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SENSITIVITY ANALYSIS OF MULTISPECIES ASSESSMENTS AND PREDICTIONS FOR THE NORTH SEA

by

John T. Finn

Department of Forestry & Wildlife Management

University of Massachusetts, Amherst, MA 01003

Josef S. Idoine

NEFC, NMFS, Woods Hole, MA 02543

and

Henrik Gislason

Danish Institute for Fisheries & Marine Research

Charlottenlund Castle, 2920 Charlottenlund, Denmark.

Introduction

Sensitivity of the MSVPA model to small changes in its input parameters is of great interest. The hope is that those parameters that are not well known, do not have a large impact on model output. The major predictions of the MSVPA are recruitment, Stock sizes, M2s, Fs and suitabilities. In 1986, the MSWG did a sensitivity analysis using long term yields as predicted by MSFOR as the response variables (Anon. 1986). In this paper, we examine the sensitivity of six outputs from the MSVPA model itself to 'small' changes in 33 of the MSVPA parameters, including M1s, predator ration, and terminal Fs. We also examine the sensitivity of long term yields (both biomass and value) from the MSFOR model to the same 33 MSVPA parameters, and to 29 MSFOR parameters, namely recruitment rates, fishing fleet efforts, and terminal Fs. Finally, we looked at the sensitivity of diets in the third quarter of 1991 to both MSVPA and MSFOR parameters.

MSVPA response variables were chosen to give an idea of the sensitivity relationships, but not to exhaustively assess the sensitivities of all responses to all parameters. The six response variables are:

1) total biomass in 1974,

2) total biomass in 1989,

3) average F for Age 1 Cod,

4) average N for Age 1 cod,

5) average predation deaths (D) for age 1 cod, and

6) average M2 for age 1 cod.

These analyses focussed on the effects of parameters on cod primarily because of the overall importance of that species as a predator, and because several important management scenarios previously assessed were intended to improve its stock status. All averages are for years 1983-1988. The 33 parameters are listed in Table

1 with the nominal value, lower value and upper value used in the simulation experiments. Sensitivity runs were undertaken with the nominal values of food consumption set at 150% of the levels used in the MSVPA. The lower and upper bounds of food consumption were set at 100% and 200% of the MSVPA values. It was felt by the working group that consumption levels currently used in the MSVPA model are minimum estimates for most species, and the higher consumption estimates used in the sensitivity runs were probably more realistic. This subject is considered in more detail in Section 8.6.

Long-term yields were considered the most important responses to examine, because they directly affect the advice given to managers. Yields were expressed in biomass (t), and total yield of the system was expressed in biomass (t), and value (European Currency Units, ECUs).

The main objective of this paper is to identify the parameters in MSVPA and MSFOR that are most important to the model results, and to the management advice that comes out of the model simulations.

Methods

MSVPA Model

The MSVPA model is an extension of the single species VPA (Gulland 1965) in which natural mortality is split into mortality due to predation, M2, and a constant residual natural mortality, M1, due to all other causes.

Only predation among commersially important fish stocks is explicitly considered. Predation is estimated as a function of food composition, the predators' total food intake requirements, and the biomass of the predators. Total food intake per predator is assumed to be constant. The food composition is modelled by an expression borrowed from Andersen and Ursin (1977) in which the biomass of each prey species age group is weighted by a constant which reflects its suitability to predation by a particular predator age group. These suitability constants may be estimated within the model provided data on the food composition of the predators is available (Gislason and Sparre 1987).

MSFOR Model

The MSFOR model is the predictive counterpart of MSVPA. The predation parameters and terminal stock sizes are output from the MSVPA and used by MSFOR, but as in traditional single species forecasts, MSFOR also requires estimates of future recruitment and fishing mortality.

Both models have been used by the ICES Multispecies Assessment Working Group over a number of years and additional information may be found in the reports of this working group (Anon. 1984, Anon. 1986, Anon. 1987, Anon. 1988, Anon. 1989, Anon. 1991). At the 1986 and 1990 meetings, sensitivity analysis of tne models was performed (Anon. 1987, Anon. 1991). This paper extends the analysis carried out at the last meeting further. The MSVPA and MSFOR programs and associated databases are identical to those used at the 1990 meeting (Anon. 1991).

Sensitivity Analysis

Response surface methods (Box and Draper 1987) were used to determine the sensitivities of the response variables to the parameters. The overall process was done in two steps. First, an efficient, fractional factorial design was produced for not only the 33 MSVPA parameters in Table 1, but also for the 29 MSFOR parameters in Table 2. We used a 2^{k-p} fractional factorial design determined by the 'fold-over' method (Box and Draper 1987, Finn 1986) where k=62 and p=55. This produced a set of 128 experimental runs in addition to the central run (the 'key run' with food consumption parameters at 150%). This set of runs allowed us to determine the main effects. In order to test second order terms, axial (or star) points were added. The star runs are determined by setting each parameter at a value of $\pm\alpha$, while every other parameter is set to the nominal value. The value of α is $(128)^{0.25} = 3.36359$, where 128 is the number of fractional factorial runs made (Box and Draper 1987, p. 508).

Sensitivities are expressed as the percent change in the response variable caused by a 10% change in the parameter. A value of 10 indicates that the response changed the same percent as the parameter. A value of 1 indicates that the response changed only one-tenth as much as the parameter.

RESULTS

Sensitivity of Selected MSVPA Responses to MSVPA Parameters

None of the response variables were sensitive to the technical parameters (Table 3). Total biomasses in 1974 and 1989 were not sensitive to any of the M1s (no sensitivities > 3). For one year old cod, N will increase 5.56% while F will decrease 3.3% with a 10% increase in Cod M1. No other M1 values had a greater than 2.5% effect on the 1-year old cod responses. Biomass totals were relatively insensitive to food consumption multipliers (no value greater than 3.5). The number of one-year old cod deaths will increase 7.78% for a 10% increase in cod food consumption, and cod N will increase 3.3%. Whiting food consumption was the only other predator feeding estimate that influenced one-year old cod (a 2% increase in cod M2 for a 10% increase in whiting consumption). Terminal Fs had no significant effect on MSVPA responses.

Sensitivity of Yields

Table 4 summarizes the sensitivity coefficients of 13 MSFOR dependent variables (11 species yields in weight, plus total species yield in weight [t] and value

[ECUs]) to various MSVPA parameters (Table 1). Small coefficients in the table (≤ |0.4|) may result from the assumption of linear sensitivity coefficients, even where there is obviously no effect present (e.g., between flatfish and other species). Thus, sensitivity coefficients ≤ |0.4| should be considered zeros in Tables 4 and 5.

Again, MSFOR predictions were not sensitive to the eight technical parameters in the MSVPA model (Table 4). None of the MSVPA parameters had a sensitivity coefficient greater than 5. Generally, individual species yields were most sensitive to their own M1 levels. Increases in food consumption by predators affected prey negatively and direct competitors positively. Mackerel yields were not affected by any food consumption parameter including their own. The highest sensitivity was of Norway pout yield to saithe M1 (4.9), followed by the sensitivity of Norway pout yield to its own M1 (-4.8). Mackerel food consumption had the greatest influence on total system yield in biomass (1.8).

MSFOR predictions were, in some cases, very sensitive to terminal fishing mortality rates, recruitment levels, and fleet effort (Table 5 and Figures 13). The highest sensitivities overall were Norway pout yield to: Norway pout recruitment (16.4), saithe recruitment (-13), and saithe terminal F (12.9). Haddock yield was very sensitive to saithe terminal F (10.8), and saithe recruitment (-10.7). Cod yield was moderately sensitive to cod recruitment (5.8), and to a lesser extent to roundfish fleet effort (2.9).

Total multispecies yield in biomass was most sensitive to sandeel recruitment (4.5), Norway pout recruitment (3.4), saithe terminal F (3.0) and saithe recruitment (-3.0). Total value was most sensitive to saithe terminal F (2.1), Norway pout recruitment (2.0), saithe recruitment (-1.7), and sandeel recruitment (1.7). The dependence of total value on these parameters is plotted in two-dimensional parameter space in Figures 1-3. The linear sensitivity coefficients (equivalent to multiple linear regression slopes) are used to extrapolate the dependent variable (in this case total value) over a range of ±30% of the nominal parameter values (Table 2.8.1.2). Figure 3 is especially illuminating, since it essentially evaluates the consequences of large increases in effort in the Industrial Demersal fishery, if there are underlying positive stock-recruit relationships for sandeel and Norway pout. A 50% increase in Industrial Demersal fishing effort results in significantly lower sandeel (-28%) and Norway pout (-12%) standing stock biomasses (Anon. 1991, Table 4.2.2). If S-R relations are positive for these two species, then the additive effects as suggested in Figure 3 indicate rather substantial declines in the total value derived from the North Sea system.

