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IS THE POPULATION OF ADRIATIC SARDINE (*SARDINA PILCHARDUS* WALB.) HOMOGENOUS?

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ABSTRACT

The position and distribution of constant spawning areas of the sardines in the Adriatic Sea, and the trophic characteristics of the sardines are probably the causes of different direction of migration of sardines, and they indicate the genetic heterogeneity of this species. This hypothesis is supported by morphometric and meristic characteristics of fish, which indicate that there are differences between the sardines populating the different areas of the Adriatic (north, central, south). However, analyses of genetic identity, genetic distance and genetic diversity show that genetic differences between the sardines from the different areas of the Adriatic did not exist.

Key words: sardines, population, Adriatic Sea

DA LI JE POPULACIJA JADRANSKE SRDELE (*Sardina pilchardus* Walb.) HOMOGENA?

REZIME

Položaj i raspored stalnih mrestilišta srdele u Jadranskom moru i njene trofičke karakteristike verovatno uzrokuju različite puteve migracija ove vrste, što upućuje na genetičku heterogenost njene populacije. Ovoj pretpostavci idu u prilog morfometrijske i merističke karakteristike koje pokazuju da postoje razlike između srdele koja naseljava severni, srednji i južni Jadran. Međutim, analize genetičkog identiteta, genetičke distance i genetičkog diverziteta pokazuju da genetičke razlike između srdela iz različitih područja Jadrana nisu značajne.

Ključne riječi: srdela, populacije, Jadransko more

INTRODUCTION

Sardine (*Sardina pilchardus* Walb.) generally occur in the zone of the continental shelf of the Adriatic sea, but are the most prevalent in its north and central parts. Extensive research on sardines have been carried out, so that there are a lot of data on the biology and ecology of sardines (Fage, 1920; Gamulin, 1954; Gamulin & Karlovac, 1956; Gamulin & Zavodnik, 1961; Karlovac, 1958, 1964, 1967; Boscolo, 1965; Krajnović- Ozretić, 1969; Krajnović-Ozretić & Žikić, 1975, 1978, 1982; Mozzi, 1963; Mozzi & Duo, 1958, 1961, 1968; Mužinić, 1954, 1958, 1959; Mužinić, Vučetić, 1963; Zavodnik, 1962; Žikić, 1974, 1978; Žikić & Krajnović-Ozretić, 1976; Žikić et al. 1994.).

One characteristic of sardines is their periodical migration which is repeated every year, and which is related to the location of hatcheries and the mode of nutrition. In autumn, sardines migrate to their spawning areas where they spawn till the beginning of June and then, in search for food, they return to the coastal area where they stay till the end of autumn (Gamulin, 1954; Mužinić, 1954).

In northern, shallower area of the Adriatic sea, the fluctuations of ecological factors can be detected (water temperature, salinity, oxygene and CO_2 concentration). Due to the increased concentration of mineral salts, the bioproduction and the presence of plankton organisms are increased. In this area of the Adriatic, sardines do not always spawn to higher degree, except in the area of Dugi Otok (i.e. Unije and Susak), (Gamulin,1954). That is way it is thought that sardines in the north Adriatic migrate longitudinally (spawning area - Venice gulf - spawning area), (Mužinić, 1954).

In the area of central Adriatic, constant spawning areas can be found on the high seas beyond the central Dalmatian islands and around the Island of Palagruža (Gamulin, 1954; Karlovac, 1958). On the basis of trophic reason of migrations-towards the coastal areas, it is thought (Mužinić, 1954) that sardines in that part of the Adriatic migrate transversally (coastal area - high seas - coastal area).

In the south Adriatic, sardines spawn near Bar (Gamulin, 1954) and the direction of their migrations has not been investigated yet.

The results of the previous investigations on the populations indicate that there are some differences in morphometric and meristic characteristics in the sardines populating the different areas of the Adriatic Sea. However, exact mutual relationships within the population of the sardines populating the Adriatic have not been determined yet - it has not been determined whether and to what extent sardines from different areas mingle their routes to the hatcheries, where they come from and what is common for the sardines

populating the Adriatic Sea and those populating the Mediterranean (the Ionic Sea), (Žikić et al., 1994).

Sardines production is very important for Adriatic countries where the total catch is more than 300,000 tones. However, in southeast area of the Adriatic Sea belonging to FR Yugoslavia, only about 300 tones of all kinds of fish are caught every year. The quantity of the caught sardines varies periodically. These fluctuations are especially obvious after 8 to 12 years, what happens due to the ingression of seawater with higher content of salts, and warmer water from the Mediterranean, what causes higher concentrations of phosphates in water and an increased bioproduction (Županović, 1968).

In order to estimate the total number of fish to plan and carry out its rational and biologically justifiable exploitation, it is necessary to investigate the structure and dynamics of the population, including the space arrangement, density, growth rate, control mechanisms and regulation of migrations and other characteristics of the population (Žikić et al. 1994).

MATERIAL AND METHODS

In this study, the results obtained in previous extensive investigations of the number of vertebrae of the sardines were analysed. We also analysed the results obtained in serological analyses (Krajnović - Ozretić, 1969), as well as the results of the investigation of genetically controlled isozymic esterase (Es-I) in the liver of sardines (Žikić, 1974; Krajnović-Ozretić & Žikić, 1975, 1982; Žikić et al. 1994). On the basis of obtained results, we can conclude the possible degree of homogeneity or heterogeneity in sardines in some areas of the Adriatic.

RESULTS AND DISCUSSION

In order to determine the direction of migrations of Adriatic sardines, a few attempts of marking fish made. Sardines can hardly survive the method of classic marking, and since only few marked specimens can be caught again, this method was not very successful in practice.

