

Growth, Mortality and Yield-per-Recruit of the Poor Cod, *Trisopterus minutus capelanus*, from the Strait of Sicily

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Abstract

Length-based methods (LBMs) were used to study the growth of *Trisopterus minutus capelanus* in the Strait of Sicily (Central Mediterranean Sea). A total of 16 304 'merluzzetto' or poor cod collected by experimental trawling off the southern coast of Sicily during spring, summer, autumn 1986 and winter 1987 were measured in order to estimate the length structure of the population. Length-frequency distributions were analyzed and normal components were discriminated. Von Bertalanffy growth parameters were derived from the mean length of the normal components. The growth parameters obtained by weighted non-linear regression were: $K = 0.462(\text{yr}^{-1})$, $L_{\infty} = 222.3$ (TL, mm) and $t_0 = -0.679$ yr. The resulting growth performance index (ϕ') was 4.36, a value slightly lower than those derived for Western Mediterranean (mean $\phi' = 4.45$) and Adriatic ($\phi' = 4.58$) populations and slightly higher than that derived for Hellenic waters ($\phi' = 4.27$). On the basis of the von Bertalanffy parameters estimated, an array of age-specific instantaneous natural mortality rate ($M_t = 0.5 - 1.1$) and an average value of total annual mortality rate ($Z = 2.1 \text{ yr}^{-1}$) were estimated and used in the Thompson and Bell yield-per-recruit (Y/R) analysis in order to evaluate the status of the fishery and forecast the effects of changes in the fishing pattern. Results indicate that this resource is overexploited and that Y/R could be increased by postponing the age at first capture from 0.5 to 1.0 yr. Even a slight reduction in fishing mortality could improve the performance of the fishery. At the present level of exploitation, and assuming a constant recruitment, the spawning stock biomass per recruit (SPR) is well below the conservative threshold of 30% of the pristine or unexploited SPR.

Introduction

The poor cod (*Trisopterus minutus capelanus* Lacépède 1800) is a small-sized, short-lived (4-6 years) opportunistic feeder. This benthopelagic and gregarious gadoid fish shoals in the Mediterranean Sea and the South Atlantic up to the African coasts. It is found on muddy or sandy bottoms to depths of 500 m, mostly from 50 to 200 m (Fischer et al. 1987; Cohen et al. 1990). Often confused in the past with other relatives (*T. luscus* and *T. minutus minutus*), its taxonomic status is still the object of speculation. For example, Gaemers (1976) has proposed the 'species' level *Trisopterus capelanus*. Although its flesh tastes like that of other gadoids, and it has generally been reputed a 'good' fish (Boudarel 1948; Tortonese 1970), its small size has reduced its use

for human consumption in the past years. At present, it is found regularly in domestic markets, representing a by-catch species mainly of the trawl fisheries directed at circalittoral and epybathyal targets such as Mediterranean hake (*Merluccius merluccius*), red and striped red mullets (*Mullus barbatus* and *M. surmuletus*) and pandora (*Pagellus erythrinus*). The overall landed catch is in the order of a few thousand tons per year (Fischer et al. 1987) and given the growing interest in the poor cod, many authors have investigated different aspects of its biology and fishery (Frogliola 1981; Tangerini and Arneri 1984; Politou and Papaconstantinou 1991, 1994; Biagi et al. 1992; Giannetti and Gramitto 1993).

In the Strait of Sicily, *Trisopterus minutus capelanus* ('gintili') occurs commonly on muddy-sandy

bottoms between 100 and 300 m, being mainly associated with the biocoenosis of the muddy detritic assemblages and epibethyal muddy bottom.

According to a catch and effort survey carried out in Sicily, where the species is sold fresh or transformed into fish meal (Cohen et al. 1990), the landed catch in 1982 was less than 1 000 t (Ragonese and Cingolani 1993). However, from data gathered in more recent experimental trawl surveys (Garofalo et al. 1995) a (minimum) estimate of only 110 t of standing stock was derived for the shelf of the investigated area (ca. 16 500 km²). No landing data are recently available, but it is likely that the stock of poor cod of the Strait of Sicily has been strongly depleted. It is worth noting that discards for this species is now very low, the smallest size (3-10

cm TL) being sold in mixed category as "fish to be fried" ('frittura'). The retail price is about 6 000 and 12 000 Italian lira (US\$1=.000559 Lira) per kg for small (<12 cm TL) and large fish, respectively.

Despite exploitation of the stock in the Strait of Sicily, information about the life history of poor cod in this area is limited to notes on geographical distribution and associated species (Bouhlef 1979; Arena 1985). No data exist on the length structure and dynamics of this population. This study attempts to assess the growth mortality and exploitation of the stock in the Strait of Sicily based on the analysis of length-frequency distributions derived from experimental trawling.

Materials and Methods

Samples of poor cod were collected using a chartered commercial trawler and a commercial trawl net (mouth opening of 0.7 x

12 m; cod-end mesh size of 18 mm in the Strait of Sicily (Fig. 1). The sampling periods were: 20 May to 6 June; 29 August to 17 September; 20 November to 8 December 1986; and 19 February to 14 March 1987 (Levi 1988). All the hauls were made in daylight and the length of each haul was about 5 000 m (1 h at 2.8 knots).

