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A DYNAMIC PRODUCTION MODEL

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A dynamic production model was designed, based on the discrete form of the traditional equilibrium production model. A new parameter, called inertia, was introduced to represent the stock's resistance to adapt to changes in the exploitation pattern. The method presented here can be applied to modify any of the well-known production models. Modified Schaefer and Fox models were applied to the historical data series of Cape hake in ICSEAF divisions 1.3 + 1.4, 1.5, and 1.6 and the estimations made were compared to those obtained applying the traditional approaches. The main result is the improvement, in all cases, of the correlation coefficient between the estimates and the data observed.

Les auteurs ont conçu un modèle de production dynamique basé sur la forme discrète du modèle de production équilibrée traditionnel. Un nouveau paramètre, appelé inertie, a été introduit pour représenter la résistance du stock à l'adaptation aux changements du schéma d'exploitation. La méthode présentée ici peut être appliquée pour modifier n'importe quel modèle de production connu. Les auteurs ont appliqué les modèles modifiés de Schaefer et Fox aux séries de données historiques de merlu du Cap pour les divisions 1.3 + 1.4, 1.5 et 1.6 de l'ICSEAF et ils ont comparé les estimations en découlant à celles obtenues en appliquant les modèles traditionnels. Le résultat principal est l'amélioration, dans tous les cas, du coefficient de corrélation entre les estimations et les données d'observation.

Se diseñó un modelo de producción dinámico basado en la forma discreta del modelo de producción equilibrada tradicional. Se introdujo un nuevo parámetro, el llamado inercia, para representar la resistencia del stock a adaptarse a los cambios en el modelo de explotación. El método que se presenta aqui puede aplicarse para modificar cualquiera de los modelos de producción ya conocidos. Los modelos de Schaefer y Fox modificados se aplicaron a las series históricas de datos de merluza del Cabo en las Divisiones 1.3 + 1.4, 1.5 y 1.6 de ICSEAF, y se compararon las estimaciones realizadas con las obtenidas aplicando los modelos tradicionales. El resultado principal es la mejora, en todos los casos, del coeficiente de correlación entre las estimaciones y los datos observados.

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COLLECTION OF SCIENTIFIC PAPERS 12(I)

ERRATA

The paper by Lleonart **et al.**, "A dynamic production model", (pages 119-146) should be amended as follows:

P. 125:	Add at the bottom of Table 3 -	Inertia	= 0,623
P. 127:	" " " " " " 5 -	"	= 0,617
P. 129:	" " " " " " 7 -	"	= 0,550
P. 131:	" " " " " " 9 -	"	= 0,452
P. 133:	" " " " " " 11 -	"	= 0,818
P. 135:	" " " " " " 13 -	"	= 0,649

RECUEIL DE DOCUMENTS SCIENTIFIQUES 12(I)

ERRATA

Les corrections ci-après sont à apporter à l'étude de Lleonart **et al.**, "A dynamic production model", (pages 119-146):

p. 125,	ajouter au bas du tableau 3:	Inertie	= 0,623
p. 127,	" " " " " 5:	"	= 0,617
p. 129,	" " " " " 7:	"	= 0,550
p. 131,	" " " " " 9:	"	= 0,452
p. 133,	" " " " " 11:	"	= 0,818
p. 135,	" " " " " 13:	"	= 0,649

COLECCION DE DOCUMENTOS CIENTIFICOS 12(I)

FE DE ERRATAS

Debe enmendarse el trabajo de Lleonart **et al.**, "A dynamic production model", (páginas 119-146) según se indica a continuación:

P. 125:	Añadir, al final del Cuadro 3 -	Inercia	= 0,623
P. :	" " " " " -	"	= 0,617
P. :	" " " " " -	"	= 0,550
P. :	" " " " " -	"	= 0,452
P. :	" " " " " -	"	= 0,818
P. :	" " " " " -	"	= 0,649

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INTRODUCTION

Production models are based on the hypothesis that the stock is in a steady state, i.e., exploitation is counterbalanced by natural growth of the stock, so that the biomass is maintained. The use of such models on a stock that is not in equilibrium renders biased results, widely deviating from the actual state of the stock. Therefore, non-dynamic models seem to be inappropriate for fisheries management.

To mitigate this bias, a series of modifications on the traditional production models have been devised in the form of "dynamic models" which can be described as models "with a memory" (they take into consideration the immediate history of the fishery to explain the current state of the stock). The most important outcome is that the fishery need not be in equilibrium to be simulated by such a production model.

Dynamic models are more complex than the traditional models, and require the introduction of at least one new parameter to provide for the above-mentioned "memory". In some cases, more than one new parameter is needed.

The traditional models are based on a differential equation to simulate growth of a stock in a limited and constant environment. It is assumed that fishing mortality is proportional to the fishing effort and, consequently, that biomass is proportional to cpue. Thus, changing the variables, the equation relates the variation in cpue to cpue and effort. The relationship between catch and effort is obtained by setting the variation of cpue to zero in the equation. Thus, the resulting curve represents the geometric loci of the equilibrium states of an exploited stock, according to the production model.

The dynamic models designed by Walter (1973), Schnute (1977) and Butterworth and Andrew (1984), based on the differential equation, are rather complicated. Other dynamic models tend to be simpler in concept; this is the case of Roff's (1983) model, based on the equation in its discrete form, and of Gulland's (1961) method.

The model discussed herein also pertains to the latter group. It has been developed in discrete terms according to the data available. It is assumed that for a given year, if equilibrium exists, the relationship between total catch and total effort is defined by a production model equilibrium equation. The model introduces a new parameter termed "inertia". This parameter represents the stock's resistance (per time unit) to adapt to a new exploitation pattern. A stock with 0 inertia is always in equilibrium, and a stock with inertia = 1 remains constant irrespective of changes in the exploitation pattern.

DESCRIPTION OF THE MODEL

If all the assumptions inherent in the production model, with the exception of equilibrium, prove to be true, it can be postulated that with a given level of effort, maintained over a certain period of time, the stock will reach equilibrium as defined by the corresponding point on the catch/effort curve.

If the units of time employed in the production model represent very small fractions of the species' lifetime, the equilibrium point will move along the line defined by the origin and the final known catch value, i.e., according to a constant cpue. This behaviour is due to the fact that the stock "does not have time" to react to the change in the exploitation level.

If, on the contrary, the unit of time employed in the model is many times greater than the lifetime of the species, after each change in effort, equilibrium will probably be reached within each time unit. This is because the stock "has time" to react and adapt to the new exploitation level.

It can be assumed that, in general, the actual situations encountered will fall somewhere between the two extremes described above. The time unit used in the production model (usually one year) represents a reasonable fraction of the species' lifetime; thus, when the effort level varies, the corresponding catch is found between the line representing constant cpue and the equilibrium curve, on the vertical line running through the corresponding effort value (Figure 1).

A stock found to be very close to equilibrium, as described by the equilibrium curve, would be responding rapidly to changes in the exploitation level, that is, it has little inertia or a high recovery rate. If, on the contrary, it is found to be close to the constant cpue line, its inertia is high, and recovery rate low.

Inertia, symbolised as "G", is illustrated in Figure 1. Exploitation is assumed to shift from level f_1 to level f_2 over a one-year period. If the stock responds immediately to the changes in effort, that is, if it has 0 inertia, the yield corresponding to the effort level f_2 would be Y_e (deduced from the equilibrium curve). If, on the contrary, the inertia level of the stock is at its maximum value, the yield would be Y_b, as shown on the constant cpue line, since in this case cpue would remain constant. Actually, the point reached (Y_2) will fall somewhere between the two extremes on the segment Y_bY_e. Inertia is thus defined to be the fraction:

$$\frac{\overline{Y_2Y_e}}{\overline{Y_bY_e}}$$

G, then, is dimensionless, and ranges between 0 and 1:

$$G = \frac{Y_2 - Y_e}{Y_b - Y_e}\,; \qquad 0 \le G \le 1 \qquad (1)$$

The recovery rate is, then, equivalent to 1 - G. In this study, G is considered to be constant for all levels of effort.

The point (f_1,Y_1) shifts to point (f_2,Y_2); in the traditional model, $Y_2 = Y_e$. The value of Y_2 in the dynamic model is calculated as follows. It is obvious that Y_b can be equated to the expression:

$$Y_b = \frac{Y_1}{f_1} f_2 \qquad (2)$$

Substituting (2) in (1) and rearranging terms:

$$\frac{Y_2}{f_2} = G\frac{Y_1}{f_1} + (1-G)\frac{Y_e}{f_2} \qquad (3)$$

where Y_e can be expressed in terms of f_2, which depends on the model used (Schaefer, Fox, etc.). Thus, the dynamic Schaefer model would take the following form:

$$\frac{Y_2}{f_2} = G\frac{Y_1}{f_1} + (1-G)(a + bf_2)$$

where the parameters a and b can be estimated (if $G \neq 1$) by linear regression:

$$\frac{\frac{Y_2}{f_2} - G\frac{Y_1}{f_1}}{1 - G} = a + bf_2 \qquad (4)$$

The Fox dynamic model, on the other hand, would be expressed as follows:

$$\frac{Y_2}{f_2} = G\frac{Y_1}{f_1} + (1-G)(ae^{-bf_2})$$

where parameters a and b can be estimated, as usual, from the equation:

$$\frac{\frac{Y_2}{f_2} - G\frac{Y_1}{f_1}}{1 - G} = ae^{-bf_2} \qquad (5)$$

It will be noted that equations (4) and (5) are general formulae for curve fitting; since the traditional, non-dynamic model is covered by the case where G = 0, the terminal value of cpue (Y_1/f_1) does not have to be used.

