

VIRTUAL POPULATION ANALYSIS OF THE FORKBEARD, *PHYCIS PHYCIS* (LINNAEUS, 1766), IN THE AZORES

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ARQUIPÉLAGO



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An assessment of the forkbeard was conducted in the ICES fishing area X. Virtual Population Analysis estimates of stock size indicate a decrease in abundance from 8590 thousand individuals in 1983 to 4631 thousand in 1990. During the same period, stock biomass decreased from 10780 to 8013 tonnes. Reported landings from this stock in 1990 were only 531 tonnes, an increase of 245 tonnes (86%) over 1983.

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Os resultados da aplicação de um modelo de avaliação à população de abrótea dos Açores (área de pesca X do CIEM) são apresentados. As estimativas de abundância obtiveram-se através da Análise de Populações Virtuais. O manancial total foi estimado em 8590 mil indivíduos em 1983 e 4631 mil em 1990. Durante este período, a biomassa que era de 10780 toneladas, diminuiu para 8013 toneladas. As capturas reportadas em 1990 foram de 531 toneladas, que representou um aumento de 245 toneladas (86%) relativamente a 1983.

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INTRODUCTION

In the Azores, there are two major demersal fisheries whose catches include the forkbeard, *Phycis phycis* (Linnaeus, 1766). One is the longline fishery, which, according to the depth at which the fishing operation occurs will catch a mixture of blackspot seabream, *Pagellus bogaraveo* (Brünnich, 1768), and several other species. Down to 150 m the catch is mostly represented by juvenile blackspot seabream and porgy, *Pagrus pagrus* (Linnaeus, 1758). Between 150 and 300 m the catch includes mostly preadult blackspot seabream and forkbeard, whose sizes will also increase over this depth range. At depths greater than 300 m, a mixture of adult blackspot seabream, the scorpionfish, *Pontinus kuhlii* (Bowdich, 1825), bluemouth, *Helicolenus dactylopterus dactylopterus* (Delaroche, 1809), alfonsino, *Beryx decadactylus* (Cuvier, 1829), and conger eel, *Conger conger* (Linnaeus, 1758) dominate in the catches (DIAS & al. 1986 and DIAS & MONTEIRO 1986).

The other fishery that catches large amounts of forkbeard is that for wreckfish *Polyprius americanus* (Schneider, 1801). This is also a longline fishery but the hooks used are much larger, which results in a different selectivity, towards larger forkbeard sizes. Recent changes in the forkbeard catches for the ICES area X and changes in the fishing pattern have raised questions about the stock size. The present study collates the information available on these fisheries and presents a fish assessment of stock size using Virtual Population Analysis (VPA).

MATERIAL AND METHODS

Traditional VPA is based on the iterative solution of the formula (GULLAND 1965):

$$N_{t+1}/C_t = [(F+M)e^{-(F+M)}]/[F(1-e^{-(F+M)})];$$

where F and M are the annual instantaneous rates of fishing and natural mortality, respectively, N is the size of a year-class in numbers, C is the catch

of a year-class in numbers, and t and $t+1$ are subscripts indexing years t and $t+1$.

The method used in the present study is a simplification of Gulland's VPA, referred as cohort analysis, and based on the approximate formula (POPE 1972):

$$N_t = e^M N_{t+1} + e^{M/2} C_t$$

A VPA program developed by the MAFF Directorate of Fisheries Research (Lowestoft) was used in the present analysis (FLATMAN & STEVENS 1988).

The catch at age matrix (Table 1) was compiled from the length composition of the landings and from the following length at age relationship (SILVA 1985):

$$L_t = 65.32[1 - e^{-0.19(t+0.28)}]$$

Mean weights at age (Table 2) were computed from the following length to weight relationship (SILVA 1985):

$$W = 0.0054L^{3.2045},$$

where weights, W , are in kg and lengths, L , are in cm.

These weights at age were mean weights in the catch during the entire fishing year, and were used to report mean annual population biomass and annual yield.

No attempt was made to account for discards or misreporting, on which there is little information at present.

