SENSITIVITY ANALYSIS FOR PARAMETERS OF PREDATORY SPECIES CCAMLR ECOSYSTEM MONITORING PROGRAM

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Abstract

Following the request of the Scientific Committee of CCAMLR to conduct sensitivity analyses on existing data regarding predator breeding biology parameters, this report presents such a treatment of data obtained at the Magnetic Island Adélie penguin colony in Prydz Bay in the 1987/88 and 1988/89 breeding seasons.

The data on the following parameters were analyzed:

- adult weight on arrival at breeding colonies;
- duration of first incubation shift;
- duration of adult foraging trips;
- breeding success; and
- chick fledging weight.

Résumé

A la demande du Comité scientifique de la CCAMLR portant sur la conduite d'analyses de sensibilité sur les données existantes concernant les paramètres biologiques de reproduction des prédateurs, ce rapport présente un tel traitement de données obtenues à la colonie de manchots Adélie de l'île Magnetic, dans la baie de Prydz, pendant les saisons de reproduction 1987/88 et 1988/89.

Les données se rapportant aux paramètres suivants ont été analysées:

- poids des adultes à l'arrivée aux colonies de reproduction;
- durée du premier tour d'incubation;
- durée des sorties alimentaires des adultes;
- réussite de la reproduction; et
- poids des jeunes à la première mue.

Резюме

В ответ на просьбу Научного комитета АНТКОМа о проведении анализа чувствительности параметров воспроизводства хищников с учетом существующих данных, в настоящей работе представлены результаты такого анализа данных по колонии пингвинов Адели, полученных на острове Магнетик в заливе Прюдс в течение сезонов размножения 1987/88 и 1988/89 гг.

Были проанализированны данные по следующим параметрам:

- вес взрослых особей по прибытии в гнездовую колонию;
- продолжительность первой инкубационной смены;
- продолжительность периодов кормления взрослых особей;
- репродуктивный успех; и
- вес птенцов при оперении.

Resumen

Siguiendo la solicitud hecha por el Comité Científico de la CCRVMA para conducir análisis de sensibilidad en los datos ya existentes con relación a los parámetros biológicos de reproducción de los depredadores, este informe presenta tal tratamiento de datos obtenidos en las colonias de pingüinos Adelia en la Isla Magnetic, Bahía de Prydz, durante las temporadas reproductivas de 1987/88 y 1988/89.

Se analizó la información de los siguientes parámetros :

- peso del ejemplar adulto a la llegada a la colonias de reproducción;
- duración del primer turno de incubación;
- duración de los viajes de alimentación como adulto;
- éxito en la reproducción; y
- peso del polluelo al emplumaje.

1. INTRODUCTION

Since the establishment of the Biological Investigation of Marine Antarctic Systems and Stocks (BIOMASS) program, vertebrate predators have been considered potentially useful environmental monitors, assuming that their populations are sensitive to conditions within their foraging ranges (e.g. BIOMASS, 1982).

This interest in the use of vertebrate predators in environmental monitoring continued in discussions of the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) and its Scientific Committee (SC-CAMLR). In 1988 this culminated in the publication by the Working Group for the CCAMLR Ecosystem Monitoring Program (WG-CEMP) of a handbook entitled Standard Methods for Monitoring Parameters of Predatory Species (CCAMLR, 1988).

This booklet summarized the parameters recommended for monitoring studies of penguins and seals. Previous meetings of CCAMLR had identified a range of breeding biology parameters likely to be sensitive to perturbations in the marine environment, which could act as indicators of marine conditions when monitored annually. A few species were deemed most likely to be useful in this capacity, based on their population sizes and accessibility, and on their likelihood of reflecting fluctuations within the krill-based ecosystem. Species identified included the Adélie penguin *(Pygoscelis adeliae).*

The monitoring methods which seemed the most likely to yield useful results were selected for each identified species. The methodology proposed is in many cases based on few data. It is important therefore to determine whether the scope and precision of the observations are sufficient to monitor the vertebrate population parameters of interest with acceptable reliability.

To comment on the suitability of the sampling methodologies proposed, it is necessary to have an idea of some characteristics of the data generated; most importantly, the degree of variance around the mean. While data sets can be simulated, and variances estimated if no real data exist, the use of actual data with 'real' variance enables estimates of required sample sizes for specified detection capabilities to be made with greater confidence. This was recognised by the Scientific Committee (SC-CAMLR-VII, paragraph 5.22 (i) and (ii)) and led to the instructions for sensitivity analysis set out by the CCAMLR Secretariat and Convener of CEMP.

This report summarizes some preliminary data on various Adélie penguin breeding biology parameters, collected at the Magnetic Island colony in Prydz Bay (68°33'S, 77°54'E) in the 1987/88 and 1988/89 breeding seasons.

Though assessed and presented under the parameter headings given by CCAMLR (1988), it should be realised that differences did exist between methods of data collection recommended for the Ecosystem Monitoring Program (CCAMLR,1988) and those used for the analysis in this report. In most instances the data were collected in conjunction with other research programs with their own specific aims. The characteristics of the data upon which the subsequent 'sensitivity' analyses are based are described in the following section.

2. DATA ACQUISITION AND CHARACTERISTICS

2.1 Parameter A1 - Weight on Arrival at Breeding Colonies

This parameter is considered likely to reflect pre-breeding season conditions within the penguins foraging range. The CEMP Standard Methods Sheets (CCAMLR, 1988) recommend the capture and weighing of between 50 and 75 (depending on whether sex can be determined) adults every five days during the occupation period.

The data presented here are based on the weighing of 100 unsexed adults on 17 October 1987 and again on the 17 October 1988. Adults were captured as they moved across the sea-ice toward their colonies, and weighed to the nearest 25 g.

