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SEASONAL AND MULTIANNUAL DYNAMICS OF COPEPODS IN THE MIDDLE ADRIATIC

SEZONSKA I VIŠEGODIŠNJA DINAMIKA POPULACIJA KOPEPODA SREDNJEG JADRANA

Dubravka Regner

Institute of Oceanography and Fisheries, Split, Yugoslavia

This study comprises the results of five years investigations of copepods in the coastal, channel and open sea waters of the middle Adriatic.

Based on several-year monthly observations, it deals with the horizontal distribution of the copepods in the middle Adriatic, seasonal and multiannual changes in the qualitative and quantitative composition of the copepods, and the seasonal oscillations of copepods number as the consequence of the oscillations of abiotic and biotic factors of the environment.

Study comprises the statistical elaboration of the periodical fluctuations of copepods depending on temperature, salinity, primary production and number of fish eggs, all based on a the data of five year investigations.

INTRODUCTION

Copepods are quantitatively best represented zooplankton group, and therefore one of the most important link in trophic dynamics of marine ecosystems. Omnivore and particularly herbivore copepods are the first step of the food chain being the food of other zooplankters, and what is even more important, many of the commercially important fish species feed on them.

As a part of this dynamic entity, copepods are liable to certain changes (diurnal, seasonal and multi-annual), the knowledge of which is of invaluable importance both for idioecological and synecological studies.

Rather detailed conclusions on the pattern of seasonal and long-term copepod variations may be drawn only from a large number of data. Effects of ecological factors are also interdependent thus that in observing the effects of each individual ecological factor on the plankton copepod community, the fact that they, as well, are only a part of the entire marine environment must not be ignored.

Therefore, this paper attempts to interpret statistically the five year data series on copepod species composition and number in the coastal, channel and open sea areas of the middle Adriatic and to relate them to some abiotic and biotic factors of marine environment. The former ones refer to temperature, salinity and density of the sea water and the latter ones to phyto- and ichthyoplankton. We believe that this first statistical interpretation of a large number of data will contribute much to the earlier copepod studies in this area and provide the basis for the further interpretation of long-term collections from this Adriatic part.

Species diversity index, as a numerical expression of copepod group structure, will be observed in this paper (based on a large number of data for the first time) as well as its seasonal and long-term fluctuations.

Further, seasonal pattern of changes in total copepod numbers will be observed in relation to the mentioned abiotic (temperature, salinity) and biotic (phytoplankton, ichthyoplankton) environmental factors.

Earlier investigations of the Adriatic copepods

Copepods, the major zooplankton group as to the quantity, has been given much more attention than other zooplankton groups. Thus, the first copepod investigations can be traced back to the end of the nineteenth century when the zoological stations were founded in Trieste (1875) and Rovinj (1891) and first zooplankton investigations carried out in the northern Adriatic.

The reports of the workers include the morphology and anatomy of individual species (Claus, 1881; Car, 1884, 1890, 1890a, 1895—1896; Steuer, 1895, 1902a; 1902b, 1903, 1907, 1910a, 1910b; 1913; Graeffe, 1900; Grandori, 1910, 1913; Stiasny, 1907; Leder, 1913; Car and Hadži, 1914a, 1914b; Pesta, 1920; Fruchtl, 1920, 1924, 1934) and species inventory lists for individual localities. Brackish water copepods were also studied (Car, 1902; Hadži, 1930) and the differences between them and marines copepods due to different features of waters they inhabit established. These copepods were recorded from the Bay Novigradski zaljev, Port of Gruž, Bay Boka Kotorska, Port of Zadar and the Bays of Bakar, Rijeka and Pula.

The data on eastern Adriatic coast zooplankton and particularly copepods were collected by the R. WIRCHOW trips (1907, 1909, 1911). This large collection was almost completely worked out and it provided a basis for studies of the Adriatic copepod biology and distribution (Steuer, 1910; Früchtl, 1920, 1924, 1934).

From the material collected in the course of the first two cruises Steuer (1910) reported on the horizontal distribution of the Adriatic copepods, that is their reduciton in number and increase in species number going southwardly from the northern Adriatic. This was supported by several later investigations. The differences between neritic, euryvalent copepods — phaeoplankters and pelagic knefoplankters which are more stenovalent (Frü-

c h t l, 1924) were also described and all the copepods known so far reviewed

These researches were particularly intensified at the beginning of twentieth century when the permanent International Commission for the Investigations of the Adriatic was founded. Periodical exploring voyages of the Austrian NAJADE (1911—1914) and Italian CICLOPE (1911—1914) expeditions were organized by this Commission. Even though all the material collected by these expeditions has never been fully worked out, S t e u e r (1913), L e d e r (1917), G r a n d o n i (1913), P e s t a (1920) and some other authors reported on the distribution of individual copepod species and on some new species recorded during these voyages.

The University of Zagreb and Yugoslav Academy of Sciences and Arts, Zagreb organized the first Croatian scientific expedition in the northern Adriatic by the ship VILA VELEBITA. Zooplankton of the Kvarner Bay (C a r and H a d ž i, 1914a and 1914b) was also studied in the course of this expedition.

Later on, by the foundation of the Institute of Oceanography and Fisheries in Split, these investigations were intensified, particularly in the middle Adriatic, the results of which added much to the first inventory, monographic and ecological reports on the Adriatic copepods, particularly those from the northern Adriatic.

G a m u l i n (1939) gave the first rather complete data on copepods from this area from the material collected from the »Kaštela Bay« and »Maslinica« stations in the November 1936—October 1937 period. Annual variations of copepod species composition and numbers were also described from these first systematic researches. Hydrogarphic features of this area were simultaneously recorded. The differences in copepod composition between the coastal area and area among the islands, affected by the open and deeper sea, were given as well as the list of Adriatic copepods comprising 76 species.

Later on, the data on copepods from the Brač, Hvar and Neretva channels were given as well as those from Pelegrin and Drvenik-Vis profile (G a m u l i n, 1948). They were obtained by analysing the collections of June 1939 from the central Adriatic stations. They made a significant contribution and supported the earlier reports on zooplankton distribution in the Adriatic, that is species number increase and specimen number decrease going from the coast towards the open sea.

In the postwar period a variety of zooplankton papers were published by a large number of authors which dealt with different zooplankton groups and species.

Yugoslav Fishery-Biology Expedition HVAR, undertaken after World War II (1948—1949) covered almost the whole Adriatic basin. Zooplankton was later worked out by H ö e n i g m a n (1955, 1958, 1961) and V u č e t i ć, (1963a, 1963b, 1965).

A number of papers report on the copepod distribution, biology and ecology (P u c h e r, 1952; H ö e n i g m a n, 1958; H u r e and S c o t t o d i C a r l o, 1967, 1968, 1970; R e g n e r, D., 1971, 1974a, 1974b, 1975; V u č e t i ć, 1957, 1963, 1964, 1965a, 1965b, 1965c, 1966a, 1966b, 1969, 1973, 1976; V u k a n i ć, 1971; Z a v o d n i k, 1956, 1961).

Quantitative ecological observations of the total zooplankton, including copepods (Vučetić, 1957, 1958, 1961, 1966, 1969) were carried out within the studies of fertilization effects on the bioproduction of the lake of Veliko jezero on the Mljet Island as well as within ecological studies with respect to fertilization of the Bay of Marina.

Copepod distribution was, further, related to hydrographic features of defined studied areas (Vukanić, 1971) as well as to the changes in the distribution of water masses and different Adriatic water types all over the Adriatic (Vučetić, 1963, 1969, 1970, 1971, 1973; Hure, 1969; Hure and Scotto di Carlo, 1977, 1979).

Regular monthly copepod studies were carried out at some localities (Regner, D., 1970, 1973, 1974b; Vukanić, 1971) and the occasional ones at some other localities, that is when required, such as for the errection of some industrial plants (Buljan, Hure and Pucher-Petković, 1973). 1973).

Seasonal and long-term fluctuations of the total zooplankton and copepod group, as well as of some quantitatively predominant copepod species have also been regularly studied in the central Adriatic (Pucher-Petković and Vučetić, 1969; Regner, D., 1970; Vučetić, 1965, 1969, 1970; Vučetić and Pucher-Petković, 1969; Vučetić and Regner, D., 1973).

The data on the quantity of the Adriatic copepods have been continuously supplemented (Hoenigman, 1955, Hure and Scotto di Carlo, 1968c, 1969a, b; Regner, D., 1974c, 1975).

Diurnal migrations and vertical distribution of zooplankton and copepods in particular, have been studied in detail (Hure, 1955, 1961; Hure and Scotto di Carlo, 1968c, 1969a,b,c, 1970, 1974). This provides the basis for »rather full explanation of zooplankton horizontal distribution« Extent of vertical diffusion, the causes it is due to and the whole series of other factors which accompany this phenomenon are also reported on.

Many of the papers deal with the relationship between zooplankton and its main predator — pelagic fish. This relationship was studied from feeding (Mužinić, S., 1936; Ercegović, 1940; Gamulin, 1954; Vučetić, 1954, 1955, 1963a,b,c; Karlovac, J., 1964; Mužinić, 1969, 1963; Škrivanić, and Zavodnik, 1973), from catches (Vučetić, 1960) and comparison between the zooplankton standing crop and echo-traces (Vučetić and Kačić, 1973, 1973a).

The Adriatic zooplankton biomass has also been studied and reports on its size in the northern, central and southern Adriatic given (Vučetić, 1957, 1958, 1961, 1963a, 1966), as well as those on seasonal and long-term biomass oscillations (Vučetić, 1965, 1966, 1970; Vučetić and Pucher-Petković, 1969; Pucher-Petković and Vučetić, 1969), Benović (1976) reported on the biomass of individual zooplankton groups.

Results of comparisons between the zooplankton, and particularly copepods from the southern Adriatic and those from the stations in the Gulf of Naples (Hure and Scotto di Carlo, 1968c, 1970) and Tyrhenian Sea (Hure and Scotto di Carlo, 1969a, 1974) were also published.

List of copepods known in the Adriatic has continuously been supplemented by describing new species (Hure and Scotto di Carlo, 1967, 1968, 1970). Data of Šmeljeva (1964, 1965) collected during the Soviet expeditions KRISTAL and AKADEMIK KOWALEVSKI also added to the list of known copepods.

Adriatic biological resources have been assessed from the plankton and consequently from the zooplankton, as well (Karlovac et al., 1974).

Effects of urbanization and industrialization of our coastal areas on natural ecological balance of the adjacent sea and consequently the pollution effects on copepod population changes have also been observed (Regner, D., 1977; Vučetić, 1977; Benović et al., 1978).

The Adriatic zooplankton biochemical composition was separately studied (Vučetić, Damjanić and Čubretović, 1969). Some of the papers dealt with the mercury level fluctuations in the central Adriatic (Vučetić, Vernberg and Anderson, 1974).

This large number of papers dealing with a variety of topics point to the significance of copepods as quantitatively predominant zooplankton group, to which more attention has been given than to any other component of the plankton by a large number of authors both in our country and all over the world.

The Adriatic zooplankton biomass has also been studied and reports on its size in the northern, central and southern Adriatic given (Vučetić, 1957, 1958, 1961, 1963a, 1966), as well as those on seasonal and long-term biomass oscillations (Vučetić, 1965, 1966, 1969, 1970; Vučetić and Pucher-Petković, 1969; Pucher-Petković and Vučetić, 1969), Benović (1976) reported on the biomass of individual zooplankton groups.

Programme and goal of investigations

Even though the Adriatic copepods were studied in detail our present knowledge of the central Adriatic copepods is still unsatisfactory.

Therefore the aim of our study was to report on:

1. the horizontal copepod distribution in the coastal part of the eastern middle Adriatic,
2. seasonal and long-term changes in copepod species composition and variations of species diversity index,
3. seasonal and long-term variations of total copepod numbers as influenced by some abiotic environmental factors (temperature, salinity, sea water density, current system),
4. variations of copepod proportion in total zooplankton,
5. predominant copepod species which account for the total copepod numbers,
6. variations of the total copepod number as influenced by some biotic environmental factors (phytoplankton, fish, etc.), and

7. pattern of total copepod number variations as influenced by abiotic and biotic environmental factors from a five-year series of data collected from three permanent stations of which one is in the coastal area, one in the channel area and one under relatively strong open sea influence.

STUDY AREA

Samples were taken from the coastal part of the eastern Adriatic at the »Kaštela Bay« station (43°31'N; 16°19'E), from the channel area between the islands at »Pelegrin« station (43°12'N; 16°19'E) and from the open sea out of island area at »Stončica« station (43°00'N; 16°20'E) Fig. 1.

The »Kaštela Bay« station — 42 m depth — is in the closed coastal area under the strong and direct land influence. The Kaštela Bay is situated between the foot of Kozjak mountain, northern side of the Čiovo Island and

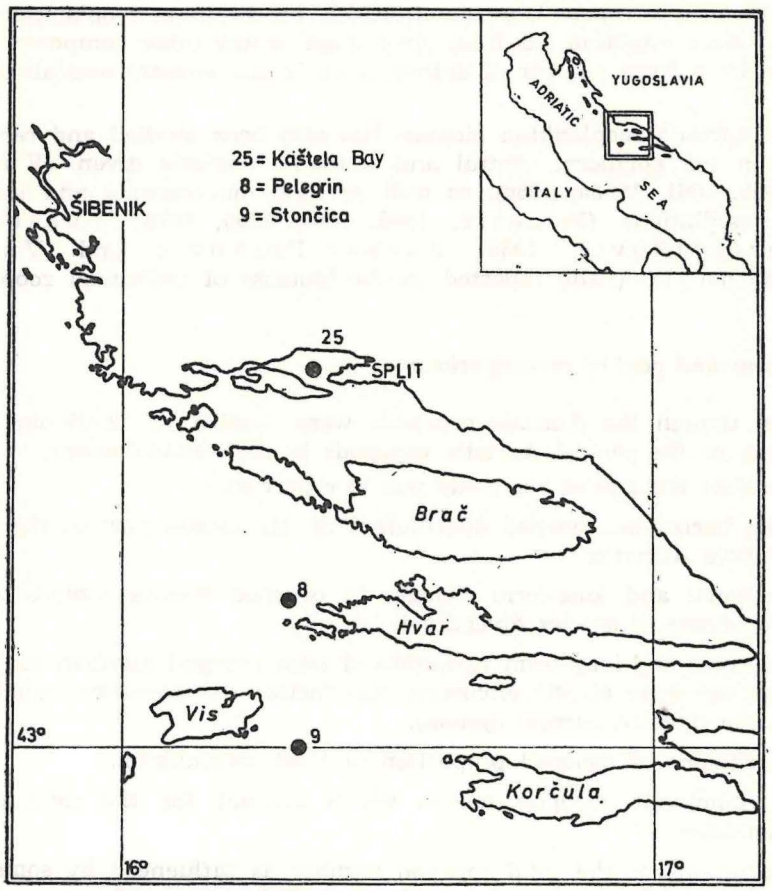

Fig. 1. Study area

northern side of Marjan peninsula. It is open through a narrow strait near Trogir and connected to the Brač Channel through a considerably wider strait.

Bottom is muddy, partly rocky with the average depth of about 23 m. Maximum depth of 47 m was recorded from the middle of the bay.

Freshwater land inflows originate from the Jadro river, small Pantan stream and freshwater springs of which some are the submarine springs.

Temperature and salinity variations are considerable owing to small depths and strong land effects. Their minima and maxima occur earlier there than in the open sea. In the five-year period of our investigations maximum temperature of 23.47°C was recorded from the 0—10 m layer in August 1972 and minimum temperature of 11.05°C in March 1970 (Buljan, unpublished data).

Maximum salinity of 37.88‰ was recorded in November 1973 and minimum of 34.04‰ in May 1974.

Maximum sea-water density of 28.48 was recorded from the same layer in January 1974 and minimum of 24.72 in July of the same year.

Lower temperature and salinity values recorded along the northern side of Čiovo Island indicate that cooled and less saline sea water flows out of the Kaštela Bay into the Brač Channel near the eastern cape of this island.

Great variations of current pattern are caused by relatively small depths, poor tidal currents and strong local wind forcing. W direction is prevalent in winter, NW in spring and early summer, E in summer, particularly in the surface layer and S in winter (Zore-Armanda, 1974). The fact particularly relevant to horizontal copepod distribution should be pointed out on this occasion. Zore-Armanda (1974) established that annual current roses in the Kaštela Bay were almost identical to the current roses at Stončica station which is strongly affected by the open sea. However, the flow was shifted somewhat to the left in the Kaštela Bay what is easily understandable with respect to the position of the bay in relation to the Vis Island. Outgoing flow prevails in September and November and the ingoing one in winter and summer. In addition, it should be mentioned that water enters the Kaštela Bay predominantly in the surface and bottom layers.

Mean resultant current speed is 6 cm s^{-1} on the surface, 4 cm s^{-1} in the intermediate layer and 3 cm s^{-1} in the bottom layer, that is it decreases from surface to bottom. The greatest speeds were recorded in autumn and winter — from November to February. They coincide with the intensified water exchange with the adjacent Brač Channel and freshwater inflows.

Wind forcing was found to be best marked in summer since only the surface layer is exposed to air motions owing to summer stratification. Wind accounts for 40% of current directions in the Split Channel.

Tidal currents, measured also in Split area Zore-Armanda, (1975) are particularly marked in the intermediate and bottom layers. Tidal wave is of N-S direction, that is it proceeds perpendicularly from the open sea onshore.

After the most recent studies and on the basis of current roses constructed by seasons, Zore-Armanda, (1975) calculated that total water exchange of the bay with the adjacent Brač Channel took place two times

in a month's period. The fact that the ingoing transport somewhat exceeds the outgoing transport may indicate that a part of the water flows out of the bay through the strait near Trogir nevertheless the water exchange there is much less than that with the Brač Channel.

»Pelegrin« station — 78 m depth is situated west from the Hvar Island. Bottom is sandy of coarser detritus (Šimunović, personal communication).

Since this station is neither in the coastal area nor in the open sea and, accordingly, the properties of which differ from those in the respective areas, temperature variations range is not so wide as in the coastal area (Zore-Armanda, 1973). The highest temperature of 24.21°C of the 0—10 m layer was recorded in August 1972 and the lowest of 12.25°C in March 1973. The difference between these two extreme temperatures is for 0.46°C lower than this difference in the Kaštela Bay.

Maximum salinity of 33.71‰ was recorded in January 1971 and minimum of 36.89‰ in April 1970. The difference between these two extreme salinities is for 2.02‰ lower than this difference in the Kaštela Bay.

The greatest density of 28.94 was recorded from this station in January 1971 and the lowest of 25.86 in July 1974. The difference between these two extreme densities is for 0.68 lower than this difference in the Kaštela Bay.

Surface current direction is somewhat altered in this area due to the position if islands. Thus, even though principal inflowing Adriatic current is of N and NW direction, W direction is prevalent in this area in spring and NE in autumn.

Current speed varies from 13—23 cm s^{-1} (Zore-Armanda, 1975) and also decreases from surface to bottom.

»Stončica« station — 107 m depth — is 4 Nm southeast offshore the cape Stončica on the Vis Island.

Bottom is sandy of finer detritus with some muddy ingredients (Šimunović, personal communication).

This station is under the strongest open sea influence and hydrographic properites fluctuations are lower than those at other two stations.

The highest tempearture of 24.43°C of the 0—10 m layer was recorded in August 1973 and the lowest of 12.72°C in March 1973. The difference between these two extreme values is for 0.71°C lower than this difference in the Kaštela Bay.

Maximum salinity of 38.74‰ was recorded in November 1970 and minimum of 37.26‰ in March 1974. This area is affected by rivers, particularly by the Neretva river. This influence is intensified in spring. They do not affect only the salinity reduction but flow directions, as well, thus that W direction is prevalent. In autumn-winter and, very often, even in spring the open sea effect from NE direction is rather intensive. It carries more saline water which disperses throughout the coastal area of the middle Adriatic. Difference between extreme temperatures in the Kaštela Bay exceeds for 2.36‰ this difference in this area. The highest density of 28.79‰ was recorded in March 1973 and the lowest in August 1971 and the difference between these values is for 0.19 lower than this difference in the Kaštela Bay.

Current speed at this station shows great variations and ranges between 1 and 30 cm s^{-1}. Winter curent speed variation exceed the summer ones.

All the aforementioned data are indicative of the close connexion between studied stations. It may be even said that, with respect to their hydrographic properties, these stations make an entity in the coastal middle Adriatic which is a part of much larger entity the changes of which are reflected there.

MATERIALS AND METHODS

Continuous collection of zooplankton material from the permanent stations »Kaštela Bay«, »Pelegrin« and »Stončica« in the coastal middle Adriatic was started in 1957 by Vučetić (Vučetić, 1961). This material has been worked out in a large number of papers Many of the reports dealt with the long-term zooplankton fluctuations (Vučetić, 1965d, 1970; Vučetić and Pucher-Petković, 1969; Vučetić and Regner, D., 1973).

Results of copepod investigations from a part of this material, collected at monthly intervals from January 1970 to December 1974 are brought out. Hydrographic parameters were simultaneously observed at the same stations.

Samples were taken with a »HENSEN« plankton net (Küne, 1929) of 73 cm mouth aperture. Silk (silk No 3) net part of 130 cm length is attached to a linen part which does not filter the sea water. Net was hauled vertically from bottom to surface at 0.3 m/sec speed.

Collected material was preserved in 2% formol. Sub-sample (1/20 of the catch) was counted. The whole catch was examined for rare species.

Global species diversity index d was calculated after Margalef (1951):

$$d = \frac{S - 1}{\log_n N},$$

where S in the species number, N number of individuals per m^3 and $\log_n$ natural logarithm of the number of copepods.

Statistical analysis of the material was carried out by the correlation, regression and autocorrelation methods.

Correlation coefficient r was calculated from the results not grouped by classes after the following formula:

$$r = \frac{N\Sigma XY - (\Sigma X)(\Sigma Y)}{\sqrt{[N\Sigma X^2 - (\Sigma X)^2]\,[N\Sigma Y^2 - (\Sigma Y)^2]}}$$

and the significance of the difference of correlation coefficient from zero was tested by the following formula:

$$t = r\frac{\sqrt{(N-2)}}{\sqrt{1 - r^2}}$$

Regresion was estimated by the formula:

$$y = a + bx$$

where slope coefficient b =

$$b = \frac{\Sigma x_i - x\, y_i - y}{(\Sigma x_i - x)^2} \text{ i } a = y - bx$$

Autocorrelation coefficient for the partial shift p was obtained by the formula:

$$r_{(p)} = \frac{\Sigma x_i\, x_i + p}{\Sigma\, x_i^2}$$

RESULTS

Results of the analysis of the material collected from all three stations over the five-year period, 1970—1974, are brought out in this papir. They include horizontal species distribution and percentage proportion of each individual species at each of the stations in the coastal, channel and open sea areas of the eastern Adriatic. Frequency of occurrence of each species going from the inshore waters offshore was also observed as well as the percentage proportion of each species in the total number of copepods.

A total of 98 species were recorded. Some of the species are given in tables under the common genera names (Oithona — 3 species, Oncaea — 5 species and Sapphirina — 3 species). Results obtained for individual species are given in tables as a number of individuals by each month of the 1970—1974 period. To make the data intercomparable the number of individuals was recalculated for 10.5 m^3 for all three stations. Absence of a species is marked as O, whereas — means that no sample was taken in the respective month.

Calanidae

1. *Calanus helgolandicus* (CLAUS), 1863 — Approximatively the same number of individuals was recorded from all three stations. The highest number of individuals was recorded from »Pelegrin« (35.4%), somewhat less from the Kaštela Bay (35.1%) and the smallest number from »Stončica« (29.5%).

Frequency of occurrence of this species increases if one proceeds from the inshore waters offshore, that is it was recorded from 40% coastal samples, 70% channel samples and 72% open sea samples.

Precentage proportion in the total number of copepods increases in the offshore direction (from 0.6‰, 1‰ to 1.2‰), which is another indication of the character of this species which prefers the open sea.

CALANUS HELGOLANDICUS (CLAUS)

KAŠTELA BAY

MONTH	1	2	3	4	5	6	7	8	9	10	11	12
1970	5	20	—	—	60	40	160	40	0	5	0	0
1971	0	5	20	60	20	60	20	0	5	0	0	0
1972	20	0	5	40	20	20	0	0	0	0	0	0
1973	0	0	0	0	40	0	0	0	0	0	0	0
1974	0	0	5	60	0	0	0	20	5	0	0	0

PELEGRIN

MONTH	1	2	3	4	5	6	7	8	9	10	11	12
1970	20	40	0	10	10	0	3	3	0	3	0	0
1971	0	0	30	70	30	3	10	0	20	10	0	0
1972	0	0	10	50	20	3	10	10	3	0	0	3
1973	3	3	10	40	30	20	10	0	10	0	10	10
1974	3	20	10	20	40	30	40	10	40	10	3	20

STONČICA

MONTH	1	2	3	4	5	6	7	8	9	10	11	12
1970	42	7	21	7	63	7	0	0	0	0	0	0
1971	2	14	14	2	28	7	2	2	0	0	0	0
1972	2	84	14	42	14	0	7	0	2	0	2	2
1973	0	28	14	21	14	7	7	7	2	0	2	0
1974	2	2	7	7	7	49	42	7	2	0	14	7

CALANUS TENUICORNIS (DANA)

KAŠTELA BAY

MONTH	1	2	3	4	5	6	7	8	9	10	11	12
1970	40	20	—	—	140	40	40	80	0	0	0	60
1971	5	120	0	20	0	0	40	0	0	0	5	40
1972	5	80	5	120	40	0	20	5	5	0	80	80
1973	20	40	60	120	280	0	0	0	0	0	0	0
1974	20	5	20	0	0	5	0	0	0	0	0	40

PELEGRIN

MONTH	1	2	3	4	5	6	7	8	9	10	11	12
1970	30	40	60	80	50	70	30	20	10	0	30	10
1971	3	3	3	60	3	10	0	0	10	10	10	10
1972	3	50	50	20	20	60	30	0	10	0	10	10
1973	10	10	20	0	20	40	10	20	10	0	0	20
1974	10	40	30	100	30	10	20	20	0	10	0	10

STONČICA

MONTH	1	2	3	4	5	6	7	8	9	10	11	12
1970	7	14	28	35	28	70	14	21	49	21	7	0
1971	2	35	28	14	7	0	2	42	7	7	0	2
1972	28	14	7	21	21	14	2	49	7	0	14	14
1973	14	2	7	70	91	0	42	42	56	7	7	2
1974	14	7	21	35	42	112	56	14	14	14	0	7

The highest number of individuals was recorded from the Kaštela Bay in April-July, from Pelegrin in February-May and in July and September, an dfrom tSončica in February-June. A decrease in the number of individuals was recorded from the coastal area in the five year period of our investigations. No regular pattern could be established at other two stations.