Nonexistence of a time series of abundance indices from cruise surveys in the area, commonly used in VPA tuning (LAUREC & SHEPHERD 1983 and POPE & SHEPHERD 1985) and the unsuitability of the effort data available for the demersal fishery, given the lack of information on the depths at which each year effort was applied, made the tuning of this analysis by the standard techniques impossible. However, forkbeard fishing mortality in the area is known to be very low. In 1986, a fishing mortality rate of $F = 0.04/\text{year}$ was estimated (SILVA 1988). On the other hand, the relative catch of ages 4-9 seabream, the target species, which is caught in the depth strata 150-300 m, and whose catch is associated with the catch of fork-

Table 1

Catch numbers at age in thousands. Total numbers (N Total), total weight (W Total) in tonnes and average weight (W Mean) in kg are also shown.

AGE	YEAR							
	1983	1984	1985	1986	1987	1988	1989	1990
2	7	15	4	5	16	5	1	2
3	34	23	6	14	14	34	3	9
4	42	14	24	16	15	63	17	19
5	38	27	22	20	23	64	41	34
6	35	35	18	18	20	39	34	30
7	24	28	23	16	21	31	40	36
8	21	22	27	15	20	31	40	35
9	12	14	18	12	14	16	23	23
10	3	11	8	6	6	7	11	12
11	2	3	12	3	3	7	10	10
12	3	1	9	6	6	3	6	9
13	3	7	9	7	5	4	9	11
14	3	3	7	5	5	3	6	10
15+	8	8	14	30	32	16	28	42
N Total	234	212	201	172	201	324	267	282
W Total	286	290	348	306	343	423	476	531
W Mean	1.22	1.37	1.73	1.78	1.71	1.31	1.78	1.88

Table 2
Mean weight (kg) at age in each year

AGE	YEAR							
	1983	1984	1985	1986	1987	1988	1989	1990
2	0.230	0.242	0.234	0.247	0.199	0.251	0.191	0.244
3	0.426	0.409	0.453	0.447	0.417	0.445	0.485	0.433
4	0.677	0.707	0.707	0.699	0.696	0.686	0.731	0.702
5	0.980	0.979	0.952	0.969	0.969	0.966	0.982	0.970
6	1.231	1.215	1.240	1.228	1.231	1.226	1.243	1.240
7	1.507	1.507	1.507	1.513	1.489	1.503	1.498	1.507
8	1.795	1.790	1.819	1.806	1.819	1.815	1.799	1.814
9	2.099	2.095	2.107	2.101	2.092	2.098	2.093	2.096
10	2.286	2.286	2.286	2.286	2.286	2.286	2.286	2.286
11	2.417	2.417	2.417	2.417	2.417	2.417	2.417	2.417
12	2.553	2.553	2.553	2.553	2.553	2.553	2.553	2.553
13	2.695	2.695	2.695	2.695	2.695	2.695	2.695	2.695
14	2.841	2.841	2.841	2.841	2.841	2.841	2.841	2.841
15+	3.432	3.084	3.320	3.375	3.514	3.455	3.455	3.446

beard, gives some indication of the relative changes which occurred in the forkbeard effort (SILVA, unpublished analysis). As to the wreck fish fishery no effort data is available.

Terminal fishing mortality rates (in 1990) were estimated by running some previous analyses and using the mean fishing mortalities at age to successively approach a stable terminal fishing mortality distribution. These values were then adjusted to fit the fishing mortality, $F = 0.07/\text{year}$ in 1990, estimated from the value of $F = 0.04/\text{year}$ in 1986 (SILVA 1988) and the relative change in fishing effort from 1986 to 1990 (SILVA, unpublished analysis).

A natural mortality rate of $M = 0.2/\text{year}$ was assumed in the present study.