In the area of central Adriatic sardines spawn from November to March, and in the area of north Adriatic they spawn from October to the beginning of June (Gamulin, 1954; Morović & Županović, 1958). Investigations of body

length of fishes show that the sardines caught in the water of the west coast of Istria are mostly young (with a mode of body length of 13 to 13.5 cm). At the same time, the area of Middle Adriatic is populated by older sardines (a mode of body length of 16 to 16,5 cm). The study of sardines also show that sardines populating the north Adriatic reach sexual maturity earlier and spawn earlier in comparison to the sardines populating the central Adriatic (Mužinić, 1958).

In previous investigations of Adriatic sardines the number of vertebrae, as well as the body length, were analysed. Sardines populating different areas of the Adriatic were analysed and a few researches at different periods. It was determined that the number of vertebrae varies from 48 - 54. Analyses of vertebrae in sardines populating the north Adriatic show that this area is populated by sardines with a mode of 52 vertebrae, but also by sardines with modes of 50 and 51 vertebrae (Fage, 1920; Mozzi & Duo, 1958, 1961, 1968; Zavodnik, 1962). On the basis of these results (Mozzi & Duo, 1968) we set up a hypothesis, according to which the basis of the population of sardines in the north Adriatic are the sardines with modes of 50 and 51 vertebrae, while the sardines with a mode of 52 vertebrae migrated from the Middle Adriatic.

However, the analyses of vertebrae number on more than 5,600 samples of sardines populating the waters of the west Istrian coast (Krajnović-Ozretić and Žikić, 1978), which were caught during the five fishing seasons from 1969 - 1973, show that the population of sardines in this area is homogenous, with a mode of 52 vertebrae. These results correspond with the results obtained by previous investigations in period 1946 - 1950 (Mužinić, 1954).

The analyses of the number of vertebrae in sardines populating the central area of the Adriatic showed that the basis of homogenous population are the sardines with a mode of 52 vertebrae, while the sardines with a modal number of 51, which appear exceptionally, are characterized as immigrants into this area, either from the north Adriatic or the Mediterranean, i.e. the Ionic and Aegean Sea (Mužinić, 1954). This hypothesis is supported by the data, which show that, parallelly with periodical ingression of salt-enriched waters from the Mediterranean into the Adriatic, the catch of sardines is significantly increased first in south and central areas and then in north areas of the Adriatic.

The analyses of the number of vertebrae were carried in the region of west Adriatic coast from Chioggia to Manfredonia in period from 1957 to 1964 (Mozzi and Duo, 1958, 1968, 1961; Mozzi, 1963; Boscolo, 1965). It was determined that the mode of vertebrae varies from 50-53. These investigators think that the population of sardines in the north Adriatic is not homogenous and that the characteristic mode of vertebrae is 51, and that the samples of sardines with a mode of 52 vertebrae migrated from the Middle Adriatic.

We analysed the number of vertebrae on sardines populating the South Adriatic and the number shows that this area is populated by the sardines with modes of 52 and 51 vertebrae (Mužinić, 1954; Rakaj, 1959). These results show that the population of sardines in South Adriatic is not homogenous, what is, according to the previously mentioned hypothesis, the consequence of the migration of sardines from the Mediterranean (Mužinić, 1954).

Morphometric and meristic characteristics in fish were analysed, but not continually and simultaneously in the whole Adriatic. Besides that, the changeability of these characters can be the consequence of the influence of changeable ecological factors (Tåning, 1952; Nyman & Westin, 1968). They cannot be taken as a true indicator in the identification of genetically isolated subpopulations within a species (Mayr, 1970). (That is why we cannot confirm with certainly whether the subpopulations in some areas of the Adriatic are homogenous or heterogeneous.

Some serological analysis of sardines populating the west coast of Istria indicates a certain degree of heterogeneity of the population (Krajnović-Ozretić, 1969).

Analyses of polymorphic isozymic esterase in the tissue of sardines showed that in the first esterase group (Es-I), isozymics are genetically controlled by four co-dominant alleles. That is why these isozymics were taken as genetic markers in the studies on populations of Adriatic sardines (Žikić, 1974, 1978; Krajnović-Ozretić & Žikić, 1975, 1982; Žikić et al., 1994). In these investigations (5,572 sardine specimens in the fishing seasons in 1972, 1973, 1974, 1975, and 1976), the $\chi 2$ (chi-square) test of heterogeneity showed that the sardines from the north Adriatic were not significant. No significant differences between samples from the North Adriatic and two samples from the Middle Adriatic were found either.

CONCLUSION

The previous extensive but discontinuous studies of meristic and morphometric characteristics indicate a certain degree of heterogeneity of the population of the Adriatic sardines. These characteristics can change, what depends on the changeability of ecological factors so they cannot be considered as genetically controlled characteristics in the analysis of population.

Analyses of genetically controlled esterase isozymes (Es-I) in liver indicate that the population of sardines in north and Middle Adriatic is homogenous.

In order to determine whether the population of the sardines in the Adriatic is homogenous or heterogeneous, what the directions of migration are and what the relationship between the sardines from the Adriatic and the Mediterranean is, it is necessary to do the following:

- to introduce new methods of marking
- to analyse morphometric and meristic characteristics
- to analyse, beside esterase, some other polymorphic markers and gene loci
- all analyses on the sardines inhabiting the Adriatic Sea should be continually and all Adriatic countries should be involved in this project.

The results of this investigation will contribute, the complete understanding of the biology and ecology of this species, what can help the planning of rational and biologically justifiable catch.

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