STANDARDIZATION OF FISHING EFFORT FOR *CHAMPSOCEPHALUS GUNNARI* IN THE SOUTH GEORGIA AREA (SUBAREA 48.3)

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Abstract

Traditional calculation of catch-per-unit-effort series is inflexible in its use of data types and has no estimate of accuracy. A standardized CPUE index for *Champsocephalus gunnari* fishing in Subarea 48.3 is derived using a multiplicative model and data from many different classes (countries, types of vessel, fishing gear, months and years). Multiple regression is used to solve the model and the resultant yearly standardized CPUE shows the same trends independent of the values selected to standardize the model. The mean coefficient of variation for the CPUE values was 0.399.

Résumé

Le calcul traditionnel des séries de capture par unité d'effort est rigide dans son utilisation des types de données et sa précision n'a pas été estimée. Un indice de CPUE standardisé pour la pêche de *Champsocephalus gunnari* dans la sous-zone 48.3 est dérivé au moyen d'un modèle multiplicatif et de données de nombreuses classes distinctes (pays, types de navires, engins de pêche, mois et années). La régression multiple est utilisée pour résoudre le modèle et la CPUE résultante annuelle standardisée révèle les mêmes tendances indépendantes des valeurs sélectionnées pour standardiser le modèle. Le coefficient moyen de variation pour les valeurs de CPUE était de 0,399.

Резюме

При традиционных вычислениях набора величин вылова на единицу промыслового усилия неизменно используются одни и те же типы данных, а также при таких вычислениях не выводится показатель степени точности. Стандартизированный показатель СЗГУ для промысла *Champsocephalus gunnari* в Подрайоне 48.3 был получен путем использования мультипликативной модели и данных широкого ряда классов (страны, типы судов, орудия лова, месяцы и годы). При выполнении расчетов по этой модели используется многократная регрессия, при этом полученные стандартизированные годовые показатели CPUE проявляют одни и те же тенденции, независимо от величин, использованных в стандартизации модели. Средний коэффициент изменчивости показателей СЗГУ равняется 0,399.

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Resumen

El método de cálculo empleado comúnmente para estimar las series de captura por unidad de esfuerzo es bastante limitado en los tipos de datos utilizados y no da lugar a la estimación de la precisión. Mediante el uso de un modelo multiplicativo y datos de muchos tipos (países, tipos de embarcación, aparejos de pesca, meses y años), se logra inferir un índice de CPUE normalizado para la pesca de *Champsocephalus gunnari* en la Subárea 48.3. Se usa la regresión múltiple para resolver el modelo, y la CPUE anual normalizada resultante muestra las mismas tendencias, independiente de los valores que fueron seleccionados para normalizar el modelo. El coeficiente de variación promedio para los valores de CPUE fue de 0.399.

1. INTRODUCTION

The principal method for determining the stock of *Champsocephalus gunnari* from the South Georgia area (Subarea 48.3) is virtual population analysis (VPA) (Borodin and Kochkin, 1988; Basson *et al.*, 1989; Frolkina and Gasiukov, 1989). It is known that in order to use the method correctly it is necessary to substantiate the selection of terminal coefficients of fishing mortality. For this purpose values of fishing effort for a number of years of fishing are used as additional information (Pope and Shepherd, 1985).

An attempt to use fishing effort to tune the VPA when studying *C. gunnari* stocks was made in the paper by Frolkina and Gasiukov (1989).

This task is complicated by the fact that fishing for *C. gunnari* is characterized by a considerable intra-annual irregularity and marked dynamics. Whereas fishing was at first carried out by means of bottom trawls, in recent years midwater trawls have been used. This impedes the formation of a sequence of monotypical (standardized) values of fishing effort. In the abovementioned paper fishing effort was standardized in the following way. A certain type of vessel was selected as standard and, on the basis of information recorded in the STATLANT B form, a sequence of catch-per-unit-effort values was developed by years of fishing. Standardized values of fishing effort were then calculated by dividing summary catch by respective values of catch-per-unit-effort.

This method is simple, but possesses a number of disadvantages. It does not use information on fisheries of other countries and other types of vessels, and does not take into account the intra-annual heterogeneity of the fishery. When this method is in practical use, an index of accuracy is not defined. The situation becomes particularly complex if the commercial significance of the vessel selected as a standard changes with the passage of time.

The method of standardizing fishing effort based on a multiplicative model (Robson, 1966; Gavaris, 1980) is free of the disadvantages mentioned above and is considered to have potential for use in this fishery.

