ASSESSING CHICK GROWTH FROM A SINGLE VISIT TO A SEABIRD COLONY

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SUMMARY

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We tested an approach to the collection of seabird chick growth data that utilizes a one-time sampling of chick measurements obtained during a single visit to a seabird colony. We assessed the development of Black-legged Kittiwake *Rissa tridactyla* chicks from a sample of measurements made on a single day during six years and compared these results to linear growth rates (g/day), determined from repeated measurements of the same chicks. We used two one-time sampling methods to obtain indices of "chick-condition", 1) overall body-size (wing, head-plus-bill, tarsus) vs. mass, and 2) wing vs. mass; both were consistent with repeated measurements in identifying annual variations in chick growth. Thus, we suggest that chick-condition indices obtained from measurements collected on a single visit to a seabird colony are a useful tool for monitoring chick growth, especially at colonies where multiple visits and/or repeated measurements of individual chicks are impractical.

Keywords: Alaska, Black-legged Kittiwake, body-condition, chick growth, *Rissa tridactyla*, seabird monitoring

INTRODUCTION

Postnatal development of seabird chicks can be a sensitive indicator of local environmental conditions (Fendley & Brisbin 1977, Ricklefs 1983, Cairns 1987, Montevecchi 1993, Boersma & Parrish 1998). However, collection of detailed growth data, for seabird chicks is often limited by logistics (remote or difficult access to colonies), disturbance to breeding birds, or funding. Depending on the species, it may require 2-4 months of frequent measurements to assess chick growth from hatching to fledging. While studies of chick growth and physiology often demand such detailed measures, investigators often wish to use growth only as an indicator of food abundance during the breeding season. Thus, if we wish to use seabirds as monitors of the marine environment (Cairns 1987, Montevecchi 1993) it will be useful to develop and validate simple methods of assessing chick growth.

Recognizing the inherent difficulty of obtaining growth rates from colonial oceanic species, Ricklefs and White (1975) developed a method to construct an average growth curve for chicks at a seabird colony by collecting wing measurements during two visits to a colony over a 10-day interval. This approach both reduced the sampling effort needed to construct a growth curve and eliminated the need to carefully monitor chick hatch dates and ages. However, it required a second visit to the colony and the ability to recapture and measure previously banded chicks, which would be extremely difficult with species that are loosely nidicolous or form crèches.

A few prior investigators have used single measures from chicks of unknown age to obtain an index of chick growth (Hamer *et al*. 1991, Phillips *et al*. 1996, Suddaby & Ratcliffe 1997). In each of these studies, chick wing-length was used to estimate age, so that age-mass relationships could be evaluated. However, while individual chicks may have been measured only once in these studies, measurements were collected during multiple visits over an entire chick-rearing season, and these results have never been corroborated by comparison with repeated measurements from the same chicks. Furthermore, Øyan and Anker-Nilssen (1996) reported preferential growth of the head in times of food stress for Atlantic Puffin chicks, suggesting that wing length alone may be a poor substitute for chick age.

The simplest method of assessing chick growth would be one that allowed researchers to measure chicks of unknown age while visiting a colony only once per year. For example, to estimate chick growth with minimal disturbance, Uttley *et al*. (1994) measured wing-length and mass of Common Murre *Uria aalge* chicks during a single visit. However, for reasons of differential growth allocation noted above, wing length alone may not always be an accurate estimator of age on which to regress body mass. Therefore, we borrowed a technique often used by studies to compare the body-condition of full-grown animals where multiple body measures are taken and principal components analysis (PCA) is used to calculate a body-size index, which is then regressed with mass (Hamer *et al*. 1993, Jakob *et al*. 1996, Golet *et al*. 1998). We tested these methods on chicks for which there also was a full complement of growth data. We used detailed growth data collected at one colony over a 6 yr period to compare two different single sample methods to one method that incorporates repeated measurements of individual chicks. Our goal was to determine whether chick measures obtained during a single visit to a seabird colony could provide a reliable "chick-condition index". If valid, this approach could be useful to a wide array of seabird biologists.

METHODS

We measured and weighed chicks at a Black-legged Kittiwake *Rissa tridactyla* colony in Shoup Bay, Prince William Sound, Alaska in 1990, 1995-1999. We checked nests daily to determine hatch dates. We measured chicks every four days from hatching to near-fledging (30 days). Recorded measurements included right tarsus (± 0.1 mm), head-plus-bill (± 0.1 mm), right wing (± 1 mm; from wrist to tip of the longest primary, flattened and straightened), and body-mass (± 1 g). We banded chicks with United States Fish and Wildlife Service stainless steel bands for identification.