Since the calculation of the new cpue in the dynamic model depends on the last cpue affected by the inertia factor, the "length" of the "memory" of the model presented here may be considered to be one time unit (one year). The authors mentioned above also built their dynamic models around the concept of a "memory". Walters (1973), for example, introduced a term which he called time-delay, corresponding to the time elapsed between spawning and recruitment, characteristic for each species, and independent of the time units considered in the observations.

TOTAL ALLOWABLE CATCH

The TAC projections are also based on equation (3), that is:

$$TAC_{MSY} = f_{MSY}\, G\frac{Y_L}{f_L} = (1 - G)Y_{MSY}$$

and:

$$TAC_{0,1} = f_{0,1}\, G\frac{Y_L}{f_L} + (1-G)Y_{0,1}$$

where Y_L and f_L are last year's catch and effort, and f_{MSY}, $Y_{0,1}$ and $f_{0,1}$ are computed as usual (Figure 2).

FITTING THE DATA

The procedure used to estimate G, like the one proposed by Butterworth and Andrew (1984), is based on Kirkwood's (1981) method, which consists of minimizing:

$$ss = \left[\sqrt{Y_i} - \sqrt{Y_i}\right]^2$$

To compare the results obtained with the model presented in this paper with those from

Gulland's (1961) standard method, Butterworth and Andrews' (1984) general formula:

$$ss = f_i\left[\sqrt{\frac{Y'}{f}}_i - \sqrt{\left(\frac{Y}{f}\right)}_i\right]^2$$

was applied to the Gulland method.

The fitting procedure can be summarized as follows:

- a trial value for G was applied
- parameters a and b were calculated as usual
- ss was computed
- where ss was found to be minimal, the process was considered to be complete; otherwise, the procedure was repeated, with a new trial value for G.

Figure 3 shows the relationship between ss and G using the data for Division 1.6 as an example. For Fox's model there is a single minimum and an upper limit of G less than 1, above which no computation can be made; for the Schaefer model there are two relative minima. In this case, it was possible to determine which was correct by plotting Y against f.

RESULTS AND DISCUSSION

The dynamic model described above was applied to the historical data series on Cape hakes from ICSEAF Divisions 1.3 + 1.4, 1.5 and 1.6 (Table 1) (ICSEAF 1983, unpublished manuscript), and the results compared to those obtained with the traditional models as modified according to Gulland's method; the effort figures represent three-year running averages (Tables 2 to 13 and Figures 4 to 21). The main result is the improvement, in all cases, of the correlation coefficient between the estimates and the observed data (Tables 14 and 15). The values of ss are also better in the dynamic model than in the traditional one.

The most relevant aspect of this dynamic model is that the same value of inertia is used both for fitting the curve and obtaining TAC projection estimates. This seems to be more coherent, at least in theory, than the traditional approach which assumes equilibrium for fitting (0 inertia), but uses a constant cpue (inertial = 1) for TAC estimation.

If a family of curves for various values of inertia is plotted, the resulting curves at low values of this parameter are not widely divergent; however, the differences increase when inertia is high. High-inertia are sharper in shape than low-inertia curves.

The equilibrium condition is asymptotic: when f remains constant for a long period of years, the cpue (or Y) series is derived from equation (3), as follows:

$$\frac{Y_{(i+1)}}{f} = G^i \frac{Y_{(1)}}{f} + (1 - G^i) \frac{Y_e}{f} \quad (6)$$

where:

f - constant effort
$Y_{(1)}$ - yield in the first year
i - number of years

It will be observed that when i increases, $Y_{(i=1)}/f$ approaches Y_e/f.

As a result of equation 6:

- G has to remain strictly below 1, for otherwise convergence is impossible.
- If G = 0 the terms of the succession are always equal to Y_e/f.
- The lower the value of G, the faster equilibrium is approached.

The use of the parameter "inertia" provides a good approximation of the "real" solution to the differential equation without actually having to solve it. The fact that it involves only three parameters, is easily understandable, and readily applicable to the data, makes this model particularly appealing.

REFERENCES

BUTTERWORTH, D.S. and P.A. ANDREW 1984 - Dynamic catch-effort models for the hake stocks in ICSEAF Divisions 1.3-2.2. **Colln scient. Pap. int. Comn SE. Atl. Fish.** 11(II): 29-58.

GULLAND, J.A. 1961 - Fishing and the stocks of fish at Iceland. **Fish. Invest.** (Ser.2) 23(4): 52pp.

KIRKWOOD, G.P. 1981 - Estimation of stock size using relative abundance data - a simulation study. **Rep. int. Whal. Commn** 31: 729-735.

ROFF, D 1983 - Analysis of catch/effort data: a comparison of three methods. **Can. J. fish. Aquat. Sci.** 40: 1496-1506.

SCHNUTE, J. 1977 - Improved estimates from the Schaefer production model: theoretical considerations. **J. Fish. Res. Board Can.** 34: 583-603.

WALTER, G.G. 1973 - Delay-differential equation models for fisheries. **J. Fish. Res. Board Can.** 30: 939-945.

TABLE 1. Cape hakes in Divisions 1.3 + 1.4, 1.5 and 1.6: catch and effort, 1955-1984. Data used for assessments.

Division / Year	1.3 + 1.4 (ESP)		1.5 (ESP + ZAF)		1.6 (ESP)	
	Catch (t)	Fishing effort (h)	Catch (t)	Fishing effort (h)	Catch (t)	Fishing effort (h)
1955					115 400	6 667
1956					118 200	7 558
1957					126 400	7 675
1958					130 700	8 038
1959					146 000	8 979
1960					159 900	9 237
1961					148 700	12 299
1962					147 600	10 409
1963					169 500	12 133
1964					162 300	11 116
1965	93 500	52 500	99 700	475	203 300	18 755
1966	212 400	162 500	122 200	495	195 000	18 344
1967	195 000	214 000	199 400	1 466	176 700	17 652
1968	382 700	399 000	247 700	1 877	143 600	14 346
1969	320 500	364 000	206 200	1 909	165 100	19 153
1970	402 500	447 000	224 700	2 182	142 500	19 710
1971	365 600	420 000	229 700	1 714	202 000	28 491
1972	606 100	842 000	214 000	2 140	243 900	49 776
1973	377 600	662 456	290 300	3 088	157 800	31 751
1974	318 800	697 333	195 500	2 962	123 000	26 452
1975	309 400	737 000	178 700	2 351	89 600	19 227
1976	369 800	880 476	209 700	3 883	143 400	26 804
1977	177 500	565 173	157 700	2 426	97 500	20 145
1978	258 100	590 618	124 200	2 435	101 700	17 237
1979	172 300	423 342	130 000	1 884	90 400	14 747
1980	90 500	201 111	70 100	1 001	101 500	18 422
1981	92 100	165 946	116 400	1 386	99 600	17 143
1982	176 400	327 282	131 800	1 607	86 900	14 804
1983	215 800	367 632	123 300	1 284	97 000	14 742
1984	198 500	312 106	121 400	1 202		

TABLE 2. Cape hakes in Divisions 1.3 + 1.4. Catch, effort, and cpue, 1965-1984, and output for the Schaefer model (modified according to Gulland's method)

Year	Fishing effort (h)	Fishing effort (h) ($\bar{f}_{3y}$)	Catch (t)	Cpue (t/h)	Cpue (est.) (t/h)
1967	214 000	143 000	195 000	0,911 215	0,879 537
1968	399 000	258 500	382 700	0,959 148	0,697 058
1969	364 000	325 667	320 500	0,880 495	0,731 581
1970	447 000	403 333	402 500	0,900 447	0,649 712
1971	420 000	410 333	365 600	0,870 476	0,676 344
1972	842 000	569 667	606 100	0,719 834	0,260 094
1973	662 456	641 485	377 600	0,570 000	0,437 191
1974	697 333	733 930	318 800	0,457 170	0,402 790
1975	737 000	698 930	309 400	0,419 810	0,363 663
1976	880 476	771 603	369 800	0,420 000	0,222 142
1977	565 173	727 550	277 500	0,491 000	0,533 149
1978	590 618	678 756	258 100	0,437 000	0,508 051
1979	423 342	526 378	172 300	0,407 000	0,673 047
1980	201 111	405 024	90 500	0,450 000	0,892 251
1981	165 946	263 466	92 100	0,555 000	0,926 936
1982	327 282	231 446	176 400	0,538 985	0,767 799
1983	367 632	286 953	215 800	0,587 000	0,727 998
1984	312 106		198 500	0,636 002	0,782 768

	Effort (h)	Equilibrium catch (t)	TAC (t)
MSY	552 843	301 471	351 609
0,1	497 559	298 457	316 448

$a = 1,09\ 062$

$b = -0,986\ 375 \times 10^{-6}$

$r = -0,623\ 178$

$ss = 11\ 074,5$

TABLE 3. Cape hakes in Divisions 1.3 + 1.4. Catch, effort, and cpue, 1965-1984, and output for the dynamic Schaefer model

