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THE UTILIZATION OF SEABIRD CENSUSES FOR KRILL MONITORING

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Abstract

The possibility of using bird observations made at sea as a means of monitoring krill in the Antarctic ocean is explored. No variation source directly linked with krill was identified by means of correspondence analysis. Contour plotting, profile analysis and tests for equality of covariance matrices proved capable of detecting changes in bird abundance and/or species composition, associated with three levels of krill abundance.

A vector close to multi-normality was obtained, thus suggesting that refinements of the technique will allow the discrimination of krill levels by means of bird counts thereby providing an efficient tool for statistical tests of significance. The most promising approach seems to be the application of discriminant analysis.

Further developments of the method are possible only with greater databases, calling for international cooperation on the subject.

Résumé

Est explorée la possibilité d'utiliser les observations sur les oiseaux faites en mer pour contrôler le krill dans l'océan Austral. Aucune source de variation liée directement au krill n'a été identifiée au moyen d'une analyse de correspondance. Les levés de contour, les analyses de profil et les tests d'égalité des matrices de covariance se sont avérés capables de détecter des changements dans l'abondance des oiseaux et/ou la composition des espèces, liés à trois niveaux de l'abondance de krill.

Un vecteur proche de la multi-normalité a été obtenu, suggérant ainsi qu'un affinement de la technique permettra de distinguer les niveaux de krill par les dénombrements d'oiseaux, ce qui fournira un outil efficace pour les tests statistiques de signification. L'approche la plus prometteuse semble être l'application de l'analyse discriminante.

La méthode ne connaîtra de nouveaux développements que grâce à des bases de données plus importantes, ce qui suppose une collaboration internationale en la matière.

Resumen

Se estudia la posibilidad de utilizar las observaciones de aves hechas en el mar como un medio de controlar el krill en el océano antártico. No se identificó ninguna fuente de variación ligada directamente con el krill por medio de análisis de correspondencia. El trazado de contornos, el análisis de perfiles y las pruebas para detectar la igualdad de las matrices de covarianza demostraron ser capaces de detectar cambios en la abundancia de las aves y/o composición de las especies, asociados con tres niveles de abundancia de krill.

Se obtuvo un vector cercano a la multinormalidad lo cual, por lo tanto, sugiere que los refinamientos de esta técnica permitirá la discriminación de los niveles de krill por medio de recuentos de aves, proveyendo de este modo una herramienta eficaz para pruebas estadísticas significativas. El enfoque más promisorio parece ser la aplicación del análisis discriminante.

Los desarrollos ulteriores del método son sólo posibles con mayores bancos de datos, lo que requiere una cooperación internacional en el tema.

Резюме

Рассматривается возможность применения результатов проведенных в море наблюдений морских птиц в качестве одного из средств мониторинга криля в Антарктическом океане. Анализ совпадений не выявил никаких непосредственно связанных с крилем источников отклонений. Оказалось, что с помощью вычерчивания контуров, профильного анализа и проверки равнозначности ковариантных матриц можно выявить изменения в численности птиц и/или видовом составе, связанном с тремя уровнями численности криля.

Был получен вектор, близкий к мультинормальному, что дает основания предположить, что усовершенствованный метод позволит определить различные уровни количества криля при помощи подсчета птиц, что, таким образом, явится эффективным средством для получения статистических критериев значимости. Наиболее обещающим кажется применение дискриминантного анализа.

Дальнейшее развитие этого метода возможно только при наличии больших баз данных, что требует международного сотрудничества в этом вопросе.

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INTRODUCTION

Man-induced changes in the Antarctic ecosystem will first appear as changes in biological parameters of the species suffering the pressure of fisheries. It was the case with whales, seals, fishes, etc. While the mentioned species are more or less suitable for direct observation, at the present state of the art it is economically impossible to keep track of biological parameters of krill populations on a regional basis by means of direct measurements. This represents a significant shortcoming in our capability to provide in time the advice needed by the Commission and calls for indirect measures of krill population status.

Ecosystem monitoring in the open ocean represents an important and difficult task. It is a necessary complement to the land-based monitoring programs being developed by CCAMLR members and can provide information on areas not reached by indicators when studied in their reproductive sites but crucial to ecosystem evolution and management.

For monitoring purposes it is necessary to define a sampling unit where measurements can be taken regularly, which is more difficult in the open ocean due to the high variability of the abiotic component of the marine ecosystem. It is impossible to sample the same spot under the same conditions in two consecutive years.

Moreover, other parameters of value to the ecosystem are still less suitable for sampling : rates, variations in zooplankton abundances and composition, etc. calling for indirect estimators.

Bird observations made from ships are an inexpensive and simple methodology which can be performed with a minimum of training, thus allowing the utilization of practically any platform. Observations give information on factors governing distribution and abundances. The rationale behind the present exploratory work is that the vector composed by the bird counts per species will show differences associated with krill, either in its position measures or in other distributional properties. Such changes will be more efficiently detected if parametric statistics can be applied.

In the Reports of previous meetings of the Working Group on Ecosystem Monitoring a list of interesting variables and parameters was identified. As well as minke whales and penguins, bird populations will reflect changes in abundance of krill in a given area.

On the other hand, if changes detected are to be used by administrators, it is necessary to make every effort to obtain a measure of statistical significance associated with every statement produced.

The present paper is the result of exploring the possibility of using bird observations made at sea, for the purpose of krill abundance monitoring. Bearing in mind the concept of the CCAMLR Working Group on Ecosystem Monitoring that recommends the survey of parameters and variables easily obtained and sensitive to changes in the actual object of the monitoring program, this possibility was considered worthy of being investigated. It is to be noted that bird observations can be carried out from any ship operating in the area, thus becoming an inexpensive way of monitoring krill abundances over great areas, least as accurate as any of the already proposed indicators (seals, minke whales, etc.), and not tied to the operations of a fishing fleet as is the case with catch per unit effort.

To this end, 72 bird observations made during FIBEX (1981) cruise of R/V Dr Eduardo L. Holmberg taken together with acoustic records of krill abundance were studied by some multivariate techniques. The main objective was to identify which bird species can be used as indicators of krill abundance and to outline the methodology of data analysis in order to obtain parametric exact tests for hypothesis testing.

The same data set has been analysed by Visbeek and Fontana (1983) from the viewpoint of the autecology of bird species. This analysis has proven the sensitivity of the bird variates to slight variations in abiotic conditions and was based on an ANOVA approach to profile analysis developed by Gneisser and Greenhouse (1958) followed by planned contrasts according to Bonferroni.

MATERIAL AND METHODS

Along the January-February 1981 cruise of R/V Dr Eduardo L. Holmberg, realised as part of the FIBEX exercise, birds within 500 m of the sides of the ship were recorded in the 10-minute Seabird Record Cards. The area sampled lies between 57 and 62 degrees South and 42 and 48 degrees West; more details on the methods are to be found in Visbeek and Fontana (1983).

From the records of a Simrad EK120 echosounder, five levels of krill abundance have been determined associated with each bird observation. It should be noted that the fifth level is several orders of magnitude greater than the fourth.

The statistical methodology employed was selected in order to obtain :

- Graphic displays purporting dimensionality reduction, readily understandable in biological terms.
- Methods allowing hypothesis testing with the material at hand.
- Methods that can be used for comparison with other data sets, thus allowing for monitoring of different parameters. For the sake of clarity, the methods applied will be briefly described :

Correspondence Analysis

Descriptions of the method can be found in Lebart, Morineau and Fenelon (1979).

The method is closely related to principal components; it is based on the eigenanalysis of the moment of inertia of the given set of points. Masses are allocated as total birds observed when considering the sighting-points in the p-space of bird species; or as the total number of birds of a given species when species-points in the n-space of observations are considered. These two representations of the set of observations are reduced in dimensions by considering only those eigenvectors associated with a high contribution to total inertia. It can be shown that the eigenvectors are the same and that representations in both spaces (birds and observations) are equivalent. This allows the representation in a single plot of bird and sighting points, providing good insight on the interrelations of species and localities of observation.

The main output is formed by a table of eigenvalues and percentages of total inertia explained, and bidimensional plots of the points using as coordinates the projections on the directions of eigenvectors.

Contour Plotting

This method is due to Andrews (1972) and also described in Gnanadesikan (1977). Given a vector (x) in a p-dimensional space, a bidimensional representation is obtained defining a set of directions in the p-space and projecting the interesting points on these. Useful sets of directions are generated by means of the vector of parametric orthogonal functions :

(1) $a'(t) = (1/\sqrt{2}\ ), \sin t, \cos t, \sin 2t, \cos 2t, \ldots)$

the parameter t is kept between pi and minus pi.

The projections are calculated as a linear function of t for the point x :

(2) $Fx(t) = a'(t) . x$,

and the values of Fx(t) represented as ordinates of the abscissa (t). In that way, each point will be replaced by a curve, allowing for graphic comparisons. Those directions where differences occur can be identified for ulterior investigation by the values taken by a'(t).