To simulate a one-time visit to the breeding colony we used a sub-sample of chick measurements that were obtained on a single day each year between 24 July and 27 July. We then calculated body-size vs. mass relationships for each year using both a single wing measure and principal component scores of multiple body measures. We conducted the PCA on standardized wing, head-plus-bill, and tarsus (measurements were standardized to means of zero and standard deviations of one; Manly 1994). We regressed body-mass on both wing and PCA scores and used the residuals, expressed as a percentage of predicted body-mass, to obtain the chick-condition indices, to be compared among individuals and/or treatment groups. To test the effectiveness of this method with respect to age, we also calculated chick-condition indices (based on PCA scores only) for both younger and older groups of chicks using sub-samples of chick measures occurring approximately 10 days before and after the 24 July and 27 July period.

As a basis for comparison, we regressed body-mass on age to calculate growth rates (g/day) of individual chicks within the mass range of 60 to 300 g (Coulson & Porter 1985). The 60 to 300 g growth phase is a sufficiently narrow range to include the near-linear portion of kittiwake growth, except during years when growth is extremely poor; in these cases, some additional points outside the near-linear phase (beyond the asymptotic mass) may be included (Suryan *et al*. 1999).

For comparisons among annual means we used a single factor analysis of variance and Tukey multiple comparison test. We did not use analysis of covariance because it assumes homogeneous slopes and because there is no evidence that hatching weights of kittiwakes differ among years or colony. We conducted all analyses using SAS software. Results were considered significant at α = 0.05.

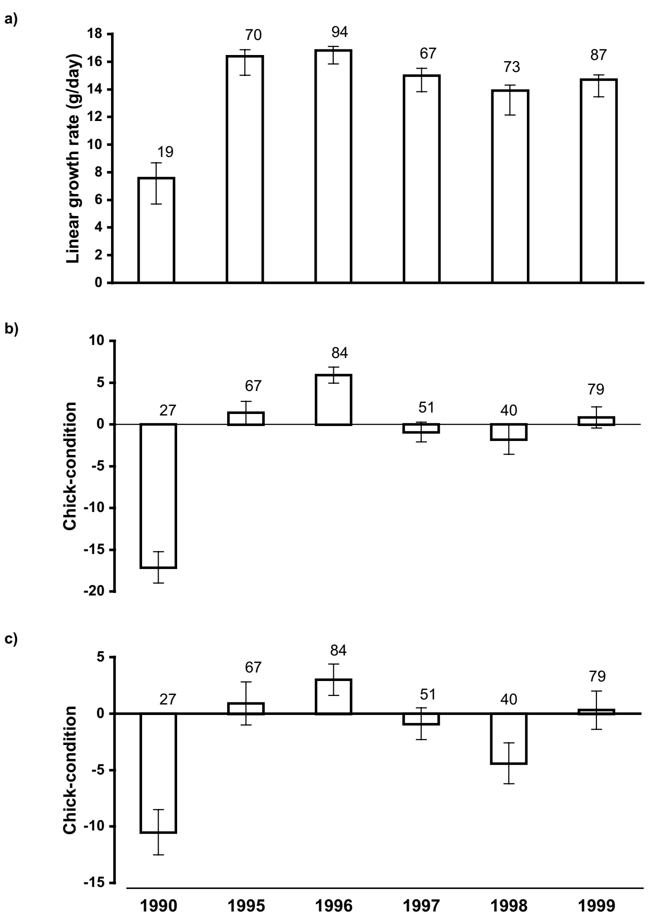

Fig. 1. Linear growth rates as measured over the near-linear 60 to 300 g mass range (a) and chick-condition indices based on overall body-size (b) and wing only (c), both of which used single measures obtained between July 24–27 at the Shoup Bay colony, Prince William Sound, Alaska. Results are presented as means (± standard error) with sample sizes indicated above.

RESULTS

One-time sample methods proved successful in detecting the differences observed in chick growth among years; annual trends in both chick-condition indices were similar to those in linear growth rates (Fig. 1). There was a significant difference among years for linear growth rate ($F_{5,404}$ = 24.8, P < 0.0001; Fig. 1a). Multiple comparisons revealed that growth rates in 1990 were significantly lower than other years, while growth rates in 1996 were greater than other years, statistically significant in all years except 1995. Additionally, growth rate in 1995 was significantly greater than in 1998 and 1999.

Measures of chick-condition using the PCA based body-size scores were significantly different among years ($F_{5,341}$ = 21.4, P < 0.0001;

TABLE 1

A comparison of chick-condition for Black-legged Kittiwake chicks measured during 6 yr at the Shoup Bay colony, Prince William Sound, during three periods: July 24-27 (middle period), 10 d earlier (early) and 10 d later (late). The residuals are from linear regression relationships between principal component scores for chicks measured during middle vs. early (R^2 = 0.60, $F_{4,5}$ =5.84, P = 0.073) and middle vs. late (R^2 = 0.81, $F_{4,5}$ =17.18, P = 0.014).