The total length (TL; mm) of individual fish was measured with a measuring board (ichthyometer); a total of 16 304 specimens were measured. Since sex and maturity were not determined, the results refer to combined sexes. This simplification introduces some bias since sex-related differences in growth rates (females grow faster) and length-weight relationships (at a given length, females weigh more than males) have been documented. However, considering that the bulk of the sample is represented by 0+ and 1+ age groups for which the sex differences are less pronounced, the effect of the sex-pooling can be considered minimal.

After preliminary trials, lengths were pooled into 5 mm classes and smoothed (x3) to reduce sampling noise (Rosenberg and Beddington 1988). The smoothed length frequencies were analyzed using the "Compleat ELEFAN" software (Gayanilo et al. 1989) in order to discriminate length components (using Bhattacharya's method) and estimate the instantaneous coefficient of total annual mortality, Z, according to the length-converted catch curve method (ELEFAN II). The selection of points to discriminate normal groups in the length-frequency distributions (LFDs) were aimed at minimizing the value of the chi-square statistic and increasing the number of degrees of freedom. Modal components were "aged" based on the general knowledge of the biology of the species, whereas plausible linkages of selected modes were made on the basis of the "integrated approach" (Caddy 1986; Pauly 1987). The components with the smallest modal length were considered as recruits to the gear (i.e., that part of the juvenile population which joins the vulnerable stock).

The von Bertalanffy growth function (VBGF) has always been the conventional choice for fish growth studies. However, different curves can fit the same data set equally well. In order to assess any substantial failure of the VBGF in describing the present data in comparison with other models (i.e., Gompertz, logistic, power and exponential models), an exploratory analysis of the relationships between the specific growth rates ($G = |\log S_i + 1 - \log S_{i+1}| / \Delta t$) and the corresponding sizes (S_i) was performed following the procedure described by Kauffman (1981). The strength of the linear association was generally poor ($0.280 < r^2 < 0.310$) but no particular difference was

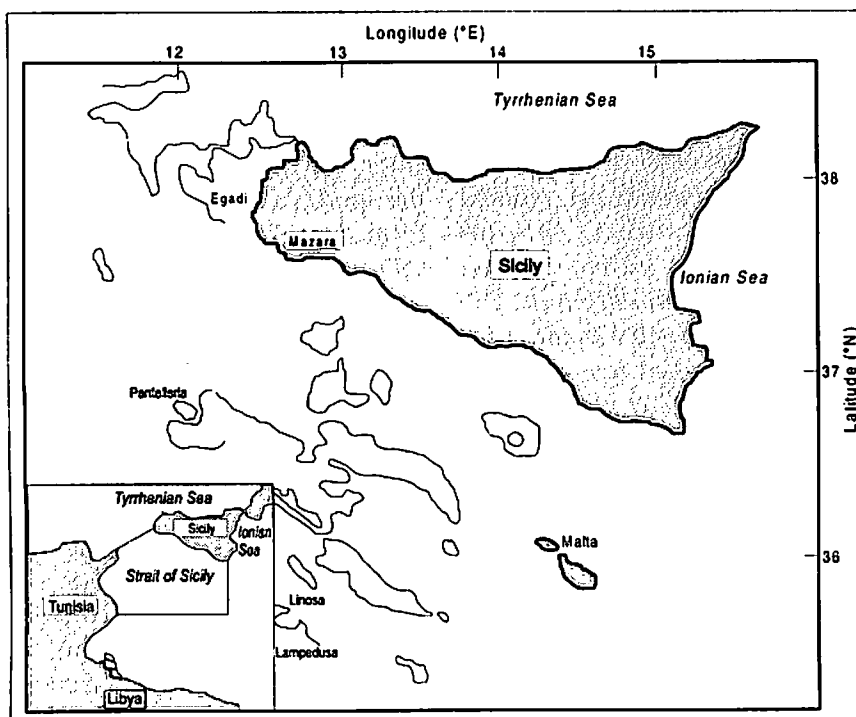


Fig. 1. Distribution of *Trisopterus capelanus* (lightly shaded area) in the Strait of Sicily.

observed among the different models tested; consequently the VBGF was chosen as the growth model.

A weighted (by the reciprocal of the standard error of the modal length) non-linear, least squares technique was employed to fit the VBGF to the data, both classic and modified with the introduction of seasonality (Pauly 1987). The mean square error was used as an index of goodness of fit. The upper and lower limits of the growth estimates available from the literature, i.e., $L_{\infty} = 322$ mm and $K = 0.179$ yr⁻¹ (Politou and Papaconstantinou 1991) and $L_{\infty} = 220$ mm and $K = 0.39$ yr⁻¹ (Planas and Vives 1952), represented the seed values. The non-linear procedure was preferred to the linear alternatives since the latter require *a priori* knowledge of the asymptotic size; when this parameter is also estimated, the accuracy of the other estimates is lowered but remains accurate enough to be used in practical applications (Hanumara and Hoenig 1987). After preliminary trials, the more complex seasonal model (5 parameters to be estimated vs. 3 parameters of the classic formula) was not considered further since it did not improve the fit and yielded inconsistent estimates of asymptotic length ($L_{\infty} < 200$ mm).

