ELSEVIER

Fisheries Research 22 (1995) 299–308

FISHERIES RESEARCH

Short communication

Growth, mortality and yield per recruit model of picarel (*Spicara smaris* L.) on the eastern Turkish Black Sea coast

Ali Ismen

Institute of Marine Sciences, Middle East Technical University, P.O. Box 28, 33731, Erdemli-Icel, Turkey

Accepted 7 June 1994

Abstract

The growth and mortality of the picarel, *Spicara smaris* (L., 1758), were determined from specimens collected on the eastern Turkish Black Sea coast during September and October 1991 and 1992.

From the length–age data for both sexes and all areas combined, the following population parameters were estimated: length–weight relationship, $W=0.005L^{3.26}$; Von Bertalanffy growth constants, $W_\infty(\mathrm{g})=87.20$, $L_\infty(\mathrm{cm})=20.05$, $K=0.44$, $t_0=-0.01$; total mortality and its components, $Z=1.58$, $M=0.87$, $F=0.71$.

The steady-state yield per recruit model of Beverton and Holt (Fish. Invest. Minist. Agric. Fish. Food, 19: 533 (1957)) was applied to evaluate regulatory options for the picarel stock.

Keywords: Growth, fish; Modelling, population dynamics; Mortality; *Spicara smaris*; Yield-per-recruit analysis

1. Introduction

Picarel (*Spicara smaris* L.) is a common fish species in the Black Sea basin, usually found at depths ranging from 15 m to 170 m. It is a protogynous hermaphrodite (Salekhova, 1979; Fischer et al., 1987), and has not yet been much studied, but it is significant in Turkish waters and commerce. According to the State Institute of Statistics of Turkey, the total catch of *Spicara smaris* doubled during the years 1976–1991 (from 1853 tonnes to 4137 tonnes). Production of picarel in the eastern Black Sea has been the highest of all regions of Turkey during recent years. In the same region, the total catch of picarel during 1976–1991

SSDI 0165-7836(94)000324-6

contributed about 8.8% of the total weight of commercial landings. However, total picarel production in the eastern Black Sea, which is closed to trawl fishing from Sinop Cape to Georgia (excluding Samsun Bay), has shown a slightly decreasing trend since 1980 (DIE, 1976–1991).

This study gives preliminary estimations of the growth parameters and mortality rates of *Spicara smaris*, using length–age data. The yield per recruit model of Beverton and Holt (1957) was used to evaluate the regulatory options for the picarel stock.

2. Materials and methods

Samples from the eastern Black Sea were collected on board *R/V Surat 1* in bottom-trawling surveys during 1991 and 1992. The sampling positions are shown in Fig. 1. Sampling stations were located in two strata (0–50 m and 50–100 m). The cod-end mesh size of the bottom trawl net was 18 mm stretched. Hauling lasted about half an hour. Total length of all specimens was measured on board and subsamples were collected according to the procedure described by Holden and Raitt (1974). Sampled specimens were preserved in a solution of 10% formalin.

For each specimen, sex was determined and total length measured to the nearest millimeter and body weight to the nearest gram in the laboratory. Age determination was based on the otoliths of 517 fish examined under reflected light using a binocular microscope.

Growth parameters were determined using the Ford–Walford plot technique

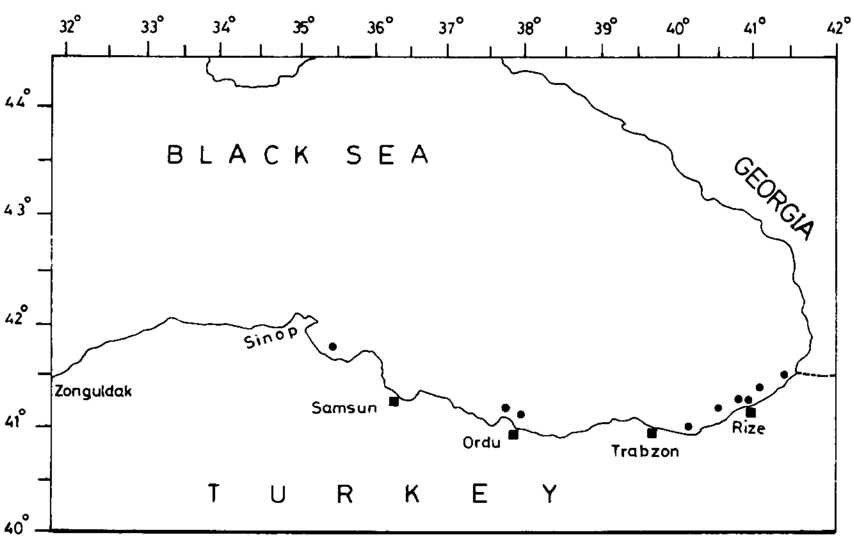

Fig. 1. Location of sampling stations along the eastern Turkish Black Sea coast.