	Chick-condition			Residuals	
Year	Early	Middle	Late	Middle vs. Early	Middle vs. Late
1990	-8.77	-17.1	-12.21	-0.01	-0.07
1995	1.95	1.39	3.03	1.27	1.95
1996	3.26	5.9	4.33	0.28	0.02
1997	4.88	-0.93	3.18	5.38	3.76
1998	-3.71	-1.79	-2.76	-2.77	-1.57
1999	-3.76	0.83	-3.4	-4.15	-4.08

Fig. 1b), and multiple comparisons revealed results nearly identical to those of linear growth rate analysis; this method was not able to identify chick-condition in 1995 as significantly greater than in 1998 and 1999.

Measures of chick-condition using wing alone revealed similar trends to both the PCA based index and linear growth rates, however this technique was less sensitive in identifying statistically significant differences in chick development among years (Fig 1c); there was a significant difference among years overall ($F_{5,342}$ = 5.07, P < 0.0002), but multiple comparison tests were unable to show that chick-condition in 1999 was significantly less than in 1995 and 1996, nor that 1990 was a year of substantially slower growth than 1998.

The initial sub-sampling of one-time chick measures on 24 July and 27 July (roughly middle chick-rearing period) included chicks with a mean age of 20 d (± 5.3 SD, range = 1-33 d, for those chicks of known age) and mass of 308 g (± 78.4, range = 30-463 g). The additional testing of chicks 10 d younger and 10 d older produced results that were mostly similar to the first PCA chick-condition index (R^2 = 0.60 and 0.81 for middle vs. early and late, respectively). These relationships would have been even more similar if it were not for the relatively large residuals for 1997 and 1999 (Table 1). These were the only two years in which chick-condition, relative to the other four years, changed between early, middle, and late chick-rearing (Table 1).

DISCUSSION

Our results suggest that measurements obtained during a single visit to a seabird colony can be used to detect variation in chick growth among years. Given the two methods that we tested, we demonstrated that collecting wing, head-plus-bill, tarsus, and body mass measures to calculate an overall body-size was preferable to collecting only wing and body mass. However, if time or personnel are extremely limited (especially regarding colony or chick disturbance), measuring only wing and body mass is an adequate approach to evaluating chick development during a single visit to the colony.

We selected days from mid-July to simulate a single visit to each colony for two reasons. First, for kittiwakes in the northern Gulf of Alaska, this is typically a period of maximum growth rate (Suryan *et al*. 2002) leading to peak energetic demand for kittiwake chicks (Gabrielsen *et al*. 1992). Therefore, variation in chick development should most likely be expressed at this time. Second, we wanted to use simple linear regression to analyze residual body mass, therefore we restricted our selection of data to the linear growth phase.

However, it is possible employ the one-sample technique at various stages of chick-rearing depending on the question of interest. We demonstrated that the one-sample technique is useful in detecting inconsistent growth patterns within a given year. Indeed, the inconsistent chick-condition indices that we found between early, middle, and late chick-rearing for 1997 and 1999 were also observed with growth trends where, based on logistic curves, in 1997 there was slow initial growth (delayed inflection point) followed by recovery to a high asymptotic mass and in 1999 there was average initial growth (average inflection point) but subsequently reduced growth and lower asymptotic mass (Suryan *et al*. 2002). Such inconsistent, within-year growth patterns were not observed in our chick-condition indices or the logistic growth curves for 1996 (consistently high) or 1998 (consistently low).

Ideally, if chicks are measured only once, they should be measured late in the phase of linear growth so that the index provides an integrated measure of chick growth throughout the chick-rearing period. However, measurements of chicks should be made prior to pre-fledging weight recession (common among seabirds; Ricklefs 1968a,b) because body mass would decline while body size continued to increase, creating misleading results. We also do not recommend applying this method to very young chicks because they are relatively homogeneous in body size and mass in early development. Therefore, this method should work best for a species with a relatively predictable breeding schedule so that a visit to the colony can be made during the appropriate sampling window. Conversely, its usefulness may be limited for species' whose timing of breeding varies a lot. Additional consideration should be given to species that have multi-chick broods; if possible, chick order should be distinguished and analyzed separately.

This snapshot approach to assessing variation in chick growth is not recommended as a substitute for measuring complete growth curves. Variations in food supply or environment at different stages of chick rearing can alter the growth rate, duration of growth, and asymptotic mass of chicks so that birds growing at a slower rate may complete growth at a higher mass and vice-versa (Ricklefs 1968a, Suryan *et al*. 2002). For some birds, e.g. the Alcidae (Gaston 1985, Øyan and Anker-Nilssen 1996) growth in all linear dimensions may be retarded when rate of mass gain is slow, so this method may not be able to discriminate between a year of late hatching and a year of slow growth. This flexibility warrants caution when interpreting results. On the other hand, for kittiwakes in this study, it appeared that growth of the organs measured was fairly determinate and that mass was affected more than body parts, thus we recommend this approach for kittiwakes and believe that it should be a useful tool for monitoring other species at colonies subject to brief visits. Such a chick-condition index should provide a useful indication of chick growth and development, and indirectly allow inference about abundance of food supplies during the breeding season.

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