In order to compare present estimates with those derived for other geographical areas, the growth performance index, ϕ' (Munro and Pauly 1983), was computed. This index has been shown to be more useful than other indices proposed to compare different VBGFs (Sparre and Venema 1992).

The estimated VBGF parameters were used to derive a length-converted catch curve (Pauly 1987) and to estimate an average value of Z according to the ELEFAN II procedure (Gayaniilo et al. 1989).

The older ages were not considered in order to reduce the bias of Z (Isaac 1990). Some bias is still expected for such estimate of Z as a consequence of the variability in the VBGF growth estimates; however, since Z estimates are positively correlated with both L_{∞} and K (which are inversely correlated), the bias tends to compensate (Isaac 1990).

The VBGF coefficient K and the theoretical age at zero length t_0 were used to compute the values of the age-specific natural mortality rates, M_t (t , year), using the following expression (Chen and Watanabe 1989):

$$M = \begin{cases} \frac{K}{1 - \exp -K(t-t_0)}, & t \leq t_m \\ \frac{K}{a_0 + a_1(t-t_m) + a_2(t-t_m)^2}, & t > t_m \end{cases} \quad \dots 1)$$

where t_m denotes the age at the end of the reproductive span (2.16 years in this case) and a_0 , a_1 and a_2 are coefficients to be estimated (0.730, 0.1244 and -0.00287, in this case). The algorithms to compute t_m , a_0 , a_1 and a_2 are given in Chen and Watanabe (1989). The M_t estimates were used to derive an array of age-specific fishing mortality rates according to $Z - M_t = F_t$.

The age-based yield-per-recruit (Y/R) model of Thompson and Bell (see Sparre and Venema 1992) was used to assess the present status of the resource and to forecast the effect on Y/R, catch value and spawning stock biomass per recruit (SPR) of the changes in the age at first capture (from 0.5 to 1.0 yr) and fishing mortality (-30% to +30% of the present value). Since no length-weight relationship was available for the investigated population, the weights (g) at length (TL, mm) were estimated by

averaging the relationships reported for the Tyrrhenian (Matta 1958; Biagi et al. 1992; Righini et al. 1995), Adriatic (Giannetti and Gramitto 1993) and Hellenic waters (Politou and Papaconstantinou 1991), i.e., $a = 0.0000056$ ($sd = 0.0000006$); $b = 3.2029$ ($sd = 0.0694$); $n = 5$.

Unit values per size category were derived from the observed prices at the Mazara fish market on the island of Sicily where two categories are generally recognized: 'frittura' and large fish. Although some overlap does occur, fish below 120 mm (TL) were considered as 'frittura'. Gear selectivity was assumed to be knife-edged: this introduces some bias in the computation of Y/R, the magnitude of which mainly depends on D_c , i.e., the "discrepancy between the assumed and the true probability of capture" (Silvestre et al. 1991). Independent studies, however, have indicated that mesh sizes used by Sicilian trawlers (smaller than 20 mm) are practically unselective (Ragonese et al. 1994). Given the small mesh size used in the present study (18 mm), knife-edge selection seems even more a realistic hypothesis. The length at 50% retention (l_c) was assumed to be 93 mm (corresponding to 0.5 years of age), a length lower than those estimated for other stocks by using similar (low vertical opening) or different (high vertical opening) gears (104-125 mm) (Ferretti and Frogliia 1975; GFCM 1981). An estimate of the maximum theoretical (or 'ecological') life span (t_x) was derived according to the formula

$$t_x = t_m + \frac{1}{K} \quad \dots 2)$$

(Chen and Watanabe 1989), where t_m and K denote the age at the end of the reproductive span

and the VBGF growth coefficient, respectively.

Results

The smoothed length-frequency distribution of *Trisopterus minutus capelanus* from spring 1986 to winter 1987, with the estimated

normal groups resulting from the modal progression analysis, is illustrated in Fig. 2. The smallest and greatest mid-length class represented in the samples were 47.5 and 237.5 mm (TL), respectively, but very few fish (29 out of 16 304, i.e., less than 0.2%) fell above the 190 mm class.

