Empirical Equations for the Estimation of Natural Mortality in Mediterranean Teleosts

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Abstract

Empirical relationships were established linking estimates of the instantaneous rate of natural mortality (M), the von Bertalanffy growth parameters, L_∞ (or W_∞) and K, and annual mean water temperature in 56 stocks of Mediterranean teleost fish. It is suggested that these relationships generate for these fish more reliable estimates of M than the widely-used model of Pauly (1980, J. Cons. CIEM 33(3):175-192), which was based on 175 fish stocks, but included only five stocks from the Mediterranean.

Introduction

This paper is a follow-up of Pauly (1980) who proposed an empirical model for the estimation of the instantaneous rate of natural mortality of fish (M) based on their growth parameters and an environmental parameter (mean annual water temperature). Pauly's original model, while based on 175 "stocks" from polar to tropical areas, included only five Mediterranean data sets.

The Mediterranean environment has its own characteristics, and the wide use of Pauly's equation in this region may thus lead to errors. Our aim is thus - as initially suggested by Arréguin-Sanchez (1990) to derive a "regional model" for the estimation of M.

Material and Methods

Growth parameter estimates, L_∞ and W_∞ (obtained via the relationship $W=a \cdot L^3$), K and the estimate of M were compiled for 24 species of Mediterranean teleosts, belonging to 56 "stocks" (with the two sexes of the same population counting as different "stocks" where sufficient data were available). These values were complemented with estimates derived from Guibout (1987) of the mean annual water temperature in the habitat of each stock (Table 1).

Note that none of the estimates of M in Table 1 was derived from a method which required L_∞, W_∞, K or temperature as input (i.e., we did not use Pauly's or any related equation to derive these estimates of M). Rather, we used published estimates of M based on the nomogram of Tanaka (1960; 48 cases), plots of total mortality on effort (Gulland 1969; 3 cases), catch curves in stock that suffered little or no exploitation (Gulland 1969; Farrugio 1981; 3 cases) or the method of Chauvet (1986; 2 cases).

The empirical models that were derived have the same form as that of Pauly (1980), i.e., consist of a logarithmics multiple linear regression, *viz:*

$$y = a_2 + b_1x_1 + b_2x_2 + b_3x_3 \qquad ...1)$$

where

$y = \log_{10}M$ (year^{-1})
$x_1 = \log_{10}L_\infty$ (TL, cm) or $\log_{10}W_\infty$ (wet weight, g)
$x_2 = K$ (year^{-1})
$x_3 = T$ (°C)

All statistical analyses were performed using the STAT-ITCF package (ITCF 1987).

Results and Discussion

The models that were obtained are

$$\log_{10}M = 0.736 - 0.114 \log_{10}L_\infty + 0.522 \log_{10}K + 0.583 \log_{10}T ...2)$$

and

$$\log_{10}M = 0.549 - 0.023 \log_{10}W_\infty + 0.558 \log_{10}K + 0.509 \log_{10}T ...3)$$

with $R^2=0.82$ in both cases. Thus 82% of the variance of the M values in Table 1 can be explained by either (2) or (3).

The F values are 36.68 for (2) and 34.93 for (3), with 3:55 degrees of freedom in both cases. Given the critical value of F (4.13), the hypothesis that the parameters of (1), i.e., a, b_1, b_2 and b_3 are all equal to zero can be rejected ($P<0.01$).

The Durbin-Watson statistic d is 1.60 for (2) and 1.58 for (3), suggesting that the residuals are independent of each other ($P<0.01$). Table 2 shows that these residuals are normally distributed; 95% of them occur within the range of ±1.96 standard deviation units.

These tests suggest that the form of Pauly's model (1) is appropriate for our data on Mediterranean fish. Other models have been tested. However, only (2) and (3) are presented here, both because they give the best fit and because they represent a regional "answer" to Pauly's model.

While some problematic estimates of M, all associated with Tanaka's method were noted, i.e., stock numbers 2,

Table 1. Data used to estimate parameters of equations (2) and (3).

