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SIMULATION OF RECOVERY RATES OF FISH STOCKS IN THE SOUTH GEORGIA AND KERGUELEN ISLANDS AREAS

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Abstract

The benefits of conservation measures are generally based on the rebuilding of the depleted stocks and improvement in yields. It is desirable that such measures be based on the expected rate of recovery relative to rates of fishing.

A simulation model based on a probabilistic recruitment function was developed to provide long-term projections of the magnitude and rate of recovery of important fish stocks. While annual recruitment is the primary factor affecting recovery, the age of first recruitment is also an important consideration.

The simulated yields correspond, on the average, with the past observations. The simulations may prove useful in comparing observed performance of regulations to the expected outcomes from the simulations.

Résumé

Les avantages des mesures de conservation sont généralement basés sur la reconstitution des stocks dépeuplés et l'amélioration des rendements. Il est souhaitable que de telles mesures soient basées sur le taux prévu de repeuplement par rapport aux taux d'exploitation.

Un modèle de simulation basé sur une fonction de recrutement probabiliste a été mis au point afin de fournir des projections à long terme sur la magnitude et le taux de repeuplement des stocks de poissons importants. Bien que le recrutement annuel soit le principal facteur affectant le repeuplement, l'âge au premier recrutement est aussi une considération importante.

Les rendements simulés correspondent dans l'ensemble aux observations antérieures. Les simulations peuvent s'avérer utiles si l'on compare la performance observée de la réglementation aux résultats prévus des simulations.

Resumen

Los beneficios de las medidas de conservación se basan generalmente en la reconstrucción de las reservas agotadas y el mejoramiento en los rendimientos. Es deseable que tales medidas estén basadas en la tasa esperada de recuperación relativa a las tasas de pesca.

Se desarrolló un modelo de simulación basado en una función probabilística de restablecimiento para proporcionar proyecciones a largo plazo de la magnitud y tasa de recuperación de importantes reservas de peces. Mientras que el restablecimiento anual es el principal de los factores que afectan la recuperación, la edad de primer restablecimiento es también una consideración importante.

Los rendimientos simulados guardan correspondencia, en el promedio, con las observaciones pasadas. Las simulaciones pueden resultar útiles para comparar el desempeño observado de los reglamentos con los resultados esperados de las simulaciones.

Резюме

Польза мер по сохранению заключается в основном в восстановлении истощенных запасов и увеличении вылова. Желательно, чтобы эти меры основывались на ожидаемых величинах темпов восстановления по отношению к интенсивности промысла.

С целью получения долгосрочных прогнозов относительно уровня и темпа восстановления важных рыбных запасов была разработана имитационная модель, основанная на вероятностной функции пополнения. В то время, как ежегодное пополнение является основным фактором, влияющим на процесс восстановления, также очень важно учитывать и возраст при первом вхождении в облавливаемый запас.

Полученные с помощью имитационной модели величины уловов в среднем соответствуют сделанным ранее наблюдениям. Эти имитационные модели могут оказаться полезными при сравнении наблюдаемых результатов применения мер с ожидаемыми результатами, полученными с помощью имитационных моделей.

SIMULATION OF RECOVERY RATES OF FISH STOCKS IN THE SOUTH GEORGIA AND KERGUELEN ISLANDS AREAS

I. INTRODUCTION

The Fish Stock Assessment Working Group concluded from analysis completed at its 1986 meeting that the stocks at South Georgia Island (Subarea 48.3) and Kerguelen Island (Subarea 58.5) have been depleted by heavy fishing (Report of the Fifth Meeting of the Scientific Committee, 1986). N. rossii was deemed severely depleted, and the Commission agreed that only small, unavoidable by-catches should be taken. The group also estimated that the stock could be expected to increase at an approximate rate of 30% per year with no fishing on it. C. gunnari and N. gibberifrons around South Georgia Island were also deemed to have been reduced to low enough stock sizes to cause concern.

The Scientific Committee recommended that the Commission take steps to ensure recovery of the fish stocks. Several options for action with respect to C. gunnari and N. gibberifrons were put forward which included a range from no fishing to limiting catch to the 85-86 season level. None of the options proved acceptable.

This paper presents projections of the stocks and catch over the next 20 years for the major species of concern at different fishing mortalities. These projections provide estimates of the expected annual rate of change of the stock sizes and yield.

Recruitment of new cohorts to the stock is the most important factor determining the rate of recovery of the stocks. The 1986 Fish Stock Working Group analysis provided some estimates of the sizes of past recruiting year classes. The time series for estimates is rather short, and the data upon which they were based rather poor. The effect of factors such as stock size and environment on the size of recruiting year classes is not known.

The simulations provide a measure against which the actual results of any recovery program can be compared.

II. METHODS

Because of the state of available data, we have taken a data-based modeling approach. Annual recruitment is estimated from a probablistic model. This is used in a simulation model which is otherwise deterministic. The projections, in effect, represent samples from some rather large universe of possibilities from which expected rates of recovery and measures of variability are obtained.

In the model for projecting future fish stock size, natural mortality and growth parameters may be assumed to not change much over time, at least relative to the effects of recruitment. With these fixed parameters, the recruitment and structure, stock size and yield for the next year are calculated using the Murphy catch equation. The size of the recruiting year class affects the future stock size far more than the growth and mortality factors, except for fishing.

1. Recruitment Function

The approach used in this paper is to fit a mixture of lognormal distributions by a modified kernel method to recruitment data and to use this distribution to generate observations for recruitment. The nonparametric method employed is a variation of the kernel technique. The distribution to be estimated is approximated by a mixture of lognormal distributions. There is one lognormal (known as a Kernel) for each available observation. Each kernel is "centred" so that its geometric mean is located at the corresponding observation. The logarithmic standard deviation of the various kernels is known as the bandwidth. The bandwidth was taken to be proportional to the geometric mean; i.e., the coefficient of variation was constant.

The central theme in application of kernel methodology is determination of suitable bandwidth. Overly small bandwidths yield estimated pdf's whose graphs have a rough, jagged appearance. Excessively large bandwidths smooth the probability mass over a wide interval, losing most of the local features of the data. There is extensive literature on kernel methods (Wertz and Schneider, 1979) and we will not here dwell upon the technical aspects except to point out that bandwidth determination was done through cross-validation.

A universal recruitment model was fitted to pooled data consisting of recruitment series for 18 fish stocks from various parts of the world (Hennemuth et al., 1982). The pooled data were scaled to normalize magnitudes which varied among species, and combined into a single large data set consisting of 325 observations. The histogram of the combined data set is shown in Figure 1. Superimposed is the fitted kernel estimate. The kernel fit, while generally acceptable, does exhibit a leftward bias for small year classes. We have been able to remove most of this bias by using variable bandwidths. As noted, recruitment data for the South Georgia and Kerguelen Islands area stocks are limited and could not be used for direct fitting.

In order to use this method of generating recruitment for the present study, the recruitment curve was adjusted to the arithmetic mean of the size of recruiting year classes of the South Georgia stocks. Figure 2 displays some of the frequency distributions of the size of annual recruitment generated for the various simulation runs.

2. Age of First Recruitment

The age of first recruitment to the fishery stock was determined by analyzing the instantaneous fishing mortality rates from the VPA for each year. The mortality rates of each age within a year were scaled from the age of maximum mortality rate within that year to the lowest age of fish caught. The estimated fishing mortality at age was rather variable from year to year. The age of first recruitment was chosen based on the most consistent significant catches of the younger age groups. The age of first recruitment generally corresponds to 10% of full F. Table 1 displays the initial age and average size in numbers of recruitment for each species. The arithmetic mean of the size of the recruit was used to adjust the scale of the generalized recruitment function. The arithmetic mean of all years was used as the average of the size of the recruiting age groups. The age of first recruitment derived from the VPA data was also used for the survey analysis of one year's data.

3. Simulation Model

The simulation model calculates, using the Murphy catch equation, a time-series of catch and remaining stock sizes given various levels of fishing and natural mortality, initial stock size, and recruitment. Recruitment was generated by the kernel method described in the preceding paragraphs. The starting parameters used in this analysis are displayed in the data section.

The output of the model includes stock size (numbers) and biomass, catch numbers, and weight; averages and standard errors are also produced for each of the 20-year runs. For each set of parameters, ten simulation runs were made. The average of the ten runs for each year was also calculated to show major trends. This average is not, however, a valid measure of the expected yearly simulated values.

III. DATA

1. South Georgia

The VPA's used by the CCAMLR Fish Working Group (see Working Group Report, SC-CAMLR-V/4), which included fisheries for N. rossii, N. gibberifrons, and C. gunnari in South Georgia Island waters, were used as one data base for age composition, recruitment, fishing and natural mortality rates, initial stock size, and biomass. A second estimate of initial stock size, biomass, and age composition was based on 1987 US/Polish research vessel survey data, where biomass estimates were based on swept-area calculations (Gabriel, 1987, SC-CAMLR-VI/BG/12, Rev.1).

Estimates of initial stock composition (numbers at age) were calculated by averaging years 1983 and 1984 for all three species in the VPA's. SURVAN, a groundfish survey analysis program, processed the 1987 research vessel survey data into biomass estimates and population estimates by length. K.-H. Kock's age/length table for N. rossii from South Georgia in January/February, 1985 (SC-CAMLR-IV/BG/12) was applied to convert the research vessel survey length data to population estimates by age. Split-year Polish age/length tables from fishery catch samples were available for N. gibberifrons : 76/77, 77/78, 78/79, 80/81, 81/82; and C. gunnari : 76/77, 77/78, 78/79, 80/81, 81/82 and 83/84. The annual age/length keys for each of the two species were combined and normal curves of ages were fit within each length interval to obtain estimates of population numbers at age. A von Bertalanffy age/length equation was used when the age/length keys did not cover the range of lengths. The parameter estimates for von Bertalanffy's equation came from the BIOMASS Scientific Series No. 6, 1985, by K.-H. Kock, G. Duhamel, and J.-C. Hureau.

The terminal-year fishing mortality coefficients in the VPA's were used for the fully recruited age groups. A vector of partial fishing mortality rates was developed from a multiplicative analysis of variance model ($\ln F = \ln age + \ln year$) incorporating year and age effects which was fit to a matrix of log F's from the 1980-1984 VPA's. The retransformed vectors of age-specific coefficients were used as the partial recruitment vector. The coefficient of determination (R^2) for the models for N. rossii, N. gibberifrons, and C. gunnari was 0.897 and 0.599, and 0.740, respectively.

Table 2 displays the final format of the data.

2. Kerguelen

The VPA's estimated by Duhamel (1987, PhD. unpublished), for N. rossii and N. squamifrons fisheries on the Kerguelen Island shelf, were used to obtain the parameters for simulation (Table 3).

Estimates of initial stock composition (numbers at age) were calculated averaging years 1982 and 1983 for N. rossii, and 1985 and 1986 for N. squamifrons in the VPA's. The coefficient for determination (R^2) for the models for N. rossii and N. squamifrons was 0.878 and 0.496, respectively.

IV. RESULTS

Graphs of the ten stock size projections and the mean for the various species and fishing mortalities are presented in Figures 3 to 18 for South Georgia stocks and 19 to 22 for Kerguelen stocks. The averages of the ten 20-year projections for the stock size and catch in numbers and weight are given in Table 4 (South Georgia) and Table 5 (Kerguelen). It may be useful to reiterate here that the higher F is the terminal F value used in last year's VPA's, and the lower is half that excepting N. rossii at South Georgia where the highest F of 0.5 is taken from Saila et al. (MS) (see SC-CAMLR-VI/3) analysis. The SURVAN projections are in units relating to the Polish research vessel catchability factor which is obviously less than that of the commercial vessels. One can compare only the relative rates of change.

1. Stock Recovery Rates

1.1 N. rossii

1.1.1 South Georgia

For the VPA-based projections at F = 0.089, the stock size increases steadily to its peak at about 2.5 times the starting value in seven years; it doubles in five years. For F = 0.177, the stock size increases to its peak again at about 2.5 times the starting point in about 12 years; doubling in about seven years. For F = 0.55, the stock does not exhibit any trend of recovery.

With the survey data, the stock declines by a third or more for all F values in from six to eight years, after which it stabilizes at the lower size.

1.1.2 Kerguelen

The VPA-based projections indicate that at F = 0.38 the stock increases by a factor of 2 in about five years; however, the recovery is only 1.7 times the initial size with F = 0.76.

1.2 N. gibberifrons (South Georgia)

The VPA-based projections indicate that at F = 0.071 the stock increases to about 2.8 times the initial size in ten years; it doubles in about five years. At F = 0.142, the stock peaks at about 2.5 times the initial size in 15 years and doubles in 11 years. For the survey data base, the stock increases slowly by about 50% over the 20 years at F = 0.071. For F = 0.142, the stock does not change significantly.

1.3 C. gunnari (South Georgia)

The projections for this stock do not indicate any recovery at any of the fishing mortality coefficients for either of the data sets. The mortalities are higher than those applied to other species, as is the magnitude of stock size (note the different ordinal scale on the plots).

1.4 N. squamifrons (Kerguelen)

At F = 0.36, the stock almost doubles in five years and increases slowly but continuously over the 20 years. For the VPA-based projection at F = 0.72, the stock size increases to about 2.3 times the initial value in five years.

2. Biomass and Yield Changes

The projections of stock biomass and yield for the same data sets used to describe stock size trends are portrayed in Figures 23-29 (South Georgia) and 30-31 (Kerguelen); the data are contained in Tables 4 and 5.

2.1 South Georgia

2.1.1 N. rossii

The trends in stock biomass are, of course, similar to those of stock numbers, but the biomass doubles in less time than it takes for the numbers of fish to do so. This results from the increasing numbers of older fish compared to the initial age composition. For the VPA data set at F = 0.55, the catch peaks in about five to nine years at a level double the initial yields; thereafter it declines slowly. At F = 0.177, the yield rises slowly, peaking in 15 years at about 5 times the initial yield. At F = 0.089, the yield peaks at ten years at 6 times the initial yield.

The survey data set indicates continuously declining yields at F = 0.55, while at the lower fishing mortalities the yield increases slightly at first, but does not change significantly over the projection period.

2.1.2 N. gibberifrons

As with N. rossii, the trends in stock biomass have a pattern similar to that of stock numbers but with the biomass doubling in less time.

The yields increase steadily to about 4 times the initial yield at the end of the 20-year simulation, doubling in four years for both mortalities.

For the SURVAN data set, the yields do not change.

2.1.3 C. gunnari

Projections from the VPA data set indicate immediate drop in yields at both fishing mortality levels, followed by increases in the 4-10-year period and further decreases thereafter. Projections from the survey data base illustrate highly variable changes in yield, but no long-term trend at F = 3.5; a short-term increase by 2X in six years, decreasing thereafter at F = 1.75; a doubling in yield in 11 years at F = 0.875.

2.2 Kerguelen

2.2.1 N. rossii

The trends in stock biomass show a similar pattern to the stock numbers. For the VPA data set at F = 0.76, the yield peaks in six years at double the initial level; thereafter, it declines slowly. At F = 0.38, the catch peaks in ten years at about 4.2 times the initial yield and is followed by a small decline.

2.2.2 N. squamifrons

The trends in stock biomass again show a similar pattern to the stock numbers. The yields increase by a factor of 4 for F = 0.72 and by 6 for F = 0.36 at the end of the 20 years simulated.

3. Summary of Trends

3.1 South Georgia

The entries in Table 6 summarize the points of reference for the various projections. In general, for N. rossii and N. gibberifrons, the stock size recoveries were larger for the lower F's used, and indicated recovery to over double the initial size in from 8 to 15 years. Recovery of stock biomass was relatively larger and faster. The survey-data-based projections indicated recovery only for C. gunnari at lower F's. N. gibberifrons indicated no significant changes, while N. rossii yields and population decreased at high F and did not recover at lower F's. The differences are likely due to the fact that only the one year's point was available for determinig recruitment year-class size in the survey catchability units. The accuracy is unknown. This applies as well to the numbers at age for the initial population, but this is of less concern since the simulation will tend to equilibrate after a few years.

The situation for C. gunnari is obviously different. The stock does not recover but rather declines, except for the lowest mortality in the SURVAN data set. The relatively high fishing mortality is likely responsible. Another factor is that the full mortality is applied from the age of recruitment, which corresponds to the pattern observed in the data. Perhaps a marginally significant increase in yield would occur at F = 0.875.

3.2 Kerguelen

The entries in Table 7 summarize the points of reference for various projections. In the Kerguelen area, the stock size recoveries are larger for the lower F's. At F = 0.38, the stock size for N. rossii doubles in five years. Note that for N. squamifrons, the higher F doubles in four years and the lower F in ten years. However, the stock population over 20 years remains relatively low and constant. If the maximum increase factor for the high F is compared with the low F, there is a relatively smaller change in stock size, but a significantly larger change in the yield. The larger change in yield would be due to the shift in the age composition.

V. DISCUSSIONS AND CONCLUSIONS

The results have defined, under the constraints of the fishing mortality rates applied, the probable recovery rates of the stocks. It has been demonstrated for the simulations based on the VPA data set for N. rossii, N. gibberifrons, and N. squamifrons, that recovery within a reasonable time period might indeed be expected. For C. gunnari, this is not the case. With the initial stock size and age composition taken from the 1987 US/Polish research cruise data, the stock simulations indicated less and slower recovery; some declined.

The major factors affecting the results are the recruitment and fishing--both the level of F and the age at which it is applied.

1. Recruitment

The probability density function used, and the random year-by-year selection from it, assume that the past average recruitment will continue, and that the frequency distribution of various sizes of the recruiting year class follow the "universal" set of data. In the simulation, stock size is not a directly dependent variable, but the historical set of observations from which the pdf is derived would implicitly account for the influence of the various factors. Use of the usual stock and recruitment relations, however, would not much affect the results of the relative recovery rate.

2. Fishing Mortality

The F applied to the terminal year of the VPA's (1985) was derived from the Federal Republic of Germany's 1985 survey results for the South Georgia stocks. The VPA indicated considerably higher F's in previous years. Higher fishing mortality rates would certainly reduce the amount and rate of recovery illustrated in the analysis. This is demonstrated for N. rossii if the higher 1986 mortality rate in Saila et al. is applied. Another aspect of fishing mortality is the distribution over the young ages. This is demonstrated in the simulations for C. gunnari, where the full F was applied to the recruiting year class. The stock declined and both the stock size (and biomass) and yield illustrated large changes from year to year; they were highly dependent on the size of the annually recruiting year class. Past data indicate that for some years the other stocks also had high mortalities on younger age classes.

The lack of data about the Kerguelen stocks before the establishment of an Exclusive Economic Zone (1978) must be pointed out, but from the beginning of exploitation (1970) to this date, high levels of catch were reported and, hence, probably also mortality. The current fishing rates have been reduced following the conservation measures (lower F level or F = 0) and now the rate of recovery must be close to the simulation model results.

3. Yields

The magnitude and pattern could change markedly from those simulated, depending on the pattern of fishing. It may be noted that the fluctuating yields of C. gunnari simulated here tend to be similar to past observations.

The application of a constant F and partial recruitment over the years in the simulations is not what has been observed in the past fisheries. Also observed is that fishing mortality is increased on large recruiting year classes. The yield and population is most likely higher in the simulations than in practice, because a constant F is the more optimal method for longer-term yields.

The magnitudes of average annual yields from the simulations (VPA-based) compared to the reported catches are given in Table 8.

The close correspondence of average simulated yield to average observed catch cannot be used simplistically to validate the simulations, nor to judge the correct magnitude of F. Because the simulations were based on the VPA's which are calculated from fishery data, the average reported catches are not independent of the simulated yields. However, it does provide an indication that if the input parameters are suitably scaled to the commercial fishing practices, the recruitment model and the simulations provide results which can be used to judge probable future realizations.

The simulated yields point out the important result that the yield per unit F is higher, particularly for C. gunnari, for the lower fishing rates.