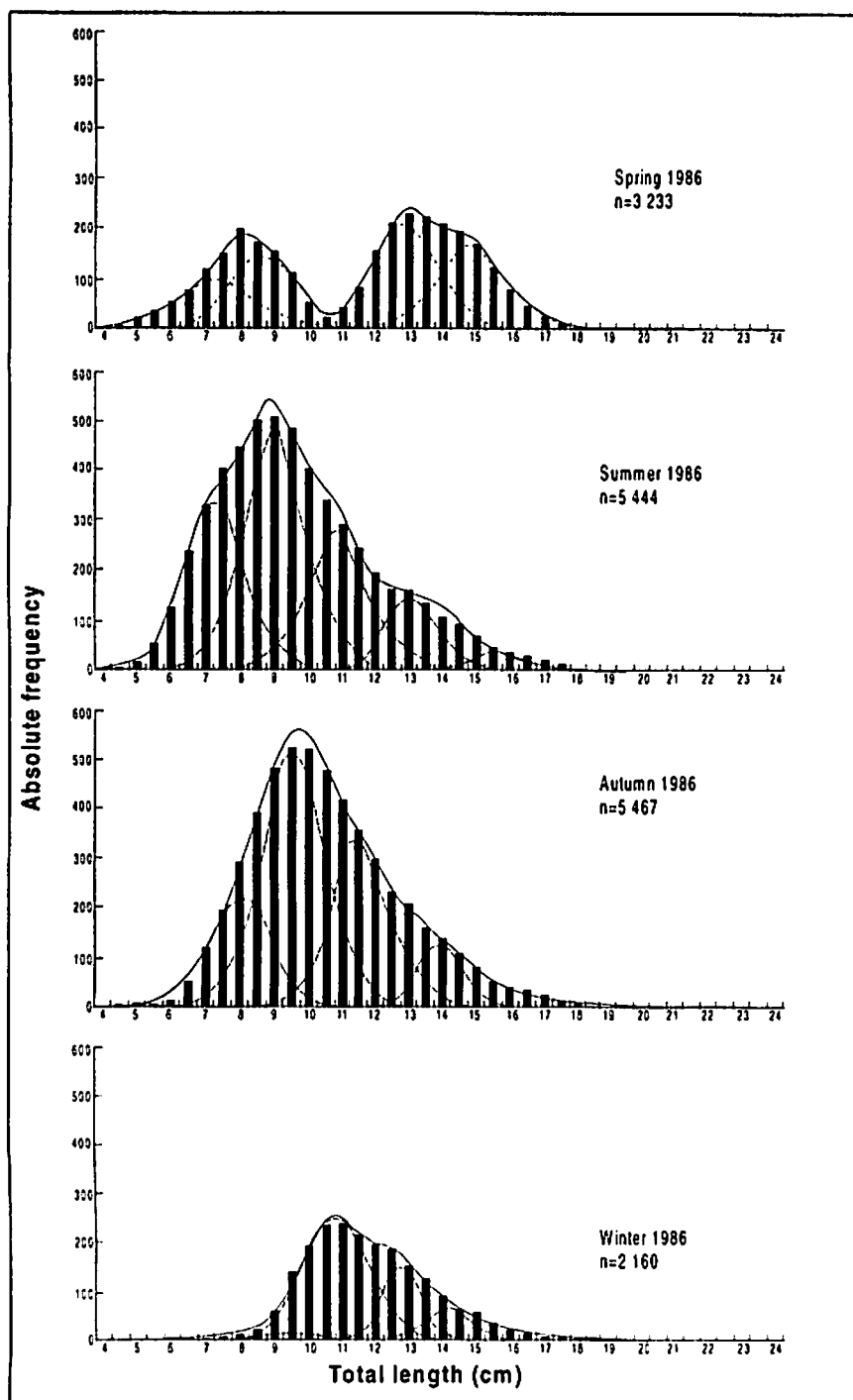


Fig. 2. Length-frequency distribution of *Trisopterus minutus capelanus*. Dotted line: modal groups; solid line: estimated (expected) resultant curve. See Table 1.

Up to six groups were identified with modal lengths ranging from 72.9 mm (in spring) to 182.4 mm (in winter) (Table 1). These are almost always well-discriminated according to the separation index values, which must be over 2 to allow an objective separation of adjacent groups (Rosenberg and Beddington 1988). The first two groups appeared to be highly overlapping (Separation Index < 2) in spring, winter and for seasons pooled. In all seasons except pooled data, the estimated LFDs were not significantly different from the observed LFDs.

Recruitment is evident in spring, with two overlapping "pulses" at 73 and 88 mm (code A and B, respectively) (Table 1), and in summer, with another well-defined pulse at 74 mm (code F); consequently, at least three pulses of recruits are recognizable. The integration of the modes (Fig. 3) results in three separate plausible trajectories which correspond to different intra-annual cohorts. Since the third recruitment pulse was detected in summer (about three months after the spring sample), it seems realistic to assume a similar delay between the two pulses in spring assuming that the first group (88.5 mm) is derived from the eggs spawned in early winter (the conventional birthdate of this species and more generally of temperate stocks is 1 January) (Giannetti and Gramitto 1993). Putative ages can be assigned to the three recruitment pulses as follows: two months for the smallest group in spring (72.9 mm, birthdate 1 April) and summer (74 mm, birthdate 1 July), and five months for the second group in spring (88.5 mm, birthdate 1 January). By maintaining this delay period (three months), the corresponding ages were assigned to the other groups (Table 1).

Table 1. Results of the modal progression analysis on *Trisopterus minutus capellanus* length frequency distribution. Putative ages assigned to groups E, K, V, and from AA to FF were assigned a posteriori on the basis of the estimated VBGF.