RESULTS

Yields from the azorean forkbeard stock have increased from 286 tonnes in 1983 to 531 tonnes in 1990 (Fig. 1). Catch in numbers, however, show a much smaller increase in the same period (Fig. 2), which suggests that the incidence of the catch has increased in the older specimens. In fact, ages 3-8 predominated in the catches (68% by number) and, ages 9+ that in 1983 contributed 15% (by numbers) to the total catch, in 1990 represented

42%, which denotes the shift observed in the length composition of the catches (Fig. 3). This should result from two major changes occurred in the two fisheries referred above. On the one hand, the increasing depths at which the demersal longline fishery has been taking place during the 1980s and early 1990s, resulted in smaller catches of forkbeard being made as opposed to the catches of the bluemouth, alfonsino and conger eel that have been increasing steadily. The decreasing trend in the catches of forkbeard from this fishery has been compensated by an increasing effort in the wreck fish fishery and the resulting increasing catches of large-sized forkbeard. Fig. 4 gives the species composition of the landings from the demersal community of the Azores, which also includes the catches from the kitefin shark fishery (data from ANON. 1981-1991).

It should be noticed, however, that the average weight in the catches increased from 1.22 kg, in 1983, to between 1.7 and 1.9 kg in 1985-1990, except for 1988 (Table 1). The average weight of 1.31 kg in 1988 is due to the very large proportion of forkbeard aged 3 to 6 years old in the catches (Fig. 3). The analysis of preadult blackspot seabream landings in this period shows an increase by 4% from 1987 to 1988 (35% and 39%, respectively), and then a decrease in 1989 and 1990 of 1% and 6%, respectively (ANON. 1988-1991).

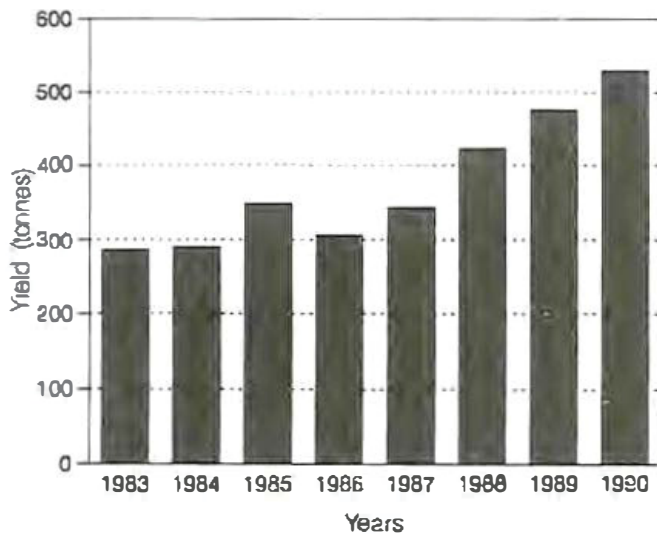


Fig.1 - Total yields, in tonnes, of forkbeard to the Azores from all fisheries over the period 1983-1990. Data obtained from LOTAÇOR (Serviço Açoriano de Lotas, E.P.).

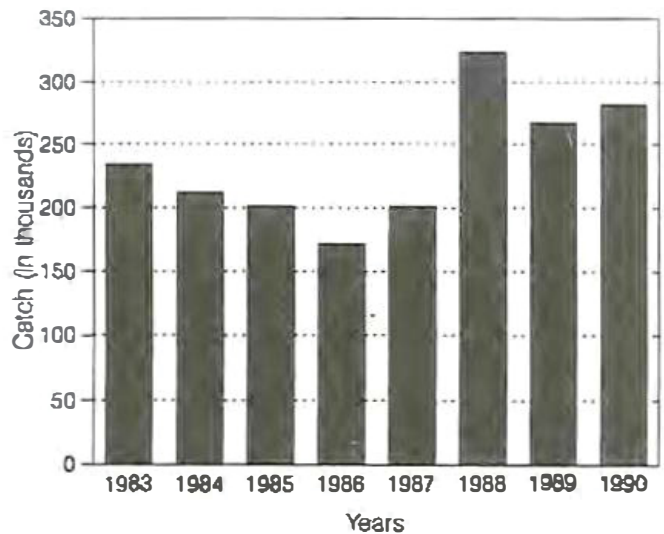


Fig.2 - Estimated catches, in numbers, of forkbeard to the Azores from all fisheries over the period 1983-1990.

Furthermore, the reported landings of wreck fish were 229, 191, and 235 tonnes in 1987, 1988, and 1989, respectively (Fig. 4). The association of these two factors may explain the increased proportion of forkbeard ages 3-6 in the catches and the consequent abrupt decrease in the average weight of forkbeard in 1988.

