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Age Determination in California Brown Pelican (*Pelecanus occidentalis californicus*) Chicks in the Gulf of California

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Abstract.—A rapid and reliable method to age California Brown Pelican (*Pelecanus occidentalis californicus*) pre-fledged young based on exposed culmen measurements is presented. In 1997, 1998, and 1999, a total of 52 unknown-age young were marked and recaptured one to three times throughout the nesting season on Isla Piojo, Bahía de Los Angeles, Mexico. From culmen growth increments of these young, we developed an age scale. The linear equation that described the age/culmen relationship was: estimated age (week) = exposed culmen length (cm) x 0.378 - 0.565. The accuracy of the model, as calculated by the k-Fold cross validation method, was 0.149. California Brown Pelican chicks can thus be aged by culmen length measurements. The application of this aging technique allows the mass of chicks to be plotted against their ages to obtain an average body mass growth curve for any sampled cohort of young California Brown Pelicans based on less frequent visits to the colony to minimize the potential effects of disturbance. *Received 6 September 2017, accepted 21 October 2017.*

Key words.—aging technique, California Brown Pelican, chick growth, exposed culmen length, *Pelecanus occidentalis californicus*.

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The ability to accurately determine ages of young birds prior to fledging is important for many studies (Starck and Ricklefs 1998; Cooch *et al.* 1999). This is especially important for the determination of growth rates of colonially nesting seabirds (Schew and Collins 1990; Gilliland and Ankney 1992; Piatt *et al.* 2007) like the California Brown Pelican (*Pelecanus occidentalis californicus*) where colony disturbance can be an issue.

The growth rates of seabird chicks has been used as an indicator of food supply (reviewed by Cairns 1987; Montevecchi 1993; Benson *et al.* 2003; Piatt *et al.* 2007) and this measurement often reflects variation in environmental variability over the chick-rearing period (Boersma and Parrish 1998; Piatt *et al.* 2007). However, detailed growth data for Brown Pelicans is difficult to obtain because of logistical constraints involved in measuring a large sample of young Brown Pelicans of known age throughout their long development periods (e.g., 12-14 weeks in the California Brown Pelican). Furthermore, Brown Pelicans are susceptible to disturbance, and gathering chick growth data over the growth periods of individuals causes multiple disturbances to the colony, leading to potential mortality and/or nest abandonment especially in the early phases of nesting (Anderson and Keith 1980; Anderson 1988).

Methods for examining seabird growth data rely on either "mixed-longitudinal" (systematic or random selection of data points per individual) or "cross-sectional" (random selection of individuals from the populations) sampling designs (Ricklefs 1983; Bradley *et al.* 1984). With either method, an age scale is needed for the calculation of growth rates. In this study, we used a technique developed by Ricklefs and White (1975) for constructing an average age scale for any given population cohort based on a cross-sectional data set.

Here, we present a reliable method to determine the age of California Brown Pelicans from exposed culmen measurements, which we refer to as culmen length. Our goal was to provide a technique that would allow construction of average growth curves for any sampled cohort of pre-fledged California Brown Pelicans with shorter and less frequent visits to colonies, without requiring repeated sampling (Benson *et al.* 2003), and based on cross-sectional data sets (*sensu* Ricklefs and White 1975).

METHODS

Study Area

The California Brown Pelican nesting colony where this study was conducted is located on Isla Piojo in Bahía de Los Angeles, Baja California, Mexico (29° 01′ 12″ N, 113° 28′ 02″ W), where on average about 500 pairs of California Brown Pelicans typically nest in smaller subcolonies of different sizes (Anderson *et al.* 2013), usually from February through July. Subcolonies are defined here as clusters of birds within a colony that are separated from adjacent clusters by a habitat discontinuity (Gochfeld 1980).

Data Collection

During the breeding seasons of 1997 (n = 21) and 1999 (n = 28), we studied the growth of California Brown Pelican chicks at Isla Piojo (Table 1). This sample of 49 unknown-age young from five subcolonies was marked and recaptured one to three times at 5- to 22-day intervals throughout the nesting season on Isla Piojo. We assumed a linear growth pattern of culmen length (Schreiber 1976; Eggert and Jodice 2008). Culmen measurements were standardized to weekly intervals by extrapolating or interpolating the values attained within 7 days based on each individual culmen growth rate. Measurements of the exposed culmen (from the end of feathering on the upper mandible to the tip of the bill, including the nail, in a straight-line distance) were obtained using a ruler (nearest 0.1 cm). Nestlings were weighed with a calibrated Pesola spring balance (5- or 12-kg capacity), and individual chicks were marked with uniquely numbered aluminum bands.

