KITTIWAKES AS INDICATORS OF FORAGE FISH AVAILABILITY

Restoration Project 98163E
Annual Report

This annual report has been prepared for peer review as part of the
Exxon Valdez Oil Spill Trustee Council restoration program for the
purpose of assessing project progress. Peer review comments have
not been addressed in this annual report.

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<u>Study History:</u> Field work for project 163E began during the summer of 1995 and consisted of detailed studies of the reproductive biology and foraging ecology of Black-Legged Kittiwakes (*Rissa tridactyla*) in Prince William Sound (PWS), Alaska. In 1995, studies were conducted at one colony in northeastern (Shoup Bay) and two colonies (Eleanor Island and Seal Island) in central PWS. Research at Shoup Bay was conducted in conjunction with ongoing studies funded by the U.S. Fish and Wildlife Service (USFWS). Since 1996, we have expanded the study to include North Icy Bay rather than Seal Island, thereby having sites representing northeastern (Shoup Bay), central (Eleanor Island), and southwestern (North Icy Bay) PWS. Additionally, we can make comparisons with long-term demographic (Shoup Bay) and population studies (all of PWS) conducted by the USFWS. This allows us to more accurately address relationships of variation in prey and decadal trends in populations. In 1998, we conducted work at the same three sites as in 1996 and 1997.

<u>Abstract and Summary:</u>

Progress of Manuscript Preparation and Analyses

Within the past year, we revised and submitted two manuscripts that were presented in draft form in last year's annual report (FY97). The first paper (Suryan and Irons, in review) involved a population analysis of Black-legged Kittiwakes in PWS using data from 1972 to 1997. We discussed temporal and regional differences in population dynamics of kittiwakes in PWS and concluded populations were regulated by both prey availability and predation, depending on colony location and size. We also noted that breeding success and population trends of colonies in southern PWS were more similar to colonies in the Gulf of Alaska (GOA) then colonies in northern PWS. Our results were discussed in regards to current theories concerning the regulation of seabird populations. This paper was submitted to the Auk in November 1998.

The second manuscript (Suryan et al., in review) concerned the diets and foraging effort of Black-legged Kittiwakes from the Shoup Bay and Eleanor Island colonies in years of varying prey abundance (data from 1989 to 1997). Years of low prey abundance were associated with declines primarily in the availability of age-one Pacific herring (*Clupea pallasi*). Years of low prey abundance resulted in increased foraging effort (trip duration and distance) of adult kittiwakes (supporting Cairns' 1987 hypothesis) and prey switching. The ability to prey switch, however, was limited for kittiwakes at Shoup Bay (northern PWS), where few alternatives to reduced herring abundance existed in close proximity to the colony. In contrast, kittiwakes at Eleanor Island (central PWS) were able to take advantage of Pacific sand lance (*Ammodytes hexapterus*) in relatively close proximity to the colony and capelin (*Mallotus villosus*) schools associated with GOA waters.

Four manuscripts that are currently in progress are attached to this annual report. These manuscripts are in various stages of completion, nonetheless, they provide good summaries of our recent efforts. The first paper (Kaufman *et al.*) addresses the response of adult kittiwakes to within-season changes in prey availability. Using data collection computers, we were able to determine daily foraging trip durations of radio-tagged birds. This allowed us to quantify daily changes in foraging effort of kittiwakes in relation to increased energy requirements of nestlings and changes in the availability and species composition (detected in nestling diets) of their prey. In the latter three papers we address methods of data analysis and collection. One of these papers (Suryan *et al.*) involves an evaluation of methods used in determining nestling growth rates. Several methods for determining nestling growth have been used in past years by APEX and other investigators and results of this paper will determine which method is best to use in various situations (particularly valuable for APEX synthesis papers). A second "method" paper (Benson *et al.*) addresses the application of multivariate analyses for comparing nestling development when repeated measures of individual nestlings are not feasible (e.g. birds are intolerant of human disturbance or nestlings are difficult to access). These multivariate analyses will be particularly valuable for species such as Common Murres (*Uria aalge*) and Tufted Puffins (*Fratercula cirrhata*). In a third paper (Benson and Suryan, in review) we present a technique that was developed for capturing adult kittiwakes. This capture design has proven invaluable in recapturing kittiwakes for doubly-labeled water experiments, attaching radio transmitters, and determining body condition.

Preliminary Results of the 1998 Field Season

The breeding chronology of kittiwakes throughout PWS can be synchronous or asynchronous among regions, depending on environmental conditions. Timing of nesting at individual colonies relies, in-part, on over-wintering conditions for adults and local conditions during the month(s) prior to egg laying. With the winter of 1997-98 being one of the strongest El Ninos recorded in the North Pacific Ocean, it was possible that the 1998 breeding season for seabirds in the GOA would be affected. The strongest indication of possible El Nino effects in PWS was late hatch dates and reduced clutch sizes at Eleanor Island and N. Icy Bay colonies (Fig. 1). Our observations of delayed breeding in central and southern PWS were consistent with reports from colonies in Lower Cook Inlet (APEX component M). This was not the case, however, for kittiwakes at Shoup Bay in northwestern PWS. Median hatch date and clutch size was consistent with previous years, with no initial indication of delayed or disrupted breeding (Fig. 1). It is plausible that conditions in the Gulf of Alaska affected initial stages of breeding, but local conditions in northern PWS buffered kittiwakes from this disruption.

These conditions and trends, however, did not persist throughout the breeding season. In fact, the regional trends described for early breeding season (May and June) reversed during the chick-rearing period (July to early August). At Shoup Bay foraging conditions became poor during chick-rearing, resulting in increased foraging trip duration, increased brood reduction, decreased nestling growth, and decreased fledgling mass compared to years of moderate to high

reproductive success (Fig. 2). In contrast, foraging conditions during the chick-rearing period at Eleanor Island and N. Icy Bay were equal to or above average compared to Shoup Bay in 1998 and other years at these two colonies (Fig. 2). This regional discordance between reproductive success within PWS is likely explained by mechanisms described above (Suryan et al., in review). The abundance of age class 0 and 1 herring in northeastern PWS appeared to be low in July and August, resulting in reduced reproductive success of kittiwakes at Shoup Bay (where limited prey alternatives to herring existed in close proximity to the colony). Whereas prey availability appeared greater in central and southwestern PWS where kittiwakes at Eleanor Island and N. Icy Bay obtained herring (N. Icy Bay only), sand lance and capelin in relatively close proximity to the colonies and Gulf of Alaska waters (Fig. 3).

We are approaching a point of effectively describing causes and mechanisms for observed variation in prey abundance, breeding success, and population dynamics of kittiwakes in PWS. These relationships can then be incorporated into a long-term monitoring program and to model the effect of environmental perturbations on kittiwake populations in PWS; with applications throughout the range of this species and to seabird ecology and predator-prey relationships in general.

Key Words: Black-legged Kittiwake, Rissa tridactyla, foraging effort, Pacific herring, Pacific sand lance, capelin, prey abundance, reproductive success, regional concordance, Prince William Sound, Alaska.

Project Data: (will be addressed in the final report)

Citation: Irons, D. B., R. M. Suryan, J. Benson, and M. Kaufman. 1999. Kittiwakes as indicators of forage fish availability. Exxon Valdez Oil Spill Restoration Project Annual Report, (Restoration Project 98163E), U.S. Fish and Wildlife Service, Anchorage, Alaska.

In addition to the summary of 1998 data presented, this report is comprised of four draft manuscripts.

Kaufman, M., R.M. Suryan, D.B. Irons and J. Benson. Detecting intra- and inter-annual variation in prey availability using daily foraging trip durations.

Suryan, R.M., D.D. Roby, D.B. Irons and J.F. Piatt. An evaluation of methods for determining growth rates of nestling seabirds.

Benson, J., R.M. Suryan and J.F. Piatt. A multivariate approach to assessing nestling growth from one-time measurements. Will be submitted to Condor.

Benson, J. and R.M. Suryan. In review. A leg-noose for capturing adult kittiwakes on the nest site. J. Field Ornithology.

Literature Cited

Cairns, D. K. 1987. Seabirds as indicators of marine food supplies. Biol. Oceanogr. 5:261-267.

Suryan, R. M. and D. B. Irons. In review. Black-legged kittiwakes in Prince William Sound, Alaska: Population dynamics in a heterogeneous environment. Auk.

Suryan, R. M., D. B. Irons, and J. Benson. In review. Interannual variation in diet and foraging effort of kittiwakes in relation to prey abundance. Ibis

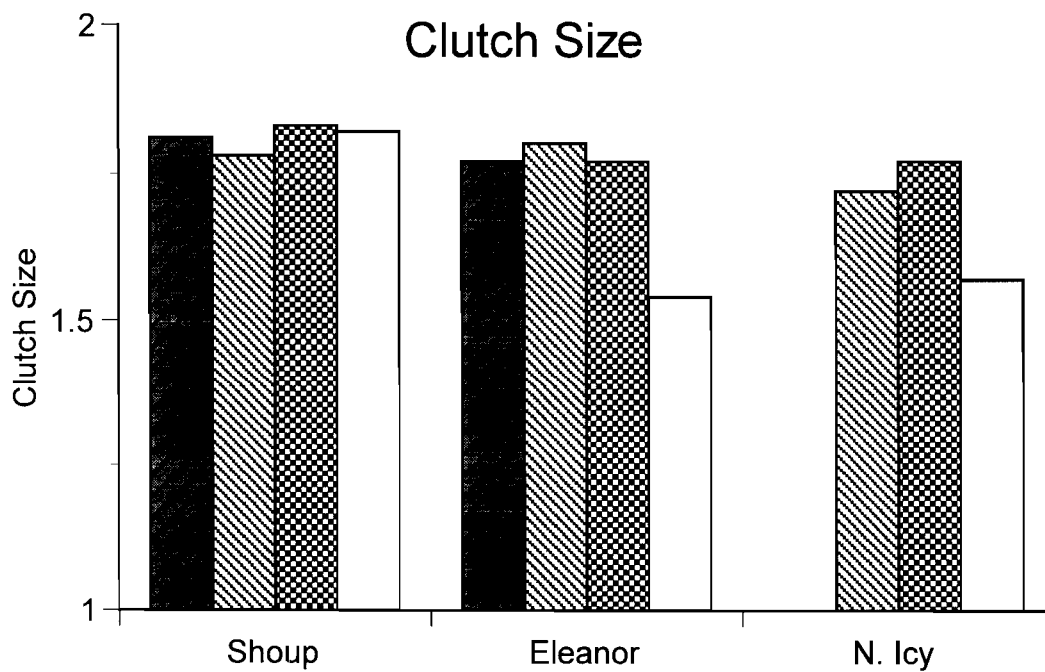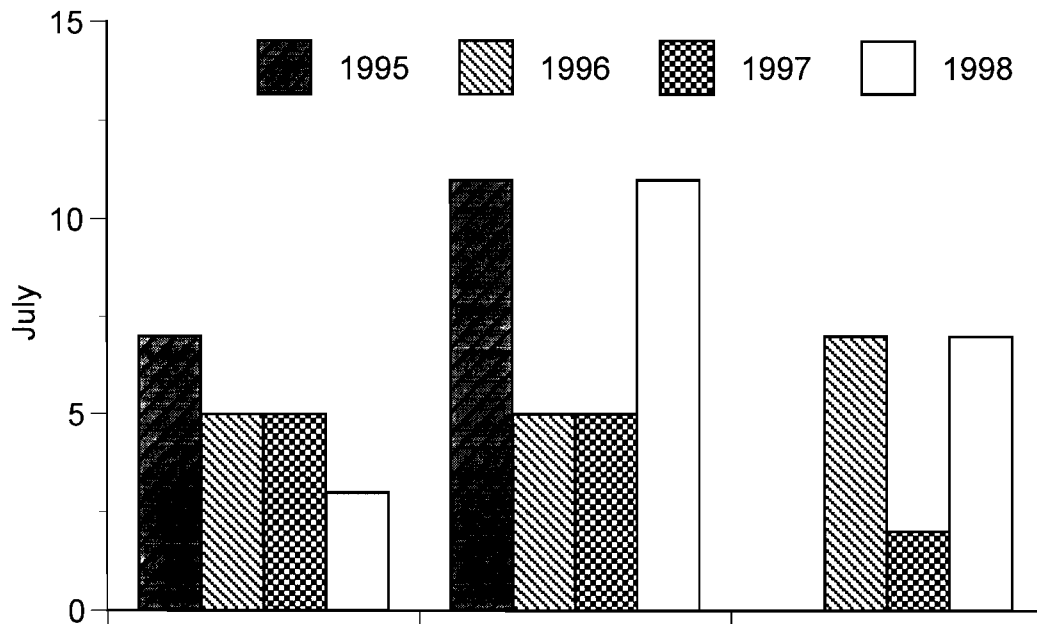## Median Hatching Date

Clutch Size

Figure 1. Median hatching date and clutch size of Black-legged Kittiwakes nesting in Prince William Sound, Alaska 1995-1998