LITERATURE CITED

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Table 1. Initial age and numbers in millions of individual recruits

	South Georgia Average Recruitment			Kerguelen Average Recruitment	
	Age	VPA	Survey	Age	VPA
N. rossii	4	4.152	0.151	5	1.725
N. squamifrons				7	1.189
N. gibberifrons	8	15.132	3.322		
C. gunnari	3	228.540	260.218		

Table 2. Parameters used for simulation model (South Georgia)

Age	Initial Stock Size (millions) VPA	SURVAN	F Vector	Biomass (kg)
		N. rossii		
4	-	-	0.3036	0.735
5	3.235	1.033	0.5228	1.526
6	2.299	0.903	0.6501	2.382
7	1.071	0.535	0.9664	3.090
8	0.285	0.255	1.0000	3.808
9	0.091	0.127	1.0000	4.430
10	0.071	0.051	1.0000	5.013
11	0.023	0.022	1.0000	5.586
12+	0.006	0.029	1.0000	6.077
		N. gibberifrons		
8	-	-	0.4496	0.331
9	9.220	3.603	0.5807	0.433
10	4.102	3.598	0.6695	0.522
11	2.391	2.939	0.8597	0.578
12	1.651	2.070	1.0000	0.659
13	1.006	1.361	1.0000	0.708
14	0.877	0.769	1.0000	0.784
15	0.304	0.409	1.0000	0.877
16	0.000	0.214	1.0000	0.923
17	0.000	0.093	1.0000	0.999
18	0.000	0.037	1.0000	1.079
19+	0.012	0.022	1.0000	1.124
		C. gunnari		
3	-	-	1.0000	0.132
4	60.985	20.844	1.0000	0.256
5	35.113	7.196	1.0000	0.359
6	8.853	2.432	1.0000	0.435
7	2.918	1.152	1.0000	0.480
8	0.836	0.745	1.0000	0.534
9	0.418	0.282	1.0000	0.582
10+	0.626	0.191	1.0000	0.665

Table 3. Parameters used for simulation model (Kerguelen)

Age	Initial Stock Size (millions)	F Vector	Biomass (kg)
	N. rossii (Kerguelen)		
5	-	0.1978	0.988
6	0.959	0.3662	1.490
7	0.483	1.0000	2.058
8	0.172	1.0000	2.672
9	0.121	1.0000	3.319
10	0.103	1.0000	3.975
11	0.051	1.0000	4.632
12	0.038	1.0000	5.271
13+	0.028	1.0000	5.897
	N. squamifrons (Kerguelen)		
7	-	0.0979	0.245
8	0.640	0.2278	0.349
9	0.420	0.3061	0.457
10	0.241	0.3210	0.549
11	0.118	0.4674	0.707
12	0.043	0.6418	0.846
13	0.012	1.0000	0.991
14+	0.001	1.0000	1.142

Table 4. Average of the Ten 20-Year Projections for Stock Size in Numbers (X 10^{-6}) and Weight (X 10^{-3})

Year	Stock Weight	Catçh Weight	Stock (No's)	Catch (No's)
		N. rossii VPA F = 0.177		
1985	18.935	2.006	11.441	0.990
1986	26.454	3.122	13.346	1.319
1987	34.053	4.293	15.532	1.624
1988	42.097	5.497	18.590	1.968
1989	48.721	6.558	18.741	2.146
1990	55.269	7.513	21.162	2.367
1991	59.713	8.295	21.869	2.542
1992	64.645	8.699	25.625	2.746
1993	67.412	9.223	24.601	2.859
1994	69.213	9.468	25.111	2.893
1995	71.749	10.103	25.581	3.040
1996	73.570	10.228	26.417	3.055
1997	76.771	10.381	30.624	3.288
1998	81.222	11.151	28.672	3.380
1999	80.340	11.248	26.452	3.259
2000	80.181	11.625	26.671	3.312
2001	74.125	10.669	24.071	3.004
2002	75.144	10.603	25.678	2.991
2003	73.373	10.395	24.555	2.949
2004	74.520	10.228	27.455	3.027
AVE	63.380	8.570	23.110	2.640
		N. rossii VPA F = 0.089		
1985	18.930	1.041	11.433	0.511
1986	28.540	1.737	14.891	0.742
1987	38.203	2.544	16.552	0.937
1988	49.001	3.414	20.325	1.163
1989	60.182	4.326	23.028	1.375
1990	70.416	5.126	24.443	1.514
1991	79.099	5.838	27.372	1.685
1992	84.242	6.279	27.913	1.772
1993	86.570	6.485	27.245	1.775
1994	86.589	6.560	27.554	1.793
1995	85.008	6.511	25.561	1.733
1996	86.274	6.626	25.336	1.702
1997	80.869	6.256	23.762	1.612
1998	79.120	5.964	25.561	1.589
1999	79.855	5.959	25.842	1.617
2000	75.118	5.556	23.865	1.530
2001	73.395	5.579	22.618	1.519
2002	74.454	5.666	24.119	1.548
2003	71.571	5.411	22.508	1.477
2004	75.960	5.636	25.292	1.546
AVE	69.170	5.130	23.260	1.460

Table 4 (continued) N. rossii SURVAN F = 0.177

Year	Stock Weight	Catch Weight	Stock	Catch
1987	7.56	.96	3.08	.35
1988	8.28	1.16	2.80	.36
1989	8.50	1.29	2.54	.36
1990	8.22	1.26	2.18	.31
1991	7.59	1.16	1.91	.27
1992	6.65	1.02	1.59	.22
1993	5.34	.81	1.29	.18
1994	3.75	.55	1.05	.13
1995	2.34	.33	.80	.09
1996	2.35	.33	.79	.09
1997	2.28	.32	.80	.09
1998	2.22	.31	.81	.09
1999	2.32	.32	.87	.10
2000	2.34	.32	.85	.10
2001	2.41	.34	.82	.10
2002	2.42	.34	.82	.10
2003	2.37	.33	.84	.10
2004	2.42	.34	.86	.10
2005	2.50	.34	.92	.10
2006	2.49	.35	.85	.10
AVE	4.22	.61	1.33	.17

N. rossii SURVAN F = 0.089

Year	Stock Weight	Catch Weight	Stock	Catch
1987	7.58	.50	3.10	.18
1988	8.79	.65	2.87	.20
1989	9.55	.77	2.68	.21
1990	9.88	.80	2.50	.19
1991	9.73	.79	2.34	.17
1992	9.08	.73	2.10	.15
1993	7.65	.61	1.80	.13
1994	5.32	.42	1.35	.09
1995	2.95	.22	.93	.06
1996	2.94	.22	.93	.06
1997	3.05	.23	.94	.06
1998	3.06	.23	.93	.06
1999	2.99	.23	.92	.06
2000	2.94	.22	1.02	.06
2001	2.99	.22	1.02	.06
2002	2.98	.22	1.01	.06
2003	3.11	.23	1.02	.07
2004	3.16	.24	.98	.07
2005	3.14	.24	.94	.06
2006	3.13	.24	.97	.06
AVE	5.20	.40	1.52	.10

Table 4 (continued)

Year	Stock Weight	Catch Weight	Stock (No's)	Catch (No's)
		N. rossii VPA F = 0.55		
1985	18.858	5.472	11.336	2.745
1986	26.184	7.401	17.758	3.963
1987	30.838	9.321	16.803	4.381
1988	33.217	10.475	16.459	4.422
1989	33.894	11.416	16.400	4.576
1990	33.904	11.168	16.684	4.475
1991	34.029	11.119	16.688	4.474
1992	35.353	11.336	18.325	4.731
1993	34.201	11.418	15.242	4.410
1994	32.387	10.945	14.535	4.097
1995	29.177	10.187	12.725	3.744
1996	28.656	9.391	14.484	3.730
1997	28.126	9.254	13.461	3.686
1998	27.530	8.987	12.991	3.529
1999	26.704	8.979	12.595	3.502
2000	26.331	8.645	13.033	3.466
2001	26.038	8.494	12.816	3.445
2002	26.918	8.662	13.729	3.582
2003	29.244	9.176	16.152	4.035
2004	32.566	10.043	17.973	4.506
AVE	29.710	9.600	15.010	3.980
		N. rossii SURVAN F = 0.55		
1987	7.56	2.57	3.08	.96
1988	6.25	2.31	2.13	.74
1989	4.77	1.88	1.51	.55
1990	3.39	1.33	1.01	.36
1991	2.38	.91	.72	.24
1992	1.75	.65	.62	.19
1993	1.36	.47	.56	.16
1994	1.10	.37	.48	.13
1995	.96	.31	.47	.13
1996	.96	.32	.47	.13
1997	.94	.31	.44	.12
1998	.89	.30	.40	.11
1999	.82	.28	.35	.10
2000	.78	.26	.38	.10
2001	.78	.25	.40	.10
2002	.79	.25	.39	.10
2003	.82	.26	.42	.11
2004	.84	.27	.42	.11
2005	.85	.27	.42	.11
2006	.89	.29	.47	.12
AVE	1.94	.69	.76	.23

Table 4 (continued)

Year	Stock Weight	Catch Weight	Stock (No's)	Catch (No's)
		N. gibberifrons VPA F = 0.142		
1985	17.174	1.418	40.381	3.078
1986	21.613	1.908	46.180	3.831
1987	25.930	2.421	52.258	4.580
1988	30.901	3.037	60.974	5.564
1989	33.582	3.493	61.779	6.002
1990	35.877	3.804	63.821	6.302
1991	38.629	4.141	67.991	6.728
1992	42.955	4.544	76.376	7.364
1993	46.307	4.872	81.429	7.834
1994	48.705	5.181	83.243	8.149
1995	49.209	5.378	80.894	8.214
1996	50.043	5.500	82.831	8.398
1997	49.611	5.427	83.242	8.381
1998	50.822	5.519	85.244	8.497
1999	54.902	5.790	96.273	9.195
2000	55.450	5.909	94.855	9.301
2001	56.689	6.100	95.166	9.459
2002	55.146	6.136	88.785	9.251
2003	53.200	6.044	83.521	8.893
2004	51.814	5.839	83.075	8.663
AVE	43.430	4.620	75.420	7.380
		N. gibberifrons VPA F = 0.071		
1985	15.462	0.674	35.211	1.416
1986	20.984	0.958	44.784	1.905
1987	27.036	1.297	55.052	2.457
1988	33.705	1.699	66.247	3.092
1989	40.309	2.111	75.969	3.679
1990	43.829	2.417	76.385	3.951
1991	47.727	2.708	80.267	4.253
1992	51.993	2.999	85.626	4.579
1993	54.968	3.205	87.174	4.723
1994	59.540	3.429	94.869	5.012
1995	63.316	3.649	99.761	5.274
1996	64.760	3.743	100.560	5.360
1997	64.440	3.735	100.259	5.376
1998	64.600	3.785	99.347	5.405
1999	64.770	3.789	100.325	5.429
2000	63.308	3.718	97.342	5.317
2001	62.102	3.655	95.011	5.203
2002	63.148	3.732	95.686	5.251
2003	63.700	3.748	97.148	5.277
2004	64.991	3.762	101.551	5.380
AVE	51.730	2.940	84.430	4.420

Table 4 (continued)

Year	Stock Weight	Catch Weight	Stock	Catch
		N. gibberifrons SURVAN F = 0.142		
1987	9.83	1.01	18.30	1.75
1988	10.65	1.13	19.13	1.88
1989	11.36	1.23	19.84	1.98
1990	11.63	1.28	19.40	1.99
1991	11.58	1.30	18.51	1.94
1992	11.86	1.32	19.13	1.97
1993	11.96	1.33	19.28	1.97
1994	11.86	1.31	19.03	1.93
1995	11.58	1.28	18.51	1.89
1996	11.26	1.25	18.10	1.85
1997	10.62	1.19	16.82	1.75
1998	10.46	1.16	16.97	1.73
1999	10.38	1.15	16.89	1.72
2000	10.54	1.14	17.63	1.74
2001	10.54	1.14	17.69	1.75
2002	10.87	1.17	18.36	1.81
2003	11.33	1.21	19.32	1.89
2004	11.99	1.26	21.11	2.02
2005	12.17	1.29	20.98	2.05
2006	12.40	1.33	21.11	2.09
AVE	11.24	1.22	18.80	1.89
		N. gibberifrons SURVAN F = 0.071		
1987	9.99	.52	18.77	.91
1988	11.73	.63	21.49	1.07
1989	12.52	.71	21.07	1.12
1990	12.98	.76	20.38	1.14
1991	13.36	.81	20.21	1.15
1992	14.24	.85	21.83	1.20
1993	15.32	.88	24.17	1.26
1994	15.42	.89	23.45	1.25
1995	15.02	.88	22.14	1.22
1996	14.47	.87	21.38	1.20
1997	13.80	.83	20.44	1.15
1998	13.30	.79	19.80	1.10
1999	13.49	.78	21.04	1.12
2000	13.15	.76	20.76	1.10
2001	14.24	.80	23.27	1.19
2002	15.52	.87	25.68	1.30
2003	15.96	.91	25.41	1.33
2004	16.00	.91	25.71	1.36
2005	15.96	.92	26.11	1.39
2006	16.77	.96	27.31	1.44
AVE	14.16	.82	22.52	1.20

Table 4 (continued)

Year	Stock Weight	Catch Weight	Stock (No's)	Catch (No's)
		C. gunneri VPA F = 3.50		
1985	63.974	60.159	332.466	312.642
1986	23.855	22.433	169.194	159.105
1987	21.781	20.482	160.517	150.946
1988	30.620	28.794	227.841	214.255
1989	33.554	31.553	248.388	233.577
1990	38.627	36.324	286.269	269.199
1991	27.488	25.849	200.916	188.936
1992	40.957	38.515	305.074	286.883
1993	32.151	30.234	235.800	221.739
1994	48.264	45.386	359.549	338.109
1995	29.094	27.359	211.253	198.656
1996	40.695	38.268	302.790	284.735
1997	21.303	20.033	153.665	144.502
1998	30.969	29.123	230.588	216.839
1999	32.756	30.803	242.277	227.830
2000	19.392	18.235	140.696	132.306
2001	32.989	31.022	246.247	231.564
2002	35.396	33.285	261.890	246.274
2003	27.711	26.058	203.218	191.101
2004	39.052	36.723	290.595	273.268
AVE	33.530	31.530	140.460	226.120

C. gunneri VPA F = 1.75

1985	61.785	48.866	315.884	249.832
1986	50.357	39.827	317.556	251.155
1987	38.416	30.384	237.343	187.714
1988	48.015	37.975	322.742	255.256
1989	64.018	50.632	433.245	342.653
1990	52.485	41.511	328.525	259.829
1991	62.267	49.247	415.551	328.659
1992	64.380	50.918	420.677	332.712
1993	49.896	39.463	308.802	244.231
1994	56.795	44.919	376.959	298.136
1995	31.391	24.827	176.700	139.752
1996	31.758	25.117	207.375	164.012
1997	31.839	25.181	207.129	163.819
1998	46.686	36.924	319.490	252.684
1999	57.766	45.687	387.180	306.220
2000	43.099	34.087	264.218	208.969
2001	56.082	44.355	378.849	299.631
2002	43.013	34.019	265.390	209.897
2003	33.798	26.731	210.090	166.160
2004	36.546	28.904	240.772	190.426
AVE	48.020	37.980	306.720	242.590

Table 4 (continued)

Year	Stock Weight	Catch Weight	Stock	Catch
		C. gunnari SURVAN F = 3.5		
1987	52.92	49.77	356.34	335.09
1988	58.26	54.78	431.47	405.74
1989	42.99	40.43	314.66	295.89
1990	43.46	40.87	321.09	301.95
1991	30.01	28.22	219.07	206.01
1992	25.15	23.65	184.84	173.82
1993	44.15	41.52	329.70	310.04
1994	28.98	27.25	211.13	198.54
1995	28.87	27.15	213.26	200.54
1996	34.95	32.87	259.32	243.86
1997	40.45	38.04	299.80	281.92
1998	30.12	28.33	220.53	207.38
1999	75.40	70.90	565.47	531.75
2000	43.62	41.02	316.12	297.27
2001	32.15	30.24	235.34	221.31
2002	36.31	34.15	269.01	252.97
2003	53.07	49.90	395.15	371.59
2004	61.10	57.45	452.79	425.79
2005	43.05	40.49	314.58	295.82
2006	36.52	34.34	268.51	252.50
AVE	42.08	39.57	308.91	290.49
		C. gunnari SURVAN F = 1.75		
1987	40.21	31.80	260.06	205.68
1988	38.56	30.50	249.15	197.06
1989	48.10	38.04	323.05	255.50
1990	70.33	55.62	480.95	380.38
1991	60.19	47.61	380.01	300.55
1992	73.30	57.97	490.79	388.16
1993	62.72	49.61	396.21	313.36
1994	49.47	39.13	307.61	243.29
1995	46.64	36.88	300.46	237.63
1996	40.39	31.95	256.02	202.48
1997	49.24	38.95	329.81	260.84
1998	52.90	41.84	347.70	275.00
1999	48.33	38.22	309.20	244.55
2000	46.38	36.68	299.57	236.93
2001	31.03	24.54	185.28	146.54
2002	35.57	28.13	236.47	187.02
2003	42.34	33.48	282.45	223.39
2004	61.37	48.54	419.31	331.63
2005	55.90	44.21	357.19	282.50
2006	39.36	31.13	238.20	188.39
AVE	49.62	39.24	322.47	255.04

Table 4 (continued)

Year	Stock Weight	Catch Weight	Stock	Catch
		C. gunnari VPA F = 0.875		
1985	69.54	38.50	374.60	207.41
1986	66.57	36.86	330.57	183.03
1987	63.27	35.03	313.54	173.60
1988	64.18	35.53	328.69	181.99
1989	65.86	36.47	338.89	187.64
1990	59.99	33.21	289.82	160.47
1991	58.01	32.12	290.63	160.92
1992	62.67	34.70	330.40	182.94
1993	57.55	31.86	279.20	154.59
1994	66.59	36.87	361.41	200.10
1995	82.80	45.85	460.15	254.78
1996	78.04	43.21	382.38	211.72
1997	74.27	41.12	368.17	203.85
1998	73.35	40.61	371.08	205.46
1999	76.83	42.54	399.35	221.11
2000	76.81	42.53	389.75	215.80
2001	70.35	38.95	341.13	188.88
2002	72.60	40.20	375.39	207.85
2003	71.67	39.68	361.92	200.39
2004	87.57	48.49	484.68	268.36
AVE	69.93	38.72	358.59	198.54
		C. gunnari SURVAN F = 0.875		
1987	50.61	28.02	338.82	187.60
1988	79.98	44.28	475.56	263.31
1989	80.07	44.33	402.47	222.84
1990	86.85	48.09	457.53	253.33
1991	94.42	52.28	497.99	275.73
1992	92.41	51.16	463.36	256.55
1993	85.26	47.21	415.22	229.90
1994	79.82	44.19	392.73	217.45
1995	79.79	44.18	406.31	224.97
1996	79.44	43.98	403.01	223.14
1997	70.61	39.09	336.67	186.41
1998	112.48	62.28	677.18	374.94
1999	108.83	60.26	538.82	298.34
2000	88.71	49.12	400.09	221.52
2001	76.00	42.08	357.03	197.68
2002	76.84	42.55	395.07	218.75
2003	73.63	40.77	366.12	202.71
2004	61.03	33.79	278.89	154.42
2005	64.60	35.77	338.64	187.50
2006	64.99	35.98	331.56	183.58
AVE	80.32	44.47	413.65	229.03

Table 5. Average of the Ten 20-Year Projections for Stock Size in Numbers (x 10-6) and Weight (x 10-3)

Year	Stock Weight	Catch Weight	Stock	Catch
	N. rossii, Kerguelen F = 0.76			
1984	5.79	2.04	3.47	.96
1985	6.25	2.17	3.86	1.09
1986	7.05	2.48	4.43	1.27
1987	7.96	2.76	5.03	1.42
1988	9.74	3.25	6.40	1.73
1989	10.57	3.72	6.47	1.91
1990	10.54	4.18	5.98	2.03
1991	10.27	3.98	5.92	1.88
1992	9.26	3.64	5.03	1.67
1993	8.89	3.56	4.97	1.64
1994	8.10	3.11	4.48	1.42
1995	8.45	3.15	5.05	1.51
1996	8.30	3.04	4.82	1.46
1997	8.30	3.23	4.77	1.55
1998	8.18	3.08	4.78	1.47
1999	8.71	3.13	5.31	1.54
2000	8.83	3.25	5.19	1.59
2001	9.17	3.47	5.43	1.69
2002	9.44	3.43	5.67	1.68
2003	9.21	3.53	5.23	1.69
AVE	8.65	3.21	5.11	1.56
	N. rossii, Kerguelen F = 0.38			
1984	5.84	1.18	3.52	.54
1985	7.13	1.54	4.08	.71
1986	8.97	2.02	5.15	.93
1987	10.92	2.41	6.15	1.08
1988	12.55	2.94	6.67	1.28
1989	14.22	3.44	7.36	1.45
1990	15.91	3.80	8.14	1.56
1991	16.52	4.15	7.82	1.65
1992	18.65	4.53	9.59	1.83
1993	18.15	4.52	8.24	1.74
1994	17.88	4.97	7.71	1.88
1995	16.72	4.43	7.12	1.57
1996	15.79	4.15	6.73	1.46
1997	15.27	3.97	6.67	1.42
1998	14.70	3.77	6.52	1.37
1999	14.49	3.67	6.70	1.37
2000	14.62	3.66	6.81	1.38
2001	14.57	3.59	7.14	1.42
2002	14.81	3.75	6.87	1.45
2003	15.26	3.89	7.23	1.50
AVE	14.15	3.52	6.81	1.38

Table 5 (continued)

Year	Stock Weight	Catch Weight	Stock	Catch
1987	.84	.15	2.15	.33
1988	1.18	.21	3.05	.44
1989	1.44	.29	3.46	.57
1990	1.77	.36	4.20	.69
1991	2.06	.44	4.80	.81
1992	2.25	.51	4.87	.90
1993	2.31	.55	4.75	.93
1994	2.28	.59	4.43	.93
1995	2.29	.60	4.51	.92
1996	2.35	.60	4.95	.94
1997	2.28	.60	4.59	.95
1998	2.27	.56	4.75	.91
1999	2.28	.55	4.81	.91
2000	2.35	.57	4.88	.95
2001	2.39	.59	4.91	.97
2002	2.35	.61	4.67	.96
2003	2.46	.60	5.23	.97
2004	2.41	.60	4.96	.99
2005	2.49	.62	5.15	1.01
2006	2.48	.61	5.16	1.00
AVE	2.13	.51	4.51	.85
1987	1.03	.09	2.90	.20
1988	1.41	.14	3.50	.29
1989	1.80	.21	4.02	.38
1990	2.15	.27	4.47	.46
1991	2.50	.35	4.91	.55
1992	2.78	.42	5.24	.62
1993	2.90	.48	5.20	.67
1994	2.96	.49	5.28	.67
1995	2.86	.46	5.25	.65
1996	2.90	.47	5.26	.66
1997	3.16	.49	6.29	.70
1998	3.17	.50	5.90	.73
1999	3.15	.50	5.72	.72
2000	3.13	.49	5.62	.70
2001	3.51	.54	6.82	.77
2002	3.58	.57	6.72	.82
2003	3.77	.61	7.23	.87
2004	3.84	.59	7.20	.85
2005	3.68	.55	6.77	.82
2006	3.83	.62	6.74	.87
AVE	2.91	.44	5.55	.65

Table 6. Summary of standard reference points for projections (South Georgia stocks)

Species	Data Set F	Stock Size 1	Stock Size 2	Stock Size 3	Yield 1	Yield 2	Yield 3
N. rossii	VPA 0.55	1.6	7	-	2.1	4	4
	0.177	2.7	12	7	5.8	15	2
	0.089	2.4	7	4	6.4	11	4
	SUR 0.55	**			**		
	0.177	**			*		
	0.089	**			*		
N. gibberifrons	VPA 0.142	2.4	14	8	4.3	16	3
	0.071	2.9	11	4	5.6	11	3
	SUR 0.142	*			*		
	0.071	1.5	20+	-	*		
C. gunnari	VPA 3.5	**			**		
	1.75	*			*		
	0.875	*			*		
	SUR 3.5	*			*		
	1.75	*			2	11	11
	0.875	*			2	11	11

1 Maximum increase factor
2 Time to reach maximum--years
3 Time to reach 2X increase--years
* No increase
** Actual decrease

Table 7. Summary of standard reference points for projections (Kerguelen)

Species	Data Set	F	Stock Size			Yield		
			1	2	3	1	2	3
N. rossii	VPA	0.76	1.7	6	*	2.1	6	*
		0.38	2.7	8	5	4.2	10	3
N. squamifrons	VPA	0.72	2.3	9	4	4.0	8	3
		0.36	2.5	16	10	6.8	16	2

1 Maximum increase factor
2 Time to reach maximum--years
3 Time to reach 2X increase--years
* Nc increase

Table 8. Comparison of simulated and past reported yields.

