

SEASONAL RHYTHM OF VERTICAL DISTRIBUTION OF COPEPODS IN DEEP WATERS OF SOUTH ADRIATIC

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ABSTRACT

This paper represents a short analysis of vertical distribution of zooplankton group *Copepoda* in deep South Adriatic. It is a part of a large study on seasonal vertical and horizontal distribution as well as circadian vertical migrations. In South Adriatic Valley, the deep-sea species remain in the layers below 300 m in depth, comprising a unique category of organisms that do not join the surface populations of productive zone in any season of the year. Only the completely pelagic and deep-sea communities are well vertically defined. The larger copepods of intermediary layers perform intensive seasonal and circadian vertical migrations. They represent a very mobile community that is occasionally present in all parts of deep South Adriatic.

Key words: *Copepoda*, vertical distribution, South Adriatic

SEZONSKI RITAM VERTIKALNE DISTRIBUCIJE KOEPEODA U DUBOKIM VODAMA JUŽNOG JADRANA

REZIME

U radu se daje kraća analiza o vertikalnoj distribuciji zooplanktonske grupe *Copepoda* u južnom dubokom Jadranu. Dio je obimne studije o sezonskoj vertikalnoj i horizontalnoj distribuciji kao i dnevno-noćnim vertikalnim migracijama. U južno-jadranskoj kotlini dubokomorske vrste zadržavaju se u slojevima ispod 300 m dubine, čineći jedinstvenu kategoriju organizama koji se ni u jednom godišnjem dobu ne pridružuju površinskoj populaciji produktivne zone. Vertikalno su dobro izdvojene samo izrazito površinska i dubinska zajednica. Krupniji kopepodi intermedijernih slojeva imaju intenzivne sezonske i dnevno-noćne vertikalne migracije. Predstavljaju veoma mobilnu zajednicu povremeno prisutnu u svim slojevima dubokog južnog Jadrana.

Ključne riječi: *Copepoda*, vertikalna distribucija, Južni Jadran

INTRODUCTION

Adriatic is a relatively shallow edge sea of Mediterranean, where only the South Adriatic Valley shows characteristic features of an ocean biotope. That is the only area of Adriatic Sea where numerous copepods of all depth zones are present throughout the year. In this part of Adriatic, the subsurface and intermediary species are present in late winter (period February-March) closest to the surface during the isotherm stratification. The upper boundary of population nucleus of subsurface copepods then somewhat exceeds 50 m of depth, while in intermediary species it reaches the depths of cca 100 m. These seasonal changes in depth distribution enable surface copepods to spread their range in winter to shallow waters near shore and into North Adriatic.

The goal of this paper was to determine the vertical distribution and depth of maximal concentration of dominant species populations, as well as to acknowledge the basic kinds of circadian and seasonal migrations.

MATERIAL AND METHODS

Zooplankton was caught at a locality in deep area of South Adriatic, at depth of 1000 m. In order to catch it, Nansen plankton nets were used, with diameter of 0.57 m and length of 2.5 m. The diameter of net holes was 200 microns.

In order to study seasonal vertical distribution and circadian migrations of copepods, 4 seasonal 24-hour series of catch were made. In each season, during 24 hours, 4 catch series were made on following levels: 50-0 m; 100-50m; 150-100m; 200-150m; 300-200m; 500-300m; 700-500m and 900-700m. In a 24h period, one catch in 900-0m range was also always made. The study is based on defined ecological categories of depth distribution, zones of greatest abundance and depths of maximal concentrations according to technical-technological statements by Mooro (1949) and Vinogradov (1968).

