ICES CM 1998 /O:8 THEME SESSION (O) DEEPWATER FISH AND FISHERIES

Mediterranean deep-water fish age determination and age validation: the state of the art

Beatriz Morales-Nin

CSIC/UIB-Institut Mediterrani d'Estudis Avançats

Campus Universitari, 07071 Palma de Mallorca, Spain [tel:+34971401877, fax: +34971404945, e-mail: bmorales@tinn.net]

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INTRODUCTION

Otolith formation involves rhythmical variations in the deposition and size of organic matrix fibres and carbonate crystals resulting in the formation of macroscopic and microscopic zonations. For these structures to be of use in age estimation they must be regulated by an endogenous rhythm linked to a periodic environmental cycle or synchronised to periodic events. Macroscopic zonations were considered as time-signals and first used to determine age in the XIX century (Reibisch, 1899) and have been extensively applied world wide in age determination of teleost fishes (Williams and Bedford, 1974). The formation of opaque and translucent zones has been attributed to various factors, such as seasonal temperature variations and reproductive cycles (Dannevig, 1956; Kimura, 1984). However, the timing of formation of opaque or translucent zones often did not agree (Irie, 1960; Bagenal and Tesch, 1978). In a world wide literature review of seasonal timing of otolith opaque zone formation (Beckman and Wilson, 1995), it was concluded that there is a general concurrent pattern of seasonal formation of opaque rings in spring and summer. However at higher latitudes of the northern hemisphere, opaque formation was later in the year and over a more extended period of time. No clear association between spawning and timing of otolith opaque zone formation was found (Beckman and Wilson, 1995).

There are several studies of deep-water fish age determination using different techniques. In general these studies have related the zone formation to seasonal events, even in the Mediterranean Sea where the waters below the thermocline are stable all year around (Salat and Font, 1987). Some species, like *Hoplostethus atlanticus*, a deep water species occurring between 600 m and 1200 m, have arisen a considerable controversy with some studies giving maximum ages of 127 yr and others of 30 yr due to their complex otolith structure (Gauldie, 1987). This point out the necessity to answer the main question: What is the mechanisms that makes certain marks in the otolith related to the age of the fish?

In this contribution the published methods used to age deep-water fish in the Mediterranean area, are reviewed so as to contribute some hypotheses regarding the time-signal encoded in the otoliths.

MEDITERRANEAN SEA DEEP-WATER FISH AGEING

On the 1960 the first data on *Trachrhynchus trachyrhynchus* biology was published (Motais, 1960) while in the 70´s the first size modal composition (Relini-Orsi and Wurtz, 1979) and ageing studies on deep-water Mediterranean fish were carried out using the annulus found in the otoliths of two species of Macrourids (Rannou, 1973; 1976). The otolith microstructure of an abyssal Macrourid was determined (Rannou and Thiriot-Quievreux, 1975) showing analogous structures to the ones described as daily by Pannella (1971). In the 80´s a preliminary work with six species caught between 1000 m and 2300 m depth in the NW Mediterranean showed the presence of rhythmical growth patterns similar to daily growth increments and annuli (Morales-Nin, 1980). With the development of the interest in the deep-sea and the comercialization of new species such as *Lepidopus caudatus*, several studies have been carried out dealing with age and growth (Fig. 1).