Stock		F	Average Simulated Yield	Years	Average Reported Catch
N. rossii	S. Georgia	0.550	9.6		
		0.177	8.6	72-85	4.3
		0.089	5.1	76-85	5.7
	Kerguelen	0.770	3.2	80-86	0.9
		0.380	3.5		
N. gibberifrons		0.142	4.6	76-85	4.7
		0.071	2.9		
N. squamifrons		0.720	0.5	79-86	5.3
		0.380	0.4		
C. gunnari		3.500	31.5	72-85	30.2
		1.750	38.0	76-85	41.9
		0.875	38.7		

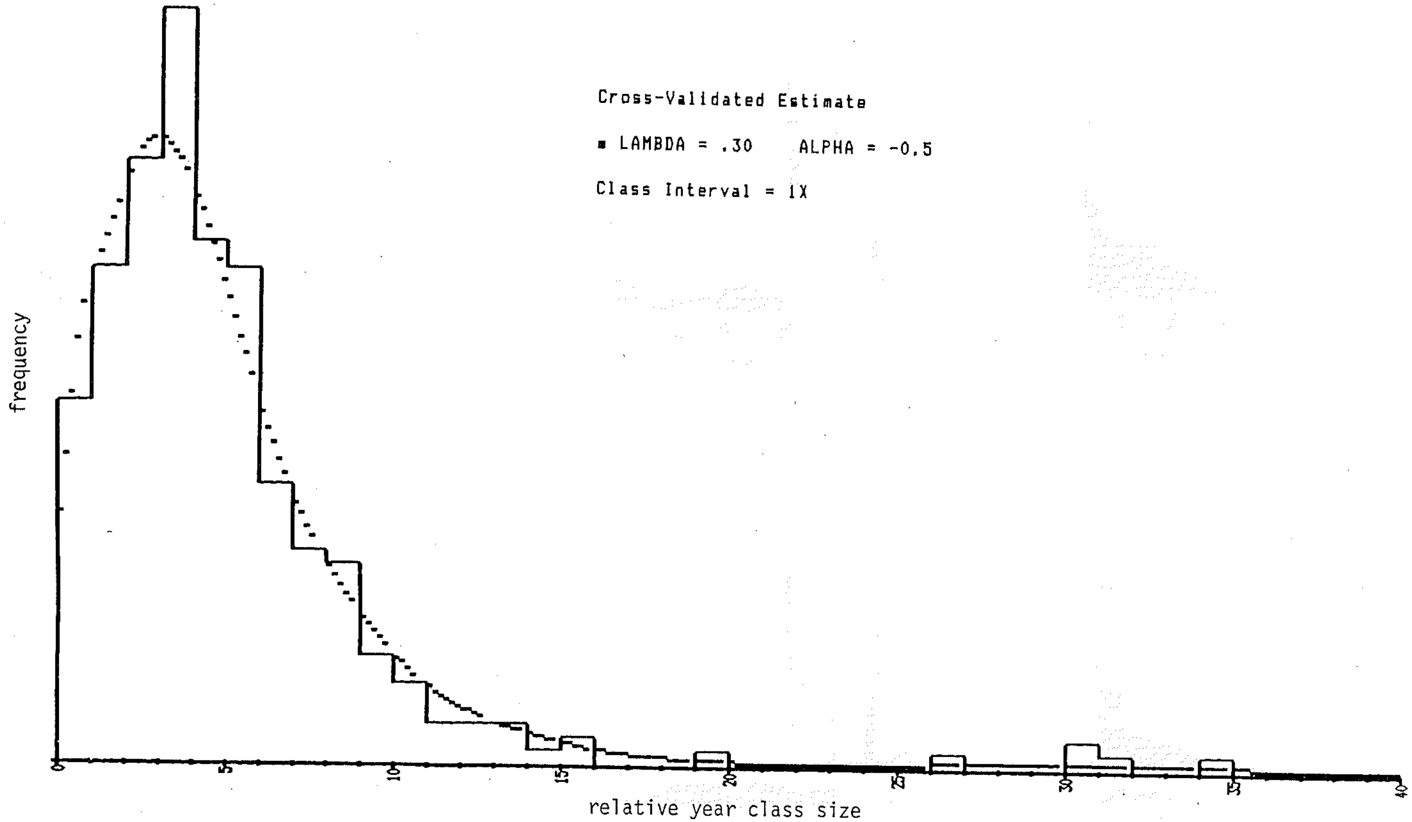

Figure 1. Universal recruitment probability density function used in simulation

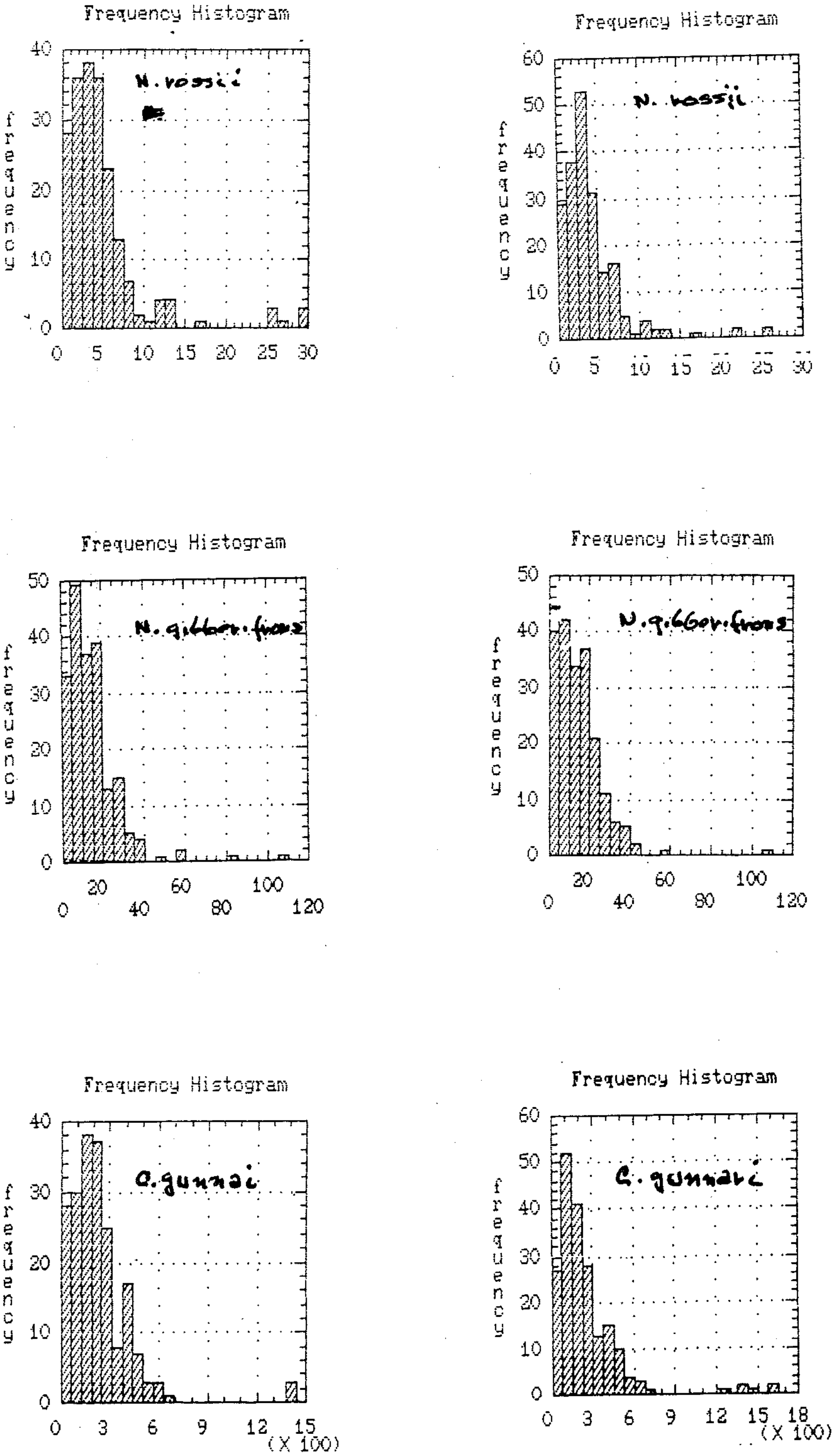

Figure 2. Randomly generated recruitment frequencies (no's fish x 10^{-6}).

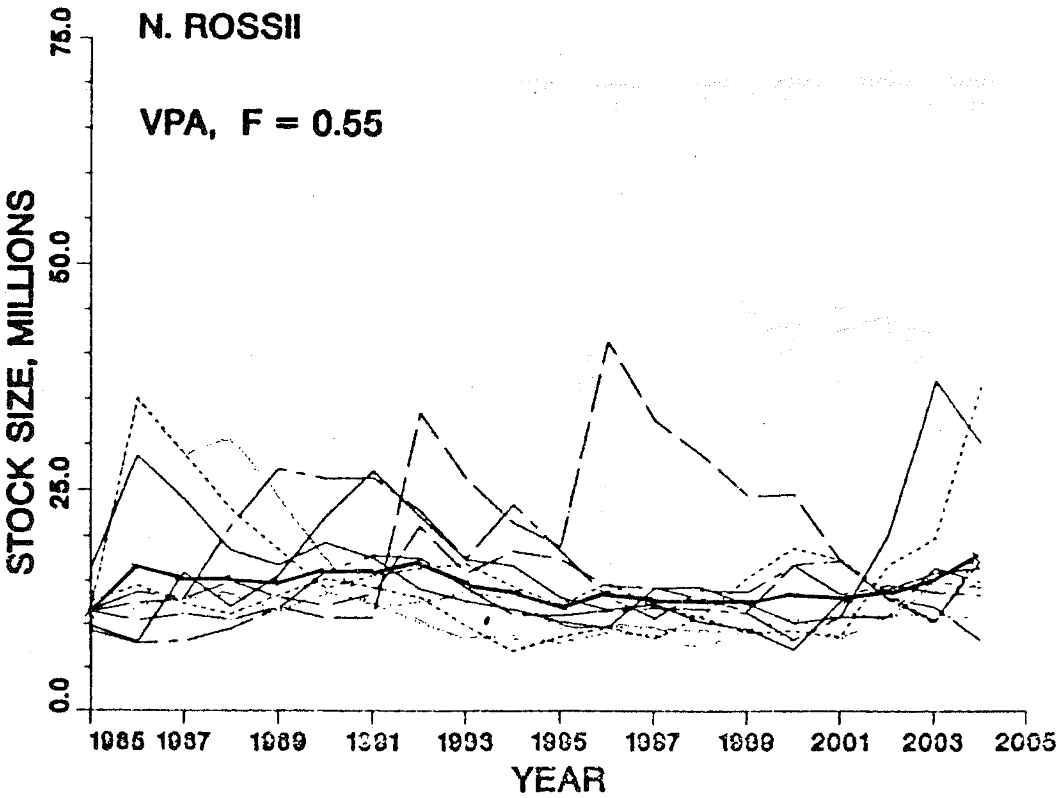

Figure 3. Simulations of stock size (millions of fish) of N. rossii, South Georgia subarea, F=0.55, based on VPA.

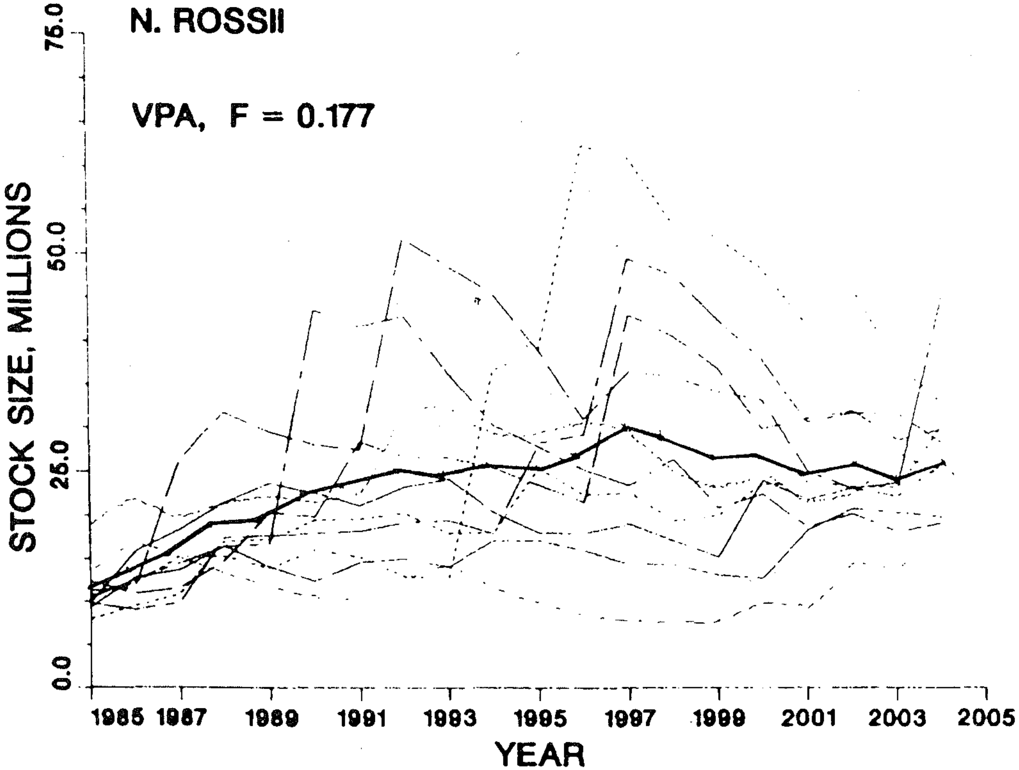

Figure 4. Simulations of stock size (millions of fish) of <u>N. rossii</u> South Georgia subarea, F=0.177, based on VPA.

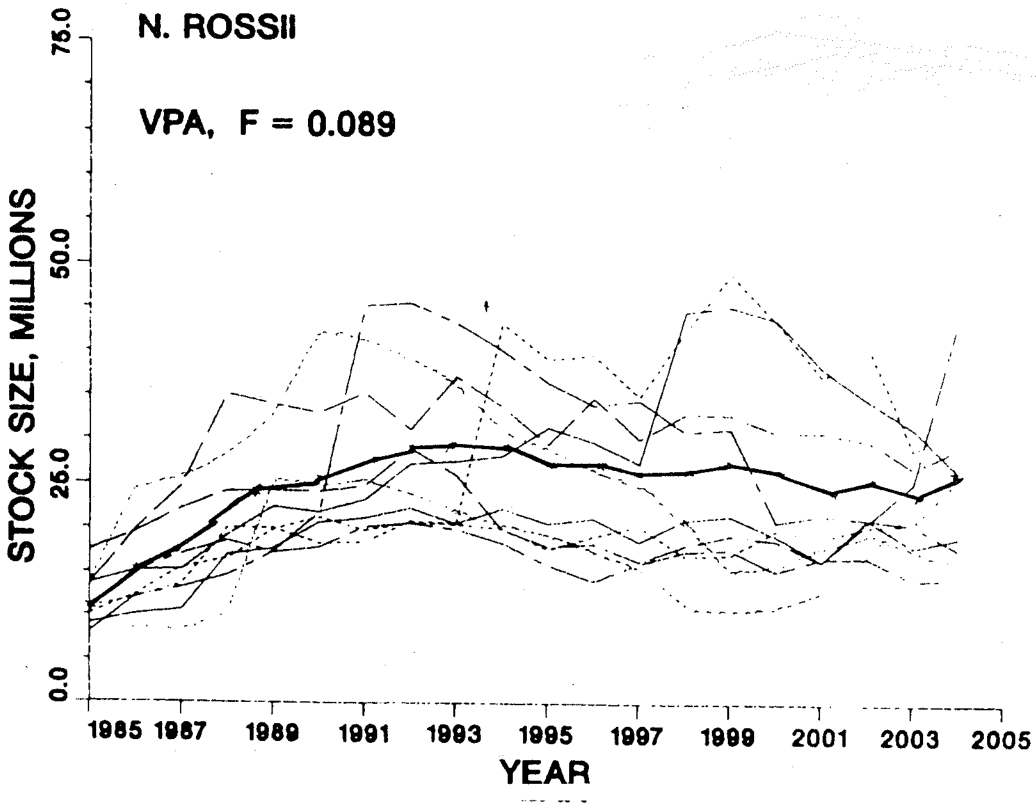

Figure 5. Simulations of stock size (millions of fish) of <u>N. rossii</u> South Georgia subarea, F=0.089, based on VPA.

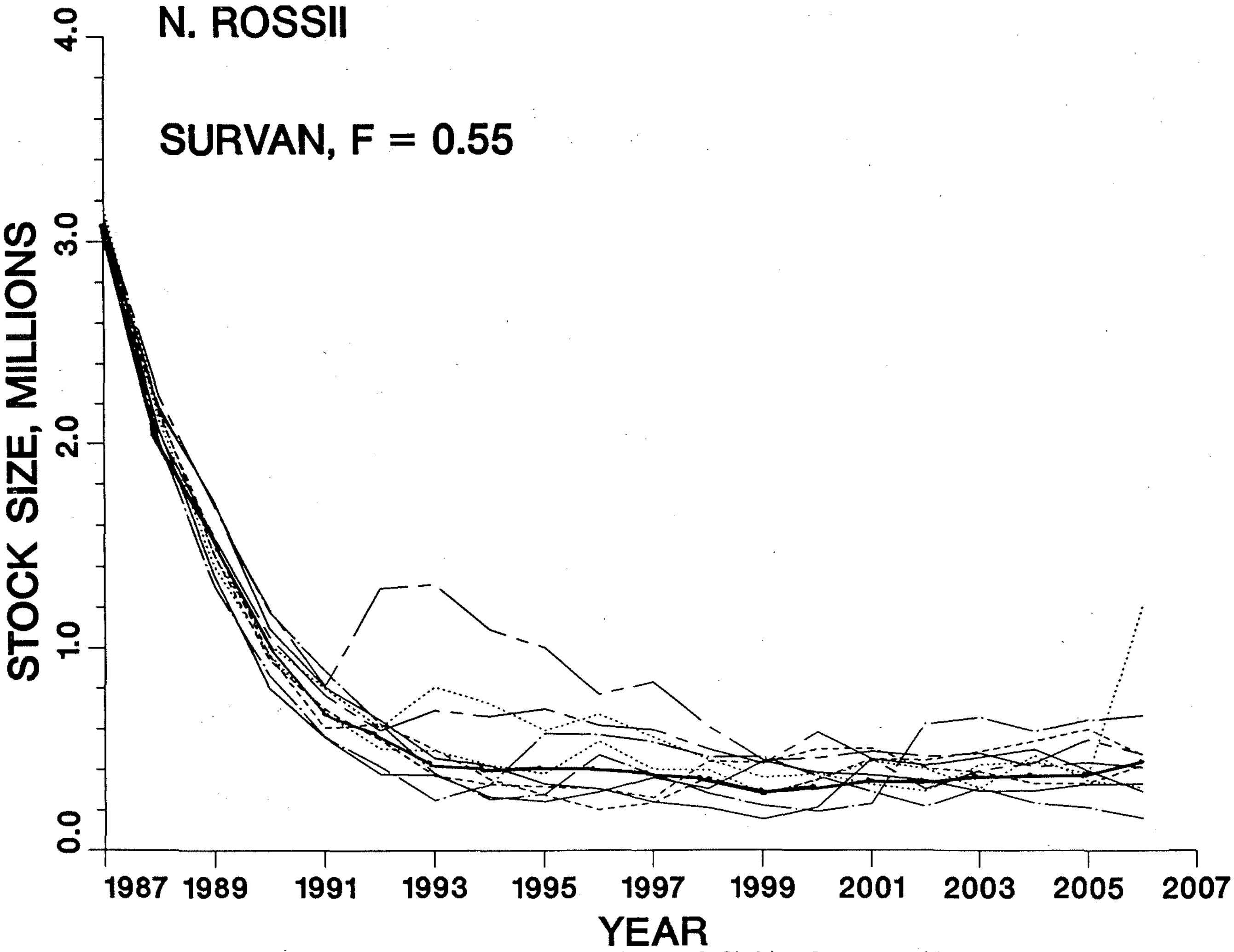

Figure 6. Simulations of stock size (millions of fish) of N. rossii, South Georgia subarea, F=0.55, based on SURVAN.