The distribution of the data did not differ significantly from normality in either year (Kolmogorov-Smirnov one-sample test (K-S); z=0.037, p=0.354 and z=0.071, p=0.239 for 1987 and 1988 respectively). The means and variances of the data were similar for both years (Figures 1a and 1b) and sample size analysis was based on the 1987 data.

2.2 Parameter A2 - Length of the First Incubation Shift

The length of the first incubation shifts has been shown to be very closely related with Adélie penguin breeding success (Davis, 1982). This parameter is considered likely to be sensitive to variable food availability during the foraging trip of the incubating bird's partner. The CEMP Standard Methods Sheets (CCAMLR, 1988) recommend that 100 nests be monitored daily and the length of the first incubation shift by both members of the pair be recorded.

I recorded attendance of a sample of male and female Adélie penguins at two colonies on Magnetic Island. Checks of marked nests were made every two days, and the presence of either male or female recorded. The length of the first incubation shift was recorded for both male and female of 26 pairs, and male only at an additional 31 nests, at the Turner colony. At the East colony, length of the first incubation shift was recorded for both male and female of 79 pairs, and male only at an additional 22 nests. Length of incubation shift was calculated assuming that changeovers occurred midway between observation periods.

Distribution of data on first incubation shift length did not differ significantly from normality for either sex at either study colony (K-S; p > 0.120 in all cases) (Figures 2a to 2d). There was no significant difference between the study colonies in length of either male or female first incubation shifts (t=0.261, p=0.791 and t=0.880, p=0.615 respectively), so data from each colony were pooled, and sensitivity analyses conducted for each sex. Pooled data did not differ significantly from normality for either males (K-S; z=0.088, p=0.134) or females (K-S; z=0.133, p=0.086) (Figures 2e and 2f).

2.3 Parameter A5 - Duration of Foraging Trips

This parameter is considered sensitive to the availability of food during the foraging trip. The CCAMLR Standard Methods Sheets indicate that changes in this parameter can only be satisfactorily detected by precise monitoring of adult attendance patterns using radio transmitters and a continuous scanning receiver/logger.

Data collected for this study were from direct observation of two study colonies at Magnetic Island. At the Turner colony, 21 nests were monitored and at the East colony, 68 nests were monitored. Nest sites were visited daily and the attendance of either adult of the pair recorded. Foraging trip length was calculated assuming that changeover occurred midway between observation periods. This strategy was only effective until the end of the guard-stage, after which time both parents began to feed simultaneously, and colony attendance could not be monitored without 24 hour watches or automatic recording devices.

The data used here were the estimated foraging trip lengths of the first post-hatching (of first egg) foraging trip for each nest site. At the Turner colony this comprised nine male and 12 female foraging trips, and at the East colony it comprised 36 male and 32 female foraging trips. Foraging trips are relatively short during early chick rearing, so detection of fluctuation in this parameter at this stage may require larger sample sizes (but more importantly more frequent sampling), than when trips are longer. There was no significant difference between estimated length of foraging trips for either sex at either location (ANOVA; F=0.747, p=0.527), so data were pooled for sensitivity analysis. Although the distribution of these data did differ significantly from normality (K-S: z=0.219, p=0.019) (Figure 3), it was used for the sensitivity analysis.

2.4 Parameter A6 - Breeding Success

This parameter probably reflects the perturbations in food availability integrated over an entire breeding season. The CEMP Standard Methods Sheet suggests that three separate counts be made of adults and/or chicks in study colonies, so that a measure of the variation in counting accuracy may be obtained. It recommends counting a sample of discrete colonies from the entire breeding site, though not as replicates.

In this study, adults and chicks at four colonies on Magnetic Island were counted, however, replicated data (from independent counters) were only available for chick counts. Between three and five independent counts were made of the number of chicks surviving in these study colonies in late January (Table 1). As sample sizes were small ($n \leq 5$ in all cases), the distribution of the data were not examined. Sensitivity analyses were conducted on data from colonies 3 and 4.

2.5 Parameter A7 - Fledging Weight

It is suggested that the weight of chicks at fledging in any particular season may reflect food availability over the whole of that season. WG-CEMP recommends that 100 fledglings be weighed every five days during the fledging period.

Chicks fledging from the Magnetic Island colony were weighed daily from the commencement of fledging (early February) in the 1987/88 season until 21 February 1988, when the author departed the area. This period encompassed the majority of the fledging period. Chicks were weighed (to the nearest 25 g) as they milled around the waters edge, marked with dye and released.

These data were pooled into five-day periods. The frequency distribution of each data set corresponded closely with normality (K-S; p > 0.235 in all cases)(Figures 4a to 4d) and the mean fledging weights of the four sequential fledging periods were not significantly different (ANOVA; F=1.782, p=0.150), so data were pooled for sensitivity analysis. The frequency distribution of the combined data set conformed closely with normality (K-S; z=0.037, p=0.278) (Figure 4e).

There was clearly discrepancy between the methods stipulated for CEMP data (CCAMLR data) and the data upon which the analyses in this report were based. In some cases our methods were about as rigorous as those required by the CEMP (e.g. parameters A1, A7), while in others they were not (e.g. parameter A5). As a result, the variances upon which the sensitivity analyses were based were not always representative of the variances had the data been collected according to the CEMP. This should be taken into account when considering the recommended sample sizes.

3. SAMPLE SIZE (='SENSITIVITY') ANALYSES

From these data it is possible to decide what sample size would be necessary if we wished to detect a true fluctuation in the mean of any of these parameters, at some stipulated significance level, with a specified probability of the significance being found. It is important to realize that such an analysis of the data presented here gives an indication of the sample size necessary to detect a given parameter fluctuation if the data collected have a variance the same as that upon which the sensitivity analysis was based. If a sampling methodology different to that used here was employed, the variance would be effected, and the necessary sample size would be different. These data do however give an indication of real variance and allows fairly realistic estimates of sample size.