2. *Calanus tenuicornis* DANA, 1849 — It was recorded from all three stations. The highest number of individuals was recorded from the coastal station (39.9%), somewhat less from the open sea station (30.7%) and the lowest number from the channel area (29.3%). Frequency of occurrence increases in the offshore direction (57%, 80%, 90%) as well as their percentage proportion in the total number of copepods, from 1.3% to 1.5% and 2.4%.

Maximum numbers were recorded from the Kaštela Bay in December--May, from Pelegrin in April-June, from Stončica in February-June. Accordingly, distribution and numbers of this species coincide with the *C. helgolandicus* ones.

Total number of individuals was somewhat reduced in the Kaštela Bay; it was almost constant at »Pelegrin« and decreased at »Stončica« only in 1971 and thereupon mainly increased up to the termination of the investigations.

3. *Nannocalanus minor* (CLAUS), 1863 — It was recorded from all three stations. In the Kaštela Bay, however, it occurred more rarely with only 3.43% of the total number of this species. It was somewhat better represented at »Pelegrin« with 43.8%. The highest numbers were recorded from »Stončica« (52.8%).

It was rarely recorded from the bay, on only six occasions. It was recorded from 73% of Pelegrin samples and from 90% of Stončica samples.

Their percentage proportion in the total number of copepods increases from the inshore waters towards the open sea, from 0.05 to 1.08 and 1.98.

NANNOCALANUS MINOR (CLAUS)

KAŠTELA BAY

MONTH	1	2	3	4	5	6	7	8	9	10	11	12
1970	0	0	—	—	0	0	0	0	0	0	5	0
1971	0	0	0	0	0	20	0	0	0	0	0	20
1972	5	0	0	0	0	0	0	0	0	0	0	20
1973	0	0	0	0	0	0	0	0	0	0	0	0
1974	0	0	0	0	0	0	0	0	0	0	0	0

PELEGRIN

MONTH	1	2	3	4	5	6	7	8	9	10	11	12
1970	40	150	70	10	10	10	3	3	3	40	60	10
1971	0	3	3	0	0	0	3	0	3	100	10	0
1972	0	80	0	0	3	0	10	10	0	3	10	10
1973	10	3	3	20	0	10	10	0	0	10	40	3
1974	10	3	10	0	0	10	3	10	10	30	20	20

STONČICA

MONTH	1	2	3	4	5	6	7	8	9	10	11	12
1970	63	21	14	35	14	14	21	7	28	28	21	0
1971	2	0	10	7	21	7	7	7	21	21	7	2
1972	2	14	21	0	21	0	7	7	28	42	21	28
1973	2	14	14	21	0	7	7	7	2	14	7	21
1974	21	7	7	21	7	14	0	14	49	140	91	21

PARACALANUS PARVUS (CLAUS)

KAŠTELA BAY

MONTH	1	2	3	4	5	6	7	8	9	10	11	12
1970	160	20	—	—	80	0	40	80	5	0	0	20
1971	0	60	20	20	40	5	40	40	0	20	0	20
1972	120	0	20	40	100	260	40	40	0	5	0	40
1973	0	100	0	60	220	60	100	80	160	80	80	40
1974	120	40	20	100	60	80	20	40	40	20	40	0

PELEGRIN

MONTH	1	2	3	4	5	6	7	8	9	10	11	12
1970	0	0	0	20	60	10	10	0	0	0	0	0
1971	10	20	30	10	40	20	0	0	10	10	3	0
1972	10	0	0	0	0	20	0	0	3	0	0	0
1973	0	0	50	30	30	440	10	0	30	10	0	0
1974	0	0	10	10	60	90	10	30	10	0	0	0

STONČICA

MONTH	1	2	3	4	5	6	7	8	9	10	11	12
1970	14	0	0	0	0	0	0	0	0	0	0	0
1971	0	14	0	21	14	0	7	0	0	0	0	0
1972	0	0	0	0	0	0	0	0	0	0	0	0
1973	0	0	7	0	28	0	0	14	7	0	0	0
1974	0	0	0	0	7	35	0	14	7	0	0	0

It occurred in the Kaštela during colder months, at Pelegrin it is best represented in February, October and November, and at Stončica it is most numerous in spring and autumn.

The number of individuals was not essentially changed at Pelegrin and Stončica throughout the period of investigations despite the annual oscillations.

4. *Neocalanus gracilis* (DANA), 1849 — Even though this species was recorded from all three stations it is still very rare occurring in quite insignificant quantities. It was recorded only once from the Kaštela Bay in March 1971. Frequency of occurrence at other two stations was also very low; only seven and six records respectively were reported during the five year period.

The highest number of individuals was recorded from »Pelegrin«.

Eucalanidae

Two species of this family were recorded only occasionally from »Pelegrin« and »Stončica«.

5. *Eucalanus attenuatus* (DANA), 1849 — This high sea form was very rarely recorded in small numbers. It was recorded from both stations only in winter, in February and March.

6. *Eucalanus elongatus* (DANA), 1849 — It was recorded only occasionally and in insignificant quantities. It occurred at Pelegrin and Stončica mainly up to August. Its numbers were somewhat higher at Stončica in 1970.

Paracalanidae

Two *Paracalanidae* species: *Paracalanus nanus* and *P. parvus* were found, *P. parvus* in somewhat higher quantities.

7. *Paracalanus nanus* G. O. SARS, 1907 — Small numbers of individuals were occasionally recorded from all three stations. The highest numbers were recorded from the Kaštela Bay where it made up 0.13% of the total copepod numbers. Quantities recorded from Pelegrin and Stončica were quite insignificant.

8. *Paracalanus parvus* (CLAUS), 1863 — This most numerous species of *Paracalanidae* family was recorded from all three stations. The highest number of individuals was recorded from the Kaštela Bay (69.13%). Their number was considerably lower at Pelegrin (26.30%) and lowest at Stončica (only 4.6%). Frequency of occurrence was, as well, reduced in the offshore direction, that is it occurred in 79%, 48% and 22% of the samples respectively.

It made up 2.15% of the total copepod number in the Kaštela Bay, 1.31% at Pelegrin and only 0.35% at Stončica.

The highest numbers of this species occurred at »Pelegrin« and »Stončica« in spring.

Number of individuals varied from one year to another but it was not significantly changed over the five-year period of investigations.

Calocalanidae

Out of all the species of this family recorded throughout our studies only *Calocalanus pavo* and *Mecynocera clausi* occurred in higher numbers. Their quantities were quite insignificant in the coastal area. However, they occurred more frequently and in higher number in the open sea what is in agreement with other reports from the Adriatic (Gamulin, 1939; Vukanić, 1971).

9. *Calocalanus pavo* (DANA), 1849 — Even though it was recorded from all three stations its numbers were highest in the channel area (43.6%). It was somewhat less numerous in the open sea (35.16%) ond least numerous in the inshore waters (21.19%).

CALOCALANUS PAVO (DANA)

								KAŠTELA BAY				
MONTH	1	2	3	4	5	6	7	8	9	10	11	12
1970	0	0	—	—	0	0	0	0	0	20	100	20
1971	5	0	0	0	0	0	20	0	20	40	0	60
1972	40	0	0	0	0	0	0	0	0	0	60	0
1973	0	0	60	0	0	0	0	0	0	40	60	0
1974	5	0	0	0	0	0	0	0	0	40	80	5
								PELEGRIN				
MONTH	1	2	3	4	5	6	7	8	9	10	11	12
1970.	50	0	20	0	0	0	0	10	70	50	70	0
1971	10	10	20	0	0	10	10	20	20	20	50	0
1972	40	0	10	0	0	10	0	0	10	0	30	40
1973	30	0	0	0	0	0	0	0	20	70	330	0
1974	0	0	0	0	10	0	0	10	30	10	180	120

STONČICA

MONTH	1	2	3	4	5	6	7	8	9	10	11	12
1970	7	21	0	0	7	21	7	21	14	77	28	14
1971	21	0	7	0	0	14	7	42	63	21	42	28
1972	0	0	0	0	7	0	0	7	21	35	21	56
1973	35	7	0	7	0	14	0	0	14	126	119	28
1974	14	14	7	0	0	0	0	7	28	42	14	35

ISCHNOCALANUS PLUMULOSUS (CLAUS)

KAŠTELA BAY

MONTH	1	2	3	4	5	6	7	8	9	10	11	12
1970	5	20	—	—	0	0	0	0	0	0	0	0
1971	0	0	0	0	0	0	0	0	0	40	0	40
1972	0	0	0	0	0	0	0	0	0	0	0	0
1973	0	0	0	0	0	0	0	0	0	20	4	0
1974	0	0	0	0	0	0	0	0	0	0	0	5

PELEGRIN

MONTH	1	2	3	4	5	6	7	8	9	10	11	12
1970	20	3	30	0	0	30	3	0	0	30	20	60
1971	0	30	3	3	0	0	0	0	0	50	10	10
1972	0	0	0	0	3	0	0	0	20	20	20	10
1973	0	0	0	20	0	0	0	10	3	70	210	10
1974	30	0	0	0	10	0	0	0	0	20	50	0

STONČICA

MONTH	1	2	3	4	5	6	7	8	9	10	11	12
1970	14	14	7	7	7	14	21	0	0	49	7	21
1971	0	0	2	0	0	0	7	21	28	84	14	0
1972	0	0	0	0	0	0	2	14	35	7	98	21
1973	7	0	0	0	0	0	0	0	7	21	42	21
1974	28	0	0	0	14	0	0	0	14	7	77	14

It occurred most frequently at Stončica and its frequency decreased in the onshore direction.

It made no more than 0.51% of the total copepod number in the coastal waters, 1.68% in the channel area whereas it was rather numerous in the open sea with 2.06%. No regular pattern of variations in number of individual was established.

10. *Calocalanus contractus* FARRAN, 1926 — It was rather rarely found. No specimen was recorded from the coastal area. It occurred in small numbers. Even though its numbers were somewhat higher at Stončica its quantities were quite negligible.

11. *Calocalanus stylimeris* GIESBRECHT, 1888 — It was the rarest and least numerous species of this family. Only several specimens were recorded from Pelegrin and Stončica.

12. *Ischnocalanus plumulosus* (CLAUS), 1863 — It was rather rare, particularly in the Kaštela Bay where its quantity was quite insignificant.

It was most frequent at Stončica where almost half the samples contained its individuals. Its percentage proportion in relation to other copepods was also highest at this station (1.37%).

It was mainly recorded during the latter part of the year with the highest numbers from October to December.

13. *Mecynocera clausi* THOMPSON, 1888 — This is the most numerous species of the *Calocalanidae* family. It was rarest in the Kaštela Bay where it also occurred in smallest quantities. However, its percentage presence by stations, frequency of occurrence and percentage proportion in the total number of copepods (even 3.5%) significantly increased in the offshore direction.

It occurred in much higher numbers from August to February particularly at »Stončica«.

It is of a particular interest that in the course of our investigations, between 1970 and 1974, its numbers increased in the coastal area and gradually decreased in the open sea.

MECYNOCERA CLAUSI THOMPSON

KAŠTELA BAY

MONTH	1	2	3	4	5	6	7	8	9	10	11	12
1970	5	0	—	—	0	0	0	0	0	0	20	40
1971	0	5	0	0	0	0	0	0	0	0	0	40
1972	5	0	0	0	0	0	5	20	40	0	0	20
1973	0	20	0	0	0	80	0	0	0	0	0	20
1974	20	0	0	0	0	0	0	0	0	0	80	20

PELEGRIN

MONTH	1	2	3	4	5	6	7	8	9	10	11	12
1970	100	0	40	30	10	40	30	0	20	20	30	40
1971	2	2	21	7	42	28	70	14	35	112	49	70
1972	40	30	10	0	40	20	30	30	20	40	20	20
1973	70	20	10	0	10	10	0	10	0	10	20	10
1974	20	20	20	10	0	20	10	10	80	3	10	30

STONČICA

MONTH	1	2	3	4	5	6	7	8	9	10	11	12
1970	28	42	14	49	28	91	105	14	21	105	70	49
1971	2	2	21	7	42	28	70	14	35	113	49	70
1972	14	14	7	0	21	42	7	14	28	28	56	14
1973	63	28	7	14	14	28	21	14	2	14	14	91
1974	42	28	31	49	42	35	0	7	35	14	21	35

CLAUSOCALANUS LIVIDUS FROST AND FLEMINGER

PELEGRIN

MONTH	1	2	3	4	5	6	7	8	9	10	11	12
1970	20	40	60	0	10	0	0	0	0	0	0	0
1971	20	50	60	20	10	0	0	0	0	0	0	10
1972	0	30	30	0	0	0	0	0	0	0	0	30
1973	30	0	10	140	0	3	0	0	0	10	0	0
1974	10	0	0	0	0	0	0	0	0	0	0	0

STONČICA

MONTH	1	2	3	4	5	6	7	8	9	10	11	12
1970	14	0	42	7	0	14	14	0	0	0	0	0
1971	7	0	49	49	14	0	28	0	0	7	7	7
1972	2	0	35	7	21	0	0	0	0	21	0	7
1973	14	14	0	7	14	0	7	0	0	2	7	0
1974	0	7	0	0	0	0	0	0	0	0	0	0

Pseudocalanidae

Species of genus *Clausocalanus* belong to this family. After the recent revisions eight species of this genus were recorded from the southern Adriatic (Hure and Scotto di Carlo, 1970), eight from the middle Adriatic. A total of 13 species was determined in the Mediterranean (Frost and Fleminger, 1968).

14. *Clausocalanus mastigophorus* (CLAUS), 1863 — It was rather rare occurring in small numbers. It was not found in the Kaštela Bay; small numbers of individuals were recorded from Pelegrin and Stončica rather frequently.

Its quantity in the total copepod quantity was quite insignificant at both stations.

Annual variations showed higher number of individuals in autumn. Maxima were recorded both from Stončica and Pelegrin in November.

Number of individuals was gradually reduced over the five-year period.

15. *Clausocalanus lividus* FROST and FLEMINGER, 1968 — This species was more frequently recorded than the preceding one. Its number of individuals was also higher. No specimen was recorded from the coastal area. It was somewhat more numerous at Pelegrin than at Stončica. Higher number of individuals was recorded from December to July.

16. *Clausocalanus arcuicornis* (DANA), 1849 — It is widely ditributed form in the Adriatic. It was recorded from all three stations, best represented at Pelegrin (48.76%).

It was recorded from 79% of the samples in the Kaštela Bay and from as high as 90% of the samples at other two stations.

CLAUSOCALANUS ARCUICORNIS (DANA)

KAŠTELA BAY

MONTH	1	2	3	4	5	6	7	8	9	10	11	12
1970	40	20	—	—	80	20	40	20	0	180	60	20
1971	20	0	20	20	20	20	40	40	60	20	20	20
1972	60	100	20	40	20	0	60	80	60	20	0	60
1973	0	0	20	20	220	0	20	160	280	0	60	20
1974	20	0	5	80	20	0	40	0	0	160	80	80

PELEGRIN

MONTH	1	2	3	4	5	6	7	8	9	10	11	12
1970	50	60	110	70	80	30	60	100	10	10	90	50
1971	20	20	50	80	30	0	0	0	0	40	10	40
1972	20	60	90	20	0	190	10	0	150	5	80	0
1973	20	0	20	0	0	20	70	20	30	0	0	10
1974	0	30	50	50	50	40	50	0	50	30	140	40

STONČICA

MONTH	1	2	3	4	5	6	7	8	9	10	11	12
1970	56	7	14	42	21	42	0	7	7	14	42	35
1971	0	0	28	21	70	14	42	0	21	21	7	28
1972	77	42	91	14	126	133	42	21	49	42	28	14
1973	42	0	42	133	154	14	196	70	245	112	21	56
1974	70	133	70	217	154	182	42	21	42	7	0	28

CLAUSOCALANUS JOBEI FROST AND FLEMINGER

KAŠTELA BAY

MONTH	1	2	3	4	5	6	7	8	9	10	11	12
1970	140	60	—	—	160	60	120	40	140	280	180	140
1971	20	20	20	20	40	60	220	180	220	20	220	40
1972	120	20	0	20	80	20	40	0	60	5	180	20
1973	0	0	80	0	0	60	40	120	0	60	20	0
1974	0	0	0	0	20	0	0	0	5	0	200	40

PELEGRIN

MONTH	1	2	3	4	5	6	7	8	9	10	11	12
1970	210	70	1030	270	20	150	380	240	310	120	240	20
1971	20	90	90	100	110	30	110	110	60	140	60	30
1972	20	60	90	20	0	190	10	0	150	5	80	0
1973	20	0	20	0	0	20	70	20	30	0	0	10
1974	0	30	50	50	50	40	50	0	50	30	140	40

STONČICA

MONTH	1	2	3	4	5	6	7	8	9	10	11	12
1970	21	28	42	70	98	91	182	196	112	147	28	7
1971	35	0	21	84	28	35	98	21	42	28	56	42
1972	0	7	0	7	63	56	35	56	140	63	63	21
1973	0	7	35	98	84	35	7	56	14	14	14	14
1974	21	42	21	28	77	441	63	28	49	77	0	49

It made up 1.94% of the total copepod number in the coastal area, and 6.72 and 6.01% respectively at Pelegrin and Stončica. Spring and autumn density maxima were recorded from all three stations.

Its numbers slightly varied in the coastal area during the time of our investigations and showed considerable increase at other two stations.

17. *Clausocalanus jobei* FROST and FLEMINGER, 1968 — It was more numerous than the preceding copepod and similarly distributed. It was recorded from all the stations with the highest percentage of individuals in the channel area (56.91%).

It was almost continuously present at all the stations with slight frequency increase in the offshore direction.

The number of individuals and its percentage proportion in the total number of copepods increased in the offshore direction. Thus, it made up 2.62% of the total number of individuals in the Kaštela Bay, 5.89% at Pelegrin and 10.66% at Stončica. It was best represented at all the stations from June to October. It maximum was recorded at »Pelegrin« in March.

Its numbers considerably decreased at all the stations during the time of our investigations.

18. *Clausocalanus pergens* FARRAN, 1926 — It was recorded from all three stations, its number of individuals increasing from the inshore area towards the open sea.

It occurred in small number in the Kaštela Bay wherefrom individual specimens were occasionalyy recorded. It was more frequent at Pelegrin and Stončica, its numbers somewhat higher from April to June. Its quantites were quite insignificant.

19. *Clausocalanus parapergens* FROST and FLEMINGER, 1968 — It occurred rarely and in small number, particularly in the Kaštela Bay. Its quantities were quite insignificant and its percentage proportion in the total copepod number was highest at Stončica (0.72%). The highest numbers were recorded in spring.

20. *Clausocalanus paululus* FARRAN, 1926 — Higher number of individuals was recorded only from the open sea. It occurred in small numbers of individuals and only occasionally at station in the channel area. No specimen was recorded from the Kaštela Bay.

Its quantites were insignificant. Its highest percentage proportion in relation to other copepods was recorded from »Stončica« (0.68%).

21. *Clausocalanus furcatus* (BRADY), 1883 — Considerable numbers of this species were recorded from all the stations. Highest numbers were recorded from Pelegrin (41.88% of the total number of individuals recorded). Frequency of occurrence was also highest at this station since it was recorded from 81% of the samples.

It made up 2.35% of the total copepod number in the Kaštela Bay, 4.65% at Pelegrin and 4.09% at Stončica. Its percentage proportion increased in the offshore direction.

22. *Ctenocalanus vanus* GIESBRECHT, 1888 — It was distributed at all the stations. Its percentage presence was highest at Pelegrin (38.87%).

Its frequency was very high at all the stations exceeding 90%.

Great numbers of individuals were recorded from all the stations. It counts among the quantitatively dominant species. Its percentage proportion in the total number of copepods was 9.35% in the Kaštela Bay, as high as 15.38% at Pelegrin and 14% at Stončica.

It occurred in greater numbers mainly in spring and summer.

CLAUSOCALANUS FURCATUS (BRADY)

KAŠTELA BAY

MONTH	1	2	3	4	5	6	7	8	9	10	11	12
1970	20	0	—	—	0	0	0	20	20	160	340	0
1971	20	0	0	0	0	0	0	60	100	20	520	20
1972	0	0	5	5	20	0	0	0	0	160	440	20
1973	0	0	0	0	60	0	40	0	0	180	440	80
1974	0	0	0	0	0	20	20	20	240	0	60	20

PELEGRIN

MONTH	1	2	3	4	5	6	7	8	9	10	11	12
1970	370	40	100	10	30	50	0	0	50	40	30	0
1971	30	30	0	10	10	10	40	10	130	120	110	0
1972	160	50	30	10	20	60	40	10	10	140	80	130
1973	10	20	20	30	60	0	60	20	80	30	340	90
1974	30	60	10	0	0	40	40	20	470	220	250	10

STONČICA

MONTH	1	2	3	4	5	6	7	8	9	10	11	12
1970	14	21	0	14	7	42	28	28	7	56	28	91
1971	0	0	21	0	21	7	28	7	21	56	35	21
1972	14	0	28	0	28	231	49	154	91	98	140	63
1973	28	42	21	0	0	7	7	14	14	21	196	21
1974	7	14	0	0	0	0	14	112	21	231	28	0

During our investigations its numbers were increased at all the stations, particularly in the Kaštela Bay.

CTENOCALANUS VANUS GIESBRECHT

KAŠTELA BAY

MONTH	1	2	3	4	5	6	7	8	9	10	11	12
1970	520	60	—	—	440	220	400	240	60	20	160	20
1971	0	40	20	60	40	60	20	140	20	0	5	120
1972	340	340	0	260	500	60	560	480	120	0	0	140
1973	60	60	140	380	380	40	340	660	580	60	100	20
1974	880	120	320	1060	60	280	200	280	60	100	340	480

PELEGRIN

MONTH	1	2	3	4	5	6	7	8	9	10	11	12
1970	110	60	640	1240	370	230	270	60	10	30	90	150
1971	20	0	160	210	230	60	70	30	20	10	0	30
1972	190	340	630	400	140	350	220	120	180	160	130	80
1973	140	180	90	1180	150	960	290	270	270	290	40	230
1974	100	180	290	430	150	240	50	30	0	100	0	60

STONČICA

MONTH	1	2	3	4	5	6	7	8	9	10	11	12
1970	273	70	154	98	238	91	49	35	168	28	42	14
1971	42	14	42	133	77	84	42	28	35	7	21	7
1972	105	56	280	63	301	343	14	63	42	14	133	56
1973	98	70	161	441	154	84	203	301	98	140	21	133
1974	273	371	196	427	140	406	203	0	266	126	28	28

Aetidaeidae

Three species of this family were recorded. However, they occurred sporadically and in very small numbers. There is no record from the coastal area.

23. *Aetidus armatus* (BOECK), 1872 — Several individuals only were recorded from Pelegrin and somewhat higher number from Stončica. However, its quantity was insignificant in relation to the total copepod number.

24. *Euaetidus giesbrechti* (CLÈVE), 1904 — Like the preceding species it was recorded from Stončica only occasionally and in small numbers of individuals. It was somewhat more numerous at Stončica, however its quantity was insignificant in relation to the total copepod quantity.

Euchaetidae

Four species of this family were rarely recorded. Somewhat higher number of individuals was found at the open sea stations. With the exception of *E. hebes* there was no record of this family from the Kaštela Bay.

25. *Euchaeta acuta* GIESBRECHT, 1892 — Several individuals only were recorded from Stončica.

26. *Euchaeta hebes* GIESBRECHT, 1888 — This species occurred rarely and in small number of individuals in the coastal area. Its quantity gradually

increased towards the open sea thus that it was rather numerous at Stončica. Its frequency was considerably increased in the offshore direction. Thus even though it was recorded from the Kaštela Bay on only three occasions it was recorded from more than 50% of the samples at Stončica.

EUCHAETA ACUTA GIESBRECHT

								STONČICA				
MONTH	1	2	3	4	5	6	7	8	9	10	11	12
1970	0	0	0	0	0	0	0	0	0	0	0	0
1971	0	0	0	2	2	0	0	0	14	0	2	0
1972	0	2	0	0	0	0	0	0	0	0	7	0
1973	2	0	0	0	0	0	0	0	0	0	0	0
1974	0	0	0	0	0	0	0	0	0	0	0	0

EUCHAETA HEBES GIESBRECHT

								KAŠTELA BAY				
MONTH	1	2	3	4	5	6	7	8	9	10	11	12
1970	0	0	0	0	0	0	0	0	0	0	0	0
1971	0	0	0	5	0	0	0	0	0	0	0	0
1972	0	0	5	0	0	0	0	0	0	0	0	0
1973	0	0	0	0	0	0	0	0	0	0	0	0
1974	0	0	0	0	20	0	0	0	0	0	0	0
								PELEGRIN				
MONTH	1	2	3	4	5	6	7	8	9	10	11	12
1970	3	10	20	10	70	3	3	3	0	3	0	3
1971	10	3	3	20	3	10	3	0	3	0	0	10
1972	10	3	20	70	0	0	0	0	3	70	3	10
1973	3	10	0	10	0	0	0	0	0	0	0	10
1974	0	0	0	0	10	3	0	0	0	0	0	0
								STONČICA				
MONTH	1	2	3	4	5	6	7	8	9	10	11	12
1970	21	7	7	21	21	63	35	0	2	0	7	0
1971	2	0	2	2	0	2	7	14	14	7	7	2
1972	2	0	42	14	21	0	2	0	28	42	70	0
1973	7	2	0	7	0	2	7	2	2	2	2	7
1974	0	0	7	7	7	7	0	0	7	2	2	0

27. *Euchaeta marina* (PRESTANDREA), 1883 — It was recorded only once from Pelegrin and six times from Stončica.