Season	Code	Group	Mean length (mm)	Population	S.I.	S.E. mean	Putative age (months)
Spring 1986 $X^2=10.546$ d.f.=18	A	1	72.9	545	-	0.487	2
	B	2	88.5	705	1.5	0.346	5
	C	3	129.5	1 021	4.6	0.272	14
	D	4	149.7	915	2.1	0.341	17
	E	5	179.5	43	3.7	0.854	-30
Summer 1986 $X^2=7.898$ d.f.=14	F	1	74.0	1 346	-	0.225	2
	G	2	91.9	1 903	2.2	0.184	5
	H	3	109.9	1 182	2.1	0.254	8
	I	4	132.7	693	2.5	0.360	17
	J	5	152.7	232	2.2	0.550	20
	K	6	171.2	80	2.6	0.680	-30
Autumn 1986 $X^2=10.206$ d.f.=14	L	1	78.7	579	-	0.315	5
	M	2	97.2	2 545	2.1	0.192	8
	N	3	118.1	1558	2.1	0.266	11
	O	4	141.2	553	2.4	0.358	20
	P	5	166.3	227	2.4	0.812	23
Winter 1987 $X^2=4.309$ d.f.=11	Q	1	93.8	88	-	0.985	8
	R	2	110.4	1 196	1.8	0.278	11
	S	3	130.0	514	2.4	0.311	14
	T	4	145.8	252	2.2	0.466	23
	U	5	160.9	77	2.1	0.778	26
	V	6	182.4	32	2.5	1.837	-36
Seasons pooled $X^2=28.903^*$ d.f.=17	AA	1	80.5	4 066	-	0.175	-6
	BB	2	98.7	4 836	1.8	0.136	-6
	CC	3	116.6	2 900	2.1	0.140	-12
	DD	4	134.0	2 754	2.3	0.148	-18
	EE	5	151.5	1 348	2.2	0.214	-24
	FF	6	171.2	374	2.3	0.474	-30

* Significant X^2 value at $p < 0.05$ (d.f.: degrees of freedom; S.I.: separation index; S.E. mean: standard error of the mean).

Specific growth rates (G , month⁻¹) decline with size, resulting in a highly scattered plot; a negative value was detected between the 166.3 mm (code P) and 160.9 mm (code U) modes (but this occurrence may be considered anomalous when average lengths are compared). Positive values fall in the ranges 0.072-0.007 (mean = 0.035; $n=6$), 0.077-0.008 (mean = 0.033; $n=7$) and 0.59-0.021 (mean = 0.040; $n=2$) for the 1st, 2nd and 3rd cohorts (Fig. 3). It is worth noting that the 1st and 2nd cohorts (the 3rd one is not strictly comparable, given the limited data) show almost identical range and mean value of G , therefore supporting the hypothesis that they represent different pulses of the same annual cohort ('microcohorts'). The re-

sulting VBGF growth parameter 1st and 2nd pooled and all pooled for the 1st and 2nd microcohorts, data are summarized in Table 2.

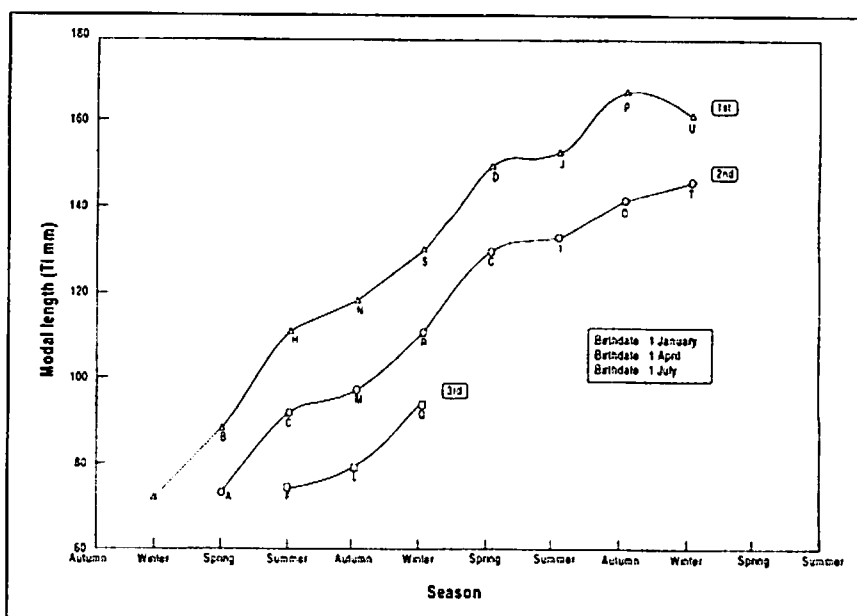


Fig. 3. Growth trajectories for different pulses of recruits for *Trisopterus minutus capellanus* derived after modal linkage (see also Fig. 2 and Table 2 for the letter codes of the cohorts).

Despite the wide gap of the seed values used, the convergence in these estimates was very fast and consistent. Differences between microcohorts affect mainly the K coefficient but the pooling leads to a significant improvement of the fits.