The appropriate formula for calculating the necessary sample size to detect a given 'true' difference between means is:

$$n \geq 2(sd/\Delta)^2 \{t_{a,[v]} + t_{(1-P,[v]}\}^2$$

where n = the required sample size (samples per year per site)

sd = true standard deviation

Δ = the smallest true difference that is desired to detect

v = degrees of freedom for error in the ANOVA or t-test [v=r(n-1), where r is the number of years or replicates]

a = significance level (i.e. probability of rejecting a true null hypothesis of no difference among years)

P = desired probability that a difference will be found if it is large as Δ (P is the statistical power)

$t_{a,[v]}$ = value from a two-tailed t-table with v degrees of freedom and corresponding to probability a, and

$t_{2(1-P),[v]}$ = value from a two-tailed Student's t-table with v degrees of freedom and corresponding to probability 2(1-P)

(Sokal and Rohlf, 1981)

This equation is solved iteratively, and calculations of the necessary sample sizes for detecting differing degrees of change in the mean, at different levels of statistical significance and power are given for these various parameters in the Tables 2 to 7. The effect of number of years of sampling on the required sample size is also considered.

4. SUMMARY

Before continuing field work aimed at providing monitoring information it is important to assess with whatever data available the degree of annual variation in these breeding biology parameters. This will assist in deciding the minimum change in any parameter that it is desirable to be able to detect. Some information has recently become available in this respect (see Croxall et al., 1988) and should be considered as future monitoring strategies are considered. With information such as that provided in this report it is possible to then decide on the sample sizes required to detect changes in specific parameters.

The development of annual indices for each parameter, on which to base comparisons, was discussed in the "Instructions for the Preparation of Sensitivity Analyses" provided by CCAMLR. For monitored parameters that give five-day running means (Parameters A1, A5 and A7), it is suggested that the annual index derived should reflect the importance of each five-day period in calculation of the annual mean. In this report, the only parameter for which data were collected over five-day periods was Parameter A7 (fledging weight). As no significant difference was detected among five-day periods, the mean value from randomly weighed fledglings or from a single five day period will probably serve as a suitable annual index. Further data and analysis is required before a suitable annual index for the other two parameters in this category can be decided.

For Parameters A2 and A6 the suggested annual index upon which to base comparisons was the mean of the data. This was the basis of the sensitivity analysis for these two parameters in this report and is the obvious index to use.

The sensitivity analyses presented here provide those sample sizes for arbitrarily chosen levels of fluctuation, however, the variances of the parameters themselves will enable calculation for any desired level of detection.

ACKNOWLEDGEMENTS

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Table 1: Counts of surviving chicks in Magnetic Island study colonies - late January 1989. Number of independent counts (n), mean (x), and standard deviation (sd) are indicated.

Colony	n	x	sd
1	5	162	3.03
2	3	53	1.00
3	4	104	6.38
4	4	74	3.74

Table 2: Parameter A1: Adult weight on arrival at breeding colony (1987 data). Sample size = number of arriving penguins that must be weighed.

		Statistical Power (P)		
		0.6	0.8	0.9
Sample sizes required for two years of monitoring and a = 0.05				
	(5%)	42	66	88
Smallest Difference (d)	(10%)	12	19	25
(% Current Value)	(20%)	5	5	7
	(30%)	2	3	4
Sample sizes required for five years of monitoring and a = 0.10				
Smallest Difference (d)	(5%)	30	51	71
(% Current Value)	(10%)	9	14	20

Table 3: Parameter A2: Length of the first incubation shift (males). Sample size = number of nests that must be monitored.

		Statistical Power (P)		
		0.6	0.8	0.9
Sample sizes required for two years of monitoring and a = 0.05				
Smallest Difference (d)	(10%)	34	54	72
(% Current Value)	(20%)	9	14	19
	(30%)	5	7	9
Sample sizes required for five years of monitoring and a = 0.10				
Smallest Difference (d)	(10%)	33	53	71
(% Current Value)	(20%)	9	14	18
	(30%)	4	6	8

Table 4: Parameter A2: Length of the first incubation shift (females). Sample size = number of nests that must be monitored.

		Statistical Power (P)		
		0.6	0.8	0.9
Sample sizes required for two years of monitoring and a = 0.05				
Smallest Difference (d)	(10%)	24	38	51
(% Current Value)	(20%)	7	10	14
	(30%)	4	5	7

Table 5: Parameter A5: Duration of foraging trips (post-hatching trip 1). Sample size = number of nests that must be monitored.

		Statistical Power (P)		
		0.6	0.8	0.9
Sample sizes required for two years of monitoring and a = 0.05				
Smallest Difference (d)	(10%)	165	264	352
(% Current Value)	(20%)	42	67	89

Table 6: Parameter A6: Breeding success. Sample size = number of independent counts of colony that must be made.

		Statistical Power (P)		
		0.6	0.8	0.9
Colony 3 - late January chick counts				
Sample sizes required for two years of monitoring and a = 0.05				
Smallest Difference (d)	(10%)	5	7	9
(% Current Value)	(20%)			3
Colony 4 - late January chick counts				
Sample sizes required for five years of monitoring and a = 0.10				
Smallest Difference (d)	(10%)	4	5	7
(% Current Value)	(10%)			2

Table 7: Parameter A7: Chick weight at fledging (2 to 21 February 1988). Sample size = number of fledging chicks that must be weighed.