28. *Euchaeta spinosa* G i e s b r e c h t, 1892 — It counts among the rarest copepods. It was recorded only once from Pelegrin and twice from Stončica during the time of our studies.

Scolecithricidae

Single individuals of the species of this family were only occasionally recorded mainly from Pelegrin and Stončica. Their numbers were somewhat higher only at Stončica.

29. *Scolecithrix bradyi* GIESBRECHT, 1888 — Few individuals were recorded from »Pelegrin« and somewhat more from Stončica. Quantitatively insignificant.

30. *Scolecithricella dentata* (GIESBRECHT), 1892 — Its number was small at Pelegrin wherefrom it was rarely recorded. However, at Stončica it was more frequently recorded and in higher number of individuals.

31. *Scolecthricella tenuiserrata* (GIESBRECHT), 1892 — About 60 individuals were recorded from the channel area and about 60 individuals from the open sea station.

Diaixidae

Only one species of this family was recorded from all three stations.

32. *Diaxis pygmea* (T. SCOTT), 1889 — Its highes percentage presence was recorded from the Kaštela Bay, 73.17% of the total number of individuals of this species.

Since it was recorded from more than 50% of the samples at this station its frequency is also highest there.

Its quantity is not significant in the total copepod number, since in the Kaštela Bay, where its number is highest, its proportion did not exceed 0.63%.

DIAIXIS PYGMAEA (T. SCOTT)

KAŠTELA BAY

MONTH	1	2	3	4	5	6	7	8	9	10	11	12
1970	60	0	—	—	0	5	0	20	0	0	100	40
1971	5	5	5	0	0	0	0	0	0	5	5	5
1972	20	20	5	5	20	0	5	60	5	5	40	20
1973	0	40	20	0	60	0	0	60	0	0	0	0
1974	5	0	20	60	20	20	0	20	20	0	20	0

PELEGRIN

MONTH	1	2	3	4	5	6	7	8	9	10	11	12
1970	3	0	0	0	10	0	0	10	0	0	0	0
1971	0	3	0	30	3	3	0	0	3	0	0	3
1972	0	10	3	0	0	0	0	0	0	3	0	3
1973	10	0	0	0	0	3	0	0	0	0	0	0
1974	0	0	0	0	3	10	3	10	10	10	0	0

STONČICA

MONTH	1	2	3	4	5	6	7	8	9	10	11	12
1970	14	7	7	7	0	0	0	0	0	0	0	7
1971	0	2	14	0	0	7	0	0	0	0	0	0
1972	0	0	0	0	0	0	0	0	2	0	0	0
1973	2	0	0	14	0	7	0	7	0	0	0	7
11974	2	0	7	0	7	7	21	0	7	0	0	7

Centropagidae

This family includes *C. typicus* and *C. kroyeri* species which are dominant copepods in the coastal area as well as *C. violaceus* and *Isias clavipes* which are very rare ocurring in small numbers.

33. *Centropages typicus* KRÖYER, 1849 — Its percentage proportion of 53.7% of the total number of recorded individuals is highest in the coastal area.

It was almost constantly present at all the stations, its absence somewhat more frequently recorded from the open sea.

It made up as high as 16.25% of the total copepod number in the Kaštela Bay and 17.84% at Pelegrin. It counts among the species the number of which affects the variations in the total copepod numbers. This percentage was somewhat lower in the open sea, however great in relation to other copepod species. The highest numbers occurred in the warmer part of the year.

Total number of this species individuals was not significantly changed in the Kaštela Bay, while it slightly increased at other two stations from 1970—1974.

CENTROPAGES TYPICUS (KRÖYER)

KAŠTELA BAY

MONTH	1	2	3	4	5	6	7	8	9	10	11	12
1970	140	340	—	—	460	520	480	440	140	440	480	40
1971	20	140	320	100	480	520	40	60	700	130	160	8
1972	40	180	260	360	920	360	160	320	460	440	980	500
1973	320	180	220	360	840	400	840	180	360	220	860	320
1974	80	160	140	80	260	260	180	500	240	40	320	80

PELEGRIN

MONTH	1	2	3	4	5	6	7	8	9	10	11	12
1970	80	80	220	280	290	230	320	90	80	60	0	3
1971	10	10	180	180	630	60	150	220	1800	70	140	0
1972	210	70	90	440	100	190	380	110	280	20	40	0
1973	70	110	130	990	560	1440	730	130	400	60	20	10
1974	50	270	190	230	240	1280	530	100	0	20	90	30

STONČICA

MONTH	1	2	3	4	5	6	7	8	9	10	11	12
1970	91	0	0	0	21	63	49	196	56	42	0	14
1971	7	56	0	63	112	35	84	0	7	14	0	21
1972	0	21	14	0	35	133	126	91	28	0	0	42
1973	28	10	560	1330	210	350	1750	560	4830	140	140	2
1974	2	63	49	112	189	399	413	14	91	7	7	35

34. *Centropages kröyeri* GIESBRECHT, 1892 — Making up even 99.4% of the total number of recorded individuals this copepod was the best represented copepod in the Kaštela Bay.

Its frequency of occurrence was highest at this station (occurring in more than 75% of the samples). Only several individuals were occasionally found at other stations. As to the quantity, this species counts among the dominant Kaštela Bay copepods where it makes up 15.08% of the total copepod numbers. Its numbers were highest in autumn. Its quantities were insignificant at Pelegrin and Stončica.

35. *Centrogapes violaceus* (CLAUS), 1863 — It occurred at all the stations only occasionally, mainly in September-November. Its frequency somewhat increased in the offshore direction .Its number of individuals was considerably higher at outer stations, however quantitatively insignificant.

CENTROPAGES KRÖYERI (GIESBRECHT)

KAŠTELA BAY

MONTH	1	2	3	4	5	6	7	8	9	10	11	12
1970	180	440	—	—	160	80	0	240	260	60	420	40
1971	20	100	160	160	20	120	3100	140	480	2380	200	80
1972	180	340	120	0	20	700	120	180	120	720	0	0
1973	90	30	10	40	20	20	30	80	360	1060	440	60
1974	140	460	0	180	0	0	80	700	2480	380	120	60

PELEGRIN

MONTH	1	2	3	4	5	6	7	8	9	10	11	12
1970	0	0	0	0	0	0	0	0	10	0	0	0
1971	0	0	0	0	0	0	0	0	0	20	3	0
1972	0	0	0	0	0	0	0	0	0	0	0	0
1973	0	0	0	0	0	0	0	0	0	0	0	0
1974	0	0	0	0	0	0	35	0	0	0	0	0

STONČICA

MONTH	1	2	3	4	5	6	7	8	9	10	11	12
1970	0	0	0	0	0	0	0	0	0	0	0	0
1971	0	35	0	7	0	0	0	0	0	0	0	0
1972	0	0	0	0	0	0	0	0	0	0	0	0
1973	0	0	0	0	0	0	0	0	0	0	0	0
1974	0	0	0	0	0	0	0	35	0	0	0	0

36. *Isias clavipes* BOECK, 1864 — It is rather of interest that this species was much more numerous in the Kaštela Bay during some earlier investigations, from 1960—1969 (R e g n e r, D., 1970) than recently. It was found in highest percentages in the Kaštela Bay, however rare and occurring in insignificant quantities at this and other two stations.

Temoridae

Two species of this family were recorded. *T. stylifera* is widely distributed. Adriatic species and counts among the most numerous copepods. However, *T. longicornis* is rather rare and occurs in small numbers. Only sporadical records of this species have been reported.

37. *Temora stylifera* (DANA), 1848 — Its highest percentage presence was recorded from the coastal station where it made up 56.44% of the total number of collected individuals.

It was almost continuously present at all three stations, that is in 86 to 90% of the samples.

It made up the highest percentage proportion in the total number of copepods (12.79%) in the Kaštela Bay. However, at Pelegrin and Stončica these percentages were as well high, 10.79 and 7.41% respectively. Maximum numbers were recorded in summer and autumn.

38. *Temora longicornis* (MÜLER), 1792 — It occurred occasionaly at all the stations and in small number of individuals.

The highest numbers were recorded from the Kaštela Bay, even though these quantities were not significant either.

TEMORA STYLIFERA (DANA)

KAŠTELA BAY

MONTH	1	2	3	4	5	6	7	8	9	10	11	12
1970	40	20	—	—	5	20	400	320	1980	1400	460	20
1971	5	60	40	20	20	120	120	620	1520	440	180	40
1972	20	0	40	60	220	400	500	480	820	180	460	80
1973	20	0	0	0	40	0	600	960	1340	580	40	60
1974	5	5	60	0	0	0	140	260	700	160	520	420

PELEGRIN

MONTH	1	2	3	4	5	6	7	8	9	10	11	12
1970	140	50	140	60	130	30	80	380	300	190	90	10
1971	0	30	30	30	30	10	100	270	270	190	110	20
1972	10	60	100	30	0	190	60	0	350	200	110	150
1973	90	30	10	40	20	20	3	80	360	1060	440	60
1974	20	30	40	70	10	60	60	240	1070	510	570	230

STONČICA

MONTH	1	2	3	4	5	6	7	8	9	10	11	12
1970	91	28	21	28	7	77	35	175	210	77	35	28
1971	49	21	14	0	35	21	84	84	98	196	0	35
1972	28	14	7	0	7	21	77	84	63	70	42	77
1973	42	7	49	42	0	21	7	28	182	455	98	21
1974	7	28	0	21	21	119	77	175	203	273	49	182

Metridae

This family includes three rather rare species which occur in small numbers.

39. *Pleuromamma abdominalis* (LUBBOCK), 1856 — It was not recorded from the Kaštela Bay, and only few individuals were recorded from Pelegrin and Stončica.

40. *Pleuromamma gracilis* (CLAUS), 1863 — It was recorded only once from the coastal area. Going offshore its frequency of occurrence increased thus that it was found in more than 50% of the samples collected from »Stončica«.

The number of individuals also increased going towards the open sea where it made up 0.97% of the total number of copepods.

Its quantities were quite insignificant both in the channel area and in the open sea.

Lucicutidae

Three species of this family were recorded. *L. clausi* was very rare while the other two species were slightly more frequent even though occurring in small numbers. The number of individuals increased in the offshore direction. However, their quantities were not significant at »Stončica« either.

41. *Lucicutia clausi* (GIESBRECHT), 1889 — Only two individuals were found at »Stončica« in December 1974.

42. *Lucicutia flavicornis* (CLAUS), 1863 — It occurred rather frequently and in small number of individuals. It was recorded from the Kaštela Bay

from time to time, in more than 50% of the samples at Pelegrin and in almost all the samples at Stončica.

Its quantities were quite insignificant in the coastal and channel area, while it made up 1.76% of the total number of copepods in the open sea.

43. *Lucicutia ovalis* WOLFENDEN, 1906 — This rather rare species occurred in small numbers only at »Pelegrin« and »Stončica«. Its quantities were insignificant.

Heterorhabdida

Two species of this family were noted at »Pelegrin« and »Stončica«.

44. *Heterorhabdus papilliger* (CLAUS), 1863 — Small number of individuals was occasionally recorded. Even though its numbers were somewhat higher at »Stončica« it was quite insignificant among the other copepods.

45. *Heterorhabdus spinifrons* (CLAUS), 1863 — It occurred very rarely and in small numbers. Greater numbers were recorded from »Stončica«.

Augaptilidae

Only one species of this family was found at »Pelegrin« and »Stončica«. There were no records from the coastal area.

46. *Haloptilus longicornis* (CLAUS), 1863 — Its numbers were somewhat higher at the open sea station. However, its quantity in relation to other copepods is not significant — not exceeding 0.55%.

HALOPTILUS LONGICORNIS (CLAUS)

								PELEGRIN				
MONTH	1	2	3	4	5	6	7	8	9	10	11	12
1970	0	0	0	0	20	0	0	0	0	0	0	0
1971	0	0	0	0	0	0	0	0	0	0	0	3
1972	0	10	0	0	0	3	0	0	0	0	0	0
1973	0	0	0	0	0	0	0	0	0	0	0	0
1974	0	0	0	10	0	0	0	0	0	0	0	0
								STONČICA				
MONTH	1	2	3	4	5	6	7	8	9	10	11	12
1970	14	0	7	21	21	7	28	0	21	0	14	84
1971	0	0	0	0	0	0	0	0	0	0	7	14
1972	0	0	0	0	0	0	14	2	0	2	0	2
1973	0	2	0	0	0	0	2	0	7	7	0	0
1974	0	0	0	0	0	0	7	0	0	7	7	0

Candaciidae

All of the eight species of this family occurred rarely and in small numbers with the exception of *Candacia armata* and *Paracandacia simplex* species. Few individuals of other six species were recorded mainly from »Pelegrin« and »Stončica«.

47. *Candacia aethiopica* (DANA), 1848 — Only three individuals were recorded from »Pelegrin« in 1972.

48. *Candacia armata* (BOECK), 1872 — It was best represented species of this family, recorded from all three stations. Its percentage of the total number of individuals was lowest at »Stončica« — 15.17%. It was found in about 50% of the samples from the coastal and open sea areas, and in about 70% of the samples from the channel area.

Its numbers were lowest in the open sea, exceeded considerably by those in the Kaštela Bay and Pelegrin at which their numbers were almost the same.

Its percentage proportion in the total number of copepods was highest at »Pelegrin«, however insignificant.

Its number of individuals showed slight decrease both in the coastal area and in the channel one throughout the period of investigations.

CANDACIA ARMATA (BOECK)

KAŠTELA BAY

MONTH	1	2	3	4	5	6	7	8	9	10	11	12
1970	20	20	—	—	5	20	0	20	0	0	40	20
1971	5	5	0	0	0	5	20	5	0	20	5	40
1972	80	20	5	20	20	0	5	0	40	5	0	40
1973	20	0	0	0	20	0	5	0	40	0	5	0
1974	0	5	0	0	0	0	20	0	0	0	5	0

PELEGRIN

MONTH	1	2	3	4	5	6	7	8	9	10	11	12
1970	3	30	80	50	10	10	3	0	3	0	0	3
1971	10	20	3	20	0	10	0	0	0	0	3	0
1972	10	10	30	10	10	10	10	0	10	10	0	10
1973	10	10	30	0	0	10	50	0	10	30	0	10
1974	10	10	10	0	0	10	0	0	20	3	3	20

STONČICA

MONTH	1	2	3	4	5	6	7	8	9	10	11	12
1970	0	0	7	7	7	0	2	14	0	0	0	0
1971	2	2	7	2	0	0	2	0	0	0	0	28
1972	7	0	0	21	0	0	0	0	2	0	2	0
1973	2	2	0	2	0	0	7	7	7	7	2	0
1974	7	14	7	14	14	0	7	0	0	7	0	0

49. *Candacia bipinnata* (GIESBRECHT), 1889 — About 50 individuals were recorded from »Pelegrin« in 1970.

50. *Candacia elongata* (BOECK), 1872 — It was recorded on only one occasion from the open sea station.

51. *Candacia tenuimana* (GIESBRECHT), 1889 — Only few individuals were recorded from »Pelegrin« and »Stončica«.

52. *Candacia varicans* (GIESBRECHT), 1892 — Seven individuals were recorded from the open sea station.

53. *Paracandacia bispinosa* (CLAUS), 1863 — Only occasionally recorded from the open sea station.

54. *Paracandacia simplex* (GIESBRECHT), 1889 — It occurred in small numbers at »Pelegrin« and »Stončica«. Its quantities quite insignificant.

Pontellidae

All five species of this family were rather rare and occurred in small numbers. *Pontella lobiancoi* was somewhat more numerous but quite insignificant among the other copepods.

55. *Anomalocera patersoni* TEMPLETON, 1873 — Few individuals of this species were found at »Pelegrin« in 1972.

56. *Pontella lobiancoi* (CANU), 1988 — Small numbers occasionally occurred throughout the study area.

57. *Pontella mediterranea* (CLAUS), 1863 — It was rarely recorded from the coastal and open sea areas.

58. *Labidocera wollastoni* (LUBBOCK), 1857 — Even though this species occurred rarely and in small numbers it was recorded from all the stations. Its numbers were somewhat higher in the Kaštela Bay.

59. *Pontellopsis regalis* (DANA), 1849 — Only two individuals were recorded from the open sea station in January 1970.

60. *Pontellina plumata* (DANA), 1849 — Only few individuals of this rare species were found at »Pelegrin«.

Acartiidae

Four species of this family were recorded during our investigations. *Acartia clausi* was continuously present in all the samples. It counts among the quantitatively dominant copepods in the coastal area. Other species of this family were sporadically recorded and in small numbers.

61. *Acartia clausi* GIESBRECHT, 1889 — This widely distributed surface species was recorded from all the stations. However, its percentage proportion in the total number of recorded individuals, which amounted to 83.31%, was highest at the coastal sea station.

Its frequency decreased in the offshore direction thus while it was recorded from almost all the samples in the coastal area it was found in about 66% of the »Stončica« samples.

ACARTIA (ACARTIURA) CLAUSI GIESBRECHT

								KAŠTELA BAY				
MONTH	1	2	3	4	5	6	7	8	9	10	11	12
1970	240	1440	—	—	740	440	380	160	120	20	260	1240
1971	40	500	1380	2060	260	220	60	100	260	60	80	40
1972	70	10	50	30	100	130	170	350	20	0	0	0
1973	420	460	100	620	280	440	740	120	360	120	440	1480
1974	440	360	760	1660	160	1220	920	200	620	80	1220	680
								PELEGRIN				
MONTH	1	2	3	4	5	6	7	8	9	10	11	12
1970	0	80	0	110	140	30	10	0	10	0	0	10
1971	0	40	70	80	110	40	20	20	3	10	30	0
1972	70	10	50	30	100	130	170	350	20	0	0	0
1973	10	30	150	0	120	40	420	80	40	20	0	10
1974	170	120	750	30	10	240	100	90	10	40	0	0

STONČICA

MONTH	1	2	3	4	5	6	7	8	9	10	11	12
1970	21	7	0	7	7	42	7	0	0	0	0	0
1971	2	259	35	14	42	21	0	7	7	7	0	20
1972	0	14	0	0	7	553	21	28	0	0	0	28
1973	35	42	0	63	0	42	28	56	7	2	7	7
1974	14	28	49	14	217	0	14	7	0	0	7	6

The number of individuals rapidly decreased in the offshore direction. It counts among the dominant copepods in the Kaštela Bay, where it made up about 1/5 of their total numbers. Its percentage proportion in the total copepods was also reduced going towards the open sea. However, it was relatively significant at »Pelegrin« with 5.16% and at »Stončica« with 3.39%. The numbers of this species were higher in winter and spring.

It is of interest to point out that the number of individuals continuously increased throughout the period of investigations.

62. *Acartia longiremis* (LILJEBORG), 1853 — Only three individuals were recorded from »Pelegrin« in February 1972.

63. *Acartia adriatica,* STEUER, 1910 — It was recorded only from the channel area in November 1970. It is rare Adriatic copepod.

64. *Acartia negligens* DANA, 1849 — Few individuals occurred at »Stončica« in January 1970.

Oithonidae

Three species of this family were determined. They are listed under the common genus name.

These three species occurred at all the stations in almost the same quantities. Their quantity was slightly higher in the Kaštela Bay.

OITHONA SP.

KAŠTELA BAY

MONTH	1	2	3	4	5	6	7	8	9	10	11	12
1970	40	60	—	—	160	320	60	280	220	100	180	180
1971	60	130	20	20	40	120	60	220	180	80	0	340
1972	80	140	40	120	80	440	280	340	100	60	0	20
1973	140	0	60	40	0	120	420	360	120	20	0	0
1974	220	100	180	120	40	80	80	220	20	360	120	440

PELEGRIN

MONTH	1	2	3	4	5	6	7	8	9	10	11	12
1970	40	40	180	310	80	100	180	130	270	220	180	180
1971	20	30	90	100	120	40	150	140	160	70	30	70
1972	90	70	60	40	130	230	140	270	70	130	90	50
1973	290	150	50	40	30	70	140	120	210	80	40	150
1974	140	80	50	70	20	30	230	320	130	120	140	150

STONČICA

MONTH	1	2	3	4	5	6	7	8	9	10	11	12
1970	161	35	84	189	252	539	238	322	252	168	126	56
1971	35	42	49	126	35	56	35	98	91	63	63	49
1972	70	0	21	21	28	70	91	112	203	70	98	28
1973	56	112	49	133	140	35	273	252	273	133	63	112
1974	119	189	126	126	84	28	21	98	42	56	119	84

Frequency of occurrence was also high at all the stations.

The species 65. *Oithona nana* GIESBRECHT, 1892 was most numerous in the Kaštela Bay. Percentage proportion of the species 66. *Oithona helgolandica* (CLAUS), 1863 and 67. *Oithona plumifera* BAIRD, 1843 increased going towards the open sea.

Ectinosomidae

Only one species of this family was occasionally recorded and in small numbers.

68. *Microsetella norvegica* (BOECK), 1864 — Even though recorded from all the stations this species is very rare and occurs in small numbers.

It was recorded once from the Kaštela Bay and twice from Pelegrin and Stončica.

Macrosetellidae

69. *Macrosetella gracilis* (DANA), 1852 — It is the only species of this family. It occurred at all the stations but rarely and in small numbers. Its numbers were somewhat higher in the Kaštela Bay.

Tachydiidae

70. *Euterpina acutifrons* (DANA), 1852 — It is also the only species of this family, occurring rather rarely and in small numbers. Only two individuals were found at the open sea station in 1971. Considerably greater numbers were recorded from the coastal area. Its quantities were quite insignificant.

Clytemnestridae

71. *Clytemnestra rostrata* (BRADY), 1883 — It is the only species of this family. Small number of individuals occurred only once at each of the stations.

Oncaeidae

A total of seven species of this family were recorded of which five are given under the common genus name.

72. *Oncea venusta* PHILIPPI, 1843 — It was recorded from time to time and in small numbers from all the stations.

73. *Oncaea mediterranea* (CLAUS), 1863 — Frequency, number of individuals and percentage proportion of this species considerably increased going towands the open sea. However, its quantities were insignificant at »Stončica«, either.

74. *Oncaea media* GIESBRECHT, 1891 — It is one of the best represented species of this family. It occurred at all the stations and in greatest numbers in the open sea.

75. *Oncaea dentipes* GIESBRECHT, 1892 — Only few individuals were recorded from »Kaštela Bay« and »Pelegrin«.

76. *Oncaea subtilis* GIESBRECHT, 1892 — It was recorded from all three stations. The highest number of individuals occurred in the coastal waters at the »Kaštela Bay« station.

ONCAEA SP.

								KAŠTELA BAY				
74 MONTH	1	2	3	4	5	6	7	8	9	10	11	12
1970	5	0	—	—	0	20	0	20	20	0	0	0
1971	0	0	0	0	0	20	0	20	60	0	0	20
1972	5	20	5	0	20	0	5	0	0	20	0	5
1973	40	40	5	40	0	0	0	0	0	0	0	0
1974	0	0	20	0	0	0	0	40	0	0	20	20
								PELEGRIN				
MONTH	1	2	3	4	5	6	7	8	9	10	11	12
1970	80	30	120	40	10	70	60	160	40	20	0	80
1971	10	3	50	3	20	60	10	20	20	20	0	0
1972	10	20	30	30	120	30	40	30	60	20	80	90
1973	130	20	0	40	40	40	20	40	100	130	0	70
1974	50	10	40	10	10	10	20	10	20	20	10	0
								STONČICA				
MONTH	1	2	3	4	5	6	7	8	9	10	11	12
1970	42	14	49	42	35	70	70	98	140	84	59	35
1971	28	2	28	42	7	35	28	28	0	28	56	7
1972	35	21	35	14	35	56	84	154	63	21	133	56
1973	49	63	28	98	28	7	49	112	196	217	7	49
1974	133	35	14	42	35	84	21	56	56	21	49	21
								KAŠTELA BAY				
76 MONTH	1	2	3	4	5	6	7	8	9	10	11	12
1970	20	0	—	—	0	80	0	40	20	5	60	20
1971	5	0	20	5	20	120	20	80	140	80	5	5
1972	20	5	0	0	20	20	5	20	60	5	0	20
1973	0	0	20	0	0	0	80	0	0	100	40	0
1974	20	20	20	80	20	0	5	160	5	20	20	20
								PELEGRIN				
MONTH	1	2	3	4	5	6	7	8	9	10	11	12
1970	30	30	110	120	20	30	3	20	10	20	90	30
1971	20	30	20	0	20	20	10	0	3	80	50	30
1972	20	50	10	20	50	30	10	10	70	10	30	0
1973	30	20	10	40	0	0	20	10	10	50	10	20
1974	50	70	70	40	40	0	20	0	10	20	70	40
								STONČICA				
MONTH	1	2	3	4	5	6	7	8	9	10	11	12
1970	63	0	7	21	0	7	7	21	98	77	21	28
1971	28	0	42	70	28	28	21	133	7	28	35	35
1972	7	42	21	14	21	42	28	28	14	21	35	35
1973	35	14	14	42	0	28	7	21	7	42	7	63
1974	7	35	35	105	21	42	28	7	14	42	28	0

77. *Lubbockia squillimana* CLAUS, 1863 — Its frequency increased going offshore. The number of individuals and percentage proportion among the other copepods was considerably high at »Pelegrin«.