RESULTS AND DISCUSSION

Faunistic list. - In Adriatic there are about 220 known species of pelagic copepods, which is relatively high considering other edge seas of Mediterranean. The greatest numbers are in South Adriatic where almost complete fauna of Adriatic copepods is present. Only a score of species is absent and these mostly belong to estuary fauna. They mostly belong to families *Cetropagidae*, *Acertidae* and *Oithonidae*. In Middle Adriatic, number of known copepods decreases by a quarter due to absence of species characteristic of diverse deep-sea community of South Adriatic Valley, made up mostly of

representatives of families: *Spinorcalanidae*, *Scolecithricidae*, *Lucicutidae* and *Heterorhabdidae*. Decrease of number of species in North Adriatic is even more intensified, so there are only about a hundred species present. Besides the deep-sea forms, also missing are most ocean species that inhabit intermediary strata of deep South Adriatic and mostly belong to families *Eucalanidae*, *Aetideidae*, *Metridiidae* and *Augaptilidae*. During the seasonal research on Adriatic surface, only 137 species were recorded, which is only about 62% of total fauna of Adriatic copepods (expedition »A. Mohorovičić« in 1982). Not recorded are mostly rare species from families *Scolecithricidae*, *Metridiidae* and *Saphirinidae*, as well as small forms from families *Calocavanidae*, *Acartidae*, *Oithonidae* and *Ponceidae*. This is probably due to longer time intervals of research and determined methodic of catching zooplankton in nets with larger hole diameter. However, the tendency of decrease in number of copepod species from south toward north of Adriatic is obvious.

Somewhat more than 50% of recorded species in open waters of Adriatic are present sporadically in small number of specimens. Greater abundance is present in 8 species that represent on average 68,9 % of total number of specimens recorded in 4 seasons: *Ctenocalanus vanus* with abundance of 19,9 % is the most abundant copepod of Adriatic Sea. This species is followed by *Paracalanus parvus* (14,4%), *Oithona plumifera* (10,8%), *Acartia clausi* (7,1%), *Centropages typicus* (5,5%), *Temora longicornis* (4,8%), *Clausocalanus pergens* (4,4%), *Temora stylifera* (3,0%). Important quantitative value is also recorded in 11 other copepod species where it exceeds $\geq 1,0\%$ of total number of collected specimens. The other species may be considered a less important quantitative component of copepod community in surface area of Adriatic Sea.

Vertical distribution. – Vertical distribution and depth of maximum abundance of dominant copepods in South Adriatic at about 1000 m of depth is presented on Graph 2. There are three clearly distinguishable species groups with specific forms of depth presence.

FIRST GROUP is composed of 12 epipelagial copepods distributed from surface up to 500 m of depth, with mean yearly maximum of abundance in layer from 0 to 100 m of depth. Most of such species, such as *Paracalanus parvus*, *Clausocalanus furcatus*, *Clausocalanus jobei*, *Temora stylifera*, *Centropages typicus*, *Acartia clausi*, *Calanus helgolandicus* and *Oncaea media* represent typical surface forms, very abundant in narrower shore areas. In Deep South Adriatic, they are present in smaller quantities and show very important seasonal variations in abundance, so during the cold season they are either missing or very rare. Seasonal and circadian vertical movements are weakly developed. During the winter, in full daylight they show up little closer to the surface than in other seasons. The circadian movement is more clearly present

only in spring and summer. The other abundant species of this group (*Clausocalanus arcuicornis*, *Ctenocalanus vanus*, *Oithona plumifera* and *Corycaeus rostratus*) inhabit deeper waters of epipelagial and are well abundant almost throughout the year in deep South Adriatic. The seasonal vertical movements are somewhat more intensive than in previously mentioned species group. In winter, during the anotherm stratification, they are present very close to the surface, and in other seasons, especially summer, they are present below 50 m of depth. The weak circadian migration is present more-or-less throughout the year.

SECOND GROUP includes a very large number of species that are distributed in deep South Adriatic throughout the year from the surface to greatest depths. Almost all of them belong to the ocean community.

Numerous subsurface species (*Calusocalanus pergens*, *Calusocalanus paululus*, *Lucicutia flavicornis*, *Pleuromamma gracilis*, *Oithona setigera*) are present in zooplankton of deep South Adriatic throughout the year, and their mean yearly maximum of abundance is in layers between 100 and 300 m of depth. The seasonal vertical migration is well developed by gradual rise to surface of population nucleus from early Autumn to late Winter, and swift descent in deeper layers during Spring. Circadian vertical migration is also well developed, and the organisms often congregate in full darkness in surface layer of the sea above 50 m of depth.