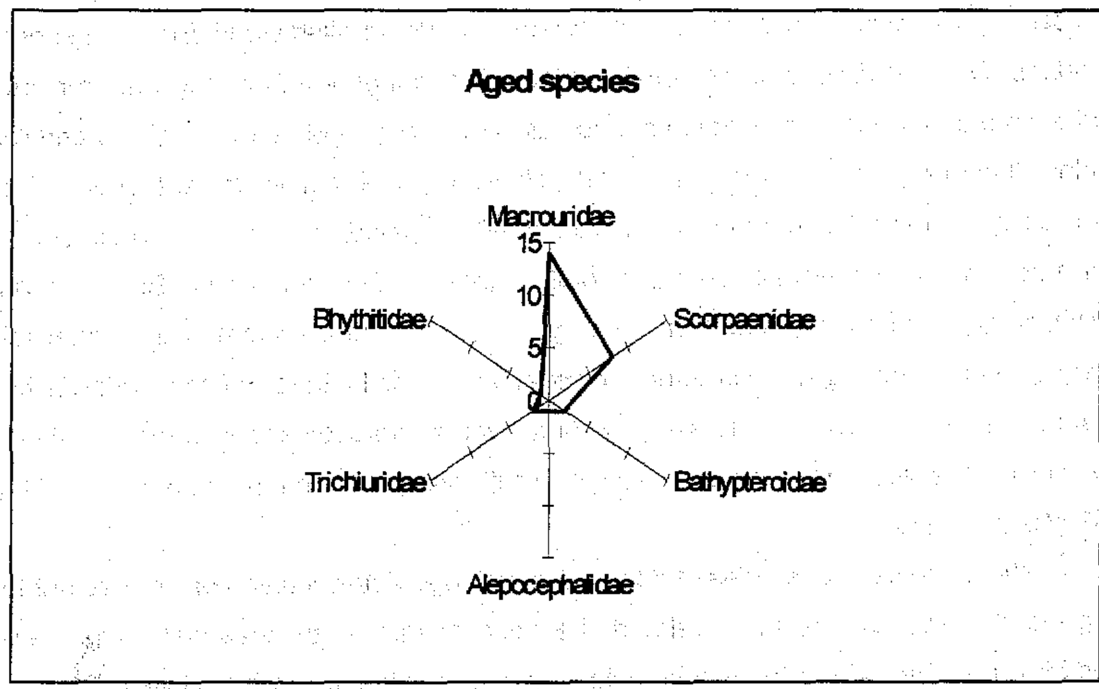

Fig.1. Number of species by Family aged in the Mediterranean.

The best studied fish are the Macrourids with most age and growth studies dedicated to them and specially to *Coelorhynchus coelorhynchus* and *Nezumia aequalis*, the Scorpenidae are the second most studied with *Helicolenus dactylopterus* as the main species (Fig.1).

All the studies have used annuli for age determination, using daily growth rings only for validation of the first ring (Massutí et al., submitted). However, the daily nature of the increments could not be proved and they were considered as daily by analogy with other fish.

The age ranges varied from young-of-the-year (age 0) to maximum ages of 30 years (Table 1). Although, most of the fish corresponded to younger ages, like in *H.dactylopterus* where between 55% and 77%, depending on the area, were fish 0-3 yr old (Massutí et al., submitted). The growth parameters show low growth rate (Table 1). The mesopelagic *Lepidopus caudatus* inhabiting the shelf and slope down to 450 m depth in the Mediterranean, shows a different life strategy with fast growth and attaining a maximum age of 8 yr (Molí et al., 1990; Demestre et al., 1993).

The growth performance expressed as the logarithmic relationship between the von Bertalanffy growth coefficient and asymptotic length shows a linear relationship with negative slope (Fig.2). The y-intercept of the regression provides an index of growth performance ϕ. The resulting regression line is given by: $\log_{10} k = -0\text{-}645 - 0.137 \log_{10} L\infty$, while the $r^2 = 0.27$. When the regression of $\log_{10} k$ on $\log_{10} L\infty$ is restricted to a number of stocks within a species, the slope should equal –2 (Pauly, 1980). Although the correlation encreases notably if only the available data on *H.dactylopterus* are considered ($r^2=0.789$), the slope is different from the proposed value (b=-1.247). This might suggest that besides the stock variability some discrepancies in the ageing methodology are present.

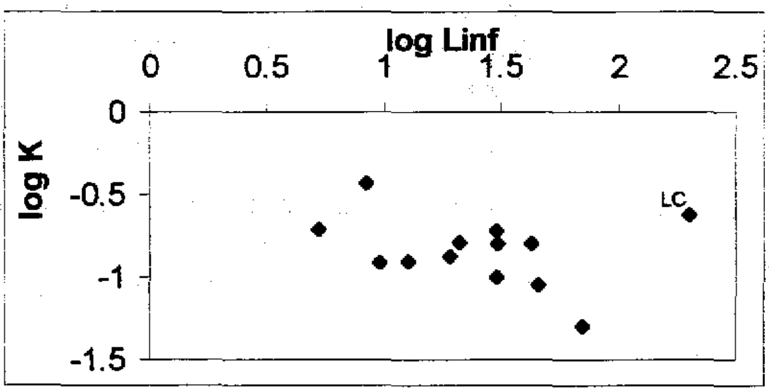

Fig.2. Plot of the von Bertalanffy growth parameters of Mediterranean deep-water species (Table 1). LC: *Lepidopus caudatus*.