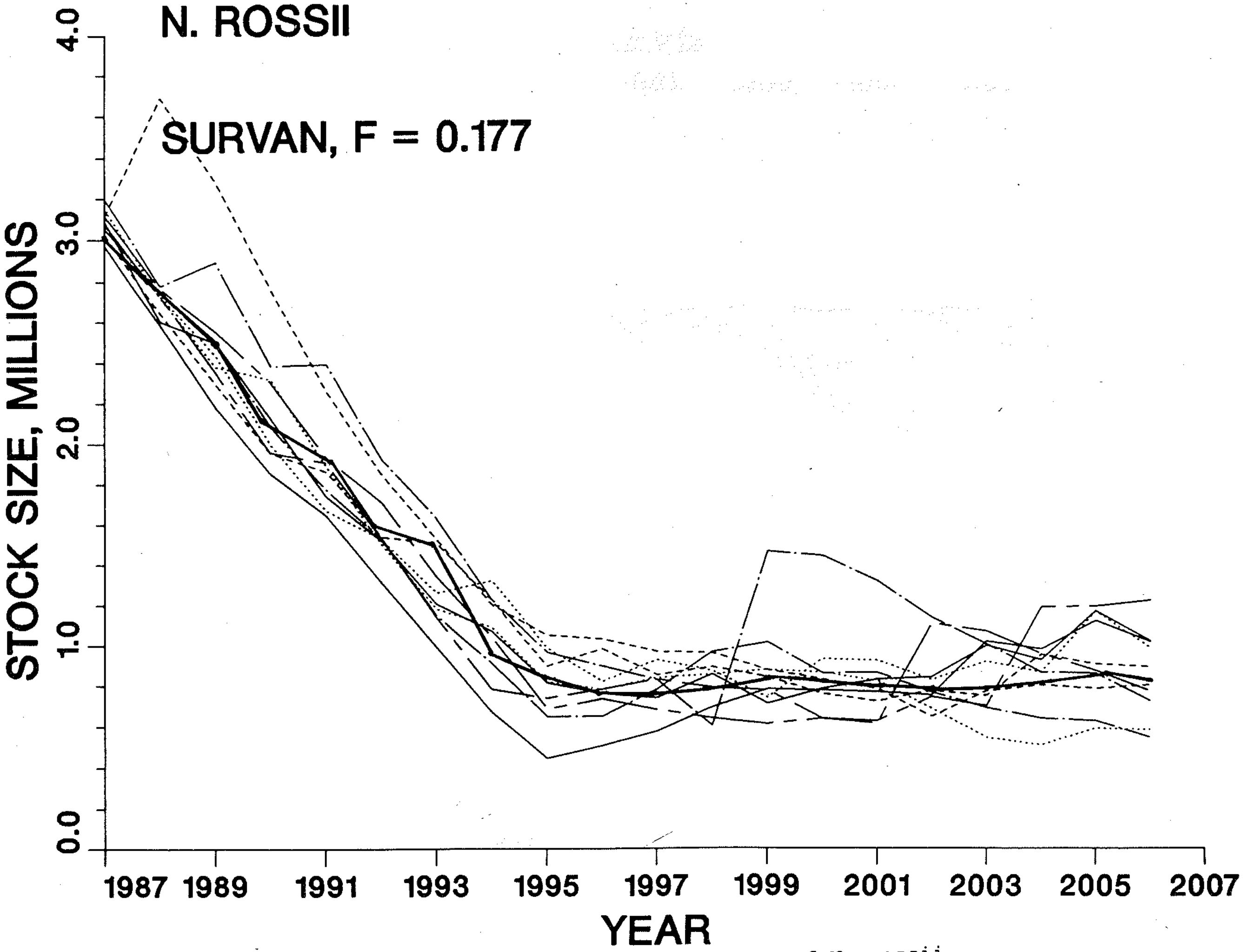

Figure 7. Simulations of stock size (millions of fish) of N. rossii, South Georgia subarea, F=0.177, based on SURVAN.

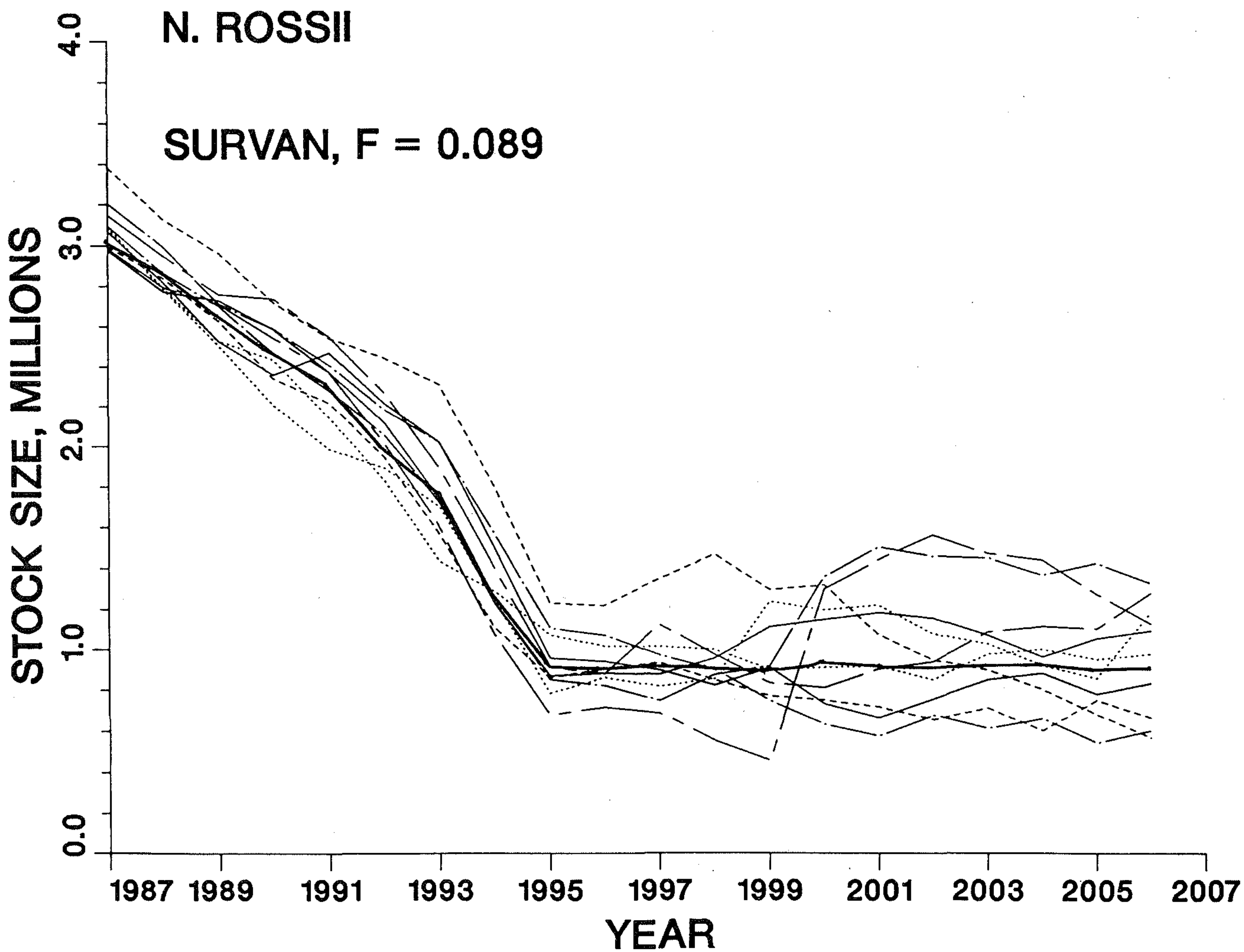

Figure 8. Simulations of stock size (millions of fish) of N. rossii, South Georgia subarea, F=0.089, based on SURVAN.

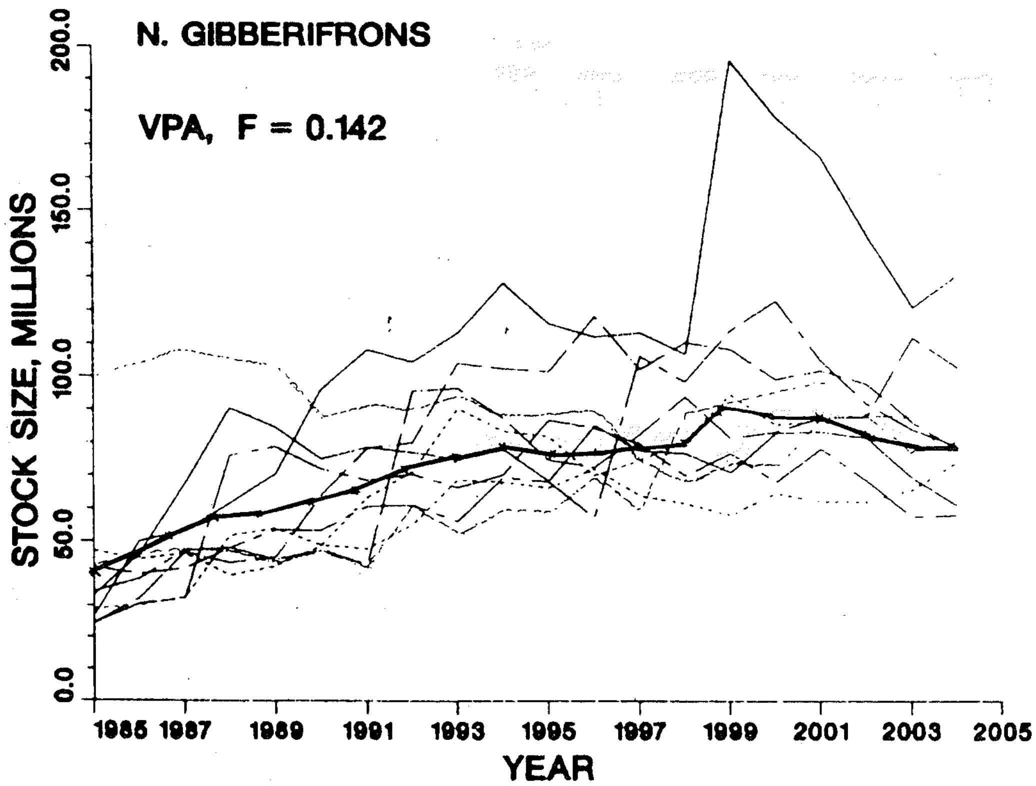

Figure 9. Simulations of stock size (millions of fish) of <u>N. gibberifrons</u>, South Georgia subarea, F=0.142, based on VPA.

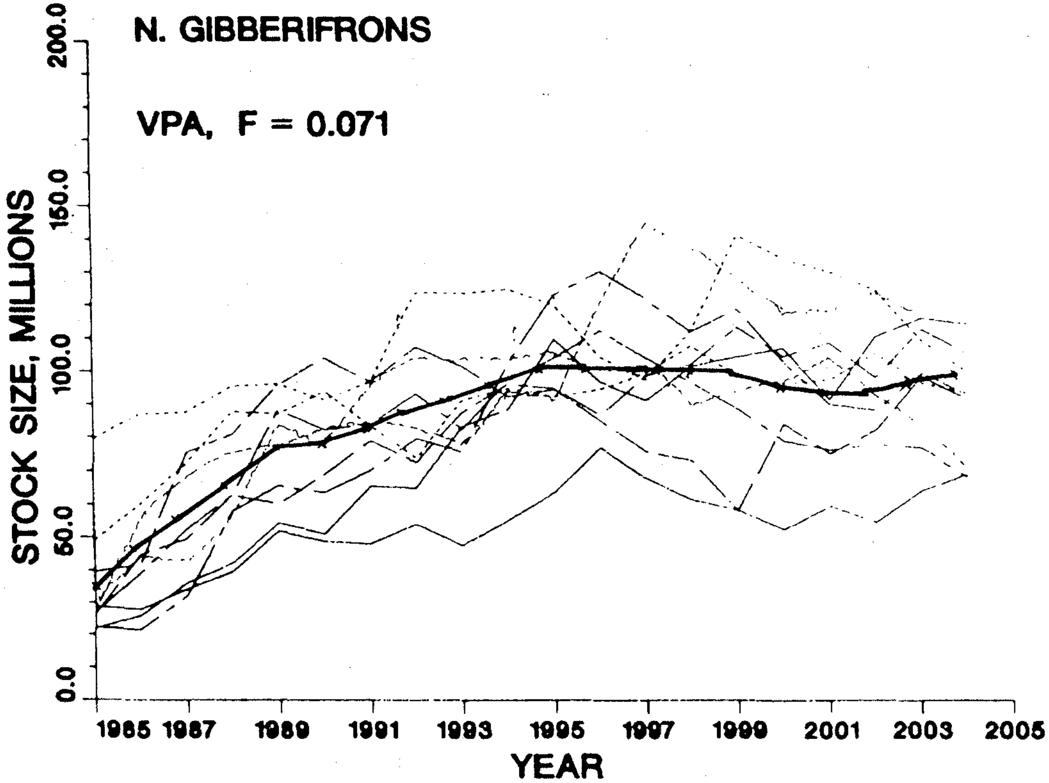

Figure 10. Simulations of stock size (millions of fish) of <u>N. gibberifrons</u>, South Georgia subarea, F=0.071, based on VPA.

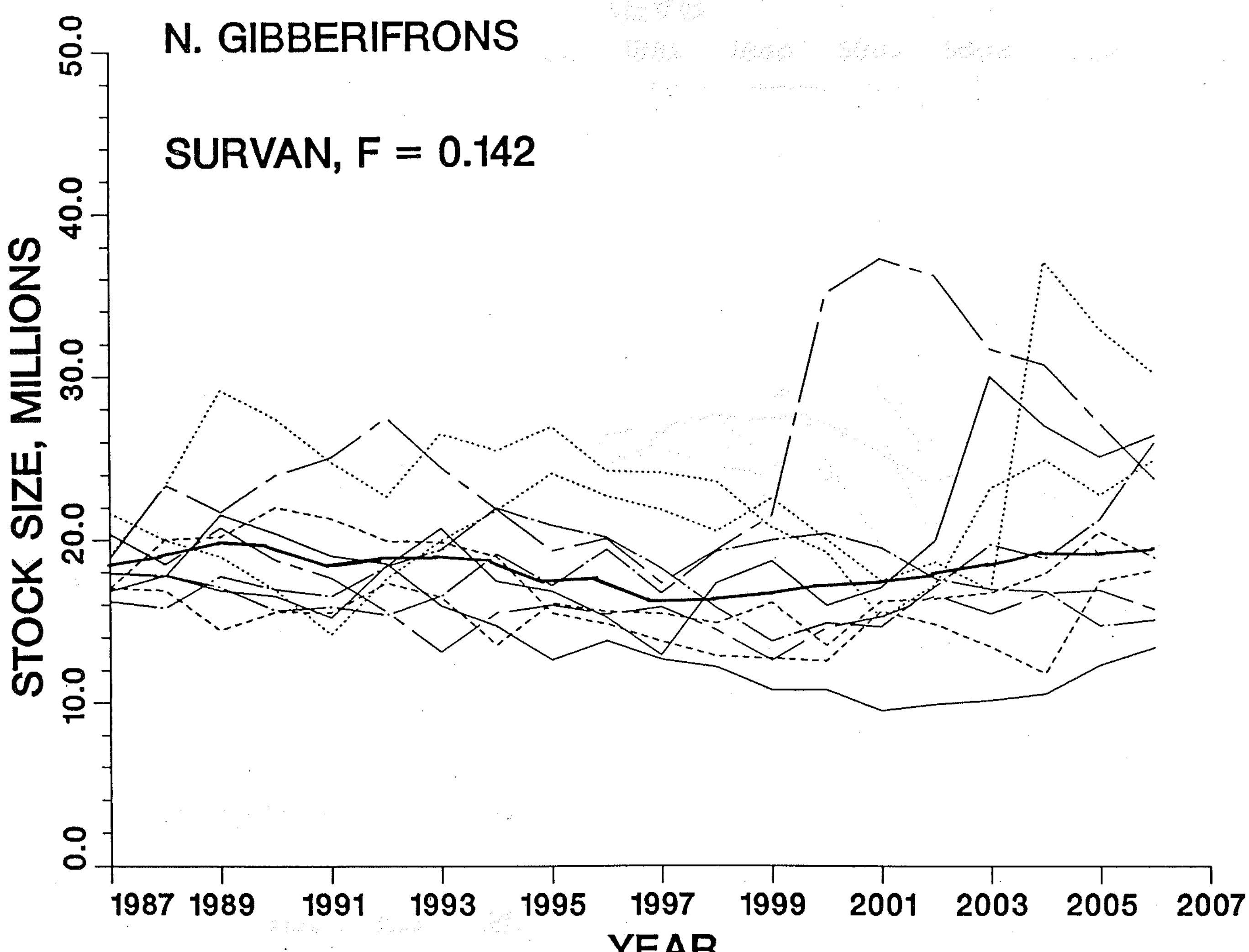

Figure 11. Simulations of stock size (millions of fish) of <u>N. gibberifrons</u>, South Georgia subarea, F=0.142, based on SURVAN

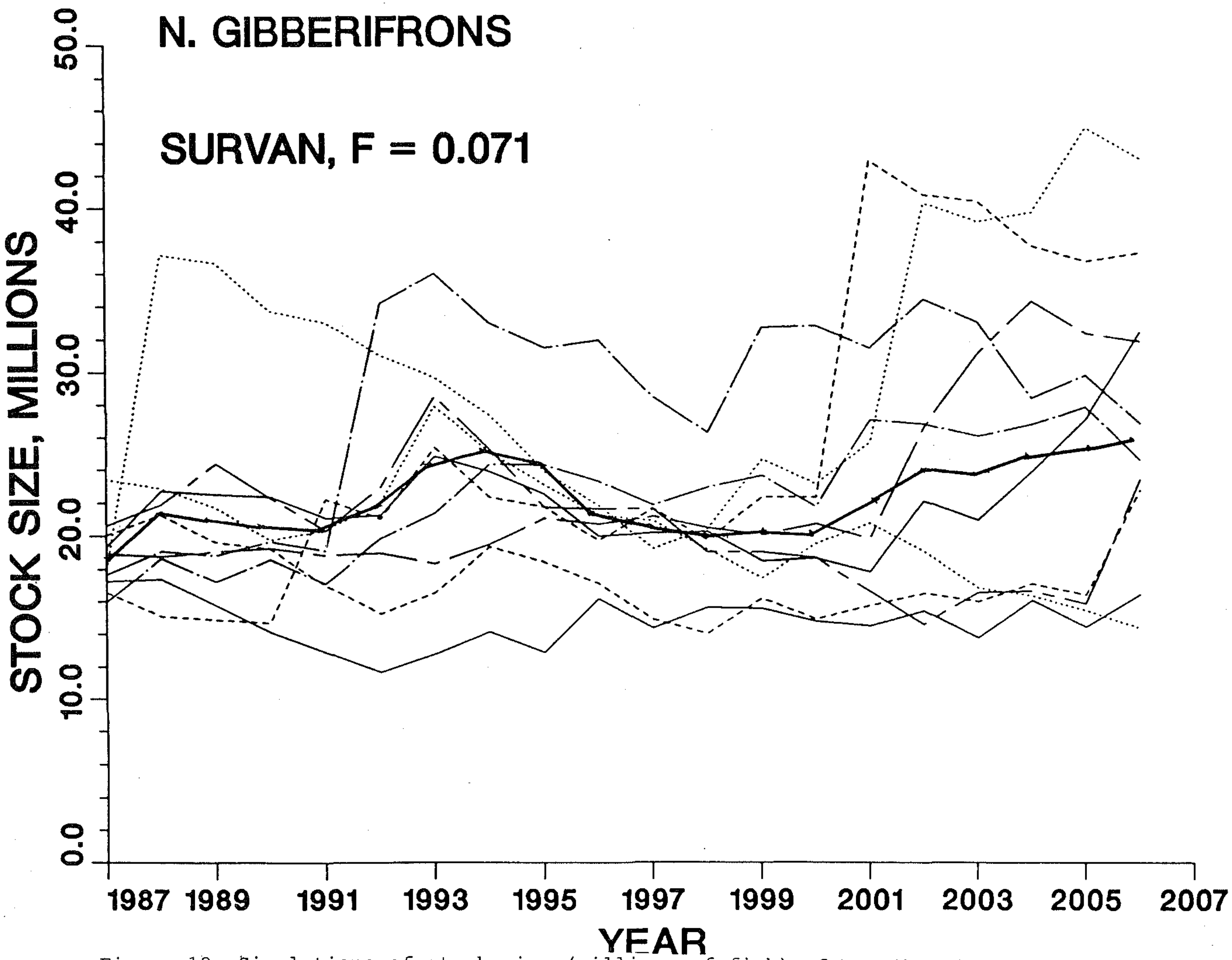

Figure 12. Simulations of stock size (millions of fish) of N. gibberifrons, South Georgia subarea, F=0.071, based on SURVAN.