The intermediary species of ocean community, must abundant of which are *Euchaeta acuta*, *Pleuromamma abdominalis* and *Haloptilus longicornis*, have a mean yearly abundance maximum in the layer between 20 and 400 m of depth. These are mostly very intensive migrants that are most often present closest to the surface during the winter. The depth differences in circadian movements of population nucleus of certain species (*Euchaeta acuta* and *Pleuromamma abdominalis*) reach maximum values.

THIRD GROUP is comprised of 6 (six) relatively abundant deep-sea species that are absent in surface waters above 100 m, with mean yearly maximum of abundance in depths below 400 m. The circadian migration of most of these species (*Spinocalanus longicornis*, *Spinocalanus oligospinosus*, *Temoropia mayumbaensis*, *Nannocalanus minor* and *Oncaea ornata*) is reversed – in night during total darkness, the animals are present somewhat lower than in late morning or early afternoon. *Monacilla typica* and probably some other rare species stay throughout the day about the same depth. The seasonal vertical migration of deep-sea copepods is also weakly developed as a rule.

Numerous characteristic species of continental shelf such as *Calanus helgolandicus* in South Adriatic Valley show a different kind of vertical distribution throughout the year. In winter and most of spring they are present in

Seasonal rhythm of vertical distribution of copepods

surface layer up to 200 m of depth, and in summer exclusively in layers below 300 m of depth.

The studies of vertical plankton migrations began relatively early. Cuvier (1817) was first to record that *Daphnia* are present closest to the surface in morning and evening than during intensive daylight. The later authors have been recording similar movements in most species of plankton animals. Especially important in order to fully explain this phenomenon are works of Russell (1925-1934) in English Channel. They have inspired many similar studies in other seas in last 60 years.

In Adriatic Sea, vertical migrations were studied on several localities in its southern area during almost a quarter of a century (Hure, 1955, 1961, 1965, 1980; Hure and Scotto di Carlo, 1964, 1965, 1974; Vukanić, 1988).

In these studies, almost all characteristic kinds of vertical migration present in other seas were also recorded. However, for the first time in our research we have recorded the inverse migration of small deep-sea copepod species, and pointed to the importance of more detailed study on circadian and seasonal vertical migration in order to more fully explain the seasonal oscillations of horizontal distribution of pelagic species in a sheltered, closed sea such as Adriatic.

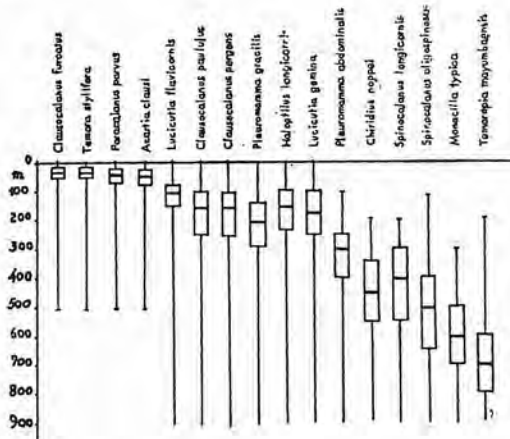


Fig. 1. Vertical distribution of dominant copepods with the percentage of $\geq 1\%$ of all species (population nucleus is represented by a rectangle, and depth of maximum abundance by a horizontal line in the middle)

Circadian depth distribution of copepod population into layers shows that the quantity is relatively greater in surface layer (0 – 100 m of depth) than in deeper water (Fig 2). However, the differences in copepod abundance are

most developed during night (24-2 h), as in deep pelagic of South Adriatic there are many organisms with intensive night migration toward the surface of the sea.