Given the general sensitivity of MSFOR results to recruitment levels (Table 5), it should be reiterated that long-term advice must be regarded as contingent upon the validity of the underlying stock-recruitment relationship assumed in such scenarios.

Diet

Table 6 (4.3.3.3) shows the relative sensitivity of diets in quarter 3 of 1991 to MSVPA parameters (Table 1). Diets of cod, whiting, saithe, mackerel and haddock are listed. Each column in Table 6 represents a predator-prey interaction. The mean prey consumed in quarter 3 is shown at the top of the column as well as the R^2 for the regression. The effect of saithe M1 on the diet of cod, for example, can be determined by reading across the 'SAITHM1' row. An increase of saithe M1 of 10%, would cause a 2.3% decrease in cod consumed, a 1.1% decrease in whiting, a 1.9% increase in haddock, a 1.7% decrease in herring, a 3% increase in Norway pout, and a 1% decrease in sandeel consumed.

In general, diets are not very sensitive to MSVPA parameters. The highest sensitivity in Table 6 is a decrease of 4.9% in consumption of Norway pout by haddock in response to an increase of haddock M1 by 10%. Haddock consumption of N. pout decreases 4.6% with a 10% increase in saithe food consumption. No other sensitivities in the table are above 4.

Table 7 (4.3.3.4) shows the relative sensitivity of diets in quarter 3 of 1991 to MSFOR parameters. In general, diets are much more sensitive to MSFOR parameters, especially recruitment, tahn to MSVPA parameters. A 10% increase in haddock terminal F decreases haddock consumption of Norway pout by 11.8%. A 10% increase in saithe terminal F decreases saithe herring consumption by 6.2%.

Discussion

The six MSVPA response variables analyzed were not very sensitive to any of the 33 parameters from the MSVPA program. No sensitivity coefficient was higher than 10, and only two coefficients were higher than 5. Even food consumption parameters do not have a large effect. Food consumption was changed by ±33% (from 150% nominal to 100% and 200%). Even multiplying the sensitivities by 3.33 gives overall low values. The largest sensitivity is the effect of cod food consumption on 1-year old cod deaths, a change of 7.8% for a 10% change, or a 25% change for a 33% increase in cod food consumption. An increase of 33% of all of five food consumption parameters at once, would increase biomass in 1974 by 22%, in 89 by 11%, D by 33%, M2 by 24.6%, and N by 13% (assuming no interactions).

Although only a few of the many potential response variables from the MSVPA model were analyzed in these sensitivity analyses, the runs nevertheless illustrate the damping of the responses to variations in input variables. Only two of the response variables varied by more than half of the perturbation on the input variables, and most responses were about an order of magnitude smaller than the variation in the parameters simulated. These sensitivity analyses further strengthen the overall conclusion of the robustness of the results of the MSVPA, despite continuing uncertainties about specific input parameters.

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Table 1. MSVPA Parameters Used in the Sensitivity Analyses.

Variable #	Variable Name	Nominal Value	Lower Value	Upper Value
1	MIXSUI	0.30	0.27	0.33
2	MIXM2	0.30	0.27	0.33
3	EPFSF1	0.1E-5	0.09E-5	0.11E-5
4	EPFMS2	0.1E-5	0.09E-5	0.11E-5
5	EPSUI	0.1E-5	0.09E-5	0.11E-5
6	OTHER FOOD	30.0E+6	15.0E+6	45.0E+6
7	Lower Limit WS/W	0.1E-5	0.1E-6	0.1E-4
8	Upper Limit WS/W	0.1E+7	0.1E+6	0.1E+8
9	COD M1 Multiplier	1	0.9	1.1
10	WHITING M1 Multiplier	1	0.9	1.1
11	SAITHE M1 Multiplier	1	0.9	1.1
12	MACKEREL M1 Multiplier	1	0.9	1.1
13	HADDOCK M1 Multiplier	1	0.9	1.1
14	HERRING M1 Multiplier	1	0.9	1.1
15	SPRAT M1 Multiplier	1	0.9	1.1
16	N. POUT M1 Multiplier	1	0.9	1.1
17	SANDEEL M1 Multiplier	1	0.9	1.1
18	PLAICE M1 Multiplier	1	0.9	1.1
19	SOLE M1 Multiplier	1	0.9	1.1
20	COD Food Consumption	1.5	1.0	2.0
21	WHITING Food Consumption	1.5	1.0	2.0
22	SAITHE Food Consumption	1.5	1.0	2.0
23	MACKEREL Food Consumption	1.5	1.0	2.0
24	HADDOCK Food Consumption	1.5	1.0	2.0

Table 1. (Continued)

25	COD Terminal F	1	0.9	1.1
26	WHITING Terminal F	1	0.9	1.1
27	SAITHE Terminal F	1	0.9	1.1
28	MACKEREL Terminal F	1	0.9	1.1
29	HADDOCK Terminal F	1	0.9	1.1
30	HERRING Terminal F	1	0.9	1.1
31	SPRAT Terminal F	1	0.9	1.1
32	N. POUT Terminal F	1	0.9	1.1
33	SANDEEL Terminal F	1	0.9	1.1

Table 2. MSFOR Parameters Used in the Sensitivity Analyses.

Variable #	Variable Name	Nominal Value	Lower Value	Upper Value
34	COD Terminal F	1	0.9	1.1
35	WHITING Terminal F	1	0.9	1.1
36	SAITHE Terminal F	1	0.9	1.1
37	MACKEREL Terminal F	1	0.9	1.1
38	HADDOCK Terminal F	1	0.9	1.1
39	HERRING Terminal F	1	0.9	1.1
40	SPRAT Terminal F	1	0.9	1.1
41	N. POUT Terminal F	1	0.9	1.1
42	SANDEEL Terminal F	1	0.9	1.1
43	PLAICE Terminal F	1	0.9	1.1
44	SOLE Terminal F	1	0.9	1.1
45	COD Recruitment	1	0.9	1.1
46	WHITING Recruitment	1	0.9	1.1
47	SAITHE Recruitment	1	0.9	1.1
48	MACKEREL Recruitment	1	0.9	1.1
49	HADDOCK Recruitment	1	0.9	1.1
50	HERRING Recruitment	1	0.9	1.1
51	SPRAT Recruitment	1	0.9	1.1
52	N. POUT Recruitment	1	0.9	1.1
53	SANDEEL Recruitment	1	0.9	1.1
54	PLAICE Recruitment	1	0.9	1.1
55	SOLE Recruitment	1	0.9	1.1
56	Roundfish Fleet F	1	0.9	1.1

Table 2. (Continued).

57	Industrial Dem. Fleet F	1	0.9	1.1
58	Industrial Pel. Fleet F	1	0.9	1.1
59	Herring Fleet F	1	0.9	1.1
60	Saithe Fleet F	1	0.9	1.1
61	Mackerel Fleet F	1	0.9	1.1
62	Flatfish Fleet F	1	0.9	1.1

Table 3. Relative Sensitivities of MSVPA Responses to MSVPA Parameters. Sensitivities are expressed as the percent change in the response variable (% of mean) caused by a 10% change in the parameter.