The representations obtained are not unique, in the sense that the order of the variates in the p-space determines the coefficients associated with each variate. Each permutation purports a strict association of variates and coefficients defined in (1) (each permutation might be considered as a different definition of space orientation), thus permutations provide different insights into data structure.

At variance with discriminant analysis this method is not aimed to obtain a direction where differences between treatments are maximal, but to obtain a picture of the directions where the differences occur.

Two applications of the method will be developed in the sequel :

1. Quantile contour plotting :

   On each of the directions generated by (1), F(t) functions are calculated for the 72 observations according to (2). These 72 values are ordered and First Decile (D1), First Quartile (Q1), Median (M), Third Quartile (Q3) and Ninth Decile (D9) evaluated. Then quantiles are plotted against t values and the ratios : (D1-M)/(Q1-M) and (D3-M)/(Q3-M) calculated and listed. The plot will give information on the presence of multimodality and highly correlated variates, while the ratios should be approximately equal to 1.9 if joint normality of the variates is assumed.

   It is to be noted that quantile contour plotting is not a formal test for multinormality, but will give an idea of the distributional properties of data, which is sufficient with the data set at hand.

2. Function contour plotting :

   Taking the centroids of different treatments and treatment levels as the points in p-space to be analysed, function contour plotting as described above provides a method of classification which permits clustering (provided number of points is kept low). At variance with conventional clustering methods based in the definition of ultrametrics, it allows the inclusion or not of a point in some of the clusters formed as well as identifying directions that result in similarities or differences in the plot. Furthermore, as a consequence of the selection of orthogonal functions as components of vector a'.

3. As $\int_{-\pi}^{\pi}$ [fi(t)-fj(t)]^2 dt
   is proportional to the euclidean distance defined between points xi and xj, closeness of the curves might be considered as closeness in the original p-space.

Comparison of Covariance Matrices

A Chi-square statistic is constructed as an extension of Bartlett's test (Morrison, 1977), to provide an exact test of the null hypothesis of equality of several covariance matrices. The statistic is also highly sensitive to non-normally distributed variables and not defined if one or more of the matrices is singular, thus precluding the inclusion of variates not observed in one of the data subsets.

Profile Analysis

Given a set of groups of p-dimensional data, with non-singular covariance matrices (not necessarily equal), we can define the profile of one of the groups as the values of the mean vector of the group. This technique, fully detailed in Morrison (1977), allows the construction of a test for the profile parallelism hypothesis and tests for group mean level and variate levels, the last two only if the first test resulted non-significant.

Fortran source programs for correspondence analysis are those published in Lebart, Morineau, Fenelon (1979). Other methods were run utilizing Fortran programs developed by authors on IBM PC-XT 640K.

RESULTS AND DISCUSSION

Bird sightings have been used by fishermen and sailors as indicators of fishing targets and geographical features for many years. Our goal should be to translate this fact into a mathematically tractable form, defining a model to be applied in hypothesis testing. Results given by each of the methods used will be discussed prior to general evaluation of results.

Correspondence Analysis

Table I. presents the percentage of inertia associated with each of the eigenvalues obtained considering all variates and krill related variates (as per literature information) alone.

Data dimensionality can be sensibly reduced applying this method, but neither of the new coordinate axes obtained can be attached to the variables of our interest (figs. 1-4). This approach might prove to be significant to the biology of avian communities, but to our present purpose they show that krill influence is at least correlated with other factors. Thus a methodology allowing for specific representation of interesting directions in the space defined by the bird variates is necessary.

Contour Plotting

Figs. 5-9 show the application of the method to raw and log-transformed data, with and without considering the *Pygoscelis* spp. variate. From the comparison it results that log transformed data are more stable, both representations showing not only the differences between treatments, but also the fact that without penguins their discrimination is still possible.

From Figure 5 and other permutations of variates (random, according to food regime and abundances) several directions where treatments show differences have been identified. The next step was the identification of the coefficients associated to each variate in these directions. The analysis showed clearly the influence of Pygoscelis spp., Pagodroma nivea and Pachyptila spp. in treatment discrimination. Results were not so clear for Daption capense.

Krill treatments resulted in different curves that can be grouped:
1) Sightings where krill was highly abundant
2) Sightings where krill was abundant
3) Sightings where krill was scarce or absent.

In the sequel, only these three levels will be considered. Figs. 8 and 9 present the results obtained applying the method to the species considered as possible krill feeders with and without penguins.

Contour plotting in the space defined by indicators identified here was not attempted because the same set of data provided the selection of species and the representation.

Profile Analysis

Due to the fact that under the assumptions of this method all groups to be compared must possess a non-singular covariance matrix, we were restricted to the use of following species (present under all krill levels) :
Diomedea exulans + D.epomophora, Daption capense, Pagodroma nivea, Pachyptila spp. and Oceanites oceanicus.

Results of the test were significant at the .01 level, thus indicating that the species considered react differentially to the presence of krill. A simple inspection of the profiles shown in Figure 10 indicates that it is Pagodroma nivea and to a lesser extent Pachyptila spp. that can be used as krill indicators.

Equality of Covariance Matrices

In all cases tested and with the transformations (raw data, square root and log) used, covariance matrices were significantly different. It is impossible to decide with the evidence at hand, whether this result is due to an inequality of covariances or to non-normality of data. Anyhow any of the origins of the significant difference will lead to a useful insight : if it is non-normality, data can be transformed in order to get a multinormal set of variates thus allowing for a highly efficient test of hypothesis. If the matrices are essentially different, this inequality can be used to detect variations in krill abundance and comparisons from year to year. Contour plotting of the position measures for treatments 1 and 2, (log transformed data) shown in Figures 12 and 13, as well as their quotients, strongly suggest the possibility of obtaining a normalized variable by means of the log transformation or a related one. These plots also show that if non-normality actually exists it is not very great. Further work should be devoted to this approach.

Based on the above results, we can now develop a line of analysis :

I. From the correspondence analysis of the whole set of data, no major axis can be extracted with a high correlation with krill abundance. This means that the general linear model (purporting a regression) will be of little use until a set of interesting contrasts is defined. Krill appears always correlated with other factors, thus calling for a line of analysis enabling the selection of specifically interesting directions.

II. Contour plotting is strictly descriptive in nature, no significance can be attached to the graphics obtained, but they showed that the method is sensible to krill presence, that penguins are not essential for discrimination, but only three levels of abundance were detected. It must be noted that the plots are scaled to make full use of a 130 spaces printer, so curves coming from different plots should be compared with caution after rescaling the drawings.

Plots made on 3 or 5 krill levels identified the species responsible for the discrimination between treatments. These species might be considered as sensitive to krill presence, but not considered as good indicators until further validation is done.

III. A Vector was constructed with all species present at different krill levels and latitudes. This restriction is needed if non-singular covariance matrices are to be obtained in each treatment level. Covariances at three different krill levels and four latitudes were found to be significantly different. Significant results might be the outcome of a non-normally distributed variable, or of differences in covariance matrices. In either case, a multivariate general linear model cannot be fitted if probability levels are to be used outside the present body of data.

IV. With the same subsets defined for krill and latitude treatments in III, profile analysis was performed. Significant results prove that species do not react homogenously to changes in latitude or krill abundance. Direct inspection of profiles showed that Pagodroma nivea and Pachyptila spp. are the variates responsible for the non parallelism of profile of the third treatment.

V. A vector of variates supposed to be sensitive is constructed and analysed with the same methods with the following summary of results :

- No krill regression on species is worth trying (correspondence analysis).
- Highly different contours resulted.
- Significantly different covariance matrices have been found as well as profiles resulted non-parallel.

VI. Quantile Contour Plotting was performed on the vector of sensitive variates showing minor deviations from normality.

This result strongly suggests the possibility that covariance matrices comparison results are rather due to actual differences in covariances and not to the lack of joint normality. This leaves open the possibility of finding a set of treatments that leaves multinormally distributed residuals. In that case a conservative degree of freedom ANOVA, as developed by Geissen and Greenhouse (1958) and described in Morrison (1977) and Winer (1971), can be applied. This will give a powerful tool for monitoring by means of the formulation of adequate contrasts, and eventually to obtain regression curves. No such method is attempted here, because of the fact that directions to be tested are defined from the same set of data.

CONCLUSIONS

1. The present analysis has been developed mainly on a Fibex data set restricted to the summer 1981 north of South Orkneys Islands. Its results cannot be extrapolated to other areas and years, until the analysis is validated by subjecting other data sets where krill and birds have been registered simultaneously, to the same or refined statistical techniques. Moreover, the exploratory work performed does not preclude the application of other methodologies not used (discriminant analysis, canonical correlation, non-parametric statistics, etc.).

2. A set of sensitive bird species has been identified. This set would allow either :

   a) detection of krill concentrations by means of classical discriminant analysis. This will be possible if normality analysis and comparisons with other data sets allow for the restrictions of the method (mainly normality) and the analysis made under different well-identified conditions;

   b) detection of krill concentrations by means of univariate ANOVA under the conservative degrees of freedom formulation;

c) detection of krill concentrations by associating to its presence a certain covariance structure. Thus intensive cruising of a certain region will provide a data set to be compared with those where krill has been independently evaluated. Comparisons can be tested by means of covariance matrices comparisons or profile analysis.