Year	Effort (h)	Catch (t)	Catch est. by model (t)	Equilibrium catch (t)	Catch at constant cpue (t)	Observed cpue (t/h)	Cpue est. by model (t/h)	Cpue est. at equil. (t/h)	Cpue est. at constant cpue (t/h)
1965	52 500	93 500							
1966	162 500	212 400	233 311	140 614	289 405	1,307 08	1,435 76	0,865 316	1,780 95
1967	214 000	195 000	239 829	173 917	279 714	0,911 215	1,120 69	0,812 694	1,307 08
1968	399 000	382 700	320 321	248 843	363 575	0,959 148	0,802 809	0,623 667	0,911 215
1969	364 000	320 500	308 000	240 032	349 130	0,880 495	0,846 154	0,659 429	0,959 148
1970	447 000	402 500	342 036	256 856	393 581	0,900 447	0,765 180	0,574 621	0,880 494
1971	420 000	365 600	330 965	252 928	378 188	0,870 476	0,788 012	0,602 209	0,900 447
1972	842 000	606 100	510 910	144 000	732 941	0,719 834	0,606 782	0,171 021	0,870 476
1973	662 456	377 600	385 611	234 824	476 858	0,570 000	0,582 093	0,354 474	0,719 834
1974	697 333	318 800	331 451	222 336	397 480	0,457 170	0,475 312	0,318 838	0,570 000
1975	737 000	309 400	287 238	205 113	336 935	0,419 810	0,389 739	0,278 307	0,457 170
1976	880 476	369 800	274 000	115 965	369 633	0,420 000	0,311 195	0,131 708	0,419 810
1977	565 173	277 500	244 591	256 518	237 373	0,491 000	0,432 771	0,453 876	0,420 000
1978	590 618	258 100	275 938	252 712	289 994	0,437 000	0,467 203	0,427 877	0,491 000
1979	423 342	172 300	210 823	253 495	185 000	0,407 000	0,497 997	0,598 795	0,437 000
1980	201 111	90 500	113 610	166 090	81 852	0,450 000	0,564 911	0,825 864	0,407 000
1981	165 946	92 100	100 438	143 011	74 676	0,555 000	0,605 247	0,861 795	0,450 000
1982	327 282	176 400	199 156	228 098	181 641	0,538 985	0,608 514	0,696 946	0,555 000
1983	367 632	215 800	214 327	241 063	198 148	0,587 000	0,582 993	0,655 718	0,538 985
1984	312 106	198 500	197 967	222 361	183 206	0,636 002	0,634 296	0,712 452	0,587 000

	Effort (h)	Equilibrium catch (t)	Catch at constant cpue (t)	TAC (t)
MSY	504 689	260 256	320 983	298 089
0,1	454 220	257 654	288 885	277 111

a = 1,03 135
b = $-0,102\ 177 \times 10^{-5}$
r = $-0,356$ 150
ss = 1 384,09

TABLE 4. Cape hakes in Divisions 1.3 + 1.4. Catch, effort, and cpue, 1965-1984, and output for the Foxa model (modified according to Gulland's method)

Year	Fishing effort (h)	Fishing effort (h) ($\bar{f}_{3y}$)	Catch (t)	Cpue (t/h)	Cpue (est.) (t/h)
1967	214 000	143 000	195 000	0,911 215	0,883 848
1968	399 000	258 500	382 700	0,959 148	0,665 921
1969	364 000	325 667	320 500	0,880 495	0,702 561
1970	447 000	403 333	402 500	0,900 447	0,618 758
1971	420 000	410 333	365 600	0,870 476	0,644 860
1972	842 000	569 667	606 100	0,719 834	0,338 061
1973	662 456	641 485	377 600	0,570 000	0,444 963
1974	697 333	733 930	318 800	0,457 170	0,421 836
1975	737 000	698 930	309 400	0,419 810	0,396 991
1976	880 476	771 603	369 800	0,420 000	0,318 730
1977	565 173	727 550	277 500	0,491 000	0,516 393
1978	590 618	678 756	258 100	0,437 000	0,496 671
1979	423 342	526 378	172 300	0,407 000	0,641 570
1980	201 111	405 024	90 500	0,450 000	0,901 455
1981	165 946	263 446	92 100	0,550 000	0,951 296
1982	327 282	231 446	176 400	0,538 985	0,743 170
1983	367 632	286 953	215 800	0,587 000	0,698 667
1984	312 106		198 500	0,636 002	0,760 631

	Effort (h)	Equilibrium catch (t)	TAC (t)
MSY	653 445	294 796	415 593
0,1	510 681	286 646	324 794

$a = 1,22633$

$b = -0,153\ 035 \times 10^{-5}$

$r = -0,637\ 805$

$ss = 8\ 562,74$

TABLE 5. Cape hakes in Divisions 1.3 + 1.4. Catch, effort, and cpue, 1965-1984, and output for the dynamic Fox model

Year	Effort (h)	Catch (t)	Catch est. by model (t)	Equilibrium catch (t)	Catch at constant cpue (t)	Observed cpue (t/h)	Cpue est. by model (t/h)	Cpue est. at equil. (t/h)	Cpue est. at constant cpue (t/h)
1965	52 500	93 500							
1966	162 500	212 400	234 508	146 072	289 405	1,307 08	1,443 13	0,898 903	1,780 95
1967	214 000	195 000	230 648	175 101	279 714	0,911 215	1,119 85	0,818 230	1,307 08
1968	399 000	382 700	313 522	232 890	363 575	0,959 148	0,785 771	0,583 684	0,911 215
1969	364 000	320 500	302 156	226 482	349 130	0,880 495	0,830 098	0,622 202	0,959 148
1970	447 000	402 500	334 382	239 014	393 581	0,900 447	0,748 058	0,534 707	0,880 494
1971	420 000	365 600	323 701	235 925	378 188	0,870 476	0,770 718	0,561 727	0,900 447
1972	842 000	606 100	536 056	218 881	732 941	0,719 834	0,636 646	0,259 954	0,870 476
1973	662 456	377 600	385 764	239 015	476 858	0,570 000	0,582 324	0,360 801	0,719 834
1974	697 333	318 800	335 662	236 076	397 480	0,457 170	0,481 351	0,338 541	0,570 000
1975	737 000	309 400	296 773	232 073	336 935	0,419 810	0,402 676	0,314 889	0,457 170
1976	880 476	369 800	309 778	213 355	369 633	0,420 000	0,351 831	0,242 318	0,419 810
1977	565 173	277 500	239 739	243 551	237 373	0,491 000	0,424 187	0,430 932	0,420 000
1978	590 618	258 100	271 981	242 962	289 994	0,437 000	0,460 502	0,411 370	0,491 000
1979	423 342	172 300	204 670	236 356	185 000	0,407 000	0,483 462	0,558 310	0,437 000
1980	201 111	90 500	115 028	168 474	81 852	0,450 000	0,571 963	0,837 714	0,407 000
1981	165 946	92 100	102 848	148 234	74 676	0,555 000	0,619 771	0,893 265	0,450 000
1982	327 282	176 400	195 473	217 756	181 641	0,538 985	0,597 262	0,665 346	0,555 000
1983	367 632	215 800	209 286	227 229	198 148	0,587 000	0,569 282	0,618 089	0,538 985
1984	312 106	198 500	194 806	213 493	183 206	0,636 002	0,624 166	0,684 040	0,587 000

	Effort (h)	Equilibrium catch (t)	Catch at constant cpue (t)	TAC (t)
MSY	547 687	243 673	348 330	308 246
0,1	428 029	236 937	272 227	258 711

a = 1,209 40

b = $-0{,}182\ 586 \times 10^{-5}$

r = -0,377 353

ss = 1 129,80

TABLE 6. Cape hakes in Divisions 1.5. Catch, effort, and cpue, 1965-1984, and output for the Schaefer model (modified according to Gulland's method)

Year	Fishing effort (std)	Fishing effort (std) ($\bar{f}_{3y}$)	Catch (t)	Cpue	Cpue (est.)
1967	1 466	812,00	199 400	136,016	112,458
1968	1 877	1 279,33	247 700	131,966	95,979 5
1969	1 909	1 750,67	206 200	108,015	94,696 5
1970	2 182	1 989,33	224 700	102,979	83,751 1
1971	1 714	1 935,00	229 700	134,014	102,515
1972	2 140	2 012,00	214 000	100,000	85,435 0
1973	3 088	2 314,00	290 300	94,009 1	47,426 7
1974	2 962	2 730,00	195 500	66,002 7	52,478 5
1975	2 351	2 800,33	178 700	76,010 2	76,975 4
1976	3 883	3 065,33	209 700	54,004 6	15,552 7
1977	2 426	2 886,67	157 700	65,004 1	73,968 4
1978	2 435	2 914,67	124 200	51,006 2	73,607 5
1979	1 884	2 248,33	130 000	69,002 1	95,698 9
1980	1 001	1 773,33	70 100	70,030 0	131,101
1981	1 386	1 423,67	116 400	83,982 7	115,665
1982	1 607	1 331,33	131 800	82,016 2	106,805
1983	1 284	1 425,67	123 300	96,028 0	119,755
1984	1 202		121 400	100,998	123,042

	Effort (h)	Equilibrium catch (t)	TAC (t)
MSY	2 135,46	182 832	215 678
0,1	1 921,91	181 003	194 110

a = 171,234
b = $-0{,}400\ 931 \times 10^{-1}$
r = -0,728 292
ss = 6 158,80

TABLE 7. Cape hakes in Division 1.5. Catch, effort, and cpue, 1965-1984, and output for the dynamic Schaefer model