			Cod 1-year-olds (Mean for 83-88)			
	TOTBIOM74	TOTBIOM89	F	N	D	M2
(Means)	14385759	8946229	0.176	401997	126093	0.451
R^2	99.3	99.8	99.7	99.7	99.8	99.9
MIXSUI	0.00	0.00	0.00	0.00	0.00	0.00
MIXM2	-0.01	0.00	0.00	0.00	-0.01	0.00
EPFSF1	0.00	0.00	0.00	0.00	0.00	0.00
EPFMS2	0.00	0.00	0.00	0.00	0.01	0.00
EPSUI	0.00	0.00	0.00	0.00	0.00	0.00
OTHFood	0.00	0.00	0.00	0.00	-0.01	0.00
LLimWSW	0.00	0.00	0.00	0.00	0.00	0.00
ULimWSW	0.00	0.00	0.00	0.00	0.00	0.00
CODM1	0.21	0.02	-3.13	5.56	2.46	0.00
WHITGM1	0.43	0.35	-0.02	0.48	1.42	0.00
SAITNM1	0.89	0.10	0.00	0.01	0.02	0.00
MACKLM1	2.39	-0.03	0.00	0.02	0.06	0.00
HADDKM1	0.22	0.06	0.00	-0.03	-0.08	0.00
HERRGM1	0.04	0.18	0.00	0.00	0.00	0.00
SPRATM1	0.66	0.03	0.00	-0.22	-0.67	0.00
NPOUTM1	0.60	0.25	0.01	-0.03	-0.08	0.00
SandeM1	1.34	0.87	0.00	-0.08	-0.22	0.00
PLAICM1	0.10	0.06	0.00	0.00	0.00	0.00

Table 3. (Continued)

	TOTBIOM74	TOTBIOM89	Cod 1-year-olds (Mean for 83-88) F	N	D	M2
SOLEM1	0.01	0.00	0.00	0.00	0.00	0.00
CODFC	0.46	0.21	-0.98	3.30	7.78	0.00
WHITGFC	1.13	1.71	0.00	0.75	2.25	0.00
SAITHFC	1.74	1.20	0.02	-0.04	-0.08	0.00
MACKLFC	3.26	0.20	-0.01	0.02	0.04	0.00
HADDKFC	0.06	0.03	0.00	0.00	0.00	0.00
CODTFM	-0.01	0.00	0.00	0.00	0.00	0.00
WHITTFM	0.00	0.00	0.00	0.00	0.00	0.00
SATHTFM	-0.02	0.00	0.00	0.00	-0.01	0.00
MACKTFM	-0.11	0.00	0.00	0.00	0.00	0.00
HADDTFM	0.00	0.00	0.00	0.00	0.00	0.00
HERRTFM	0.00	-0.01	0.00	0.00	-0.01	0.00
SPRTTFM	0.01	0.00	0.01	0.00	-0.01	0.00
N.PTTFM	0.00	0.01	-0.01	0.02	0.04	0.00
SANDTFM	0.06	-0.01	0.00	0.01	0.03	0.00

Table 4. Relative Sensitivities of Long Term Yields to MSVPA Parameters. Sensitivities are expressed as the percent change in the response variable (% of mean) caused by a 10% change in the parameter.

Long Term Yields (Biomass)

	COD	Whiting	Saithe	Mackerel	Haddock	Herring	Sprat
(Means)	269404	201745	163043	34528	302507	422139	274205
R^2	54.7	43.0	46.8	44.4	45.4	53.0	46.0
MIXSUI	0.29	-0.07	-0.33	0.19	0.55	0.37	0.12
MIXM2	0.05	0.24	-0.42	-0.12	-0.04	-0.36	0.30
EPFSF1	0.12	-0.11	0.42	-0.10	-0.25	0.33	0.23
EPFMS2	-0.17	0.38	0.45	-0.09	-0.96	-0.24	-0.26
EPSUI	-0.38	-0.10	0.44	0.11	-1.90	-0.39	-0.18
OTHFood	0.06	-0.03	0.06	-0.01	0.00	0.05	-0.02
LLimWSW	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ULimWSW	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CODM1	-1.59	0.13	0.44	0.00	-1.58	-0.38	-0.15
WHITGM1	0.08	-0.63	0.43	0.00	-0.60	0.14	0.61
SAITNM1	0.50	0.46	-1.34	0.00	3.84	0.24	0.44
MACKLM1	0.97	0.14	-0.44	0.97	0.00	1.00	0.73
HADDKM1	-0.15	-0.50	-0.41	0.00	-2.85	-0.07	0.60
HERRGM1	0.14	0.21	-0.45	0.00	0.00	-1.13	-0.66
SPRATM1	-0.15	-0.17	0.44	0.00	-0.44	0.07	-0.87
NPOUTM1	-0.31	0.30	0.44	0.00	-2.61	-0.39	-0.25
SandeM1	0.05	-0.53	-0.44	0.00	1.04	0.09	0.18
PLAICM1	-0.01	0.11	-0.44	0.00	0.37	-0.36	-0.30

Table 4. (Continued)

Long Term Yields (Biomass)

	COD	Whiting	Saithe	Mackerel	Haddock	Herring	Sprat
SOLEM1	-0.13	-0.23	0.44	-0.01	-0.16	0.21	0.68
CODFC	-0.70	0.17	0.11	-0.03	-0.61	-0.80	-0.11
WHITGFC	-0.52	0.00	0.11	0.03	-1.09	-0.79	0.29
SAITHFC	0.58	0.04	0.10	-0.03	3.01	0.13	-0.16
MACKLFC	1.28	0.31	-0.12	-0.03	0.86	1.37	2.22
HADDKFC	0.07	-0.01	-0.11	0.03	0.28	0.05	0.00
CODTFM	-0.24	-0.02	0.44	-0.11	0.12	-0.37	-0.84
WHITTFM	-0.07	-0.42	0.43	-0.09	-0.42	-0.14	0.74
SATHTFM	-0.08	0.25	-0.42	-0.09	0.09	-0.13	-0.13
MACKTFM	0.38	0.12	-0.44	-0.10	1.76	0.31	0.00
HADDTFM	0.24	-0.39	-0.45	0.09	1.13	0.24	0.26
HERRTFM	-0.06	0.11	-0.42	0.11	0.41	-0.34	-0.23
SPRTTFM	-0.01	-0.26	0.42	0.11	-0.04	0.36	-0.20
N.PTTFM	0.02	0.46	0.46	0.09	0.15	0.06	0.42
SANDTFM	0.05	0.40	0.40	0.11	0.48	-0.03	0.47

Table 4. (Continued).

	Long Term Yields (Biomass) N. Pout	Sandeel	Plaice	Sole	Total	Total Value
(Means)	516654	1072684	162781	19564	3443004	1248880
R^2	52.4	58.1	46.1	48.0	59.7	39.7
MIXSUI	0.96	-0.13	-0.27	-0.22	0.39	0.06
MIXM2	1.11	-0.85	0.43	-0.49	0.08	-0.02
EPFSF1	0.33	-0.38	-0.43	0.36	0.17	0.03
EPFMS2	-1.09	0.35	0.43	0.49	-0.33	-0.09
EPSUI	-1.58	0.78	0.43	0.50	-0.41	-0.22
OTHFood	0.16	0.22	-0.06	0.06	0.06	0.03
LLimWSW	0.00	0.00	0.00	0.00	0.00	0.00
ULimWSW	0.00	0.00	0.00	0.00	0.00	0.00
CODM1	-1.72	0.38	-0.43	-0.49	-0.65	-0.80
WHITGM1	0.43	0.47	0.43	-0.36	0.04	0.04
SAITNM1	4.89	0.31	-0.42	0.48	1.02	0.71
MACKLM1	0.06	3.34	0.43	0.36	1.13	0.58
HADDKM1	0.22	1.01	0.43	0.36	-0.09	-0.36
HERRGM1	1.80	0.45	-0.43	0.49	0.01	-0.02
SPRATM1	0.55	-0.33	0.43	-0.35	0.09	-0.03
NPOUTM1	-4.84	-0.74	-0.43	-0.49	-1.07	-0.67
SandeM1	1.32	-3.10	0.43	0.49	-0.48	0.11
PLAICM1	-0.29	-1.06	-1.63	0.36	-0.30	-0.31
SOLEM1	-1.52	0.84	0.43	-1.20	-0.08	-0.16
CODFC	-0.29	-0.47	-0.11	-0.09	-0.46	-0.42
WHITGFC	-0.65	-1.00	-0.10	-0.09	-0.68	-0.45

Table 4. (Continued)

	Long Term Yields (Biomass) N. Pout	Sandeel	Plaice	Sole	Total	Total Value
SAITHFC	2.21	-0.43	0.11	-0.13	0.58	0.63
MACKLFC	0.93	3.51	-0.11	0.09	1.82	0.82
HADDKFC	-0.11	-0.34	0.10	0.12	-0.02	0.07
CODTFM	0.06	-1.10	0.43	0.36	-0.22	0.06
WHITTFM	-1.30	-0.56	-0.45	0.49	-0.20	-0.14
SATHTFM	-0.31	-0.89	0.43	-0.36	-0.14	-0.04
MACKTFM	1.75	-0.68	-0.43	-0.48	0.43	0.19
HADDTFM	1.63	-0.43	-0.43	-0.49	0.40	0.15
HERRTFM	-0.10	0.42	0.43	-0.36	-0.10	0.01
SPRTTFM	-1.40	0.90	-0.43	0.49	-0.11	-0.01
N.PTTFM	0.15	0.45	0.43	0.36	0.10	0.20
SANDTFM	0.62	0.51	0.43	0.36	0.21	0.24

Table 5. Relative Sensitivities of Long Term Yields to MSFOR Parameters. Sensitivities are expressed as the percent change in the response variable (% of mean) caused by a 10% change in the parameter.