SEASONAL FORMATION OF ANNULAE

The main validation method applied is the evolution of the marginal increment and secondly the length frequency analysis (Table 1). The formation of the opaque ring is seasonal with most species laying the ring in summer (Fig.3), although there is some variability. For instance, *H.dactylopterus* opaque ring frequency distribution peaks in spring (Fig.3). Most of the studied *H.dactylopterus* were caught on the Alboran sea, which is characterised by differentiated oceanographic conditions with a strong Atlantic influence in spring (Beckers et al., 1997). *C.coelorhynchus* and *C.labiatus* might have two translucent rings per year laid down in spring and autumn (Fig.3). *C.coelorhynchus* and *N.sclerorhynchus* have the highest proportion of translucent edges in January and the minimum in August in Greek waters (Labropoulou et al., 1998).

However, in a recent study the formation of the rings in *Merluccius merluccius* from the Gulf of Lions have been proved not to be related to seasonal cycles (Morales-Nin et al, in press). The ring pattern depended on the sex and sexual activity of the fish. Probably the lack of a clear environmental cycle between the depths of 50 and 750 m where the species is found (Recasens et al., 1998), determined the lack of periodicity of these growth structures.

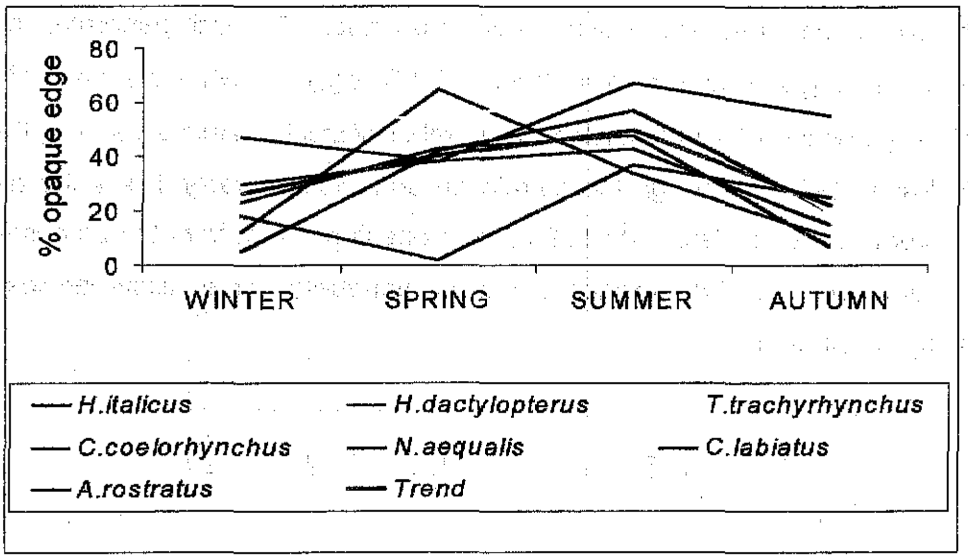

Fig.3. Formation of opaque rings from data on Massutí et al. 1995, Morales-Nin et al. 1996 and Massutí et al. 1998.

DISCUSSION

Deep-sea fish otoliths show the typical pattern of teleost fish with opaque and translucent growth zones laid down around a nucleus. In several species false rings appear in the nucleus, dificulting the age interpretation on the younger fish. The formation of these rings is generally considered associated to an ontogenic or habitat change, although there is not a clear trend in the formation that can be attributed to settlement or metamorphosis. In general the opaque zones are wider than the translucent rings and present several faint rings. After several rings are laid down, the thickness of the opaque rings decrease sharply becoming similar to the translucent rings. This change in the opaque ring formation has been attributed to the onset of sexual maturity (Massutí et al., 1995), although more detailed studies would be necessary to assess this aspect.

Most Mediterranean deep-water species are relatively long living with moderate growth rates, except the Trichiuridae *Lepidopus caudatus* which shows a high growth performance index (ϕ=3.979). This might be due to the special morphology of this family, because *Aphanopus carbo* from Madeira showed similar growth rates (ϕ=3.65) (Morales-Nin and Sena-Carvalho, 1996).