2. MULTIPLICATIVE MODEL OF STANDARDIZING FISHING EFFORT

The multiplicative model described in the paper by Gavaris (1980) is summarized here. The basic model involves representing a standardized value of catch-per-effort by means of the following formulae:

$$U = U_R \cdot P_{1J_1}^{X_{1J_1}} \cdot P_{2J_2}^{X_{2J_2}} \cdot P_{TJ_T}^{X_{TJ_T}} \qquad (1)$$

where U is the standard value of catch-per-unit-effort,
U_R is the value of catch-per-effort for a certain combination of categories selected as references,
P_{ij_i} is the relative power of the J_i^{th} category in the i^{th} category type,
X_{ij} is 1, if u is pertinent to j categories, and is 0 in other cases,
T_k is a number of different category types.

It is suggested that each element ***u*** may be classified as belonging to a definite category ***j*** in category type ***i***. For example, type of vessel, fishing division, month within year and finally fishing year may be considered to be category types.

The value U_R is a number which is characteristic for a given combination of categories. A given combination (i.e., reference categories) is determined beforehand from each type of category. Their characteristic feature is the equality to 1 of a respective coefficient of relative power.

The concept of a 'standard' is a set of categories which corresponds to a certain value of catch-per-effort; all other values of catch-per-effort are given in relation to the latter. For example, a standard may be catch-per-effort for a certain type of vessel using a certain gear in a certain month of a certain year.

A standardized value for catch-per-effort for a given type of category is calculated by formula (1), if the respective indices are substituted. Having selected 'year of fishing' as a type of category, one may calculate standardized values of catch-per-effort for a sequence of fishing years and consider them to be an abundance index. At the same time, total value of fishing effort is obtained by dividing total catch by a standardized value of catch-per-effort.

Parameters of the multiplicative model are calculated with multiple linear regression after logarithmic transformation (1):

$$\ln U_\iota = \ln U_R + \sum_{i=1}^{T} \ln P_{ij_i} \cdot X_{ij_i} \qquad (2)$$

where $\ln u_\iota$ is a dependent variable,
ι is the number of the set, $\iota=1,\ldots,M$,
X_{ij} is an independent variable.

At the same time, model parameters satisfy the following limitations:

$$\sum_{i=1}^{K_i} \ln P_{ij_i} = 0 , i=1,2,\ldots,T \qquad (3)$$

where K_i is the number of categories in i category types.

The sequence of calculations when defining model parameters is made in accordance with the algorithm of multiple regression (Draper and Smith, 1966). Goodness of fit test is characterized by the multiple coefficient of correlation. Estimates of the values of standard errors and confidence intervals possess some peculiarities. These are described in detail by Gavaris (1980).

The practical application of the multiplicative model for standardizing fishing effort may entail some complications which are caused by a possible lack of correlation of the system matrix (2). Corresponding modifications of the algorithm for the standardization of model parameters are described in the paper by Gasiukov (1990).

3. DATA USED

Standardizing fishing effort for *C. gunnari* in the South Georgia area (Subarea 48.3) is made with the aid of statistical data which are stored in the CCAMLR data base. A study of available information showed that in order to solve a problem the data since 1981/82 could be used. However, it should be noted that for the first two years of this period, data on fishing effort were scanty.

The whole of the commercial statistics allows for classification into the following categories:

- country;
- type of vessel;
- fishing gear;
- month within year; and
- year of fishing.

The total number of all the types is 31, the volume of the set being 103 elements.

4. RESULTS OF CALCULATIONS AND DISCUSSION

Results of standardizing fishing effort for the *C. gunnari* fishery for the period from 1981/82 to 1989/90 are represented in Tables 1 to 3. Since the selection of reference categories does not effect algorithm activity, they are not referred to in this paper, but such information is contained in Table 2. It is adopted as a standard value (tonnage class 10) in October which used bottom-fishing gear.

The multiple coefficient of correlation is 0.801, i.e., goodness of fit is high enough. Figure 1 shows a plot of the temporal trend of standardized values of catch-per-fishing-effort with 95% confidence intervals. A considerable vagueness in the estimates for the first two fishing seasons used for calculations is especially noticeable on the graph. This is obviously due to the small volume of the sample for these seasons. In the 1981/82 season the data on fishing effort were available for only 5% of the total catch for the season. Therefore, it is not recommended to use these estimates for the subsequent calculations, taking into account their high degree of uncertainty.

A calculation was also made in which the data for the 1980/81 and 1981/82 seasons were excluded. These results are not given as they are practically identical to those given in Table 3.

Use of the multiplicative model showed that the temporal trend of values of catch-per-unit-effort obtained was independent of the values selected as a standard, although absolute values differed. The values obtained may be used as an index of abundance when assessing the stocks.