Shoup Bay   Eleanor Island   N. Icy Bay

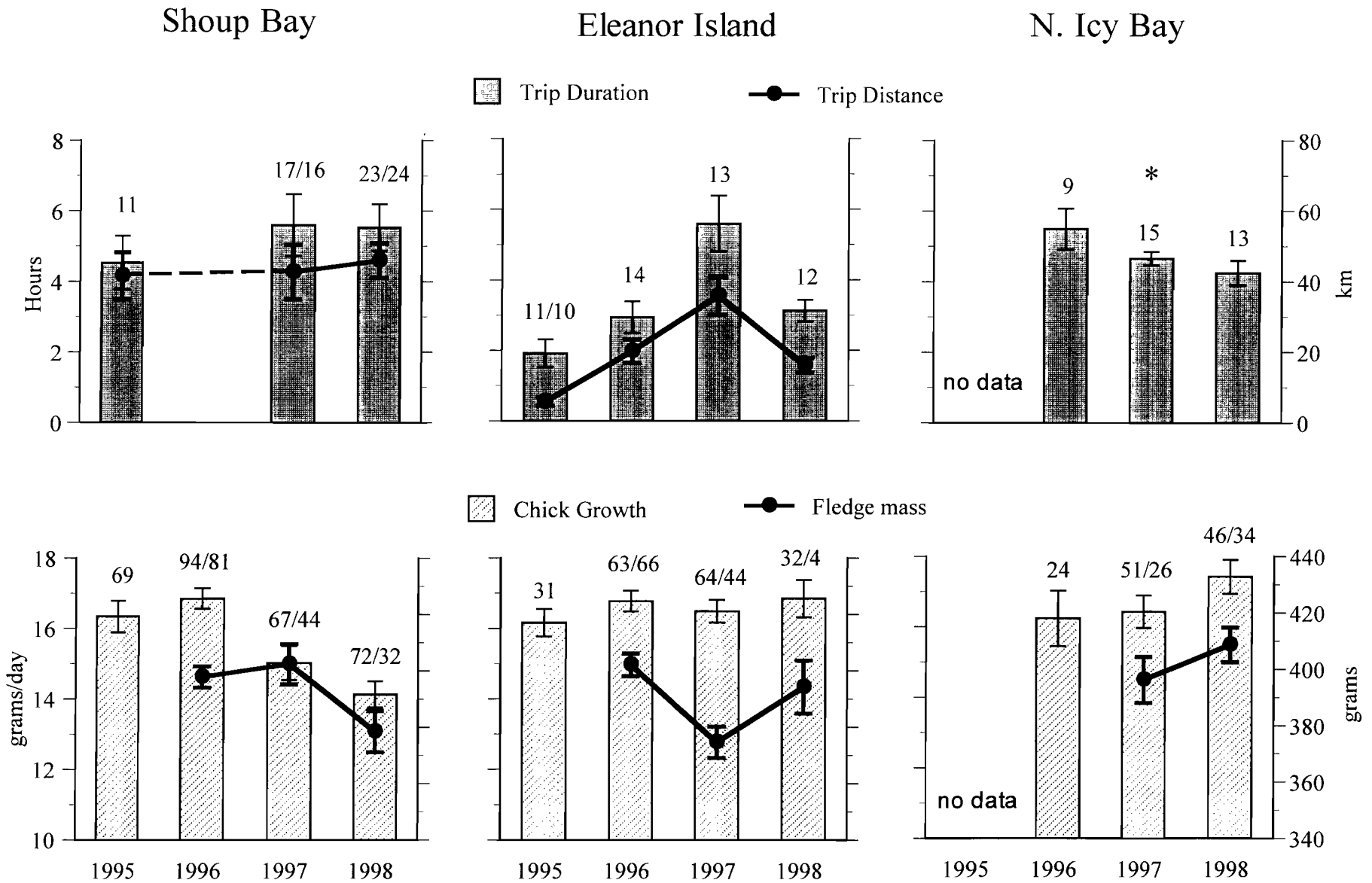Trip Duration   Trip Distance
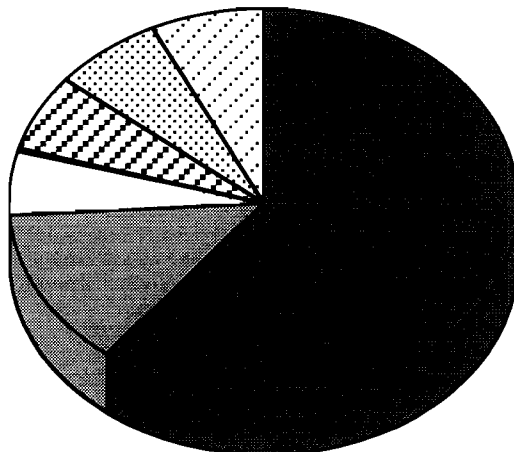
Chick Growth   Fledge mass

Figure 2. Foraging effort of adult kittiwakes (trip duration and distance) and nestling development (growth rate and near-fledging mass) for birds nesting at the Shoup bay, Eleanor Island, and N. Iorth Icy Bay colonies, Prince William Sound 1995-1998. Note (*) that trip duration for North Icy bay is reported from data collection computers which are typically greater on average than those determined by radio tracking (as for Shoup Bay and Eleanor Island).
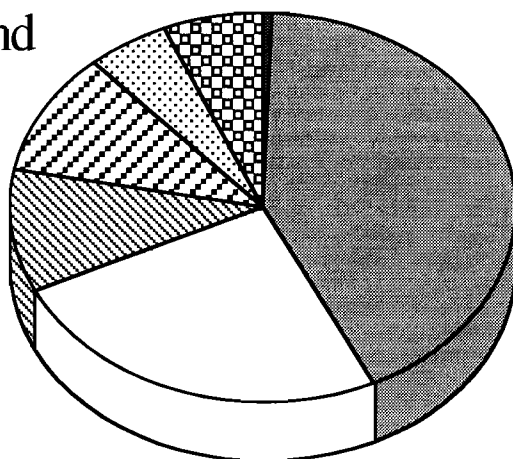
Kittiwake Diets 1998
(% Mass)

Shoup Bay

Eleanor Island

N. Icy Bay

- ■ Herring
- ▨ Sand lance
- □ Capelin
- ▨ Smelt
- ▨ Salmon
- ▨ Offal
- ▨ Salmon eggs
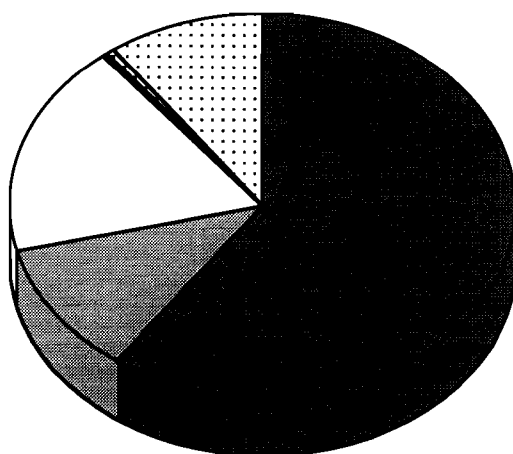- ▨ Pacific cod
- ▨ Euphausiids

Figure 3. Diets (% mass) of Black-legged Kittiwakes at our three study colonies in Prince William Sound, Alaska, in 1998

DETECTING INTRA- AND INTER-ANNUAL VARIATION IN PREY AVAILABILITY USING DAILY FORAGING TRIP DURATIONS.

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Running head: Kittiwake Foraging Trip Duration and Prey Availability

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INTRODUCTION AND OBJECTIVES

The daily energy expenditure (kj/day) of Black-legged Kittiwake nestlings steadily increases until 23 days of age (Gabrielsen et al. 1992). Response in foraging activities of adult kittiwakes to increasing energetic requirements of their nestlings should differ in three predictable ways depending on prey availability. A) If prey are easily obtained and the distribution is unchanged throughout nestling development, then negligible effort is required to obtain additional prey and foraging trip duration should remain relatively constant throughout the chick rearing period (Fig. 1, A). B) If prey are difficult to obtain and availability does not change, then we would predict a steady increase in foraging trip duration and an asymptote when nestlings reach 23 days old (Fig. 1, B). The slope of the curve should reflect the relative difficulty of obtaining prey. C) If there is within season variation in prey availability, then we should observe an unexpected change in foraging trip duration that is inconsistent with response A or B (Fig. 1, C).

Analysis of mean daily trip durations provided examples of the three responses described above. Abrupt or otherwise unexpected changes in trip duration (response C) typically corresponded with changes in species and/or quantities of prey consumed. Preliminary results indicated that comparing daily foraging trip durations to our three hypothetical responses may provide valuable information about intra- and inter-annual variation in prey availability.

METHODS

Three kittiwake colonies in Prince William Sound (PWS) were selected for study. The Shoup Bay colony is the largest (ca. 8000 breeding pairs) in PWS and is located in a fjord in the northeastern region. The Eleanor Island colony is much smaller (ca. 300 breeding pairs) and located among the islands of central PWS. The north Icy Bay colony (ca. 2400 breeding pairs) is located in the southwestern region of PWS, closer to the Gulf of Alaska.

Adult Black-legged Kittiwakes were captured at their nests, usually during incubation, using a noose-pole (Hogan 1985) or leg-noose (Benson and Suryan unpubl. ms.). Radio transmitters (164 - 167 MHZ, 9 g Advanced Telemetry Systems, Inc (ATS), Isanti, Minnesota,

USA) were attached to 15 - 40 birds at each colony per year. Transmitters were secured ventrally to the base of the tail feathers (Anderson and Ricklefs 1987; Irons 1992) with two nylon cable ties and Loctite 494 instant adhesive (Loctite Corporation, Rocky Hill, Connecticut, USA). Nest contents of radio-tagged birds were observed every three days.

An automated data logging system recorded the daily colony attendance of radio-tagged kittiwakes through the breeding season. The receiving stations consisted of an ATS data collection computer (DCC II) linked to an ATS R4000 receiver with a limited-range H or dipole antenna. The system drew power from a 12 v deep cycle marine battery charged by a 3.3 amp photovoltaic panel. For each transmittered bird, the DCC was programmed to listen for an optimal frequency, and two "bracket" frequencies 2 kHz to either side: this prevented reception problems caused by possible frequency drift. A reference transmitter was deployed to later assess the continuity of the record and "dummy" frequencies were programmed in to monitor noise levels. The DCC scanned through 15 to 40 birds three times every 17 to 42 minutes (20 seconds each frequency).

Data were downloaded to laptop computer in the field and processed using Paradox (Borland International, Inc., Scotts Valley, CA USA) and Quattro Pro (Corel Corp., Ottawa, Ontario, Canada) software. Absences over 45 minutes were counted as foraging trips. For this study we included only foraging trips of adults provisioning nestlings. Our sampling unit was individual birds; therefore, an average trip duration was calculated for each adult kittiwake initiating foraging trips on a particular day. Daily mean trip durations were then determined by calculating a mean among birds for each day of the chick rearing period. Only daily means derived from the records of five or more kittiwakes were used.

Diet samples (regurgitations) were collected opportunistically from nestlings throughout the colony, not specifically from the young of radio-tagged birds. Samples were collected while handling chicks and frozen for later analysis. Typically, no more than one sample was collected per nestling. Prey were identified using otoliths, morphological characteristics, scales, and bones. To relate foraging trip duration and diet we were interested in the week to week changes in occurrence of various prey types, therefore diet data are presented as percent occurrence.

DATA ANALYSIS AND PRESENTATION

Figures 2 through 4 are records of mean daily foraging trip durations of adult kittiwakes from three study colonies in PWS during 1995 to 1997. Each figure contains trip duration records that represent a particular response described above. The assignment of a trip duration record to a response category was based on simple visual (qualitative) comparisons. We are working with APEX component O to develop methods for statistically quantifying which hypothetical response best fits a particular record.

RESULTS

Mean daily trip duration and chick diet data were used to illustrate three ways we predicted black-legged kittiwakes would respond to variation in the distribution and availability of prey.

Response A: Eleanor Island trip duration records from 1995 (Fig. 2a) and 1997 (Fig. 2b) are examples of the response to a prey supply that is abundant and easily obtained and whose distribution remains relatively unchanged throughout chick rearing.

• The flat to very low slopes of the mean daily trip duration lines indicate food was readily available and that, through time, minimal additional foraging effort was required to meet the increasing energy demands of growing chicks.

• The percent occurrence of different prey species remained fairly constant indicating prey species composition remained steady through the period.

• A comparison of Y-intercepts of the two figures yields an interesting insight. In 1995, short durations indicated food was readily available near the colony. In 1997 greater mean trip durations (double those of 1995) indicated the foraging areas were farther away. Diets and radio tracking support this (Suryan et al, in review).

Response B: The records of Eleanor Island 1996 (Fig. 3a) and North Icy Bay 1996 (Fig. 3b)

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illustrate a kittiwake foraging response to a prey supply that was stable in its availability (as response A) but was relatively <u>more difficult to obtain</u>. In this case, additional energy required by growing chicks required detectable increases in effort by the adult.

- The steeper slopes of figures 3a and 3b show that through time, foraging adult kittiwakes were forced to stay out progressively longer to collect the additional prey required by their young.

- As in figures 2a and 2b, there were no consistent changes in nestling diets in 1996 at Eleanor Island (Fig. 3a). The prey availability and species composition remained relatively constant.

- Trip durations at N. Icy Bay 1996 (Fig. 3b) were longer, in the first two weeks, than those of Eleanor Island 1996 (Fig. 3a), indicating prey was more difficult to obtain for kittiwakes at N. Icy Bay.

Response C: Within season changes in forage fish availability are predicted to cause unexpected or sudden shifts in mean daily foraging trip duration inconsistent with responses A and B. Plots of mean daily foraging trip duration from Shoup Bay contain slope breaks which often correspond to significant changes in the species composition of kittiwake diets.