Although mean fishing mortality has been increasing during this period (from about 0.03 in

1983 to 0.07 in 1990), it is still apparently at a very low level (Table 3).

Both 2+ biomass and stock size in numbers are estimated to have decreased since 1983 and are now approximately 74% and 41%, respectively, of their values in 1983 (Tables 4 and 5). 1976 and 1977 year-classes (aged respectively, 7 and 6 in 1983) comprised about 22% of the total biomass in the years 1983-1985.

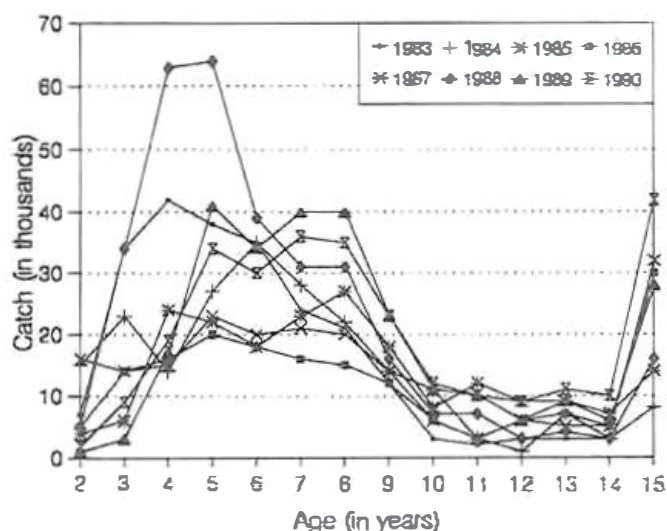


Fig.3 - Forkbeard catches in numbers at age during the period 1983-1990.

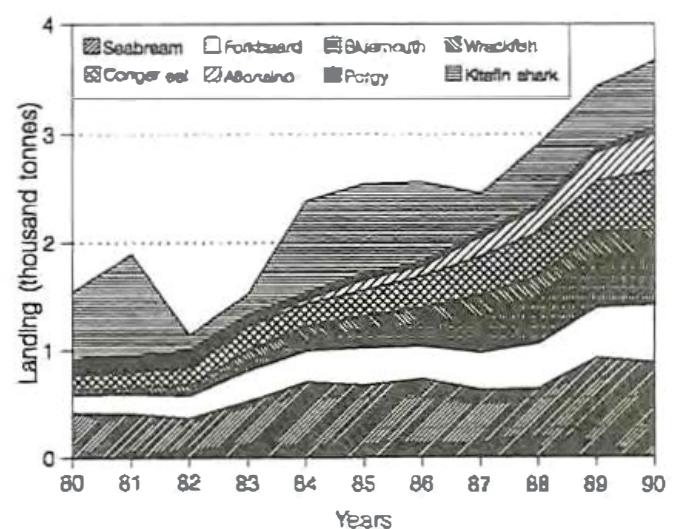


Fig.4 - Reported landings, in tonnes, of the major demersal fish species to the Azores from all fisheries over the period 1980-1990. Data obtained from LOTAÇOR (Serviço Açoriano de Lotas, E.P.).

Table 3

Fishing mortality (F) at age

AGE	YEAR							
	1983	1984	1985	1986	1987	1988	1989	1990
2	0.005	0.011	0.003	0.005	0.016	0.009	0.003	0.010
3	0.004	0.021	0.006	0.012	0.016	0.043	0.005	0.030
4	0.051	0.018	0.028	0.018	0.017	0.094	0.027	0.050
5	0.051	0.042	0.035	0.028	0.032	0.092	0.082	0.070
6	0.042	0.061	0.035	0.036	0.036	0.069	0.065	0.080
7	0.033	0.044	0.052	0.041	0.054	0.073	0.092	0.090
8	0.053	0.038	0.052	0.043	0.065	0.105	0.128	0.110
9	0.047	0.045	0.041	0.030	0.051	0.069	0.104	0.100
10	0.013	0.055	0.033	0.016	0.020	0.035	0.058	0.070
11	0.009	0.015	0.081	0.017	0.012	0.029	0.058	0.070
12	0.009	0.007	0.052	0.049	0.036	0.014	0.030	0.070
13	0.017	0.022	0.072	0.050	0.061	0.029	0.048	0.070
14	0.020	0.020	0.030	0.050	0.050	0.050	0.060	0.070
15+	0.020	0.020	0.030	0.050	0.050	0.050	0.060	0.070
F Mean	0.029	0.031	0.040	0.030	0.036	0.055	0.058	0.069