(length–age data) given by Sparre et al. (1989), and increase in weight according to the length–weight equation. Fultons' condition factor was determined using the equation given by Ricker (1975).

Natural mortality was estimated from the equation derived by Pauly (1980). In this equation, T was taken as 14.8°C, which is the mean annual water temperature in the Black Sea (Oguz et al., 1992).

The total mortality coefficient (Z), was estimated by means of a length-converted catch curve (Pauly, 1983). Values of Z for each year were also computed using the equation of Beverton and Holt (1956). The exploitation rate was calculated using the equation given by Pauly (1980, 1984). Values of the average lengths at first capture (L'_c) were derived from the ascending parts of the length-converted catch curves (Pauly, 1984). Finally, the simplified version of the Beverton and Holt yield-per-recruit model given in Ricker (1975) was applied.

3. Results

3.1. Age and length distribution

Picarel lengths in the eastern Turkish Black Sea region ranged from 10.0 cm to 18.5 cm (age 2–5 years), the most of the catch consisting of specimens 11.5–14.0 cm long (age 2–3 years) in 1991 and 11.5–17.5 cm long (age 2–4 years) in 1992. Young individuals of 7.0–9.0 cm (age group I) escaped through the mesh used and could not be sampled.

Female picarels exhibited smaller modes (12.0–13.0 cm) in both sampling periods than males, which ranged in length from 15.0 cm to 18.0 cm; lengths of females did not exceed 17.0 cm. The dominant age group was 3 years for males and 2 years for females in the 1991 sample, and 4 years for males and 3 years for females in the 1992 sample. Picarels older than 4 years very seldom appeared in the samples.

Table 1
Growth rate (length) based on observed and theoretical data as a function of age between September 1991 and October 1992

Age (years)	Length (cm)				Growth rate (%)	
	Theoretical		Observed		Theoretical (91–92)	Observed (91–92)
	1991	1992	1991	1992		
1	7.02	7.18	–	–	–	–
2	11.53	11.78	12.23	12.28	24	–
3	14.50	14.68	14.42	14.22	16	11
4	16.48	16.58	16.26	16.85	10	14
5	17.81	17.80	17.90	17.80	7	9

Table 2
Growth rate (weight) based on observed and theoretical data as a function of age between September 1991 and October 1992

Age (years)	Weight (g)				Growth rate (%)	
	Theoretical		Observed		Theoretical (91–92)	Observed (91–92)
	1991	1992	1991	1992		
1	2.75	3.09	–	–	–	–
2	14.35	15.22	17.81	17.83	14	–
3	30.79	30.93	31.23	28.05	19	16
4	47.15	45.78	44.47	48.65	17	27
5	61.05	57.55	64.30	64.53	12	31

Table 3
Length–weight relationship constants for each sex and for different sampling periods

	a	*b*	*r*	*N*
September 1991				
Male	0.0050	3.268	0.936	112
Female	0.0063	3.161	0.947	260
Pooled	0.0042	3.329	0.967	372
October 1992				
Male	0.0063	3.171	0.985	64
Female	0.0084	3.044	0.972	81
Pooled	0.0054	3.223	0.986	145
1991–1992				
Male	0.0068	3.155	0.965	176
Female	0.0073	3.104	0.957	341
Pooled	0.0050	3.255	0.975	517

3.2. Growth in length

For estimation of growth in length, the sexes were not considered separately because of the sex reversal of picarel, which occurs at the age of 2–3 years. The estimated von Bertalanffy growth constants for pooled data of Black Sea picarel are: L_∞(cm), 20.05; K, 0.44; $t_0 = -0.01$; r^2, 0.95.

Picarel grow rapidly in length during the first year of life, and attain about 7.0–9.0 cm. After completion of the first year, the growth rate gradually decreases from 24% between age groups I and II to 7% between age groups IV and V (Table 1). Growth decreases sharply after the second year and becomes relatively constant thereafter.

