HOMOGENEITY OF ADELIE PENGUINS AS KRILL SAMPLERS

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Abstract

A nested ANOVA design was used to measure the variance component due to differences between individual Adélie penguins in the length of krill eaten, using data from Esperanza Bay. The variance component -0.26 was not significantly different from zero (F = 0.093; P = 0.54). This finding supports the argument for using individual penguins to estimate parameters of the prey population without discriminating by sex, weight or other factors pertaining to the predator.

Résumé

A partir de données de la baie Esperanza, on s'est servi d'un modèle ANOVA à emboîtements pour mesurer l'élément de variance dû à la différence de longueur du krill ingéré par des individus de manchots Adélie. L'élément de variance -0,26 n'était pas très différent de zéro (F = 0,093; P = 0,54). Cette découverte soutient l'argument selon lequel pour ne pas discriminer les sexes, le poids ou d'autres facteurs relatifs au prédateur, les paramètres de la population de proies doivent être estimés à partir d'individus de manchots.

Резюме

Компонент вариации, вызванный разницей в длине криля, съеденного отдельными пингвинами Адели измерялся с помощью гнездового метода ANOVA и с использованием данных из проб, собранных в бухте Эсперанза. Компонент вариации (-0,26) не отличался значительно от нуля (F=0,093; З = 0,54). Этот результат поддерживает довод в пользу использования проб криля из пищи пингвинов для оценки параметров популяции криля, не делая различия по полу, весу или другим факторам, как в случае других хищников.

Resumen

A partir de los datos de bahía Esperanza, se utilizó un diseño inclusivo ANOVA para medir el componente de variancia del kril de distintas longitudes consumido por algunos pingüinos adelia. El componente de variancia -0.26 obtenido variaba poco de cero (F = 0.093; P = 0.54). Este dato corrobora la tesis de utilizar pingüinos individuales para estimar los parámetros de las poblaciones de presas, sin discriminar sexo, peso u otros factores propios de los depredadores.

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1. INTRODUCTION

The size of krill eaten by penguins is probably an important factor in assimilation rates and energetic requirements of these birds. The analysis of length distributions of krill eaten by penguins will also provide information on the degree of overlap between commercial catches and predator needs. Unfortunately, the analysis of length distributions obtained from random samples of a patchy target population is statistically complex.

One of the problems is that krill occur in swarms and are not randomly distributed. This patchiness determines that, for statistical purposes, individual specimens in a given sample cannot be considered independent because their lengths are spatially correlated. Sampling strategies to estimate the population frequencies in each length class should take into account this fact. Heterogeneity between the lengths of krill in different swarms also has implications on sampling protocols aimed to the estimation of population parameters (Watkins *et al.*, 1986). Frequency distributions might prove to be impossible to calculate without knowledge of the relative volume occupied by the different patches sampled, and the bias introduced will depend on the relation between sample size, number of samples and properties of the sampling gear.

Using an appropriate sampling design however, Marschoff and Gonzalez (1989 and 1990) have shown that it is possible to obtain estimators for mean lengths from samples obtained from a patchy distribution. These might be used in the assessment of penguin energetic requirements as well as to statistically compare the lengths of krill eaten by penguins under different conditions. In order to do this it is necessary to determine if all penguins might be considered as yielding homogenous samples of their food or if these samples are affected by varying prey selection at the individual penguin level.

In this paper, we will not attempt to estimate overall krill population parameters or frequency distributions, but will aim to detect possible sources of variation originating from differences between penguins.

Finally, we will test the hypothesis that Adélie penguins are uniform with respect to prey selection.

2. MATERIALS AND METHODS

During summer 1989/90, 27 Adélie penguins from the Bahía Esperanza rookery were marked after obtaining a sample of their stomach contents as part of the CEMP related work being carried out there. Successive recaptures of these specimens yielded replicate samples of the stomach contents of the same penguins. The experimental design followed the proposal of Marschoff and Gonzalez (1990). Sources of variation were arranged in a nested ANOVA as follows:

Level 2: "Penguins" group;
Level 1: "Days-within-Penguins" subgroup;
Level 0: Replications ("Krill-within-Days" subgroup).