In 1998, we kept three young Brown Pelicans in captivity for about 2 months in a shaded wire-mesh pen (3 m x 6 m) and documented their growth (Table 1). These chicks were each marked with aluminum bands on their left tarsus and with color tags (white tag on green ring) on their right tarsus. When we collected them on 22 May 1998, they were 4 to 5 weeks old and weighed 1.9, 2.8 and 3.0 kg. They were measured and weighed each day from 22 May to 23 July, when they were released. Exposed culmen measurements from these three young were added to the total sample used to develop the aging technique (Table 1). These three chicks were measured daily, and measurements were standardized to weekly intervals.

Data Analysis

We evaluated culmen growth increments of individually marked young of various, but unknown, ages to obtain an age scale for the sampled population (Table 1). We used a method for deriving an absolute age scale for the population from culmen growth increments of individually marked birds of various, but not precisely-known ages (Ricklefs and White 1975). In total, 52 Brown Pelican chicks from 1997 to 1999 were re-sampled throughout the rearing period to develop our aging technique (Table 1). This method involved the construction of a scale of relative chronological age by plotting the initial culmen length of each individual on the horizontal axis vs. its final culmen length on the vertical axis (Fig. 1). A smooth curve was fitted by eye to the points (curve A). A diagonal line (B) that represented equal initial and final culmen lengths (hence zero growth) was added to the graph (Fig. 1). The time scale was adjusted to correspond to the true chronological growth data. At age 0 (i.e., hatching), average culmen length is 2.27 cm (D. W. Anderson and P. Kelly, unpubl. data). Then, we derived a simple linear regression of the age/culmen relationship obtained from Figure 1 (Fig. 2). To evaluate the prediction error of the linear model, we used the k-Fold cross validation method (k = 10).

We used the Scaled Mass Index (SMI) method (Peig and Green 2009) to provide baseline variation in body condition of young California Brown Pelicans. For comparison between captive-reared chicks fed *ad libitum* in 1998 and free-living nestlings from Isla Piojo in 1997 and 1999, we used a Kruskal-Wallis test and Multiple Comparisons. We conducted all analyses using Matlab software. Results were considered significant at $\alpha = 0.01$.

RESULTS

Mean culmen growth rate ranged from 0.358 cm/day in 1998 and 0.371 in 1999 to 0.419 cm/day in 1997, but growth rate was not significantly different among years (Kruskal-Wallis test; $P > 0.05$). Individual culmen growth rates of the three chicks we reared in captivity during 1998 were not significantly different from each other either (Kruskal-Wallis test; $P > 0.05$).

The linear equation that described the age/culmen relationship in the California Brown Pelican chicks was: estimated age (week) = exposed culmen length (cm) x

Table 1. Sample sizes by year and type of California Brown Pelican young. Numbers in parentheses are the total number of culmen increments used in Figure 1.

Type of Young	1997	1998	1999	Total
Free living (unknown age)	21 (74)		28 (28)	49 (102)
Captive reared (unknown age)		3 (19)		3 (19)
Total				52 (121)

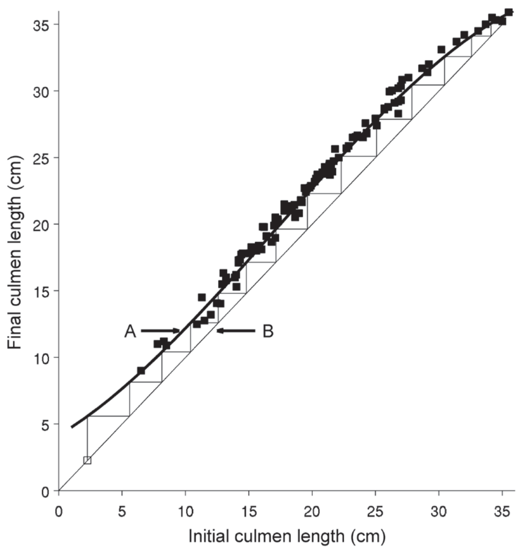

Figure 1. Initial and final culmen lengths (linear phase) of California Brown Pelican (*Pelecanus occidentalis californicus*) chicks (curve A) measured over 7-day intervals from 52 chicks of various but unknown ages. The diagonal line (B) represents equal, final and initial culmen lengths, and the vertical distance between lines A and B represents the increment of growth over 7 days. The vertical lines connecting line A to line B are 1-week time intervals (from week 0 through week 13).