		Statistical Power (P)		
		0.6	0.8	0.9
Sample sizes required for two years of monitoring and a = 0.05				
	(5%)	71	113	150
Smallest Difference (d)	(10%)	21	33	43
(% Current Value)	(20%)	6	8	10

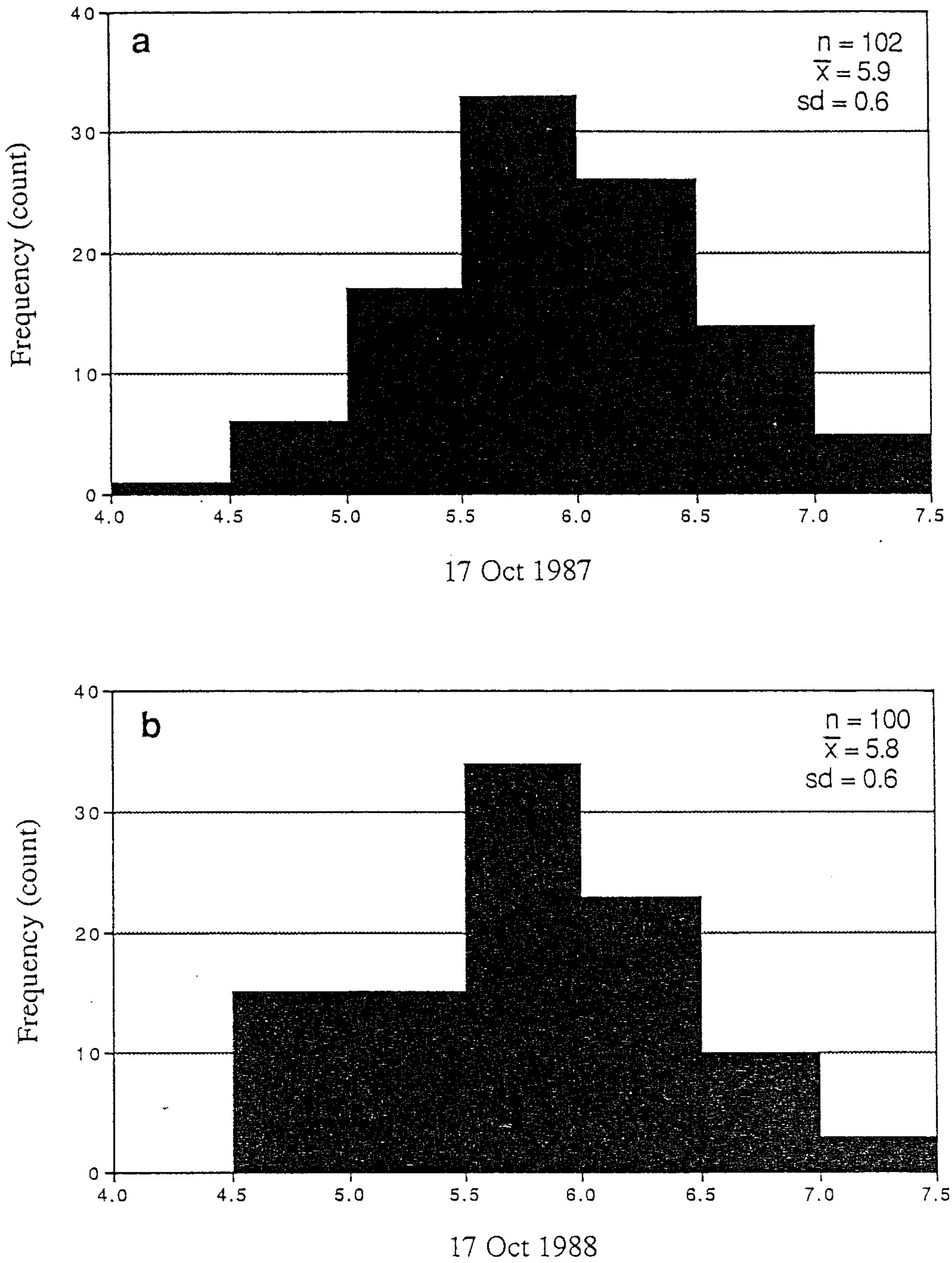
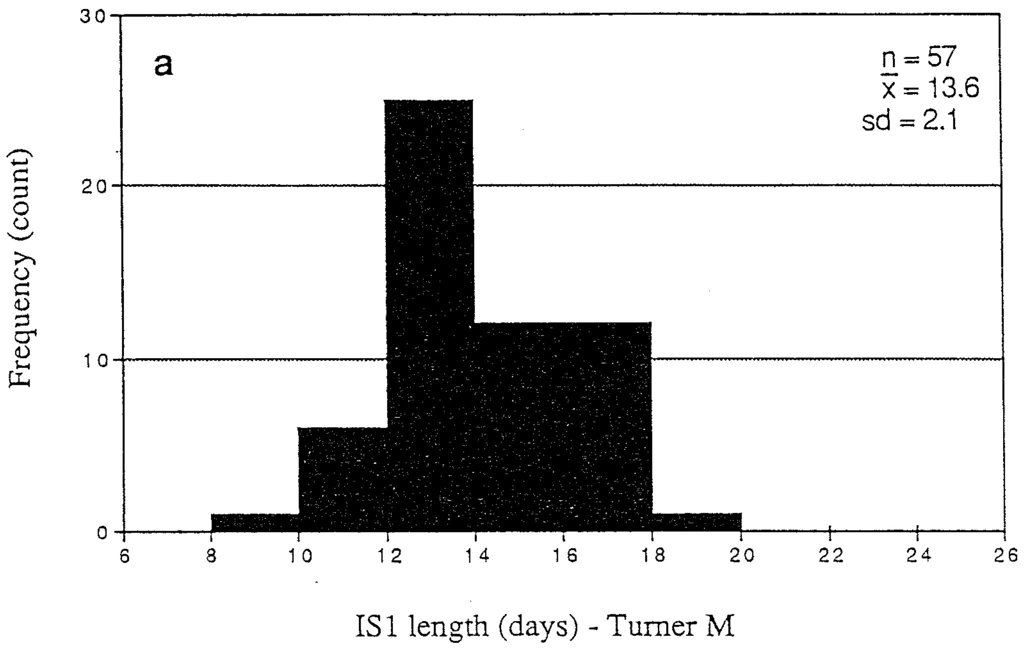