Long Term Yields (Biomass)

	COD	Whiting	Saithe	Mackerel	Haddock	Herring	Sprat
(Means)	269404	201745	163043	34528	302507	422139	274205
R^2							
CODTFF	1.52	1.38	0.45	0.09	1.46	0.50	-0.65
WHITTFF	0.75	3.22	-0.45	0.09	4.13	1.95	0.54
SATHTFF	1.98	-0.02	-2.33	0.11	10.78	1.11	0.27
MACKTFF	0.57	0.22	-0.43	0.86	1.81	0.96	0.53
HADDTFF	-0.19	0.36	-0.44	-0.11	0.32	-0.12	-0.15
HERRTFF	-0.29	-0.49	0.44	-0.11	-0.61	0.35	0.48
SPRTTFF	-0.36	-0.29	0.43	-0.09	-0.63	-0.75	4.38
N.PTTFF	0.22	0.01	-0.43	0.00	1.59	0.37	0.24
SANDTFF	-0.31	-0.08	-0.44	0.00	0.05	-0.30	-0.26
PLAITFF	-0.07	-0.36	0.44	0.00	-0.39	0.04	-0.41
SOLETFF	-0.22	-0.03	0.43	0.00	-0.30	-0.34	0.25
CODRecr	5.83	-0.98	0.44	0.00	-0.99	-1.25	-0.74
WHITNGR	-1.51	3.92	0.44	0.00	-4.18	-3.41	-2.33
SAITHER	-1.75	-0.62	7.85	0.00	-10.66	-1.10	-0.40
MACKRLR	-0.28	-0.48	-0.42	8.33	0.93	-0.29	-0.26
HADDCKR	0.10	0.38	0.44	0.00	8.18	-0.02	-0.19
HERRNGR	0.21	0.09	0.44	0.00	-0.22	9.03	0.31
SPRATR	0.59	1.01	-0.44	0.00	1.24	1.03	8.86

Table 5. (Continued).

Long Term Yields (Biomass)

	COD	Whiting	Saithe	Mackerel	Haddock	Herring	Sprat
N.POUTR	1.45	0.56	-0.44	0.00	6.89	1.33	1.14
SANDELR	1.20	1.96	-0.43	0.00	2.28	1.07	0.15
PLAICER	-0.04	0.33	-0.44	0.00	0.15	-0.04	0.39
SOLERec	0.06	-0.31	0.43	0.00	-0.62	0.06	0.17
RONDFLf	2.51	2.58	-0.72	0.19	5.79	1.69	-0.03
IDEMFLf	0.01	0.76	-0.84	-0.06	-0.09	0.08	0.91
IPELFLf	-0.07	0.10	0.14	-0.04	-0.30	0.22	3.68
HERRFLf	-0.16	0.17	0.82	-0.01	-1.65	0.21	-0.13
SAITFLf	-0.02	-0.11	0.12	0.19	-0.37	-0.46	-0.31
MACKFLf	0.35	0.09	0.80	0.72	-1.52	0.40	0.27
FLATFLf	-0.03	0.35	-0.14	0.03	-0.17	0.34	-0.62

Table 5. (Continued).

	Long Term Yields (Biomass)					
	N. Pout	Sandeel	Plaice	Sole	Total	Total Value
(Means)	516654	1072684	162781	19564	3443004	1248880
R^2						
CODTFF	-1.52	-0.81	-0.43	0.49	0.05	0.63
WHITTFF	1.19	-0.58	0.41	-0.36	1.08	0.76
SATHTFF	12.86	-0.92	-0.43	-0.49	2.96	2.13
MACKTFF	2.01	1.61	-0.43	-0.49	0.95	0.43
HADDTFF	1.07	0.70	0.43	-0.36	0.19	-0.72
HERRTFF	-1.25	0.69	-0.43	0.49	-0.19	-0.32
SPRTTFF	0.09	0.22	0.43	0.36	0.09	-0.05
N.PTTFF	4.94	1.02	0.43	0.49	1.09	0.50
SANDTFF	-0.45	3.16	-0.43	0.36	0.60	-0.07
PLAITFF	-1.87	0.74	-0.59	-0.49	-0.34	-0.50
SOLETFF	-0.28	0.20	-0.43	-1.62	-0.25	-0.37
CODRecr	0.23	-0.86	-0.43	-0.36	0.06	1.11
WHITNGR	-2.99	-4.19	0.43	-0.49	-2.38	-1.25
SAITHER	-13.03	-0.88	-0.43	0.36	-2.96	-1.68
MACKRLR	0.90	-2.99	0.43	0.49	-0.54	0.08
HADDCKR	-1.83	-0.98	-0.43	-0.49	-0.04	0.89
HERRNGR	0.43	0.78	0.43	-0.36	1.29	0.72
SPRATR	1.80	0.55	-0.43	0.49	1.26	0.64
N.POUTR	16.36	0.52	0.43	0.36	3.43	2.03
SANDELR	1.29	11.59	0.43	0.36	4.55	1.66

Table 5. (Continued).

	Long Term Yields (Biomass)					
	N. Pout	Sandeel	Plaice	Sole	Total	Total Value
PLAICER	1.47	-0.76	7.69	0.49	0.58	1.19
SOLERec	0.50	-0.26	0.43	7.74	0.22	0.82
RONDFLf	5.52	-0.25	-0.63	-0.61	1.89	1.04
IDEMFLf	3.91	1.81	0.16	-0.82	1.38	-0.09
IPELFLf	1.28	-0.25	-0.16	0.04	0.55	-0.15
HERRFLf	-1.81	-0.48	0.16	0.82	-0.36	-0.05
SAITFLf	0.42	-0.69	0.81	0.92	-0.08	0.22
MACKFLf	-1.10	1.43	-0.16	0.77	0.15	0.05
FLATFLf	1.62	0.65	-0.61	-1.23	0.25	-0.42

Table 6. Relative Sensitivities of 1991 Q3 Diets to MSVPA Parameters. Variables X_Y are interpreted as the percent of the diet of species X that is species Y. Sensitivities are expressed as the percent change in the response variable (% of mean) caused by a 10% change in the parameter.

	1991 Q3 Diets (%)						
	COD_COD	COD_WHIT	COD_HADD	COD_HERR	COD_NPT	COD_SAND	WHT_WHIT
(Means)	2.06	9.94	9.27	15.57	20.60	42.17	5.68
R^2	0.32	0.58	0.49	0.60	0.60	0.66	0.62
MIXSUI	-1.0	-0.4	-0.4	0.0	-0.2	0.2	-0.3
MIXM2	2.3	0.6	-0.4	-0.5	0.4	0.2	0.1
EPFSF1	1.0	-0.2	0.0	0.0	0.9	-0.2	-0.5
EPFMS2	0.3	0.8	-0.3	-0.1	-0.7	0.3	0.9
EPSUI	1.0	0.7	-0.1	0.3	-0.1	-0.2	-0.2
OTHFood	0.1	-0.1	-0.1	0.0	0.1	0.1	-0.1
LLimWSW	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ULimWSW	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CODM1	-0.5	0.5	-1.3	-0.9	-2.2	1.6	1.4
WHITGM1	1.0	-0.8	-0.2	-0.5	0.2	0.2	-0.4
SAITNM1	-2.3	-1.1	1.9	-1.7	3.0	-1.0	0.3
MACKLM1	-1.0	-1.5	-2.2	-1.0	-1.8	1.9	-2.8
HADDKM1	0.3	-0.6	0.6	0.3	-0.2	-0.1	-0.3
HERRGM1	-0.3	0.4	0.0	-2.1	0.8	0.4	1.0
SPRATM1	-0.3	0.1	-0.4	0.1	0.8	-0.2	-0.5
NPOUTM1	0.3	0.2	-0.5	0.3	-0.4	0.3	0.3
SamdeM1	0.3	0.0	0.5	0.5	1.2	-1.2	-0.3
PLAICM1	-0.3	0.2	0.1	-0.1	-0.6	0.2	-0.4

