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AGE AND GROWTH STUDIES ON FISHES IN CROATIAN FISHERIES SCIENCE

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ABSTRACT

Age and growth studies of fish species are one of the main analytical models to analyze the dynamics of exploited fish populations. In this study the author reviews the published data on age and growth parameters of some fish species in the Eastern Adriatic. Scales and otoliths were the main calcified tissues employed for age determination, while fin rays were scarcely used. Age and growth were determined for 17 fish species, which makes 14% of 120 commercially interesting species. According to presented results we can conclude that there is still much work to be done in age and growth determination of commercially interesting fish species.

Key words: age, growth, studies, Croatian fisheries

INTRODUCTION

The demography of living organisms constitutes the research object of the population dynamics. Since changes in the number of individuals and the age structure of a population result from interactions between the biology of the species and the biotic and abiotic environments, the population dynamics can be fully considered a branch of ecology. As a quantitative discipline, the population dynamics uses mathematical models as a main tool. Most population dynamics models require previous work with biological models, or include them as submodels. In particular the following biological studies are of a great importance in ichthyology: stock identification, length-weight relationship, length-age relationship, sex ratio, proportion of mature individuals and trophic relationship.

Biological studies of fish presently being carried out in the Mediterranean reflect the wide interest in growth being shown by scientists. However, the diversity of the studied species, which ranges from pelagic to littoral, and demersal habitats is noteworthy, and reflects the multispecies nature of the Croatian fisheries. Species normally studied correspond to the exploited populations caught by a variety of fishing techniques: trawls, longlines, trammel nets, beach seine, *etc.*

In this paper I will attempt to present age and growth studies in the Croatian fisheries science.

AGE AND GROWTH STUDIES

The study of growth means basically the determination of the body size as a function of age. Therefore all stock assessment methods work essentially with age composition data. In temperate waters, such as the Adriatic Sea, can usually be obtained through the counting of year rings on hard parts such as scales and otoliths. These rings are formed due to strong fluctuations in environmental conditions from summer to winter and vice versa. Von Bertallanfy growth model of body length as a function of age is one of the commonest models for observing growth of most fish species. The mathematical model is: $\mathbf{L(t) = L_{\infty} (1 - exp (-K (t-t_0))}$, where the parameters can to some extent be interpreted biologically. L_{∞} is interpreted as "the mean length of very old (strictly: infinitely old) fish", it is also called the "asymptotic length". K is a "curvature parameter", which determines how fast the fish approaches its L_{∞}. The third parameter, t_0, sometimes called "the initial condition parameter", determines the point in time when the fish has zero length. Biologically, this has no meaning, because the growth begins at hatching when the larva already has a certain length, which may be called L(0) when we put $t = 0$ at the day of birth.

The growth of sardine *Sardina pilchardus* (Walbaum, 1792) in the Eastern Adriatic was intensively studied (Mužinić, 1954; Sinovčić, 1983, 1986). The scales and otoliths were used for age determination. Calculated von

Bertalanffy's growth constants were: L_∞ = 20.5 cm; K = 0.46; t_0 = -0.5; and sardine specimens sampled from commercial catches belonged from 1+ to 8+ age groups (Sinovčić, 1986).

Morović (1961) using otoliths and scales established age groups of several mugilids: *Mugil cephalus* (otoliths - 3°, scales - 6°), *Chelon labrosus* (otoliths - 5°, scales - 5⁺), *Liza aurata* (otoliths - 4°), and *Liza saliens* (otoliths - 4°).

Striped mullet, *Mullus barbatus* Linnaeus, 1758, was studied by Haïdar (1970). Seven age groups were found (from 0° to 6°), using scales and otoliths, in the eastern Middle Adriatic.

Hake, *Merluccius merluccius* (Linnaeus, 1758), is, like sardine, one of commercially most important fish species in the Adriatic Sea, and it was intensively studied (Županović, 1961, 1968; Jardas, 1976; Županović & Jardas, 1986). Studying the age composition of hake from the Jabuka Pit, using otoliths, showed highest presence of age groups 1 and 2 (Županović & Jardas, 1986), while the maximum age found was 9 years (Županović, 1968).

Growth parameters of the red pandora *Pagellus erythrinus* (Linnaeus, 1758), obtained by graphic method, in the insular zone of the Middle Adriatic were: K = 0.201 and L_∞ = 37.7 cm. Scales were used for age determination and six age groups were obtained (Županović & Rijavec, 1980).

The growth of the Atlantic horse-mackerel *Trachurus trachurus* (Linnaeus, 1758) was studied by Alegria-Hernandez (1983, 1984). Calculated parameters of growth curve were: L_∞ = 37.55 cm; K = 0.22; t_0 = -1.28. Age was determined by otoliths and specimens belonged to 0 to 9 age group.