78. *Pachos punctatum* (CLAUS), 1863 — Only three individuals of this rare species were noted at »Pelegrin« in October 1970.

Sapphirinidae

A total of seven species of this family belonging to Sapphirina genus were determined in the study area:

79. *Sapphirina gemma* DANA, 1849

80. *Sapphirina iris* (DANA), 1849

81. *Sapphirina metallina* DANA, 1849

82. *Sapphirina nigromaculata* CLAUS, 1863

83. *Sapphirina ovatolanceolata* DANA, 1849

84. *Sapphirina opalina* DANA, 1849

85. *Sapphirina sali* FARRAN, 1929

Other species of this family are given in tables under common genus name. They occurred occasionally and in small numbers. Their frequency and numbers increased going towards the open sea.

Corycaeidae

There were recorded 11 species of this family. However, only few of them occurred in greater numbers and all year long.

88. *Corycaeus clausi* DAHL, 1849 — It was not recorded from the Kaštela Bay and only three individuals were found at »Pelegrin«. It occurred somewhat more frequently in the open sea. Even though its numbers were much higher in the open sea it was quite insignificant among the other copepods.

89. *Corycaeus limbatus* BRADY, 1888 — Very rare species. It was recorded only once from »Pelegrin« and on several occasions from »Stončica«.

90. *Corycaeus typicus* (KRÖYER), 1849 — It is widely distributed species recorded throughout the study area. It occurred in almost the same numbers at all three stations (from 30.61% to 34.70%).

Its frequency increased going towards the open sea. In the Kaštela Bay it was recorded from more than half the samples.

Its quantities were highest of all the species of *Corycaeus* genus determined during our investigations. The number of individuals increased going towards the open sea.

Greater numbers were recorded during the warmer part of the year.

Its percentage proportion in the total copepod numbers also increased going towards the open sea reaching 3.23% at »Stončica«.

No regular variation pattern could be established during our investigations since the number of individuals was alternatively reduced and increased.

91. *Corycaeus flaccus* GIESBRECHT, 1891 — Its percentage proportion was highest in the open sea where it made up 50.5% of the total number of recorded individuals.

Its frequency suddenly increased at the channel station, where its quantity increase was also noted. In addition, its percentage proportion in the total copepod numbers wal also increased reaching 1.48% at Stončica.

CORYCAEUS (AGETUS) FLACCUS GIESBRECHT

KAŠTELA BAY

MONTH	1	2	3	4	5	6	7	8	9	10	11	12
1970	20	0	—	—	0	0	0	0	5	0	0	20
1971	0	0	0	0	0	0	0	0	0	20	0	0
1972	0	0	0	0	5	0	0	0	0	0	0	0
1973	0	0	0	0	0	0	0	0	0	0	0	0
1974	0	0	20	20	0	0	0	0	0	0	0	0

PELEGRIN

MONTH	1	2	3	4	5	6	7	8	9	10	11	12
1970	30	20	60	0	10	10	20	10	10	3	3	3
1971	0	30	10	20	20	0	10	50	0	0	40	0
1972	20	40	3	0	0	0	0	3	3	20	3	0
1973	10	10	0	0	20	50	0	10	0	0	10	3
1974	10	3	10	10	10	20	20	0	0	3	20	10

STONČICA

MONTH	1	2	3	4	5	6	7	8	9	10	11	12
1970	14	7	42	7	7	21	7	7	21	49	21	7
1971	0	0	14	0	0	0	0	7	7	0	0	0
1972	0	28	7	7	7	0	7	2	21	0	2	14
1973	42	0	7	7	0	0	7	14	7	28	14	42
1974	28	42	14	21	7	42	21	7	42	21	42	28

92. *Corycaeus giesbrechti* DAHL, 1849 — This species was recorded only once from the Kaštela Bay and from Pelegrin, and on four occasions from »Stončica«.

93. *Corycaeus latus* (DANA), 1849 — It occurred only occasionaliy and in small numbers. Its numbers were highest at Pelegrin, however insignificant.

94. *Corycaeus ovalis* CLAUS, 1863 — Only few individuals were recorded from each of the stations. The smallest numbers were found at Pelegrin.

95. *Corycaeus anglicus* LUBBOCK, 1855 — It was recorded on two occasions from »Pelegrin«, in 1972 and 1974.

96. *Corycaeus brehmi* STEUER, 1910 — It was recorded throughout the study area. Its percentage proportion in the total number of recorded individuals was highest in the Kaštela Bay (58.13%).

It was found in slightly more than half the samples in the coastal area. It was even more frequent at other two stations.

The highest quantities occurred in the coastal area, and the number of individuals was gradually reduced going offshore.

It made up 1% of the total copepod numbers in the Kaštela Bay. Going offshore this proportion was reduced and insignificant.

97. *Corycaeus furcifer* CLAUS, 1863 — It was very rare in the coastal area, present in about 1/3 of the samples in the channel area and in more than 70% in the open sea.

The number of individuals was also considerably higher in the open sea than in the coastal area. However its proportion in the total copepod number is not significant.

The lowest number of individuals was recorded in summer.

CORYCAEUS (DITRICHOCORYCAEUS) BREHMI STEUER

KAŠTELA BAY

MONTH	1	2	3	4	5	6	7	8	9	10	11	12
1970	20	0	—	—	80	60	20	40	100	0	60	20
1971	0	0	0	0	0	100	100	0	0	0	0	0
1972	0	5	5	5	40	0	20	60	0	0	0	0
1973	0	0	0	20	20	0	20	120	140	0	40	0
1974	0	0	5	40	20	0	0	20	60	40	40	20

PELEGRIN

MONTH	1	2	3	4	5	6	7	8	9	10	11	12
1970	10	3	60	0	20	50	0	0	0	20	3	0
1971	0	0	10	10	10	10	10	0	10	0	10	3
1972	0	10	0	0	0	30	10	0	0	0	10	10
1973	20	0	10	0	0	60	0	0	10	30	10	0
1974	3	10	20	0	10	20	10	10	10	20	30	10

STONČICA

MONTH	1	2	3	4	5	6	7	8	9	10	11	12
1970	0	0	0	7	0	14	0	0	0	14	7	14
1971	14	0	0	0	7	7	7	0	0	14	7	2
1972	0	7	7	0	0	21	7	2	0	0	21	21
1973	0	0	0	0	7	7	0	14	14	35	7	0
1974	2	0	7	14	14	0	0	0	7	14	14	7

98. *Corycella rostrata* CLAUS, 1863 — It was recorded from all three stations and its percentage was lowest in the Kaštela Bay.

Its frequency also increased going towards the open sea, thus that it was recorded from more than 75% of the samples at »Stončica«.

Its quantities were lower in the coastal area.

Percentage proportion in the total copepod number increased going offshore, from 0.16 to 1.01 and 1.53%.

CORYCAEUS (CORYCELLA) ROSTRATA CLAUS

KAŠTELA BAY

MONTH	1	2	3	4	5	6	7	8	9	10	11	12
1970	0	0	—	—	0	0	0	0	0	5	40	20
1971	0	0	20	0	0	20	0	0	0	0	0	0
1972	0	0	5	0	5	40	0	0	0	0	0	0
1973	0	0	0	0	0	0	0	0	0	0	20	0
1974	0	0	0	0	0	0	0	0	0	0	40	20

PELEGRIN

MONTH	1	2	3	4	5	6	7	8	9	10	11	12
1970	30	30	0	80	10	3	10	20	10	10	3	3
1971	0	20	30	0	0	0	0	0	3	10	30	10
1972	50	20	0	10	10	0	20	10	40	0	0	0
1973	40	3	0	0	10	20	0	10	0	30	10	40
1974	20	10	40	20	10	10	10	10	20	10	20	20

STONČICA

MONTH	1	2	3	4	5	6	7	8	9	10	11	12
1970	7	14	7	14	0	0	14	0	21	21	56	14
1971	21	0	21	21	0	7	7	7	7	35	7	42
1972	7	14	7	0	0	0	0	7	35	28	2	28
1973	35	7	7	28	0	0	2	21	21	35	14	28
1974	21	21	21	14	7	7	7	7	7	21	0	28

COPEPODITS AND OTHER COPEPODS

KAŠTELA BAY

MONTH	1	2	3	4	5	6	7	8	9	10	11	12
1970	380	160	—	—	260	160	100	140	420	180	140	180
1971	80	100	580	480	740	760	260	260	220	160	20	40
1972	140	60	100	360	500	240	80	300	140	360	40	540
1973	120	360	360	480	280	240	260	260	220	140	20	20
1974	240	340	160	980	260	660	280	20	60	100	360	680

PELEGRIN

MONTH	1	2	3	4	5	6	7	8	9	10	11	12
1970	190	50	110	140	60	20	190	210	240	90	130	210
1971	60	90	370	40	530	130	80	60	20	60	80	10
1972	120	230	230	320	210	270	40	60	50	60	190	50
1973	40	140	110	290	20	470	10	10	140	30	50	160
1974	60	80	290	140	390	410	210	80	210	30	180	30

STONČICA

MONTH	1	2	3	4	5	6	7	8	9	10	11	12
1970	91	42	91	133	63	168	63	112	28	133	168	49
1971	42	336	84	483	301	133	112	28	63	21	28	28
1972	28	35	77	35	168	133	105	91	28	35	182	189
1973	7	112	98	23	266	301	196	168	7	112	105	147
1974	98	49	63	68	28	14	133	122	133	126	35	161

DISCUSSION

1. *Horizontal distribution of copepods in the coastal area of the middle Adriatic*

A total of 98 species were recorded from the coastal area of the middle Adriatic during five years of investigations. Their number by stations was af follows:

»Kaštela Bay«	53 species
»Pelegrin«	91 species
»Stončica«	90 species

Copepod species number is apparently lower in the coastal waters than at the channel and open sea stations between which there is no significant difference.

Of 53 species recorded from the Kaštela Bay only 20 species are widely distributed in other similar areas along the eastern Adriatic coast (Gamulin, 1939, 1948; Vučetić, 1957, 1958, 1960, 1961a, b, 1965, 1966a, 1969; Hure & Scotto di Carlo, 1969b, 1977, 1979; Regner, D., 1970, 1973, 1974,

1976; Buljan, Hure & Pucher-Petković, 1973; Vukanić, 1971, 1975).

The observations of frequency of occurrence of these species showed that species permanently present in all the samples throughout the period of investigations were: *Centropages typicus* and *Acartia clausi. Paracalanus parvus, Clausocalanus arcuicornis, Clausocalanus jobei, Ctenocalanus vanus, Centropages kröyeri* and *Temora stylifera* were recorded from more than 75% of the samples. They were recorded throughout the year and were only occasionally absent. They are mainly »surface species widely distributed in all inshore Adriatic areas, except along the southeastern coast where they are more rare« — Hure & Scotto di Carlo, 1977.

The following copepods were recorded from 50—75% of the samples: *Calanus tenuicornis, Diaixis pygmaea, Isias clavipes, Temora longicornis, Candacia armata* and *Corycaeus typicus,* and the following from 25—50% of the samples: *Calanus helgolandicus, Calocalanus pavo, Mecynocera clausi, Clausocalanus furcatus.* Other species occurred more rarely.

The species *Neocalanus gracilis, Eucalanus elongatus, Euchaeta hebes, Lucicutia flavicornis, Clytemnestra rostrata, Lubbockia Squillimana, Sapphirina nigromaculata, Corycaeus flaccus* and some others occurred in the Kaštela Bay predominantly in winter. This may be due to the current system by which the open sea water is carried into the Bay particularly in winter (Zore-Armanda, 1974).

A total of 91 species were recorded from »Pelegrin« station situated in the channel area of the middle Adriatic. The following species were recorded from more than 75% of the samples: *Calanus tenuicornis, Mecynocera clausi, Clausocalanus arcuicornis, Clausocalanus jobei, Clausocalanus furcatus, Ctenocalanus vanus, Centropages typicus, Temora stylifera* and *Corycaeus typicus.*

Some of these most frequent copepods occurred more frequently in the open sea (*C. tenuicornis, M. clausi*) while some are widely distributed coastal surface species and some, such as *Ctenocalanus vanus,* are species widely distributed in the Adriatic (Hure & Scotto di Carlo, 1977). This species composition was to be expected owing to the location of this station in the middle Adriatic channels affected both by the open sea and coastal waters. Species recorded from 50—75% of the samples were: *Nannocalanus minor, Calocalanus pavo, Euchaeta hebes, Lucicutia flavicornis, Candacia armata, Corycaeus flaccus, Corycaeus brehmi* and *Corycella rostrata* which mainly are, except *C. armata, C. brehmi* and *C. rostrata,* more frequent in the open sea. *Paracalanus parvus, Ischnocalanus plumulosus, Clausocalanus mastigophorus, Clausocalanus lividus, Diaixis pygmaea, Pleuromamma gracilis, Corycaeus latus* and *Corycaeus furcifer* were found in less than 50% of the samples in which the open sea species were also predominant (except *Paracalanus parvus* and *Diaixis pygmaea).* Other species were more rare. It may be of interest to mention that a large number of species (about 30) occurred in only one sample or, at most, in the several of them thoughout the period of investigations. The majority of the Adriatic species are mainly recorded from a small number of samples. Pelagic species occurred in somewhat smaller quantities. Some widely distributed species and few coastal species

were rarely recorded. However, they occurred in very low numbers particularly if compared to the abovementioned species.

Number of species recorded from this station exceeded for about 40 that recorded from the Kaštela Bay. However, one can understand this easily since these species are predominantly open sea species and »Pelegrin« is affected by the ingoing Adriatic current for the most part of the year.

Out of the total of 90 species recorded from »*Stončica*« which is strongly affected by the open sea, the following copepods were found in more than 75% of the samples: *Nannocalanus minor, Calanus tenuicornis, Mecynocera clausi, Clausocalanus arcuicornis, C. jobei, C. furcatus, Ctenocalanus vanus, Centropages typicus, Corycella rostrata.* The following species occurred in 50—75% of the samples: *Calocalanus pavo, Ischnocalanus plumulosus, Clausocalanus mastigophorus, Euatideus giesbrechti, Euchaeta hebes, Pleuromamma gracilis, Candacia armata, Acartia clausi, Corycaeus flaccus, Corycaeus brehmi* and *Corycaeus furcifer,* and the following in less than 50% of the samples: *Clausocalanus lividus, Clausocalanus pergens, Clausocalanus parapergens, Aetideus armatus, Scolecithrix bradyi, Scolecithricella dentata, Diaixis pygmaea, Centropages violaceus, Lucicutia ovalis, Haloptilus longicornis, Lubbockia squillimana* and *Corycaeus latus.* Other species were rather rarely recorded.

A part of the most frequent species at this station are widely distributed Adriatic species occurring in large quantities (Hure and Scotto di Carlo, 1977) and a part are the open sea species (*N. minor, C. tenuicornis, M. clausi, L. flavicornis* and some other).

From the data on the horizontal copepod distribution in the study area of the middle Adriatic and the results of current system investigations in the same area (Zore-Armanda, 1974, 1977), the occurrence of open sea species along the coast during winter is probably due to the intensified inflowing current from the southern Adriatic in winter. On the other side, the occurrence of neritic species at »Pelegrin« and »Stončica« may be explained in terms of horizontal distribution of surface neritic copepods which, owing to the stronger outgoing current, are in summer dispersed from neritic areas of the northern Adriatic into the open waters of the middle and southern Adriatic (Hure and Scotto di Carlo, 1977), and partly in terms of the W prevalent direction of surface current which forces the inshore water masses towards the open sea (Zore-Armanda, 1968; Vučetić, 1970, 1973).

2. *Species composition variations*

2.1. Seasonal variations of species composition

Observations of the number of copepod species showed considerable variations both by seasons and for the period of investigations.

In the Kaštela Bay the number of species ranged from 7 to 21 (with the exception of species taken under common genera names). Minima and maxima occurred as follows:

1970	11 (July)	to	21 (January)
1971	11 (May)	to	20 (December)
1972	8 (November)	to	19 (January)
1973	7 (January)	to	15 (November)
1974	9 (June)	to	19 (November, Decembrer)

Accordingly, the highest numbers were recorded in the coastal area in winter what is in agreement with the earlier results (Gamulin, 1939; Regner, D., 1970, 1973). The lowest numbers were recorded in spring-summer (May, June, July) and in autumn—winter (November, January).

The number of species varied from 9 to 30 at »Pelegrin«:

1970	19 (November)	to	30 (January, May)
1971	9 (August)	to	26 (November)
1972	14 (August)	to	30 (December)
1973	14 (April, July)	to	30 (January)
1974	19 (August)	to	29 (March)

The highest numbers were also recorded in autumn and winter (September, November, December, January) and the lowest mainly in summer (except in 1970).

The number of copepods varied from 18 to 42 at »Stončica« according to the pattern similar to those at two preceding stations:

1970	18 (August)	to	42 (January)
1971	18 (February)	to	31 (July, September)
1972	20 (April, October)	to	27 (December)
1973	19 (May)	to	32 (November)
1974	20 (July)	to	32 (January)

Maxima were recorded here at the same time of the year and, even more so, the same months as at two preceding stations with the exception of 1971.

Annual variations of species number for all the stations and for the period of investigations are given in Fig. 2. To observe the seasonal variation pattern of the number of species it was attempted to express the data as the five year means (Fig. 3). Thus it was made clearer that maximum numbers of species occurred at all three stations in winter, mainly in January and February that is in the period of intensified open sea influence on mid-Adriatic area.

Minimum numbers of species occurred mainly in spring (April, May) and summer (July, August). They were recorded first in the Bay and a month or two later in the channel area and open sea respectively.

2.2. Year-to-year variations of species composition

Long-term variations of species composition were also studied.

Out of 42 copepod species individually observed (with the exception of three genera which included 11 species more) only 17 were recorded every year while other 25 species were not recorded from all the Kaštela Bay samples.

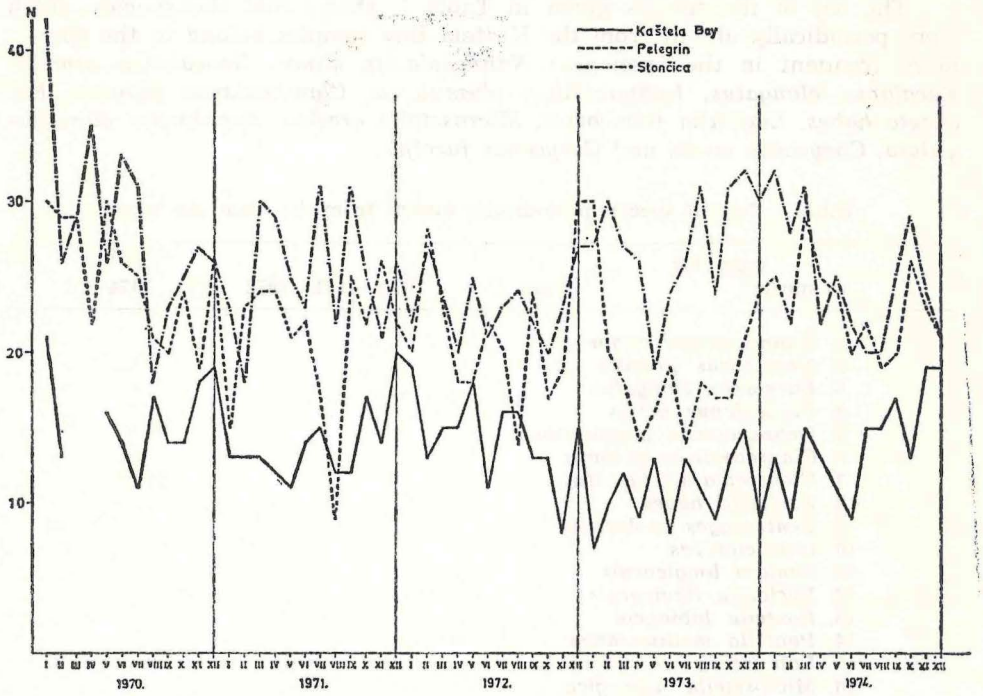

Fig. 2. Variations of copepod numbers in the study area in 1970—1974

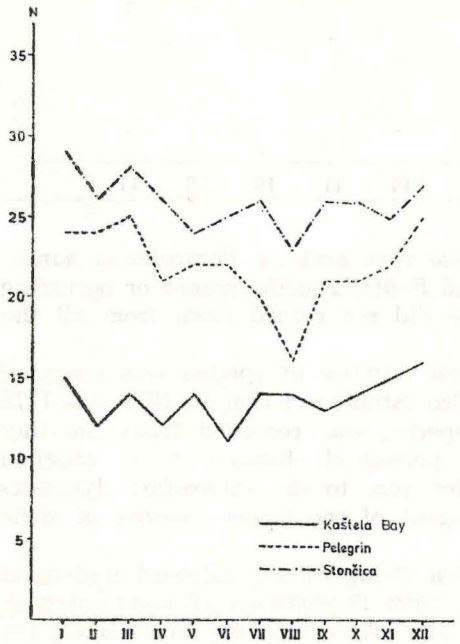

Fig. 3. Annual variations of copepod number in the study area (means for 1970—1974)

The list of the species given in Table 1. shows that the species which were periodically absent from the Kaštela Bay samples belong to the species more frequent in the open sea: *Nannocalanus minor, Neocalanus gracilis. Eucalanus elongatus, Ischnocalanus plumulosus, Clausocalanus pergens, Euchaeta hebes, Lucicutia flavicornis, Microsetella gracilis, Sapphirina nigromaculata, Corycaeus ovalis* and *Corycaeus furcifer.*

Table 1. List of species periodically absent from the »Kaštela Bay«

samples / species — year:	1970	1971	1972	1973	1974
1. *Nannocalanus minor*				.	.
2. *Neocalanus gracilis*	.		.	.	.
3. *Eucalanus elongatus*	.		.	.	.
4. *Paracalanus nanus*		.	.		
5. *Ischnocalanus plumulosus*			.		
6. *Clausocalanus pergens*	.	.		.	
7. *Clausocalanus furcatus*				.	
8. *Euchaeta hebes*	.			.	
9. *Centropages violaceus*	.		.	.	.
10. *Isias clavipes*				.	
11. *Temora longicornis*		.			
12. *Lucicutia flavicornis*			.	.	
13. *Pontella lobiancoi*			.	.	.
14. *Pontella mediterranea*	.	.		.	.
15. *Labidocera wollastoni*	.	.		.	
16. *Microsetella norvegica*	.	.		.	.
17. *Macrosetella gracilis*	.	.		.	
18. *Clytemnestra rostrata*	.	.	.	.	
19. *Lubbockia squillimana*				.	.
20. *Sapphirina nigromaculata*	.	.		.	.
21. *Corycaeus flaccus*	.	.		.	.
22. *Corycaeus giesbrechti*	.	.			.
23. *Corycaeus latus*	.				
24. *Corycaeus ovalis*	.	.	.		.
25. *Corycaeus furcifer*			.		
total number of missing species	14	11	10	18	11

A part of other species are otherwise rare such as *Paracalanus nanus, Temora longicornis, Pontella lobiancoi* and *Pontella mediterranea* or occurring in low numbers. Therefore, probably we did not record them from all the samples.

Over the five-year period the highest number of species was recorded in 1972 and the lowest in 1973. It was also established that in 1971 and 1972 the highest number of the open sea species was recorded from the Bay station. This may be indicative of the periodical changes of the copepod species composition at this coastal station due to the intensified dynamics of the open sea water masses and transport of the larger number of some of the species to the coastal area.

The hydrography of the Adriatic Sea (temperature, salinity) undergoes considerable variations due to the long term fluctuations of meteorological factors (wind, atmospheric pressure) (Zore-Armanda, 1969; Buljan

1969). One major factor affecting the Adriatic hydrographic properties is intensified ingression of the Intermediate Mediteranean Water (such as in 1963, 1964, and 1965) associated with the meteorological factors changes. The ingressions cause nutrient and oxygen enrichment of the Adriatic waters. It was established that climatic and hydrographic factors were further in close connexion with the biological production level and therefore with the increase of phyto— and zooklankton values in 1961 to 1966 period (Pucher-Petković, 1966, 1968, 1969; Vučetić, 1965, 1969). Therefore, we tried here to observe year-to-year changes of copepod species composition in the 1970—1974 period and relate them to temperature and salinity annual mean values (Table 2).

Table 2. Annual mean temperature and salinity values, departures from five year means and the number of copepod species recorded from a) Kaštela Bay, b) Pelegrin, c) Stončica

year	T°C	departures from means	S ‰	departures from means	number of copepod species
1970	16.53	0.01	35.74	— 0.51	29 + 3
1971	16.55	0.03	36.34	0.09	32 + 3
1972	16.80	0.28	36.08	— 0.17	33 + 2
1973	16.39	— 0.13	36.13	0.78	25 + 2
1974	16.35	— 0.17	36.09	— 0.16	32 + 3
mean value	16.52		36.08		a)

year	T°C	departures from means	S ‰	departures from means	number of copepod species
1970	17.20	— 0.16	37.75	— 0.13	58 + 3
1971	17.14	— 0.22	37.97	0.09	54 + 2
1972	17.45	0.09	37.83	— 0.05	57 + 2
1973	17.47	0.11	38.09	0.21	44 + 2
1974	17.52	0.16	37.78	— 0.1	55 + 3
mean value	17.36		37.88		b)

year	T°C	departures from means	S ‰	departures from means	number of copepod species
1970	17.78	— 0.15	38.18	0.05	56 + 3
1971	18.17	0.24	38.12	— 0.01	56 + 2
1972	17.87	— 0.06	38.11	— 0.02	57 + 3
1973	18.12	0.19	38.26	0.13	64 + 3
1974	17.73	— 0.20	37.96	— 0.17	53 + 3
mean value	17.93		38.13		c)

Thus it was found that temperature slightly increased in the Kaštela Bay up to 1972 to be decreased in 1973 and minimum in 1974. Salinity

alternatively increased and decreased reaching maximum in 1973. Number of copepod species increased up to 1972, decreased in 1973 and again increased in 1974. Accordingly, prominent changes of hydrographic factors could not be established during the period of our investigations and therefore neither the significant annual variations of copepod species numbers.