3. If the univariate approach is tenable, the possibility of constructing a regression line of krill abundance on the bird variates should be considered and carefully tested. Such an approach will directly yield an estimation of krill abundance from bird sightings under different affecting factors.

4. A monitoring minimum approach can be outlined :

   i) To identify areas where bird observations (with or without simultaneous krill evaluations) are carried out by ships not necessarily commited to research;

   ii) to decide the methodology to be used for krill detection by means of bird sightings (parametric statistics, covariance matrices comparison, profile analysis or non-parametric tests);

   iii) weights should be allocated providing a compensation for the total Record Cards obtained by a given cruise in the area;

   iv) numbers of bird cards indicative of krill presence can be taken as a measure of krill abundance in the area considered.

5. Due to the amount of information necessary, this monitoring development can be fruitfully envisaged only under a cooperative international basis, allowing the use of BIOMASS and CCAMLR data bases, which will provide the background for the simultaneous analysis of other factors not included in the present paper because of the insufficient number of observations (e.g. time, depth of krill patches, latitude, meteorological conditions, etc.).

Acknowledgements : Authors are grateful to Dr Aldo P. Tomo and Lic. Diego Gru, who recorded krill abundance.

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Table 1. Eigenvalues obtained from correspondence analysis

	Krill related variates			All variates		
	EIGENVALUE	PERCENT.	ACCUMUL	EIGENVALUE	PERCENT.	ACCUMUL
2	.72307	35.14	35.14	.71822	28.75	28.75
3	.61801	30.03	65.18	.56255	22.52	51.27
4	.48580	23.61	88.79	.46305	18.54	69.81
5	.17237	8.38	97.16	.30425	12.18	81.99

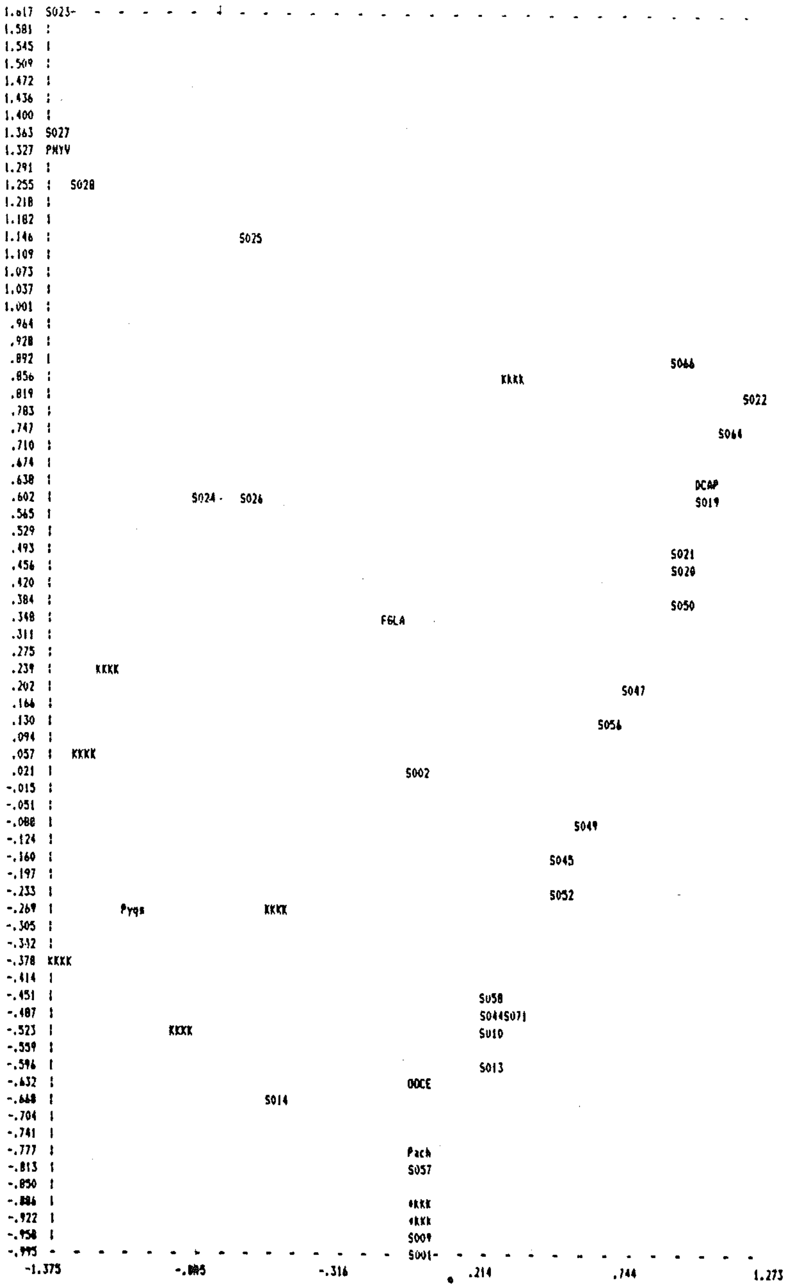

Figure 1 Correspondence analysis of krill related variates. Projection on axis 1 (horizontal) and 2 (vertical). Stations where krill was highly abundant are represented by KKKK or *KKK if stations without krill have same coordinates. Points marked with ! are out of scale. Pachyptila spp = Pach; Pygoscelis spp = Pygs; Oceanites oceanicus = OOCE; Pagodroma nivea = PNYV; Fulmarus glacialoides = FGLA; Daption capense = DCAP; Macronectes spp = Macr; Diomedea exulans ± Diomedea epomophora = Derr; Diomedea melanophris = DMEL; Phoebetria palpebrata = PPAL.

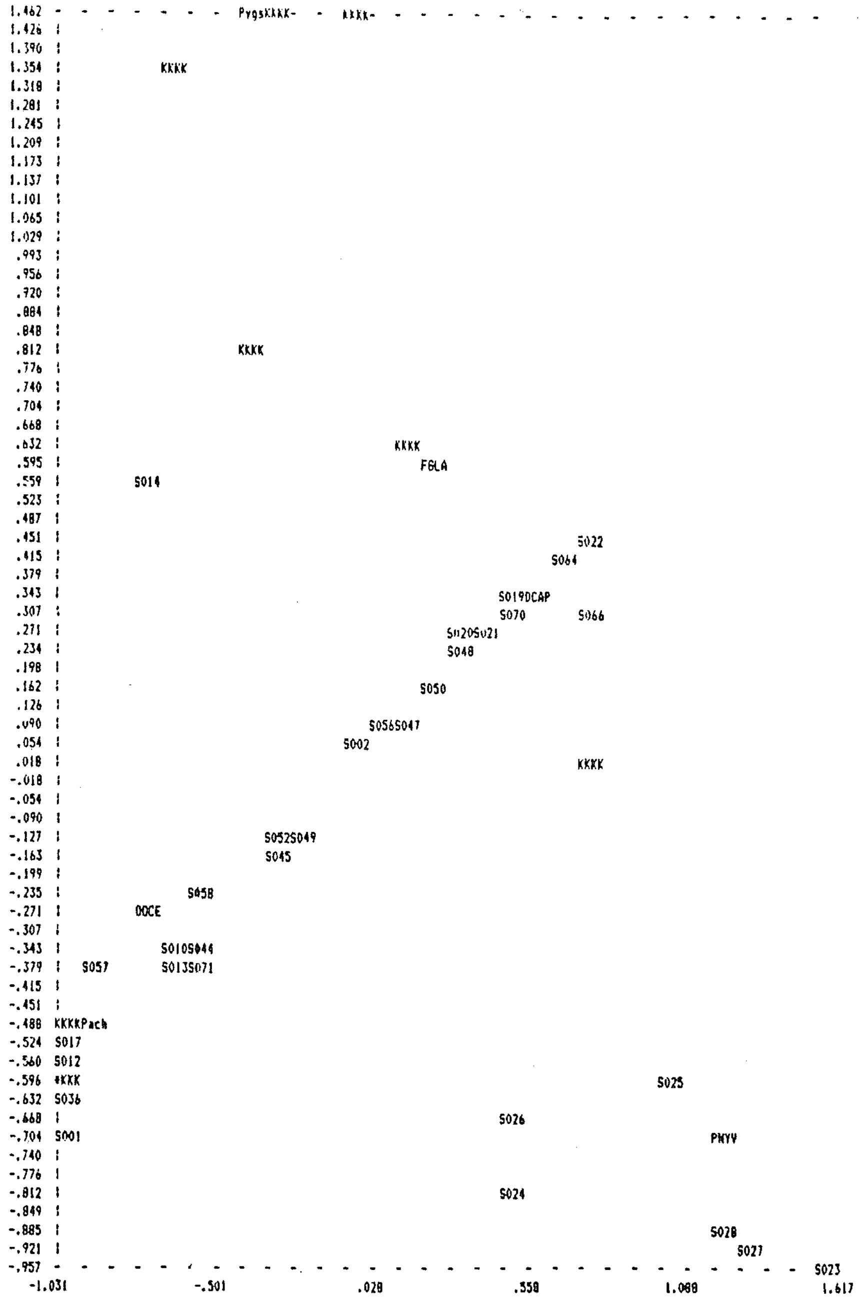

Figure 2 Correspondence analysis of krill related variates. Projection on axis 2 (horizontal) and 3 (vertical). Captions as per Figure 1.