Figure 1: Frequency distribution of Adélie penguin arrival weight data (kg).

a. 17 October 1987
b. 17 October 1988



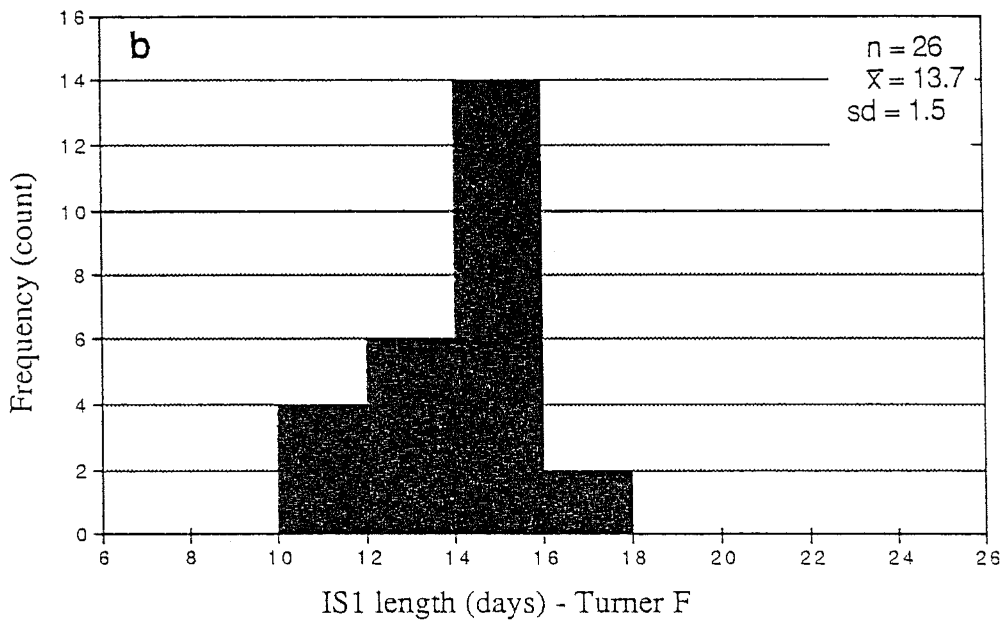
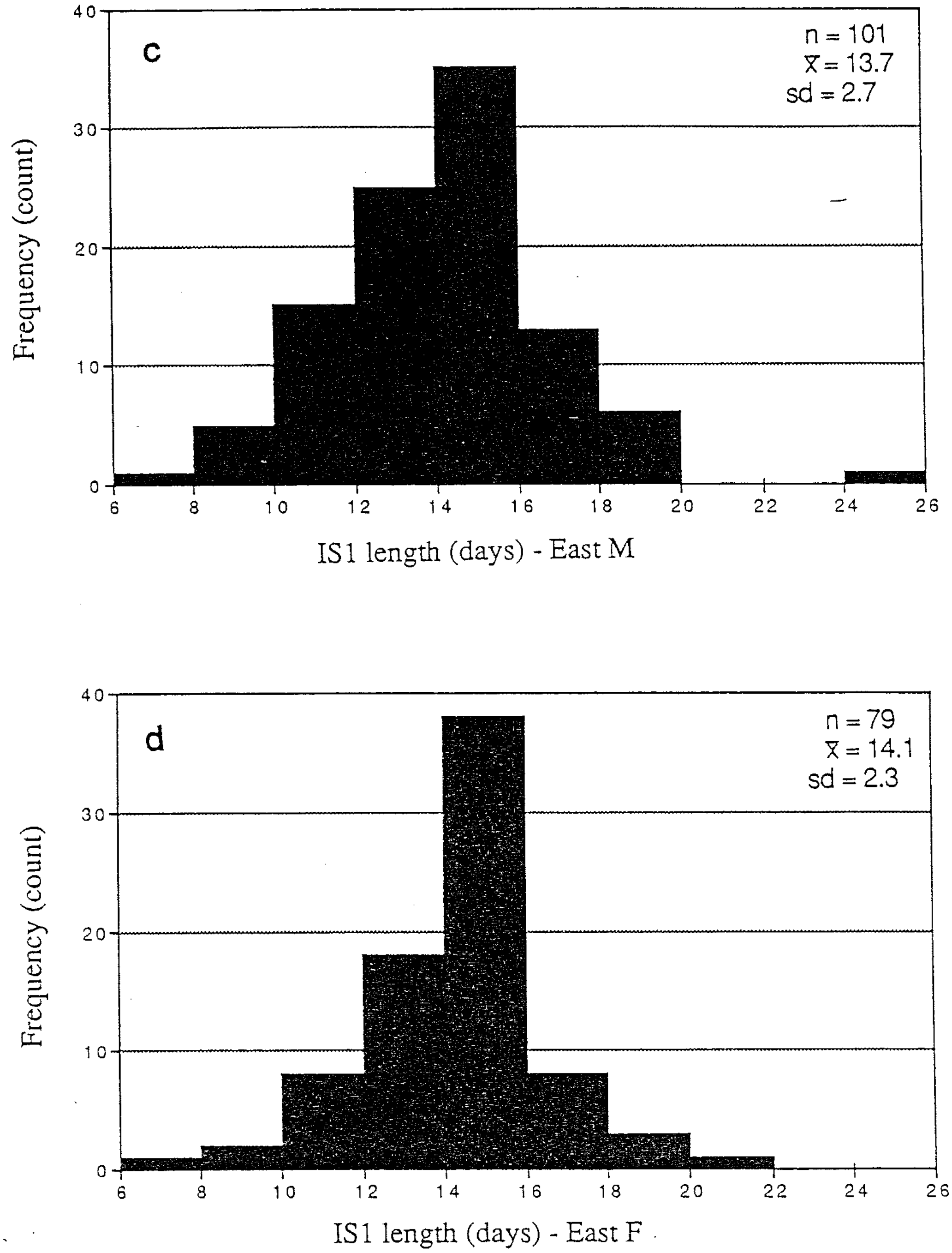