Table 6. (Continued)

1991 Q3 Diets (%)

	COD_COD	COD_WHIT	COD_HADD	COD_HERR	COD_NPT	COD_SAND	WHT_WHIT
SOLEM1	1.0	-0.6	0.9	0.5	-0.3	-0.2	-0.5
CODFC	-0.5	0.3	0.0	-1.5	-1.1	1.0	0.9
WHITGFC	1.2	0.7	0.1	-1.1	0.7	-0.2	1.3
SAITHFC	0.1	0.8	0.1	0.5	-1.3	0.2	-0.1
MACKLFC	-0.5	-1.7	-1.6	-1.3	-1.1	1.8	-2.4
HADDKFC	-0.3	-0.4	-0.1	-0.2	0.1	0.1	-0.4
CODTFM	-1.0	0.0	0.8	-0.2	0.5	-0.4	0.0
WHITTFM	-0.3	-0.6	0.0	0.1	-0.8	0.4	-0.7
SATHTFM	0.3	0.4	0.3	0.1	-0.4	-0.3	0.5
MACKTFM	0.3	-0.6	0.1	-0.5	0.1	0.3	0.0
HADDTFM	-0.3	-0.4	0.8	0.0	0.8	-0.3	-0.9
HERRTFM	-0.3	0.4	0.2	0.2	-0.8	0.3	0.5
SPRTTFM	0.3	-0.6	0.6	0.3	-0.3	-0.1	0.1
N.PTTFM	-1.0	0.0	0.1	-0.7	0.5	0.0	0.7
SANDTFM	1.0	-0.2	0.2	-0.4	0.4	0.0	0.7

Table 6. (Continued).

1991 Q3 (%)

	WHT_HADD	WHT_HERR	WHT_SPRT	WHT_NPT	WHT_SAND	STH_HADD	STH_HERR
(Means)	4.83	4.75	10.55	13.63	60.54	12.38	3.21
R^2	0.57	0.48	0.53	0.65	0.61	0.57	0.46
MIXSUI	0.7	0.3	-0.1	0.0	0.0	0.0	-0.4
MIXM2	-0.3	-0.6	0.3	0.3	-0.1	-0.7	-0.4
EPFSF1	-0.8	0.1	0.1	0.3	0.1	-0.8	0.0
EPFMS2	-1.6	-0.6	0.1	-0.6	0.2	-0.2	1.1
EPSUI	-0.3	0.4	-0.1	-0.2	0.0	-0.1	0.7
OTHFood	-0.4	0.0	-0.1	0.1	0.0	-0.1	0.1
LLimWSW	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ULimWSW	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CODM1	-0.1	-0.1	-0.3	-0.6	0.1	0.4	0.3
WHITGM1	-1.6	-2.0	-0.6	-2.3	0.8	-1.3	-0.8
SAITNM1	-0.5	-0.9	-0.7	1.8	-0.1	-1.8	-2.4
MACKLM1	-2.4	-0.7	-0.8	-1.5	0.8	-0.8	0.7
HADDKM1	0.2	0.1	0.1	-0.5	0.0	0.4	-1.2
HERRGM1	-0.9	0.1	-0.3	0.2	-0.1	-0.7	-1.2
SPRATM1	-0.1	-0.1	-1.8	0.5	0.2	-0.9	-0.8
NPOUTM1	-0.6	-0.1	-0.5	-0.5	0.2	-0.1	-1.0
SamdeM1	0.9	0.1	-0.1	0.5	-0.3	0.3	-1.1
PLAICM1	0.9	0.1	0.5	-0.5	0.0	0.9	0.4
SOLEM1	0.9	0.1	0.1	-0.3	0.1	0.6	0.4
CODFC	-0.2	-1.0	-0.5	-1.6	0.5	0.2	-1.5
WHITGFC	2.1	-1.2	-2.1	1.2	-0.1	0.5	-2.0

Table 6. (Continued).

1991 Q3 (%)	WHT_HADD	WHT_HERR	WHT_SPRT	WHT_NPT	WHT_SAND	STH_HADD	STH_HERR
SAITHFC	0.6	0.0	0.4	-1.6	0.3	1.8	0.1
MACKLFC	-2.0	-1.3	-0.5	-1.5	0.9	-0.9	-0.7
HADDKFC	0.1	-0.4	-0.2	0.0	0.1	-0.2	-0.4
CODTFM	0.6	-0.1	-0.1	0.6	-0.1	-0.1	-0.7
WHITTFM	0.3	0.1	1.0	-0.3	-0.1	0.7	0.0
SATHTFM	0.9	0.1	0.4	-0.8	0.1	0.6	0.0
MACKTFM	0.9	0.4	-0.3	0.2	0.0	-0.1	0.4
HADDTFM	0.2	0.9	-0.1	0.9	-0.1	0.1	-0.3
HERRTFM	0.5	0.1	0.3	-0.5	0.0	0.8	0.0
SPRTTFM	0.6	0.6	-0.1	-0.3	0.1	0.9	0.8
N.PTTFM	-0.4	-0.6	0.0	-0.4	0.0	0.1	-0.3
SANDTFM	1.2	-1.7	-0.3	0.0	-0.1	-0.1	-0.4

Table 6. (Continued).

1991 Q3 Diets (%)

	STH_NPT	STH_SAND	MCK_HERR	MCK_SPRT	MCK_NPT	MCK_SAND	HAD_NPT	HAD_SAND
(Means)	66.38	16.70	15.16	14.76	8.46	61.32	4.79	94.83
R^2	0.59	0.62	0.46	0.52	0.52	0.47	0.62	0.64
MIXSUI	-0.1	0.4	-0.1	0.3	-0.5	0.0	-1.0	0.0
MIXM2	0.2	-0.5	-0.1	0.1	0.2	-0.1	0.2	0.0
EPFSF1	0.3	-0.4	0.1	0.0	0.4	-0.1	0.4	-0.1
EPFMS2	-0.2	0.6	-0.1	0.1	-0.4	0.0	0.5	0.0
EPSUI	-0.1	0.5	-0.1	0.1	-0.8	0.1	-1.1	0.0
OTHFood	0.0	-0.1	0.0	0.0	0.0	0.0	0.3	0.0
LLimWSW	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ULimWSW	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CODM1	-0.1	0.4	-0.1	0.3	-0.4	0.0	-0.8	0.0
WHITGM1	0.4	-0.8	1.7	-0.2	-0.4	-0.4	-1.2	0.1
SAITNM1	1.2	-2.7	0.4	-0.4	0.8	-0.2	-0.9	0.1
MACKLM1	-0.3	1.7	-0.8	-0.6	-2.0	0.5	-1.3	0.0
HADDKM1	-0.2	0.5	-0.1	0.3	-0.1	0.0	-4.9	0.3
HERRGM1	0.3	0.0	-0.5	0.0	0.4	0.0	0.1	0.0
SPRATM1	0.2	-0.3	0.0	0.1	0.1	0.0	0.5	0.0
NPOUTM1	0.0	0.7	0.1	-0.2	-0.7	0.0	-0.8	0.0
SamdeM1	0.2	-0.9	0.9	1.5	1.2	-0.8	0.6	-0.1
PLAICM1	-0.2	0.3	-0.1	0.1	-0.6	0.0	-0.7	0.0
SOLEM1	-0.3	0.3	0.2	-0.2	-0.5	0.0	-0.9	0.0
CODFC	0.1	-0.4	0.4	0.3	0.2	-0.2	-1.5	0.1
WHITGFC	0.1	-0.4	-0.8	1.7	-0.4	-0.2	-3.7	0.2

Table 6. (Continued).