Year	Effort (std)	Catch (t)	Catch est. by model (t)	Equilibrium catch (t)	Catch at constant cpue (t)	Observed cpue	Cpue est. by model	Cpue est. at equilibrium	Cpue est. at constant cpue
1965	475	99 700							
1966	495	122 200	102 984	101 867	103 898	246,869	208,048	205,791	209,895
1967	1 466	199 400	284 487	190 659	361 910	136,016	194,302	130,054	246,869
1968	1 877	247 700	223 189	183 938	255 303	131,966	118,907	97,995 7	136,016
1969	1 909	206 200	220 597	182 309	251 923	108,015	115,556	95,499 7	131,966
1970	2 182	224 700	202 491	161 917	235 688	102,979	92,800 7	74,205 8	108,015
1971	1 714	229 700	182 469	189 756	176 506	134,014	106,458	110,710	102,979
1972	2 140	214 000	232 349	165 811	286 790	100,000	108,575	77,481 8	134,014
1973	3 088	290 300	174 756	10 925	308 800	94,009 1	56,592 1	3,537 99	100,000
1974	2 962	195 500	170 966	39 590	278 455	66,002 7	57,719 7	13,366 0	94,009 1
1975	2 351	178 700	149 905	143 467	155 172	76,0102	63,762 2	61,023 8	66,002 7
1976	3 883	209 700	61 160	-227 046	295 148	54,004 6	15,493 3	-58,471 8	76,010 2
1977	2 426	157 700	132 292	133 852	131 015	65,004 1	54,530 8	55,173 9	54,004 6
1978	2 435	124 200	146 744	132 639	158 285	51,006 2	60,264 6	54,471 9	65,004 1
1979	1 884	130 000	135 470	183 595	96 096	69,002 1	71,905 8	97,449 7	51,006 2
1980	1 001	70 100	112 910	166 490	69 071	70,030 0	112,797	166,324	69,002 1
1981	1 386	116 400	138 390	188 903	97 062	83,982 7	99,848 6	136,294	70,030 0
1982	1 607	131 800	160 323	191 322	134 960	82,016 2	99,765 5	119,056	83,982 7
1983	1 284	123 300	141 267	185 217	105 309	96,028 0	110,021	144,250	82,016 2
1984	1 202	121 400	144 968	181 076	115 426	100,998	120,606	150,646	96,0280

	Effort (std)	Equilibrium catch (t)	Catch at constant cpue (t)	TAC (t)
MSY	1 566,68	191 449	158 232	173 180
0,1	1 410,01	189 535	142 409	163 616

a = 244,401

b = -0,779 998 x 10^{-1}

r = -0,565 034

ss = 4 529,04

TABLE 8. Cape hakes in Division 1.5. Catch, effort, and cpue, 1965-1984, and output for the Fox model (modified according to Gulland's method)

Year	Fishing effort (std)	Fishing effort (std) ($\bar{f}_{3y}$)	Catch (t)	Cpue	Cpue (est.)
1967	1 466	812,00	199 400	136,016	110,977
1968	1 877	1 279,33	247 700	131,966	92,229 4
1969	1 909	1 750,67	206 200	108,015	90,901 1
1970	2 182	1 989,33	224 700	102,979	80,395 4
1971	1 714	1 935,00	229 700	134,014	99,252 5
1972	2 140	2 012,00	214 000	100,000	81,930 1
1973	3 088	2 314,00	290 300	94,009 1	53,465 8
1974	2 962	2 730,00	195 500	66,002 7	56,586 6
1975	2 351	2 800,33	178 700	76,010 2	74,505 1
1976	3 883	3 065,33	209 700	54,004 6	37,378 9
1977	2 426	2 886,67	157 700	65,004 1	71, 739 9
1978	2 435	2 914,67	124 200	51,006 2	71,739 9
1979	1 884	2 248,33	130 000	69,002 1	91,939 2
1980	1 001	1 773,33	70 100	70,030 0	136,823
1981	1 386	1 423,67	116 400	83,982 7	115,047
1982	1 607	1 331,33	131 800	82,016 2	104,151
1983	1 284	1 425,67	123 300	96,028 0	120,454
1984	1 202		121 400	100,998	124,984

	Effort (h)	Equilibrium catch (t)	TAC (t)
MSY	2 221,06	175 450	224 323
0,1	1 735,80	170 600	175 313

a = 214,728

b = $-0,450\ 236 \times 10^{-3}$

r = -0,753 001

ss = 4 207,71

TABLE 9. Cape hakes in Division 1.5. Catch, effort, and cpue, 1965-1984, and output for the dynamic Fox model

Year	Effort (std)	Catch (t)	Catch est. by model (t)	Equilibrium catch (t)	Catch at constant cpue (t)	Observed cpue	Cpue est. by model	Cpue est. at equilibrium	Cpue est. at constant cpue
1965	475	99 700							
1966	495	122 200	102 570	101 475	103 898	246,869	207,212	205,000	209,895
1967	1 466	199 400	253 992	164 979	361 910	136,016	173,255	112,537	246,869
1968	1 877	247 700	205 201	163 876	255 303	131,966	109,324	87,307 3	136,016
1969	1 909	206 200	203 417	163 408	251 923	108,015	106,557	85,598 6	131,966
1970	2 182	224 700	193 003	157 795	235 688	102,979	88,452 2	72,316 7	108,015
1971	1 714	229 700	170 472	165 495	176 506	134,014	99,458 4	96,554 6	102,979
1972	2 140	214 000	216 665	158 825	286 790	100,000	101,245	74,217 1	134,014
1973	3 088	290 300	209 509	127 613	308 800	94,009 1	67,846 3	41,325 3	100,000
1974	2 962	195 500	198 369	132 312	278 455	66,002 7	66,971 1	44,669 8	94,009 1
1975	2 351	178 700	154 072	153 165	155 172	76,010 2	65,534 8	65,148 8	66,002 7
1976	3 883	209 700	187 223	98 206	295 148	54,004 6	48,216 2	25,291 1	76,010 2
1977	2 426	157 700	141 910	150 897	131 015	65,004 1	58,495 6	62,199 7	54,004 6
1978	2 435	124 200	154 083	150 617	158 285	51,006 2	63,278 4	61,854 9	65,004 1
1979	1 884	130 000	133 185	163 777	96 096	69,002 1	70,692 8	86,930 6	51,006 2
1980	1 001	70 100	113 490	150 127	69 071	70,030 0	113,377	149,977	69,002 1
1981	1 386	116 400	133 676	163 877	97 062	83,982 7	96,447 6	118,237	70,030 0
1982	1 607	131 800	151 841	165 764	134 960	82,016 2	94,487 0	103,151	83,982 7
1983	1 284	123 300	136 205	161 689	105 309	96,028 0	106,079	125,926	82,016 2
1984	1 202	121 400	139 428	159 226	115 426	100,998	115,997	132,468	96,028 0

	Effort (std)	Equilibrium catch (t)	Catch at constant cpue (t)	TAC (t)
MSY	1 619,07	165 769	163 524	164 754
0,1	1 265,34	161 186	127 797	146 094

a = 278,311

$b = -0{,}617\ 637 \times 10^{-3}$

r = -0,634 634

ss = 1 548,17

TABLE 10. Cape hakes in Division 1.6. Catch, effort, and cpue, 1955-1983, and output for the Schaefer model (modified according to Gulland's method)

Year	Fishing effort (std)	Fishing efort (std) ($\bar{f}_{3y}$)	Catch (t)	Cpue	Cpue (est.)
1957	7 675	7 300,00	126 400	16,469 1	14,895 5
1958	8 038	7 757,00	130 700	16,260 3	14,699 4
1959	8 979	8 230,67	146 000	16,260 2	14,191 1
1960	9 237	8 751,33	159 900	17,310 8	14,051 8
1961	12 299	10 171,7	148 700	12,090 4	12,397 9
1962	10 409	10 648,3	147 600	14,180 0	13,418 7
1963	12 133	11 613,7	169 500	13,970 2	12,487 5
1964	11 116	11 219,3	162 300	14,600 6	13,036 8
1965	18 755	14 001,3	203 300	10,839 8	8,910 76
1966	18 344	16 071,7	195 000	10,630 2	9,132 75
1967	17 652	18 250,3	176 700	10,010 2	9,506 52
1968	14 346	16 780,7	143 600	10,009 8	11,292 2
1969	19 153	17 050,3	165 100	8,620 06	8,695 78
1970	19 710	17 736,3	142 500	7,229 83	8,349 93
1971	28 491	22 451,3	202 000	7,089 96	3,652 00
1972	49 776	32 659,0	243 900	4,899 95	8,394 93
1973	31 751	36 672,7	157 800	4,969 92	1,891 16
1974	26 452	35 993,0	123 000	4,649 93	4,753 33
1975	19 227	25 810,0	89 600	4,660 11	8,655 81
1976	26 804	24 161,0	143 400	5,349 95	4,563 20
1977	20 145	22 058,7	97 500	4,839 91	8,159 97
1978	17 237	21 395,3	101 700	5,900 10	9,730 68
1979	14 747	17 376,3	90 400	6,130 06	11,075 6
1980	18 422	16 802,0	101 500	5,509 72	9,090 62
1981	17 143	16 770,7	99 600	5,809 95	9,781 45
1982	14 804	16 789,7	86 900	5,870 04	11,044 8
1983	14 742		97 000	6,579 84	11,078 3

	Effort (h)	Equilibrium catch (t)	TAC (t)
MSY	17 626,1	167 810	115 977
0,1	15 863,5	166 131	104 379

a = 19,041 0

b = $-0,450\ 135 \times 10^{-3}$

r = -0,818 872

ss = 5 266,66

TABLE 11. Cape hakes in Division 1.6. Catch, effort, and cpue, 1955–1983, and output for the dynamic Schaefer model