- Shoup Bay 1995: A sharp rise in trip duration coincides with a reversal in the relative abundance of sandlance and herring in the diets (Fig. 4a). The sandlance were relatively close and easy to obtain while the herring may have been further away or more difficult to obtain.

- Shoup Bay 1997: Figure 4b is an example of a sudden change in mean daily trip duration that is directly linked to a change in both availability and distribution of different prey species. Average trip durations started high in July 1997 and climbed to

higher values, indicating prey was difficult to obtain (Fig. 4b). A sudden reduction in trip duration on 23 July corresponded to a reversal in the proportions of herring and sandlance in the nestling diets.

CONCLUSION

A comprehensive record of colony attendance and trip duration is a useful component of a long term monitoring program, especially where diet, nestling growth and breeding success are also being tracked.

- In conjunction with chick diet data, trip duration records let us a track changes in the availability of forage species at a colony within the same season. This can help explain changes in reproductive parameters. This method provides a more complete record of changes in trip duration than relatively infrequent direct or video observation sampling techniques.

- The plots also clearly demonstrate there are marked differences in trip duration within and between years at the same colony. These differences reflect the predator's response to weekly and year-to-year fluctuations in the abundance and distribution of prey. Multi-year records are crucial to obtaining more than a "snapshot" view of these long lived seabirds' interaction with their complex and changeable environment.

Is low variance in trip durations a sign of a predictabile food supply?

- When radio-tagged BLKI make trips of similar average duration each day, variability (SE) is small (e.g. Figs. 2a, 3b). We predict this happens when food is abundant and consistently found in one area or at a given distance from the colony. Large variability (e.g. Figs. 3a, 4b) indicates birds are traveling a variety of distances, employing a range of individual foraging strategies to search for a more patchy, unpredictable distribution of

prey. Assessment of relative variability among years may provide another indication of relative "difficulty" in obtaining prey and the predictability of food resources. Due to intra-specific competition, within colony variation in foraging strategies may be accentuated at large colonies (e.g. Shoup Bay) when food becomes less available.

LITERATURE CITED

Gabrielsen, G. W., M. Klassen, and F. Mehlum. 1992. Energetics of black-legged kittiwake *Rissa tridactyla* chicks. Ardea 80: 29-40.

Suryan, R.M., D.B. Irons, and J. Benson. In review. Interannual variation in diet and foraging effort of kittiwakes in relation to prey abundance. Ibis.

List of Figures

Fig. 1. Three hypothetical responses in foraging effort (trip duration) of adult kittiwakes to increasing energy requirement of nestlings - which peaks at 23 days old.

Fig. 2. a) Plot of mean daily trip duration (hours $\pm$ SE) from adult kittiwakes (n=5-7 birds/day) at the Eleanor Island colony in 1995. Bars indicate percent occurrence of prey species for three weeks beginning 22 July (n=3-13 samples/week).

b) Plot of mean daily trip duration (hours $\pm$ SE) from adult kittiwakes (n=8-17 birds/day) at the Eleanor Island colony in 1997. Bars indicate percent occurrence of prey species for five weeks beginning 1 July (n=9-29 samples/week).

Figures 2a, 2b are examples of predicted kittiwake foraging response (A): prey availability remains constant, prey is easily obtained, and negligible effort is required to obtain sufficient additional prey.

Fig. 3. a) Plot of mean daily trip duration (hours $\pm$ SE) from adult kittiwakes (n=5-8 birds/day) at the North Icy Bay colony in 1996. Bars indicate percent occurrence of prey species for one week beginning 29 July (n=4 samples).

b) Plot of mean daily trip duration (hours $\pm$ SE) from adult kittiwakes (n=5-16 birds/day) at the Eleanor Island colony in 1996. Bars indicate percent occurrence of prey species for four weeks beginning 08 July (n=7-19 samples/week).

Figures 3a, 3b are examples of predicted kittiwake foraging response (B): prey availability is constant, but prey is difficult to obtain. Note the large variability in Fig. 3a in comparison to Fig. 2a (similar sample size). Increased variability may be a sign of a less predictable food supply.

Fig. 4. a) Plot of mean daily trip duration (hours $\pm$ SE) from adult kittiwakes (n=8-11 birds/day) at the Shoup Bay colony in 1995. Bars indicate percent occurrence of prey species for two weeks beginning 15 July (n=51-73 samples/week).

b) Plot of mean daily trip duration (hours $\pm$ SE) from adult kittiwakes (n=5-24 birds/day) at the Shoup Bay colony in 1997. Bars indicate percent occurrence of prey species for four weeks beginning 08 July (n=256 total samples).