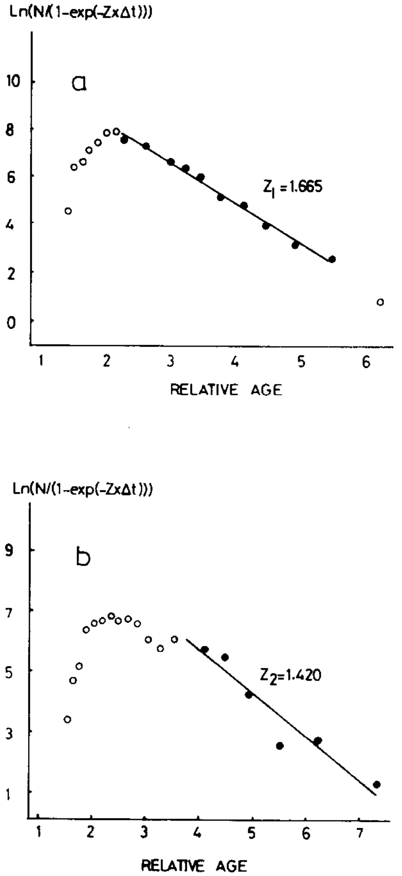

Fig. 2. Length-converted catch curve for (a) 1991 and (b) 1992 for picarel (*Spicara smaris*) on the eastern Turkish Black Sea coast.

3.3. Growth in weight

Growth in weight was maximum between the second and third years (19%). After completion of the third year, the rate decreased to 17% and 12% between age groups III and IV and IV and V, respectively (Table 2).

The length–weight relationship for picarel in the eastern Black Sea (sexes combined) was

$$W=0.0050L^{3.26}, \qquad r=0.98$$

The length–weight relationship constants for each sex and for different sampling periods are shown in Table 3. The exponent b demonstrates allometric growth.

Comparison of condition factors between the sexes showed that males were

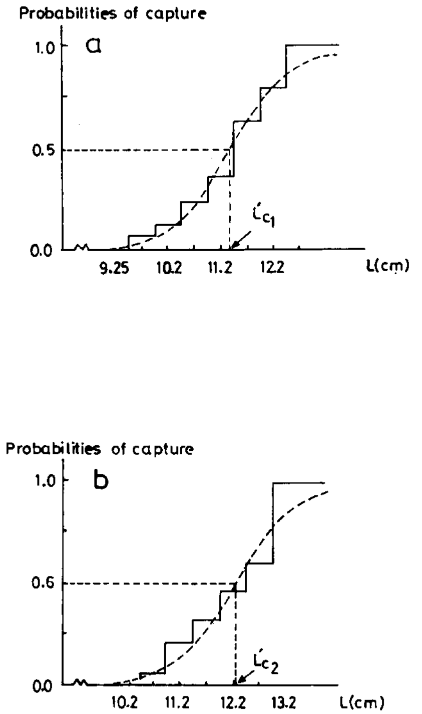

Fig. 3. Probability of capture and resultant curve for *Spicara smaris* on the eastern Turkish Black Sea coast. (a) 1991; (b) 1992.

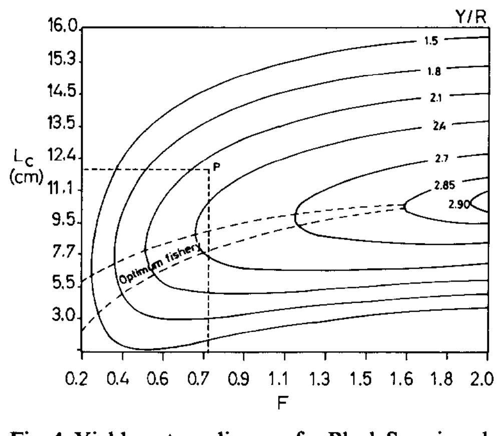

Fig. 4. Yield contour diagram for Black Sea picarel.

more robust at each period than females. The condition of the sexes was similar in both sampling periods.

3.4. Mortality

Natural mortality was calculated as $M=0.87$.

The values of Z estimated by the use of length-converted catch curves were:
$Z_1=1.665$ (catch data for 1991, Fig. 2(a));
$Z_1=1.420$ (catch data for 1992, Fig. 2(b));
$Z_{1,2}=1.543$ mean value.