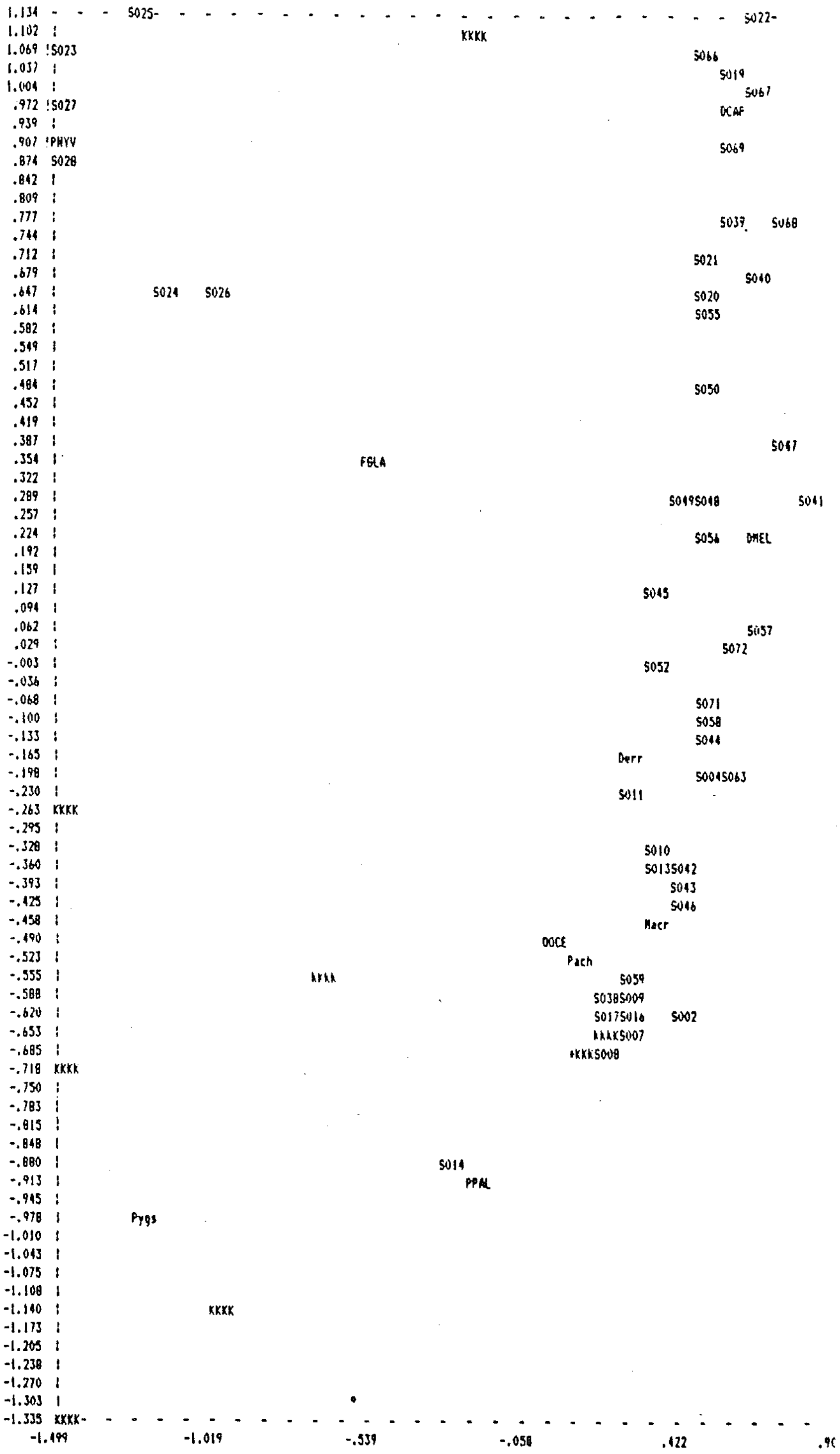

Figure 3 Correspondence analysis of all variates. Projection on axis 1 (horizontal) and 2 (vertical). Captions as per Figure 1.

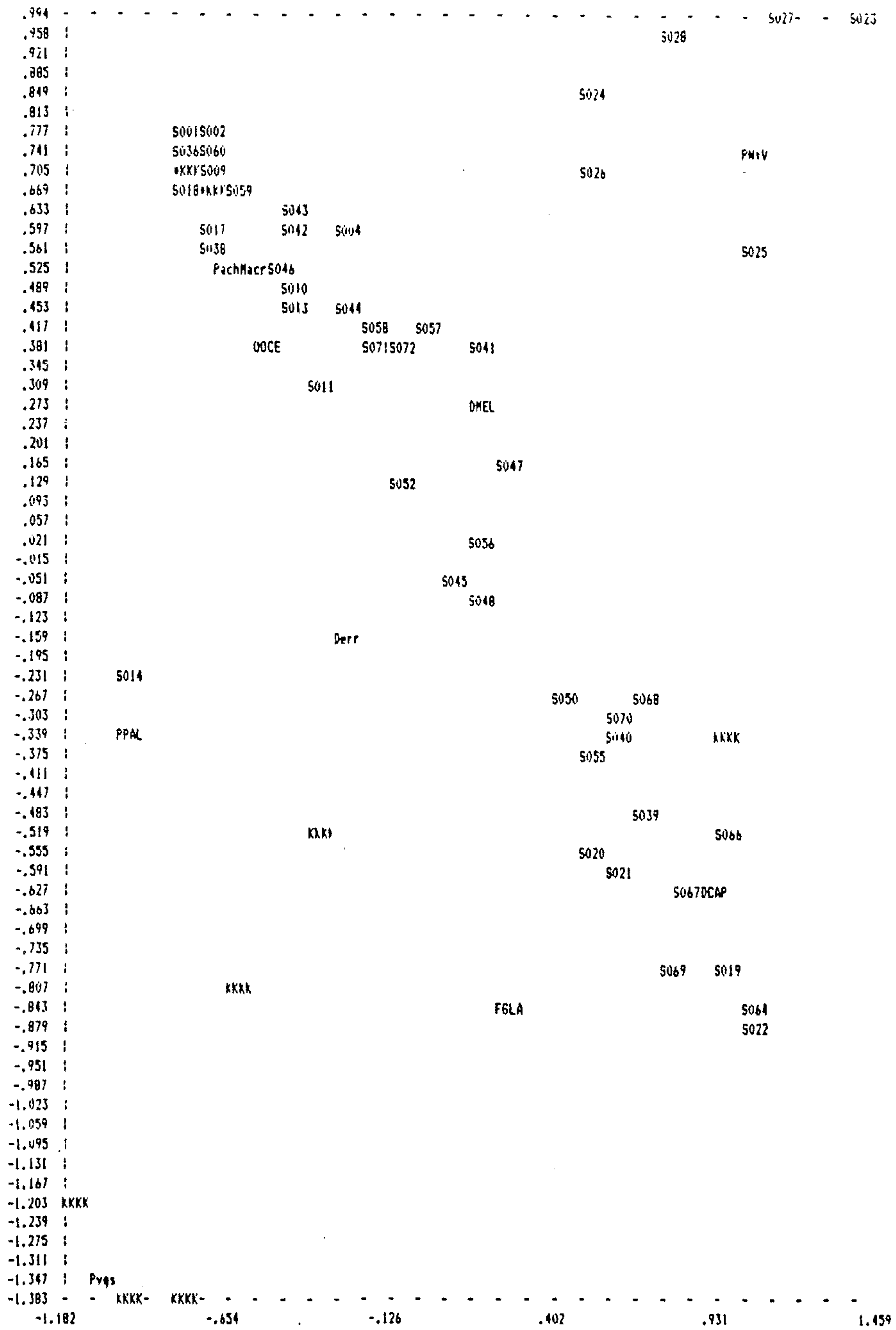

Figure 4 Correspondence analysis of all variates. Projection on axis 2 (horizontal) and 3 (vertical). Captions as per Figure 1.