A total of 83 species and 3 genera with 8 species (that is 91) were identified at »Pelegrin« station. The highest number was recorded in 1970. Afterwards this number was alternatively increased and decreased and reached minimum in 1973 (Table 2). Out of 83 species 29 occurred every year and 54 were periodically absent (Table 3). Out of these 54 species 23, that is somewhat less than a half, are the species more frequently occurring in the open sea. The highest number of open sea species was recorded in 1970 that is the same year as the maximum number of copepod species occurred. However no interdependence between the occurrence of these species and hydrographic environmental factors could be estabiliched. Namely, as shown by Table 2. temperature showed gradual increase in the five-year period (with a slight decrease in 1971) while salinity increased up to 1973 when it reached maximum and then decreased in 1974. The variations of the total number of species at this station are slightly in excess of those at the Kaštela Bay station. However, no significant changes affected by hydrographic factors were established here, either. The increase in the number of species in 1974 which followed the salinity increase in 1973 did not exceed earlier recorded values and could not be due to any peculiar conditions.

A total of 78 copepod species and three genera with 12 species (that is 90 species) were identified at »Stončica.« The highest number of species was recorded in 1973 and lowest in 1974. Of these 90 species 44 were periodically absent and their list is given in Table 4. About 20 species are species more frequent in the open sea. They occurred in highest number in 1972 and in lowest number in 1974. However, no interdependence between hydrographic factors annual changes and increase in the number of copepods species could be established here, either, since temperature also alternatively increased and decreased while salinity increased up to 1973 and afterwards decreased. Variations of the total numbers of copepod species at three studied stations in the 1970—1974 period are given separately in Fig. 4. Kaštela Bay and Pelegrin curves show an almost complete overlapping that is maximum number of copepod species was recorded from both stations in 1972 and sudden decrease with minimum in 1973. However, at the open sea station maximum was recorded in 1973 coinciding with the highest salinity values recorded in the five-year period (Table 2). The rhythm of the variations of copepod species numbers could not be related to salinity values since the situation in the channel area differred from that in the coastal area. It therefore seems possible that several environmental factors together affected these variations. However, these effects were not of the extent to cause any significant changes or these changes were due to the inflow of waters of quite different properties (like in 1963—65 period).

These results show that the variations of the number of copepod species in the 1970—1974 period coincided with the occurrence of the open sea species even though no considerable annual changes of environmental factors

Table 3. List of species periodically absent from »Pelegrin« station

species:	year: 1970	1971	1972	1973	1974
1. *Neocalanus gracilis*				.	
2. *Eucalanus attenuatus*		.	.	.	.
3. *Eucalanus elongatus*				.	.
4. *Paracalanus nanus*		.	.	.	
5. *Calocalanus contractus*	.				
6. *Calocalanus styliremis*	.		.	.	.
7. *Clausocalanus pergens*			.		
8. *Clausocalanus parapegens*		.			
9. *Aetideus armatus*	.			.	.
10. *Euaetideus giesbrechti*			.		
11. *Euchaeta marina*	.		.	.	.
12. *Euchaeta spinosa*	.	.	.	.	
13. *Scolecithrix bradyi*	.	.			.
14. *Scolecithricella dentata*		.			
15. *Scolethricella tenuiserrata*		.		.	
16. *Centropages kröyeri*			.	.	
17. *Isias clavipes*			.	.	
18. *Temora longicornis*	.	.			
19. *Pleuromamma abdominalis*		.		.	.
20. *Lucicutia ovalis*		.		.	
21. *Heterorhabdus papiliger*					.
22. *Heterorhabdus spinifrons*	.		.	.	.
23. *Haloptilus longicornis*				.	
24. *Candacia aethiopica*	.	.		.	.
25. *Candacia bippinata*		.		.	.
26. *Candacia tenuimana*		.	.	.	.
27. *Candacia bispinosa*			.	.	.
28. *Candacia varicans*		.	.	.	.
29. *Paracandacia simplex*					.
30. *Anomalocera patersoni*	.	.		.	.
31. *Pontella lobiancoi*	.		.	.	
32. *Pontella mediterranea*	.		.	.	
33. *Labidocera wollastoni*	.		.	.	.
34. *Pontellina plumata*	.	.			.
35. *Acartia adriatica*		.	.	.	.
36. *Acartia longiremis*		.	.		.
37. *Microsetella norvegica*	.	.		.	.
38. *Macrosetella gracilis*			.	.	.
39. *Euterpina acutifrons*		.	.	.	
40. *Clytemnestra rostrata*	.	.	.	.	
41 *Sapphirina* sp.	.			.	.
42. *Sapphirina metallina*		.	.		
43. *Sapphirina sali*		.			.
44. *Sapphirina nigromaculata*	.	.		.	.
45. *Sapphirina gemma*	.				
46. *Sapphirina ovatolanceolata*	.		.	.	.
47. *Sapphirina opalina*		.		.	.
48. *Copilia mediterranea*	.	.		.	.
49. *Copilia quadrata*		.		.	.
50. *Corycaeus clausi*				.	
51. *Corycaeus giesbrechti*	.	.	.	.	
52. *Corycaeus ovalis*	.	.	.		.
53. *Corycaeus limbatus*	.	.	.	.	
54. *Corycaeus anglicus*		.	.	.	.
55. *Pachos punctatum*	.	.		.	
total number of absent species:	25	31	29	40	30

Table 4. List of species periodically absent from »Stončica« station

species:	year: 1970	1971	1972	1973	1974
1. *Neocalanus gracilis*				.	.
2. *Eucalanus attenuaus*	.	.	.		
3. *Eucalanus elongatus*					.
4. *Paracalanus nanus*	.	.	.		
5. *Paracalanus parvus*			.		
6. *Calocalanus contractus*	.		.		
7. *Calocalanus styliremis*	.		.		.
8. *Clausocalanus pergens*		.			
9. *Aetideus armatus*					.
10. *Euchaeta acuta*	.				.
11. *Euchaeta marina*	.				
12. *Euchaeta spinosa*	.	.			
13. *Scolecithrix bradvi*		.			
14. *Scolecithricella tenuiserrata*		.	.	.	
15. *Centropages kröyeri*	.		.	.	
16 *Isias clavipes*			.		.
17. *Temora longicornis*		.	.		
18. *Pleuromamma abdominalis*		.	.	.	.
19. *Lucicutia clausi*	.	.	.	.	
20. *Lucicutia ovalis*		.			
21. *Heterorhabdus spinifrons*	.			.	.
22. *Candacia elongata*	.	.	.		.
23. *Candacia longimana*	.	.	.	.	
24. *Candacia bispinosa*		.		.	.
25. *Candacia tenuimana*	.	.	.		.
26. *Candacia varicans*	.	.		.	.
27. *Pontella lobiancoi*	.	.	.		
28. *Labidocera wollastoni*	.	.		.	.
29. *Pontelopsis regalis*		.	.	.	.
30. *Acartia negligens*		.	.		.
31. *Microsetella norvegica*	.		.		.
32. *Macrosetella gracilis*					.
33. *Euterpina acutifrons*	.		.	.	.
34. *Clytemnestra rostrata*	.		.	.	.
35. *Lubbockia squillimana*					.
36. *Sapphirina* sp.		.			
37. *Sapphirina metallina*		.			
38. *Sapphirina nigromaculata*	.				
29. *Sapphirina ovatolanceolata*	.			.	.
40. *Sapphirina iris*	.	.		.	.
41. *Copilia guadrata*					.
42. *Coryceaus clausi*			.		.
43. *Corycaeus limbatus*		.	.		
44. *Corycaeus giesbrechti*	.		.		.
45. *Coryceaus ovalis*	.		.	.	
total number of absent species:	24	23	24	16	25

were established which could produce significant variations of the number of species. Temperature and salinity variations were not so marked as they were in 1963—1965 period and therefore they could not affect the number of copepods. On the other hand, on the basis of such insignificant variations of copepod species numbers it could be said almost with certainty and

not knowing the hydrographic conditions of the Adriatic in that period, that in 1963—1965 period and therefore they could not affect the number since had they taken place they would have caused more considerable changes in the species composition of copepods.

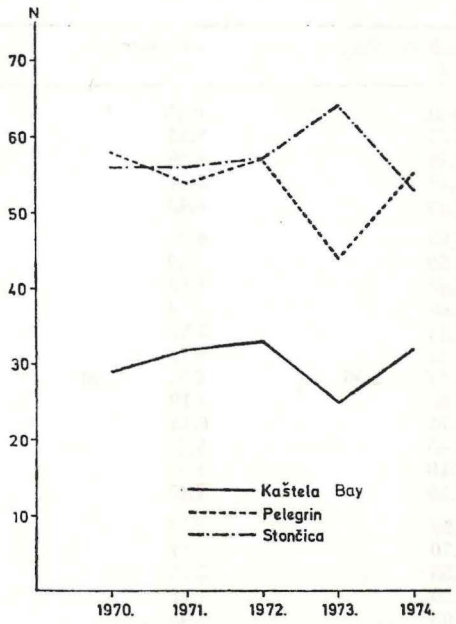

Fig. 4. Variations of the numbers of copepod species at the »Kaštela Bay«, »Pelegrin« and »Stončica« stations in the 1970—1974 period

2.3. Species diversity index

The diversity index, as a numerical experession of copepod counts in the coastal, channel and open sea areas of the middle Adriatic was evaluated from the data on seasonal and long-term variations of copepod species composition.

The diversity index was evaluated from the equation developed by Margalef (1951) calculation of the global diversity index:

$$d = \frac{S - 1}{\log_n N}$$

where S is the number of species, N number of specimens per cubic meter and $\log_n$ natural logarithm of the number of specimens. Calculated indices, their seasonal and annual variations are given separately for each of the stations in Tables 5 and 6.

»*Kaštela Bay*« — As shown by Table 5 the diversity index expressed as the relation between the number of species and number of copepods, ranged from 1.42 to 4.31 in the period od investigations. During the year the highest

Table 5. Monthly and annual values of species diversity index in the study area in 1970—1974.

	»Kaštela Bay«		»Pelegrin«		»Stončica«	
	d		*d*		*d*	
	4.31		6.35		8.85	
	2.35		6.55		7.16	
	2.77		5.20		7.19	
	2.37		3.74		8.20	
	2.90		6.43		6.22	
1970	2.90		5.85		7.16	
	2.29		5.43		7.22	
	3.55		4.69		4.22	
	2.63		4.39		5.21	
	2.52		5.52		5.72	
	3.18		4.13		6.81	
	3.62	2.95	6.51	5.40	6.60	6.71
	4.21		5.19		6.82	
	2.74		6.15		4.82	
	2.45		5.45		7.29	
	2.18		5.44		6.88	
	2.39		4.45		6.21	
1971	2.99		6.13		6.33	
	2.70		4.17		7.66	
	2.55		2.25		5.68	
	2.20		4.71		7.56	
	2.96		4.95		5.98	
	2.50		5.91		5.63	
	4.53	2.87	6.08	5.07	7.00	6.49
	4.16		4.49		5.94	
	2.47		5.54		6.73	
	3.45		4.79		5.91	
	2.95		3.83		6.01	
	3.24		4.28		6.09	
	1.97		4.51		4.27	
1972	3.42		4.29		6.01	
	2.97		3.04		5.56	
	2.46		5.14		5.13	
	2.67		3.85		5.33	
	1.42		4.36		5.46	
	3.36	2.88	7.19	4.61	6.60	5.75
	1.68		6.54		6.68	
	2.43		5.02		8.25	
	2.90		4.25		6.95	
	1.95		2.65		5.41	
	2.17		3.93		4.45	
	1.63		3.42		6.67	
1973	2.20		2.86		5.97	
	1.91		4.02		6.89	
	1.51		3.97		5.10	
	2.59		3.36		6.64	
	2.39		4.31		7.66	
	1.46	2.02	5.64	4.16	7.29	6.50

	2.48		6.31		7.42	
	1.87		4.88		6.14	
	3.17		5.92		7.57	
	2.18		5.24		4.76	
	2.58		5.52		5.74	
	1.70		3.86		4.35	
1974	2.91		5.30		4.50	
	2.89		4.19		5.40	
	2.80		4.08		5.72	
	2.64		6.00		6.53	
	3.47		4.70		6.24	
	3.64	2.69	4.67	5.06	5.34	5.81

n values were recorded in December and January, that is in winter, and the lowest values were recorded in summer. Accordingly, maximum and minimum values of diversity index coincided in time with seasonal maximum and minimum numbers of species in winter and summer respectively. The highest diversity index was found in 1970 and the lowest in 1973.

»*Pelegrin*« — showed higher species richness than the Bay. This is easily understandable since considerably higher number of species were identified from this station. Diversity index varied from 2.25 to 6.54. During the year the highest *d* was recorded in winter and from time to time in spring and autumn. Annual means were highest in 1970 and lowest in 1973.

»*Stončica*« — Diversity index varied within the 4.22—8.85 range and was also highest in winter with the exception for 1971 when it was highest in summer. The highest diversity index was calculated for 1970 and the lowet for 1972.

Table 6. Seasonal and long-term variations of species diversity index in the study area in 1970—1974

stations:	»Kaštela Bay«	»Pelegrin«	»Stončica«
parameters:			
d	2.682	4.86	6.252
max	1970	1970	1970
min	1973	1973	1972
seasonal maximum	winter, spring	winter, spring autumn	winter, spring
seasonal minimum	summer, autumn	spring, summer	summer

As shown by Table 6 species diversity index increases if one proceeds from the coast offshore. This was established also by some preliminary studies (Regner, D., 1976a) carried out in the same area. These data are, however, first long-term data on copepod species diversity index in the Adriatic. They may provide significant basis for all future copepod investigations and particularly for the studies of pollution effects on the structure of this group.

The highest species diversity index was recorded for all the stations in winter (only periodically in other seasons) and lowest in summer.

Over the five year period maximum *d* values were recorded from all the stations in 1970 and minimum in 1972 and 1973.

3. *Variations of the total number of copepods as affected by some abiotic environmental factors (temperature, salinity, seawater density)*

3.1. Seasonal variations of the number of copepods

Copepod counts also varied throughout the period of our study like did the total number of species and species composition.

The highest total number of copepods was recorded from the Kaštela Bay station. This number was considerably lower at Pelegrin and still lower at Stončica (Table 7).

Table 7. Total number of individuals (10.5 m^3) at the study area stations in 1970—1974

»Kaštela Bay«	—	133.070 individuals
»Pelegrin«	—	82.941 individuals
»Stončica«	—	54.415 individuals

This decrease of the number of individuals in an offshore direction was recorded from the same and similar areas earlier as well (Gamulin, 1939, 1948; Vučetić, 1957, 1958, 1960, 1961a, b, 1965, 1966a, 1969; Hure and Scoto di Carlo, 1969b, 1977, 1979; Regner, D., 1970, 1973, 1974, 1976; Buljan, Hure and Pucher-Petković, 1973; Vukanić, 1971, 1975). However, these data for the first time cover longer time and wider coastal area.

Therefore, we shall observe here the variations of the number of copepods during the year in as more detail as possible that is taking into account temperature, salinity and sea water density variations in the same area and at the same time (Buljan, unpublished data).

»Kaštela Bay« — even though this area was studied in detail the results on the qualitative and quantitative composition of copepods were based either on a year observations (Gamulin, 1939; Regner, D., 1973) or on the ten year series not taking into account relevant hydrographic parameters (Regner, D., 1970; Vučetić and Regner, D., 1973). Figure 5. depitcs the variations of the number of copepods in the 1970—1974 period, the variations of temperature mean values for 0—10 m layer and salinity mean values for 0—10 m layer and Fig. 6 the variations in the number of copepods and variations of sea water density.

In 1970 annual minimum number of copepods occurred in January at low temperature (12.33°C) and salinity (35.27‰). To our regret we have not available the data for March and April of this year even though graphical representation shows that the number of copepods was increased in spring. In summer, that is from July on, temperature increased and reached maximum in September. Salinity increase almost coincided with the sea water heating even though it increased up to the year end that is reached maximum in December. Sea water density was lowest in summer (from July

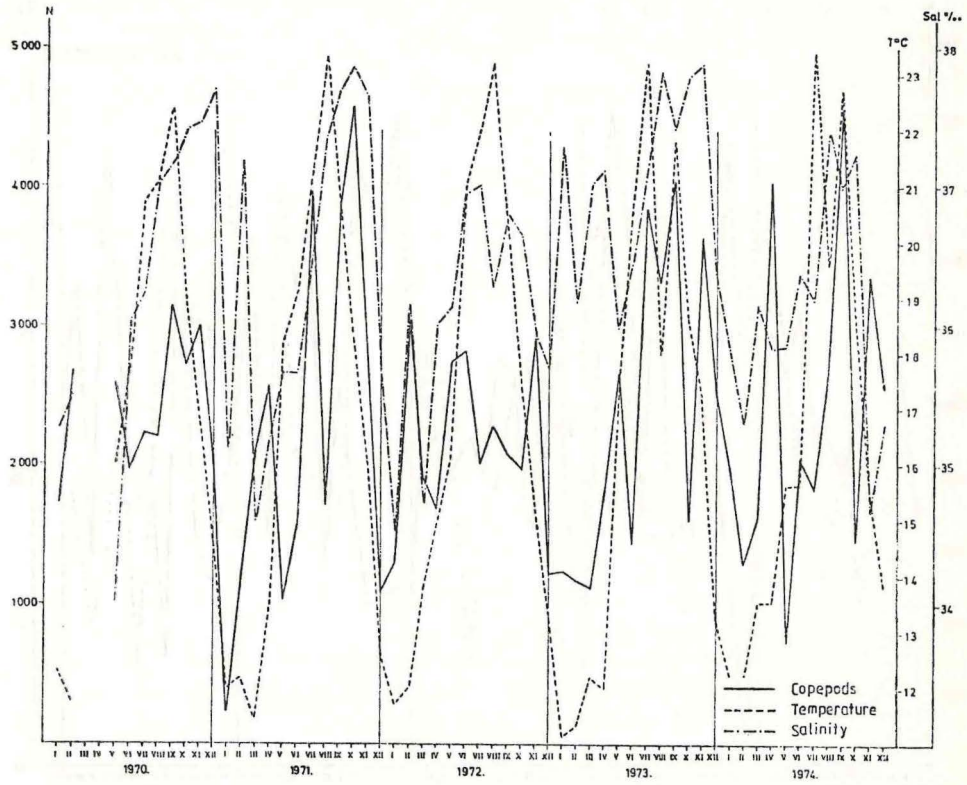

Fig. 5. Variation of the number of copepods, temperature and salinity at the »Kaštela Bay« station in 1970—1974

to September). The number of copepods started to increase in August, in September reached its secondary annual maximum coinciding vith temperature maximum. Even though copepod number was constantly high as far as December, it reached third peak in November (at maximum salinity values).

Three copepod number peaks were recorded in 1971 as well. The first one occurred also in spring — in April, second in summer — July and third and highest in autumn — October. With the exception of spring maximum which was recorded at 15°C temperature both summer and autumn maxima were recorded at highest annual values of temperature and salinity which occurred in March-October. Sea water density was also lowest in summer (in May-August).

In 1972 the number of copepods was low in January and then suddenly increased and reached first annual maximum in February following sudden salinity increase. It decreased with the gradual increase of temperature and salinity and then again increased to reach its second maximum in July, decreased once again and increased to reach third maximum in November. After that together with significant drop of temperature and reduction of

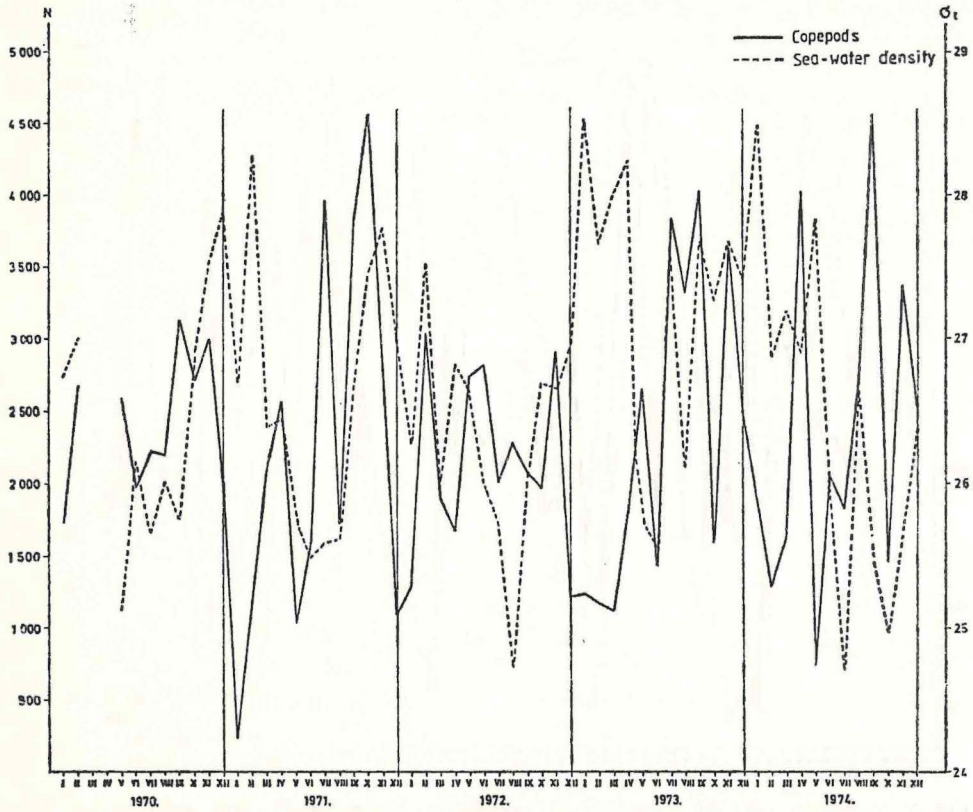

Fig. 6. Variations of the number of copepods and sea water density at the »Kaštela Bay« station in 1970—1974

salinity it decreased to the lowest value recorded this year. Sea water density was highest in February and lowest in summer.

Results of long-term researches of seasonal variations in the number of copepods differ from the earlier results for the Kaštela Bay, since Gamulin (1939), Regner, D. (1970, 1973) and Vučetić and Regner, D. (1973), reported two annual maxima of the number of copepods — in spring and summer. These most recent five-year data (1970—1974) showed the occurrence of third annual maximum in autumn which was highest from time to time.

It may be of interest to mention that similar occurrence of a larger number of maxima has recently been established in the phytoplankton of the Kaštela Bay (Pucher-Petković, 1975). This would be separately observed later.

»Pelegrin« — It has already been pointed out that this station is affected both by the coastal and open sea waters. Therefore the relationship between

the number of copepods and environmental factors could not be so clearly marked as in the Bay.

In 1970 the number of copepods showed very high spring maximum in April, sudden decrease therefrom up to June and almost unidentifiable increases in July and November. Temperature was constantly increasing from March to August and then suddenly dropped and continued to decrease up to the year end. Salinity variations showed two peaks, one in February and other higher in October. Sea water density was also lowest in summer, from June to October (Figs. 7 and 8).

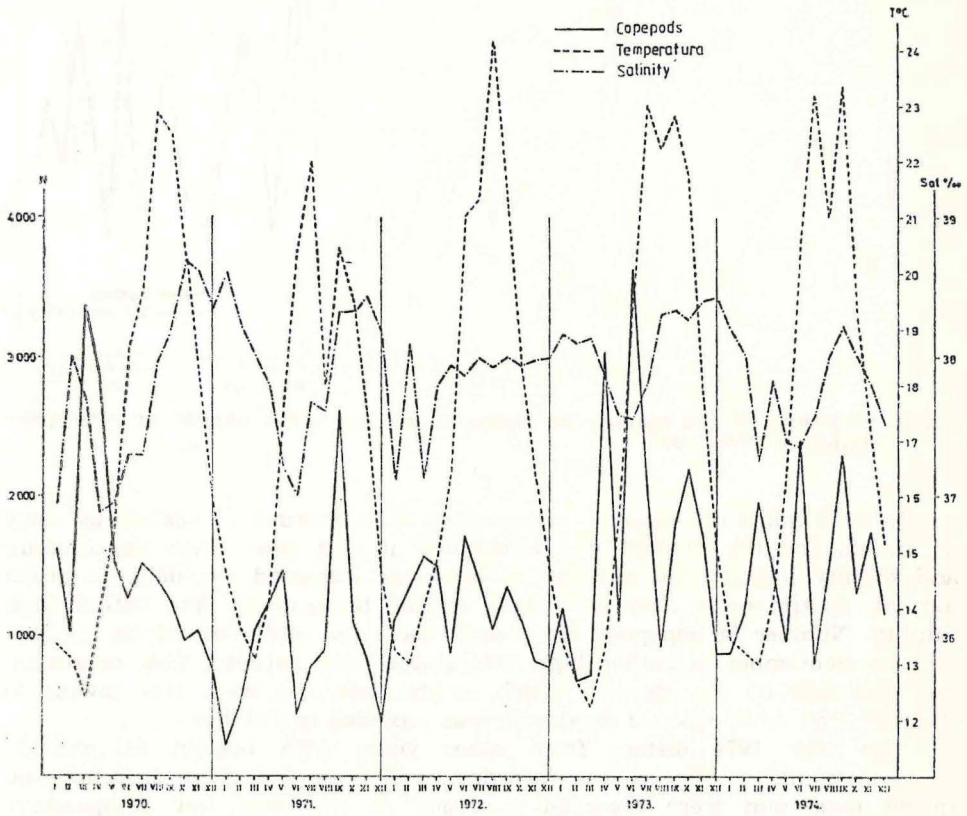

Fig. 7. Variations of the number of copepods, temperature, and salinity at »Pelegrin« station in 1970—1974

In 1971 two copepod number peaks, one in spring and other higher in autumn, were estabiliched at high salinity and temperature values.