Figure 2: Frequency distribution of Adélie penguin first incubation shift lengths (days).

a. Turner colony - male
b. Turner colony - female
c. East colony - male
d. East colony - female
e. Both colonies - male
f. Both colonies - female



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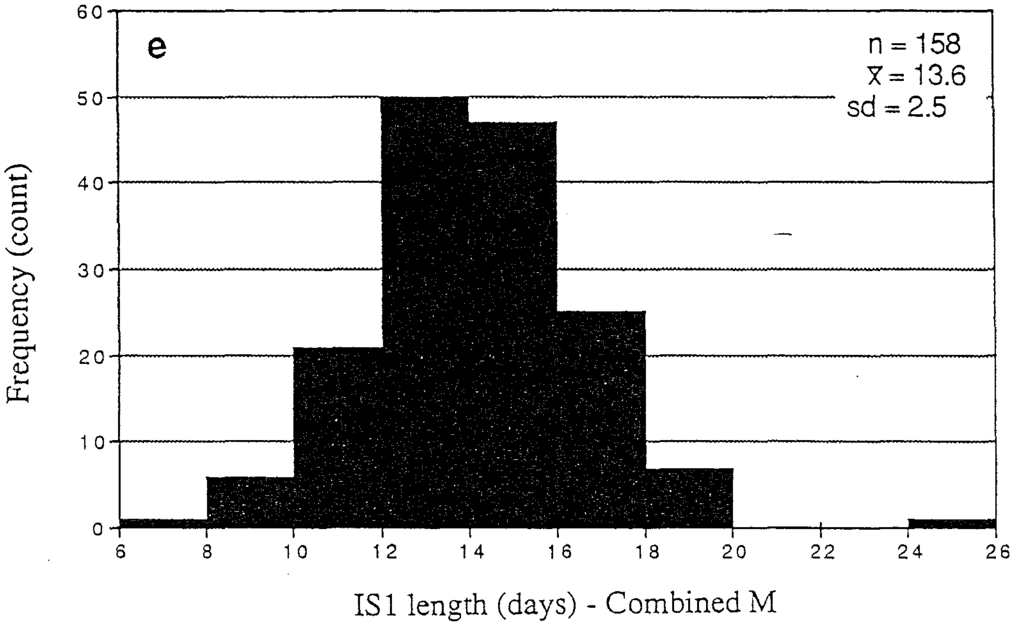