Figures 4a, 4b are examples of the predicted kittiwake foraging response (C) to change(s) in the distribution and/or availability of prey. Sudden changes in mean trip duration were concurrent with changes in diet composition.
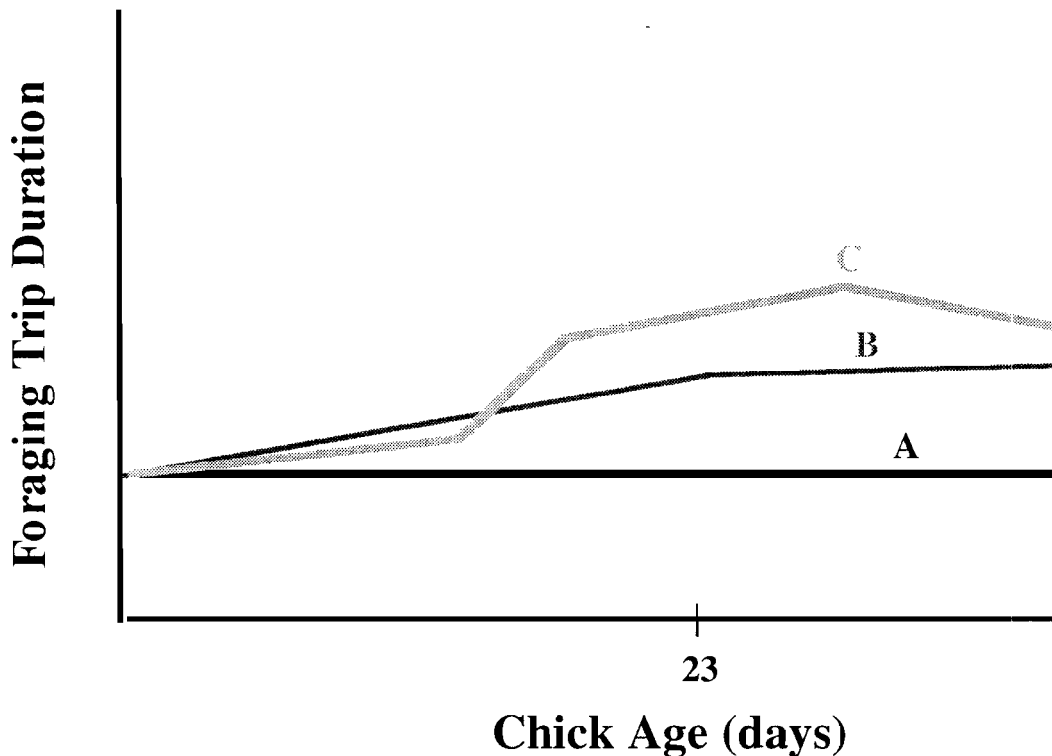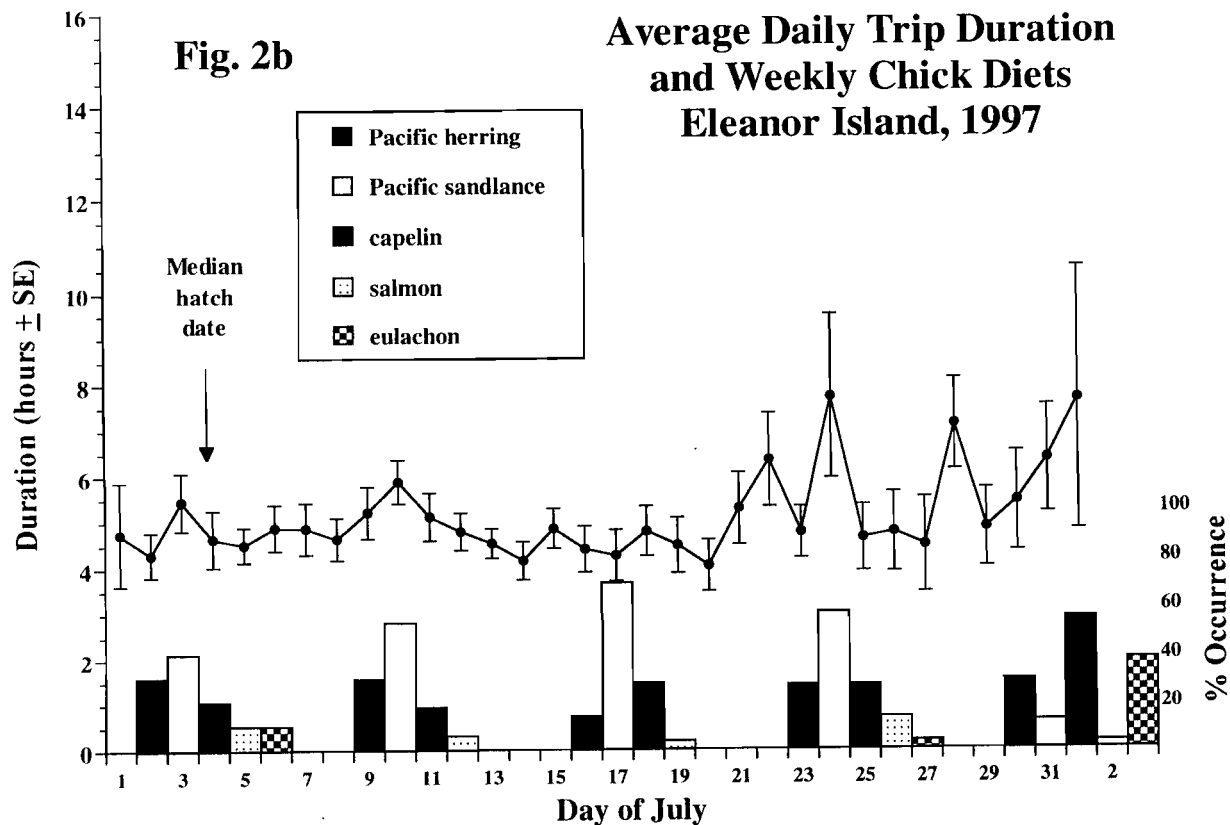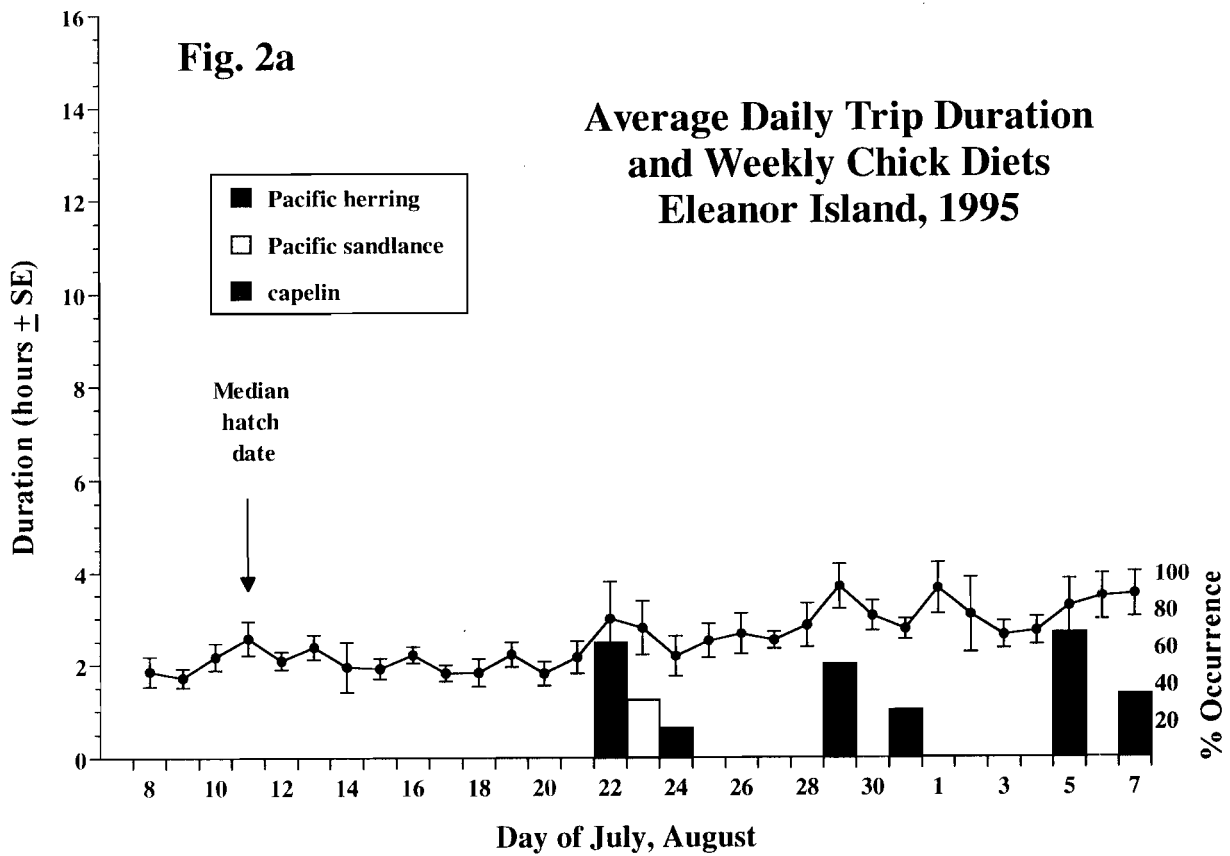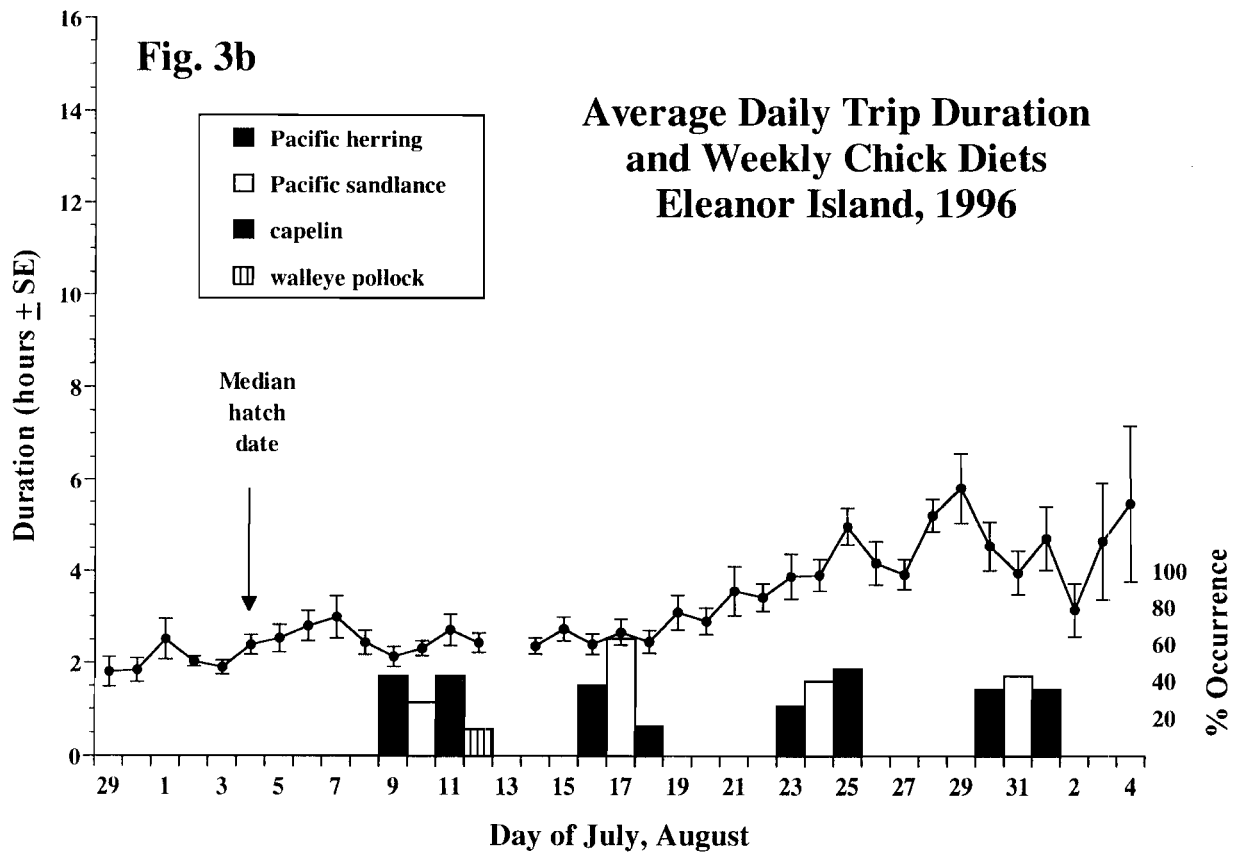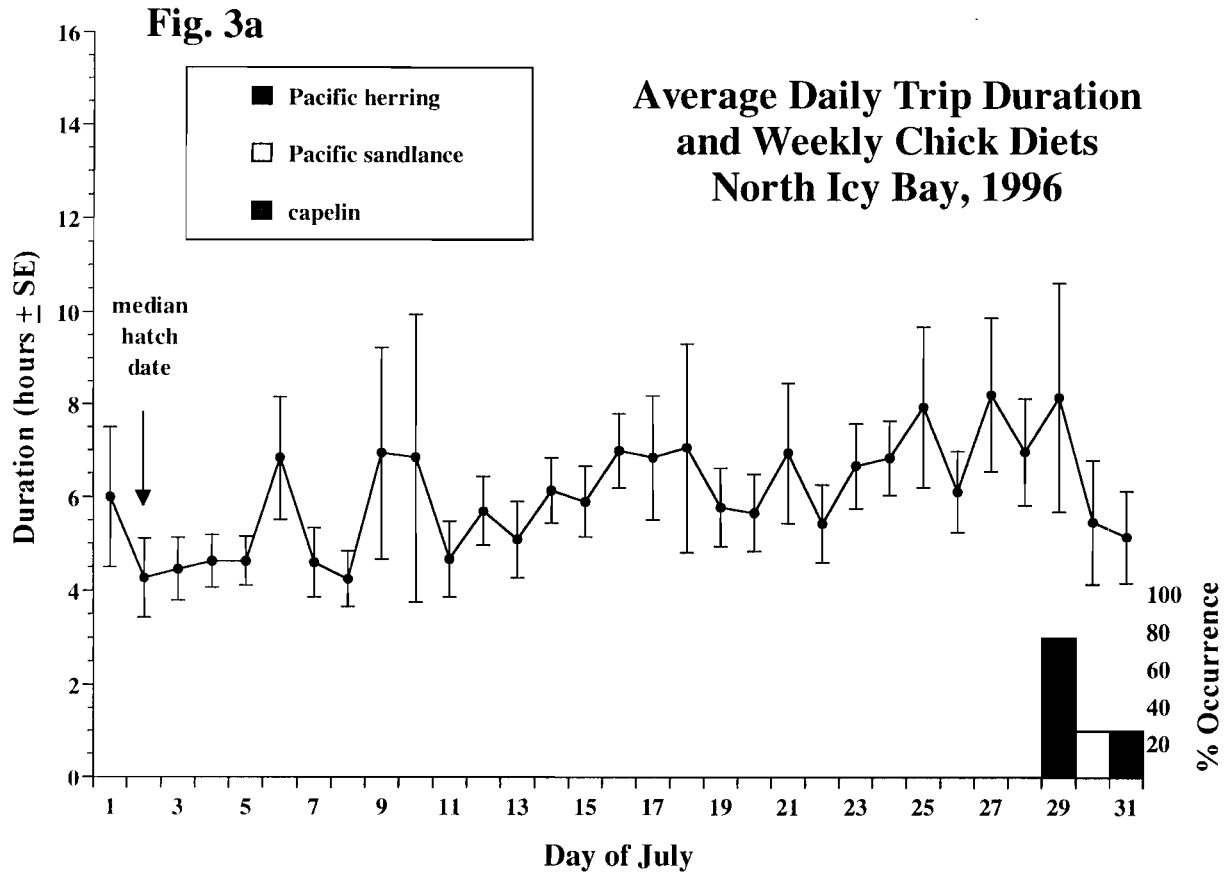
Figure 1. Hypothetical responses in foraging effort (trip duration) of adult kittiwakes to increasing energy requirements of nestlings - which peak at 23 days old.
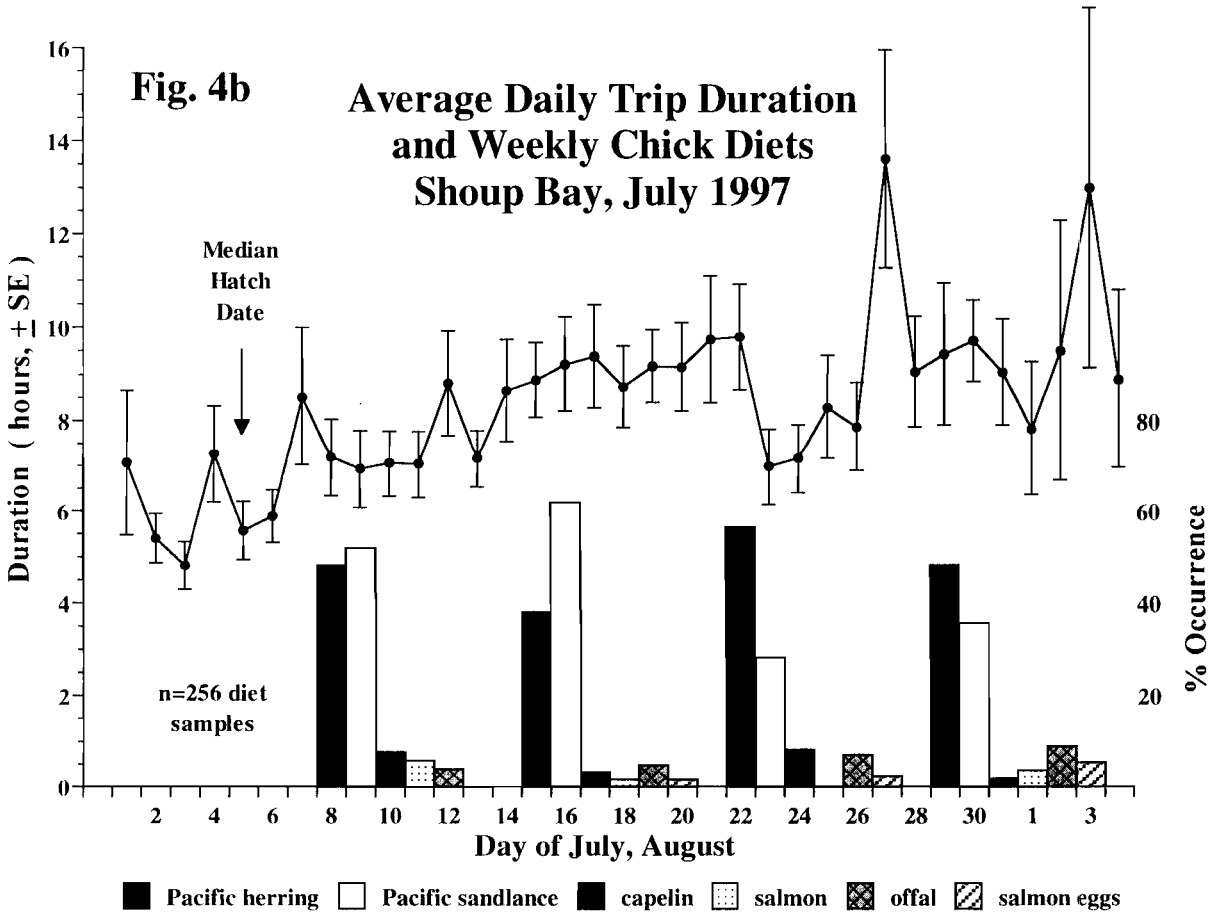
A) Prey is easily obtained and negligible effort is required to obtain sufficient additional prey.

B) Prey is difficult to obtain and availability does not change.

C) Within season variation in prey availability causes changes in foraging effort that are inconsistent with A or B.

Fig. 2a

Average Daily Trip Duration and Weekly Chick Diets Eleanor Island, 1995

Legend:
- Pacific herring
- Pacific sandlance
- capelin

Median hatch date

Duration (hours ± SE)

% Occurrence

Day of July, August

Fig. 2b

Average Daily Trip Duration and Weekly Chick Diets Eleanor Island, 1997

Legend:
- Pacific herring
- Pacific sandlance
- capelin
- salmon
- eulachon

Median hatch date

Duration (hours ± SE)

% Occurrence

Day of July

Fig. 3a

Average Daily Trip Duration and Weekly Chick Diets North Icy Bay, 1996

Legend:
- ■ Pacific herring
- □ Pacific sandlance
- ■ capelin

median hatch date

Day of July

Fig. 3b

Average Daily Trip Duration and Weekly Chick Diets Eleanor Island, 1996

Legend:
- ■ Pacific herring
- □ Pacific sandlance
- ■ capelin
- ⊞ walleye pollock

Median hatch date

Day of July, August

Fig. 4a

Average Daily Trip Duration
and Weekly Chick Diets
Shoup Bay, July 1995

Fig. 4b

Average Daily Trip Duration
and Weekly Chick Diets
Shoup Bay, July 1997

AN EVALUATION OF METHODS FOR DETERMINING
GROWTH RATES OF NESTLING SEABIRDS

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INTRODUCTION AND OBJECTIVES

The primary factor controlling the development of nestling seabirds is energy intake (KJ/day, which can be defined as meal quality (KJ/g)*meal size (g)*meal provisioning rate (#/day)). The ability for adult seabirds to meet the energetic demands of nestlings is primarily controlled by the availability and quality of their prey. The availability and quality of prey can be affected by naturally occurring processes or anthropogenic influences. Nestling growth rate, therefore, can be a sensitive indicator of natural factors influencing prey (Boersma and Parrish 1998) or serve as a biomarker of exposure to anthropogenic-originated contaminants (Fendley and Brisbin 1977); both are conditions that affect the integral health of the parent-offspring relationship. Nestling growth is also one measure of reproductive success that is, for the most part, independent of forces that confound the assessment of prey quality and availability (e.g. measures such as hatching success and fledging success can be strongly affected by predation, disturbance, or weather).