The timing of the opaque ring formation seems to be associated to spring-summer in the Mediterranean, while autumn-winter formation seems to be common in Atlantic waters (Gordon and Swan, 1996). The seasonal water temperature cycle in the North Atlantic has strong variations related to deep and area. In the Rockall Trough there is a strong seasonal signal in the water temperature from the surface to 500 m depth, while the water temperature is stable and decreasing towards the bottom at bigger depths (Mauchline, 1988). Thus, in deeper water species such as juvenile *C.rupestris,* opaque ring formation has been atributed to seasonal changes in the abundance and perhaps the quality of their mesopelagic prey (Gordon and Swan, 1996).

In the Mediterranean the formation of the translucent rings has been related to reproduction for *Nezumia sclerorhynchus* (Rannou, 1976) and for *Alocephalus rostratus* (Morales-Nin et al.,1996), while for five species of Macrourids no relationship was evident (Massutí et al., 1995). However, seasonal growth in inmature deep-sea fish suggest other mechanisms underliying the ring pattern, probably some seasonal stimulus as was noted by Rannou (1976) or seasonal fluctuations in feeding and activity patterns (Morales-Nin, 1990; Massutí et al., 1995). The Mediterranean is characterised by stable relatively high temperatures ($\cong$13°C) below the thermocline (Salat and Font, 1987) and is supposed to be aseasonal, at least with respect to temperature (Tyler, 1988). The available data on the deep Mediterranean is too scarce to determine if there is a seasonal pulse in the productivity related to the peaks found in shallower waters.

Most of the studies have been carried out with Macrourid fish (Fig.1) followed by Scorpaenidae. Moreover, the validation using the marginal increment evolution is feasible mainly in the first age classes. Thus, it is too early to consider the seasonal otolith formation as a general trend.

One of the most important questions for fisheries managers and for fish biologists is the issue of fish age determination. The relevance of this subject is clear when considering the number of papers published and research effort concentrated into fish age and the relationships between environmental variables and fish growth. However, there are several main questions that are still not solved (Morales-Nin, submitted): 1) What is the mechanism that relates the growth marks in the otoliths with the age of the fish? 2) Is it possible to validate the proposed mechanism with observed results? 3) How phylogeny and stock affect the otolith increment patterns? 4) How the environmental and physiological responses and processes affect check and zone formation?

These questions are the same for deep-water fish, although the suposed lack of a strong seasonal stimulus seems to further complicate the understanding of the mechanisms of ring formation in deep-water fish. In a recent review of the age determination of deep-water fishes, Bergstad (1995) pointed out that validation of age readings, intercalibration of readings and improvement of preparatory techniques are challenges for the future. In the Mediterranean these observations hold specially true.

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Table 1. Mediterranean deep-sea fish age and growth data. MI= Evolution of marginal increment, LFA= Length frequency analysis, DGI= Daily growth increments, (1)= for age 1 fish.

Species	Age range	L_∞ cm	K yr^{-1}	ϕ	Validation	Author
Nezumia sclerorhynchus	7-23	42.315	0.159	2.457	LFA	Rannou (1976)
Trachyrhynchus trachyrhynchus	1-11	21.07	0.164	1.86	MI	Massutí et al.(1995)
Nezumia aequalis	1-9	9.59	0.122	1.05	MI	Massutí et al.(1995)
Hymenocephalus italicus	1-9	5.28	0.196	0.738	MI	Massutí et al.(1995)
Coelorhynchus coelorhynchus	1-10	12.63	0.126	1.303	MI	Massutí et al.(1995)
C.labiatus	1-10	8.43	0.372	1.422	MI	Massutí et al.(1995)
Lepidopus caudatus	1-8	200	0.238	3.979	LFA	Demestre et al. (1993)
Alepocephalus rostratus	0-23	45.46	0.09	2.269	MI	Morales-Nin et al.(1996)
Bathypterois mediterraneus	1-15	19.11	0.134	1.689	MI	Morales-Nin et al.(1996)
Helicolenus dactylopterus	0-9	70.7	0.05	2.35		Peirano and Tunesi (1986)
Helicolenus dactylopterus	1-7	30.7	0.16	2.17		D´Onghia et al.(1992)
Helicolenus dactylopterus		29.9	0.19	2.23		Ungaro and Manaro (1995)
Helicolenus dactylopterus	0-30	30	0.1	2.065	MI+DGI (1)	Massutí et al.(submitted)

$\phi = 2 \log L_\infty + \log k$ (Pauly and Munro, 1989)