The vector of natural mortality (M_t ; Table 3) indicate higher mortality for the younger classes ($M_{0.5y} = 1.1 \text{ yr}^{-1}$) and a stable phase for the older ages ($M_{>3y}$ about 0.5 year⁻¹). The wide range of estimates (0.5-1.1) support the use of a discrete instead of a constant parameter Y/R model. The ecological life span (t_c) obtained was 4.3 yrs; consequently, an age of 4.5 yrs was put as the upper limit in the Y/R computations.

The length-converted catch curve yielded a Z value of 2.1 (yr⁻¹) confidence interval: 2.01-2.19) with

$r = -0.997$.

Results of the Y/R analysis are summarized in Table 3 whereas results of the simulations are shown in Fig. 4. The main feature is the flat-top shape of the Y/R when $t_c = 0.5 \text{ yr}$ and the conspicuous shift upward of the Y/R line when $t_c = 1 \text{ yr}$. For $t_c = 0.5 \text{ yr}$ even strong variation in fishing mortality is not expected to considerably change the Y/R value. An increase in Y/R can be obtained by increasing F when $t_c = 1.0 \text{ yr}$ but the marginal gain in production would not compensate for the higher cost required to harvest it. Concerning catch value, improvement of the fishery status by postponing age at first capture is quite evident.

The SPR vs. F plot is shown in Fig. 5. The limit of 30% of pristine SPR suggested as a conservative biological reference point when no data

are available to characterize the stock-recruitment relationship (Mace 1994) is also indicated. Note that current SPR with $t_c = 0.5 \text{ yr}$ is below this limit given the range of F values considered. Increasing t_c to 1.0 yr (and not allowing increase in F) will put SPR above this threshold.

Discussion

Representative LFDs of fish stocks contain information concerning the resultant action of recruitment, growth and mortality processes. Thus, several LBMs have been applied in fishery science to get basic information required to assess and manage exploited populations (Caddy 1986; Pauly 1987; Pauly and Morgan 1987; Rosenberg and Beddington 1988; Barry and Tegner 1989). The per-

Table 2. Von Bertalanffy growth function (VBGF) parameters and related statistics for age-at-size data derived by modal progression analysis (see Table 1 and Fig. 3).

Growth line	N	d.f.	L_∞ (TL, mm)	ASE L_∞	K (month ⁻¹)	ASE K	t_0 (month)	ASE t_0	MSE
1 st	8	5	200.3	25.4	0.057	0.021	-5 338	2 512	2.86
2 nd	8	5	207.7	37.1	0.039	0.015	-9 451	2 648	2.42
1 st + 2 nd	16	13	213.9	34.2	0.041	0.015	-8 095	2 423	2.44
1 st + 2 nd + 3 rd	19	16	222.3	35.2	0.039	0.013	-8 146	1 926	2.15

d.f.: degrees of freedom; ASE: Asymptotic standard error; MSE: Mean square error.

Table 3. Application of the Thompson and Bell model to *Trisopterus minutus capellanus* fishery in the Strait of Sicily.

Age (t; yr)	L_t (TL, mm)	W_t (g)	Value (Lira/g)	F_t	M_t	N_t	C_t	Y_t	SSB _t	Catch value
0	-	-	-	-	-	1 000 000	-	-	-	-
0.5	93.4	7.2	6.0	0.5	1.1	449 329	172 085	1 233 934	-	7 403 602
1	120.0	16.0	6.0	1.2	0.9	157 237	172 473	2 760 077	4 451 735	16 560 454
1.5	141.1	26.9	12.0	1.4	0.7	55 023	66 682	1 793 443	2 618 165	21 521 315
2	157.8	38.5	12.0	1.5	0.7	19 255	24 697	951 580	1 312 524	11 418 958
2.5	171.1	49.9	12.0	1.5	0.6	6 738	8941	446 374	595 165	5 356 486
3	181.8	60.5	12.0	1.5	0.6	2 358	3191	192 999	252 287	2 315 993
3.5	190.1	69.9	12.0	1.6	0.6	825	1131	79 050	102 001	948 605
4	196.7	78.0	12.0	1.6	0.5	289	398	31 084	39 851	373 003
4.5	202.0	84.9	12.0	1.6	0.5	101	140	11 916	15 180	142 993
							$\hat{\Delta}$	7 500 455	9386906	16 887 362
							$\hat{\Delta}/R$	7.500	9.387	16.887

Time is expressed on an annual basis. $L_t = 222.3 (1 - \exp(-0.462(t + 0.679)))$; individual mean weight at length, $W_t = 0.0000056 L_t^{3.2020}$; F_t , M_t = fishing and natural mortality at age t; N_t = number surviving at age t ($N_0 = R_0 = 10^6$); $N_{t+\Delta t} = N_t \exp(-(F_{\Delta t} + M_{\Delta t}))$; catch at age t, $C_t = (N_{t-\Delta t} - N_t) (F_{\Delta t} / (F_{\Delta t} + M_{\Delta t}))$; yield at age t, $Y_t = C_t W_t$; spawning stock biomass at age t, $SSB_t = N_t W_t$ for t_m where t_m = age at maturity (1 yr); Unit value = retail price (Italian Lira) per gram of fish; Catch value = Y_t Value; Σ/R = expressed per recruit; $\Delta_t = 0.5 \text{ yr}$; age at first capture, $t_c = 0.5 \text{ yr}$.