Comparisons of nestling growth within species have provided details of foraging conditions among geographic regions (Barrett and Runde 1980, Pettit et al. 1984) or among years at a given colony (Pettit et al. 1984). A persistent problem in the calculation of nestling growth rates, however, is the inconsistent use of methods among investigators. Some investigators have used non-linear models fitted to complete records of growth (from day 1 to near-fledging age; Ricklefs 1983, Pettit et al. 1984), while others have focused on certain portions of the development period (e.g. the near-linear phase; Coulson and Porter 1985, Coulson and Thomas 1985). Unfortunately, growth rate values calculated by these different methods are not directly comparable and, to the best of our knowledge, there has not been a rigorous comparison of accuracy and sensitivity of these methods at detecting differences in growth rates among years and among populations.

In this paper we selected measures of Black-legged Kittiwake (*Rissa tridactyla*) nestlings from several years and colonies that exhibited various patterns of growth (e.g. rapid growth but low fledging mass, slow growth but high fledging mass, etc.). We then compared the performance of three commonly used methods for determining the rate of mass increase (nonlinear, linear based on mass, and linear based on age) and one new method, an index of growth based on the relationship between transformed wing and mass values.

METHODS

The shape of the three commonly used nonlinear model (logistic, Gompertz, and Von Bertalanffy) is determined by three parameters; the asymptote (A), the growth rate constant (K), and the inflection point (I; Ricklefs 1983). Calculating the first derivative (i.e. slope of the tangent at the inflection point) of either curve provides the maximum instantaneous growth rate with units of g/day (e.g. AK/4 for the logistic model). For most seabird species, the logistic equation provides the best fit to nestling growth data.

When comparing the "linear" growth rate of nestlings, nestling mass is plotted against age for a given age or mass range, then regression analysis is used to calculate the slope or

growth rate (g/day). Investigators have used varying criteria for defining the "linear" range of the growth curve. For kittiwake nestlings Coulson and Thomas used 100 to 300 g, while Coulson and Porter (1985) used 60 to 300 g to represent the near-linear phase of growth. It is reasonable to expect that defining the upper and lower bounds of the near-linear phase would vary depending the shape of the growth curve. Other investigators have used nestling age to define the bounds of the "linear" phase of growth. The upper and lower bounds are commonly set by plotting the mean mass versus nestling age and visually defining the limits of near-linear growth. Investigators have also used quantitative means for defining these age limits (Lance 199?). In our analyses of kittiwakes we used age ranges of 6 - 22 days and 5 - 25 days to represent the near-linear phase of nestling growth.

The third method we evaluated was the growth performance index (GPI). The GPI is a regression of the square root of mass vs. square root of the natural log of wing length. Slopes of this relationship can be compared among "populations" of interest, similar to slopes or growth rates determined using "linear" methods above. The benefits of this method are that all nestling measurements are used in the analysis (as with non-linear methods) and nestling age can be unknown.

We first tested results of the various methods by applying them to basic growth curves. We generated two logistic and two Gompertz growth curves that represented observed growth patterns of Black-legged Kittiwake (*Rissa tridactyla*) nestlings. The first logistic and Gompertz curves represented a normal growth pattern and possessed equal initial masses (at day zero) and asymptotic weights (Figure 1). The second logistic and Gompertz curves represented a reduced growth pattern (similar to that of undernourished young reported by Romano et al. (1998) while also having equal initial masses and asymptotic weights (Figure 1). Logistic and Gompertz curves were also generated for wing length measures corresponding to normal and low growth (Figure 2). These wing length values were used in calculating the GPI. Parameters of these generated curves are provided in Table 1. We then calculated the linear approximation of these curves using the methods described above.

To evaluate the sensitivity of detecting differences in growth with the various measures, we ran two comparisons using four sets of data collected at kittiwake colonies in PWS. The data sets represented several different growth patterns. The first comparison was between data representing a high growth rate with high fledging mass (from alpha nestlings) and low growth rate with low fledging mass (from beta nestlings; Figure 3). The second comparison included nestlings exhibiting a high rate of growth that could not be maintained, resulting in reduced fledging masses (from alpha and beta nestlings). These nestlings were compared to a group showing an opposite effect, a lower rate of growth that was maintained for a longer period resulting in a greater fledging mass (Figure 4).

PRELIMINARY RESULTS

Model Data

All methods for calculating growth rate (g/day) responded as expected when comparing the normal versus low growth patterns of the model curves; rates during normal growth were greater than those during low growth (Table 2). There were, however, differences in values

among methods. For the logistic curve, rate determined by KA/4 produced the highest value followed by rate based on age; with rates based on age increasing as the age range of each method decreased (Table 2). The effect of age range on rate was due to narrowing age ranges representing steeper portions of the growth curve, thereby approaching the maximum instantaneous growth rate or AK/4 (for the logistic curve). Rate based on linear approximation delimited by mass was comparable to other methods for normal growth, but was biased low when applied to the curve of reduced growth. This bias resulted from the asymptotic mass of the curve representing poor growth being slightly above 300g, therefore, the 6 - 300 g range included ages of nestlings that were well beyond the "near-linear" phase of growth.

When applied to the Gompertz curves, the relative performance of the various methods were similar to that described for the logistic model. The GPI produced results that depicted conditions of fast and slow growth. A more thorough evaluation of the GPI was possible with the use of empirical data sets.

Comparisons using empirical data sets: high rate and high fledging mass versus low rate and low fledging mass.

For the non-linear method, the logistic curve best fit the data presented in Figure 3. Significant differences between the two data sets were detected using three of the methods; logistic (AK/4), linear by mass, and GPI (Table 3). The greatest difference between high and low growth and the most significant result occurred with the linear by mass method. However, the linear by mass method may have exaggerated the slow growth of the beta chicks, as described with the model data, resulting in a greater effect size and the greatest significant result. The linear by age method did not produce significant results using either age range.

Comparisons using empirical data sets: high rate and low fledging mass versus low rate and high fledging mass.

The logistic growth curve (Figure 4) was the only method that detected significantly different trends between these two sets of data (Table 4). For the logistic curve, these differences were evident in the maximum instantaneous growth rate (AK/4) and the fledging mass (asymptote). The linear by mass and linear by age (6 - 22 days) methods produced means supporting the observed trends of fast and slow growth, but the differences were not significant. The linear by age (5 - 25 days) and GPI methods produced very similar means, respectively, for the two data sets. These latter two methods likely failed to detect the differences because they averaged or "smoothed over" the opposing changes in growth the two groups of nestlings exhibited.

Additional Analyses
To provide a complete evaluation of these various methods, we will include several more empirical data sets representing additional growth scenarios of nestling seabirds.

DISCUSSION

.................see Table 5 for now.............

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Table 1. Parameters of model curves.

	Mass		Wing	
	normal	low	normal	low
Logistic				
A	417	310	255	210
K	0.1844	0.165	0.1411	0.132
I	11.65	10.5	17.82	17.2
Gompertz				
A	417	310	255	210
K	0.13	0.13	0.09	0.086
I	6.3	4.8	10.5	9.8

Table 2. Growth rates determined from model curves

	KA/4			by Age				by Weight				GPI		
	normal	low	age range (days)	normal	age range (days)	low	age range (days)	normal	age range (days)	low	age range (days)	normal	low	age range (days)
Logistic	19.22	12.09	(1 - 30)	17.93	(5 - 17)	12.21	(5 - 16)	16.93	(2 - 16)	9.15	(2 - 30)	24.41	20.24	(1 - 30)
				16.65	(6 - 22)	10.97	(6 - 22)							
				15.43	(5 - 25)	10.21	(5 - 25)							
Gompertz			(1 - 30)	19.53	(3 - 9)	14.42	(3 - 9)	18.19	(2 - 14)	8.23	(1 - 30)	24.70	20.57	(1 - 30)
				13.74	(6 - 22)	9.14	(6 - 22)							
				12.76	(5 - 25)	8.48	(5 - 25)							

Table 3. Comparisons using empirical data sets with high rate and high fledging mass versus low rate and low fledging mass

Measure	N. Icy Bay (alpha's)			Shoup Bay (beta's)			Mann-Whitney Chi-Sqr Approx.	P	Power
	X	SE	n	X	SE	n			
A	439.19	9.17	15	401.40	19.87	14	1.9505	0.1625	
AK/4	20.50	0.58	15	16.92	0.85	14	8.5500	0.0035	
Linear (Mass)	18.81	0.56	15	12.88	1.09	14	14.0880	0.0002	
Linear (Age)									
6 - 22 days	16.34	0.73	15	14.14	1.06	14	2.2019	0.1378	In
5 - 25 days	15.88	0.58	15	14.26	0.72	14	1.9505	0.1625	Progress
GPI	24.74	0.34	15	22.81	0.84	14	4.0305	0.0447	

Table 4. Comparisons using empirical data sets with high rate and low fledging mass versus low rate and high fledging mass.

Measure	Eleanor Island			Shoup Bay			t	P	Power
	X	SE	n	X	SE	n			
A	396.23	5.54	50	434.06	10.10	46	-3.355	0.001	
AK/4	19.5465	0.3108	50	18.3977	0.3713	46	2.386	0.019	
Linear (Mass)	16.60	0.36	50	15.83	0.55	46	1.178	0.242	In
Linear (Age)									
6 - 22 days	16.13	0.27	50	15.58	0.42	46	1.137	0.258	Progress
5 - 25 days	14.96	0.23	50	14.95	0.33	46	0.011	0.991	
GPI	23.28	0.28	50	23.69	0.28	46	-1.029	0.306	

Table 5.

| Method	Accuracy	Known-age Nestling?	Sensitivity	Comments
Logistic	Good in all situations	yes	high	Requires frequent measurements of nestlings. Nestlings that die or are without a complete growth record cannot be included in analyses (although see discussion section and Ricklefs 1983).
Linear by mass (60 - 300 g)	Good for normal growth Poor for slow growth with asymptote at or near 300 g	no	low	Requires relatively few measures of nestlings. Nestlings that die prematurely can still be included if two or more data points are obtained within the specified range.
Linear by age (6 - 22 days)	Good in most situations Some concern for situations of slow growth when asymptote occurs at an early age	yes	low	Same as linear by mass method.
Linear by age (5 - 25 days)	Good in most situations Definite concern for situations of slow growth when asymptote occurs at an early age	yes	low	Same as linear by mass method.
GPI	Good in most situations Poor at detecting situations where growth changes within a season (e.g. high rate, low asymptote)	no	moderate	Requires relatively few measures of nestlings. It is best that measurements are throughout the entire growth period, but they could be restricted to a defined range of wing lengths. A primary concern of this method is that the calculated rate is not in commonly used units (e.g. g/day) for comparison with other studies.