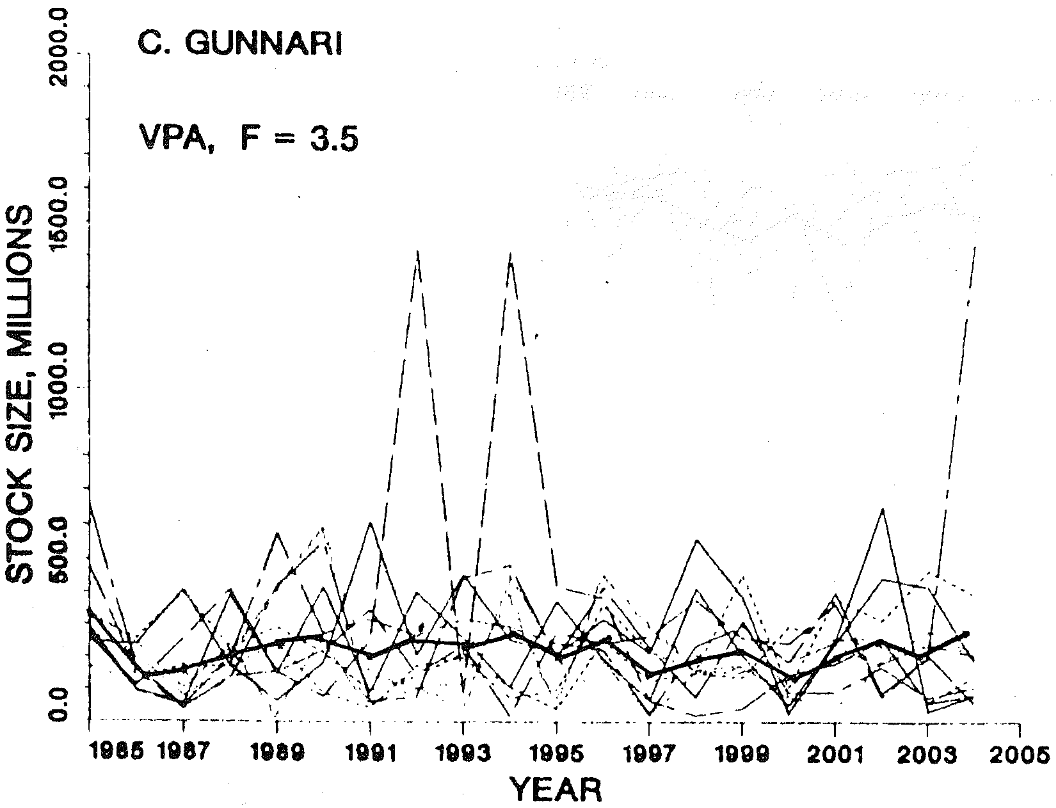

Figure 13. Simulations of stock size (millions of fish) of <u>C. gunnari</u>, South Georgia subarea, F=3.5, based on VPA.

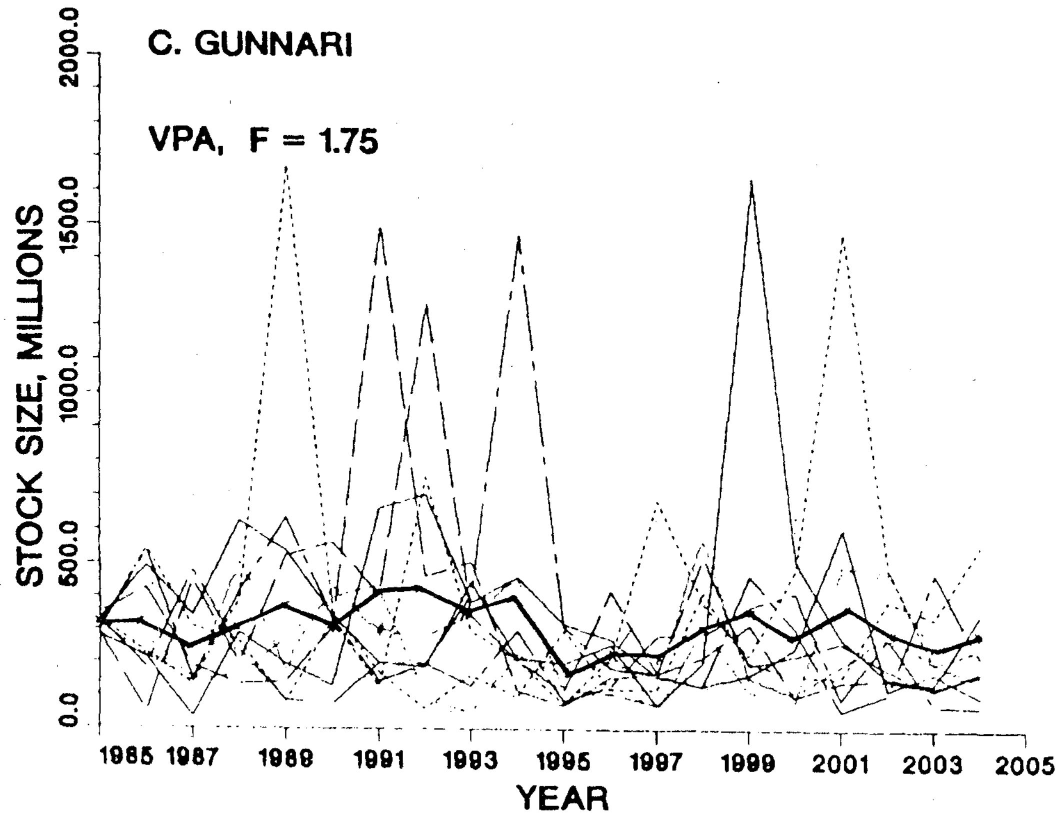

Figure 14. Simulations of stock size (millions of fish) of <u>C. gunnari</u>, South Georgia subarea, F=1.75, based on VPA.

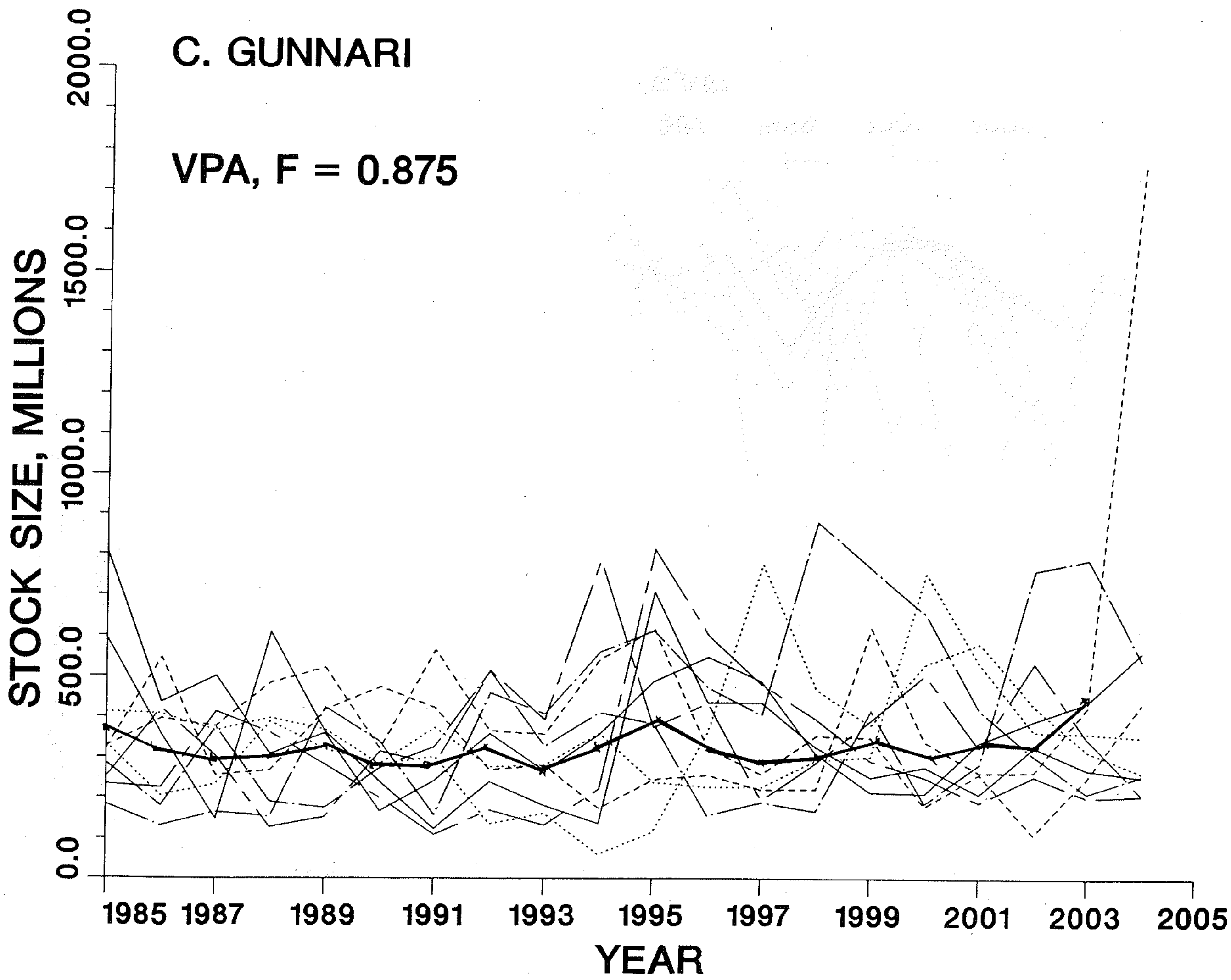

Figure 15. Simulations of stock size (millions of fish) of C. gunnari, South Georgia subarea F=0.875. based on VPA.

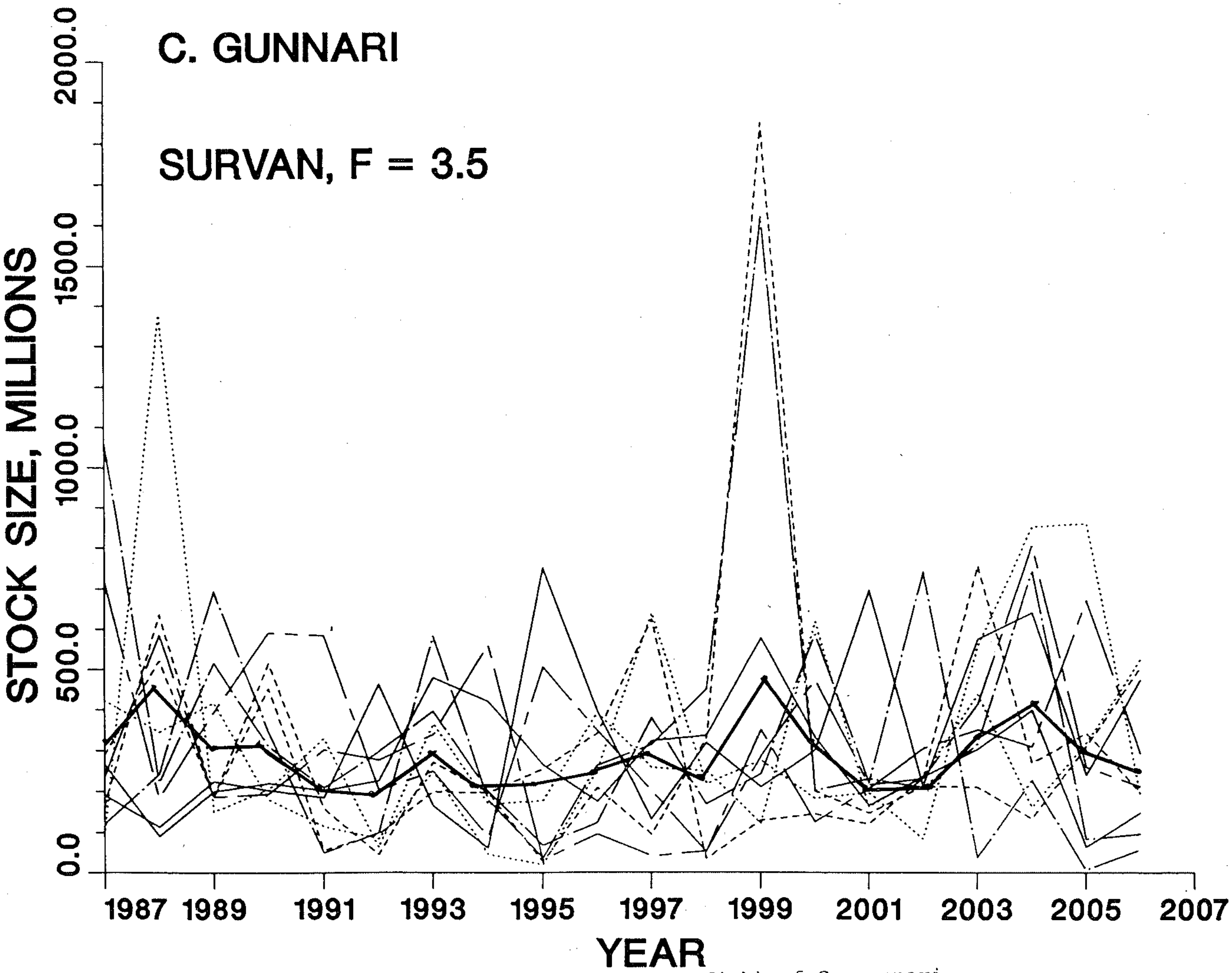

Figure 16. Simulations of stock size (millions of fish) of C. gunnari, South Georgia subarea, F=3.5, based on SURVAN.

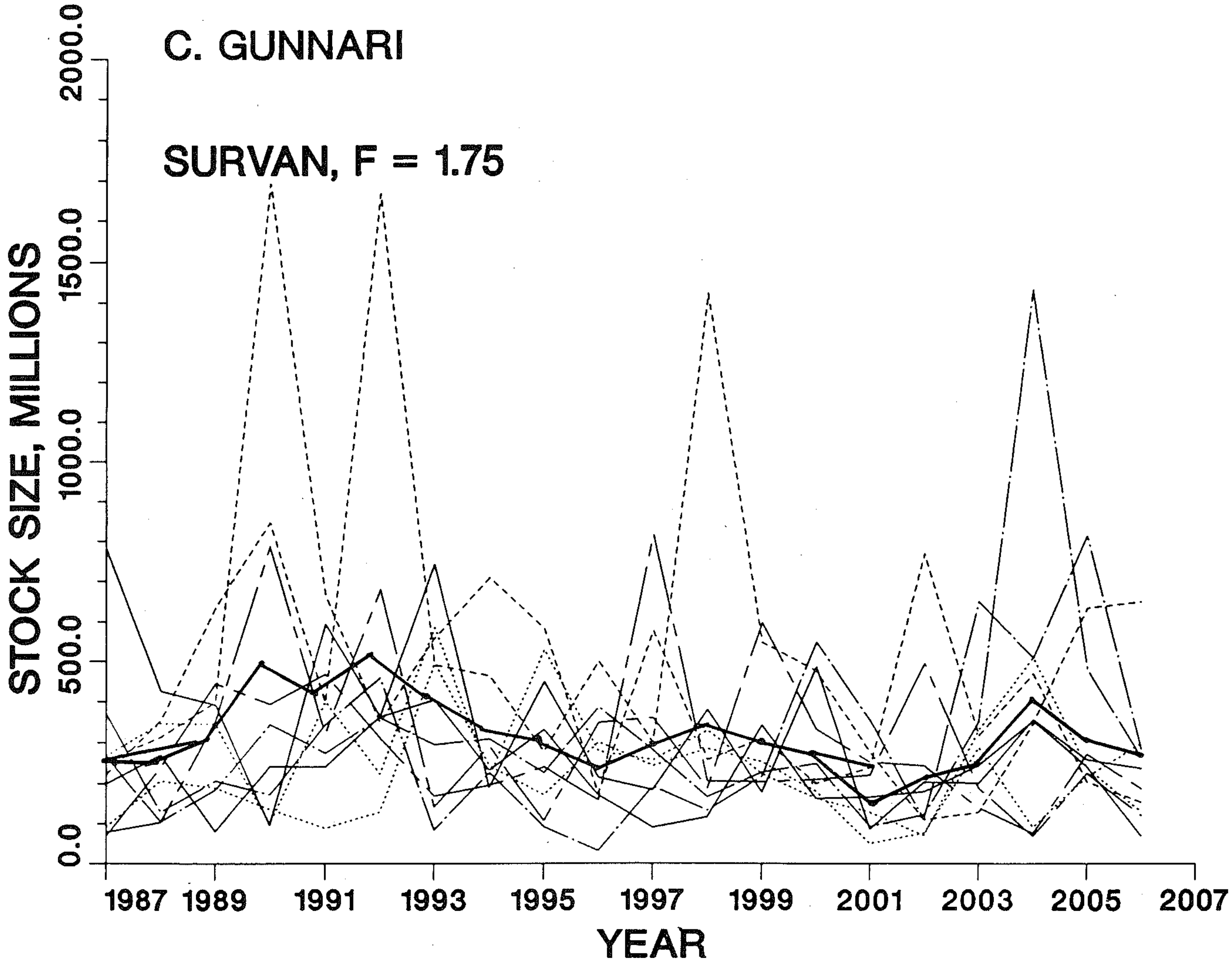

Figure 17. Simulations of stock size (millions of fish) of C. gunnari, South Georgia subarea, F=1.75, based SURVAN.

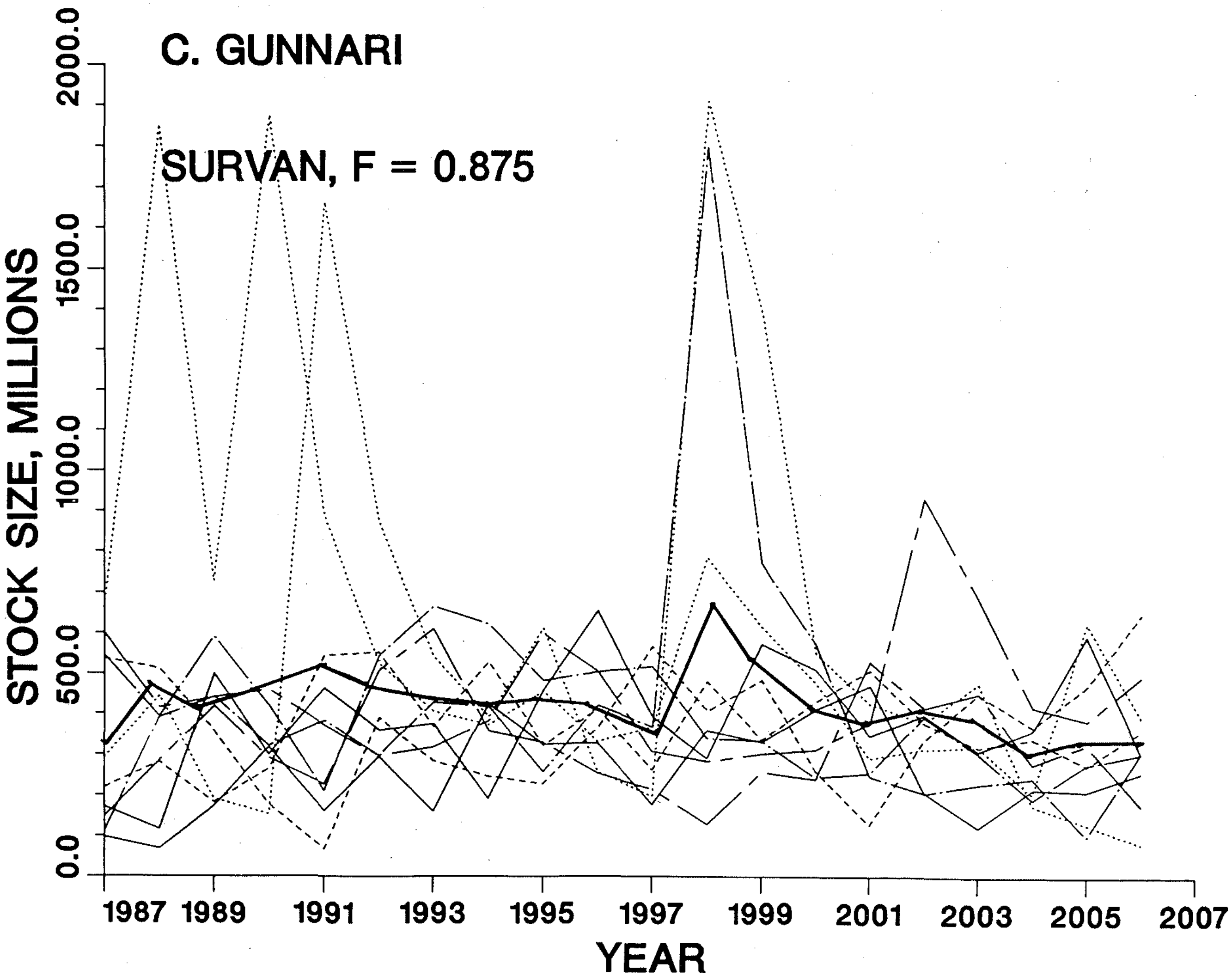

Figure 18. Simulations of stock size (millions of fish) of C. gunnari, South Georgia subarea, F=0.875, based on SURVAN.