The values of Z from application of the Beverton and Holt (1956) equation were:
$Z'_1=1.555$ (1991);
$Z'_2=1.663$ (1992);
$Z'_{1,2}=1.609$ mean value.

The mean of these pooled values of Z was $\bar{Z}=1.576$.

3.5. Exploitation rate

The exploitation rate estimated by the use of M and $\bar{Z}$ values was: $E_{current}=0.449$ with a range of 0.331–0.512.

3.6. Selectivity

The average length at first capture (L'_c) was estimated for each year separately as:
$L'_{c1}=11.71$ cm (1991, Fig. 3(a));
$L'_{c2}=12.53$ cm (1992, Fig. 3(b));
$\bar{L}'_c=12.12$ cm mean value.

3.7. Yield per recruit analysis

The yield isopleth diagram in relation to the length at first capture (L_c) and fishing mortality rate (F) is given in Fig. 4. It is clear that the picarel stock is underfished in the study area.

4. Discussion

The lack of extensive studies on Black Sea picarel does not allow comparison of growth parameters. However, there are a few studies related to the estimation of von Bertalanffy growth constants in the Mediterranean Sea. In our computations, the asymptotic length of *Spicara smaris* was found as $L_\infty=20.05$ cm and its K value as $K=0.44$. Tsangridis and Filippoussis (1988) applied two different methods (Pauly, 1983; Wetherall et al., 1987) for the estimation of L_∞ and K in samples taken in the Saranikos Gulf, Greece. They found L_∞=21.24 cm and K=0.608 according to the Pauly method, and L_∞=20.03 cm according to the Wetherall et al. method. They also reported that *Spicara flexuosa* (R), a closely related species, is characterized by a value of K=0.50, but validation of these estimates is necessary by using otoliths and size-frequency data at younger ages, i.e., 0.25–0.5 years. Hadjistephanou (1992) estimated L_∞=22.2 cm, K=0.24 and W_∞=100 g in the waters of Cyprus. It is clear that there must be some differences between the growth characteristics from one area to another (e.g. the Black Sea and the Mediterranean Sea) because of differences in the quantity and quality of food and hydrographic and climatic conditions.

Growth in weight was determined according to the length–weight equation, and a positive allometric relationship was observed between total weight and length. On a yearly basis, male individuals were heavier than females. This agrees with the observations of Mytilineou (1988) on the biology and population dynamics of picarel (*Spicara flexuosa*) in the Patraikos Gulf.

The natural mortality rate for *Spicara smaris* seems to be high (M=0.87), which in turn provides low fishing rates of F=0.71 (for Z=1.58). This may be regarded as reasonable considering its biological features (small, fast-growing, short-lived), behaviour and ecology. The same species may have different natural mortality rates in different areas depending on the density of predators and competitors, whose abundance is influenced by fishing activities (Sparre et al., 1989).

Beverton and Holt's yield-per-recruit model is used only as a rough approximation to assess the stock of *Spicara smaris* on the eastern Black Sea coast. This approach, although perhaps not justified in a multispecies fishery, may be useful in cases where there is no relevant information. The disadvantages of this model have been recorded and discussed (Gulland, 1983; Pauly, 1984); one crucial limitation is the fact that the maximum $(Y/R)'$ is produced in most cases at values of exploitation rates over 0.5, where the stock is 'overfished' (see Tsangridis and Filippoussis, 1988). The choice of E0.1, a concept analogous to F0.1, does not seem to alter the situation, as confirmed by our results (E0.1 = 1.0 for L'_c = 12.12 cm and E0.1 = 0.85 for L'_c = 10.12 cm).

It is rather difficult, and probably unwise, to describe the current position of the stock due to lack of information on the effect of fishing on recruitment, and the behaviour and migration pattern of *Spicara smaris* in the Black Sea. However, Fig. 4 shows what happens if the parameters involved have been correctly estimated. Following Gulland (1983), who notes that the derivation of M as a function of growth and temperature (Pauly, 1980) implies a single standard deviation from 0.78 to 1.28 times the 'best estimate', and the computation of Z implies a 20% error (see Tsangridis and Filippoussis, 1988), we may conclude that our M values are in the range (0.678)–0.869–(1.112) and our Z values are in the range (1.136)–(1.420–1.665–(1.998). These estimates show that the M and Z values may overlap, and the exploitation rate may vary from E=0.021 to E=0.661. These observations probably allow us to conclude that the fish stock may not yet be overfished, but they do not permit a specific definition of the current position.