formance of the LBMs, however, relies on many interacting factors (Hoenig et al. 1987; Castro and Erzini 1988; Wolff 1989; Erzini 1990; Isaac 1990). In this study, the most relevant shortcoming is the lack of biological information on the stock of *Trisopterus minutus capelanus* in the Strait of Sicily. Information from other Mediterranean populations has been used to overcome this since drastic differences in the general biology of the species are not expected.

There is a general agreement to consider *Trisopterus minutus capelanus* as a partial (serial) spawner with a prolonged spawning period. They reach sexual maturity at the end of the first year of life, at about 12-14 cm TL (Planas and Vives 1952; Vives and Suau 1956; Frogliia 1981; Biagi et al. 1992). The ripening period begins in early winter and ends in late spring, suggesting a spawning period from December to May with a peak in March. The small eggs (1 mm size) are pelagic and are found in the water column, mostly in late winter and spring with very few in summer (Bini 1970). At 45 mm TL, the post-larvae are almost identical to adults. Generally, juveniles (3-7 cm TL) appear in the fishing grounds in spring and summer and in the Gulf of Lion in autumn (GFCM 1981), thus suggesting a short period of planktonic life. One single annulus (opaque + hyaline zone) is deposited each year between November and March (Politou and Papaconstantinou 1991; Giannetti and Gramitto 1993), the young-of-the-year showing two peaks of deposition (Politou and Papaconstantinou 1991). The Atlantic populations of *Trisopterus minutus capelanus* maintain more or less the same basic pattern, although with some time delay. For example, spawning occurs from

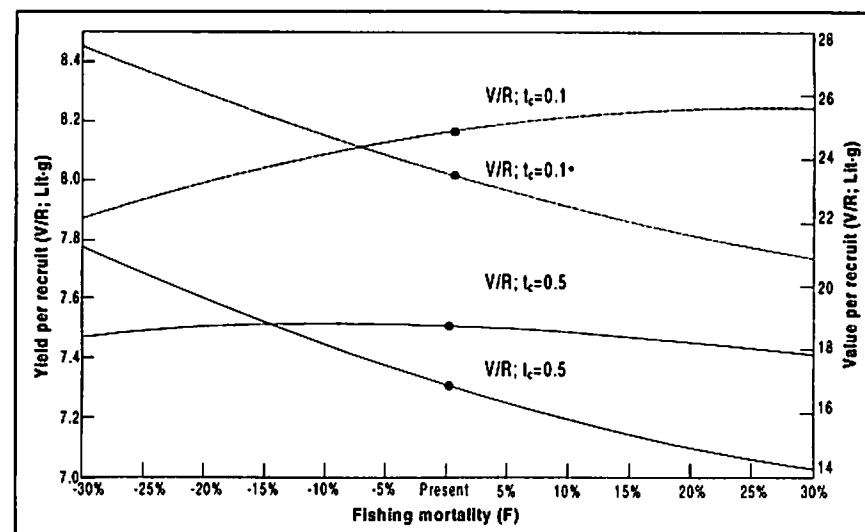


Fig. 4. Long-term expected yield and value per recruit for *Trisopterus minutus capelanus* under two age at first capture hypotheses ($t_c = 0.52$ and 1.0) and varying fishing mortality (F). Solid dots denote present levels of fishing mortality.

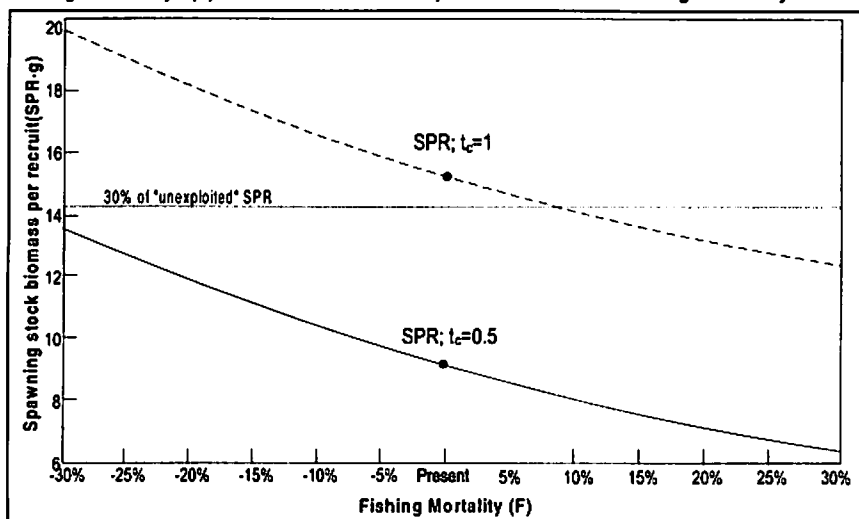


Fig. 4. Spawning stock biomass per recruit for *Trisopterus minutus capelanus* under two age at first capture hypotheses ($t_c = 0.5$ and 1.0) and varying fishing mortality (F). Solid dots denote present levels of fishing mortality.