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Table 1: Statistical characteristics of standardizing fishing effort for the *C. gunnari* fishery in the South Georgia area (Subarea 48.3).

Analysis of Variance

Source of Variation	DF	Sums of Squares	Mean Squares	F-Value
Intercept	1	6.110E0001	6.110E0001	
Regression	27	3.717E0001	1.377E0000	4.982
Type 1	2	5.981E0000	2.990E0000	10.820
Type 2	3	2.229E0000	7.431E-001	2.689
Type 3	2	5.650E-001	2.825E-001	1.022
Type 4	11	3.644E0000	3.312E-001	1.199
Type 5	9	8.724E0000	9.693E-001	3.508
Residuals	75	2.073E0001	2.764E-001	
Total	103	1.190E0002		

Coefficient of multiple correlation R=0.801
Coefficient of multiple correlation R squared = 0.682

Table 2: Coefficients of the multiplicative model.

Category	Code	Variable	Coefficient	Standard Error	Number of Observations
1	3	Intercept	1.751	0.233	103
2	2				
3	10				
4	10				
5	1983				
1	1	1	-3.332	0.720	3
	2	2	-2.051	0.583	20
2	1	3	1.560	0.640	19
	3	4	-0.133	0.134	38
	4	5	1.360	0.737	2
3	9	6	0.176	0.653	1
	11	7	0.230	0.164	19
4	1	8	-0.099	0.252	12
	2	9	0.029	0.284	7
	3	10	-0.056	0.268	7
	4	11	-0.180	0.284	7
	5	12	-0.393	0.297	5
	6	13	-0.630	0.280	6
	7	14	-0.298	0.260	9
	8	15	-0.593	0.276	7
	9	16	-0.079	0.302	5
	11	17	-0.306	0.240	12
	12	18	-0.450	0.257	13
5	1981	19	-1.084	0.368	4
	1982	20	0.346	0.808	1
	1984	21	-0.235	0.216	14
	1985	22	-0.250	0.381	3
	1986	23	-0.921	0.279	6
	1987	24	-0.592	0.196	28
	1988	25	-1.007	0.209	21
	1989	26	-0.830	0.324	5
	1990	27	-0.247	0.304	5

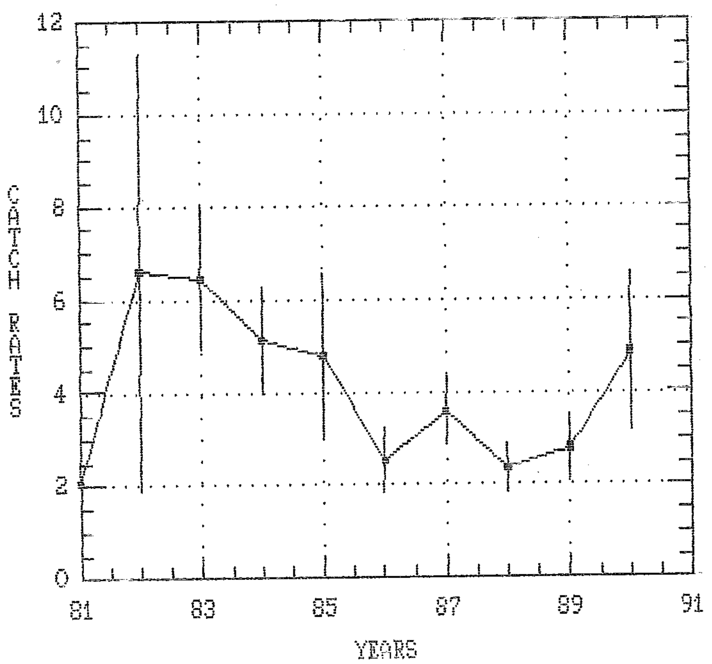
Table 3: Standardized values of catch-per-unit-effort for *C. gunnari*.

Predicted Catch Rate

Standards Used Variable Numbers: 3 2 10 10

Year	Total Catch	Catch Rate			
		Prop.	Mean	SE	Effort
1981	29 464	0.249	2.083	0.765	14 142
1982	47 454	0.057	6.607	4.680	7 182
1983	131 576	0.961	6.443	1.492	20 420
1984	80 664	0.807	5.106	1.131	15 798
1985	14 293	0.640	4.789	1.777	2 984
1986	11 368	0.893	2.536	0.699	4 483
1987	71 853	0.897	3.586	0.732	20 035
1988	37 736	0.748	2.367	0.488	15 941
1989	22 213	0.935	2.786	0.734	7 972
1990	7 268	1.000	4.856	1.676	1 497

Average CV for the mean: 0.319



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