The larger decrease in stock numbers than in biomass is mostly due to the age 2 abrupt decrease in abundance after 1987. However, these estimates are very sensitive to errors in the terminal fishing mortalities and may not represent a recruitment failure.

A sensitivity analysis (e.g. AGGER & al. 1971; POPE 1972; SHEPHERD 1988) was performed using different fishing mortalities of oldest ages. These fishing mortalities were kept constant in each year, except for those used in the present run where fishing mortalities at age were averaged in

Table 4

Stock size numbers (thousands) at age

AGE	YEAR								
	1983	1984	1985	1986	1987	1988	1989	1990	1991
2	1482	1551	1504	1174	1100	647	432	243	
3	1127	1207	1256	1228	957	886	525	353	197
4	940	892	967	1023	993	771	695	427	280
5	839	731	718	770	823	799	574	554	333
6	934	653	574	558	613	653	597	433	423
7	817	733	503	454	448	484	499	458	327
8	457	648	574	391	357	348	368	373	342
9	286	355	511	446	307	274	256	265	273
10	298	223	278	401	355	239	209	189	197
11	208	241	173	220	324	285	189	162	144
12	411	169	194	131	177	262	226	146	123
13	226	333	137	151	102	140	211	180	111
14	141	182	267	104	118	78	111	165	137
15+	424	426	533	687	723	352	532	684	648
TOTAL	8590	8344	8189	7748	7395	6217	5425	4631	3537

Table 5
Stock biomass (tonnes) at age

AGE	YEAR							
	1983	1984	1985	1986	1987	1988	1989	1990
2	341	375	352	290	219	162	83	59
3	481	494	569	548	399	395	254	153
4	636	631	684	715	691	528	508	300
5	823	716	684	746	797	772	564	537
6	1150	793	712	697	754	800	741	537
7	1232	1105	758	687	667	727	747	690
8	820	1160	1045	706	649	631	663	676
9	600	744	1076	938	641	574	537	556
10	681	511	635	918	811	546	479	432
11	503	582	418	532	782	688	456	391
12	1048	431	496	334	453	668	578	373
13	610	898	369	407	274	377	569	485
14	402	518	758	297	334	223	316	468
15+	1455	1312	1770	2319	2542	1218	1838	2357
TOTAL	10780	10268	10328	10134	10014	8310	8333	8013

the period 1983-1990. In doing so, the terminal fishing mortality of 0.07 (in 1990) for age 15+ represents an average 0.04 in the whole period. This fishing mortality was compared with the values of $F = 0.02, 0.08, 0.15$ and 0.20 . The typical convergence of these fishing mortalities when projected backwards (e.g. POPE 1972) is shown in Fig. 5. The initial range, 0.02-0.20, is reduced to

0.03-0.06 at age 10, and negligible for ages smaller than age 5.

The analysis of the changes in biomass for each fishing mortality of oldest age shows that an overestimate of this value (e.g. as 0.04 when the mortality is 0.02) results in an underestimate of the annual population biomass (Fig. 6). On the other hand, an underestimate of fishing mortality