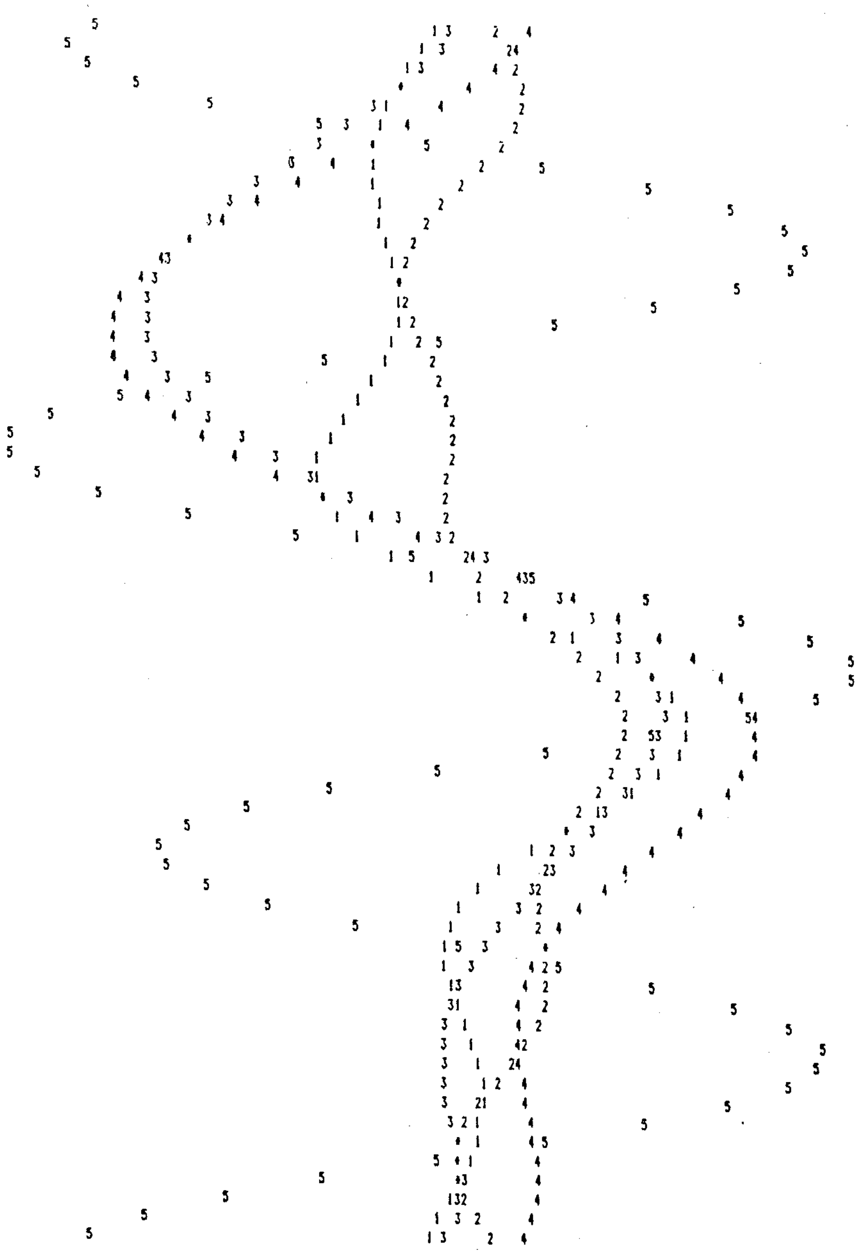

Figure 5 Contour plot of the centroids of five krill levels in the space defined by the 10 variates in decreasing order. Raw data.

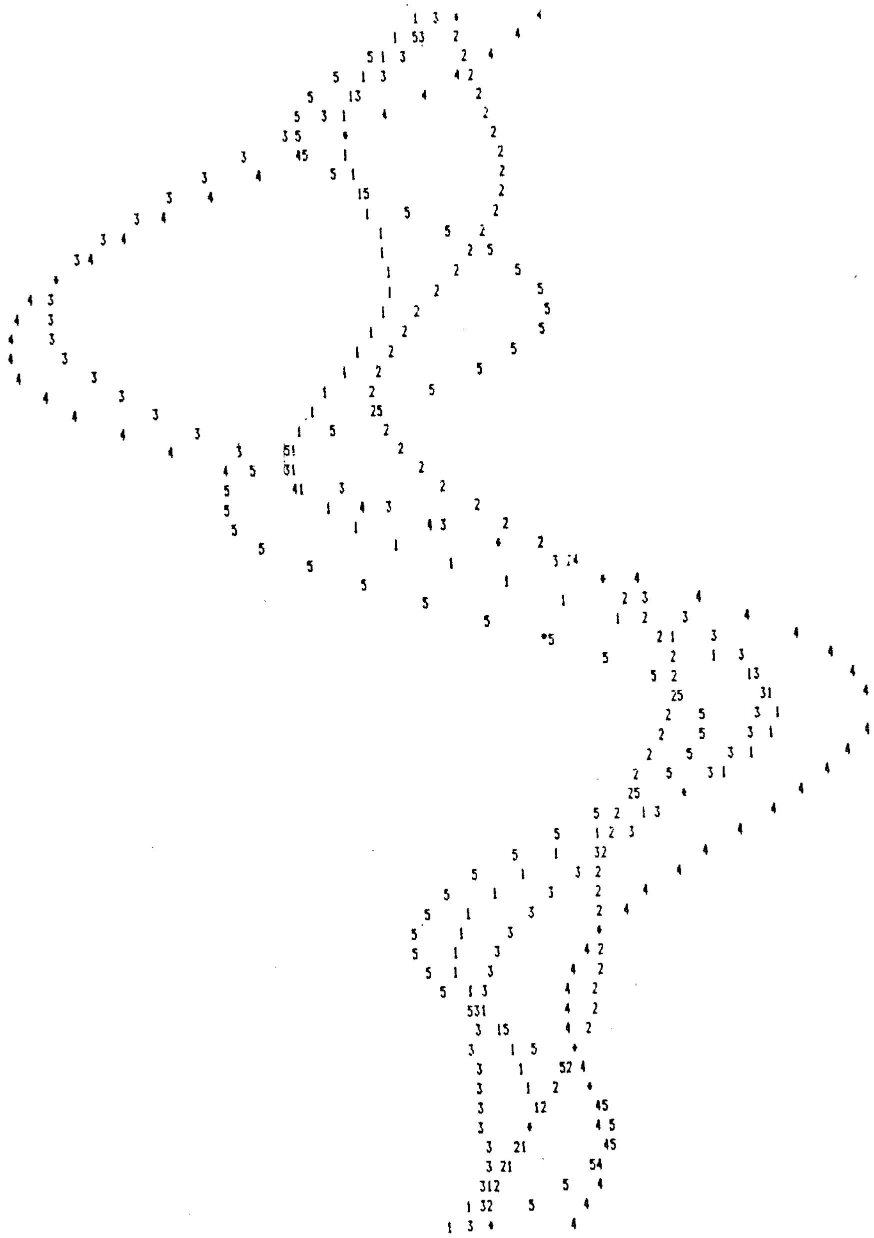

Figure 6 Contour plot of the centroids of five krill levels in the space defined by all variates except Pygoscelis spp. in decreasing order. Raw data.