A study of biological characteristics of the grey mullet *Liza ramada* (Risso, 1826) was carried out over a period of one year in Šibenik area. The following values of von Bertalanffy's growth parameters were estimated: L_∞ = 52.5 cm, K = 0.25 and t_0 = -0.1. Grey mullet attains maximum length at 12 years of age. Parameters were obatined by Ford-Walford method from mean grey mullet lengths (Sinovčić *et al.*, 1986).

Bogue, *Boops boops* (Linnaeus, 1758) is also a very important exploited species in the Croatian fisheries. Growth of the bogue from the Middle Adriatic was studied by Alegria-Hernandez (1989). Mean length-at-age values were estimated from otoliths and analysis of polymodal length frequency distributions. Growth patterns were well described by von Bertalanffy growth equation. Growth parameters L_∞ = 338.89 mm; K = 0.167, and t_0 = - 1.296 were calculated.

The growth of the Adriatic anchovy, *Engraulis encrasicolus* (Linnaeus, 1758), was studied by Sinovčić (1992). The following values of von Bertalanffy's growth parameters were estimated: L_∞ = 19.4 cm, K = 0.57 and t_0 = -0.5. The anchovy attains maximum length at 4 years of age.

Tičina (1994) studied age of the tuna fish, *Thunnus thynnus* Linnaeus 1758, in the eastern part of the Adriatic coast using the first spine of the first dorsal ray. He found that tuna between 0° and 4° age inhabit the Eastern Adriatic waters.

Age and growth were analysed for damselfish, *Chromis chromis* (Linnaeus, 1758), collected in the eastern Middle Adriatic Sea. Growth in length, not showing significant differences between sexes, was expressed for the whole sample using the Bertalanffy equation: $L_t = 142.0\ (1 - e^{-0.26\ (t+\ 0.30)})$. Scales were collected from 1230 individuals. The damselfish is a relatively long-lived species. The oldest male and female were estimaed to be 9 years old (Dulčić & Kraljević, 1995).

Age composition of the striped sea bream, *Lithognathus mormyrus* (Linnaeus, 1758), was established using the Bhattacharya method and additional observations on annual rings on scales. Six age classes were obtained from Kaštela Bay (age 3: 21.7 cm, age 4: 26.5 cm, age 5: 28.4 cm, age 6: 30.3 cm, age 7: 31.6 cm, age 8: 33.4 cm) and from Mirna Bay (age 2.5: 19.4 cm, age 3.5: 24.1 cm, age 4.5: 26.9 cm; age 5.5: 29.4 cm, age 6.5: 31.3 cm, age 7.5: 32.8 cm). Von Bertalanffy's growth equation was fitted to these mean length-at-age data resulting in parameter values of L_∞ = 36.2 cm, K = 0.297, t_0 = -0.08 for Kaštela Bay, and L_∞ = 37.3 cm, K = 0.262, t_0 = -0.38 for Mirna Bay (Kraljević *et al.*, 1995).

Aspects concerning age and growth were analysed in the golden grey mullet *Liza aurata* (Risso, 1810) collected in Mirna Bay (eastern Adriatic). Mean length and age data derived using scale readings were used to estimate the growth parameters of the Von Bertalanffy equation. The theoretical maximum length was estimated to be L_∞ = 398 mm. The growth coefficient was K = 0.21 and t_0 = - 1.14. Seven age classes, ranging from 3⁺ to 8⁺ and 11⁺ years, were defined by the scale readings (Kraljević & Dulčić, 1996).

Growth of the black sea bream *Spondyliosoma cantharus* (Linnaeus, 1758) from the eastern Middle Adriatic was studied using data on the scales from 745 fish. The Von Bertalanffy growth equations was fitted on the basis of mean length-at-age data resulting in parameter values of L_∞ = 47.7 cm, K = 0.178 and t_0 = -0.27. The black sea bream is a long-lived species. The oldest male was estimated to be 14 and female 9 years old (Dulčić & Kraljević, 1996).

The age and growth of the gilt-head sea bream *Sparus aurata* Linnaeus, 1758 were determined from specimens collected in the Mirna Estuary (northern Adriatic). Mean length at age data, as derived using scale readings, were used to estimate the growth parameters of the von Bertalanffy equation: L_∞ = 59.8 cm, K = 0.15 and t_0 = -1. 71. Twelve age classes ranging from 1 to 12 years were defined by scale readings (Kraljević & Dulčić, 1997). Maximum age of 22 years was found for the gilt head sea bream in the Eastern Adriatic with parameters L_∞ = 84.98 cm, K = 0.073 and t_0 = -2.823 (Kraljević *et al.*, 1998).