In 1972 the number of copepods was generally low with three maxima: in March, June and September. Temperatures were very high and at the time of annual maximum in August they exceeded 24°C. The lowest salinity was recorded in March, and salinity values were very little changed in April-December. Sea water density was lowest in June and July.

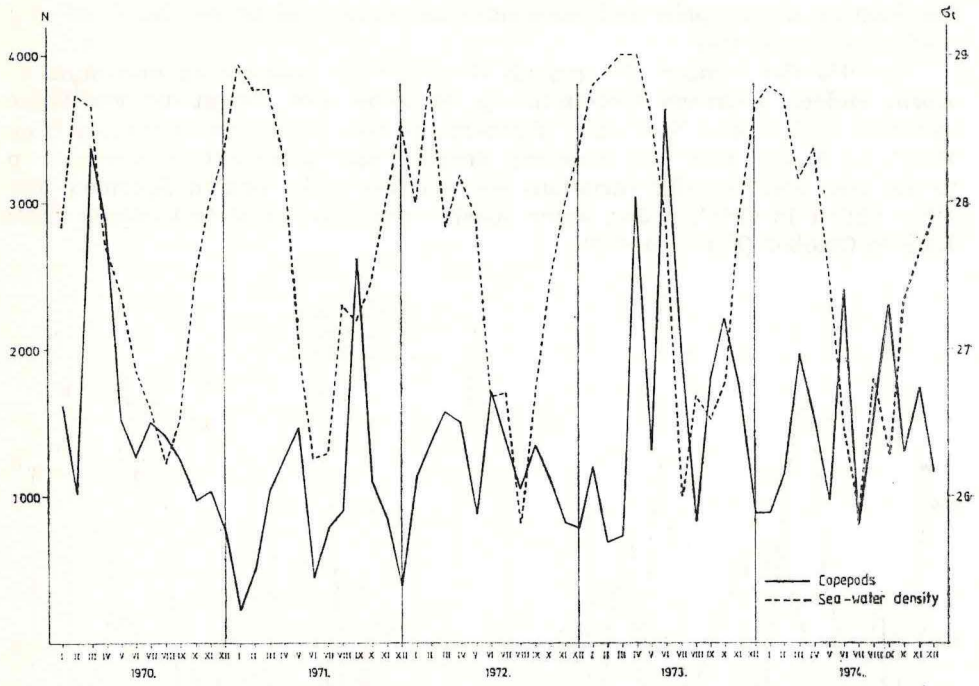

Fig. 8. Variations of the number of copepods and sea water density at »Pelegrin« station in 1970—1974

In 1973 minimum number of copepods was recorded in spring, as early as March, and temperature was fairly low at that time. With temperature and salinity increase the number of copepods increased gradually to reach autumn maximum in July at highest annual temperature and rather high salinity. Number of copepods afterwards decreased and reached the highest peak in September at rather high temperature and salinity. This maximum was preceded by low density which in this year, as well, was lowest in summer. The third copepod maximum was recorded in October.

The year 1974 differs from other years with respect to copepod number. Winter minimum was recorded in February. Sudden increase and spring maximum were recorded in April at relatively low temperature (13.55°C) and salinity (35.84‰). Seawater temperature was rather high all over the year as well as salinity while density was lowest in June-October. Summer maximum number of copepods was shifted to September and autumn maximum occurred in October.

Since all the given data as well as graphs show that the variations of copepod density during the year is dependent on the variations of temperature, salinity and sea water density this dependence was statistically analyzed and expressed. Therefore correlation coefficients were calculated and the r was highest for the correlation between the number of copepods and temperature, $r = 0.413$ and $p < 0.01$ that is significant for more than 99%.

Positive correlation was established between the number of copepods and salinity with the correlation coefficient $r = 0.312$ significant for $p < 0.05$ that is for more than 95%. Poor negative correlation between the number of copepods and sea water density was found and the correlation coefficient value was not significant, $r = -0.139$.

In 1973 the number of copepods varied considerably. As many as four peaks were recorded: in January, April, June and October. Temperature was higher during summer and salinity in spring and autumn. Density was low throughout summer, in June-October.

In 1974 four peaks were recorded like in the preceding year. However they occurred in March, June, September and November. Temperature was highest in June-September, salinity increased in winter months and in April and September. Sea water density was lowest in June-October.

The obtained results of the number of copepods did not show any regular pattern of annual variations. However, it is evident that first annual peak occurred mainly in spring and second in autumn. From 1972 to 1974 summer maxima were also recorded thus that the variations in number were still higher.

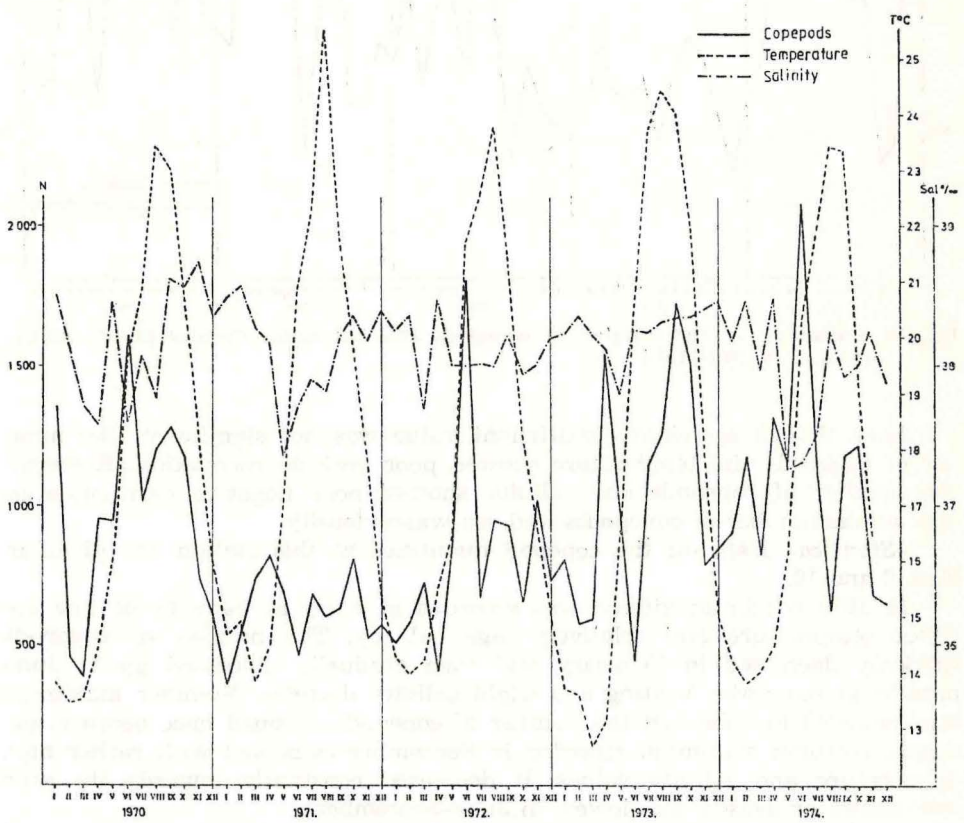

Fig. 9. Variations of the number of copepods, temperature and salinity at »Stončica« station in 1970—1974

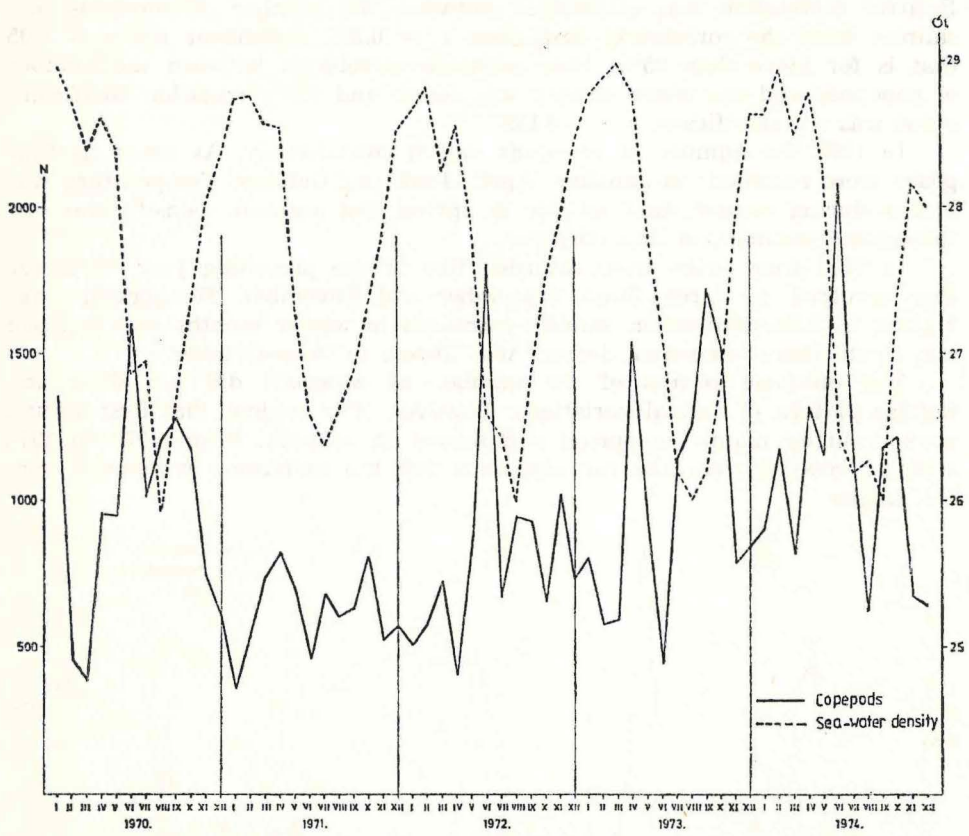

Fig. 10. Variations of the number of copepods and sea-water density at »Stončica« station in 1970—1974

Even though correlation coefficient value was not significant, the number of copepods and temperature showed poor positive correlation. However, the number of copepods and salinity showed poor negative correlation as well as the number of copepodes and sea water density.

»Stončica« Data on the copepod quantities at this station are given in Figs. 9 and 10.

In 1970 winter maximum was recorded as early as January at low sea water temperature and relatively high salinity. The number of copepods suddenly decreased in February and then gradually increased up to June parallel to sea water heating and slight salinity decrease. Summer maximum was recorded in June and the number of copepods dropped once again afterwards. Autumn maximum recorded in September coincided with rather high temperature and salinity values. It decreased constantly towards the year end. Seawater density was lowest in June-September.

In 1971 the number of copepods was rather low if compared to other years. However, three peaks were clearly marked: in April, July and October.

Temperature was highest in June-August and salinity and density lowest values almost coincided in time.

In 1972 the variations of copepod numbers were very marked and four maxima were recorded: in March, June, August and November. Temperature was highest in June-September at lowest sea water density. Salinity was high all year round.

In 1973 the first increase in copepod number was recorded in January but it was almost insignificant if compared to the spring maximum in April and particularly to the autumn maximum in September. Sea water temperature was highest in June-October and salinity exceeded 38‰ all year round except in May. Seawater density was lowest in July-October.

In 1974 the number of copepods varied considerably and four peaks were recorded: in February, April, June and October. Temperature was highest in June-September coinciding with the lowest density. Salinity was much lower than preceding year with ordinary decrease in summer.

The occurrence of a larger number of peaks during the year was recorded from this station, as well. Positive correlation was established with tem-

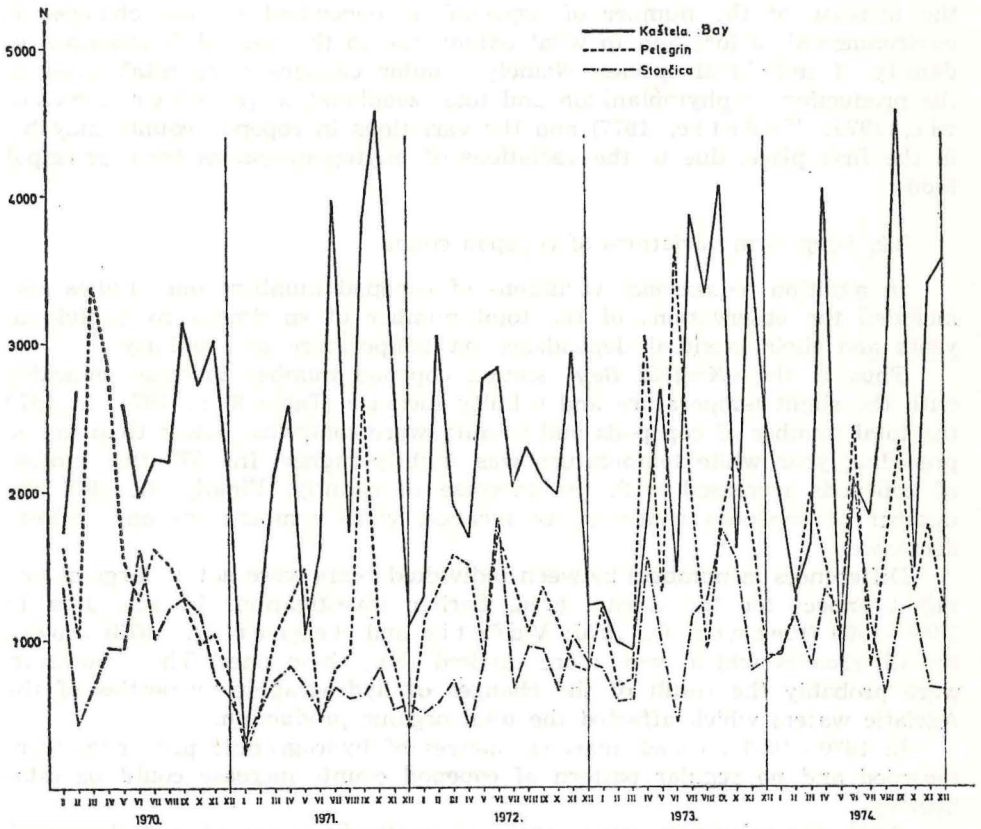

Fig. 11. Variations of the number of copepods at the »Kaštela Bay«, »Pelegrin« and »Stončica« stations in 1970—1974

perature ($r = 0.346$) and negative with salinity ($r = -0.189$) and seawater density ($r = -0.334$).

The observations of available data indicate similar annual variations of copepods at all three stations in the middle Adriatic (Fig. 11). Larger number of annual peaks were established. They occurred in spring, summer and autumn. This is particularly applicable to the 1972—1974 period. Since our observations were the first long-term observations of mid-Adriatic copepods in the channel and open sea areas they could not be compared with earlier data. However, the data from the coastal area were compared to the data collected from the Kaštela Bay in 1960—1969 (Regner, D., 1970). This comparison shows that certain changes have recently occurred. The occurrence of a larger number of peaks during the year (three or even four) at »Pelegrin« and »Stončica« may be assumed to be ordinary for those stations. However, it is more probable that due to the increased eutrophication in the coastal area and therefore increased quantities of nutrients and consequntly of the numbers of phytoplankton available to copepods all year round, copepod annual density has increased.

However, it is pretty difficult to say, for the time being, to what extent the increase of the number of copepods is dependent on the changes of environmental factors and to what extent due to the natural fluctuations in density of individual species. Namely, similar changes were established in the production of phytoplankton and total zooplankton (Pucher-Petković, 1975; Vučetić, 1977) and the variations in copepod counts may be, in the first place, due to the variations of phytoplankton as their principal food.

3.2. Long-term variations of copepod counts

In addition to seasonal variations of copepod numbers our studies also included the observations of the total number of specimens by individual years and their eventual dependence on temperature and salinity.

Thus at the *»Kaštela Bay«* station copepod number increase coincided with the slight temperature and salinity increase (Table 8) in 1971. In 1972 the total number of copepods and salinity were somewhat lower than in the preceding year while temperature was slightly higher. In 1973 the number of copepods increased with the increase of salinity. Finally, in 1974 the number of copepods continued to increase while temperature and salinity decreased.

Differences in numbers between individual years were not so large as one might expect for the coastal area. Earlier investigations in this area in 1960—1969 (Regner, D., 1970; Vučetić and Regner, D., 1973) showed the differences which were more marked than these ones. They, however, were probably the result of the changes of hydrographic properties of the Adriatic waters which affected the total organic production.

In 1970—1974 no such marked changes of hydrographic properites were recorded and no regular pattern of copepod counts increase could be established.

Total phytoplankton counts were alternatively increased and decreased, as well. However, the differences in phytoplankton number between years

were considerably higher. Marked minimum of the total number of phytoplankton organisms was recorded in 1973 (Pucher-Petković, unpublished data) at the time of increase of the total number of copepods.

Table 8. Annual temperature and salinity means and the total number of copepods at the a) »Kaštela Bay« b) »Pelegrin« and c) »Stončica« stations

Year	T°C	Sal ‰	total number of copepods
1970	16.53	35.74	24260
1971	16.55	36.34	26770
1972	16.80	36.08	25980
1973	16.39	36.13	27895
1974	16.35	36.09	28165

a)

Year	T°C	Sal ‰	total number of copepods
1970	17.20	37.35	18660
1971	17.14	37.97	11602
1972	17.45	37.83	14719
1973	17.47	38.09	20143
1974	17.52	37.78	17817

b)

Year	T°C	Sal ‰	total number of copepods
1970	17.78	38.18	12052
1971	18.17	38.12	7437
1972	17.87	38.11	9856
1973	18.12	38.26	12164
1974	17.73	37.96	12906

c)

At »*Pelegrin*« station the total copepod counts decreased in 1971 while temperature decreased and salinity increased. In 1972 the number of copepods was somewhat higher as well as temperature while salinity was decreased. In 1973 the number of copepods increased as well as temperature and salinity while in 1974 the number of copepods and salinity decreased and temperature increased. Rhythm of fluctuations of total counts is similar to that in the Bay. However, the differences between years were considerably higher and increases in number occurred much earlier than in the Bay.

The variations of the number of phytoplankton organisms were similar with alternative increases and decreases (Pucher-Petković, unpublished data). Here also higher number of copepods was recorded at low phytoplankton counts, and vice versa.

At »Stončica« station the variations of copepod counts differ from those in the coastal and channel areas. In 1971 the total copepod counts decreased and afterwards showed slight continuous increase up to 1974 irrespective of the alternative increases and decreases of temperature and salinity. Differences in the number of individuals between years were lower than at »Pelegrin« but higher than in the Bay.

The number of phytoplankton organisms showed similar behaviour, that is, it constantly increased from 1970 to 1974 (P u c h e r - P e t k o v i ć, unpublished data).

As shown by the data of the five year period, that is from 1970 to 1974, no significant changes of the properties of the Adriatic water under the influence of increased activity of the Mediterranean, like in 1962—1964 period (B u l j a n, unpublished data) were recorded in the coastal area of the middle Adriatic. Since these changes (if they had occurred) would have affected long-term increase of copepod numbers the variations of copepod numbers recorded were not significant, either. On the contrary copepod counts both in the Kaštela Bay and at Pelegrin showed slight alternative increases and decreases. Any change occurred first at Pelegrin and a year later in the Bay.

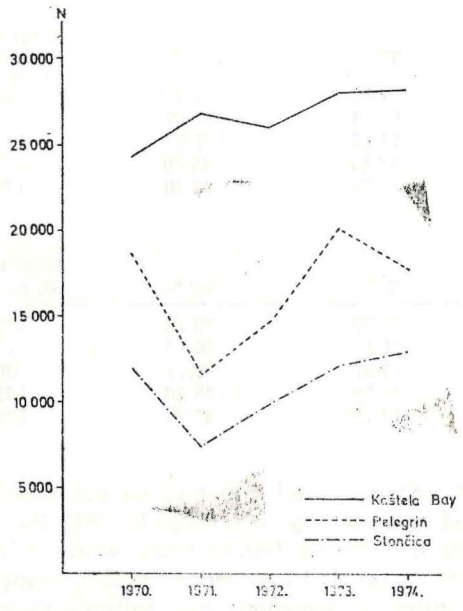

Fig. 12. Year-to-year variations of copepod number at the »Kaštela Bay«, »Pelegrin« and »Stončica« stations in 1970—1974

At »Stončica« which is most exposed to the open sea influence slight tendency of increase of the total copepod counts was recorded in 1972—1974. This increase, however, was almost insignificant if compared to that in 1970. It might be said that the year-to-year differences in numbers which were more marked here than in the Bay are due to the periodical higher decreases in number rather than to acctually considerable increase in number. Annual mean copepod counts at studied stations in the 1970—1974 period given in Fig. 12 show everything discussed here.

4. *Variations of the percentage proportions of copepods in the total zooplankton*

Quantities and trophic value of copepods in the total zooplankton has already been pointed out in this paper. Percentage proportion of copepods in the total zooplankton was attempted to be calculated from the data on their seasonal and long term variations in number as well as from the variations of the total number of zooplankton organisms in the study area (V u č e t i ć, unpublished data) (Table 9). In addition, seasonal and long term variations of the proportion of copepods were observed in the 1970—1974 period and their extent established.

Table 9. Percentage proportion of copepods in the total zooplankton at stations: a) »Kaštela Bay«, b) »Pelegrin« and c) »Stončica«

		»Kaštela Bay« %	»Pelegrin« %	»Stončica« %
	I	99.43	53.50	—
	II	—	32.55	16.01
	III	—	54.80	24.51
	IV	—	51.02	46.35
	V	42.72	55.88	38.08
1970	VI	27.13	30.07	61.72
	VII	25.61	37.87	43.31
	VIII	27.66	33.82	39.27
	IX	18.92	33.65	45.28
	X	45.79	36.78	44.46
	XI	38.62	36.73	33.80
	XII	51.23	31.16	46.36
	I	41.67	68.15	—
	II	35.47	41.93	92.00
	III	74.30	35.58	70.46
	IV	47.73	48.45	49.19
	V	36.24	77.66	69.55
1971	VI	30.12	23.74	37.03
	VII	—	34.98	38.83
	VIII	19.24	—	93.63
	IX	—	—	84.36
	X	64.75	44.41	68.90
	XI	37.30	21.64	42.02
	XII	37.93	67.18	58.81
	I	—	28.01	29.40
	II	—	25.69	33.33
	III	—	31.97	24.25
	IV	—	17.45	13.04
	V	—	19.36	30.33
1972	VI	—	21.47	56.88
	VII	—	31.40	18.95
	VIII	—	7.75	17.04
	IX	—	24.28	33.12
	X	—	25.28	26.59
	XI	—	19.19	30.55
	XII	—	23.13	47.16
	I	—	75.65	29.68
	II	27.71	34.56	31.34

	III	27.76	35.61	24.22
	IV	38.85	43.16	32.97
	V	26.89	20.34	28.64
1973	VI	18.72	56.47	9.11
	VII	26.82	47.11	38.28
	VIII	45.35	36.48	42.90
	IX	43.21	23.43	38.27
	X	35.07	47.22	42.28
	XI	65.04	31.98	30.15
	XII	51.26	34.00	33.68
	I	63.30	39.22	35.47
	II	44.66	20.74	32.18
	III	29.89	40.47	16.06
	IV	33.65	26.64	33.54
	V	33.24	22.43	27.45
1974	VI	30.69	28.74	48.60
	VII	34.84	19.76	25.16
	VIII	45.25	55.21	25.94
	IX	53.91	44.35	40.39
	X	38.78	30.10	44.42
	XI	44.95	41.22	31.55
	XII	41.46	28.60	25.42
		a	b	c

In the Kaštela Bay copepods contributed from 18.72 to 99.43% in the total zooplankton with the highest values in November, January and March. Their percentage proportion also varied from one year to another. Maximum numbers of copepods in relation to other zooplankton organisms was recorded in 1974.

After some earlier data by Vučetić (1970a) percentage proportion of copepods varied from 50 to 80% at this station whereas as shown by our data it is somewhere about 40%. However, the more recent papers of Vučetić show, as well, lower percentage proportion of copepods that is more similar to the one we found. It is pretty difficult to say, for the time being, whether this is due to some environmental factor changes or to the natural fluctuation in the density of zooplankton groups. Namely, copepod values have not essentially changed but the relationships between individual groups has changed. However, this is not subject of this paper.

At »*Pelegrin*« station percentage proportion of copepods was somewhat lower than in the Bay and showed monthly variations of 7.75 to 77.66%. As distinct from the Bay, maximum copepod percentages were recorded in spring-summer (except in 1973), that is somewhat later than in the Bay.

Percentage proportion of copepods varied significantly from one year to another. They were best represented in 1973 that is a year earlier than in the Bay.

At »*Stončica*« station copepods constituted from 9.11 to 92% of the total zooplankton. They were most abundant in summer, in June and August, that is somewhat later than at »Pelegrin«.

Annual variations were greatest at this station and maximum number of copepods was recorded in 1971.

With respect to the significance of copepod quantities in the total zooplankton the number of copepods and the total number of zooplankton organisms were statistically compared for all three stations.

Thus, positive correlation was established for the Kaštela Bay with the correlation coefficient $r = 0.673$ significant for $p < 0.001$ which proved their interdependence. The total number of copepods y is conditioned by the number of copepods after the following equation:

$$y = 1374.04 + 2.05568\ x$$

On the basis of this equation the number of copepods could be established if the total number of zooplankton organisms is known, and vice versa.

Coefficent of correlation was rather high for the *»Pelegrin«* station, as well, $r = 0.464$, and the equation of the interdependence of copepods and zooplankton is as follows:

$$y = 20257.78 + 1.51\ x$$

At *»Stončica«* correlation coefficient was $r = 0.518$ expressed by the following equation:

$$y = 1174.99 + 1.624\ x$$

As shown by the obtained results percentage proportion of copepods was highest at the »Kaštela Bay« station and lowest at »Stončica«, even though numerical values do not differ much. Copepods are best represented in the coastal area in the colder part of the year (November, January, March), in the channel area in spring-summer (March, May, August) and in the open sea in summer (June and August). After the long-term data percentage proportion of copepods in the Bay seems to have been slightly reduced (V u č e t i ć, 1974) what should be examined in the course of some future researches. The extent of monthly and annual differences between minimum and maximum percentage proportions of copepods in the total zooplankton was separately observed (Table 10). It was found that the lowest annual differences were gradually increased in an offshore direction (Table 11).