Year	Effort (std)	Catch (t)	Catch est. by model (t)	Equilibrium catch (t)	Catch at constant cpue (t)	Observed cpue	Cpue est. by model	Cpue est. at equil.	Cpue est. at constant cpue
1955	6 667	115 400							
1956	7 558	118 200	130 341	128 177	130 822	15,639 1	17,245 4	16,959 2	17,309 1
1957	7 675	126 400	121 726	129 349	120 030	16,469 1	15,860 0	16,853 2	15,639 1
1958	8 038	130 700	132 459	132 825	132 378	16,260 3	16,479 2	16,524 6	16,469 1
1959	8 979	146 000	145 041	140 724	146 001	16,260 2	16,153 3	15,672 6	16,260 3
1960	9 237	159 900	148 815	142 610	150 195	17,310 8	16,110 7	15,439 0	16,260 2
1961	12 299	148 700	202 510	155 787	212 906	12,090 4	16,465 6	12,666 7	17,310 8
1962	10 409	147 600	130 183	149 659	125 849	14,180 0	12,506 7	14,377 9	12,090 4
1963	12 133	169 500	169 036	155 508	172 046	13,970 2	13,932 0	12,817 0	14,180 0
1964	11 116	162 300	154 822	152 709	155 292	14,600 6	13,927 9	13,737 8	13,970 2
1965	18 755	203 300	247 280	127 936	273 834	10,839 8	13,184 8	6,821 41	14,600 6
1966	18 344	195 500	186 671	131 958	198 845	10,630 2	10,176 2	7,193 53	10,839 8
1967	17 652	176 700	178 616	138 040	187 644	10,010 2	10,118 7	7,820 07	10,630 2
1968	14 346	143 600	145 703	155 128	143 606	10,009 8	10,156 4	10,813 3	10,010 2
1969	19 153	165 100	179 347	123 749	191 717	8,620 06	9,363 90	6,461 06	10,009 8
1970	19 710	142 500	160 348	117 408	169 901	7,229 83	8,135 34	5,956 75	8,620 06
1971	28 491	202 000	158 159	-56 798	205 985	7,089 96	5,551 18	-1,993 55	7,229 83
1972	49 776	243 900	96 036	-1 058 490	352 910	4,899 95	1,929 36	-21,265 0	7,089 96
1973	31 751	157 800	98 687	-157 014	155 578	4,969 92	3,108 14	-4,945 15	4,899 95
1974	26 452	123 000	106 828	-3 900	131 464	4,649 93	4,038 56	-0,147 444	4,969 92
1975	19 227	89 600	95 508	122 939	89 404	4,660 11	4,967 36	6,394 06	4,649 93
1976	26 804	143 400	99 902	-12 495	124 910	5,349 95	3,727 13	-0,466 145	4,660 11
1977	20 145	97 500	108 555	112 065	107 775	4,839 91	5,388 71	5,562 91	5,349 95
1978	17 237	101 700	93 953	141 271	83 426	5,900 10	5,450 68	8,195 81	4,839 91
1979	14 747	90 400	99 221	154 110	87 009	6,130 06	6,728 23	10,450 2	5,900 10
1980	18 422	101 500	116 257	131 218	112 928	5,509 72	6,310 76	7,122 91	6,130 06
1981	17 143	99 600	103 099	141 960	94 453	5,809 95	6,014 07	8,280 91	5,509 72
1982	14 804	86 900	98 374	153 941	86 011	5,870 04	6,645 09	10,398 6	5,809 95
1983	14 742	97 000	98 837	154 124	86 536	6,579 84	6,704 46	10,454 8	5,870 03

	Effort (h)	Equilibrium catch (t)	Catch at constant cpue (t)	TAC (t)
MSY	13 144,6	156 435	86 489	99 219
0,1	11 830	154 870	77 840	91 860

$a = 23{,}802\ 2$

$b = -0{,}905\ 399 \times 10^{-3}$

$r = -0{,}540\ 132$

$ss = 2\ 070{,}23$

TABLE 12. Cape hakes in Division 1.6. Catch, effort, and cpue, 1955-1983, and output for the Fox model (modified according to Gulland's method)

Year	Fishing effort (std)	Fishing efort (std) ($\bar{f}_{3y}$)	Catch (t)	Cpue	Cpue (est.)
1957	7 675	7 300,00	126 400	16,469 1	15,172 9
1958	8 038	7 757,00	130 700	16,260 3	14,859 7
1959	8 979	8 230,67	146 000	16,260 2	14,077 7
1960	9 237	8 751,33	159 900	17,310 8	13,870 6
1961	12 299	10 171,7	148 700	12,090 4	11,633 1
1962	10 409	10 648,3	147 600	14,180 0	12,967 4
1963	12 133	11 613,7	169 500	13,970 2	11,744 6
1964	11 116	11 219,3	162 300	14,600 6	12,451 2
1965	18 755	14 001,3	203 300	10,839 8	8,028 09
1966	18 344	16 071,7	195 000	10,630 2	8,219 91
1967	17 652	18 250,3	176 700	10,010 2	8,553 29
1968	14 346	16 780,7	143 600	10,009 8	10,342 4
1969	19 153	17 050,3	165 100	8,620 06	7,846 61
1970	19 710	17 736,3	142 500	7,229 83	7,599 49
1971	28 491	2 451,3	202 000	7,089 96	4,588 71
1972	49 776	32 659,0	243 900	4,899 95	1,350 86
1973	31 751	36 672,7	157 800	4,969 92	3,804 97
1974	26 452	35 993,0	123 000	4,649 93	5,159 00
1975	19 227	25 810,0	89 600	4,660 11	7,813 32
1976	26 804	24 161,0	143 400	5,349 95	5,055 72
1977	20 145	22 058,7	97 500	4,839 91	7,411 92
1978	17 237	21 395,3	101 700	5,900 10	8,759 67
1979	14 747	17 376,3	90 400	6,130 06	10,106 8
1980	18 422	16 802,0	101 500	5,509 72	8,183 16
1981	17 143	16 770,7	99 600	5,809 95	8,807 10
1982	14 804	16 789,7	86 900	5,870 04	10,073 8
1983	14 742		97 000	6,579 84	10,109 7

	Effort (h)	Equilibrium catch (t)	TAC (t)
MSY	17 406	150 998	114 529
0,1	13 603	146 823	89 507

a = 23,581 2

b = $-0{,}574\ 515 \times 10^{-4}$

r = -0,845 034

ss = 4 149,80

TABLE 13. Cape hakes in Division 1.6. Catch, effort, and cpue, 1955-1983, and output for the dynamic Fox model

Year	Effort (std)	Catch (t)	Catch est. by model (t)	Equilibrium catch (t)	Catch at constant cpue (t)	Observed cpue	Cpue est. by model	Cpue est. at equil.	Cpue est. at constant cpue
1955	6 667	115 400							
1956	7 558	118 200	127 135	120 317	130 822	15,639 1	16,821 2	15,919 1	17,309 1
1957	7 675	126 400	120 393	121 065	120 030	16,469 1	15,686 4	15,774 0	15,639 1
1958	8 038	130 700	129 170	123 239	132 378	16,260 3	16,070 0	15,332 0	16,469 1
1959	8 979	146 000	139 644	127 889	146 001	16,260 2	15,552 3	14,243 1	16,260 3
1960	9 237	159 900	142 732	128 933	150 195	17,310 8	15,452 2	13,958 3	16,260 2
1961	12 299	148 700	185 590	135 082	212 906	12,090 4	15,089 8	10,983 2	17,310 8
1962	10 409	147 600	128 203	132 555	125 849	14,180 0	12,316 5	12,734 6	12,090 4
1963	12 133	169 500	159 044	135 002	172 046	13,970 2	13,108 4	11,126 8	14,180 0
1964	11 116	162 300	147 796	133 936	155 292	14,600 6	13,295 8	12,048 9	13,970 2
1965	18 755	203 300	221 335	124 264	273 834	10,839 8	11,801 4	6,625 64	14,600 6
1966	18 344	195 000	173 106	125 515	198 845	10,630 2	9,436 66	6,842 29	10,839 8
1967	17 652	176 700	166 535	127 504	187 644	10,010 2	9,434 33	7,223 19	10,630 2
1968	14 346	143 600	140 317	134 234	143 606	10,009 8	9,780 88	9,356 88	10,010 2
1969	19 153	165 100	167 600	123 008	191 717	8,620 06	8,750 59	6,422 38	10,009 8
1970	19 710	142 500	152 802	121 184	169 901	7,229 83	7,752 49	6,148 35	8,620 06
1971	28 491	202 000	164 603	88 088	205 985	7,089 96	5,777 38	3,091 79	7,229 83
1972	49 776	243 900	239 245	29 077	352 910	4,899 95	4,806 42	0,584 162	7,089 96
1973	31 751	157 800	127 666	76 055	155 578	4,969 92	4,020 84	2,395 37	4,899 95
1974	26 452	123 000	118 995	95 939	131 464	4,649 93	4,498 52	3,626 89	4,969 92
1975	19 227	89 600	101 116	122 770	89 404	4,660 11	5,259 04	6,385 28	4,649 93
1976	26 804	143 400	114 261	94 573	124 910	5,349 95	4,262 85	3,528 31	4,660 11
1977	20 145	97 500	111 965	119 712	107 775	4,839 91	5,557 93	5,942 49	5,349 95
1980	17 237	101 700	99 288	128 618	83 426	5,900 10	5,760 17	7,461 72	4,839 91
1981	14 747	90 400	103 405	133 721	87 009	6,130 06	7,011 93	9,067 70	5,900 10
1980	18 422	101 500	117 264	125 281	112 928	5,509 72	6,365 43	6,800 64	6,130 06
1981	17 143	99 600	106 530	128 861	94 453	5,809 95	6,214 21	7,516 83	5,509 72
1982	14 804	86 900	102 729	133 641	86 011	5,870 04	6,939 25	9,027 33	5,809 95
1983	14 742	97 000	103 101	133 728	86 536	6,579 84	6,993 66	9,071 25	5,870 03