No.	Stock[c]	Area[b]	Source(s)	Length[c] type(cm)	W_∞ (g)	a[d] (10^{-3})	K (year^{-1})	T (°C)	M (year^{-1})
1.	*Arnoglossus laterna*	Adriatic(I)	Giovanardi and Piccinetti (1983)	15.81 T	17.8	4.50	0.57	15.50	0.60
2.	*Trachurus mediterraneus*(F)	Bon-Ismail(A)	Korichi (1988)	26.88 F	275.8	14.20	0.67	17.50	0.50
3.	*Trachurus mediterraneus*(F)	Bon-Ismail(A)	Korichi (1988)	25.70 F	215.5	12.70	0.74	17.50	0.50
4.	*Trachurus trachurus*(F)	Bon-Ismail(A)	Korichi (1988)	29.48 F	384.3	15.00	0.28	17.50	0.39
5.	*Trachurus trachurus*(M)	Bon-Ismail(A)	Korichi (1988)	29.92 F	340.2	12.70	0.23	17.50	0.39
6.	*Sardina pilchardus*	Castellon(E)	Penas Lado (1978)	19.35 T	43.5	6.00	0.31	19.31	0.42
7.	*Sardina pilchardus*(M)	Alger(A)	Mouhoub (1986)	18.73 T	52.6	8.00	0.28	18.91	0.34
8.	*Sardina pilchardus*(F)	Alger(A)	Mouhoub (1986)	20.28 T	58.4	7.00	0.26	18.91	0.29
9.	*Engraulis encrasicolus*(M)	Alger(A)	Hémida (1987)	18.65 T	25.9	4.00	0.26	18.91	0.50
10.	*Micromesistius poutassou*(F)	Ligurian sea(I)	Orsi-Relini and Peirano (1985)	48.37 T	724.3	6.40	0.19	13.05	0.39
11.	*Merluccius merluccius*	Baleares(E)	Oliver et al. (1990)	94.24 T	3598.9	4.30	0.09	13.00	0.30
12.	*Merluccius merluccius*(F)	Bou-Ismail(A)	Bouaziz (1992)	51.48 T	955.0	7.00	0.20	14.00	0.29
13.	*Merluccius merluccius*(M)	Bou-Ismail(A)	Bouaziz (1992)	40.07 T	257.3	4.00	0.27	14.00	0.50
14.	Merluccius merluccius	Bou-Ismail(A)	Bouaziz (1992)	53.44 T	915.7	6.00	0.18	14.00	0.29
15.	*Merluccius merluccius*(F)	Sicily(I)	Andaloro et al. (1985)	69.38 T	2037.2	6.10	0.14	14.18	0.25
16.	*Merluccius merluccius*(M)	Golfe du Lion(F)	Aldebert (1981)	50.66 T	767.1	5.90	0.20	13.25	0.39
17.	*Merluccius merluccius*(F)	Golfe du Lion(F)	Aldebert (1981)	68.78 T	1919.7	5.90	0.15	13.25	0.34
18.	*Merluccius merluccius*(F)	Golfe du Lion(F)	Aldebert and Carries (1989)	80.20 T	3043.5	5.90	0.11	13.25	0.25
19.	*Merluccius merluccius*(M)	Golfe du Lion(F)	Aldebert and Carries (1989)	55.80 T	1025.1	5.90	0.18	13.25	0.32
20.	*Merluccius merluccius*(F)	Golfe du Tunis(T)	Bouhlal (1975)	73.00 T	1517.2	3.90	0.16	14.20	0.20
21.	*Merluccius merluccius*(M)	Golfe du Tunis(T)	Bouhlal (1975)	59.30 T	729.8	3.50	0.19	14.20	0.20
22.	*Merluccius merluccius*	Golfe du Tunis(T)	Bouhlal (1975)	69.50 T	1242.1	3.70	0.18	14.20	0.20
23.	*Merluccius merluccius*	Greece	Papaconstantinou et al. (1985)	65.90 T	2861.9	10.00	0.07	15.00	0.15
24.	*Dicentrarchus labrax*	Tunisia	Chauvet (1986)	59.70 F	2553.3	12.00	0.17	19.00	0.11
25.	*Chelon labrosus*	Tunisia	Chauvet (1986)	49.10 F	751.9	6.35	0.22	17.00	0.29
26.	*Liza aurata*	Marsal(I)	Andaloro (1983a)	24.28 T	286.3	20.00	0.63	17.30	0.43