1991 Q3 Diets (%)

	STH_NPT	STH_SAND	MCK_HERR	MCK_SPRT	MCK_NPT	MCK_SAND	HAD_NPT	HAD_SAND
SAITHFC	-0.8	1.8	-0.3	0.0	1.5	-0.1	-4.6	0.3
MACKLFC	-0.3	2.1	0.1	0.8	-0.7	-0.1	-1.4	0.1
HADDKFC	0.1	-0.2	0.1	-0.1	0.0	0.0	0.0	0.0
CODTFM	0.1	-0.6	-0.4	0.2	0.8	-0.1	0.0	0.0
WHITTFM	-0.2	0.2	-0.1	0.2	-0.8	0.0	-0.7	0.1
SATHTFM	-0.2	0.3	0.1	-0.3	-0.6	0.0	-0.9	0.0
MACKTFM	0.1	-0.6	0.3	-0.1	1.0	0.0	0.3	0.0
HADDTFM	0.2	-0.2	-0.3	0.2	1.0	0.0	0.1	0.0
HERRTFM	-0.2	0.6	0.1	0.2	0.2	0.1	-0.7	0.1
SPRTTFM	-0.2	0.5	0.0	0.0	-0.7	0.0	-1.0	0.0
N.PTTFM	0.2	-0.4	0.3	-0.3	0.2	0.0	-0.8	0.0
SANDTFM	0.1	-0.6	0.2	-0.3	0.8	0.0	-1.0	0.0

Table 7. Relative Sensitivities of 1991 Q3 Diets to MSFOR Parameters. Sensitivities are expressed as the percent change in the response variable (% of mean) caused by a 10% change in the parameter.

	1991 Q3 Diets (%)					
	COD_COD	COD_WHIT	COD_HADD	COD_HERR	COD_NPT	COD_SAND
(Means)	2.06	9.94	9.27	15.57	20.60	42.17
R^2	0.32	0.58	0.49	0.60	0.60	0.66
CODTFF	-3.5	-1.2	-2.6	-3.6	-4.5	4.8
WHITTFF	-1.0	-0.4	1.2	-0.1	-0.6	0.2
SATHTFF	-1.6	-2.1	1.9	-1.6	2.9	-0.8
MACKTFF	-0.3	-0.9	0.5	-0.5	0.2	0.2
HADDTFF	0.3	0.5	0.0	0.4	0.1	-0.2
HERRTFF	-1.0	0.2	1.0	-2.8	-0.2	0.7
SPRTTFF	1.0	0.2	0.8	-0.1	0.6	-0.4
N.PTTFF	0.3	-0.6	0.5	-0.5	-0.2	0.2
SANDTFF	1.0	0.8	1.2	1.0	0.3	-0.8
PLAITFF	1.0	-0.6	0.4	0.1	-0.7	0.4
SOLETFF	0.3	0.4	0.5	0.0	0.8	-0.5
CODRecr	0.5	-1.3	-2.9	-3.0	-2.6	3.0
WHITNGR	0.8	5.7	0.1	0.3	-0.5	-1.4
SAITHER	1.0	0.4	0.1	-0.1	-0.8	0.2
MACKRLR	0.3	0.0	0.7	0.1	0.7	-0.5
HADDCKR	-1.6	-0.7	6.3	-1.0	-1.4	-0.4
HERRNGR	-1.0	-0.5	-0.2	1.8	0.4	-0.6
SPRATR	-0.8	0.3	-0.2	-0.8	0.2	0.2
N.POUTR	-1.8	-3.4	-0.4	-3.1	8.0	-1.8

Table 7. (Continued).

1991 Q3 Diets (%)

	COD_COD	COD_WHIT	COD_HADD	COD_HERR	COD_NPT	COD_SAND
SANDELR	-1.6	-3.5	-3.8	-4.0	-3.9	5.2
PLAICER	1.6	0.2	0.0	0.1	0.8	-0.3
SOLERec	-1.0	-0.4	-0.7	-0.4	0.2	0.2
RONDFLf	1.0	1.0	-0.4	0.6	-0.2	-0.1
IDEMFLf	0.3	0.0	-0.6	0.2	-0.7	0.4
IPELFLf	1.0	0.4	-0.5	0.0	1.0	-0.3
HERRFLf	-0.3	-0.7	-0.7	-0.5	0.0	0.3
SAITFLf	1.6	0.7	-0.3	0.3	-0.1	-0.2
MACKFLf	0.3	0.4	-0.6	0.0	-0.6	0.5
FLATFLf	1.0	0.2	-0.2	0.1	0.8	-0.2

Table 7. (Continued).

1991 Q3 Diets (%)

	WHT_WHIT	WHT_HADD	WHT_HERR	WHT_SPRT	WHT_NPT	WHT_SAND
(Means)	5.68	4.83	4.75	10.55	13.63	60.54
R^2	0.62	0.57	0.48	0.53	0.65	0.61
CODTFF	-0.3	0.6	0.1	0.5	-0.3	0.1
WHITTFF	0.7	-1.1	-1.8	-1.1	-4.0	1.1
SATHTFF	0.0	0.6	-0.1	-0.5	2.2	-0.5
MACKTFF	-1.1	-0.1	-0.9	-0.1	0.4	-0.1
HADDTFF	0.9	-0.1	-0.3	0.0	-0.9	0.1
HERRTFF	0.0	1.9	-0.8	0.3	-0.3	0.0
SPRTTFF	-0.1	0.9	-1.2	-0.8	0.8	-0.1
N.PTTFF	0.0	0.0	0.1	-0.1	0.2	0.0
SANDTFF	1.2	1.2	0.7	0.3	-0.5	-0.1
PLAITFF	-0.7	0.6	-0.7	0.1	-0.1	0.0
SOLETFF	0.5	1.1	-0.1	-0.3	0.2	-0.1
CODRecr	0.7	-0.1	-0.9	-0.1	0.2	0.0
WHITNGR	7.8	-0.3	-2.7	-0.8	-2.8	0.2
SAITHER	0.0	0.8	1.5	0.1	-0.3	0.0
MACKRLR	-0.7	0.9	0.3	0.3	0.9	-0.2
HADDCKR	0.2	7.6	-0.6	-0.5	-0.9	-0.3
HERRNGR	-1.4	-1.6	8.3	-0.6	-0.3	-0.3
SPRATR	-0.3	-2.2	-1.4	6.8	-0.7	-0.8
N.POUTR	-1.7	-1.8	-1.1	-1.7	7.4	-1.0
SANDELR	-5.2	-5.3	-5.2	-5.3	-5.7	3.5
PLAICER	1.7	0.2	-0.1	-0.4	0.3	0.0

Table 7. (Continued).

1991 Q3 Diets (%)

	WHT_WHIT	WHT_HADD	WHT_HERR	WHT_SPRT	WHT_NPT	WHT_SAND
SOLERec	-0.7	-0.9	0.1	0.0	0.9	-0.1
RONDFLf	0.5	-0.3	-0.4	0.1	-0.4	0.0
IDEMFLf	0.1	-1.1	0.3	-0.3	-0.2	0.1
IPELFLf	1.0	-0.5	-0.1	-0.6	0.3	0.1
HERRFLf	-0.4	-0.1	1.2	0.3	0.8	-0.1
SAITFLf	0.7	0.4	0.6	-0.4	-0.4	0.0
MACKFLf	0.5	-0.3	-0.1	0.3	-0.5	0.1
FLATFLf	-0.3	-0.3	0.4	0.1	0.5	0.0

Table 7. (Continued).

1991 Q3 Diets (%)

	STH_HADD	STH_HERR	STH_NPT	STH_SAND	MCK_HERR
(Means)	12.38	3.21	66.38	16.70	15.16
R^2	0.57	0.46	0.59	0.62	0.46
CODTFF	0.7	0.8	-0.3	0.4	-0.1
WHITTFF	0.3	1.1	-0.1	-0.1	1.9
SATHTFF	-0.7	-6.2	0.6	-0.4	0.2
MACKTFF	0.1	0.0	0.2	-0.4	-0.9
HADDTFF	0.8	-0.1	-0.2	0.2	0.2
HERRTFF	1.1	-3.0	-0.1	0.4	-1.1
SPRTTFF	0.0	-1.2	0.1	-0.3	0.4
N.PTTFF	0.3	-0.3	-0.1	-0.3	0.1
SANDTFF	0.9	0.4	-0.2	-0.2	1.6
PLAITFF	0.8	0.7	-0.2	0.2	0.2
SOLETFF	-0.3	0.0	0.2	-0.5	-0.1
CODRecr	-0.1	-1.1	0.1	-0.5	0.1
WHITNGR	0.8	1.1	-0.2	0.2	0.3
SAITHER	0.5	1.5	-0.2	-0.1	0.2
MACKRLR	0.2	0.0	0.1	-0.5	-1.0
HADDCKR	7.2	-1.7	-1.0	-1.5	0.4
HERRNGR	-0.8	-0.7	0.3	-0.5	7.2
SPRATR	-0.7	-1.1	0.3	-0.7	-1.4
N.POUTR	-6.7	-6.3	3.5	-6.9	0.1
SANDELR	-1.6	-1.7	-1.4	6.7	-2.9
PLAICER	-0.5	-1.5	0.3	-0.3	0.1

Table 7. (Continued).