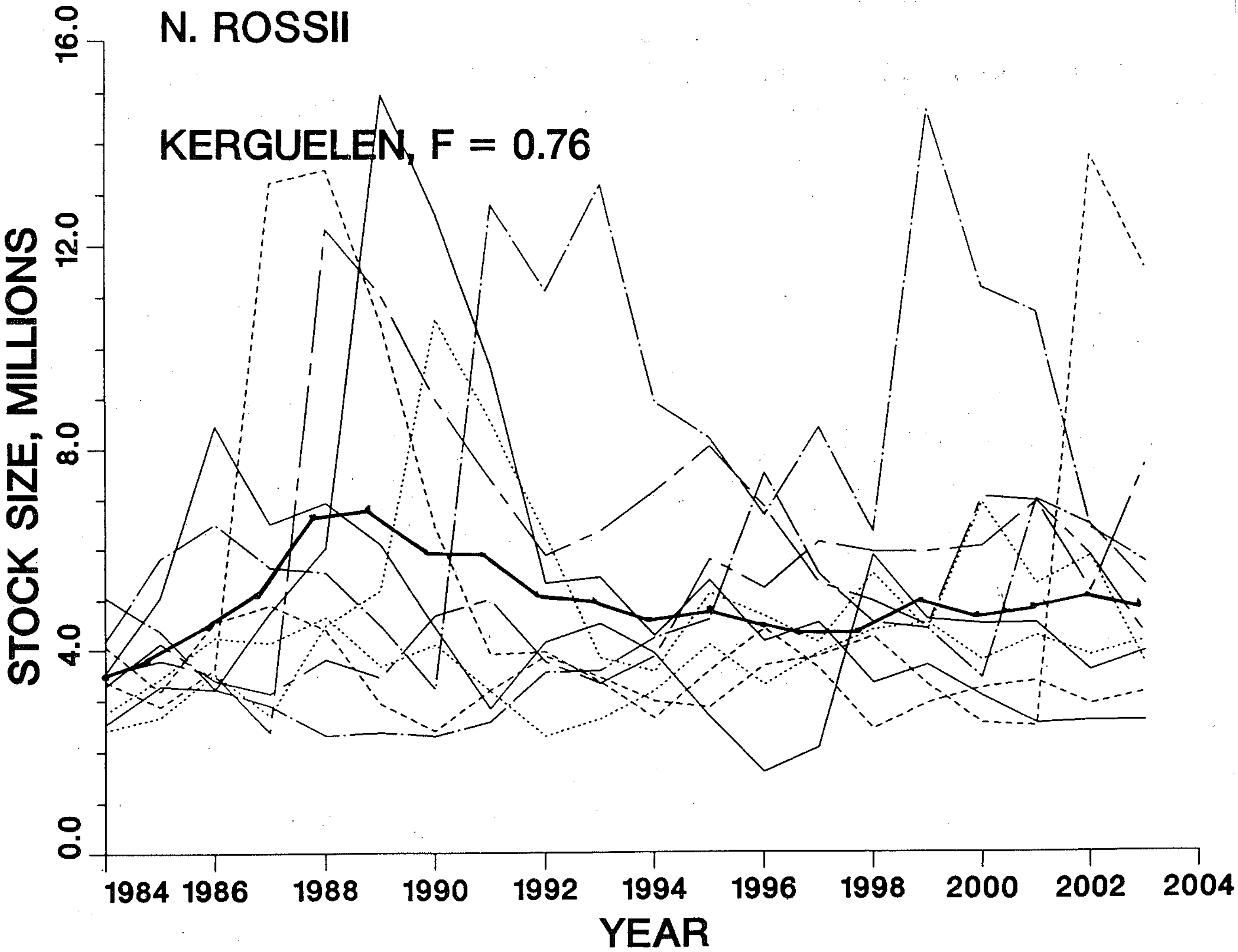

Figure 19. Simulations of stock size (millions of fish) of <u>N. rossii</u>, Kerguelen Island Shelf, F=0.76, based on VPA.

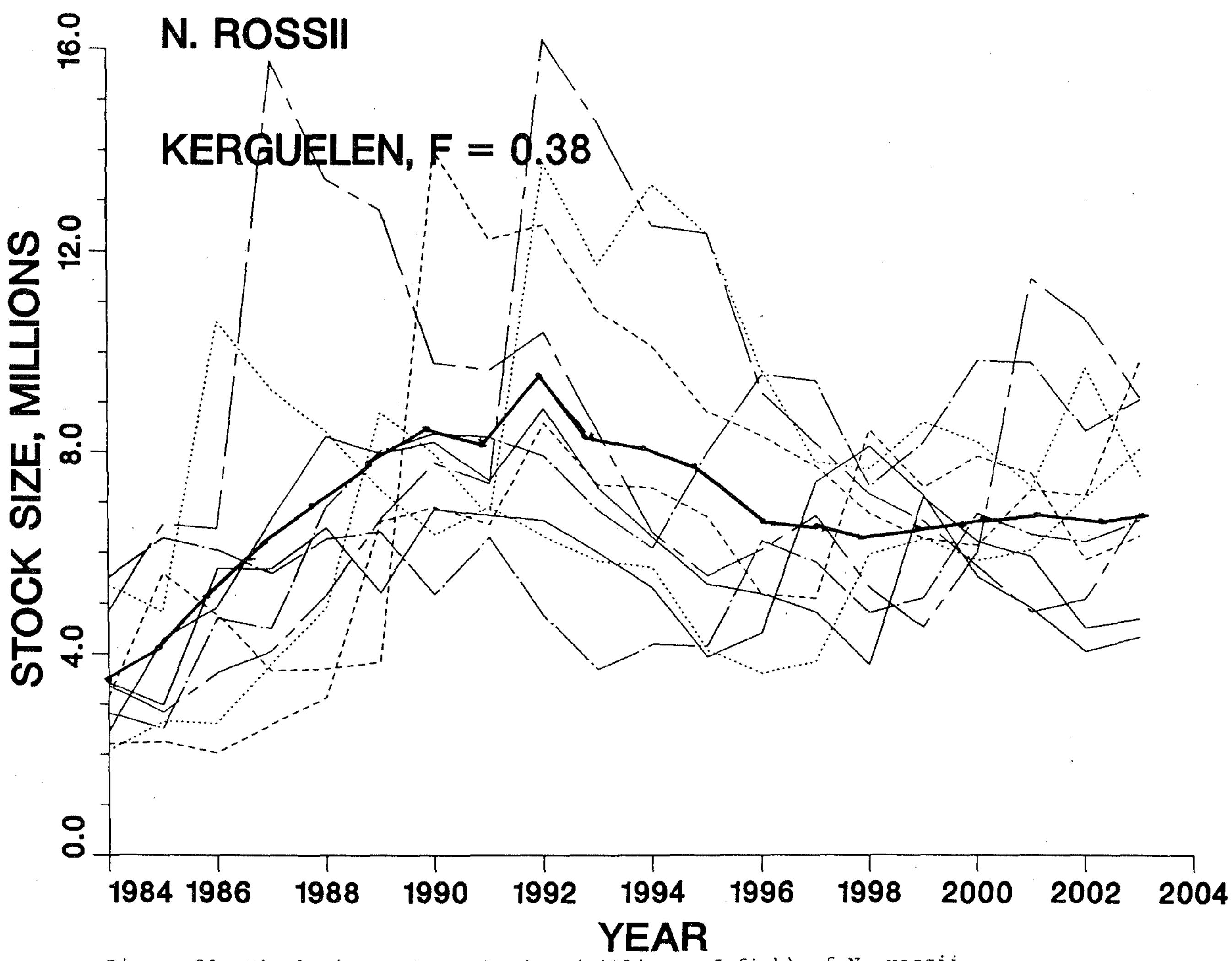

Figure 20. Simulations of stock size (millions of fish) of N. rossii, Kerguelen Island Shelf, F=0.38, based on VPA.

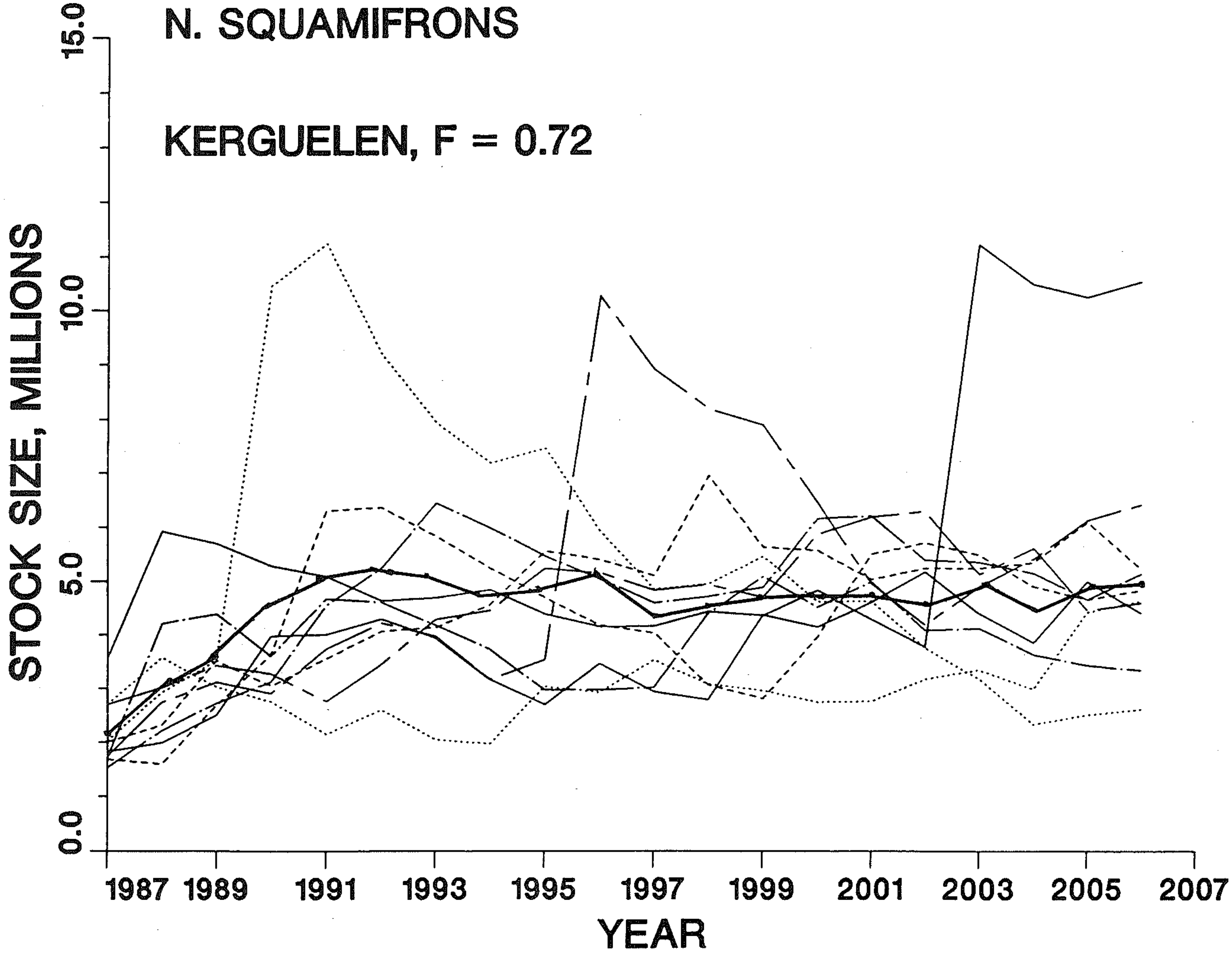

Figure 21. Simulations of stock size (millions of fish) of N. squamifrons, Kerguelen Island Shelf, F=0.72, based on VPA.

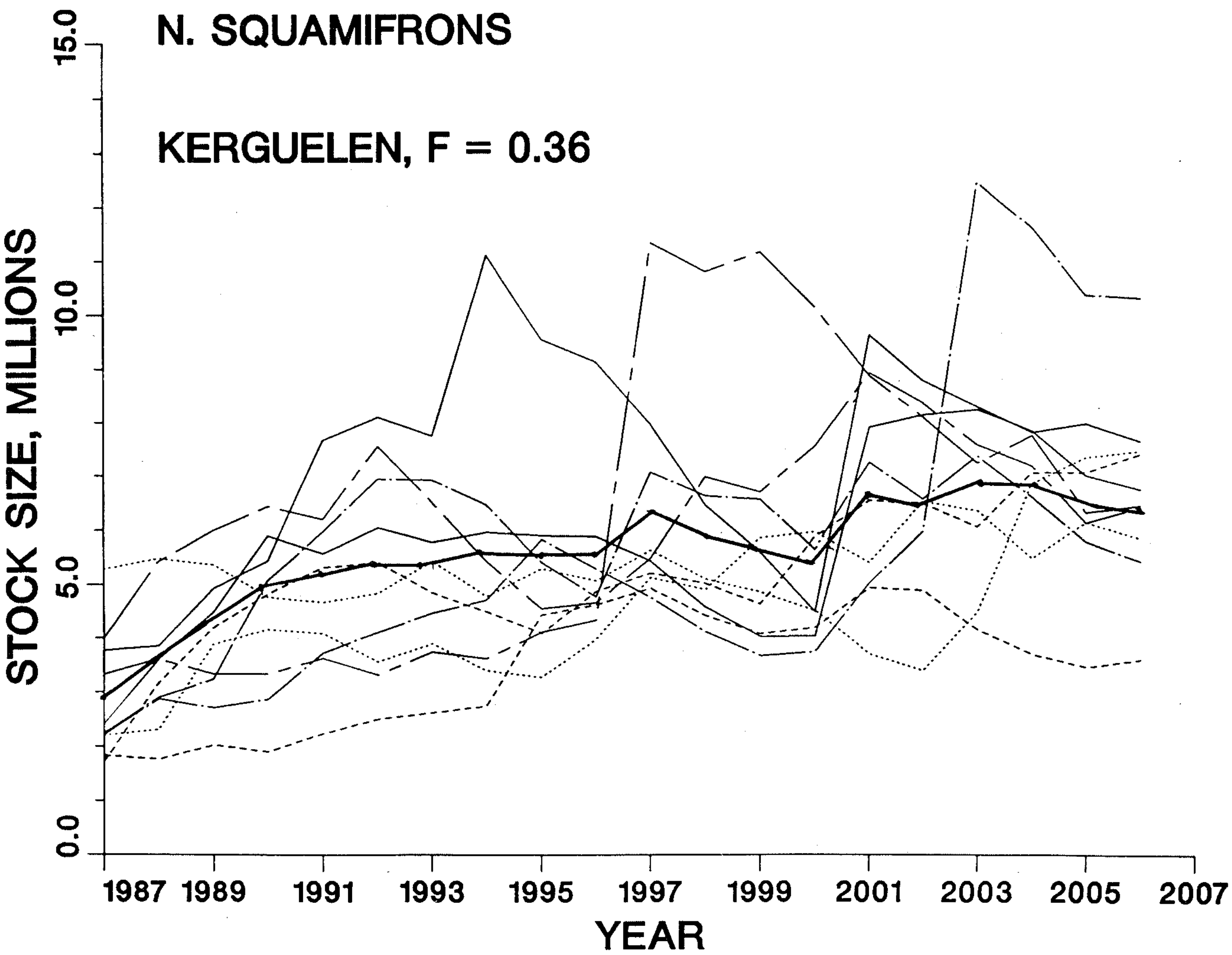

Figure 22. SImulations of stock size (millions of fish) of <u>N. squamifrons</u>, Kerguelen Island Shelf, F=0.36, based on VPA.

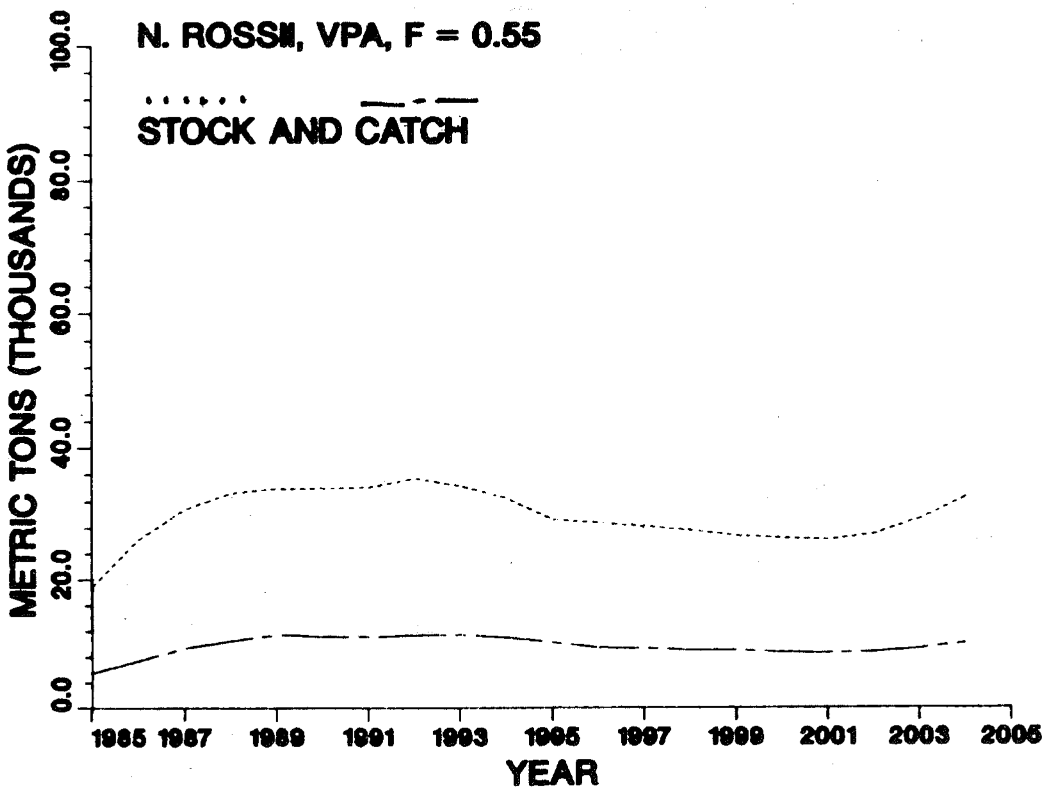

Figure 23. Simulations of weight of stock and catch for N.rossii, South Georgia subarea, F=0.55, based on VPA.

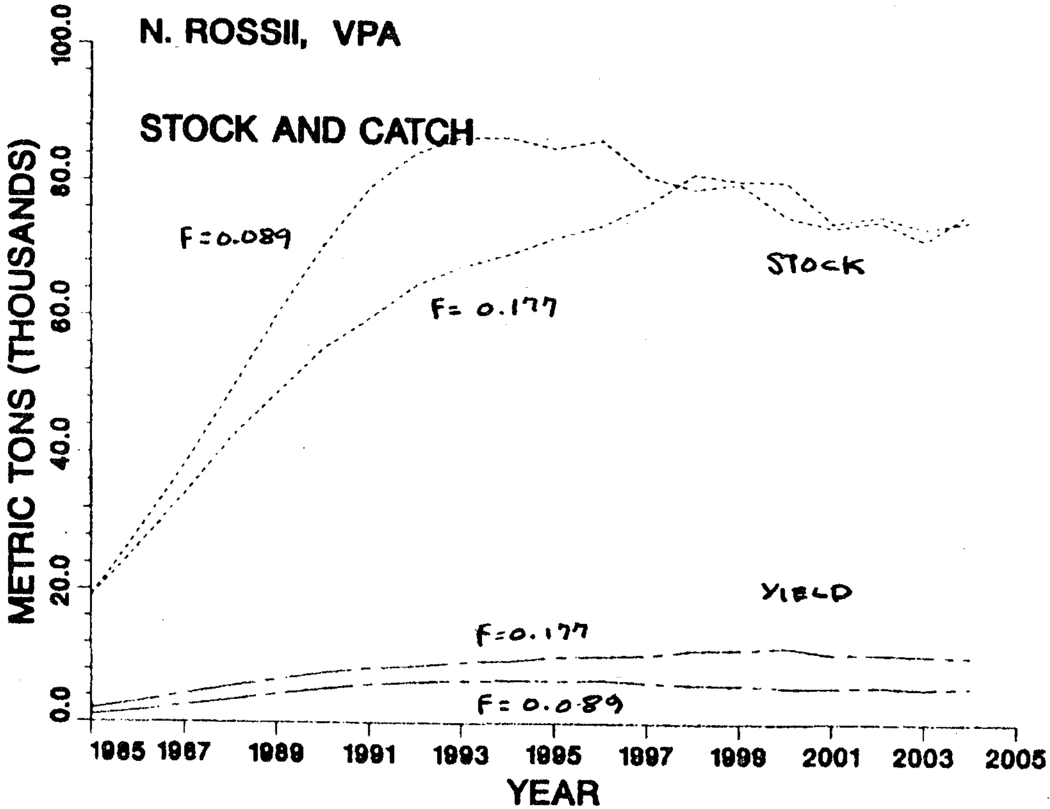

Figure 24. Simulations of weight of stock and catch for N. rossii, South Georgia subarea, based on VPA.