Table 10. Monthly differences between the highest and lowest percentage proportions of copepods in the total zooplankton of the study area

station	max	min	difference
»Kaštela Bay«	99.43%	18.71%	80.71%
»Pelegrin«	77.66%	7.75%	69.91%
»Stončica«	92.00%	9.11%	82.89%

Table 11. Annual differences between the highest and lowest percentage proportions of copepods in the total zooplankton of the study area

station	max	min	difference
»Kaštela Bay«	40.60%	30.04%	10.56%
»Pelegrin«	48.95%	20.64%	28.30%
»Stončica«	58.50%	20.81%	37.69%

5. *Quantitatively dominant copepod species in the study area*

The observations of the total numbers of copepods showed that only a small number of species affect these numbers by their high percentage presence. Variations in the number of dominant species and the total number of copepods are given separately for each of the stations of Figs. 13, 14 and

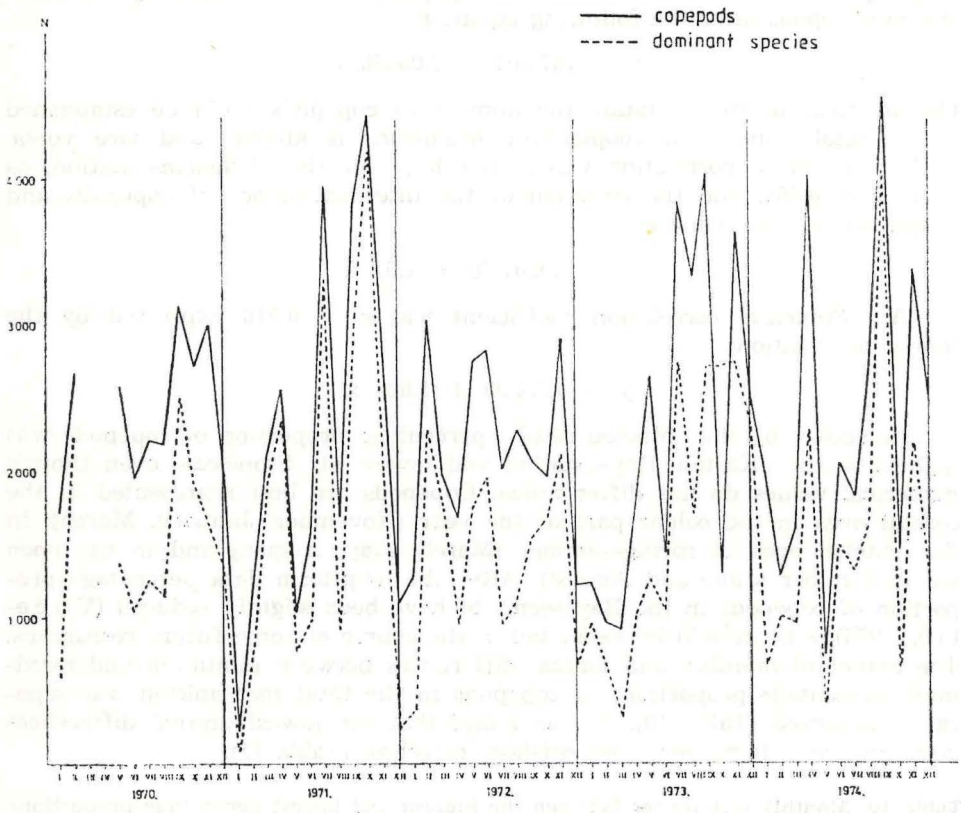

Fig. 13. Variations in the number of individuals of dominant species and total number of copepods at the »Kaštela Bay« station in 1970—1974

15 which clearly show the significance of dominant copepods among other species. Percentage presence of dominant copepods is given in Fig. 16. Other data will be given separately for each of the stations.

»Kaštela Bay« — *Ctenocalanus vanus, Centropages typicus, Centropages kröyeri, Temora stilifera and Acartia clausi* (Fig. 16), numerical represented the most important species of the zooplankton of this near-shore station of the middle Adraiatic. These five species constituted 76.29% that is more than 2/3 of the total number of copepods. This clearly indicates their significance in relation to some fifty other species. *Acartia clausi* was best represented contributing 22.83% of the total counts, followed by *Centropages*

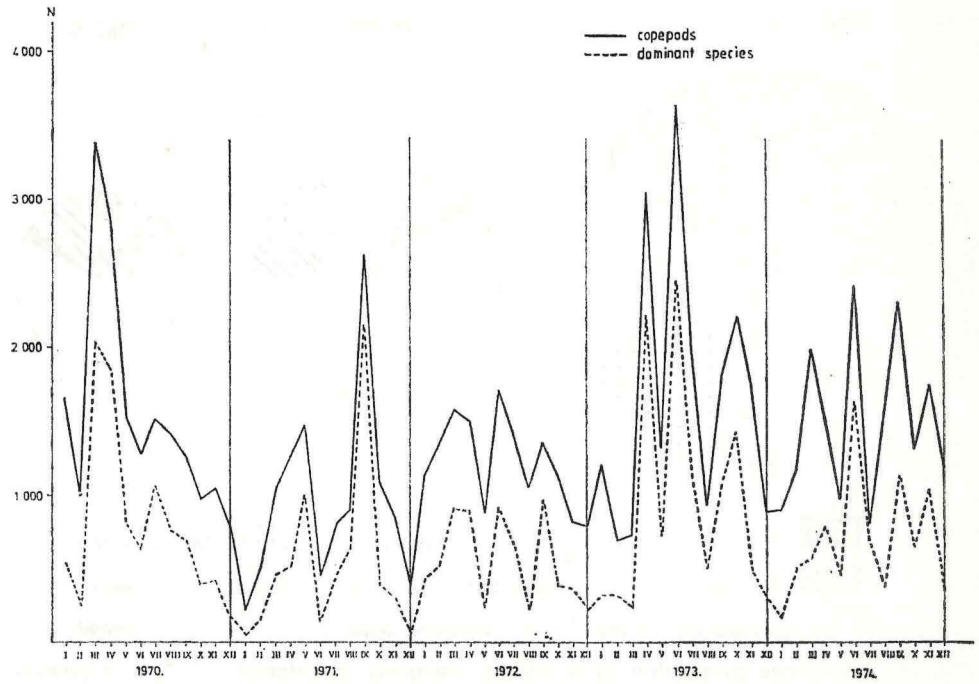

Fig. 14. Variations in the number of individuals of dominant species and total number of copepods at the »Pelegrin« station in 1970—1974

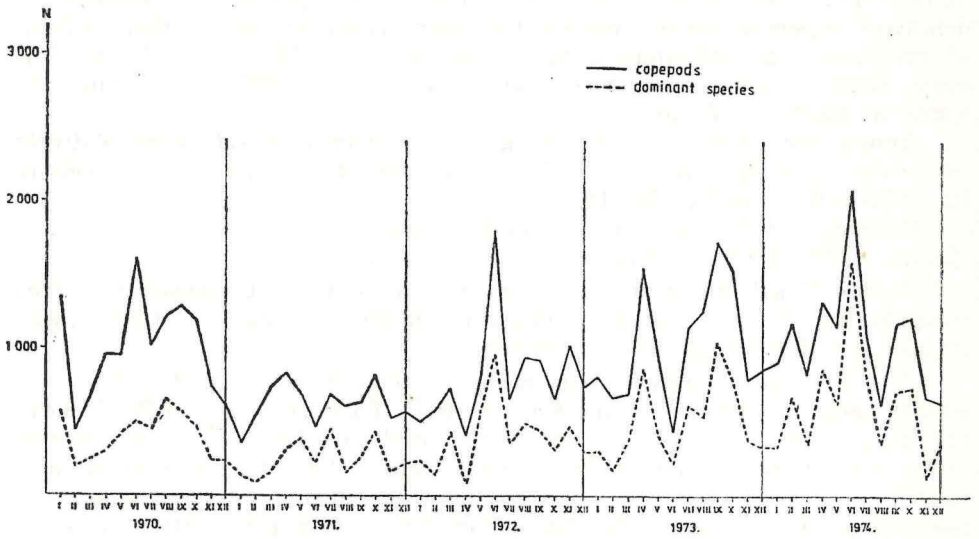

Fig. 15. Variations in the number of individuals of dominant species and total number of copepods at the »tSončica« station in 1970—1974

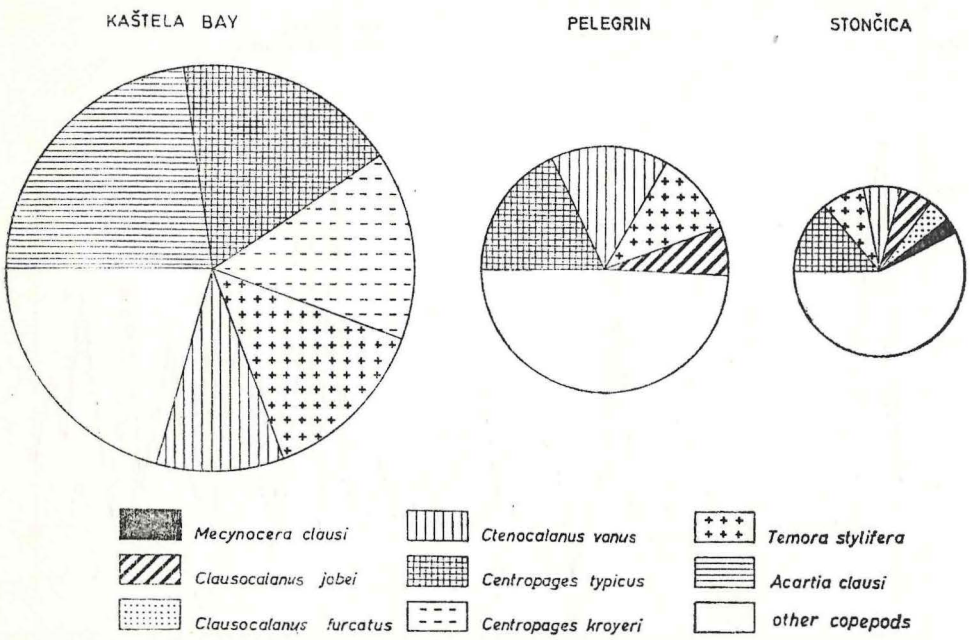

Fig. 16. Percentage proportion of dominant copepods in relation to other copepods at the »Kaštela Bay«, »Pelegrin« and »Stončica« stations

typicus with 16.24%, *Centropages kröyeri* with 15.07%, *Temora stylifera* with 12.79% and *Ctenocalanus vanus* vith 9.35%. This percentage presence of dominant copepods varied during the year. However, no regular pattern of maximum and minimum number occurrences could be established. Namely, both minimum and maximum values were recorded in spring and sumer as shown in Table 12.

Annual variations in the percentages of dominant copepods were relatively very small ranging from 70.91 to 78.78% of the total number of copepods in the 1970—1974 preiod (Table 12).

Observations of the numbers and percentage presence of each of these species showed some alternations during the year.

Acartia clausi was most numerous in winter-spring, *Ctenocalanus vanus* in spring-summer, *Centropages typicus* in summer-autumn and *Centropages kröyeri* and *Temora stylifera* in autumn.

This seasonal alternative occurrence of dominant copepod species has already been observed in the Kaštela Bay (Regner, D., 1970; Vučetić and Regner, 1973). Therefore we tried to relate this high numbers to the oscillations of some environmental factors. Thus the number of individuals of *Acartia clausi* which is predominant during the coldest part of the year showed negative significant correlation with temperature ($r = -0.353$) as well as negative significant correlation with salinity ($r = -0.357$). This statistically tested long-term behaviour of one of the most frequent

Table 12. Percentage presence of dominant copepods among other copepods at the »Kaštela Bay« station in 1970—1974

Year:	%		Year:	%	
	64.5			82.2	
	85.8			74.2	
	—			49.7	
	—			77.7	
	69.7			61.6	
	65.1			76.4	
1970	74.8		1973	80.1	
	63.6			71.7	
	81.5			81.7	
	71.3			66.2	
	59.2			77.9	
	67.8	70.91%		93.6	76.50%
	36.2			78.0	
	69.4			86.9	
	91.2			78.8	
	93.4			83.1	
	78.8			64.9	
1971	65.4		1974	85.6	
	84.2			83.3	
	62.0			72.4	
	78.0			89.3	
	91.4			52.0	
	72.3			74,8	
	33.0	78.78%		67.3	78.43%
	54.3				
	36.0				
	92.4				
	72.6				
	81.6				
1972	71.5				
	75.4				
	70.0				
	80.2				
	85.1				
	72.6				
	66.9	76.83%			

and best represented neritic species proves its preference for lower sea temperatures and salinity. This is important for experimental work in which the knowledge of optimum cirumstances for individual species is indispensable.

It should be pointed out that the influence of these factors is combined with other environmental factors influence that is that their combined influence creates the optimum circumstances for individual species. Statistical approach to optimum values of each individual factor is to a certain extent of importance since owing to a larger number of data it may better show their effects on individual species.

Over five years of our investigations the temperature of the upper layers in the Kaštela Bay varied from 11.14 to 23.47°C. Maximum number of

Acartia clausi individuals occurred at 11.79—15.63°C while minimum was recorded at 18.79°C. Salinity ranged from 34.03 to 37.88‰, the highest numbers were found at 35.17‰ and lowest numbers at 37.41‰.

Ctenocalanus vanus was predominant during spring-summer. It also showed negative correlation with temperature (r = — 0.018) and salinity (r = — 0.141). Even though these values are not significant the highest number of individuals was recorded at 13.55°C and the lowest at 16.07°C. Maximum numbers were recorded at 35.84‰ Sal and minimum at 37.63‰. Accordingly, this species shows preference for lower salinities and temperatures.

Centropages typicus was predominant in summer-autumn. Correlation between the numbers of this species and temperature was positive and although correlation coefficient value was not significant, maximum number of individuals was recorded at 16.07—18.18°C range and minimum at 12.08°C.

Positive correlation to salinity was established with the significant value r = 0.260. The highest numbers were recorded at very high values 37.63——37.86‰ and the lowest at 35.12‰. This indicates that higher temperatures and rather high salinities are favourable for this species.

Centropages kröyeri and *Temora stylifera* dominated in autumn. Both showed positive significant correlation to both temperature and salinity. This was to be expected with respect to the time of their maximum numbers. Both factors showed highest values in the Kaštela Bay. Thus the value of the coefficient of correlation between *Centropages kröyeri* and temperature r = 0.320. The highest number of individuals was recorded at 21.20°C and the lowest at 11.32 to 12.08°C range. Coefficient of correlation with salinity r = 0.294. Maximum numbers occurred at 36.48—37.86‰ Sal.

Temora stylifera showed the highest correlation coefficients both with temperature (r ‰ 0.583) and salinity (r = 0.453). Maximum number of individuals was recorded at 22.4°C temperature and 37.41‰ Sal, while minimum numbers were recorded at 16.03°C and 35.12‰ Sal. This species favours high temperatures and salinities.

This numerically dominant Kaštela Bay species are neritic species and most frequently belong to the near-shore species common along the eastern Adriatic coast (Regner, D., 1978). Therefore the effects of temperature and salinity on their numbers were studied in detail in this paper. Obtained results may be of use for making experimental conditions as close to the natural ones as possible.

Ctenocalanus vanus, Centropages typicus, Temora stylifera and *Clausocalanus jobei* were predominant at »Pelegrin« station in the channel area of the middle Adriatic (Fig. 10). These four species contributed 50.65% of the total copepods. Even though their percentage is lower than that in the Kaštela Bay it should be taken into account that they are actually better represented here than in the Bay since the number of species recorded from this station was almost twice that in the Bay.

Centropages typicus occurred in greatest numbers making up 35.21% of the total number of dominant copepods, followed by *Ctenocalanus vanus* with 30.38%, *Temora stylifera* with 21.66% and *Clausocalanus jobei* with 12.75%. It was also observed that dominant species occurred in greatest num-

bers in summer and in lowest numbers in winter. Percentage proportion of this species in the total number of copepods varied considerably over the five-year period (Table 13) as distinct from the Kaštela Bay. Highest percentage was recorded in 1973 (55.5%) and lowest in 1974 (45.5%).

Ctenocalanus vanus was predominant in spring, *Centropages typicus* in spring-summer, *Clausocalanus jobei* and *Temora stylifera* in summer-autumn.

Since the effects of temperature and salinity on the mentioned species were examined the same was applied to the species *Clausocalanus jobei*, as well. However, this species was very unevenly distributed and the correlation coefficient was significant neither for temperature nor for salinity.

Total percentages of dominant copepods were highest at this station in spring and lowest in winter.

Mecynocera clausi, Clausocalanus jobei, Clausocalanus furcatus, Ctenocalanus vanus, Centropages typicus and *Temora stylifera* were predominnat at *»Stončica«* station. They accounted for 42.05% of the total number of copepods (Fig. 16).

Ctenocalanus vanus was best represented with 14% of the total number of copepods, followed by *Temora stylifera* with 7.42%, *Centropages typicus* with 7.05%, *Clausocalanus jobei* with 5.89%, *Clausocalanus furcatus* with 4.09% and *Mecynocera clausi* with 3.5% (Fig. 19) Variations of their percentages during the year shows that they are best represented in spring-summer period and most poorly in spring (with the exception of years with maxima in summer) (Table 14).

Their percentage presence was lowest in 1971 and highest in 1972.

Ctenocalanus vanus dominanted in winter-spring, *Clausocalanus jobei* in spring-summer, *Clausocalanus furcatus, Centropages typicus* and *Temora stylifera* in summer-autumn and *Mecynocera clausi* in autumn.

Effects of temperature and salinity on species *Clausocalanus furcatus* and *Mecynocera clausi* were examined since these species did not occur among the dominant species at other two stations. Both species showed positive correlation to temperature with not significant correlation coefficient r for the species *Mecynocera clausi* and very significant correlation coefficient $r = 0.423$ for *Clausocalanus furcatus.* Highest number of individuals of this species was recorded at 19.13—21.69°C range.

Neither of these species showed significant coefficent of correlation with salinity even though r values were positive.

Results of our study of quantitatively dominant species in the Kaštela Bay, channel area and open sea showed the following:

Of the 98 copepod species determined during the time of our study eight are responsible for the variations in their total numbers. Percentages of these dominant species decrease in an offshore direction. However, it should be taken into account that the total number of species is almost doubled in the same direction. Almost all the species recorded from the study area stations are neritic and, as already pointed out, occurred all along the eastern coast of the Adriatic. The dominance of *Mecynocera clausi* species at *»Stončica«* is not surprising since this species is more frequent in the open sea and this station is an open sea station.

Table 13. Percentage presence of dominant copepods in the total number of copepods at »Pelegrin« station in 1970—1974

Year:	%		Year:	%	
	33.3			26.6	
	25.2			46.7	
	60.1			34.4	
	64.6			72.7	
	52.8			55.5	
	50.5			67.2	
1970	69.4		1973	56.0	
	97.0			53.8	
	56.0			59.0	
	41.2			64.0	
	40.3			28.8	
	23.6	54.9%		35.2	55.5%
	21.8			19.1	
	25.1			43.8	
	44.3			28.9	
	41.8			52.0	
	68.0			46.1	
	35.7			67.2	
1971	54.7		1974	85.5	
	70.0			23.6	
	82.0			48.4	
	37.3			50.3	
	36.4			46.0	
	20.5	54.6%		30.9	45.5%
	37.9				
	38.8				
	57.6				
	59.2				
	27.0				
	53.6				
1972	47.8				
	21.8				
	71.1				
	34.5				
	43.6				
	29.3	45.9%			

6. *Changes in the total number of copepods as affected by some biotic environmental factors (phytoplankton, fish)*

6.1. Relationship between the number of copepods and phytoplankton organisms as their principal food

Some earlier investigations of the relationship between phytoplankton and individual zooplankton groups (Vučetić, 1965) as well as between primary production and zooplankton standing crop at the same middle Adriatic stations (Vučetić and Pucher-Petković, 1969; Pucher-Petković and Vučetić, 1969) have already shown the dependence between these two members of plankton community (producers and predators)

Table 14. Percentage proportion of dominant copepod species in the total number of copepods at »Stončica« in 1970—1974

Year:	%		Year:	%	
	38.1			32.1	
	41.4			30.4	
	33.9			55.7	
	27.2			47.2	
	42.0			29.1	
	28.3			47.2	
1970	44.1		1973	36.8	
	53.5			37.3	
	44.8			46.0	
	35.1			43.5	
	27.3			45.5	
	32.5	37.8%		33.1	40.7%
	37.9			70.2	
	17.2			46.5	
	16.1			35.0	
	34.1			48.3	
	45.5			40.6	
	45.3			67.3	
1971	59.3		1974	69.0	
	25.5			54.0	
	37.7			56.7	
	50.9			60.0	
	30.7			19.6	
	30.6	27.4%		51.0	53.7%
	31.9				
	19.4				
	61.8				
	17.2				
	51.8				
	45.7				
1972	46.0				
	48.8				
	42.3				
	41.7				
	42.6				
	37.0	56.9%			

in the middle Adriatic. Even though these investigations as well as some later ones showed that annual variations of phytoplankton and zooplankton did not coincide during the year this was attributed to the different number of annual productive periods of phytoplankton and zooplankton. Pucher-Petković and Vučetić found that seasonal mean values of zooplankton were in broad agreement with the seasonal mean values of primary production what »shows that the quantity of produced food determines to a larger extent the size of zooplankton population« (Karlovac at al., 1974).

Further, a tendency of increase of both the total number of phytoplankton and zooplankton organisms was recorded over a rather long period with maxima in 1965 and 1966. It was also established that the long-term varia-

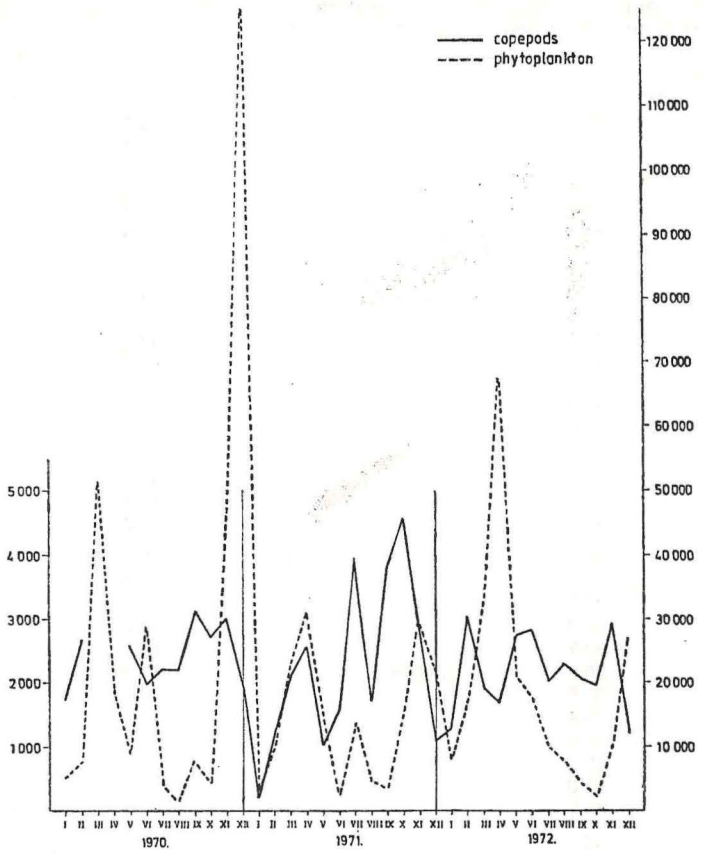

Fig. 17. Variations in the number of copepods and phytoplankton organisms in the »Kaštela Bay« in 1970—1972

tions in zooplankton biomass were of the same order of magnitude that is that maximum and minimum departures from the long-term means were equal.

These complex researches were related to all the hydrographic changes in the Adriatic. This provided a basis for the assessment and forecast of the fish production for a long time (Karlovac, et al., 1974).

The data on the number of copepods, as numerically dominant zooplankton organisms were, therefore, compared with the data on the total phytoplankton (Pucher-Petković, unpublished data) for the 1970—1972 period.

Graphical representation of these two components (Fig. 17) shows the similarity of the seasonal fluctuations in the number of individuals, particularly in 1971. This interdependence between copepods and phytoplankton as their principal food was proved statistically, as well, with positive correla-

tion and correlation coefficient value $r = 0.67$, significant for more than 99%.

For »Pelegrin« and »Stončica« (Figs. 18 and 19) stations correlation coefficient values were not significant. This was probably due to the more pronounced dynamics and more frequent changes of abiotic factors affected by the open waters of the middle Adriatic. On the other side, the number of copepod species at those two stations was almost twice that in the Bay. This further complicates the relationship with phytoplankton since the number of carnivore species of copepods was also increased.