Mass

Normal and Low Growth
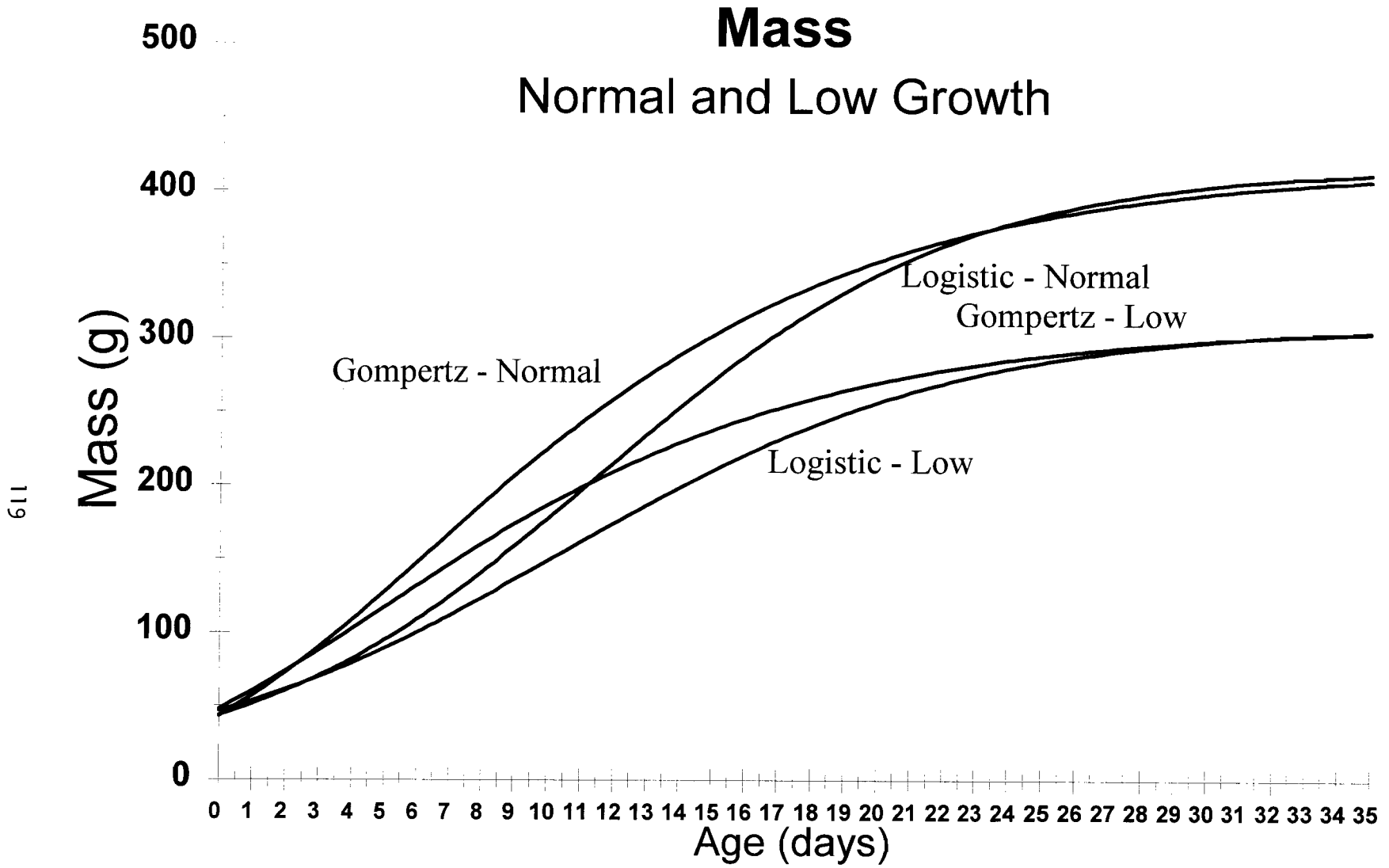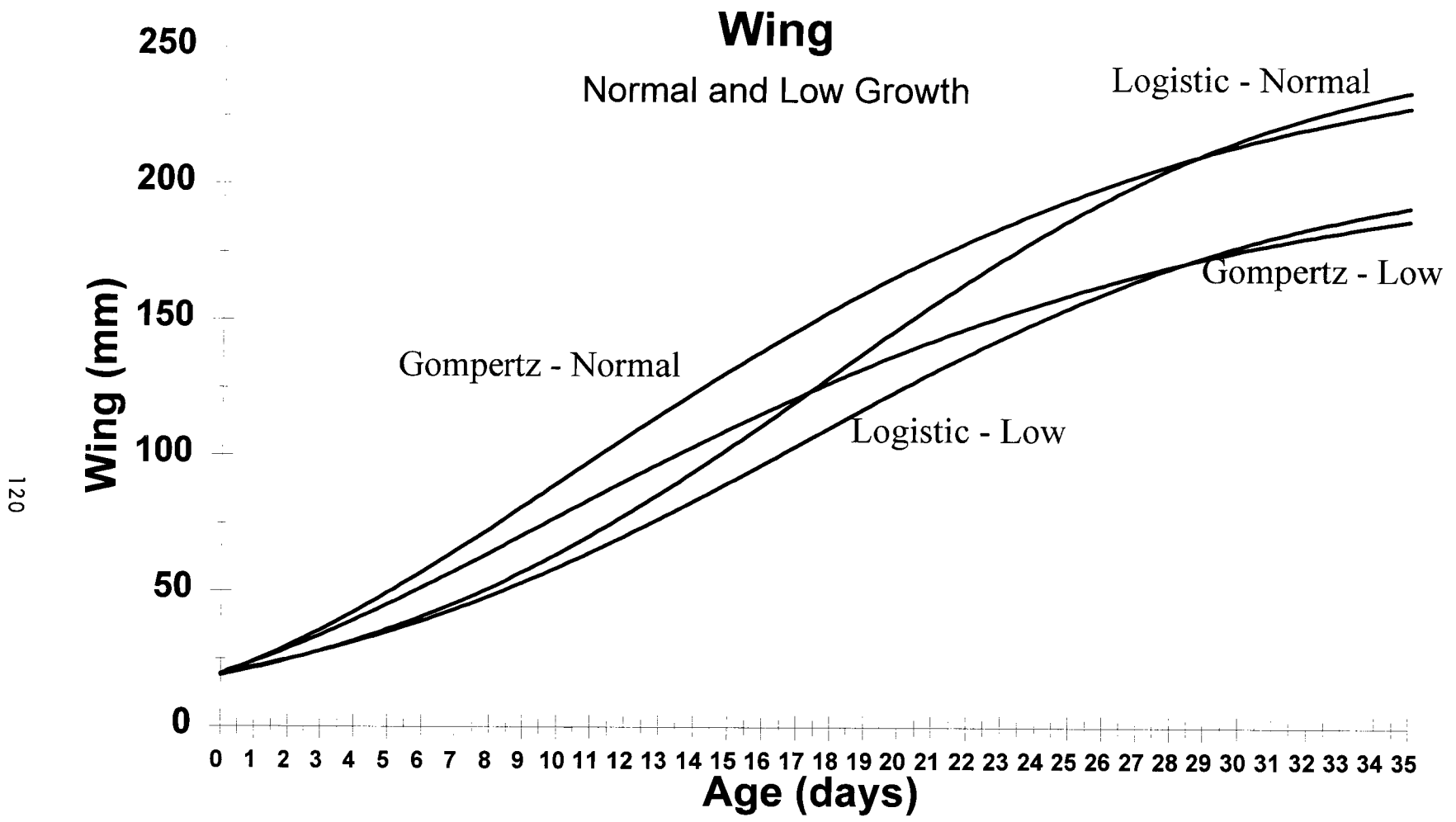
Figure 1.

Figure 2.

Logistic Growth Curves

N. Icy Bay (alpha's 1998)
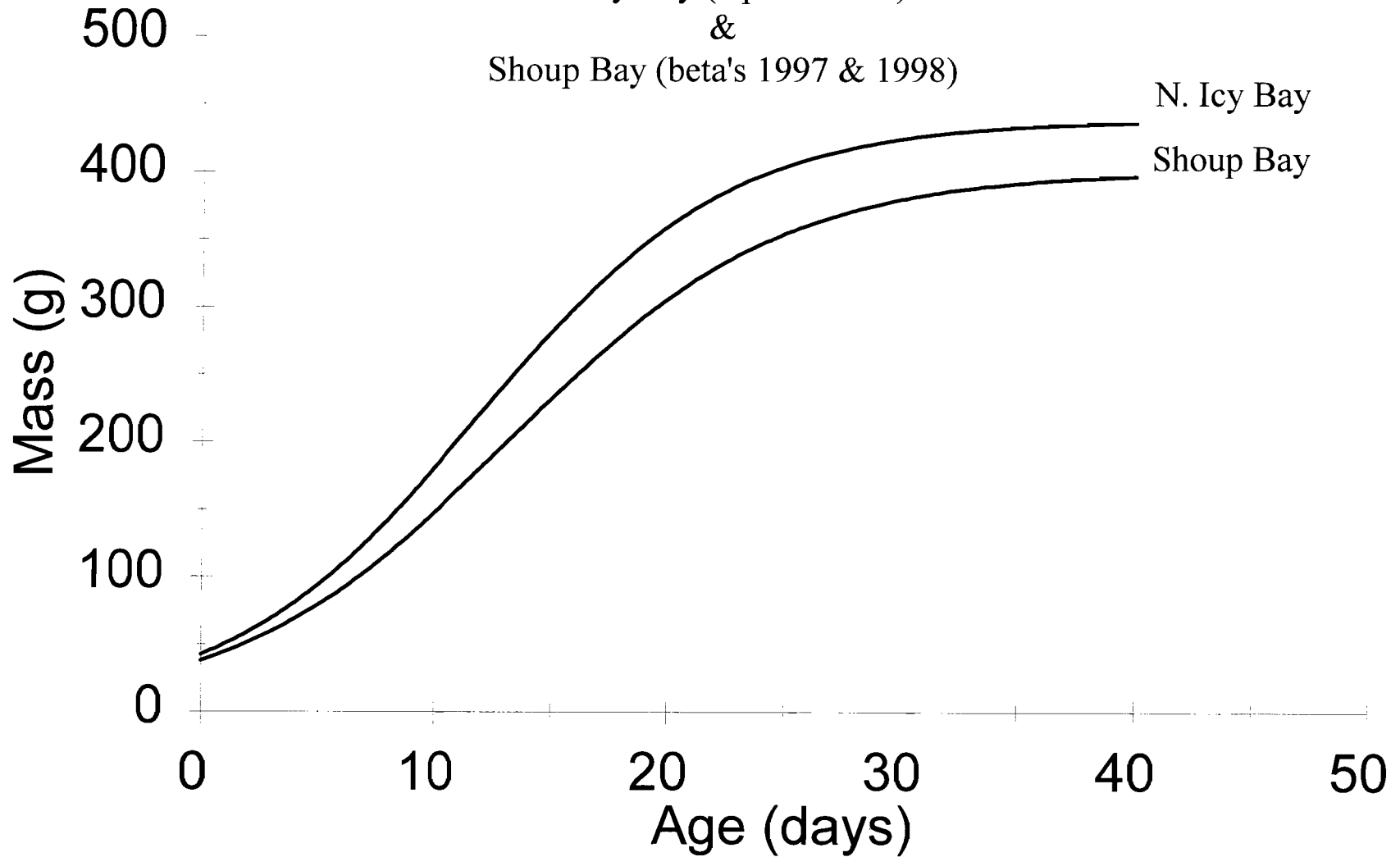## &
Shoup Bay (beta's 1997 & 1998)
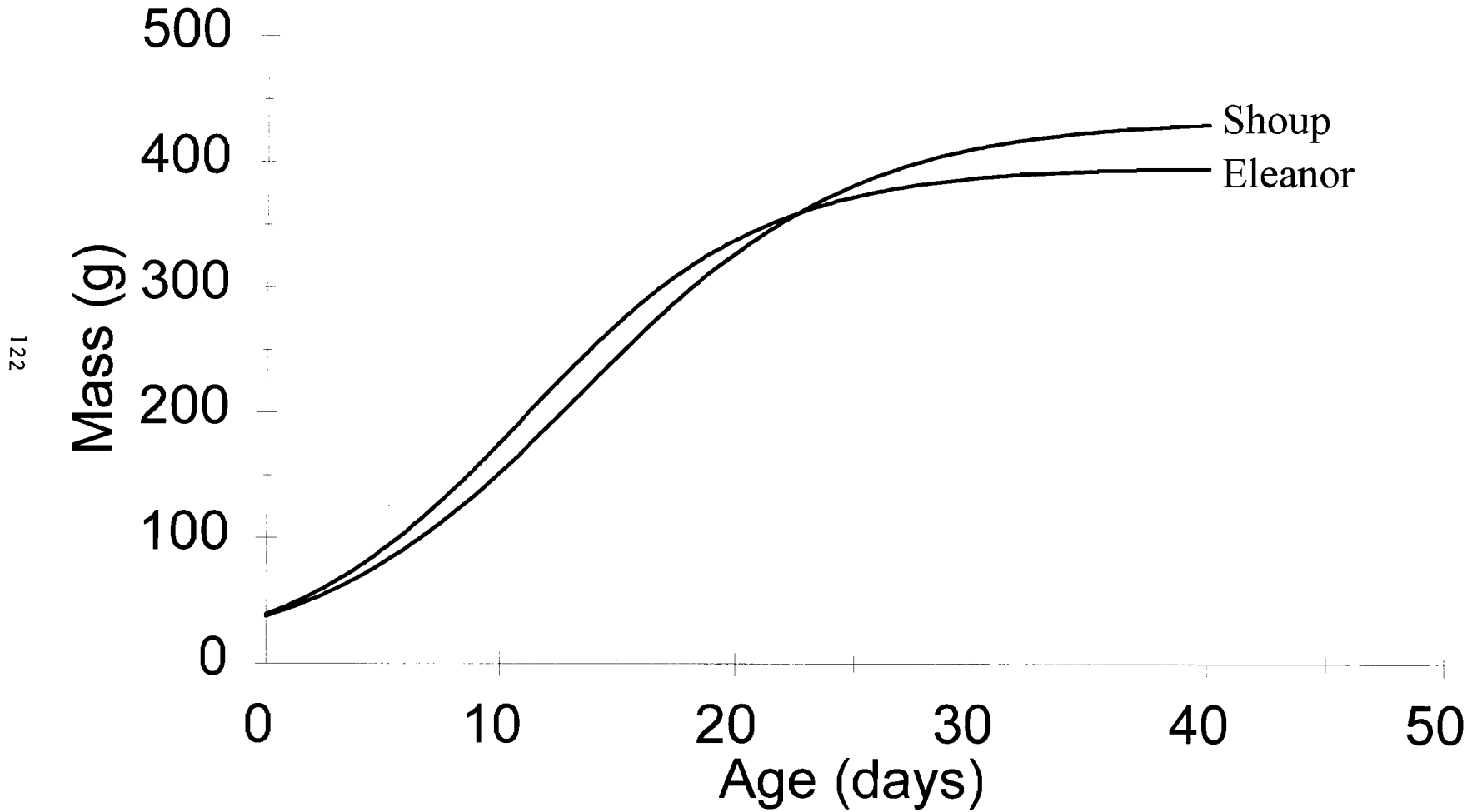

Figure 3.

Logistic Growth Curves
1997

Figure 4.

A MULTIVARIATE APPROACH TO ASSESSING GROWTH OF SEABIRD NESTLINGS FROM ONE-TIME MEASUREMENTS

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Abstract. The collection of growth data from nestling seabirds can be logistically difficult, and may take up to 3 months, depending on the species, to measure from hatching to fledging. We evaluated the feasibility of a simpler approach, which utilizes a one-time sampling of nestling measurements obtained during a single visit to a seabird colony, to assess nestling growth. To simulate a one-time visit to a colony, we used a sub-sample of nestling measures that were obtained during a single day at four Black-legged Kittiwake (*Rissa tridactyla*) breeding colonies in Alaska. We used principal components analysis to create a body-size index. In this approach, body-size becomes a proxy for age and the residuals from a regression of mass on body-size can be used to assess relative body-condition. We compared results from analysis of one-time measurements by utilizing repeated measurements of the same individual nestlings to calculate a linear growth rate. One-time measurements revealed differences and similarities in chick growth as effectively as repeated measurements. Thus, we recommend them as a useful tool for monitoring seabirds at colonies where multiple visits and/or repeated measurements of individual nestlings are impractical.