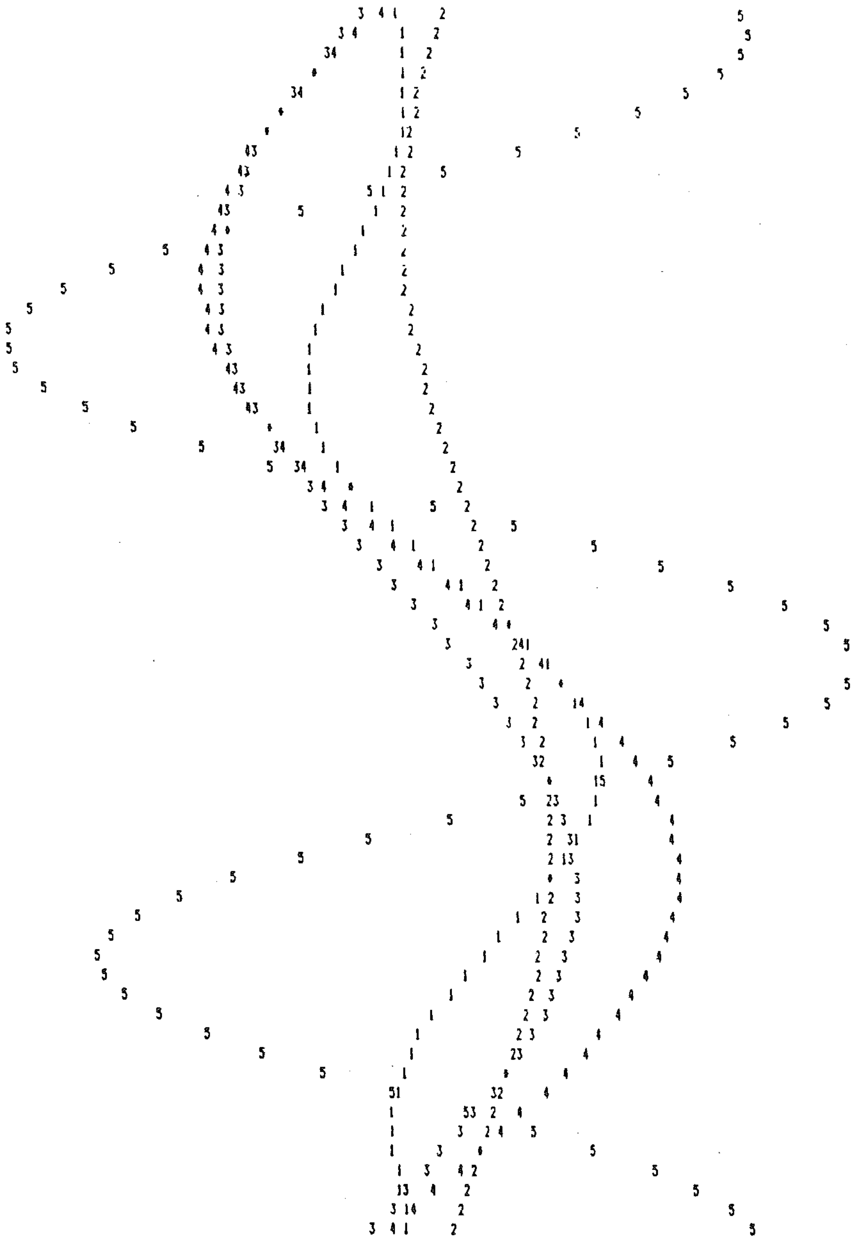

Figure 7 Contour plot of the centroids of five krill levels in the space defined by sensitive (from literature data) variates in decreasing order. Raw data.

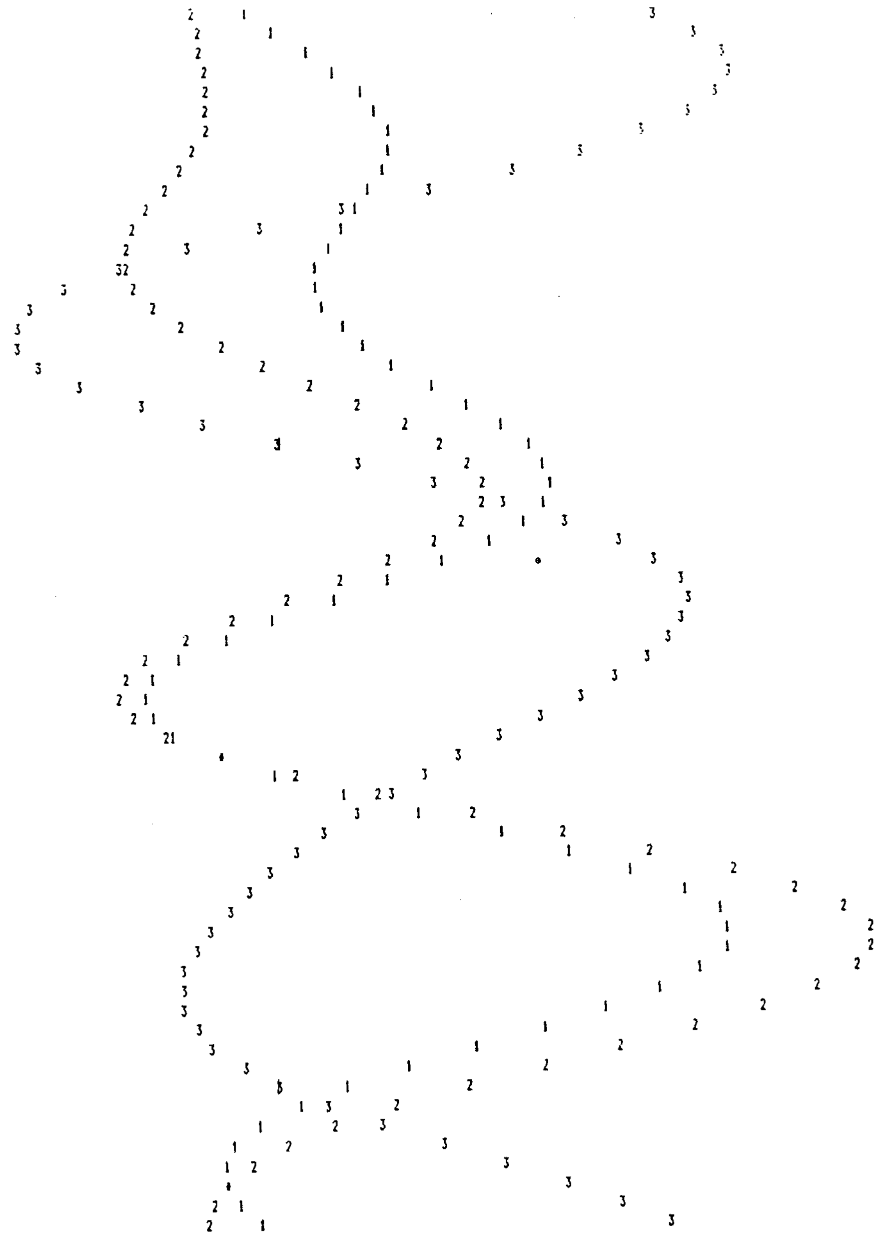

Figure 8 Contour plot of the centroids of three krill levels in the space defined by all sensitive variates in decreasing order. Log transformed data.

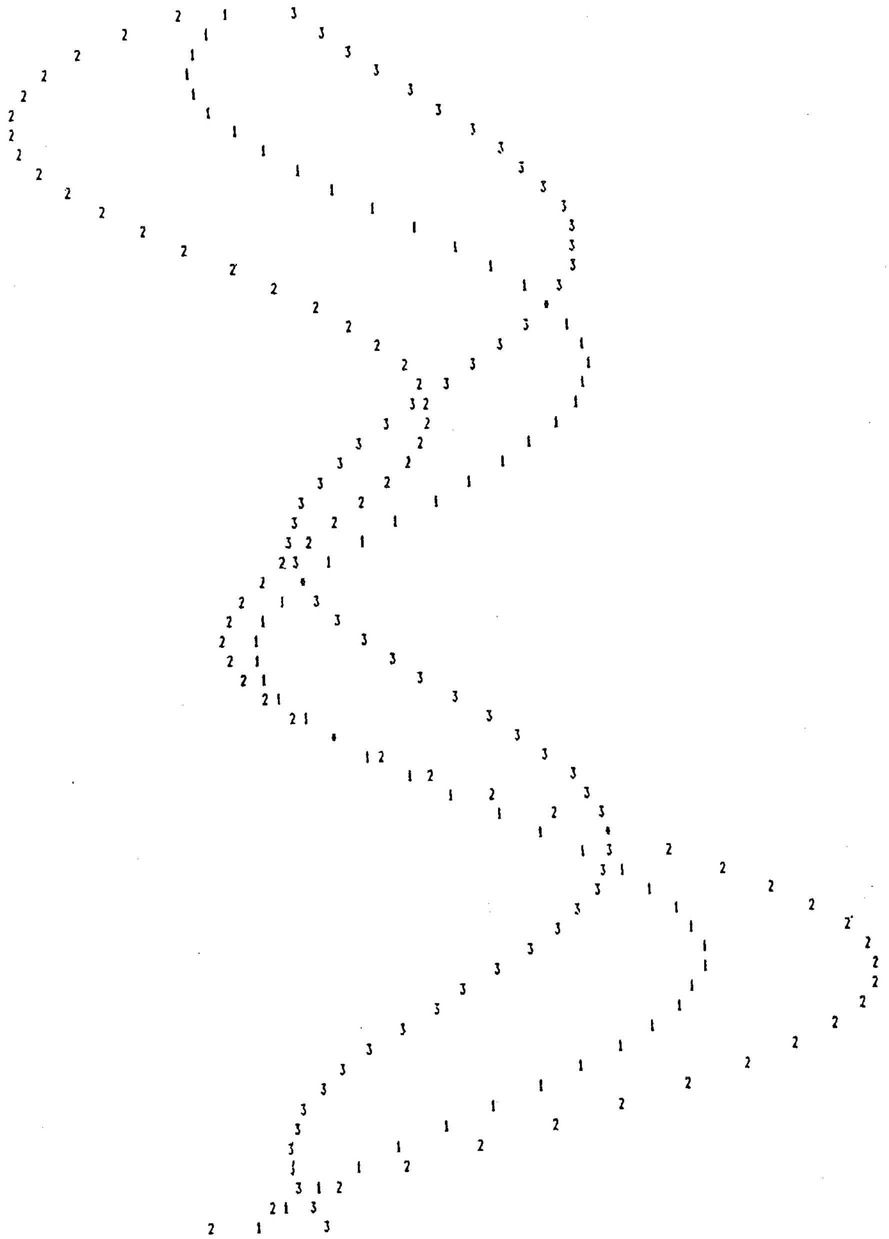

Figure 9 Contour plot of the centroids of three krill levels in the space defined by all sensitive variates except Psygoscelis spp. in decreasing order. Log transformed data.