	Effort (h)	Equilibrium catch (t)	Catch at constant cpue (t)	TAC (t)
MSY	12 774	135 178	84 048	101 995
0,1	9 983	131 441	65 686	88 766

a = 28,766 4

b = 0,782 864 x 10^{-4}

r = 0,780 060

ss = 477,769

TABLE 14 Correlation between observed catch and catch as estimated by the dynamic model for Cape hakes

Division / Month	1.3 + 1.4	1.5	1.6
Schaefer	0,961 9	0,514 6	0,581 2
Fox	0,970 4	0,805 0	0,905 8

TABLE 15 Correlation between observed cpue and estimated cpue for Cape hakes

Division / Model	1.3 + 1.4	1.5	1.6
Schaefer			
traditional	0,326 0	0,434 5	0,672 8
dynamic	0,930 6	0,833 1	0,956 8
Fox			
traditional	0,293 5	0,382 4	0,828 1
dynamic	0,927 2	0,871 8	0,970 0

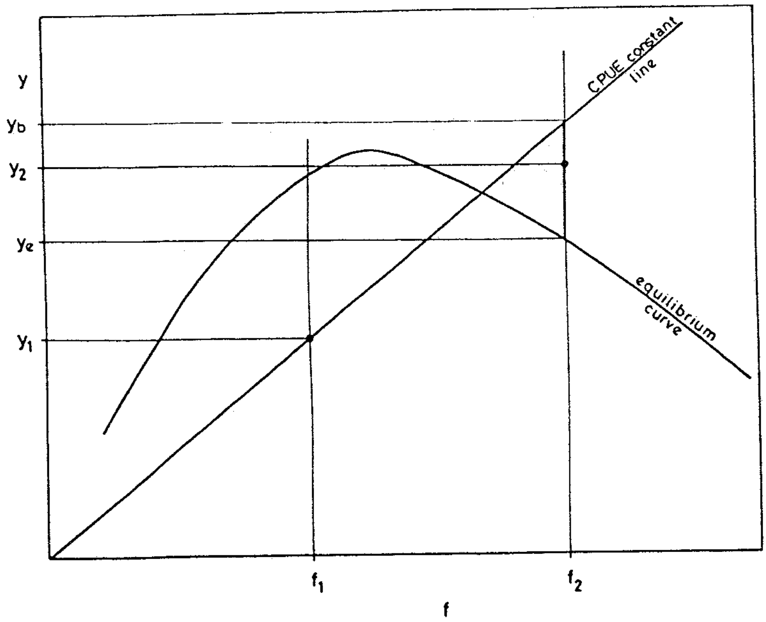

FIG. 1 Catch on effort: illustration of traditional and dynamic production models

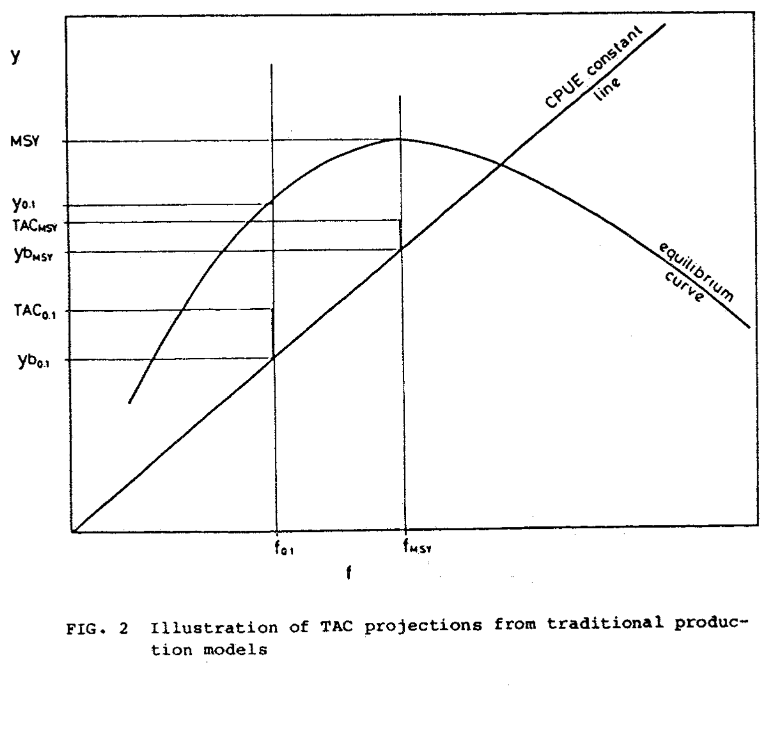

FIG. 2 Illustration of TAC projections from traditional production models

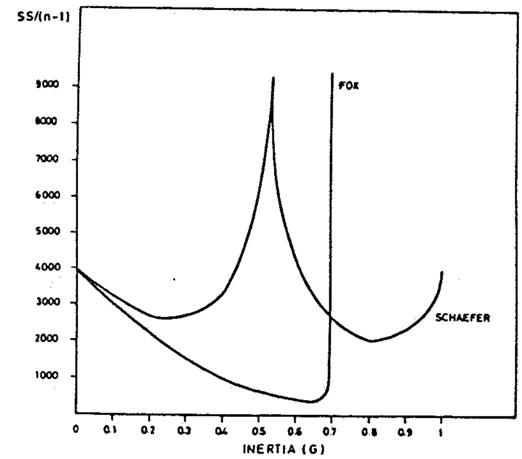

FIG. 3 Ss/(n-1) on the inertia parameter for Schaefer and Fox dynamic models fitted to the Cape hake data from Division 1.6

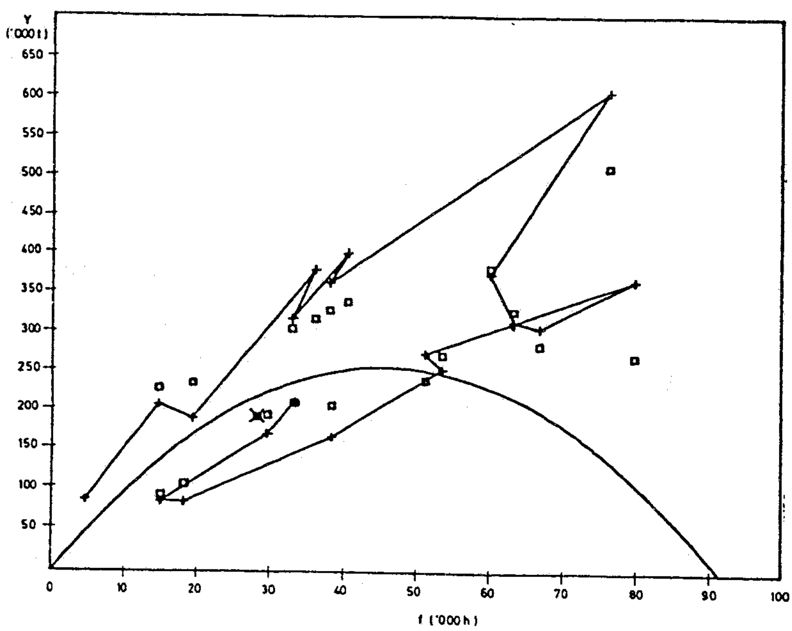

FIG. 4 Cape hake in Divisions 1.3 + 1.4: Dynamic Schaefer model

(+) observed values

(□) estimated values

(x) last year observed (for TAC estimations only)

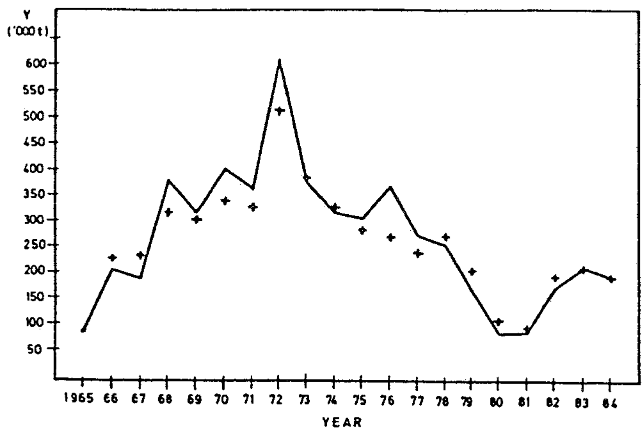

FIG. 5 Cape hakes in Divisions 1.3 + 1.4: actual catches (solid line), and catch estimates according to the dynamic Schaefer model (+)

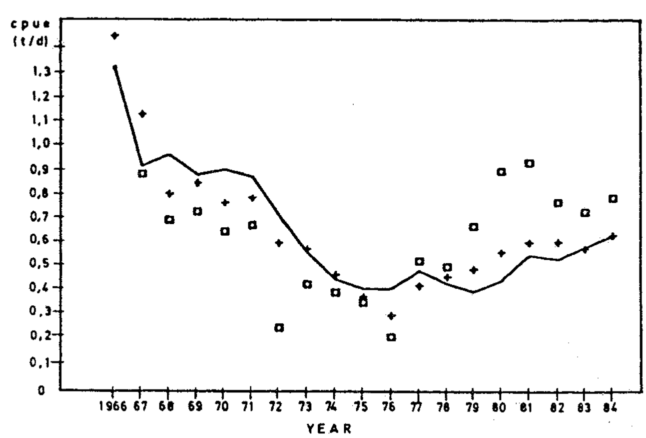

FIG. 6 Observed and estimated values of catch per unit effort for Cape hakes in Divisions 1.3 + 1.4:

(—) observed

(□) estimated by Gulland-modified Schaefer model

(+) estimated by dynamic Schaefer model

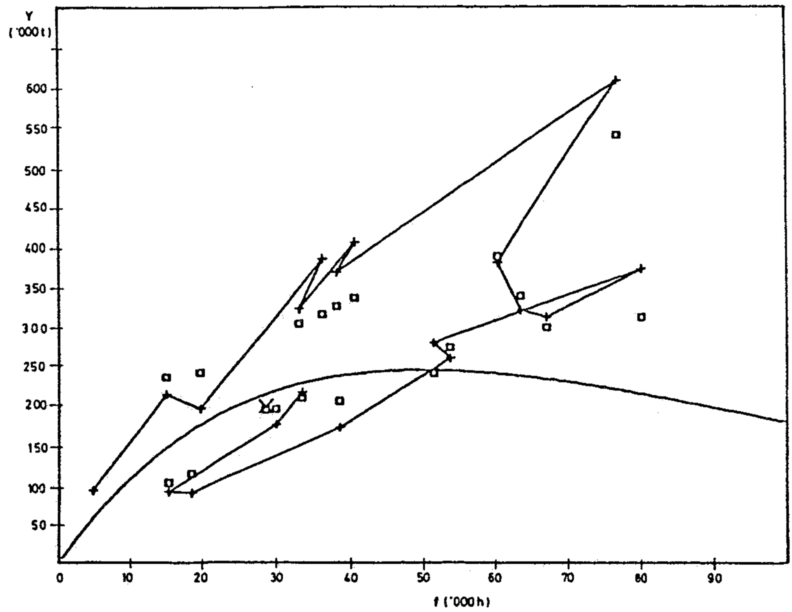

FIG. 7 Cape hakes in Divisions 1.3 + 1.4: Dynamic Fox model

(+) observed values

(□) estimated values

(x) last year observed (for TAC estimations only)

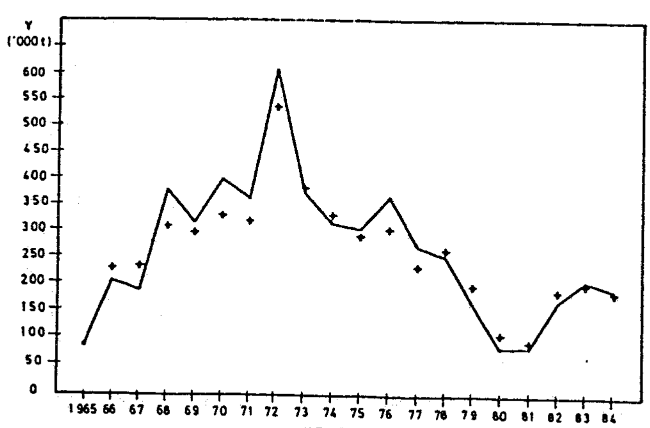

FIG. 8 Cape hakes in Divisions 1.3 + 1.4: actual catches (solid line), and catch estimates according to the dynamic Fox model (+)

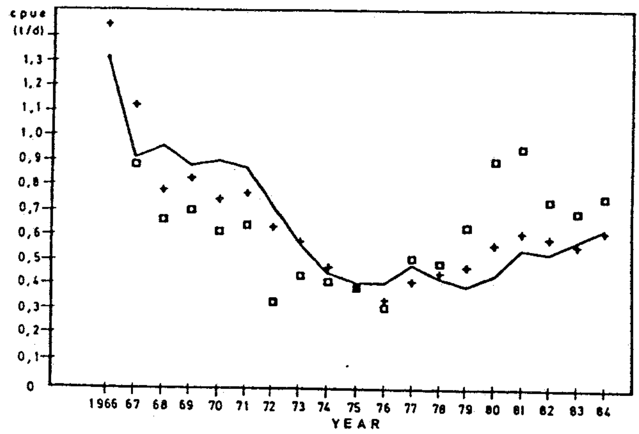

FIG. 9 Observed and estimated values of catch per unit effort for Cape hakes in Divisions 1.3 + 1.4:

(—) observed

(□) estimated by Gulland-modified Fox model

(+) estimated by dynamic Fox model

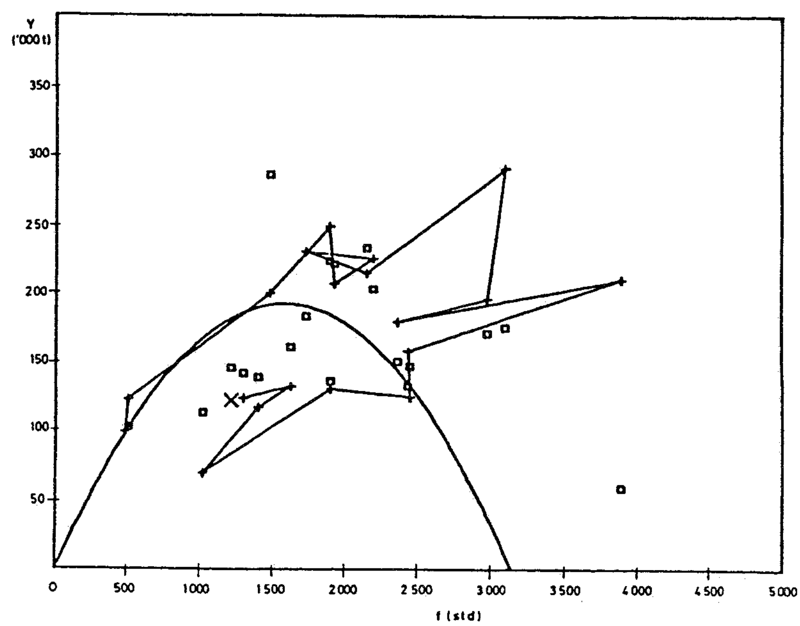

FIG. 10 Cape hakes in Division 1.5: Dynamic Schaefer model

(+) observed values

(□) estimated values

(x) last year observed (for TAC estimations only)

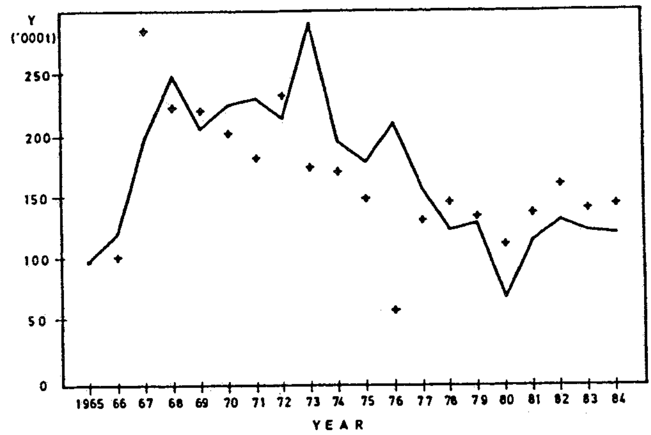

FIG. 11 Cape hakes in Division 1.5: actual catches (solid line), and catch estimates according to the dynamic Schaefer model (+)

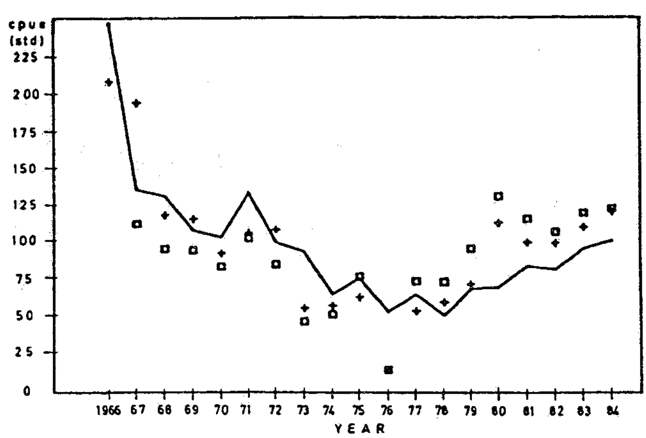

FIG. 12 Observed and estimated values of catch per unit effort for Cape hakes in Division 1.5:

(—) observed

(□) estimated by Gulland-modified Schaefer model

(+) estimated by dynamic Schaefer model

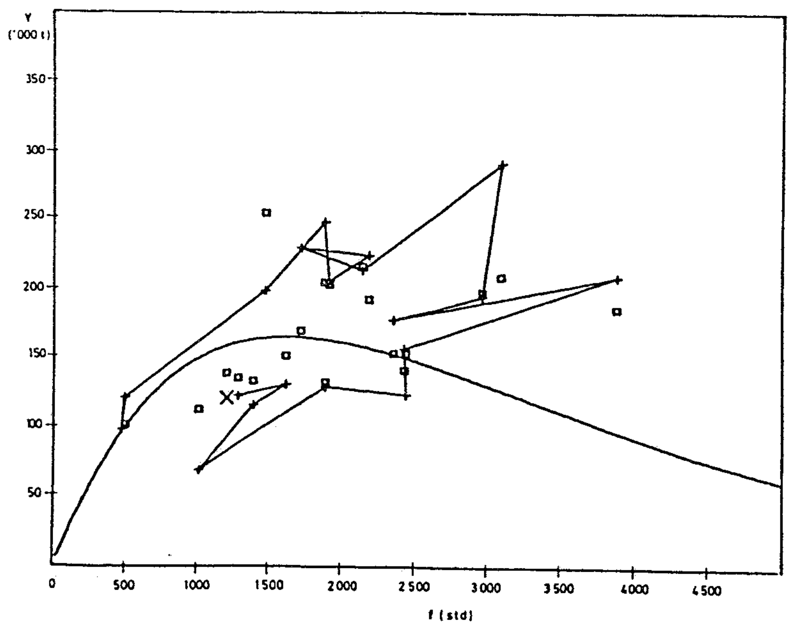

FIG. 13 Cape hakes in Division 1.5: Dynamic Fox model

(+) observed values

(□) estimated values

(x) last year observed (for TAC estimations only)