Regarding methods, it is worthwhile emphasizing the increasing number of studies using PC-computers with adequate softwares (ELEFAN, FISHPARM, FiSAT, *etc.)* to obtain data to improve understanding of recruitment and growth patterns. Scales and otoliths were the main calcified tissues employed for age determination, while fin rays were scarcely used. The daily growth rings in otoliths of fish larvae, which have been employed for both age and growth determination and for calculating birthdate distribution, are increasingly used in the Mediterranean (Morales-Nin, 1989, 1992; Palomera *et al.*, 1988) and Adriatic studies - for sardine, anchovy and sprat larvae (Dulčić, 1995, 1997, 1998). In general, it is clear that three main subjects arise: the need to validate results obtained, the problem of different stocks of the same species, and sampling limitations.

VALIDATION METHODS

Age and growth studies are basic for the analysis and management of fishery resources and for biological studies. The methods most commonly used are those involved in counting concentric rings in scales and otoliths. The growth rates of these rings are directly related to time. The periodicity of the rings laid down in the calcified structures can be proved directly or indirectly. Direct methods involve rearing young fish and marking calcified structures. Rearing experiments are the most precise way to determine ring formation and periodicity, but cannot be applied to all species according to the otolith structure. The capture, marking of the fish and calcified tissue with an agent, such as tetracycline, and subsequent release have the advantage of allowing growth in natural conditions, but they are costly and limited to a few species. Indirect methods are based on the criteria of proportionality, seasonality, and back-calculation. The proportionality of fish growth and the calcified structure growth (otolith, scale, fin ray) are determined by means of regression methods. Seasonality of ring deposition can be analyzed by the monthly distribution of margin type (opaque or hyaline). If the rings are measured, the evolution of the value of the last ring completion (R) can be used for numerical determination:

$$R = R_n \times 100 / R_{n-1}$$

where R_n = is thickness of the last-deposited in the margin, R_{n-1} = is the thickness of the previous ring. However, when comparing these values, the decreasing thickness of consecutive rings should be kept in mind. The back-calculation of lengths by age is generally performed using the Fraser-Lee equation (Duncan, 1980):

$$SL_i = a + (SL - a) * R_i / LR$$

where SL_i is the standard length at previous age i, a is the intercept of the regression line of standard length (SL) on otolith (or scale) radius (LR), and R_i is the i-th radius of the otolith. The back-calculated values should be close to the actual values obtained from recordings and should follow a Von Bertalanffy growth curve. Other methods must be developed in future based upon otolith composition, DNA/RNA ratios and lipofucsin analysis, since all the mentioned methods are already functioning in the world (Bennet *et al.*, 1982; Bulow, 1987; Hill & Radtke, 1988). The presence of various stocks in the same area could also cause differences in growth rates and age composition of a species. Stocks are discrete groups of fish, which show little mixing with adjacent groups. An essential feature is that population parameters should remain constant over the distribution area of the stock. There is still much work to be done in fish stock differentiation and delimitation, but recent advances in methodologies based on genetic analysis will bring an improvement to our knowledge and facilitate correct growth determination. One of the main problems is sampling limitations. Correct sampling is fundamental for age and growth studies, for it is necessary to sample the entire size range of the population. Sampling can be biased among the others by two main factors: equipment selectivity and unequal size (and age) distributions, for instance, bathymetric size distributions. The use of only juvenile fish for growth determination can give unrealistic growth parameters.

ŠTUDIJE O STAROSTI IN RASTI RIB V HRVAŠKI IHTIOLOŠKI ZNANOSTI

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POVZETEK

Študije o starosti in rasti ribjih vrst so ena glavnih analitičnih modelov za analizo dinamike izkoriščanih ribjih populacij. Avtor v tem članku ocenjuje že objavljene podatke o starostnih in razvojnih parametrih nekaterih ribjih vrst v vzhodnem Jadranu. Luske in otoliti so bila glavna kalcificirana tkiva, primerna za ugotavljanje starosti, medtem ko plavuti skorajda niso bile uporabljene. Starost in rast sta bili ugotovljeni za 17 ribjih vrst, kar je 14% od stodvajsetih komercialno zanimivih vrst. Glede na predstavljene rezultate pa lahko le zaključimo, da bo na področju ugotavljanja starosti in rasti komercialno zanimivih rib treba opraviti še veliko dela.

Ključne besede: starost, rast, študije, hrvaška ihtiološka znanost

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