According to the earlier data (Hure, 1961; Hure e Scotto di Carlo, 1980; Vukanić, 1988) the increase of copepod numbers in early night hours (20h) should be attributed to surface and subsurface species in ocean communities, as they reach the surface at sunset or dusk. Quantity increase in midnight hours (02h) in surface layer is caused by migration of species such as *Pleuromamma abdominalis* and *Euchaeta acuta*. The second light increase in abundance in layer between 200 and 300 m is also pronounced after midnight (02h) and is probably caused by smaller and weaker migratory species of intermediary and deep waters.

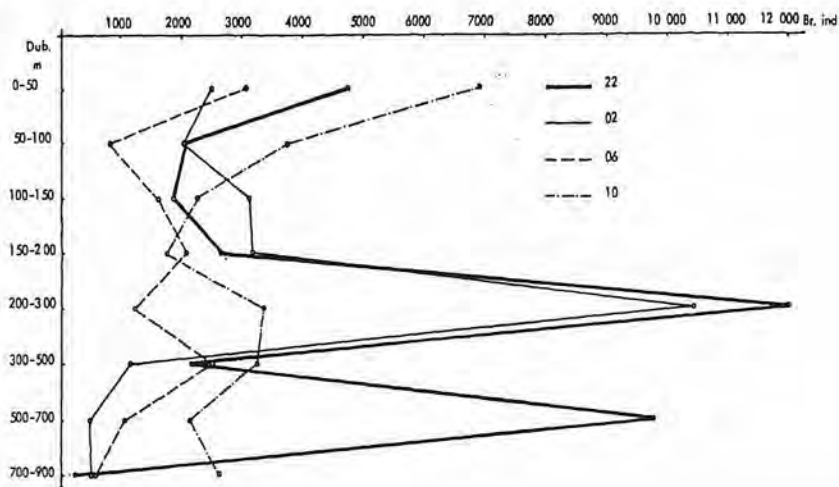


Fig. 2. Distribution of copepod quantity by layers during 24 hours in deep waters of South Adriatic

According to many authors (Russel, 1925; Moore, 1949; Hure 1961; Vinogradov 1968 etc.) such species move so slowly that they cannot reach surface waters during the night, so they concentrate in subsurface layer of deep sea.

CONCLUSIONS

Mediterranean Sea is by a shallow Gibraltar shelf (about 300m of depth) separated from Atlantic Ocean. This is a topographic hurdle to influx of deep-sea water from the ocean. Therefore in Mediterranean Sea under the shelf there is a special hydrological regime that greatly influences the qualitative and quantitative distribution of plankton organisms. One of special features is lack of typical deep-sea fauna, while in Atlantic ocean about 20% of calanide species are present exclusively at depths greater than 1000 m (Deevey and Brooks, 1977). In Mediterranean there are almost no deep-sea copepods that do not rise in some season of the year above 500 m of depth (Vinogradov, 1968; Scotto di Carlo et al., 1984).

Adriatic is a relatively shallow edge sea of Mediterranean, and only South Adriatic Valley shows characteristic features of ocean biotope. It has a rich deep-sea fauna that is by content and ways of vertical distribution of species almost identical to Mediterranean Sea. In the South Adriatic Valley the deep sea species stay in layers below 300 m of depth, comprising a unique category of organisms that not in a single season of the year join the surface population of the productive zone. In that part of Adriatic, as well as other closed seas regardless of depth of basin, only two well-defined layers are the exclusive surface and deep-sea zones. They are comprised mostly of smaller species with weak vertical migration (Hure e Scotto di Carlo, 1969; Vukanić 1988). On the other hand, larger copepods of intermediary layers, due to intensive circadian and seasonal migrations represent a very mobile community present occasionally in all layers of deep South Adriatic. This vertical connection of copepod populations through intensive migrations of intermediary species has a great trophic importance, as it enables transport of organic matter from surface productive waters to oligotrophic layers of deep sea.

On the end, it must be said that the seasonal changes of horizontal and vertical copepod (and other zooplankton) distribution are a very complex ecologically-biological problem, so further research is needed, some of which is pointed to by results of this study.

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