1991 Q3 Diets (%)

	STH_HADD	STH_HERR	STH_NPT	STH_SAND	MCK_HERR
SOLERec	-1.0	-0.4	0.2	-0.2	-0.2
RONDFLf	0.1	1.1	-0.2	0.7	0.1
IDEMFLf	-0.1	0.4	-0.2	0.6	0.2
IPELFLf	-0.8	-0.3	0.3	-0.6	0.1
HERRFLf	-0.5	-0.7	0.2	-0.4	-0.2
SAITFLf	-0.2	0.0	-0.2	0.3	-0.3
MACKFLf	-0.1	0.4	-0.1	0.5	0.3
FLATFLf	-1.1	-1.1	0.2	-0.3	0.2

Table 7. (Continued).

1991 Q3 Diets (%)

	MCK_SPRT	MCK_NPT	MCK_SAND	HAD_NPT	HAD_SAND
(Means)	14.76	8.46	61.32	4.79	94.83
R^2	0.52	0.52	0.47	0.62	0.64
CODTFF	0.2	-0.7	0.1	-1.2	0.0
WHITTFF	-0.3	-0.6	-0.2	-1.6	0.0
SATHTFF	-0.3	0.8	-0.1	-1.9	0.0
MACKTFF	-0.9	-0.1	0.4	-0.6	0.0
HADDTFF	0.4	-0.9	0.0	-11.8	0.7
HERRTFF	0.4	0.3	0.2	-0.4	0.1
SPRTTFF	-0.9	0.7	0.1	0.8	0.0
N.PTTFF	-0.1	0.1	-0.1	-0.5	0.0
SANDTFF	2.0	1.8	-1.1	-0.7	0.0
PLAITFF	0.0	-0.5	0.1	-1.0	0.0
SOLETFF	-0.3	0.3	0.0	-0.3	0.0
CODRecr	0.0	0.3	0.0	0.6	0.0
WHITNGR	-0.5	0.1	0.0	0.4	0.0
SAITHER	0.0	0.2	0.0	-0.4	0.0
MACKRLR	-0.5	0.1	0.3	-0.3	-0.1
HADDCKR	-0.2	-0.4	0.0	-8.0	0.4
HERRNGR	-1.5	-0.8	-1.4	0.9	0.0
SPRATR	6.8	-0.7	-1.2	0.2	-0.1
N.POUTR	-0.9	7.6	-0.8	5.5	-0.3
SANDELR	-3.7	-4.0	2.3	-8.6	0.4
PLAICER	0.0	0.8	-0.1	-0.1	-0.1

Table 7. (Continued).

1991 Q3 Diets (%)

	MCK_SPRT	MCK_NPT	MCK_SAND	HAD_NPT	HAD_SAND
SOLERec	0.0	0.4	0.0	0.7	0.0
RONDFLf	0.3	-0.1	0.0	0.5	0.0
IDEMFLf	0.1	-0.1	0.0	-0.3	0.0
IPELFLf	0.0	0.7	-0.1	0.9	0.0
HERRFLf	-0.2	-0.1	0.0	-0.9	0.0
SAITFLf	0.0	-0.5	0.1	0.0	0.0
MACKFLf	0.0	-0.5	0.0	-0.3	0.0
FLATFLf	0.0	0.6	-0.1	0.5	-0.1

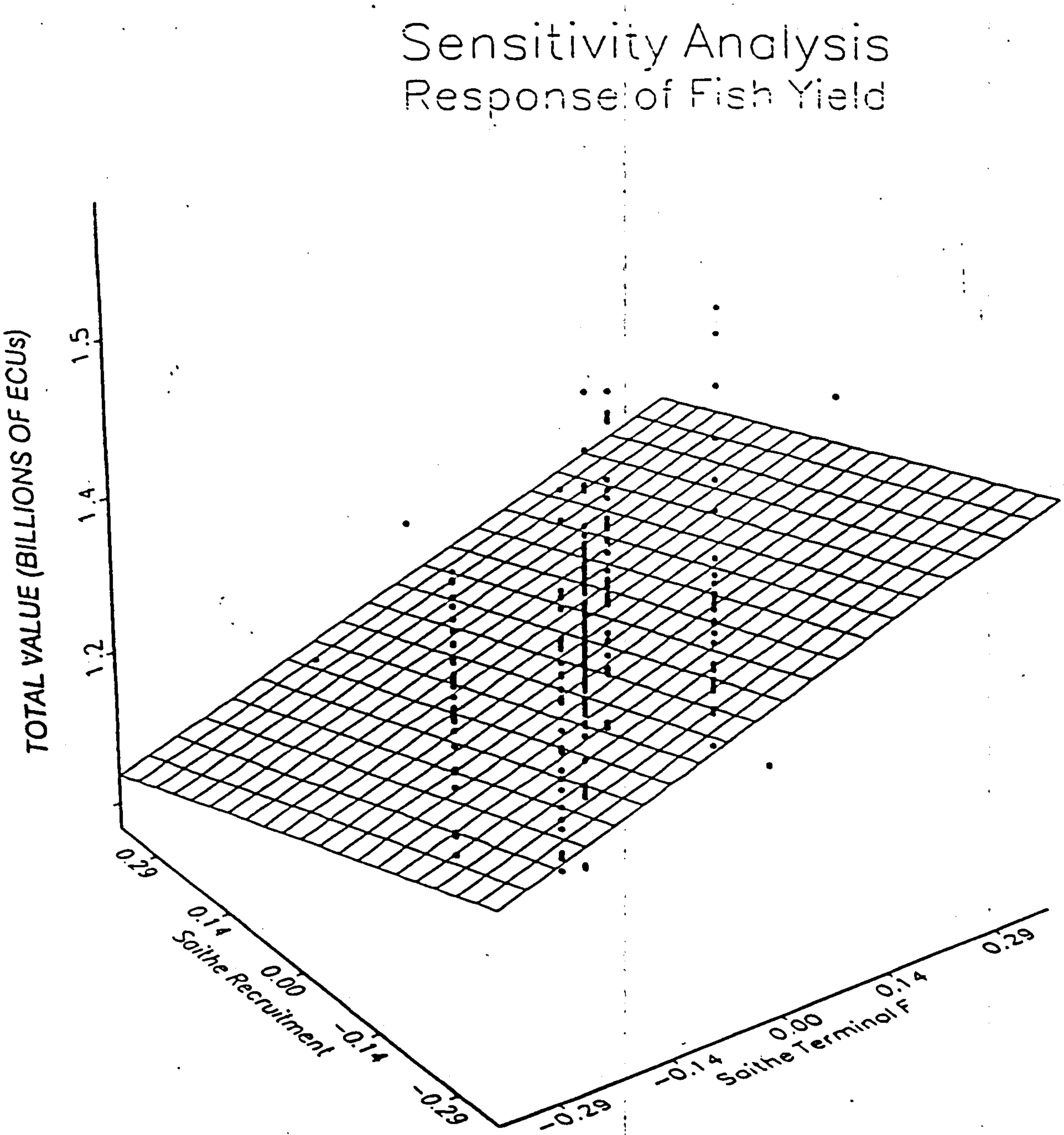

Figure 1. Sensitivity of long-term total system yield in value (billions of ECUs) to changes in average saithe recruitment and terminal fishing mortality rate on saithe. Results are from fractional factorial simulation experiments using the MSVPA and MSFOR models. Dots represent total system value calculated for each of the 253 simulation experiments in two-dimensional parameter space (i.e., parameters = saithe recruitment and saithe terminal F). Slopes of the linear plane in these two dimensions are given by the sensitivity coefficients (Table 5).