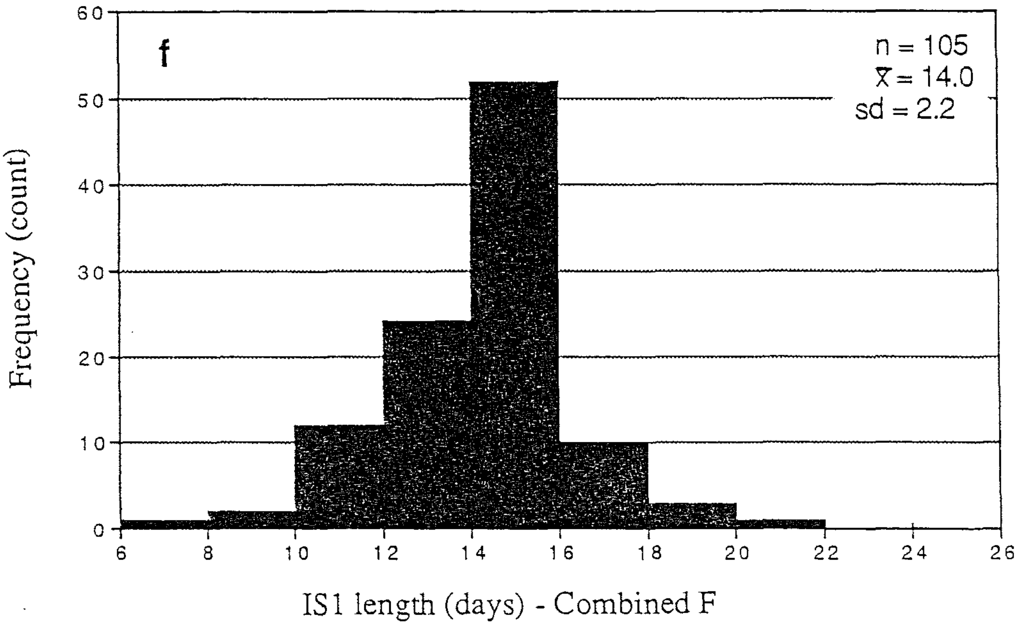

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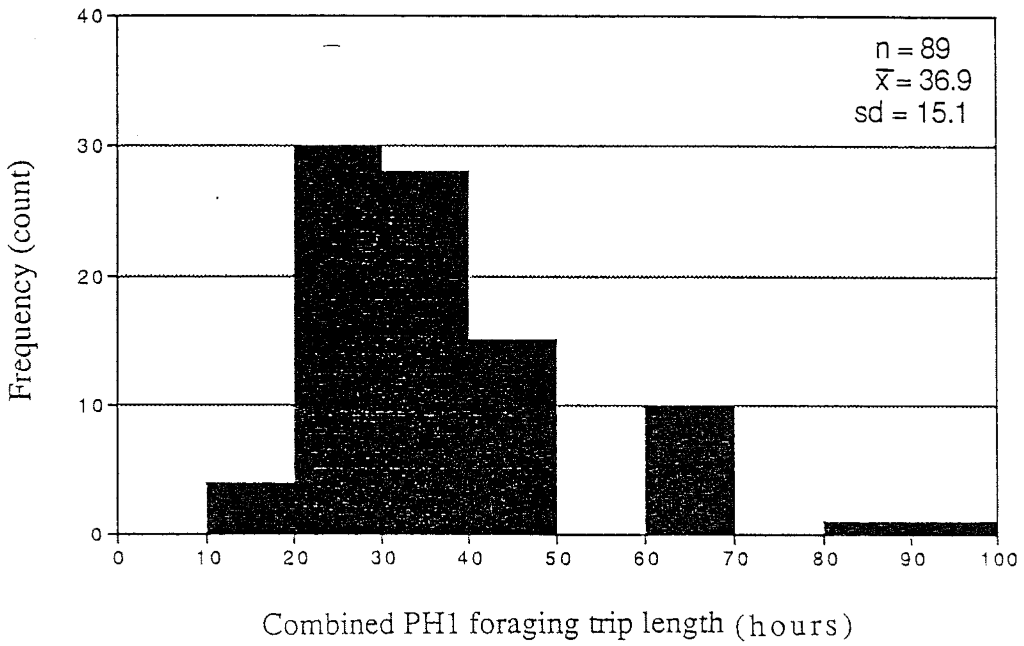


Figure 3: Frequency distribution of Adélie penguin first post-hatch foraging trip lengths. Sexes and colonies combined.

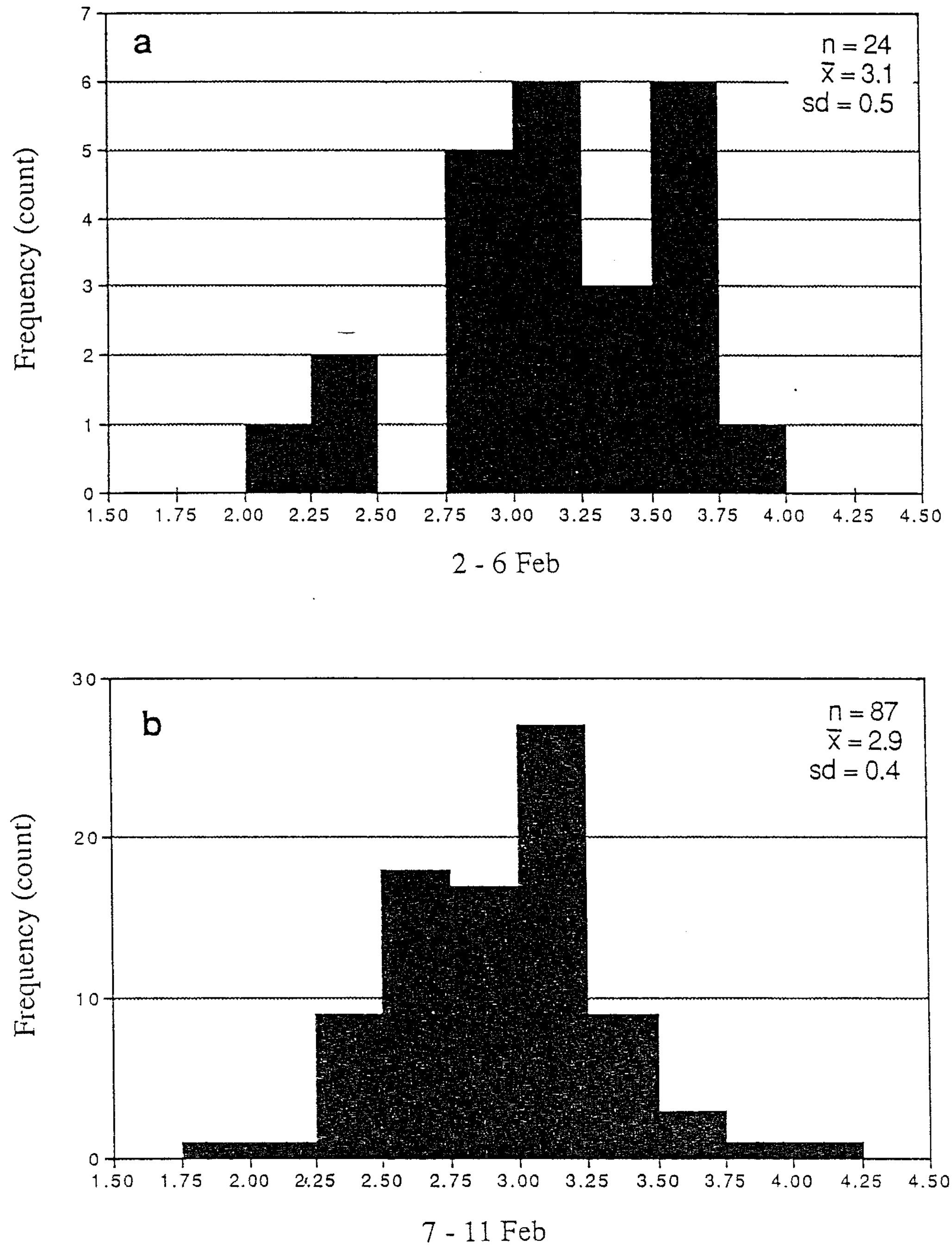
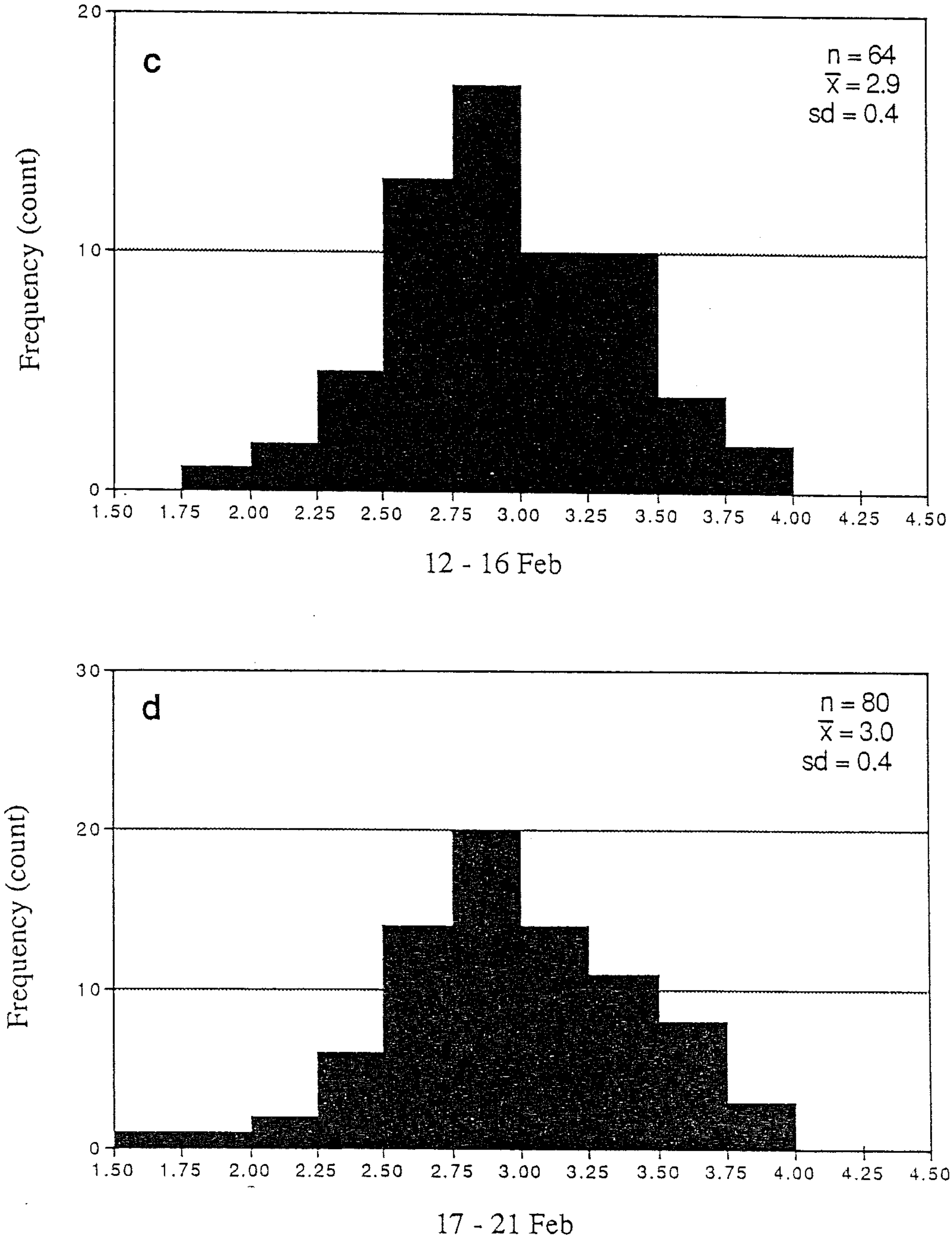


