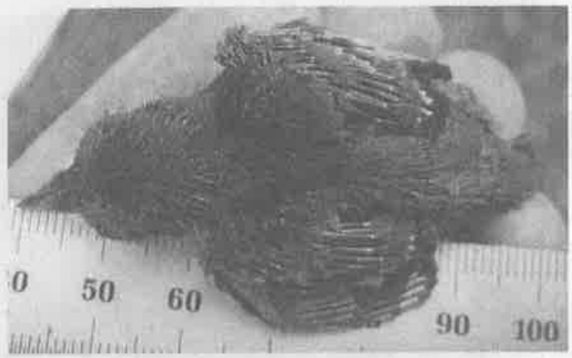

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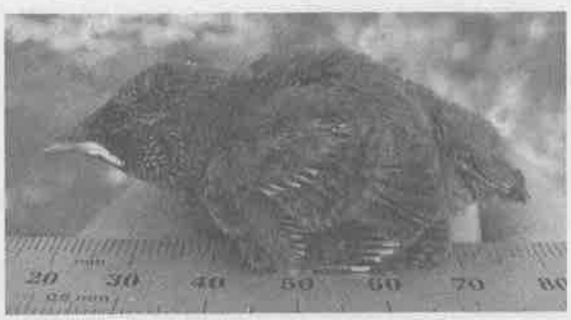

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Day12_side

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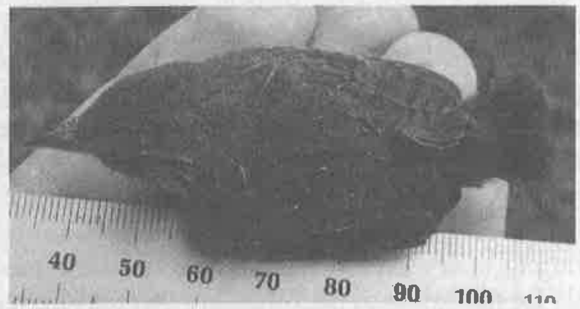
Day14_side



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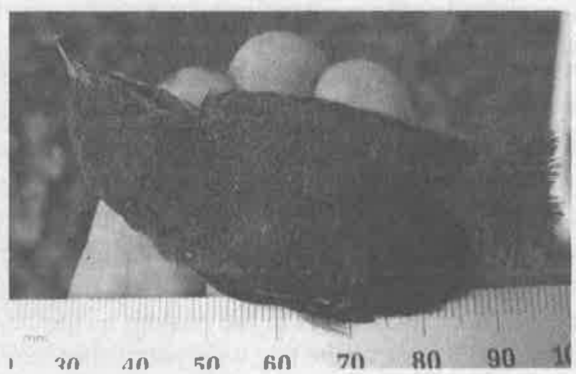

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