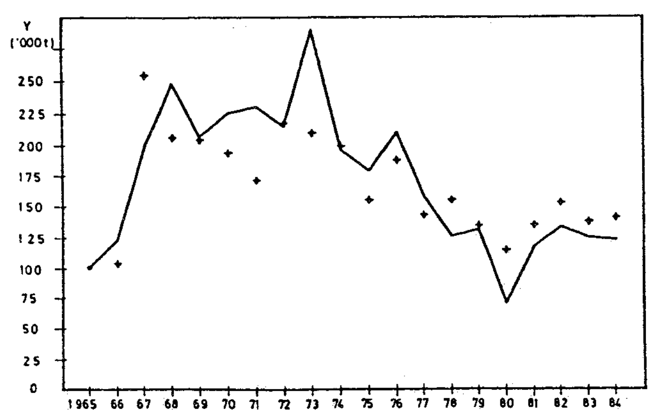

FIG. 14 Cape hakes in Division 1.5: actual catches (solid line), and catch estimates according to the dynamic Fox model (+)

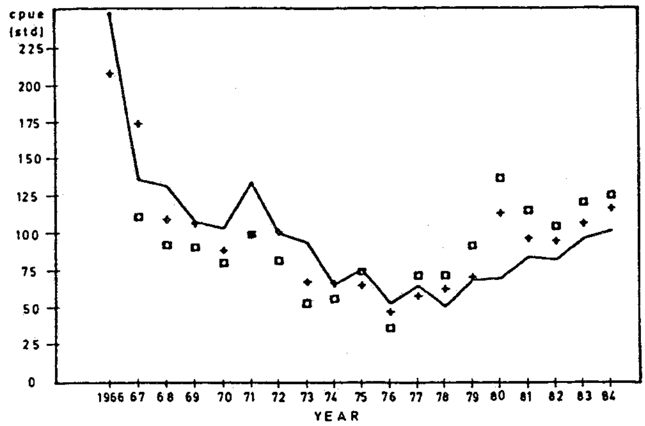

FIG. 15 Observed and estimated values of catch per unit effort for Cape hakes in Division 1.5:

(—) observed
(□) estimated by Gulland-modified Fox model
(+) estimated by dynamic Fox model

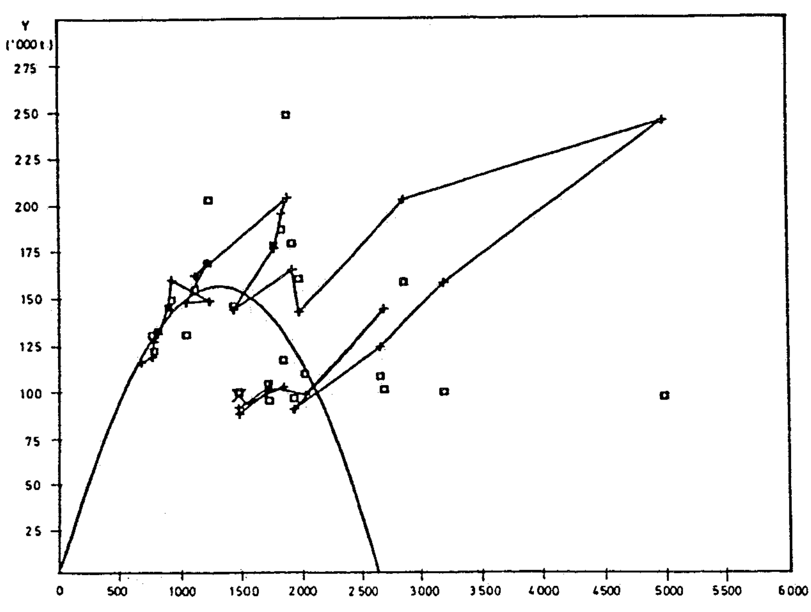

FIG. 16 Cape hakes in Division 1.6: Dynamic Schaefer model

(+) observed values
(□) estimated values
(x) last year observed (for TAC estimations only)

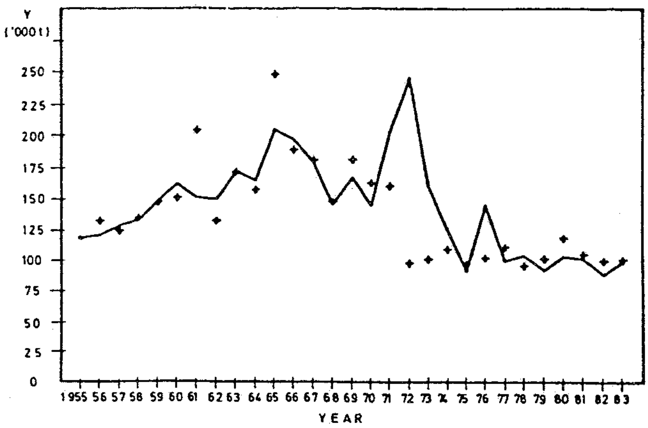

FIG. 17 Cape hakes in Division 1.6: actual catches (solid line), and catch estimates according to the dynamic Schaefer model (+)

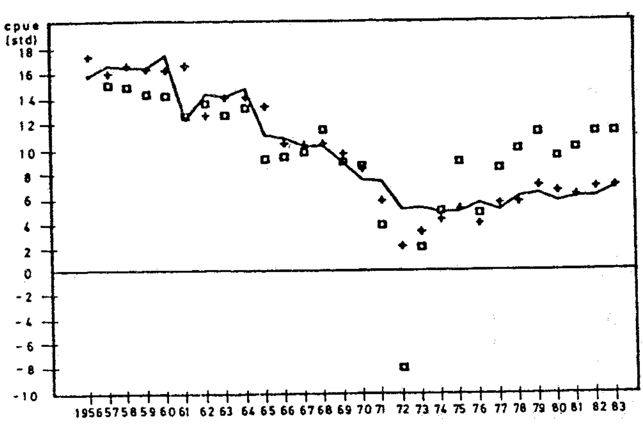

FIG. 18 Observed and estimated values of catch per unit effort for Cape hakes in Division 1.6:

(—) observed
(□) estimated by Gulland-modified Schaefer model
(+) estimated by dynamic Schaefer model

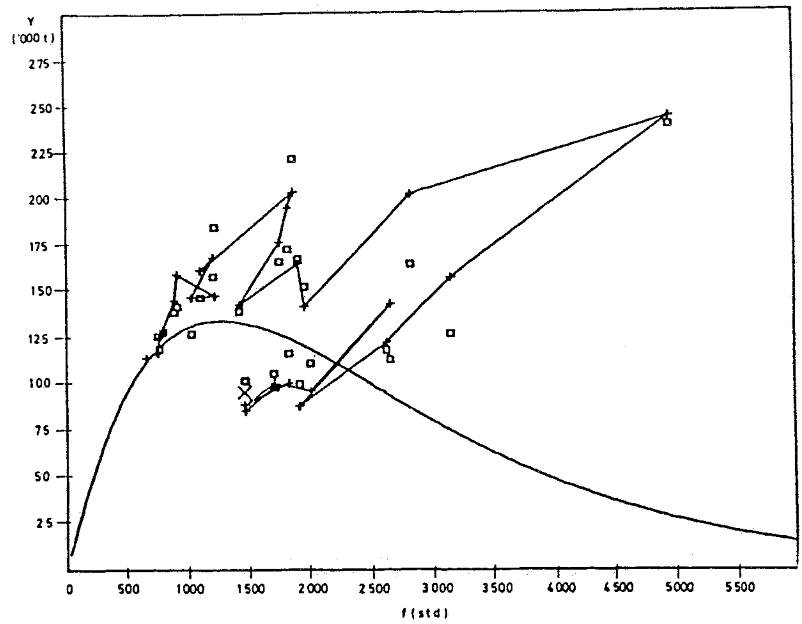

FIG. 19

Cape hakes in Division 1.6:
Dynamic Fox model

(+) observed values

(□) estimated values

(x) last year observed (for TAC estimations only)

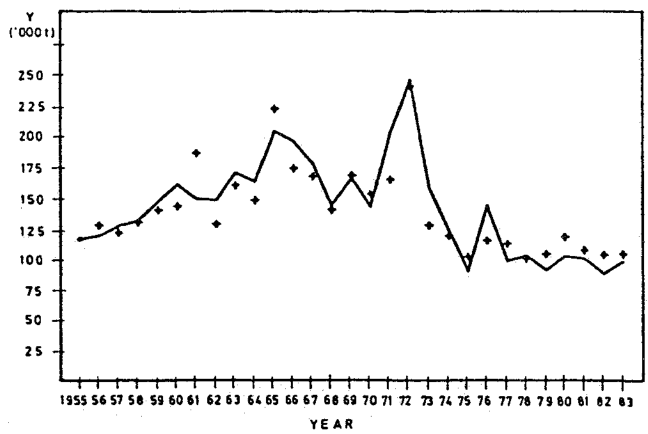

FIG. 20 Cape hakes in Division 1.6: actual catches (solid line), and catch estimates according to the dynamic Fox model (+)

FIG. 21 Observed and estimated values of catch per unit effort for Cape hakes in Division 1.6:

(—) observed

(□) estimated by Gulland-modified Fox model

(+) estimated by dynamic Fox model