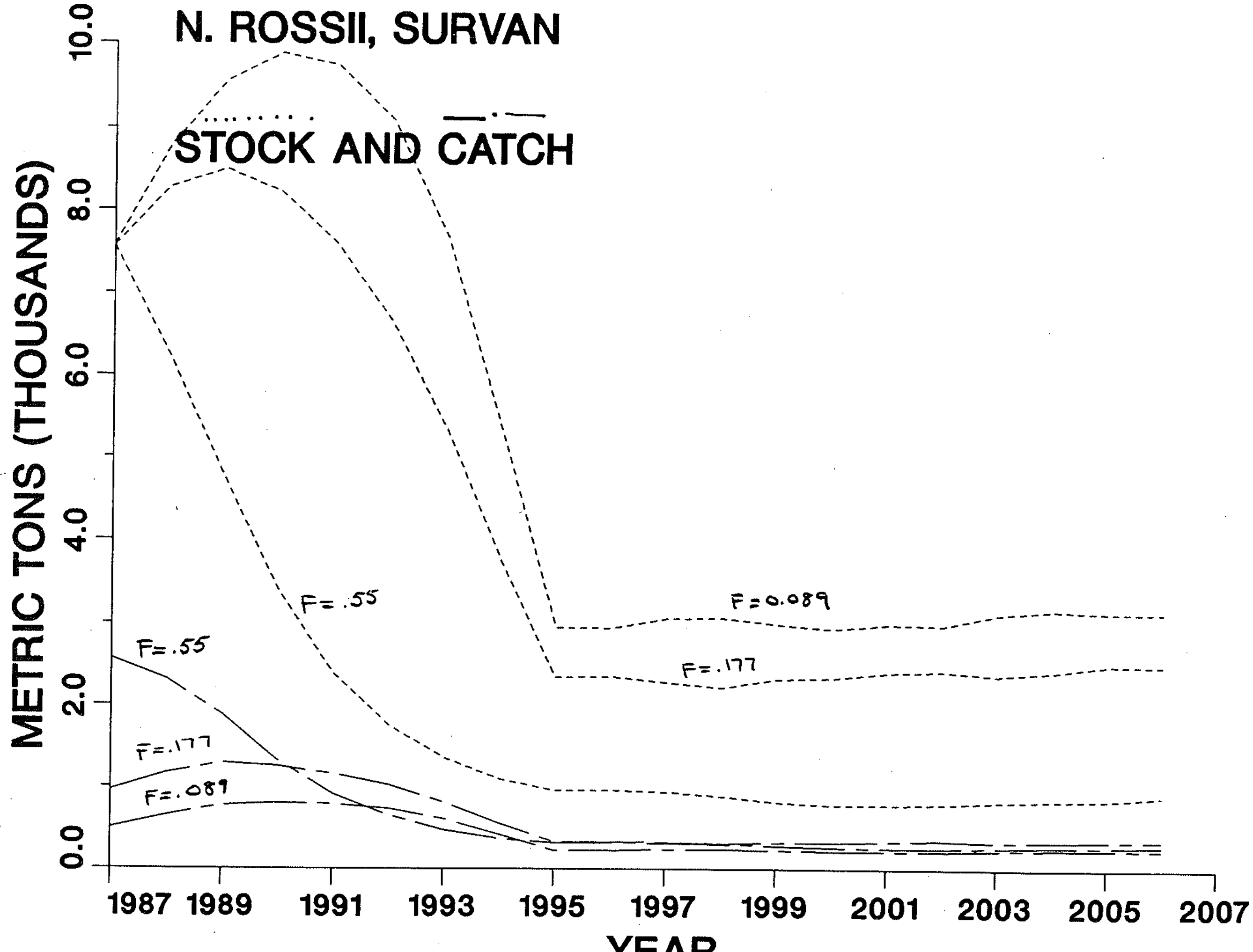

Figure 25. Simulations of weight of stock and catch for N. rossii, South Georgia subarea, based on SURVAN.

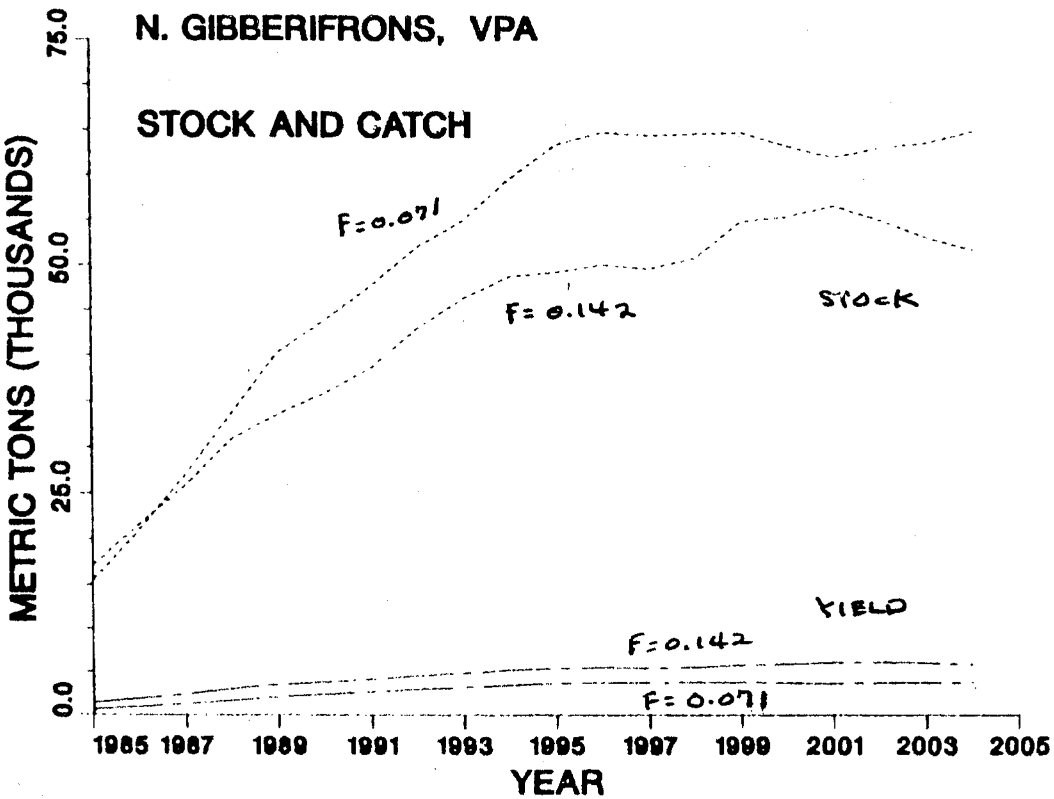

Figure 26. Simulations of weight of stock and catch for N. gibberifrons, South Georgia subarea, based on VPA.

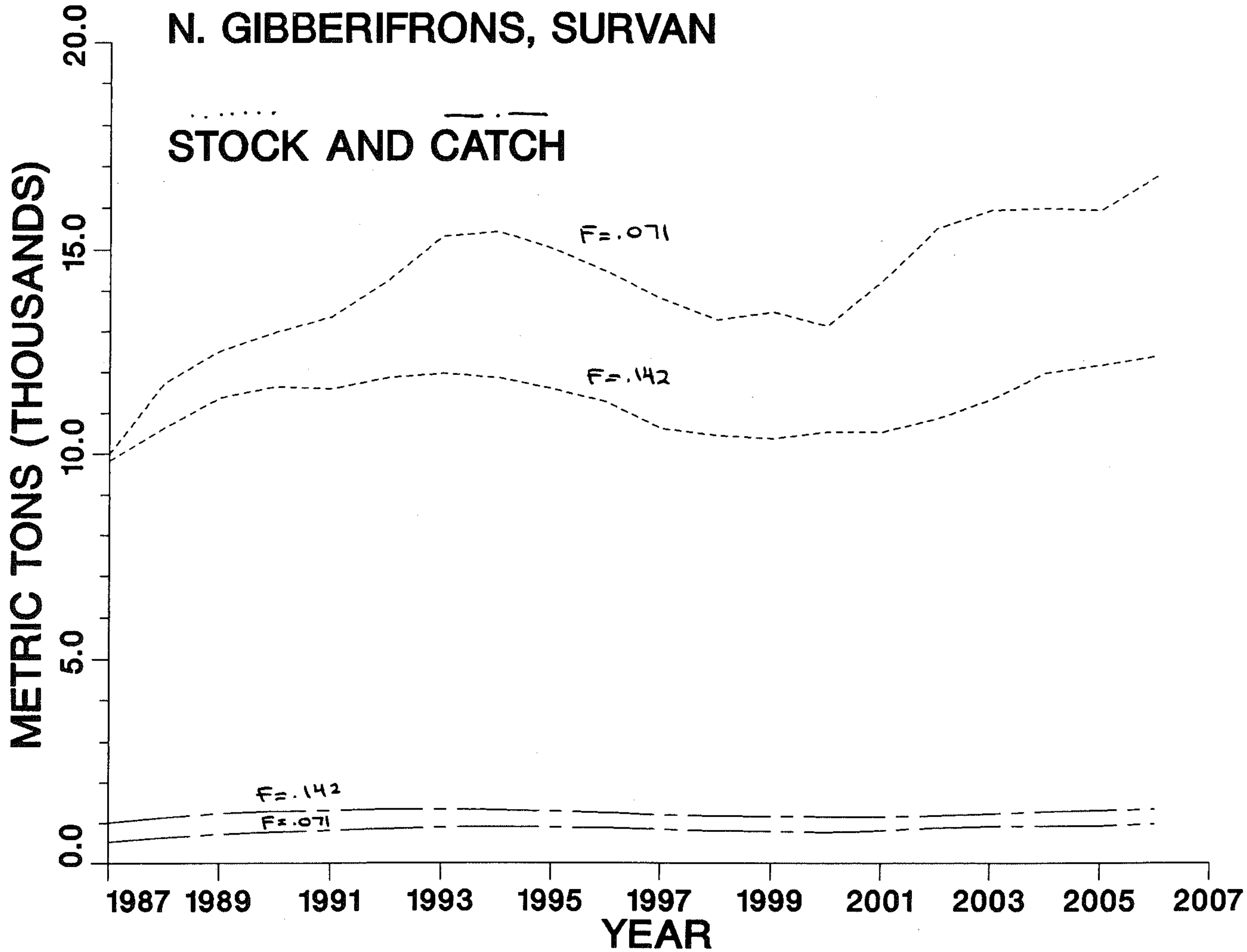

Figure 27. Simulations of weight of stock and catch for <u>N. gibberifrons,</u>
South Georgia subarea, based on SURVAN.

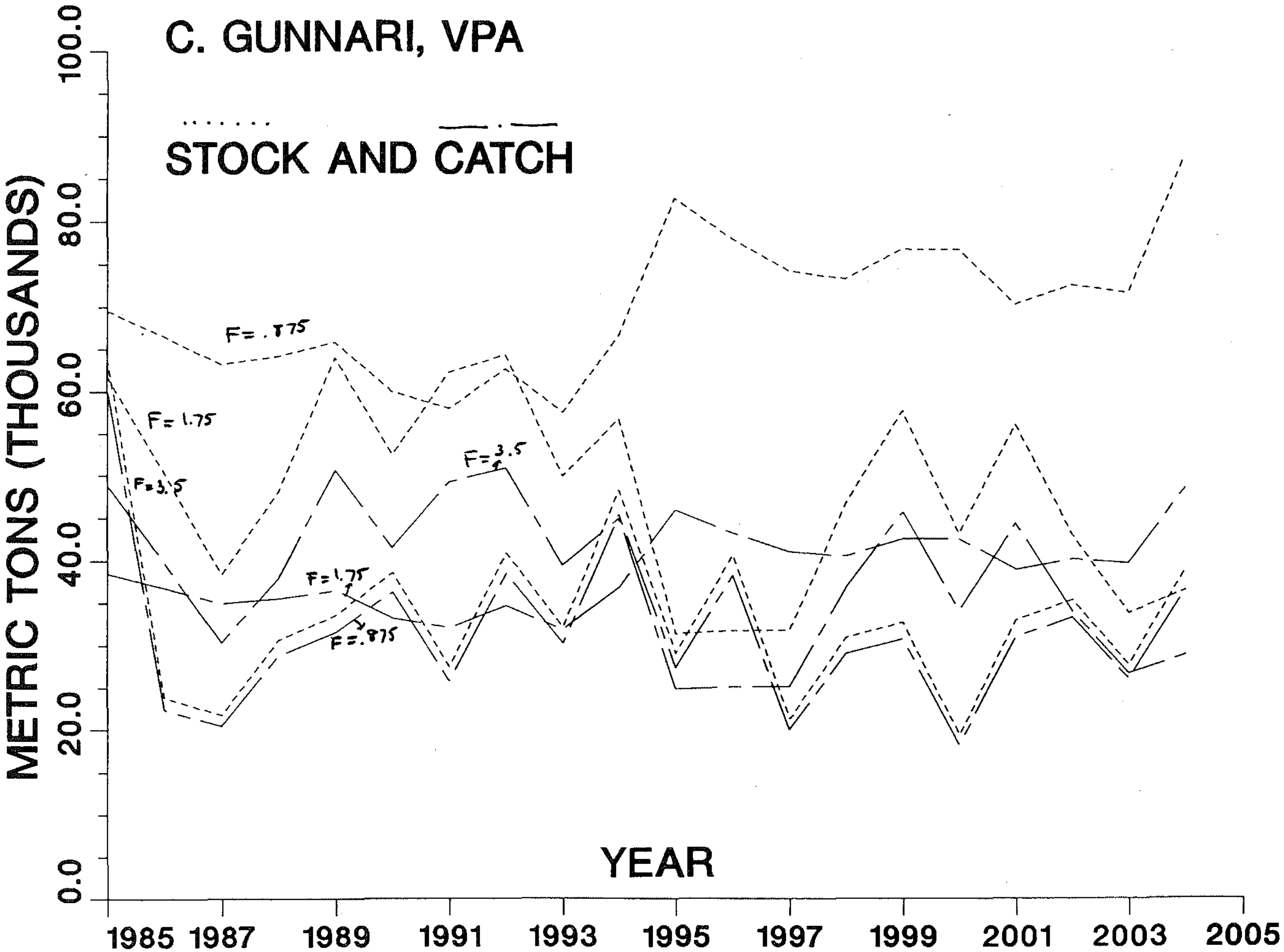

Figure 28. Simulations of weight of stock and catch for C. gunnari, South Georgia subarea, based on VPA.

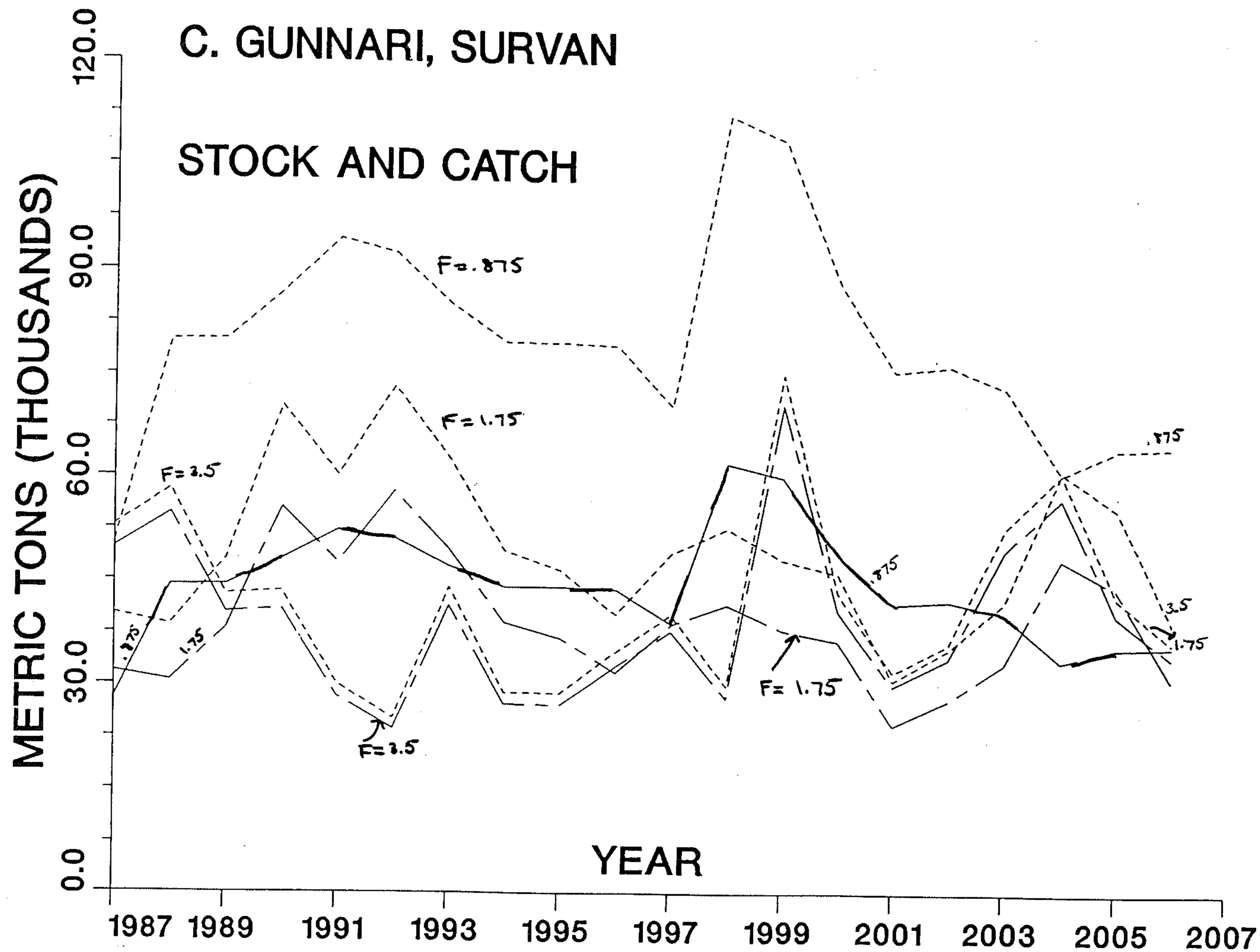

Figure 29. Simulations of weight of stock and catch for C. gunnari South Georgia subarea, based on SURVAN.

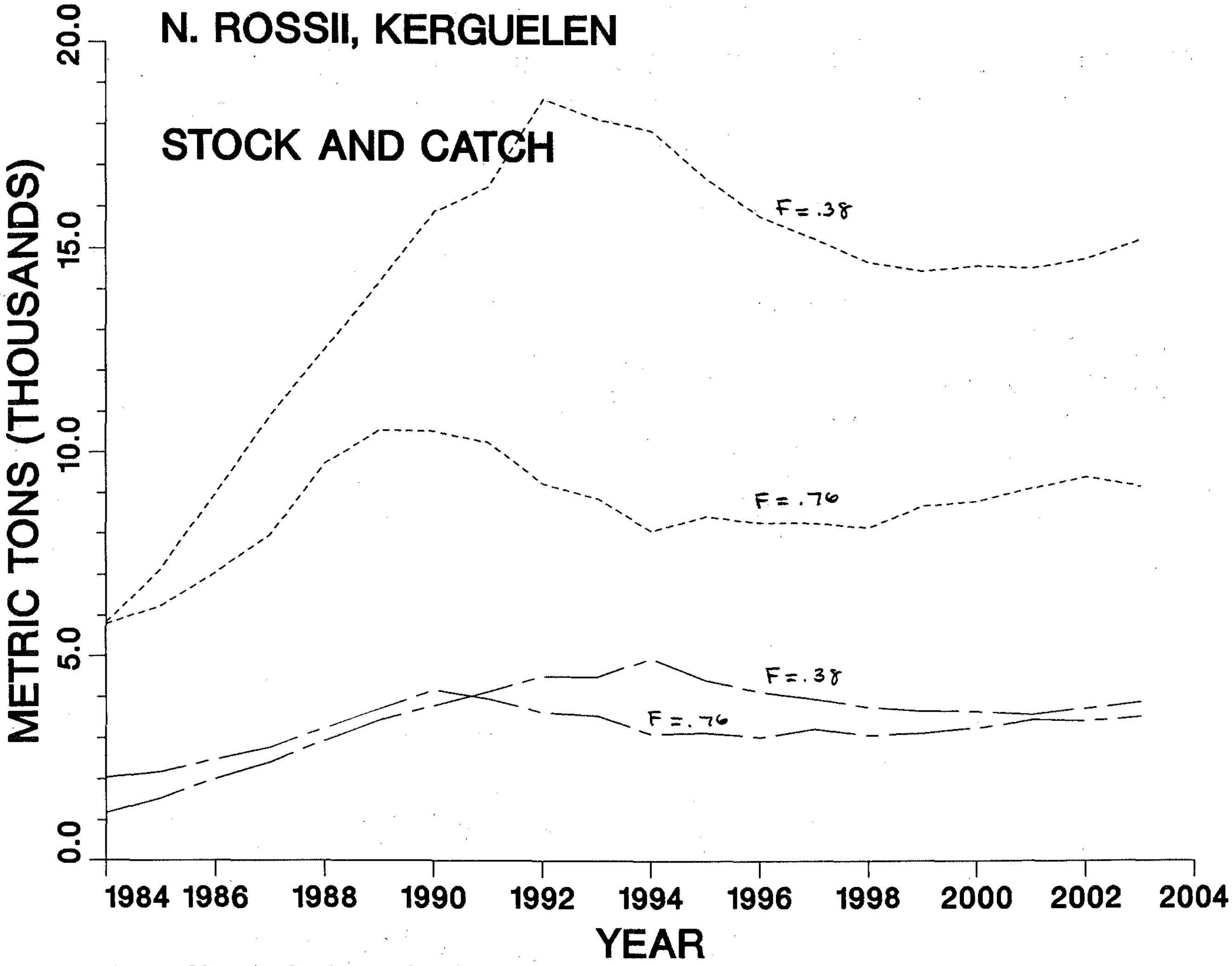

Figure 30. Simulations of weight of stock and catch for <u>N. rossii</u>, Kerguelen Island Shelf, based on VPA.