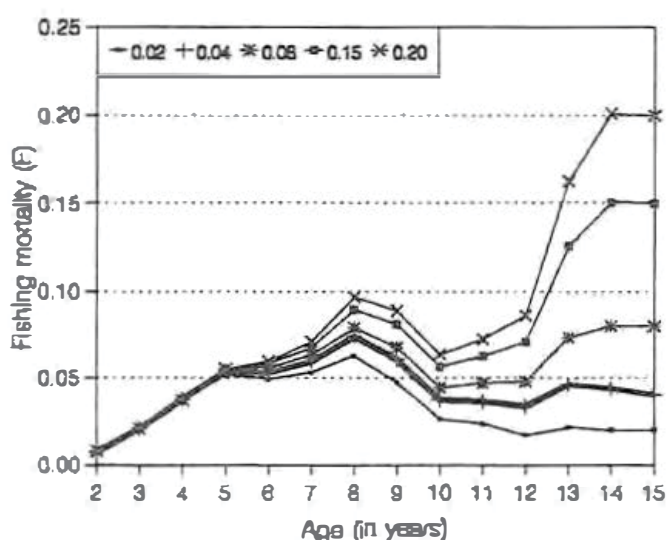


Fig.5 - Sensitivity analysis performed with different fishing mortalities of oldest ages (range = 0.02-0.20; $F = 0.04$, on average, was used in the present study).

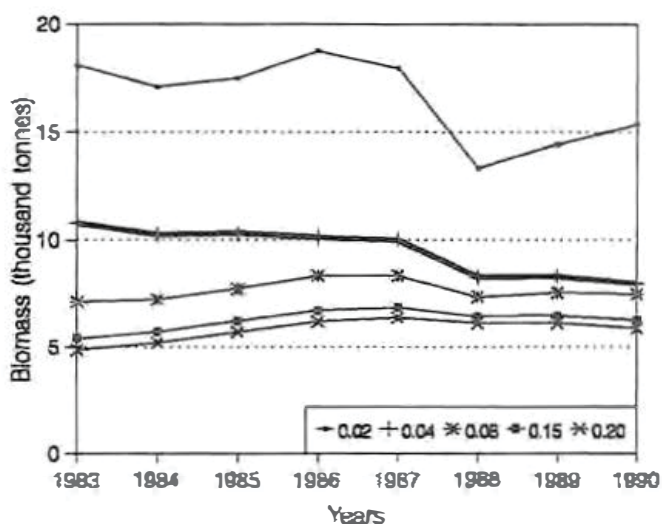


Fig.6 - Total biomass estimates, in thousand tonnes, during the period 1983-1990 assuming different fishing mortalities of oldest ages (range = 0.02-0.20; $F = 0.04$, on average, was used in the present study).

results in the population biomass being overestimated.

DISCUSSION

This analytical assessment of the azorean stock of forkbeard indicates that it is only lightly to moderately exploited. Fishing mortality rate in 1990 was set at 0.07 (on average) and the resulting estimates of stock biomass decreased from 10800 to 8000 tonnes. The analysis is, if anything, conservative in respect to the relative changes in abundance. A larger fishing mortality in the oldest ages, though resulting in smaller biomass estimates (mostly in the earlier years) gives a much more stable population through the period of the analysis.

One of the major assumptions of VPA is that the natural mortality rate is known. This is seldom the case but, since one is often looking for trends, rather than absolute numbers, in such analyses, these errors may not be serious (LAPOINTE & al. 1989). However, if the true natural mortality is constant, then the size of the bias caused by an incorrect estimate of this parameter will depend primarily on the relative values of the fishing and natural mortality rates (HILBORN & WALTERS 1992). If the fishing mortality is high relative to the natural mortality, an incorrect estimate of this parameter will have almost no impact on the estimates of cohort sizes, whereas, if the opposite is true, as in the present case, the impact will be much larger.

This is a first analysis of the state of exploitation of the forkbeard stock in the area. These results strongly suggest that this stock is much more lightly exploited than the target species in the demersal mixed fishery, the blackspot seabream (KRUG & SILVA 1987).

The results from this study should only be taken as preliminary. Growth studies must be redone in order to check possible changes in the growth parameters in the most recent years. Effort data should be further investigated, and depth information incorporated in the demersal mixed fishery. The fishing effort of wreckfish should be estimated and total fishing effort standardized in order to get a time series of catch-per-unit-effort that could be used for tuning the VPA.

CONCLUSIONS

Landings of forkbeard in the Azores have increased from 234 thousand fish (286 tonnes) in 1983 to 282 thousand fish (531 tonnes) in 1990, representing an increase by 21% in numbers (86% in terms of yield). This indicates that the incidence of the catch has increased in the larger, and consequently older, individuals. This observation was linked with the increasing yields from the wreckfish fishery, and the consequent increasing bycatches of large-sized forkbeard. Furthermore, the bycatches of medium-sized forkbeard decreased as a result of the increasing depths at which the blackspot seabream and associated species were exploited.