Sensitivity Analysis

Response of Fish Yield

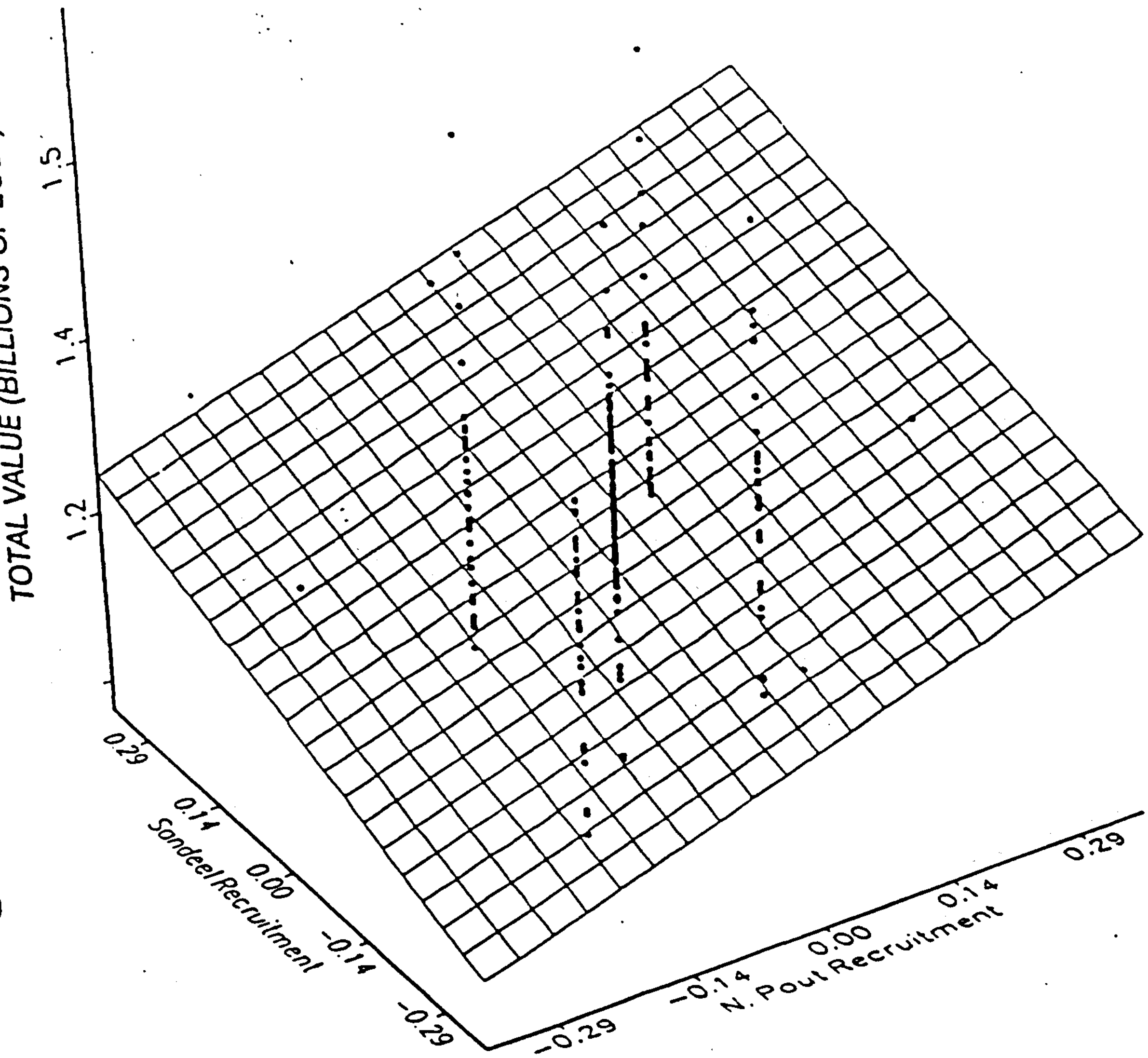

Figure 2. Sensitivity of long-term total system yield in value (billions of ECUs) to changes in average sandeel and Norway pout recruitment. Results are from fractional factorial simulation experiments using the MSVPA and MSFOR models. Dots represent total system value calculated for each of the 253 simulation experiments in two-dimensional parameter space (i.e., parameters = sandeel and Norway pout recruitment). Slopes of the linear plane in these two dimensions are given by the sensitivity coefficients (Table 5).

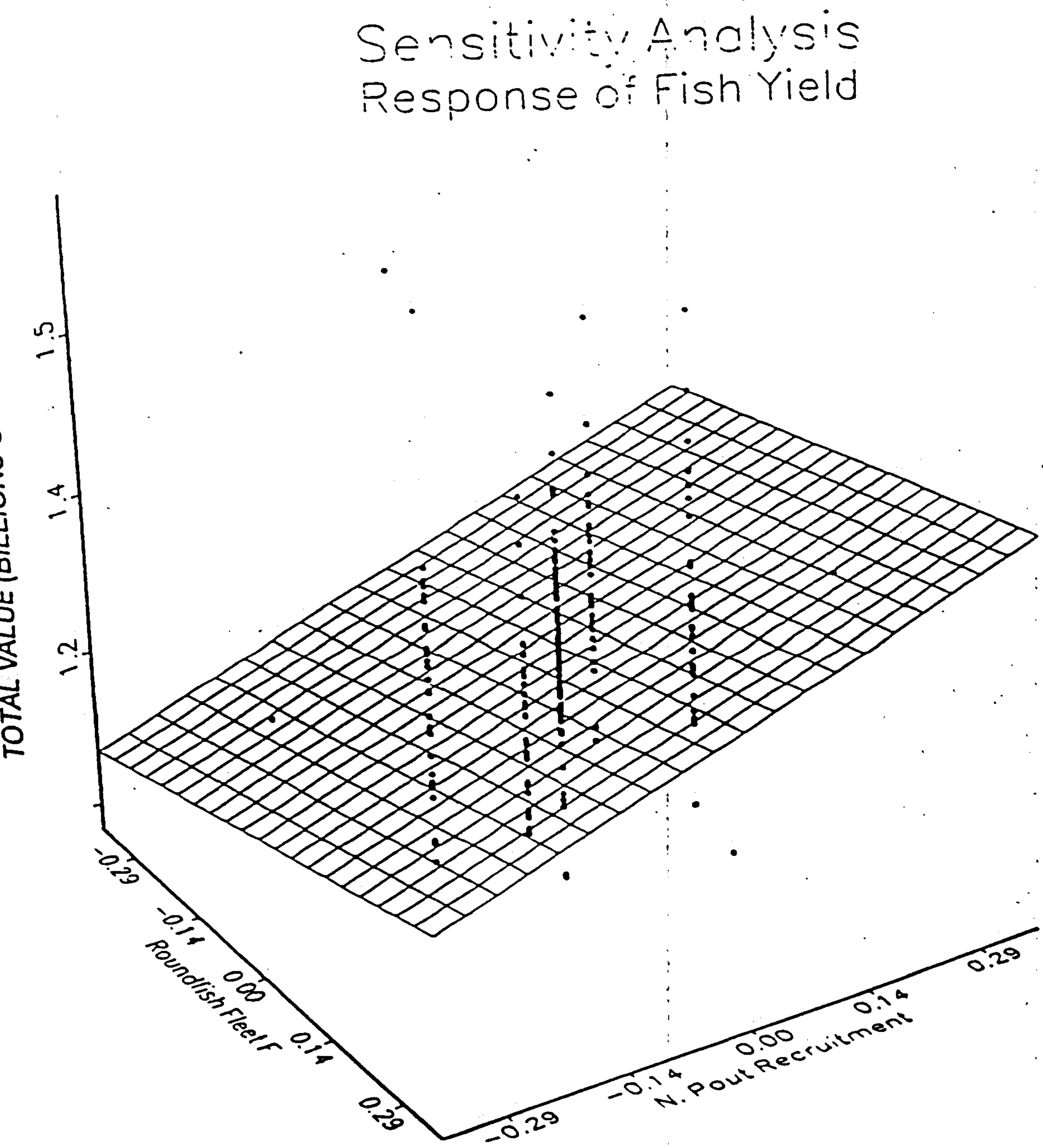

Figure 3. Sensitivity of long-term total system yield in value (billions of ECUs) to changes in roundfish fleet fishing effort and Norway pout recruitment. Results are from fractional factorial simulation experiments using the MSVPA and MSFOR models. Dots represent total system value calculated for each of the 253 simulation experiments in two-dimensional parameter space (i.e., parameters = roundfish fleet fishing effort and Norway pout recruitment). Slopes of the linear plane in these two dimensions are given by the sensitivity coefficients (Table 5).