Considering the weaknesses of the Beverton and Holt model (one of which is the important point that it takes recruitment as being independent of parent stock (Cushing, 1981)), and the lack of relevant data and any information on the effect of fishing on recruitment, it would be imprudent to proceed now to recommendations such as an increase/decrease of fishing effort or an increase/decrease of mesh size based only on our preliminary estimates.

Acknowledgements

I thank Prof. Ferit Bingel for comments, Yilmaz Bekiroglu (Director) and the technical staff of the Fisheries Research Institute of the Ministry of Agriculture in Trabzon for their help in collecting fish, and members of IMS–METU for other assistance.

References

Beverton, R.J.H. and Holt, S.J., 1956. A review of methods for estimating mortality rates in exploited fish populations, with special reference to sources of bias in catch sampling. Rapp. P.-V. Reun., Cons. Int. Explor. Mer, 140: 67–83.

Beverton, R.J.H. and Holt, S.J., 1957. On the dynamics of exploited fish populations. Fish. Invest. Minist. Agric. Fish. Food (GB) (2 Sea Fish.), 19: 533.

Cushing, D.H., 1981. Fisheries Biology. A Study in Population Dynamics. University of Wisconsin Press, Madison, WI, 295 pp.

DIE, 1976–91. Fishery Statistics. Prime Ministry State Institute of Statistics of Turkey, Publ. No: 947–1583, Ankara.

Fischer, W., Schneider, M. and Bauchot, M.-L., 1987. Fishes. FAO d'identification des espèces pour les besoins de la pêche. (Rev. 1). Méditerranée et mer Noire. Zone de pêche 37. Vol. 11. Vertébrés. FAO & E.C., project. GCP/INT/422/EEC. Rome, FAO (2): 1031–1036.

Gulland, J.A., 1983. Fish Stock Assessment: A Manual of Basic Methods. Wiley Interscience, Chichester, FAO/Wiley Series on Food and Agriculture, Vol. 1, p. 223.

Hadjistephanou, N.A., 1992. Assessment of five demersal marine fish stocks of Cyprus for the year 1989. FAO Fish. Rep. 477, pp. 23–34.

Holden, M.J. and Raitt, D.F.S. (Editors), 1974. Manual of Fisheries Science. Part 2. Methods of Resource Investigation and their Application. FAO Fish. Tech. Pap. 115, Rev. 1, p. 214.

Mytilineou, Ch., 1988. Contribution to the biology of picarel, *S. flexuosa*, in the Patraikos Gulf. National Centre For Marine Research 1945–1965–1985, Athens, pp. 86–87.

Oguz, T., La Violette, P.E. and Unluata, U., 1992. The upper layer circulation of the Black Sea: Its variability as inferred from hydrographic and satellite observations. J. Geophys. Res., 97: 569–584.

Pauly, D., 1980. A selection of simple methods for the assessment of tropical fish stocks. FAO Fish. Circ. 729, p. 54.

Pauly, D., 1983. Length-converted catch curves: A powerful tool for fisheries research in the tropics. Part I. Fishbyte, 1(2): 9–13.

Pauly, D., 1984. Fish Population Dynamics in Tropical Waters: A Manual for Use with Programmable Calculators. ICLARM Studies and Reviews 8, Manila, 325 pp.

Ricker, W.E., 1975. Computation and interpretation of biological statistics of fish populations. Bull. Fish. Res. Board Can., 191: 382.

Salekhova, L.P., 1979. Picarels (*Spicara* spp.) in the Mediterranean Basin. Kiev Academy of Science, pp. 1–172 (in Russian).

Sparre, P., Ursin, E. and Venema, S.C., 1989. Introduction to Tropical Fish Stock Assessment. Part 1. Manual. FAO Fish. Tech. Pap. No. 306.1, Rome, FAO, p. 337.

Tsangridis, A. and Filippoussis, N., 1988. Length-based approach to the estimation of growth and mortality parameters of *Spicara smaris* (L.) in the Saranikos Gulf, Greece, and remarks on the application of the Beverton and Holt relative yield per recruit model. FAO Fish. Rep., 412: 94–107.

Wetherall, J.A., Polovina, J.J. and Ralston, S., 1987. Estimating growth and mortality in steady-state fish stocks from length-frequency data. 13th ICLARM Conf. Proc., Manila.