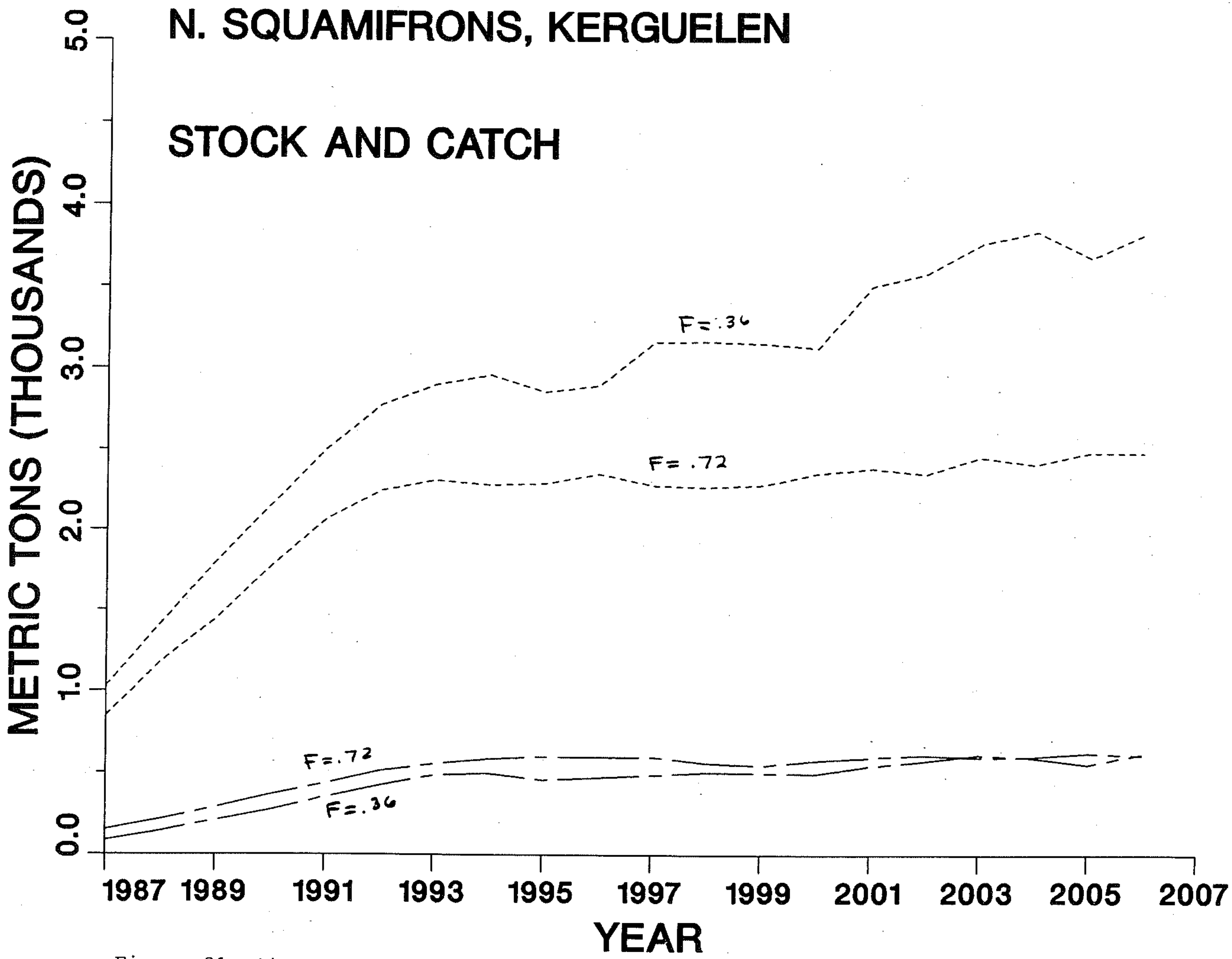

Figure 31. Simulations of weight of stock and catch for <u>N. squamifrons</u>, Kerguelen Island Shelf, based on VPA.

WG-FSA-87/8 Rev.1
and WG-FSA-87/15

Légendes des tableaux

Tableau 1 Age initial et effectifs en millions de recrues individuelles.

Tableau 2 Paramètres utilisés pour le modèle de simulation (Géorgie du Sud).

Tableau 3 Paramètres utilisés pour le modèle de simulation (Kerguelen).

Tableau 4 Moyenne des dix projections sur 20 ans concernant la taille du stock en nombre d'individus (x 10^{-6}) et en poids (x 10^{-3}).

Tableau 5 Moyenne des dix projections sur 20 ans concernant la taille du stock en nombre d'individus (x 10^{-6}) et en poids (x 10^{-3}).

Tableau 6 Récapitulatif des points de référence standard pour les projections (stocks de la Géorgie du Sud).

Tableau 7 Récapitulatif des points de référence standard pour les projections (Kerguelen).

Tableau 8 Comparaison des rendements simulés et des rendements déclarés au cours des années passées.

Légendes des figures

Figure 1 Fonction de densité universelle de probabilité de recrutement utilisée dans la simulation.

Figure 2 Fréquences de recrutement générées au hasard (nombre de poissons x 10^{-6}).

Figure 3 Simulations de la taille du stock (millions de poissons) de N. rossii, sous-zone de la Géorgie du Sud, F=0,55, basées sur la VPA.

Figure 4 Simulations de la taille du stock (millions de poissons) de N. rossii, sous-zone de la Géorgie du Sud, F=0,177, basées sur la VPA.

Figure 5 Simulations de la taille du stock (millions de poissons) de N. rossii, sous-zone de la Géorgie du Sud, F=0,089, basées sur la VPA.

Figure 6 Simulations de la taille du stock (millions de poissons) de N. rossii, sous-zone de la Géorgie du Sud, F=0,55, basées sur SURVAN.

Figure 7	Simulations de la taille du stock (millions de poissons) de <u>N. rossii</u>, sous-zone de la Géorgie du Sud, F=0,177, basées sur SURVAN.
Figure 8	Simulations de la taille du stock (millions de poissons) de <u>N. rossii</u>, sous-zone de la Géorgie du Sud, F=0,089, basées sur SURVAN.
Figure 9	Simulations de la taille du stock (millions de poissons) de <u>N. gibberifrons</u>, sous-zone de la Géorgie du Sud, F=0,142, basées sur la VPA.
Figure 10	Simulations de la taille du stock (millions de poissons) de <u>N. gibberifrons</u>, sous-zone de la Géorgie du Sud, F=0,071, basées sur la VPA.
Figure 11	Simulations de la taille du stock (millions de poissons) de <u>N. gibberifrons</u>, sous-zone de la Géorgie du Sud, F=0,142, basées sur SURVAN.
Figure 12	Simulations de la taille du stock (millions de poissons) de <u>N. gibberifrons</u>, sous-zone de la Géorgie du Sud, F=0,071, basées sur SURVAN.
Figure 13	Simulations de la taille du stock (millions de poissons) de <u>C. gunnari</u>, sous-zone de la Géorgie du Sud, F=3,5, basées sur la VPA.
Figure 14	Simulations de la taille du stock (millions de poissons) de <u>C. gunnari</u>, sous-zone de la Géorgie du Sud, F=1,75, basées sur la VPA.
Figure 15	Simulations de la taille du stock (millions de poissons) de <u>C. gunnari</u>, sous-zone de la Géorgie du Sud, F=0,875, basées sur la VPA.
Figure 16	Simulations de la taille du stock (millions de poissons) de <u>C. gunnari</u>, sous-zone de la Géorgie du Sud, F=3,5, basées sur SURVAN.
Figure 17	Simulations de la taille du stock (millions de poissons) de <u>C. gunnari</u>, sous-zone de la Géorgie du Sud, F=1,75, basées sur SURVAN.
Figure 18	Simulations de la taille du stock (millions de poissons) de <u>C. gunnari</u>, sous-zone de la Géorgie du Sud, F=0,875, basées sur SURVAN.
Figure 19	Simulations de la taille du stock (millions de poissons) de <u>N. rossii</u>, plateau des Iles Kerguelen, F=0,76, basées sur la VPA.
Figure 20	Simulations de la taille du stock (millions de poissons) de <u>N. rossii</u>, plateau des Iles Kerguelen, F=0,38, basées sur la VPA.
Figure 21	Simulations de la taille du stock (millions de poissons) de <u>N. squamifrons</u>, plateau des Iles Kerguelen, F=0,72, basées sur la VPA.

Figure 22 Simulations de la taille du stock (millions de poissons) de N. squamifrons, plateau des Iles Kerguelen, F=0,36, basées sur la VPA.

Figure 23 Simulations du poids du stock et de la prise pour N. rossii, sous-zone de la Géorgie du Sud, F=0,55, basées sur la VPA.

Figure 24 Simulations du poids du stock et de la prise pour N. rossii, sous-zone de la Géorgie du Sud, basées sur la VPA.

Figure 25 Simulations du poids du stock et de la prise pour N. rossii, sous-zone de la Géorgie du Sud, basées sur SURVAN.

Figure 26 Simulations du poids du stock et de la prise pour Notothenia gibberifrons, sous-zone de la Géorgie du Sud, basées sur la VPA.

Figure 27 Simulations du poids du stock et de la prise pour N. gibberifrons, sous-zone de la Géorgie du Sud, basées sur SURVAN.

Figure 28 Simulations du poids du stock et de la prise pour C. gunnari, sous-zone de la Géorgie du Sud, basées sur la VPA.

Figure 29 Simulations du poids du stock et de la prise pour C. gunnari, sous-zone de la Géorgie du Sud, basées sur SURVAN.

Figure 30 Simulations du poids du stock et de la prise pour N. rossii, plateau des Iles Kerguelen, basées sur la VPA.

Figure 31 Simulations du poids du stock et de la prise pour N. squamifrons, plateau des Iles Kerguelen, basées sur la VPA.

Encabezamientos de las Tablas

Tabla 1 Edad inicial y cantidades en millones de restablecimientos individuales.

Tabla 2 Parámetros utilizados en el modelo de simulación (Georgia del Sur).

Tabla 3 Parámetros utilizados en el modelo de simulación (Kerguelén).

Tabla 4 Promedio de las diez proyecciones a 20 años para el tamaño de la población en números (x 10^{-6}) y peso (x 10^{-3}).

Tabla 5 Promedio de las diez proyecciones a 20 años para el tamaño de la población en números (x 10^{-6}) y peso (x 10^{-3}).

Tabla 6 Resumen de los puntos de referencia estándar para las proyecciones (reservas de Georgia del Sur).

Tabla 7 Resumen de los puntos de referencia estándar para las proyecciones (Kerguelén).

Tabla 8 Comparación de los rendimientos simulados con los presentados en años anteriores.

Leyendas de las Figuras

Figura 1 Función de densidad de probabilidad de restablecimiento universal utilizada en la simulación.

Figura 2 Frecuencias de restablecimiento generadas aleatoriamente (N^{o} de peces x 10^{-6}).

Figura 3 Simulaciones del tamaño de la reserva (millones de peces) de N. rossii, subárea de Georgia del Sur, F=0.55, basadas en el análisis de la población virtual (VPA).

Figura 4 Simulaciones del tamaño de la reserva (millones de peces) de N. rossii, subárea de Georgia del Sur, F=0.177, basadas en el análisis de la población virtual (VPA).

Figura 5 Simulaciones del tamaño de la reserva (millones de peces) de N. rossii, subárea de Georgia del Sur, F=0.089, basadas en el análisis de la población virtual (VPA).

Figura 6 Simulaciones del tamaño de la reserva (millones de peces) de N. rossii, subárea de Georgia del Sur, F=0.55, basadas en la SURVAN.

Figura 7 Simulaciones del tamaño de la reserva (millones de peces) de N. rossii, subárea de Georgia del Sur, F=0.177, basadas en la SURVAN.

Figura 8 Simulaciones del tamaño de la reserva (millones de peces) de N. rossii, subárea de Georgia del Sur, F=0.089, basadas en la SURVAN.

Figura 9 Simulaciones del tamaño de la reserva (millones de peces) de N. gibberifrons, subárea de Georgia del Sur, F=0.142, basadas en el análisis de la población virtual (VPA).

Figura 10 Simulaciones del tamaño de la reserva (millones de peces) de N. gibberifrons, subárea de Georgia del Sur, F=0.071, basadas en el análisis de la población virtual (VPA).

Figura 11 Simulaciones del tamaño de la reserva (millones de peces) de N. gibberifrons, subárea de Georgia del Sur, F=0.142, basadas en la SURVAN.

Figura 12 Simulaciones del tamaño de la reserva (millones de peces) de N. gibberifrons, subárea de Georgia del Sur, F=0.071, basadas en la SURVAN.

Figura 13 Simulaciones del tamaño de la reserva (millones de peces) de C. gunnari, subárea de Georgia del Sur, F=3.5, basadas en el análisis de la población virtual (VPA).

Figura 14 Simulaciones del tamaño de la reserva (millones de peces) de C. gunnari, subárea de Georgia del Sur, F=1.75, basadas en el análisis de la población (VPA).

Figura 15 Simulaciones del tamaño de la reserva (millones de peces) de C. gunnari, subárea de Georgia del Sur, F=0.875, basadas en el análisis de la población virtual (VPA).

Figura 16 Simulaciones del tamaño de la reserva (millones de peces) de C. gunnari, subárea de Georgia del Sur, F=3.5, basadas en la SURVAN.

Figura 17 Simulaciones del tamaño de la reserva (millones de peces) de C. gunnari, subárea de Georgia del Sur, F=1.75, basadas en la SURVAN.

Figura 18 Simulaciones del tamaño de la reserva (millones de peces) de C. gunnari, subárea de Georgia del Sur, F=0.875, basadas en la SURVAN.

Figura 19 Simulaciones del tamaño de la reserva (millones de peces) de N. rossii, Plataforma de la Isla Kerguelén, F=0.76, basadas en el análisis de la población virtual (VPA).

Figura 20 Simulaciones del tamaño de la reserva (millones de peces) de N. rossii, Plataforma de la Isla Kerguelén, F=0.38, basadas en el análisis de la población virtual (VPA).

Figura 21 Simulaciones del tamaño de la reserva (millones de peces) de N. squamifrons, Plataforma de la Isla Kerguelén, F=0.72, basadas en el análisis de la población virtual (VPA).

Figura 22 Simulaciones del tamaño de la reserva (millones de peces) de N. squamifrons, Plataforma de la Isla Kerguelén, F=0.36, basadas en el análisis de la población virtual (VPA).

Figura 23 Simulaciones del peso de la reserva y de la captura para N. rossii, subárea de Georgia del Sur, F=0.55, basadas en el análisis de la población virtual (VPA).

Figura 24 Simulaciones del peso de la reserva y de la captura para N. rossii, subárea de Georgia del Sur, basadas en el análisis de la población virtual (VPA).

Figura 25 Simulaciones del peso de la reserva y de la captura para N. rossii, subárea de Georgia del Sur, basadas en la SURVAN.

Figura 26 Simulaciones del peso de la reserva y de la captura para Notothenia gibberifrons, subárea de Georgia del Sur, basadas en el análisis de la población virtual (VPA).

Figura 27 Simulaciones del peso de la reserva y de la captura para N. gibberifrons, subárea de Georgia del Sur, basadas en la SURVAN.

Figura 28 Simulaciones del peso de la reserva y de la captura para C. gunnari, subárea de Georgia del Sur, basadas en el análisis de la población virtual (VPA).

Figura 29 — Simulaciones del peso de la reserva y de la captura para C. gunnari, subárea de Georgia del Sur, basadas en la SURVAN.

Figura 30 — Simulaciones del peso de la reserva y de la captura para N. rossii, Plataforma de la Isla Kerguelén, basadas en el análisis de la población virtual(VPA).

Figura 31 — Simulaciones del peso de la reserva y de la captura para N. squamifrons, Plataforma de la Isla Kerguelén, basadas en el análisis de la población virtual (VPA).

Заголовки к таблицам

Таблица 1 — Начальный возраст и количество (в миллионах штук) особей пополнения.

Таблица 2 — Параметры, использованные при построении имитационной модели (Южная Георгия).

Таблица 3 — Параметры, использованные при построении имитационной модели (Кергелен).

Таблица 4 — Средние величины десяти 20-летних прогнозов для размеров запасов - по количеству ($x10^{-6}$) и весу ($x10^{-3}$).

Таблица 5 — Средние величины десяти 20-летних прогнозов для размеров запасов - по количеству ($x10^{-6}$) и весу ($x10^{-3}$).

Таблица 6 — Сводная таблица стандартных исходных пунктов для прогнозов (запасы района Южной Георгии).

Таблица 7 — Сводная таблица стандартных исходных пунктов для прогнозов (запасы Кергелена).

Таблица 8 — Сравнение полученных имитационным моделированием данных по величине уловов с фактическими величинами уловов в прошлом.

Подписи к рисункам

Рисунок 1 — Универсальная плотность распределения вероятностей для пополнения, используемая в имитационных моделях.

Рисунок 2 Выборочно образованные графики частоты пополнения (кол-во рыб x 10^{-6}).

Рисунок 3 Полученные с помощью имитационного моделирования величины объема запаса (в миллионах особей) для N. rossii, подрайон Южной Георгии, F = 0,55, расчет основан на VPA.

Рисунок 4 Полученные с помощью имитационного моделирования величины объема запаса (в миллионах особей) для N. rossii, подрайон Южной Георгии, F = 0,177, расчет основан на VPA.

Рисунок 5 Полученные с помощью имитационного моделирования величины объема запаса (в миллионах особей) для N. rossii, подрайон Южной Георгии, F = 0,089, расчет основан на VPA.

Рисунок 6 Полученные с помощью имитационного моделирования величины объема запаса (в миллионах особей) для N. rossii, подрайон Южной Георгии, F = 0,55, расчет основан на SURVAN.

Рисунок 7 Полученные с помощью имитационного моделирования величины объема запаса (в миллионах особей) для N. rossii, подрайон Южной Георгии, F = 0,177, расчет основан на SURVAN.

Рисунок 8 Полученные с помощью имитационного моделирования величины объема запаса (в миллионах особей) для N. rossii, подрайон Южной Георгии, F = 0,089, расчет основан на SURVAN.

Рисунок 9 Полученные с помощью имитационного моделирования величины объема запаса (в миллионах особей) для N. gibberifrons, подрайон Южной Георгии, F = 0,142, расчет основан на VPA.

Рисунок 10 Полученные с помощью имитационного моделирования величины объема запаса (в миллионах особей) для N. gibberifrons, подрайон Южной Георгии, F = 0,071, расчет основан на VPA.

Рисунок 11 Полученные с помощью имитационного моделирования величины объема запаса (в миллионах особей) для N. gibberifrons, подрайон Южной Георгии, F = 0,142, расчет основан на SURVAN.

Рисунок 12 Полученные с помощью имитационного моделирования величины объема запаса (в миллионах особей) для N. gibberifrons, подрайон Южной Георгии, F = 0,071, расчет основан на SURVAN.

Рисунок 13 Полученные с помощью имитационного моделирования величины объема запаса (в миллионах особей) для C. gunnari, подрайон Южной Георгии, F = 3,5, расчет основан на VPA.

Рисунок 14 Полученные с помощью имитационного моделирования величины объема запаса (в миллионах особей) для C. gunnari, подрайон Южной Георгии, F = 1,75, расчет основан на VPA.

Рисунок 15 Полученные с помощью имитационного моделирования величины объема запаса (в миллионах особей) для C. gunnari, подрайон Южной Георгии, F = 0,875, расчет основан на VPA.

Рисунок 16 Полученные с помощью имитационного моделирования величины объема запаса (в миллионах особей) для C. gunnari, подрайон Южной Георгии, F = 3,5, расчет основан на SURVAN.

Рисунок 17 Полученные с помощью имитационного моделирования величины объема запаса (в миллионах особей) для C. gunnari, подрайон Южной Георгии, F = 1,75, расчет основан на SURVAN.

Рисунок 18 Полученные с помощью имитационного моделирования величины объема запаса (в миллионах особей) для C. gunnari, подрайон Южной Георгии, F = 0,875, расчет основан на SURVAN.

Рисунок 19 Полученные с помощью имитационного моделирования величины объема запаса (в миллионах особей) для N. rossii, шельф острова Кергелен, F = 0,76, расчет основан на VPA.

Рисунок 20 Полученные с помощью имитационного моделирования величины объема запаса (в миллионах особей) для N. rossii, шельф острова Кергелен, F = 0,38, расчет основан на VPA.

Рисунок 21 Полученные с помощью имитационного моделирования величины объема запаса (в миллионах особей) для N. squamifrons, шельф острова Кергелен, F = 0,72, расчет основан на VPA.

Рисунок 22 Полученные с помощью имитационного моделирования величины объема запаса (в миллионах особей) для N. squamifrons, шельф острова Кергелен, F = 0,36, расчет основан на VPA.

Рисунок 23 Полученные с помощью имитационного моделирования величины для веса запаса и для улова N. rossii, подрайон Южной Георгии, F = 0,55, расчет основан на VPA.

Рисунок 24 Полученные с помощью имитационного моделирования величины для веса запаса и для улова N. rossii, подрайон Южной Георгии, расчет основан на VPA.

Рисунок 25 Полученные с помощью имитационного моделирования величины для веса запаса и для улова N. rossii, подрайон Южной Георгии, расчет основан на SURVAN.

Рисунок 26 Полученные с помощью имитационного моделирования величины для веса запаса и для улова Nototheniа gibberifrons, подрайон Южной Георгии, расчет основан на VPA.

Рисунок 27 Полученные с помощью имитационного моделирования величины для веса запаса и для улова N. gibberifrons, подрайон Южной Георгии, расчет основан на SURVAN.

Рисунок 28 Полученные с помощью имитационного моделирования величины для веса запаса и для улова C. gunnari, подрайон Южной Георгии, расчет основан на VPA.

Рисунок 29 Полученные с помощью имитационного моделирования величины для веса запаса и для улова C. gunnari, подрайон Южной Георгии, расчет основан на SURVAN.

Рисунок 30 Полученные с помощью имитационного моделирования величины для веса запаса и для улова N. rossii, шельф острова Кергелен, расчет основан на VPA.

Рисунок 31 Полученные с помощью имитационного моделирования величины для веса запаса и для улова N. squamifrons, шельф острова Кергелен, расчет основан на VPA.