Key words: Alaska, Black-legged Kittiwake, body-condition, nestling growth, principal components analysis, Rissa tridactyla, *seabird monitoring.*

INTRODUCTION

There are many ways to measure and contrast nestling growth data (Ricklefs 1983). The applicability of any given technique depends on the extent of data collected. Repeated measurement of known-age individuals throughout development is the most useful and informative approach to studying chick growth (Ricklefs 1983). However, collection of these data for seabird nestlings, which may require 1-3 months, is often prohibited by logistic and time constraints.

Investigators may use simpler methods to estimate growth rates. For example, Ricklefs and White (1975) used two measurements of a single body part (e.g., wing) taken at a 10 day interval as a proxy for age in order to construct an average growth curve for nestlings at a seabird colony. However, this still requires an initial visit to measure and band individual nestlings, and a return visit to find and measure the same individuals. Further, differential growth of body parts (Øyan and Anker-Nilssen 1996) may lead to biased results. Multivariate analyses incorporating several anatomical measures provides a more complete assessment of size and growth (Ricklefs 1968b).

Studies of adult birds are often limited to one-time measurements taken during capture. Given this constraint, some investigators have used principal components analysis (PCA; Manly 1994) with a residual index (Jakob et al 1996) to compare relative body-condition among adult birds (Hamer et al. 1993, Golet et al. 1998). In this approach, PCA is used to score birds by relative body-size based on several morphological measurements. This creates an index for size, and thus the residuals from a regression of mass on body-size can be used to compare body-condition among individuals and/or treatment groups.

We evaluated the feasibility of using one-time measurements for detecting differences in body-condition of nestling Black-legged Kittiwakes (*Rissa tridactyla*) at four different breeding colonies in Alaska. In this approach, the body-size index generated by PCA becomes a proxy for age. We reviewed these results by utilizing repeated measurements of the same individual nestlings to calculate a linear growth rate for comparison.

METHODS

We measured and weighed kittiwake nestlings at four breeding colonies in the northern Gulf of Alaska: Gull Island and Chisik Island in lower Cook Inlet during 1996, and Shoup Bay, in 1996, and North Icy Bay, in 1998, in Prince William Sound. We checked a sample of representative nests daily to determine hatch dates. When the first chick hatched, we began collecting measurements every four days, including new nestlings as they hatched. We recorded measurements of nestlings from hatching to near-fledging (30 days ± 1 day). Recorded measurements included right tarsus (± 0.1 mm; excluding Chisik Island), head-plus-bill (± 0.1 mm; Shoup Bay and North Icy Bay only), culmen (± 0.1 mm; Gull Island

and Chisik Island only), wing (± 1 mm; from the wrist region to the tip of the longest primary), tenth primary (± 1 mm; from skin to tip of the developing primary; excluding Chisik Island), and body-mass (± 1 g). We banded nestlings with United States Fish and Wildlife Service stainless steel bands and individual color band combinations for identification.

We regressed mass versus age to calculate growth rates (g/day) of individual nestlings during the linear growth phase of 60 to 300 g (Coulson and Porter 1985). We made comparisons using a two-sample t-test. To assess effort, we calculated mean number of measurements that were made per nestling during linear growth and the mean number of days we measured nestlings over the range of linear growth. We calculated mean age of chicks at the end of its observed linear growth phase (i.e., last day recorded where mass was under 300 g). We included all individual nestlings used to calculate linear growth rates in the sub-samples described below.

To simulate a one-time visit to each breeding colony we used a sub-sample of nestling measures that were obtained on a single day at Gull Island (July 22) and Shoup Bay (July 21) in 1996, and N. Icy Bay in 1998 (July 23). A limited number of nestling measures were present in the Chisik Island data on any single day, and therefore we took a sample of unique nestling measurements from several days (July 9,13,18,22). We calculated mean age of nestlings for each sub-sample.

We pooled data for comparisons based on the anatomical measures conducted at each site. At Chisik Island, only culmen and wing were measured. To conduct multivariate analyses we paired these data with Gull Island, the only other site where culmen was measured. Head-plus-bill, tarsus, wing, and tenth primary were measured at Shoup Bay and North Icy Bay, and therefore we paired these data and included all four variables in analyses. We standardized variables to means of zero and standard deviations of one (Manly 1994). We conducted PCA to create an index of body-size using the PRINCOMP procedure in SAS (SAS 1989). We regressed body-mass on body-size and used the residuals, expressed as a percentage of predicted body-mass, to assess relative body-condition. We made comparisons using a two sample t-test after evaluating distribution and homoscedasticity of the data.

RESULTS

Nestlings at Gull Island and Chisik Island exhibited significantly different linear growth rates (t_{30} = 4.2, P < 0.0005), but nestlings at Shoup Bay and North Icy Bay did not (t_{76} = 1.1, P > 0.05; Table 1). All data were normally distributed and homoscedastic.

For nestlings at Gull Island and Chisik Island, body-mass was related to body-size index scores (first principal component) by the equation *mass* (g) = 60.4*size* + 243.7 (Fig. 1a). Based on residuals from this regression, nestlings at Gull Island were 20% heavier for their body-size than Chisik Island nestlings (t_{30} = 3.4, P < 0.005; Table 1). Based upon

residuals from a regression equation for Shoup Bay and North Icy Bay, *mass* (g) = 34.2*size* + 292.6 (Fig. 1b), nestlings did not differ in body-condition (t_{76} = 0.7, P > 0.05; Table 1). Nestlings selected for one-time measurements from Shoup Bay were older than those from North Icy Bay (t_{76} = 2.4, P < 0.05; Table 1).

DISCUSSION

Our results suggest that a one-time sampling of nestling mass and body-size can be used to detect differences (or a lack of differences) in growth among seabird populations. Compared to the effort required to calculate linear growth rates for nestlings at Shoup Bay and North Icy Bay, the average number of measurements per nestling and the total number of days required at the colony for one-time measurements were reduced by 70% and 90%, respectively (Table 1). In addition, it appears that residuals of mass on relative overall body-size can be compared among groups of unequal age.

We extracted sub-samples of equal *n* to generate unbiased statistical comparisons, but other investigators may opt to avoid culling data. An unequal *n* will bias the regression line towards the higher *n*, but conclusions should be similar when sample sizes are approximately equal. Otherwise, separate regressions could be calculated for each sample group and their relative elevations compared (Zar 1984).

We selected days from mid-July to simulate a one-time visit to each colony for two reasons. First, for kittiwakes in the northern Gulf of Alaska, this is typically a period of optimal growth leading up to peak energetic demand for kittiwake nestlings (Gabrielsen et al. 1992), and therefore variation in chick development will most likely be expressed here. Second, we wanted to use simple linear regression to analyze residual body-mass, and we found body-size related linearly to body-mass during the linear growth phase. Measurements of nestlings 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 do not recommend applying this method to very young nestlings because they are relatively homogeneous in body-size and mass in early development.

This snapshot approach to assessing variation in nestling 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 nestlings so that birds growing at a slower rate may complete growth at a higher mass and vice-versa (Ricklefs 1968b). This flexibility warrants caution when interpreting results from one-time measurements. On the other hand, because one-time measurements can be collected relatively easily at different seabird colonies over a span of many years, we recommend them as a useful monitoring tool.

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TABLE 1. Results from two methods of analysis used to compare growth of known-age kittiwake nestlings from Gull Island versus Chisik Island and Shoup Bay versus North Icy Bay. Results are presented as means ± SE.

	Gull Island	Chisik Island	Shoup Bay	North Icy Bay
Repeated measurements, n	14[a]	11[a]	39	39
Measurements per nestling	2.4 (± 0.3)	2.1 (± 0.5)	3.7 (± 0.1)	3.5 (± 0.1)
Measurement days per nestling[b]	7.3 (± 1.1)	5.5 (± 1.3)	10.3 (± 0.4)	10.2 (± 0.4)
Age (days)[c]	16.4 (± 0.7)	16.1 (± 1.2)	14.1 (± 0.5)	14.7 (± 0.4)
Linear growth rate (g/day)	18.6 (± 1.1)	11.8 (± 1.3)	16.7 (± 0.5)	17.5 (± 0.5)
One-time measurements, n	16	16	39	39
Age (days)	15.6 (± 1.0)	16.5 (± 1.7)	17.8 (± 0.5)	15.9 (± 0.6)
Body-condition (%)	8.9 (± 3.6)	-10.9 (± 4.7)	0.7 (± 1.2)	-0.8 (± 1.5)

[a]We did not have enough measurements within the linear growth phase to calculate a growth rate for all of the nestlings used in the sub-sample of one-time measurements.

[b]The total number of days that mass was within the 60 to 300g linear phase, measured at 4 day intervals.

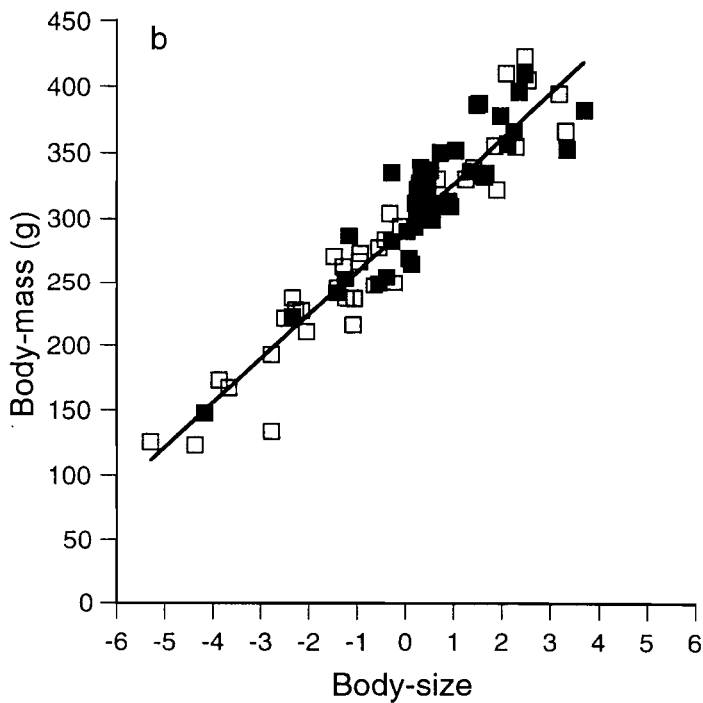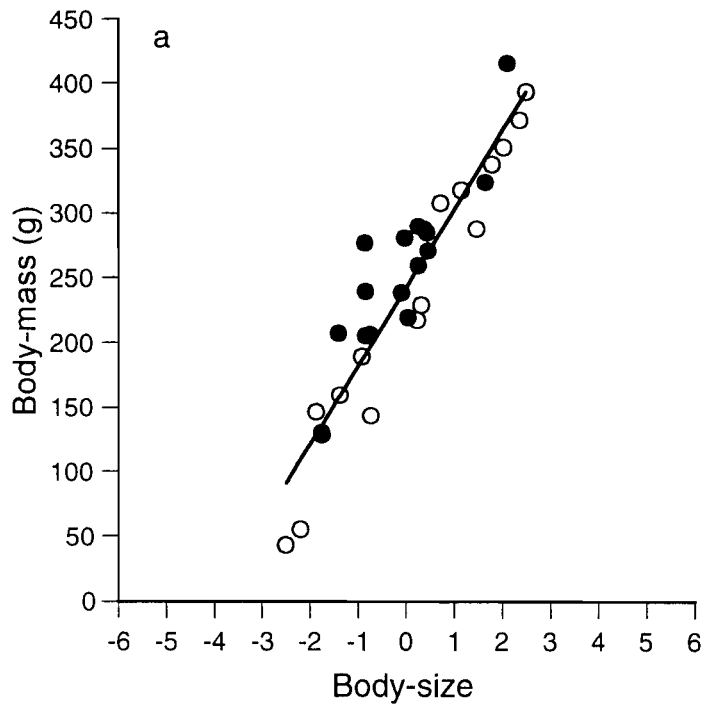[c]Mean age of chicks at the end of the linear growth phase.

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FIGURE 1. Regression of body-mass on body-size (first principal component) for kittiwake nestlings at the a) Gull Island (closed circles) and Chisik Island (open circles; $r^2 = 0.87$, $P < 0.0001$) and b) Shoup Bay (closed squares) and North Icy Bay (open squares; $r^2 = 0.88$, $P < 0.0001$).

A LEG-NOOSE FOR CAPTURING ADULT KITTIWAKES
AT THE NEST

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Abstract.—We developed a leg-noose for capturing adult Black-legged Kittiwakes (Rissa tridactyla), a cliff-nesting, colonial seabird. The capture device consisted of an adjustable wire base secured to the rim of the nest. The base is simple to construct, and we describe three design options. The base held open a circular noose that was used to snare a kittiwake around the tarsometatarsi. A spool of line attached to the noose permitted the capturer to move away from the colony, encouraging the birds' return. Using this device, we captured 75 kittiwakes in 1996 and 1997. In particular, the leg-noose proved invaluable in the safe capture and recapture of specific individuals for our study that could not be captured by noose-pole. This leg-noose concept is versatile and could be adapted for capture of other nesting avian species.