27.	*Liza aurata*	Tunisia	Chauvet (1986)	38.60 F	1178.8	20.50	0.59	17.00	0.64
28.	*Liza ramada*	Tunisia	Chauvet (1986)	47.80 F	1201.4	11.00	0.32	17.00	0.35
29.	*Liza ramada*(F)	Marseille(F)	Autem (1979)	31.60 S	378.7	12.00	0.33	17.22	0.50
30.	*Liza ramada*(F)	Marseile(F)	Autem (1979)	47.00 S	1245.9	12.00	0.15	17.22	0.34
31.	*Liza saliens*	Tunisia	Chauvet (1986)	39.40 F	1467.9	24.00	0.34	17.00	0.35
32.	*Mugil cephalus*	Tunisia	Chauvet (1986)	52.90 F	1258.3	8.50	0.27	17.00	0.17
33.	*Mullus barbatus*(F)	Sicily(I)	Andaloro and Giarritta (1985)	24.55 T	266.3	18.00	0.25	17.20	0.43
34.	*Mullus barbatus*(M)	Sicily(I)	Andaloro and Giarritta (1985)	23.39 T	230.4	18.00	0.16	17.20	0.43
35.	*Mullus surmuletus*(M)	Ionian sea(I)	Andaloro (1981)	25.02 T	104.9	6.70	0.24	17.20	0.39
36.	*Mullus surmuletus*(F)	Ionian sea(I)	Andaloro (1981)	30.12 T	183.1	6.70	0.30	17.20	0.39
37.	*Mullus surmuletus*(M)	Sicily(I)	Andaloro and Giarritta (1985)	25.25 T	244.9	9.30	0.41	17.20	0.43
38.	*Mullus surmuletus*(F)	Sicily(I)	Andaloro and Giarritta (1985)	29.75 T	244.9	9.30	0.49	17.20	0.43
39.	*Thunnus thynnus*	Italia	Scaccini (1965)	395.20 F	1111023.8	18.00	0.06	18.20	0.18
40.	*Thunnus thynnus*	Tunisia	Hattour (1978)	330.00 F	646866.0	18.00	0.09	19.50	0.18
41.	*Thunnus thynnus*	France	Farrugio (1981)	351.10 F	779049.4	18.00	0.08	18.00	0.18
42.	*Epinephelus guaza*	Gabes(T)	Bouain (1985)	197.79 T	97208.9	12.56	0.03	17.60	0.05
43.	*Epinephelus guaza*	Tunisia	Chauvet (1988)	114.49 T	18853.7	12.56	0.09	17.60	0.10
44.	*Dicologlossa cuneata*(M)	Algeria	Rousset and Marinaro (1983)	23.75 T	108.5	8.10	0.38	14.00	0.50
45.	*Dicologlossa cuneata*(F)	Algeria	Rousset and Marinaro (1983)	24.73 T	122.5	8.10	0.47	14.00	0.50
46.	*Solea vulgaris*	Adriatic(I)	Piccinetti and Giovanardi (1983)	40.10 T	444.9	6.90	0.68	15.50	0.60
47.	*Boops boops*	Bou-Ismail(A)	Chali-Chabane (1988)	25.38 F	158.6	9.70	0.29	17.50	0.39
48.	*Diplodus annularis*	Golfe du Lion(F)	Girardin (1978)	17.12 F	49.7	9.90	0.56	16.75	0.50
49.	*Pagellus acarne*(M)	Sicily(I)	Andaloro (1983b)	26.23 T	166.0	9.20	0.42	17.20	0.43
50.	*Pagellus acarne*(F)	Sicily(I)	Andaloro (1983b)	29.78 T	243.0	9.20	0.32	17.20	0.43
51.	*Pagellus erythrinus*(M)	Alger(A)	Cherabi (1987)	36.49 T	728.8	15.00	0.21	16.65	0.34
52.	*Pagellus erythrinus*(F)	Alger(A)	Cherabi (1987)	35.43 T	667.1	15.00	0.23	16.65	0.34
53.	*Sparus auratus*	Tunisia	Chauvet (1986)	46.70 F	1324.0	13.00	0.21	17.00	0.23
54.	*Sparus auratus*	Sète(F)	Lasserre (1976)	57.66 T	2683.8	14.00	0.27	19.00	0.50
55.	*Sparus auratus*	Sète(F)	Lasserre (1976)	45.52 T	1037.5	11.00	0.37	17.20	0.50
56.	*Sparus auratus*	Sète(F)	Lasserre (1976)	53.89 T	7042.7	45.00	0.25	17.20	0.50