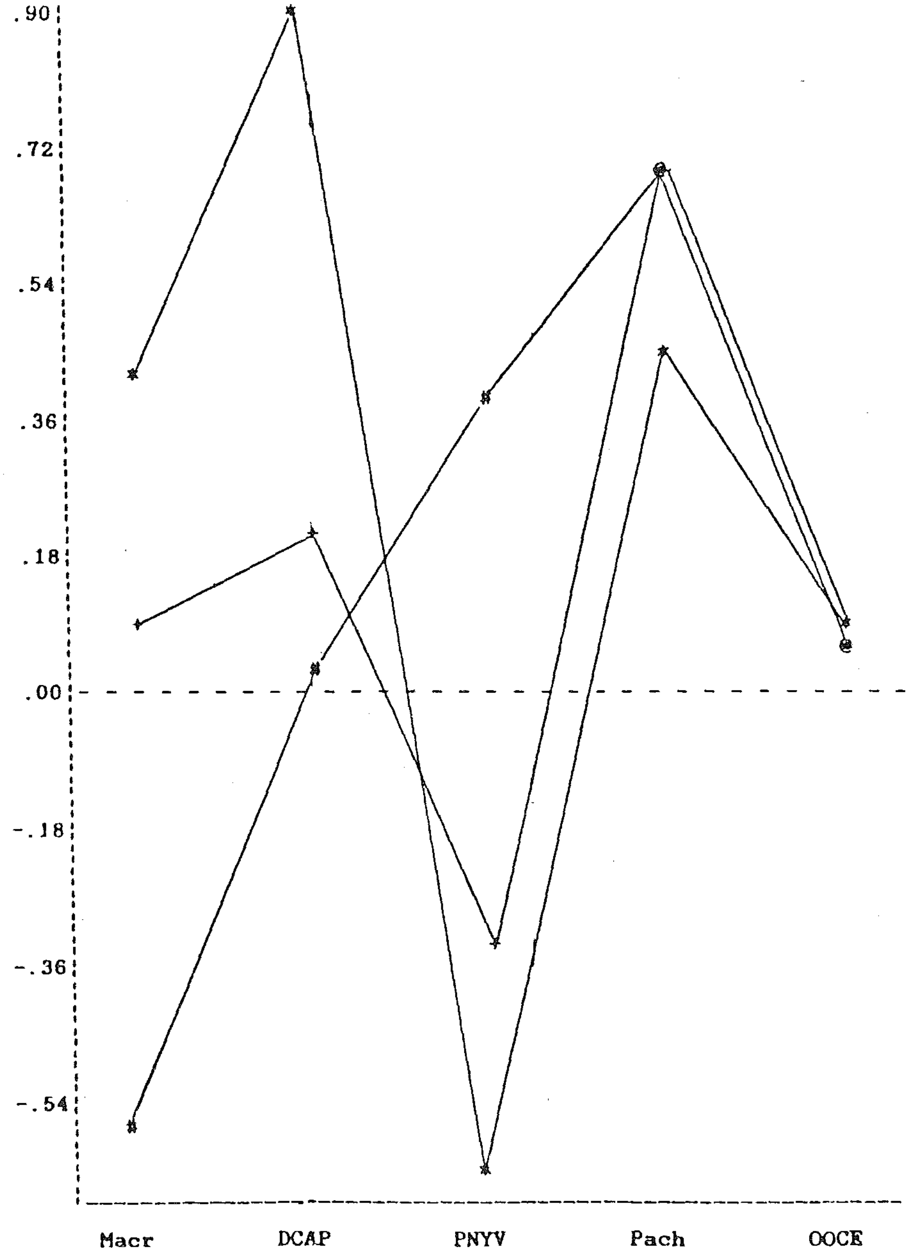

Figure 10 Profiles of the means of three levels of krill abundance. Log transformed data. (+ = scarce or absent, * = present or abundant, # = highly abundant).

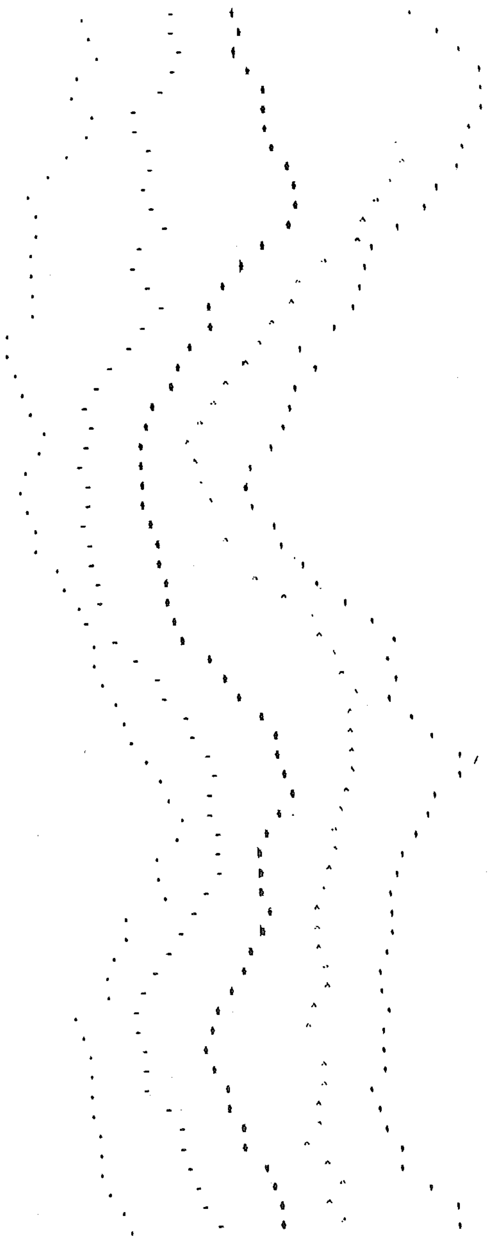

Figure 11 Quantile Contour Plot for the position measures of treatment 1 (scarce or no krill). 1st Decile (.), 1st Quartile (-), Median (*), 3rd Quartile (^) and 9th Decile (,). Log transformed.

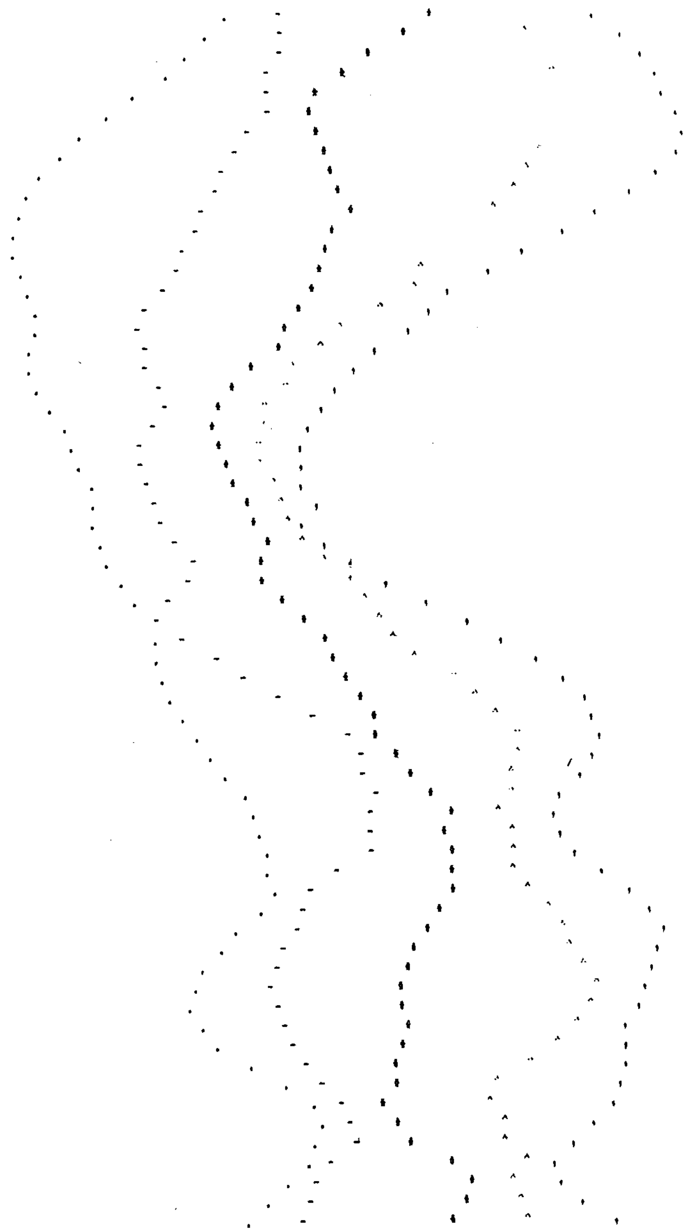

Figure 12 Quantile Contour Plot for the position measures of treatment 2 (present or abundant krill). 1st Decile (.), 1st Quartile (-), Median (*), 3rd Quartile (^) and 9th Decile (,). Log transformed.

Légende du tableau

Tableau 1 Valeurs propres obtenues à partir de l'analyse de correspondance.