The annual fishing mortality rate was estimated to be 0.07 (on average) in 1990, an increase by 138% relatively to the fishing mortality rate in 1983, but still a very low mortality comparatively to the one exerted on the population of blackspot seabream in the same area.

VPA estimates of stock size indicate that a decrease by 46%, in numbers, was observed since 1983, when the stock was estimated to be 8590 thousand. However, VPA estimates of stock biomass indicate that the reduction represented only 26% of the estimated 10780 tonnes in 1983. The larger decrease in stock numbers than in biomass is mostly due to the age 2 abrupt decrease in abundance after 1987. The high sensitivity of these estimates to errors in the terminal fishing mortalities prevents any conclusions relatively to the possibility of a recruitment failure.

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REFERENCES

- ANON. 1981-1991. *Pescado Descarregado nos Portos da Região Autónoma dos Açores em 1980-1990* (Elementos Estatísticos). Serviço Açoreano de Lotas, E.P.-LOTAÇOR.
- DIAS, M.L., H.M. KRUG & H.M. SILVA 1986. *Estudos de apoio às pescas açoreanas. Campanha "Açores*

- 1/83". - *Relatórios Técnicos e Científicos*. Instituto Nacional de Investigação das Pescas, Lisboa (22) Março 1990. 94 pp.
- DIAS, M.L. & M.C. MONTEIRO 1986. Pesca exploratória e observações hidrológicas nas águas dos Açores. Setembro/Outubro 83. - *Instituto Nacional de Investigação das Pescas*, 22 pp.
- FLATMAN, S. & S.M. STEVENS 1988. *Virtual Population Analysis: Version 2.1 User Guide*. MAFF Directorate of Fisheries Research, Lowestoft. 17 pp.
- GULLAND, J.A. 1965. Estimation of mortality rates. Annex to Arctic Fisheries Working Group Report (Hamburg, January 1965). *International Council for the Exploration of the Sea* (ICES) CM 1965. Document no. 3.
- HILBORN, R. & C.J. WALTERS 1992. *Quantitative Fisheries Stock Assessment: Choice, Dynamics and Uncertainty*. Chapman and Hall. New York. 570 pp.
- KRUG, H.M. & H.M. SILVA 1988. Virtual population analysis of *Pagellus bogaraveo* (Brünnich, 1768) from the Azores. - *International Council for the Exploration of the Sea* (ICES) CM 1988/G:19, 8 pp.
- LAPOINTE, M.F., R.M. PETERMAN & A.D. MACCALL 1989. Trends in fishing mortality rate along with errors in natural mortality rate can cause spurious time trends in fish stock abundance estimated by virtual population analysis (VPA). - *Canadian Journal of Fisheries and Aquatic Sciences* 46: 2129-2139.
- LAUREC, A. & J.G. SHEPHERD 1983. On the analysis of catch and effort data. - *Journal du Conseil International pour l'Exploration de la Mer* 41: 81-84.
- POPE, J.G. 1972. An investigation of the accuracy of virtual population analysis using cohort analysis. - *Research Bulletin of the International Commission NW Atlantic Fisheries* 9: 65-74.
- POPE, J.G. & J.G. SHEPHERD 1985. A comparison of the performance of various methods for tuning VPAs using effort data. - *Journal du Conseil International pour l'Exploration de la Mer* 42: 129-151.
- SHEPHERD, J.G. 1988. Fish stock assessments and their data requirements. Pp. 35-62 in: GULLAND, J.A. (Ed.). *Fish Population Dynamics*. John Wiley & Sons, Ltd.
- SILVA, H.M. 1985. Age and growth of the forkbeard *Phycis phycis* (L., 1766) in Azorean waters. - *International Council for the Exploration of the Sea* (ICES) CM 1985/G:72. 11 pp.
- SILVA, H.M. 1988. Estado dos stocks de goraz e abrótea. - *Relatório da VII Semana das Pescas dos Açores* 1987: 197-199.

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