This design allows the calculation of the components of variance at each level and testing of the null hypotheses that the variance component added at each particular level is zero (Bliss, 1967).

The power of the test to detect differences in krill lengths taken by different penguins whilst maintaining the days-within-penguins variation was evaluated using a simulation procedure which consisted in adding a fixed value (c) to the lengths of krill from five penguins. These were randomly selected from the original set of 11 birds. The variance component due to penguins was then recalculated with different values of c until a significant result was obtained.

3. RESULTS

A total of 11 marked Adélie penguins (Level 2) were recaptured at least once during the experiment, yielding a total of 23 samples (Level 1) and 1 062 individual specimens of krill measure (Level 0).

Table 1 shows the date of sampling, mean length, variance and number of specimens measured for each stomach content.

The nested ANOVA performed on these data (Table 2) showed that the differences between sizes taken by different penguins had a null contribution to total variance while differences due to days-within-penguins were highly significant ($P < 0.001$).

In the simulation approach, the variance component due to penguins gradually increased as the krill lengths of the five penguins were increased, until it became significantly different from zero for $C = 2.83$ mm, equivalent to 7% of the mean size.

4. DISCUSSION AND CONCLUSIONS

The null variance component due to penguins found in this study implies that at the Esperanza rookery, from 5 January to 2 February 1990, all penguins seemed to be eating similar sized krill. Mean lengths derived from stomach contents of penguins are formally equivalent to mean lengths derived from net samples in the sense that, while bias might exist it is the same for all penguins in the same way as it is the same for all nets of the same design and use. No significant sources of variation exist other than those pertaining to the food itself. However, it should be stressed that this result is valid within the limits of the power of the test used and does not mean that krill were being randomly selected by penguins.

The fact that a significant difference appears with a relatively small variation in the input data indicates that the method is powerful enough to detect size preferences in penguin food and might be used to explain changes found in other parameter; that is to say that changes in krill size eaten by penguins will reflect changes in food rather than individual variations of penguins due to factors like sex, age, weight, etc.

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Table 1: Mean length and variance of krill taken from each stomach sampled.

Penguin	Number of Specimens	Date Sampled	Mean	Variance
1	74	09/1/90	44.26	23.82
1	71	28/1/90	41.18	16.53
2	52	12/1/90	41.60	32.16
2	66	23/1/90	40.48	26.84
2	70	31/1/90	43.79	20.32
3	19	09/1/90	39.07	13.19
3	27	31/1/90	39.98	27.10
4	30	09/1/90	42.65	14.75
4	25	19/1/90	32.11	31.78
5	41	18/1/90	40.02	15.18
5	39	24/1/90	29.09	19.62
6	66	05/1/90	41.30	26.93
6	73	29/1/90	40.34	17.07
7	42	07/1/90	44.67	21.47
7	63	23/1/90	37.66	64.44
8	32	12/1/90	41.46	23.15
8	31	02/2/90	40.27	19.49
9	60	13/1/90	39.79	22.46
9	51	23/1/90	40.44	27.12
10	44	18/1/90	41.48	14.23
10	38	28/1/90	41.50	24.17
11	19	20/1/90	39.23	14.45
11	29	29/1/90	37.93	94.74

Table 2: Nested ANOVA of krill-within-days-within-penguins.

Level	Degrees of Freedom	Mean Square	F	Prob.	Variance Components	
					Value	Percent
Penguins	10	460.68	0.9270	0.54	-0.26	0.00
Days-within-penguins	12	496.95	18.8230	<0.001	10.15	27.76
Krill-within-days	1039	26.40			26.40	72.24

Légende des tableaux

Tableau 1: Longueur moyenne et variance du krill prélevé dans chaque estomac échantillonné.

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