Légendes des figures

Figure 1 Analyse de correspondance des variantes liées au krill. Projection sur l'axe 1 (horizontal) et 2 (vertical). Les stations où le krill était fort abondant sont représentées par KKKK ou *KKK si les stations sans krill ont les mêmes coordonnées. Les points marqués d'un ! ne sont pas rapportés à l'échelle. _Pachyptila_ spp = Pach; _Pygoscelis_ spp = Pygs; _Oceanites oceanicus_ = OOCE; _Pagodroma nivea_ = PNYV; _Fulmarus glacialoides_ = FGLA; Daption capense = DCAP; _Macronectes_ spp = Macr; _Diomedea exulans_ + _Diomedea epomophora_ = Derr; _Diomedea melanophris_ = DMEL; _Phoebetria palpebrata_ = PPAL.

Figure 2 Analyse de correspondance des variantes liées au krill. Projection sur l'axe 2 (horizontal) et 3 (vertical). Pour la légende, voir la Figure 1.

Figure 3 Analyse de correspondance de toutes les variantes. Projection sur l'axe 1 (horizontal) et 2 (vertical). Pour la légende, voir la Figure 1.

Figure 4 Analyse de correspondance de toutes les variantes. Projection sur l'axe 2 (horizontal) et 3 (vertical). Pour la légende, voir la Figure 1.

Figure 5 Tracé de contour des centroïdes de cinq niveaux de krill dans l'espace défini par les 10 variantes dans un ordre décroissant. Données brutes.

Figure 6 Tracé de contour des centroïdes de cinq niveaux de krill dans l'espace défini par toutes les variantes sauf _Pygoscelis_ spp. dans un ordre décroissant. Données brutes.

Figure 7 Tracé de contour des centroïdes de cinq niveaux de krill dans l'espace défini par les variantes sensibles (obtenues à partir des données de documentation) dans un ordre décroissant. Données brutes.

Figure 8 Tracé de contour des centroïdes de trois niveaux de krill dans l'espace défini par toutes les données sensibles dans un ordre décroissant. Données transformées à l'introduction.

Figure 9 Tracé de contour des centroïdes de trois niveaux de krill dans l'espace défini par toutes les variantes sensibles sauf _Pygoscelis_ spp. dans un ordre décroissant. Données transformées à l'introduction.

Figure 10 Profils des moyennes de trois niveaux de l'abondance du krill. Données transformées à l'introduction. (+ = rare ou absent, * = présent ou abondant, # = très abondant).

Figure 11 Tracé de contour du quantile pour les mesures de position du traitement 1 (krill rare ou absent). ler décile (.), ler quartile (-), médiane (*), 3ème quartile (^) et 9ème décile (,). Transformé à l'introduction.

Figure 12 Tracé de contour du quantile pour les mesures de position du traitement 2 (krill présent ou abondant). ler décile (.), ler quartile (-), médiane (*), 3ème quartile (^) et 9ème décile (,). Transformé à l'introduction.

Encabezamiento de la Tabla

Tabla 1 Autovalores obtenidos del análisis de correspondencia.

Leyendas de las Figuras

Figura 1 Análisis de correspondencia de las variables relacionadas con el krill. Proyección sobre los ejes 1 (horizontal) y 2 (vertical). Las estaciones en las cuales el krill fue sumamente abundante se representan por KKKK, o por *KKK, si las estaciones sin krill tienen las mismas coordenadas. Los puntos marcados con ! están fuera de escala. Especies Pachyptila = Pach; especies Pygoscelis = Pygs; Oceanites oceanicus = OOCE; Pagodroma nivea = PNYV; Fulmarus glacialoides = FGLA; Daption capense = DCAP; especies Macronectes = Macr; Diomedea exulans ± Diomedea epomophora = Derr; Diomedea melanophris = DMEL; Phoebetria palpebrata = PPAL.

Figura 2 Análisis de correspondencia de las variables relacionadas con el krill. Proyección sobre los ejes 2 (horizontal) y 3 (vertical). Los encabezamientos son iguales a los de la Figura 1.

Figura 3 Análisis de correspondencia de todas las variables. Proyección sobre los ejes 1 (horizontal) y 2 (vertical). Los encabezamientos son iguales a los de la Figura 1.

Figura 4 Análisis de correspondencia de todas las variables. Proyección sobre los ejes 2 (horizontal) y 3 (vertical). Los encabezamientos son iguales a los de la Figura 1.

Figura 5 Trazado de contorno de los centroides de cinco niveles de krill en el espacio definido por las 10 variables en orden decreciente. Datos en bruto.

Figura 6 Trazado de contorno de los centroides de cinco niveles de krill en el espacio definido por todas las variables, excepto las especies Pygoscelis en orden decreciente. Datos en bruto.

Figura 7 Trazado de contorno de los centroides de cinco niveles de krill en el espacio definido, por las variables sensibles (en base a datos obtenidos de la documentación) en orden decreciente. Datos en bruto.

Figura 8 Trazado de contorno de los centroides de tres niveles de krill en el espacio definido por todas las variables sensibles en orden decreciente. Datos transformados a logaritmos.

Figura 9 Trazado de contorno de los centroides de tres niveles de krill en el espacio definido por todas las variables sensibles, excepto las especies Pygoscelis en orden decreciente. Datos transformados a logaritmos.

Figura 10 Perfiles de los valores medios de tres niveles de abundancia de krill. Datos transformados a logaritmos. (+ = escaso o ausente, * = presente o abundante, # = muy abundante).

Figura 11 Trazado Cuantil de Contorno para las medidas de la posición del tratamiento 1 (krill escaso o ausente). 1er Décil (.), 1er Cuartil (-), Mediana (*), 3er Cuartil (^) y 9o Décil (,). Transformados a logaritmos.

Figura 12 Trazado Cuantil de Contorno para las medidas de la posición del tratamiento 2 (krill presente o abundante). 1er Décil (.), 1er Cuartil (-), Mediana (*), 3er Cuartil (^) y 9o Décil (,). Transformados a logaritmos.

Заголовок к таблице

Таблица 1 Собственные значения, полученные при анализе совпадений.

Подписи к рисункам

Рисунок 1 Анализ совпадений переменных, относящихся к крилю. Проекции на оси 1(горизонтальную) и 2(вертикальную). Станции, во время выполнения которых количество криля было очень велико, отмечены символом КККК или *ККК - если у станций без криля те же самые координаты. Точки, помеченные "!", выходят за пределы масштаба. Pach - виды Pachyptila, Pygs - виды Pygoscelis; OOCE - Oceanites oceanicus, PNYV - Pagodroma nivea, FGLA - Fulmarus glacialoides, DCAP - Daption capense, Macr - виды Macronectes, Derr - Diomedea exulans ± Diomedea epomophora, DMEL - Diomedea melanophris, PPAL - Phoebetria palpebrata.

Рисунок 2 Анализ совпадений переменных, относящихся к крилю. Проекции на оси 2(горизонтальную) и 3(вертикальную). Условные обозначения - как и на Рисунке 1.

Рисунок 3 Анализ совпадений всех переменных. Проекции на оси 1(горизонтальную) и 2(вертикальную). Условные обозначения - как и на Рисунке 1.

Рисунок 4 Анализ совпадений всех переменных. Проекции на оси 2(горизонтальную) и 3(вертикальную). Условные обозначения - как и на Рисунке 1.

Рисунок 5 Контурное построение центроид пяти уровней количества криля в пространстве, определенном 10-ю переменными в порядке убывания. Необработанные данные.

Рисунок 6 Контурное построение центроид пяти уровней количества криля в пространстве, определенном всеми переменными, кроме видов Pygoscelis, в порядке убывания. Необработанные данные.

Рисунок 7 Контурное построение центроид пяти уровней количества криля в пространстве, определенном чувствительными (по опубликованным данным) переменными в порядке убывания. Необработанные данные.

Рисунок 8 Контурное построение центроид трех уровней количества криля в пространстве, определенном всеми чувствительными переменными в порядке убывания. Данные, преобразованные логарифмированием.

Рисунок 9 Контурное построение центроид трех уровней количества криля в пространстве, определенном всеми чувствительными переменными, кроме видов Pygoscelis, в порядке убывания. Данные, преобразованные логарифмированием.

Рисунок 10 Профили средних величин трех уровней количества криля. Данные, преобразованные логарифмированием. (+ - редко встречается или отсутствует, * - имеется или имеется в изобилии, # - очень большое количество).

Рисунок 11 Квантильное построение контуров позиционных измерений ситуации 1 (редко встречающийся или отсутствующий криль). 1-й дециль (.), 1-й квартиль (-), медианное значение (*), 3-й квартиль (^) и 9-й дециль (,). Данные, преобразованные логарифмированием.

Рисунок 12 Квантильное построение контуров позиционных измерений ситуации 2 (имеющийся или имеющийся в изобилии криль). 1-й дециль (.), 1-й квартиль (-), медианное значение (*), 3-й квартиль (^) и 9-й дециль (,). Данные, преобразованные логарифмированием.