[a] F = Females; M = Males

[b] A = Algeria; S = Spain; F = France; G = Greece; I = Italy; T = Tunisia.

[c] T = Total length; F = Fork length; S = Standard length.

[d] Parameter "a" of a length-weight relationship of the form $W = a \cdot L^3$

3, 24, 26, 32, 38, 46 and 48 in Table 1, for which K>M, the relationship between M and K previously noted by Beverton and Holt (1959), Gulland (1969) and Pauly (1980) was again confirmed. Thus the rule

$$K < M < 2K \qquad ...4)$$

applies to Mediterranean fish.

Table 2. Frequency distribution of the residuals of equations (2) and (3).

Class limits (cm)	(2)	(3)	Class limits (cm)	(2)	(3)
-0.35 < -0.25	3	3	-0.05 < 0.05	21	21
-0.25 < -0.15	3	3	0.05 < 0.15	13	14
-0.15 < -0.05	10	9	0.15 < 0.25	6	6

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References

Aldebert, Y. 1981. Contribution à la biologie du merlu du Golfe du Lion: Premières données sur la croissance. Rapp. P.v. Réun. CIEM 27(5): 47-48.

Aldebert, Y. and J.C. Carries. 1989. La croissance du merlu dans le Golfe du Lion. Méthodologie. Problèmes posés. Report of the age-reading workshop on Mediterranean Hake and Sardine. Palma de Mallorca, Espana, 10-15 April 1989: 66-70.

Andaloro, F. 1981. Contribution on the knowledge of the age and growth of the Mediterranean red mullet, *Mullus surmuletus* (L., 1758). Rapp. P.v. Réun. CIEM 27(5): 111-113.

Andaloro, F. 1983a. Contribution on the knowledge of the age and growth of the Marsala Lagoon golden Mullet, *Liza aurata* (Risso, 1810). Rapp. P.v. Réun. CIEM 28(5):81-82.

Andaloro, F. 1983b. Résumé des paramètres biologiques sur *Pagellus acarne* de la mer Tyrrhénéenne méridionale et de la mer Ionienne septentrionale. Rapp. FAO. Pêches, 266: 89-92.

Andaloro, F., P. Arena and S.P. Giarritta. 1985. Contribution to the knowledge of the age, growth and feeding of hake *Merluccius merluccius* (L., 1758) in the Sicilian Channel. FAO Rapp. Pêches/ FAO Fish. Rep. (336):93-97.

Andaloro, F. and S. Giarritta. 1985. Contribution to the knowledge of the age and growth of striped mullet, *Mullus barbatus* (L., 1758) and red mullet *Mullus surmuletus* (L., 1758) in the Sicilian Channel FAO Rapp. Pêches 336: 89-92.

Arreguin-Sanchez, F. 1990. Letter to the Editor. Fishbyte 8(3):2.

Autem, M. 1979. Contribution à l'étude biologique des zones de dilution du littoral méditerranéen: estuaires et étangs lagunaires. USTL Montpellier (France). 343 p. Thèse 3è cycle.

Beverton, R.J.H. and S.J. Holt. 1959. A review of the lifespans and mortality rates of fish in nature, and their relation to growth and other physiological characteristics. CIBA Found. Colloq. Ageing 5:142-180.

Bouain, A. 1985. Croissance linéaire des mérous du Golfe de Gabès (Tunisie). Rapp. P.v. Réun. CIEM 29(8):99-100.

Bouaziz, A. 1992. Le merlu (*Merluccius merluccius méditerraneus*, Cadenat, 1950) de la baie de Bou-Ismail: biologie et écologie. ISMAL (Alger). 85 p. +Annexes. Thèse de Magister en océanographie biologique.

Bouhlal, M. 1975. Contribution à l'étude biologique et dynamique du merlu *Merluccius merluccius* mediterraneus (L. 1758) du Golfe de Tunis. Université de Tunis, Faculté des sciences. 177 p. Thèse de 3ème cycle de biologie marine.

Chali-Chabane, F. 1988. Contribution à l'étude biologique et dynamique de bogues, *Boops boops* (Linné, 1758) de la baie de Bou-Ismail. ISMAL. Alger. 111 p. Thèse de Magister.

Chauvet, C. 1986. Exploitation des poissons en milieu lagunaire méditerranéen. Dynamique du peuplement ichtyologique de la lagune de Tunis et des populations exploitées par des bordigues (Muges, loups, daurades). Etat, Univ. Perpignan. 555 p. Thèse de Doctorat.

Chauvet, C. 1988. Etude de la croissance du mérou *Epinephelus guaza* (L. 1758) des côtes tunisiennes. Aquatic Living Resources 1(4):277-288.