0.378 - 0.565 (ANOVA; $P < 0.001$, $R^2 = 99.8$ %) (Fig. 2). This equation accurately predicted the age and the observed culmen growth increments of 52 banded unknown-age chicks measured twice 7 days apart. The accuracy of the model as calculated by the 10-fold cross validation was 0.149, and the prediction error, as measured by the Mean Square Error (MSE), was close to zero (MSE = 0.083). Chick-condition index of captive-reared chicks fed *ad libitum* in 1998 was significantly higher than free-living nestlings from Isla Piojo in 1997 and 1999 (Mean SMI = 4.83 vs. 3.70, respectively; Kruskal-Wallis test: df = 2; $n = 386$; $P < 0.001$).

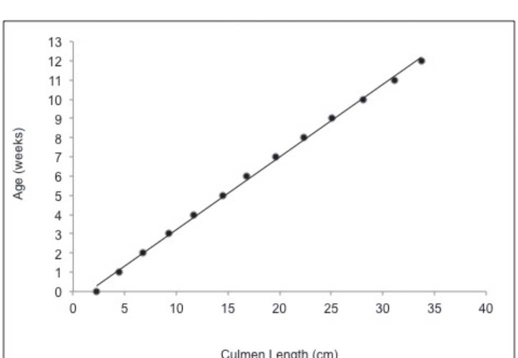

Figure 2. Simple linear regression and line-fit for age vs. culmen length in California Brown Pelican (*Pelecanus occidentalis californicus*) chicks.

Discussion

We present a reliable, rapid method where California Brown Pelican chicks can be aged based on exposed culmen length. Year-to-year variation in the culmen/age relationship appeared to be insignificant in our samples, which did not include any growing young from years of predicted food stress. Culmen length has also been used as a reliable method to estimate nestling age in the Eastern Brown Pelican (*P. o. carolinensis*) (Eggert and Jodice 2008) and other species of seabirds, including Magnificent Frigatebird (*Fregata magnificens*) (Moreno and Carmona 1988; Carmona *et al.* 1995), Blue-footed Booby (*Sula nebouxii*) (Drummond *et al.* 1991), and Grey-headed Albatross (*Diomedea chrysostoma*) (Reid *et al.* 2000). None of these studies found differences between years in the rate of culmen development.

Our aging technique should be applicable to other populations of California Brown Pelicans, but it is not applicable to populations of other subspecies of Brown Pelican because of differences in body size among the six subspecies in North America (Palacios 2001). Schreiber (1976) described the growth and development of nestling Brown Pelicans and noted that the weight-to-wing length and culmen length relationship was probably the most accurate measure of age and condition in the Eastern Brown Pelican. For our aging technique, we did not consider wing length or other body parts because the wing grows too slowly during the earliest phase of development and tarsus length reaches asymptote too soon for this application (Schreiber 1976). The culmen is the most reliable and more convenient body part to measure in the field, and is consistent with other studies (Moreno and Carmona 1988; Drummond *et al.* 1991; Carmona *et al.* 1995; Reid *et al.* 2000). Furthermore, Schreiber (1976) indicated that culmen length (after day 5) follows a linear growth pattern through fledging. No other body parts measured gave Schreiber (1976) a constant linear growth pattern. Thus, culmen length provides the closest approximation to a linear model during most of the rearing period, until reaching a length of 31 cm at week 11 in the Eastern Brown Pelican subspecies.

Our aging method for California Brown Pelican nestlings was developed to provide reliable data for determining nestling growth curves from brief visits resulting in the least disturbance to Brown Pelican colonies (Benson *et al.* 2003). Mass of chicks can then be plotted against their ages (estimated from exposed culmen length) to obtain an average mass growth curve for any sampled cohort of young Brown Pelicans.

The method we developed here combines the sexes and integrates the sampled cohort growth condition. However, unlike the other Brown Pelican subspecies, adult California Brown Pelicans exhibit asymptotic sexual dimorphism in size (Palacios 2001). This dimorphism in body size arises during chick development, thus to construct a nestling growth curve based on a cross-sectional data set for each sex, a DNA-based method for sex determination in chicks must also be employed.

Knowing the age of Brown Pelican nestlings can also be important in determining the breeding phenology of a colony. Having a reliable method of aging chicks with one to two visits to a colony allows researchers to determine the breeding phenology with minimal disturbance to the birds, and thus avoid unnecessary chick mortality (Anderson and Keith 1980; Anderson 1988).

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