Figure 4: Frequency distribution of Adélie penguin chick fledging weights (kg).

a. 2 to 6 February 1988
b. 7 to 11 February 1988
c. 12 to 16 February 1988
d. 17 to 21 February 1988
e. 2 to 21 February 1988 combined



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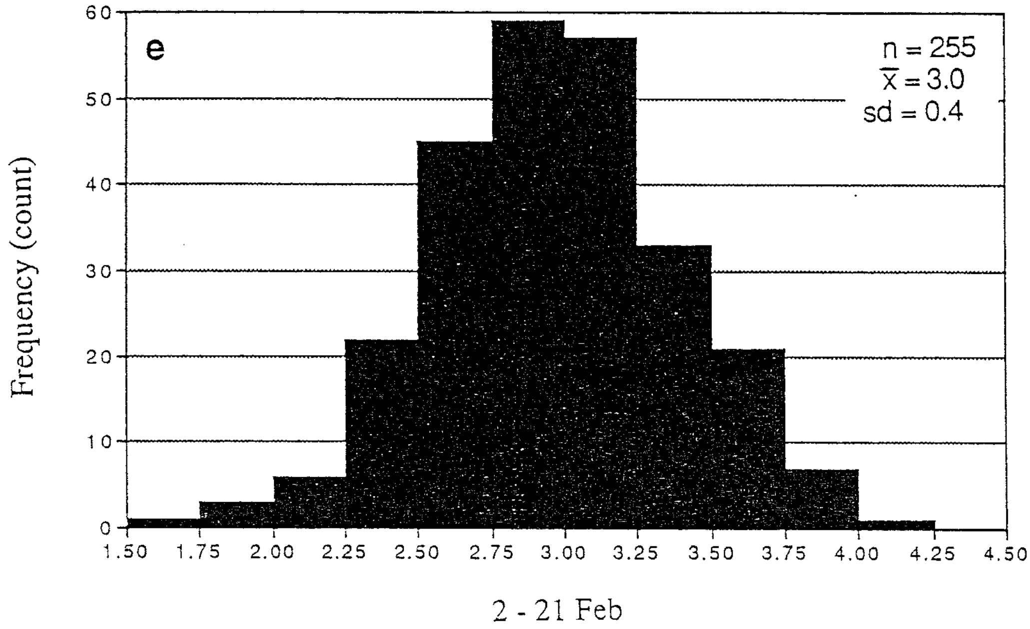

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Figura 4: Distribución de la frecuencia de los pesos al emplumaje (kg) de los polluelos del pingüino Adelia.

a. 2-6 Feb. 1988
b. 7-11 Feb 1988
c. 12-16 Feb. 1988
d. 17-21 feb. 1988
e. 2-21 Feb. 1988 combinados.