Cherabi, O. 1987. Contribution à l'étude de la biologie du pageot commun *Pagellus erythrinus* (Linné, 1758) et à l'écologie de la famille des Sparidés de la baie d'Alger. USTHB. Alger. 203 p. Thèse de Magister.

Farrugio, H. 1981. Exploitation et dynamique des populations de thon rouge *Thunnus thynnus* (Linné, 1758) atlanto-méditerranéennes. Université des sciences et techniques du Languedoc. 325 p. Thèse de Doctorat en-sciences.

Giovanardi, O. and C. Piccinetti. 1983. Biology and fishery of the scaldfish *Arnoglossus laterna* (Walbaum, 1792) in the Adriatic Sea. FAO Fisheries Report 290:161-166.

Girardin, M. 1978. Les Sparidae du Golfe du Lion. Ecologie et biogéographie. DEA. USTL. Montpellier. 140 p.

Guibout, P. 1987. Atlas hydrographie de la Méditerranée. IFREMER. SHOM. 150 p.

Gulland, J.A. 1969. Manual of methods for fish stock assessment. Part 1: Fish population analysis. FAO Man. Fish. Sci. (4). FAO, Rome.

Hattour, A. 1978. Contribution à l'étude des Scombridés de Tunisie. DEA de biologie marine et d'Océanologie. Rapport de stage. Université de Tunis, Faculté des sciences. 168 p.

Hémida, F. 1987. Contribution à l'étude de l'anchois: *Engraulis encrasicolus* (Linné, 1758) dans la région d'Alger. Biologie et exploitation. USTHB. Alger. 138 p. Thèse de Magister.

ITCF. 1987. Logiciel STAT-ITCF. Ed. ITCF. Service des études statistiques et informatiques.

Korichi, H.S. 1988. Contribution à l'étude biologique des deux espèces de saurels: *Trachurus trachurus* (Linné, 1758) et *Trachurus mediterraneus* (Steindachner, 1868) et de la dynamique de *Trachurus trachurus* (Linné, 1758) en baie de Bou-Ismail (Alger). ISMAL. Alger. 203 p. Thèse de Magister.

Lassere, G. 1976. Dynamique des populations ichthyologiques lagunaires. Application à *Sparus aurata* L. USTL. Montpellier. 306 p. Thèse de Doctorat d'Etat.

Mouhoub, R. 1986. Contribution à l'étude de la biologie et de la dynamique de la population exploitée de la sardine (*Sardina pilchardus*, Walbaum, 1792) des côtes algéroises. USTHB. Alger. 163 p. Thèse de Magister.

Oliver, P., M. Gaza and A. Morillas. 1990. Crecimiento de *Merluccius merluccius* L. de las Islas Baleares mediante analisis de la progresion modal. II Jornades del Medi Ambient de les Balears: 175-176.

Orsi-Relini, L. and A. Peirano. 1985. Biological notes on the blue whiting, *Micromesistius poutassou* Risso, of the Ligurian Sea. FAO Fish. Rep. (336):113-117.

Papaconstantinou, C., E. Caragitsou and T. Panos. 1985. Preliminary utilization of trawl survey data for hake (*M. merluccius*) population dynamics from the Western Greek waters. FAO Fish. Rep. (345):87-92.

Pauly, D. 1980. On the interrelationships between natural mortality, growth parameters, and mean environmental temperature in 175 fish stocks. J. Cons. CIEM 39(2):175-192.

Penas Lado, E. 1978. Estudio sobre la dinámica y la estrategia de explotacion del "stock" de sardina (*Sardina pilchardus*, Walbaum) de la costas de Castellon. Bol. Inst. Esp. Oceanogr. 4(3):143-160.

Piccinetti, C. and O. Giovanardi. 1983. Données biologiques sur *Solea vulgaris* Quensel en Adriatique. FAO Fish. Rep. (290):117-121.

Rousset, J. and J.Y. Marinaro. 1983. Croissance de *Dicologlossa cuneata* (Moreau) (Téléostéen Soléidé) sur les côtes d'Algérie. Rapp. P.v. Réun. CIEM 28(5):77-79.

Scaccini, A. 1965. Biologia e pesca dei tonni nei mari italiani. Ministerio Mar. Mercant. Mem. 12, 100 p.

Tanaka, S. 1960. Studies on the dynamics and the management of fish populations. Bull. Fish. Res. Lab. (28):1-200.

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