February to June and post-larvae occur between February and July, though mostly from March to May (Russell 1976).

Concerning growth, almost all data are consistent with a life span of 4-6 years, an asymptotic mean length of about 22-28 cm, a relatively high growth coefficient ($K = 0.3-0.8 \text{ yr}^{-1}$) and low t_0 values (less than -1.0 yr). The only exceptions are those reported for females in Hellenic waters, for which a very high asymptotic size (33 cm TL) and low K (0.18 yr^{-1}) were derived (Politou and Papaconstantinou 1991).

Results of this study are consistent with the biological information for

other Mediterranean populations and growth estimates are coherent with known reproductive and growth patterns. The smaller microcohorts evident in spring, summer and autumn cannot be considered different annual classes, but only as different pulses of recruits deriving from the same reproduction season (winter-spring) and from different batches of eggs. For example, the first group is derived from eggs spawned in early winter and the other overlapping groups represent different pulses of the same annual cohort. Growth is quite fast in the first year, and the rate declines thereafter.

The growth performance index derived ($\phi' = 4.36$) is lower than those reported for the Adriatic ($\phi' = 4.58$; Giannetti and Gramitto 1993), the Tyrrhenian ($\phi' = 4.57$; Righini et al. 1995) and Gulf of Lion ($\phi' = 4.52$; GFCM 1981) and higher than those reported for Balearic and Hellenic waters ($\phi' = 4.27$; GFCM 1981; Politou and Papaconstantinou 1991). Such differences can result partially from the different techniques used but more likely reflect slight environmental differences (such as food availability, temperature, etc.).

Concerning mortality estimates, comparison is more difficult given the scarcity of data. Politou and Papaconstantinou (1991) computed (constant) values of M of 0.44 yr^{-1} and F of about 0.5 yr^{-1} . Such estimates are close to those reported by Tangerini and Arneri (1984) in the Adriatic (Z about 1). Passelaguie (in GFCM 1981), using an empirical formula, computed an average value of M of about 1 yr^{-1} ($0.8-1.2$), which is closer to the M estimates in this study.

Results of the Y/R analysis denote growth overfishing and economic dissipation (similar catch values could be obtained with less fishing effort). By increasing t_c to one year, an improvement in yield and value will be expected even at the present level of fishing mortality.

Obviously, modeling the yield of an exploited population presents several caveats (Beddington and Cooke 1983), especially in data-limited situations like the present case. Apart from multispecies interactions (lowering F may increase predation intensity), a main source of bias can be the assumption of constant recruitment (i.e., density independence) which would imply high compensatory capacity of the stock for declining spawning

stock biomass (Clark 1991; Norris 1991). Unfortunately, information on the stock-recruitment relationship and the resilience to exploitation are not available for this species. The behavior of SPR in this study clearly indicates the need to reduce F to avoid drastic reduction of the spawning stock and the risk of recruitment overfishing. Serial spawning is considered an adaptive strategy to overcome high mortality in the first stages of life by boosting egg fecundity, but this does not necessarily mean higher compensation and lesser sensitivity to exploitation (Garrod and Horwood 1984).

Conclusion

Despite a theoretical lifespan of 5-6 yrs, only the first age groups of Mediterranean populations of *Trisopterus minutus capelanus* have sustained exploitation since the mid-1950s (Matta 1958) as a consequence of the fishing pattern (high fishing effort and very small mesh size) historically developed in the Mediterranean Sea (Caddy 1990). The continuous increase in fishing effort exerted over the Mediterranean (FAO 1992) has aggravated the situation and, at present, larger fish (which generally form less than 2-3% of the gross catch) do not contribute substantially to overall yield. Our analysis indicates that a dramatic improvement in the performance of the fishery of poor cod in the Strait of Sicily can be obtained by postponing the age at first capture from the present 0.5 to 1.0 yr. Such a goal could be reached (or approximated) by enforcing a legal minimum cod-end mesh size (20 mm). This modification can allow rebuilding of the spawning stock biomass and reduce the risks of recruitment overfishing.

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FISHBYTE SECTION

NEWS ITEMS

Announcements

The manual on Fish Stock Assessment, FAO Fisheries Technical Paper 306/1, will be published in a revised version (Rev. 2) in Portuguese. It has gone to press and will be distributed widely to Portuguese-speaking

countries. The English version will go to press by the end of this year. Revision 2 in Spanish is already available. The stock of the Spanish version is with the FAO Regional Office in Santiago, Chile. Revision 2 contains a number of

new sections in Chapters 2 (Bhattacharya plot), 3 (phi prime related issues), 5 (VPA), 6 (gillnet selectivity) and 8 (long-term prediction). These extensions were written by Dr. Eric Ursin. They are also included in the Spanish Rev. 1.