INTRODUCTION

The study of avian ecology increasingly demands that birds be captured and handled for banding, measurement, blood or tissue sampling, and instrument attachment. Because seabirds are long-lived, philopatric, often accessible and present in great numbers at a breeding colony, their capture offers excellent opportunities for long-term ecological research and monitoring. Cliff-nesting seabirds have been captured in previous studies using a noose-pole (Hogan 1985, Jacobsen et al. 1995, Irons 1998), rocket-net (Hatch et al. 1993, Golet et al. 1998), mist-net (Roberts and Hatch 1993), and noose-mat (Roberts and Hatch 1993). However, noose-poles tend to flush most birds in the area, leaving available for capture only those individuals tolerant of such a disturbance, rocket-nets and mist-nets are indiscriminate, and noose-mats require that a bird snare itself.

Certain studies require that either specific birds or birds in specific areas be captured. As part of a study of the reproductive and foraging ecology of Black-legged Kittiwakes (Rissa tridactyla), we captured adult birds at several breeding colonies in Prince William Sound, Alaska during 1996 and 1997. To facilitate capture of specific birds, we created a leg-noose trap that fits on the rim of a kittiwake nest and can be remotely triggered.

TRAP DESIGN AND OPERATION

The leg-noose consists of two basic parts, the base and the noose (Fig. 1). The base has several noose-supports that keep the noose open and anchors that secure the trap in place. The end of the noose passes through a line-guide and is attached with a swivel to a line wound on a spool or reel.

We created three different leg-noose designs, described below in the order that they were developed. We assembled the prototype using galvanized steel wire (2-mm diameter), foam pieces (from Pelican Case® products), lag-bolts (8 mm x 51 mm), and duct-tape. We constructed a base by shaping the wire into spring-like coils so that a three-dimensional circle was formed (Fig. 1a). We made rectangular noose-supports from foam, with a slit on the top running one-third its length, and attached these to the base simply by running the wire through the foam so that the noose-supports were free to slide along the base. For a line-guide, we formed two eyelets at opposite ends of a 5-cm long steel wire attached to the base by a loop in the middle of the wire, which we taped to a piece of foam for stability. We used wire to attach four lag-bolts to the base for anchoring the trap to the nest. We used braided Dacron® line (Western Filament®; 36 kg test) for the noose and tied this to a swivel (prevented line from twisting) and leader clip, which allowed attachment to either clear monofilament line (9 kg test) or buoyant line (9 kg test).

In the second design, we constructed a simple adjustable base (Fig. 1b) out of wire by forming a circle with overlapping ends, held in place by two nylon cable ties (127 mm X 3.2 mm; 13.5-kg pull). The cable ties were tight enough to keep the ends from slipping and expanding the circle, but loose enough to allow adjustment. The noose-supports and line-guide were fashioned and attached as described above, with the exception that the foam pieces were T-shaped. We attached four wire loops around the base, which allowed us to position the anchors before affixing

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the base to the nest with lag-bolts.

The third, less conspicuous design requires several noose-supports, a single anchor/line-guide, and a fishing rod and reel (Fig. 1c). There is no base in this design and the noose-supports are made of wire so that they can be inserted directly into the nest material. The line-guide is attached to the only anchor. The fishing gear is used to set the noose and the bird should be held to the nest by the anchor/line-guide. If the bird breaks away from the nest it can be controlled by rod and reel as it glides to the water.

To set the leg-noose, the base should be attached to the nest bowl using the anchors. The noose is held in position by leading it through the line-guide (oriented toward the direction of pull), expanding it to the width of the base, and gently placing in the noose-supports. The line is then spooled out to a suitable location. Once the bird has landed within the noose, the line should be quickly, but steadily, reeled in until the noose closes around the legs (tarsometatarsi). Gaining control of the bird should be swift and immediate and, once in hand, the noose may be loosened and removed.

FIELD RESULTS AND DISCUSSION

Kittiwakes construct nests on small ledges of oceanside cliffs from mud and vegetation. Accessibility and structure varied widely among nests, requiring the leg-noose setup to vary accordingly. To allow use of the trap, nests must be: accessible by foot, ladder, boat, or other means; strong enough to support the leg-noose anchors; and visible from a nearby, but inconspicuous location.

In 1996 and 1997 we captured 75 adult kittiwakes at three breeding colonies with the leg-noose. Adult birds were captured from 37 nests containing eggs, 18 nests containing chicks or chicks and eggs, and 20 empty nests. None of the captured birds appeared to have been injured, and there were no observed differences between the post-capture behavior of those birds captured by leg-noose versus birds captured by noose-pole or uncaptured birds. We did not see any evidence of destroyed or damaged nests in 1996, but in 1997 we damaged two nests, destroying four eggs (described below).

We recorded capture effort as attempts per successful capture in 1997 and calculated means for each method. We did not monitor capture effort in 1996. Capture effort using the leg-noose (1.4 attempts/capture, n = 57) was similar to effort using the noose-pole (1.6 attempts/capture, n = 179). The noose-pole was a more efficient method to capture many kittiwakes in a limited amount of time, thus we used it to capture large numbers of previously uncaptured adults and to recapture adults that did not exhibit trap shyness.

Our studies required the capture and attachment of radio-transmitters to previously radio-tagged adults and/or banded individuals of known-age. We observed birds becoming trap weary after successive capture attempts within and among years. This progressed until nearly all birds in certain sections of the colonies would flush at the sight of a noose-pole, preventing capture. In these situations the leg-noose proved invaluable. For example, we recorded six individuals in which repeated capture attempts ($\bar{x}$ = 3.3) with the noose-pole failed and success was achieved in fewer attempts ($\bar{x}$ = 1.7) by immediately employing the leg-noose. Even with the leg-noose some kittiwakes acquired trap shyness, hence the development of lower profile designs. Of the 75 adult

capture events using the leg-noose in 1996 and 1997, 51 were recaptures from previous years. It would have been near impossible to safely capture and/or recapture those specific birds that we targeted with any other method, especially in as few attempts. Thus, we feel the leg-noose was less disturbing to the colony than any other available methods.

The leg-noose was also used extensively during a 1998 study of the metabolic requirements of breeding kittiwake adults. The investigators employed doubly-labeled water techniques that required the capture and recapture of individuals within a 48-h period. Inherently, the recapture process and the potential disturbance that is involved (kittiwakes will usually either maintain vigilant flight or raft in the water until the disturbance ends) must be relatively quick so that the metabolic rates of the experimental birds are not artificially raised. Of 42 adults recaptured, it was estimated that 13 were caught by leg-noose. The leg-noose proved to be a reliable alternative for birds that had been captured with the noose-pole less than 48 hours previous.

Trapping technique varied depending on site-specific requirements and individual birds. Access to nests with suitable blinds far enough from the nest to encourage landing, but close enough to allow an efficient capture and retrieval, was the foremost difficulty encountered while working on land. Some captures required a third individual to watch the nest from a boat and relay signals or radio messages to the capturers hiding out of view of the nest. When calm seas allowed, we successfully used inflatable boats to access nests and capture birds. While waiting for the birds to return, tension on the line caused by the drifting boat created difficulties. To alleviate this problem, we used buoyant line and maneuvered the boat against the current and/or wind. When capturing by boat at a large active colony, we unintentionally captured two birds that flew into and became entangled in the monofilament line. Movement of the trigger line occasionally frightened birds and successful attempts were made to conceal the line in natural crevices on the colony. It also was helpful to keep the line taught so there was minimal line movement when tightening the noose during capture.

After the noose is reeled in and the bird has fallen just over the edge of the nest, the force created by the weight of the bird and the tension on the line is transferred to the anchors holding the base on the nest. Therefore, the nest must be strong and the base must be securely anchored. When possible we used irregular features in the rock to help hold the trap in place. Sometimes nests were too thin or fragile to secure the leg-noose. In this case, modifications to the third design allowed the bird to be snared and fly from the nest with little or no stress on the nest structure. It was also important that tension on the line be sustained either by the individual who reeled in the line while a coworker gained control of the bird, or by a weighted object placed on the line, if a person was capturing alone. This minimized the chance that a struggling bird would damage either itself or its nest. It is important that the noose cinches around both legs, otherwise the adult may remain upright on one leg and create enough force with its wings to lift either the trap off the nest or both the trap and the nest off the cliff. This was how we damaged the two nests mentioned above.

The three leg-noose designs performed with distinct advantages and trade-offs. All designs showed increased success if: the base was adjusted to fit on the outside top edge of the nest bowl, giving the bird an area to land; the noose-supports positioned the noose high on the legs and clear of nest material; attempts were made to camouflage the trap with nest material and/or paints; efforts were made to conceal the movement of the line being pulled by the capturer from the view

of birds in vicinity of the trap. The second and third trap designs proved highly adjustable and inconspicuous, and even non-breeding adults frequently returned to the nest when the leg noose was in place. However, these designs were not as strong or efficient for capturing birds compared to the original design, likely because the noose was positioned higher on the legs atop the coiled base, and due to the easier nest setup of this design. Preference varied among capturers and both technique and efficiency improved with increased familiarity of each design.

It was easier to capture incubating birds than birds rearing chicks with the leg-noose. If present, we left eggs in the nest during capture but removed chicks before capture. We observed that adult birds returned more often to nests with the eggs than nests where chicks had been removed. To capture birds on failed nests we placed an egg in the nest bowl, which caused some birds whom were previously trap wary to return to their nest. We sometimes replaced live eggs with a decoy egg while the leg-noose was set to reduce the potential of destroying eggs. We achieved limited success by placing a chick decoy in the nest.

We recommend the leg-noose as a reliable method for capturing kittiwakes that can not be captured with a noose-pole or other methods, and where nest structure and location permit traps to be set. Using the leg-noose allowed us to select a nest, set the trap, and move out of view and/or direct influence from the colony. As other kittiwakes returned to their nests, the selected bird usually returned with them and landed within the noose. It was invaluable in the capture and recapture of specific birds for radio-telemetry, behavioral observation, and doubly-labeled water experiments.

This leg-noose design may prove effective for capturing other avian species where conditions permit. Among seabirds, cliff-nesting cormorants and fulmars, and ground-nesting gulls and terns would seem likely candidates for the leg-noose. This method, however, could be adapted for any bird with an accessible nesting platform. Kittiwakes are relatively small birds and have little strength when suspended upside down by the leg-noose. Stronger anchoring and materials would be required for larger seabirds that prove too heavy or powerful for the leg-noose described here, especially for capturing ground-nesting birds that may remain upright after the noose is tightened.
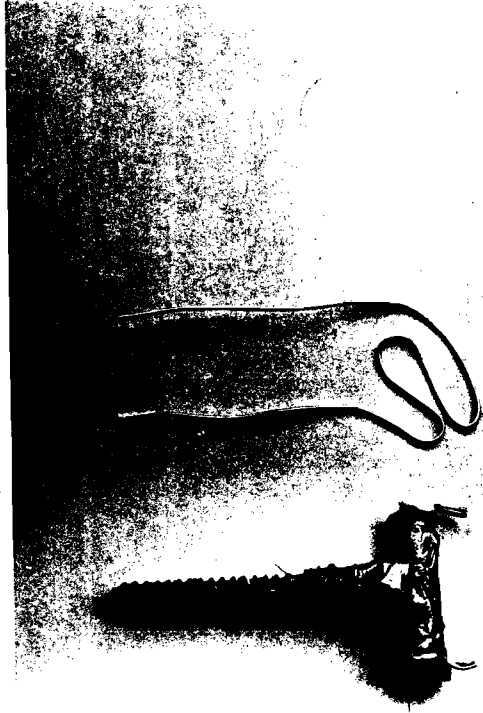
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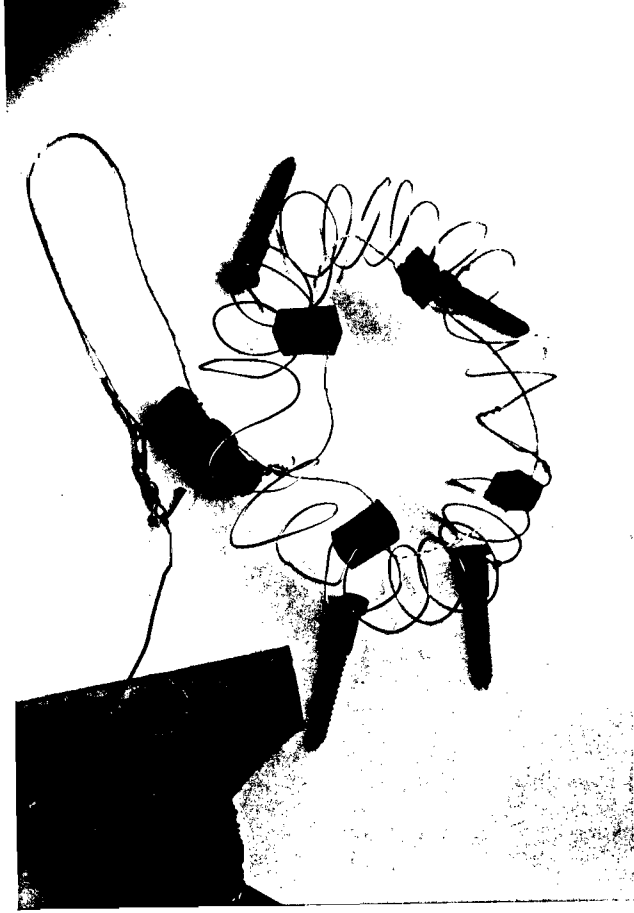
FIGURE 1. Three leg-noose designs used to capture Black-legged Kittiwakes on their nests. The trap concept remained the same, although the base designs varied from (a) coiled, (b) flat, and (c) no base in order to reduce the conspicuousness of the trap.

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