Kaštela Bay may be held as an almost closed basin with relatively regular changes of abiotic factors. In addition, herbivore copepod species dominated at the Bay station what makes the way between primary producers

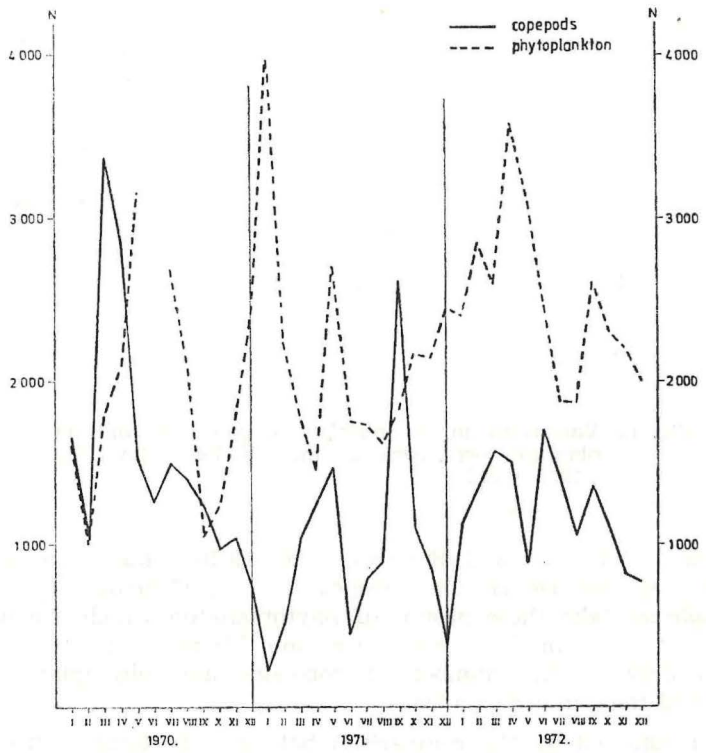

Fig. 18. Variations in the number of copepods and phytoplankton organisms at »Pelegrin« station in 1970—1972

of organic matter and its first consumers shorter. Studies of the feeding of dominant Kaštela Bay species showed that they took phytoplankton all over the year. Contents of their digestive tract was full in all seasons. This also proves that sufficient phytoplankton is at their disposal and that they consume it with no selection (Homen, B. and Regner, D. 1977; Regner,

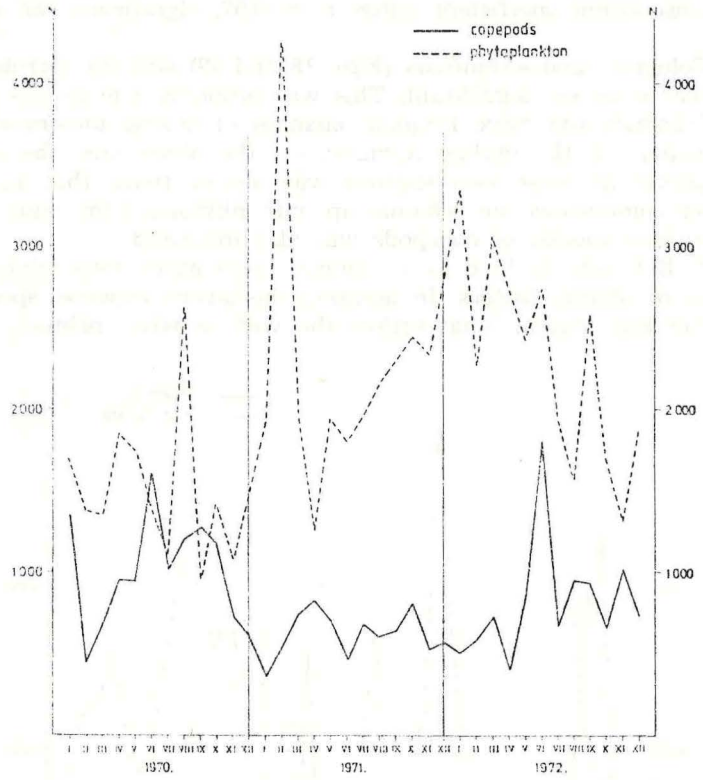

Fig. 19. Variations in the number of copepods and phytoplankton organisms at the »Kaštela Bay« station in 1970—1972

D., 1978; Marasović and Regner, D., 1979). Thus dominant Kaštela Bay species *Acartia clausi, Centropages typicus, Centropages kröyeri* and *Temora stylifera* take these groups of phytoplankton which are numerically dominant in the sea in the respective season. Therefore the relationship we established between the number of copepods and phytoplankton density clearly proved their interdependence.

Results obtained by the comparison between the total number of copepods and primary production expressed as the quantity of produced carbon in mg/m^2/day are somenhat different from the above ones. This, however, can be easily understood since in the first case we compared the phytoplankton biomass with the copepod biomass expressed as the number of specimens per unit space, while in the second case copepod number was compared with the process of organic matter production. Figs. 20 and 21 depict the relationship between the total number of copepods and produced carbon. It is obvious that the variations of these two parameters are more similar at *»Stončica«* than in the *»Kaštela Bay«*. This was also statistically proved and

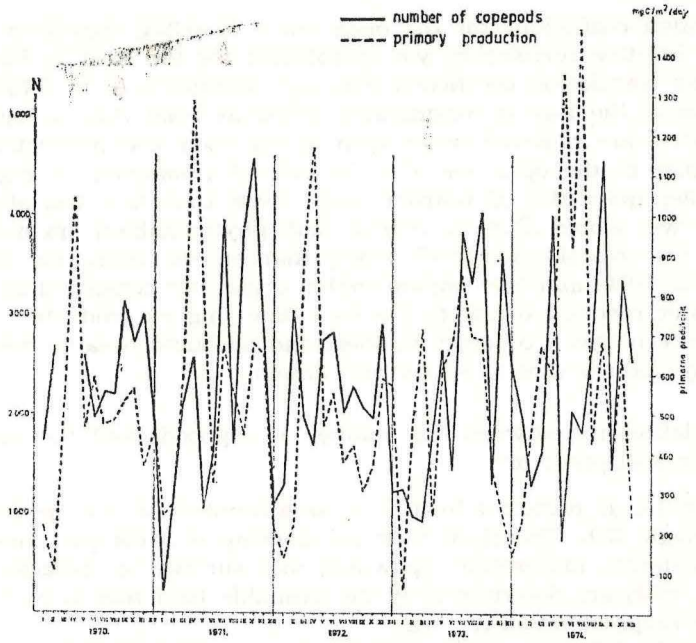

Fig. 20. Variations in the number of copepods and primary production at the »Kaštela Bay« station in 1970—1974

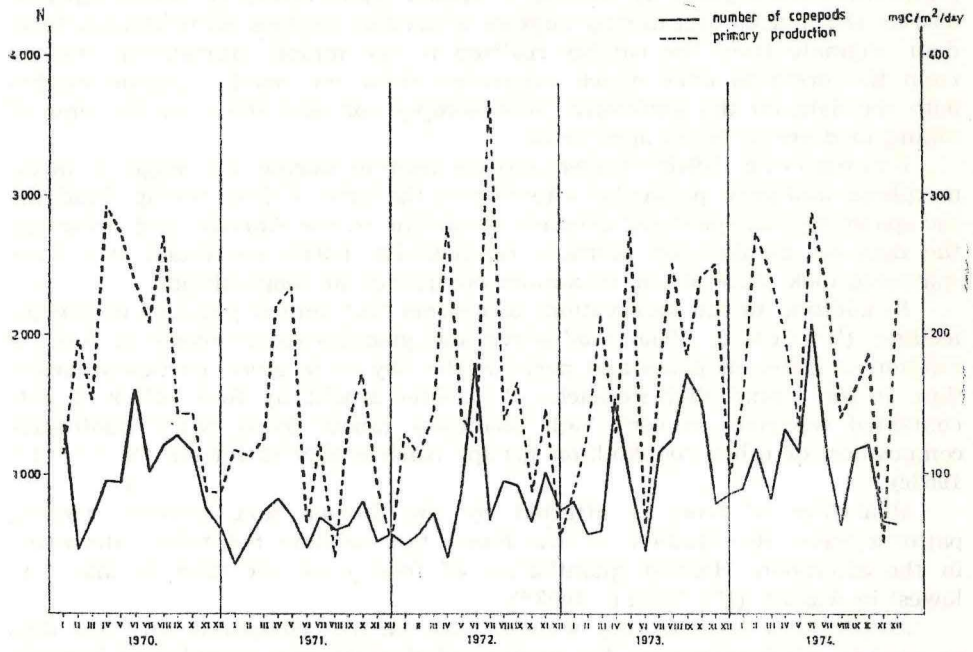

Fig. 21. Variations in the number of copepods and primary production at »Stončica« station in 1970—1974

the correlation coefficient for the open sea $r = 0.334$, significant for more than 99%. Positive correlation was established for the Kaštela Bay, as well, even though correlation coefficient was not significant ($r = 0.157$). Production process in the Bay is considerably different from that in the open sea since nutrients are renewed faster than in the open sea; production is twice to thrice that in the open sea and the rate of production is higher owing to the higher quantities of nutrient salts. Even though it has already been mentioned we should like to repeat that phytoplankton quantity is also higher in the coastal area (2—5 times) than in the open sea (Pucher-Petković, 1970) and that phytoplankton organisms consumed by zooplankton are faster renewed owing to the 2—3 times higher production. Therefore the difference between copepod numbers and produced organic matter in the Kaštela Bay exceeds that at »*Stončica*« station.

6.2. Relationship between the number of copepods and fish as their principal predator

Zooplankton is principal food to a large number of fish species, particularly to pelagic fish. Therefore their relationship is a complex one. That is: growth, fecundity, maturation, spawning and survival of pelagic fish (Nikolskii, 1969) are determined by the available food that is by a sufficient quantity of zooplankton in the sea.

Sardine feeding was particularly studied in the Adriatic owing to the commercial importance of this fish species. The first data on this fish food composition were given by Steuer (1908). Mužinić, S. (1936) reported also on the diurnal and montly rhythm of sardine feeding. Even though these data originate from the catches realized in the middle Adriatic as distinct from the previous ones which originated from the north Adriatic catches both the data on the qualitative food composition and those on the time of taking food are in broad agreement.

Ercegović (1940) studied sardine feeding during the stage of metamorphosis and gave particular attention to the time of food taking. Studying the spawning and spawning grounds of sardine in the Adriatic and observing the data on zooplankton biomass Gamulin (1954) concluded that their spawning took place at the maximum occurrence of zooplankton.

In addition to the observations of diurnal and annual patterns of sardine feeding (Vučetić, 1955) qualitative and guantitative analyses of food in relation to different gears and parts of the day were given particular attention. It was found that stomachs of sardine caught by four different nets contained copepods in very high quantities (about 30%) while qualitative composition of other zooplankton groups considerably differred (Vučetić, 1963c).

Quantities of food as affected by the diurnal and seasonal feeding patterns were also studied. It was found that sardine fed most intensively in the afternoon. Highest quantitative of food were recorded in May and lowest in August (Vučetić, 1963d).

Zooplankton biomass (dry weight) was, further, compared with the data on sardine catch statistics. An inverse relationship was established between these two components. It was also suggested that due to poorer feeding fish

are more easily moved since unavailability of food forces them to the search for food what is trophic migrations further favourable for fishing (V u č e t i ć, 1960, 1963d, 1965).

It was also indicated for the area of the middle Adriatic (Kaštlea Bay, Stončica) that zooplankton dry weight seasonal distribution coincided with the echo-traces or fish abundance. Comparison of echo traces and individual zooplankton groups gave positive correlation between echo traces and copepods in the open sea (Stončica) ($p = 0.001$), and in the Kaštela Bay rather high values of the coefficient of correlation between echo-traces and decapod larvae (V u č e t i ć, and K a č i ć, 1973, 1973a).

V u č e t i ć (1975) studied the synchronism of sardine and anchovy spawning (egg numbers) and zooplankton standing-crop (dry weight). This author found that sardine most intensive spawning preceded zooplankton maximum and anchovy most intensive spawning followed annual zooplankton maximum. Further, this author found that anchovy egg quantities during the year coincided with the numbers of copepod *Euchaeta hebes* and decapod developmental stages, while maximum sardine egg quantities preceded copepod group maximum. It was also shown in the same paper that annual correlation between echo-trace abundance of adult sardine and anchovy and variations in zooplankton quantites (dry weight) was significant.

We attempted to observe the relationship between the total copepod number and total number of fish eggs, Even though these two plankton groups are qualitatively very different positive correlation was established in the Baštela Bay ($r = 0.07$) and at Stončica ($r = 0.145$) with not significant correlation coefficents. Therefore future researches should give particular attention to the relationship between quantitatively dominant species of both groups which should throw more light on the predator-prey relationship which was here only established.

7. *Pattern of total copepod number variations as affected by some abiotic and biotic environmental factors*

Seasonal variations of the total number of copepods as affected by some abiotic environmental factors have already been discussed in detail in this paper (chapter 7. 3. 1). Rather large number of annual maxima was establised for all three stations in spring, summer and autumn. Positive correlation with temperature and salinity and negative correlation with density were recorded in the Kaštela Bay with the notsignificant correlation coefficients. However, these relationships were far more complex at »*Stončica*« and »*Pelegrin*« and correlation coefficients were mainly not significant.

Variations of the total number of individuals in different years were discussed in the chapter 7. 3. 2. It was found that no qualitatively significant Adriatic water exchanges took place in the coastal area in the 1970—1974 period which would have caused a long-term increase in the total number of copepods.

Data on copepod numbers have further, been compared with phytoplankton as their principal food as well as with the total number of fish eggs as indicators of the quantity of fish — the main copepod predators (7. 6. 1. and 7. 6. 2). Statistically proved correlation with phytoplankton was

established for the Bay with the correlation coefficient $r = 0.67$ as well as positive correlation with the number of fish eggs even though with the notsignificant correlation coeficient.

Therefore, since the calculation of correlation coefficients gave the relationship of interdependence between all these components (particularly in the Bay which is almost an uniform system) we intend here to observe the pattern of variations of these factors to establish the periods of these variations. To establish these periods and owing to a large number of data — about 60 per each station and parameter — the autocorrelation method was applied to the following series:

number of copepods
temperature
salinity
primary production
and number of fish eggs.

Autocorrelation function was applied after Southworth (1960) in the following manner: departure of each of the data (x_i) from the common mean was calculated and afterwards inserted into the autocorrelation function:

$$r_{(p)} = \frac{\Sigma X_i \cdot X_{i+p}}{\Sigma X_i^2}$$

where p is the time shift. For every shift $\Sigma X_i \cdot X_{i+p}$ was divided by the variance of p = O.

Thus the most pronounced maxima of the number of copepods for the »Kaštela Bay station were obtained at 12, 14, 22, 24, 26, 36 and 38 months (Fig. 22) which is indicative of the twelve month periods. This proves that the annual copepod cycle is very pronounced in the Kaštela Bay.

Since this study also includes the observations of the variations of copepod numbers as affected by individual biotic and abotic environmental factors the data on which were available, the method of autocorrelation was applied to establish the pattern of variations of temperature and salinity as well as the pattern of variations of primary production and number of fish eggs. Fig. 40 depicts the autocorrelation coefficient values for abiotic factors and the autocorrelation coefficient values for copepod numbers. Graphical representation shows that 12, 24 and 36 month maxima are most marked for temperature, that is that annual temperature variations follow markedly regular pattern in the 1970—1974 period.

The 11, 23 and 34 month maxima were found for salinity. They are in agreement with the mentioned 12 month cycle of copepod number and temperature variations.

Autocorrelation coefficient values for the number of copepods and biotic environmental factors — primary production and number of fish eggs are given in Fig. 23. It may be seen that the occurrence of primary production maxima is markedly regular. The period of 12 months, that is one year,

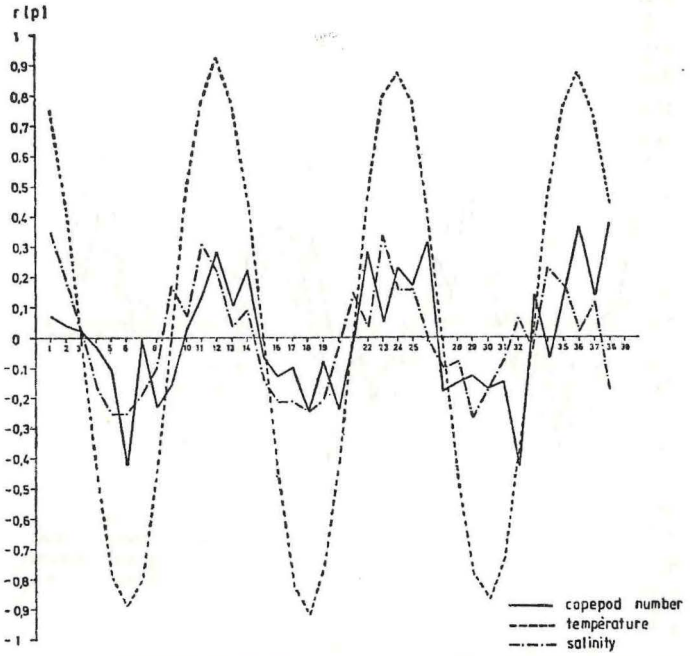

Fig. 22. Autocorrelation function of the copepod number, temperature and salinity at the »Kaštela Bay« station

is most pronounced here, as well. The number of fish eggs shows the same period (12 months).

Accordingly, regular annual variations of all biotic and abiotic factors (temperature, salinity, primary production, number of fish eggs) were established for the Kaštela Bay. Increased autocorrelation coefficent values of salinity of 23 months and of the copepod number and fish eggs of 36 and 38 months respectively even though with the shifts at the confidence level of 99%, might be indicative of the periods of two or three years. Namely, Županović (1968) in his studies of long-term fluctuations of sardine catches along the eastern Adriatic coast found the periods of 3, 8.1, 11, 17.5, 23, 37 and 57 years. Longer periods this author held due to the Mediterranean ingressions (Buljan, 1953) that is in a wider sense to the weather changes on a world scale, as well as to the oceanic current fluctuations. The same author suggests that the three year period may be in connexion with colder winters in the Adriatic. Applying spectral analysis to a hundred year data series on sardine catches and solar activity Regner, S. and Gačić (1974) found that the best pronounced year period was accompanied with the periods of 2.5 years. However they could not establish their causes.

On the basis of the results given by mentioned authors (obtained from the long data series) we also believe that the periods of two or three years are possible. However, this could not be proved due to the too short time of our observations.

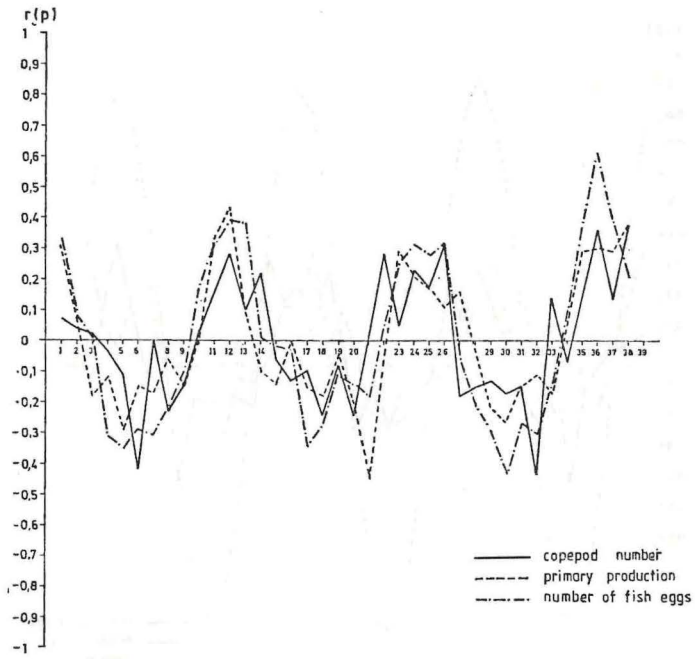

Fig. 23. Autocorrelation function of the copepod number, primary production and fish egg number at the »Kaštela Bay« station

The variations of copepod number is far less regular at »*Pelegrin*« than in the Kaštela Bay. Fig. 24 shows a larger number of maxima: the 12, 14, 17, 25 month ones as well as the best pronounced 37-month one. Only temperature showed very regular 12, 24 and 36-month periods (a year cycle) while salinity showed maxima every 11, 13, 23, 26 and 35 months. Of these the last and highest one may be indicative of a three year period. As shown by Fig. 25, 11 and 25 month maxima of fish eggs are somewhat more pronounced. However, they are not so marked as at the preceding stations. As it has already been mentioned »Pelegrin« station is affected both by land and by the open sea thus that the environmental conditions are more complex there than those in the Bay.

At »*Stončica*« — Fig. 26, variations of copepod number shows most pronounced 10, 14 and 24 month maxima. Temperature shows most regular variations here, as well, with 12, 24 and 36 month maxima, while in salinity 14 and 24 month maxima are accompanid with the most pronounced 37 month one.

Primary production shows 3, 6, 10, 13 and 23 month maxima and fish egg variations 10, 27 and 35 month maxima (Fig. 27).

These records show that 12 month oscillations of observed abiotic and biotic factors in the study area is very uniform. Namely, 12 (24

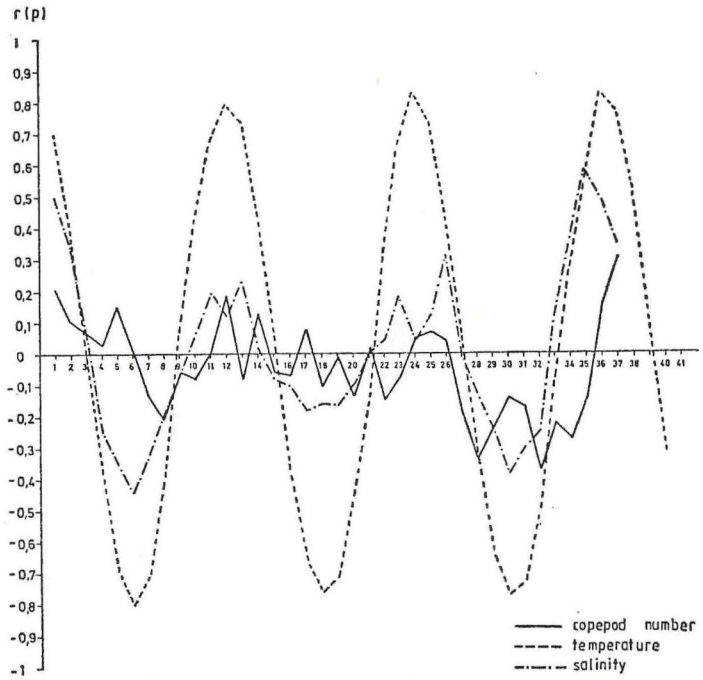

Fig. 24. Autocorrelation function of copepod number, temperature and salinity at »Pelegrin« station

and 36) month maxima were established which prove a regular annual variations of all the factors. At the same time on the basis of the autocorrelation coefficient value of salinity in the Kaštela Bay it is assumed that periods of about two years are possible. The periods of three years are assumed for copepods and salinity at Pelegrin and salinity at Stončica. These assumptions may be in agreement with some earlier results of investigations in the Adriatic (Županović, 1968; Regner, S. and Gačić, 1974) which, based on the longer data series, showed two and three year cycles of Adriatic sardine catches. Established period of 12 (24, 36) months is indicative of the regular seasonal variations of all the parameters examined in the study area.

Periods of two (for salinity in the Kaštela Bay), and three years (for copepods and salinity at Pelegrin and salinity at Stončica) could not be statistically proved due to the too short data series.

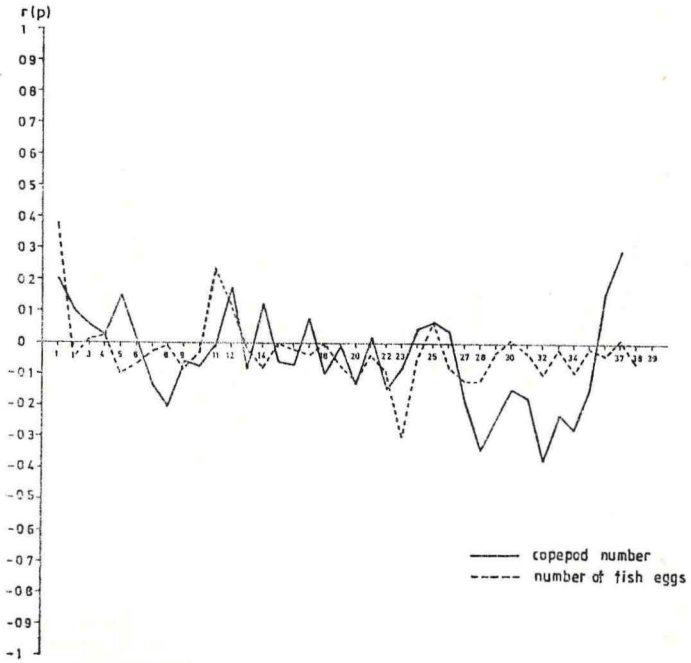

Fig. 25. Autocorrelation function of copepod number and fish eggs at »Pelegrin« station

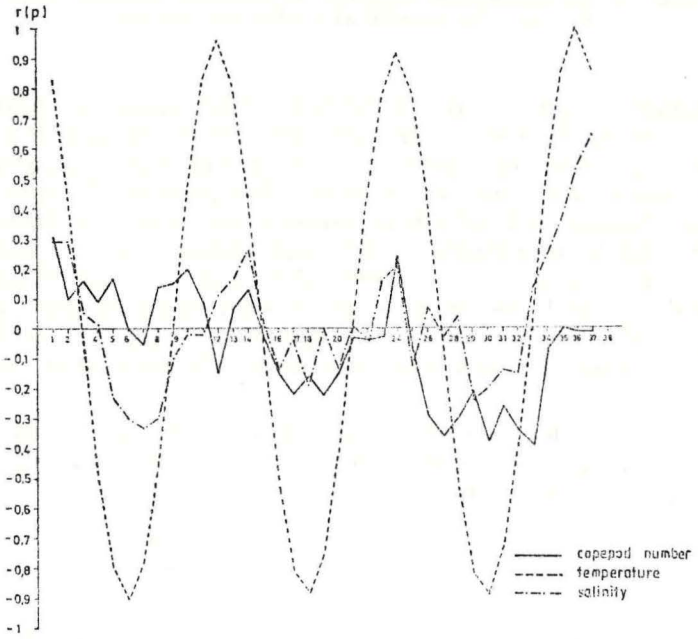

Fig. 26. Autocorrelation function of copepod number, temperature and salinity at »Stončica« station

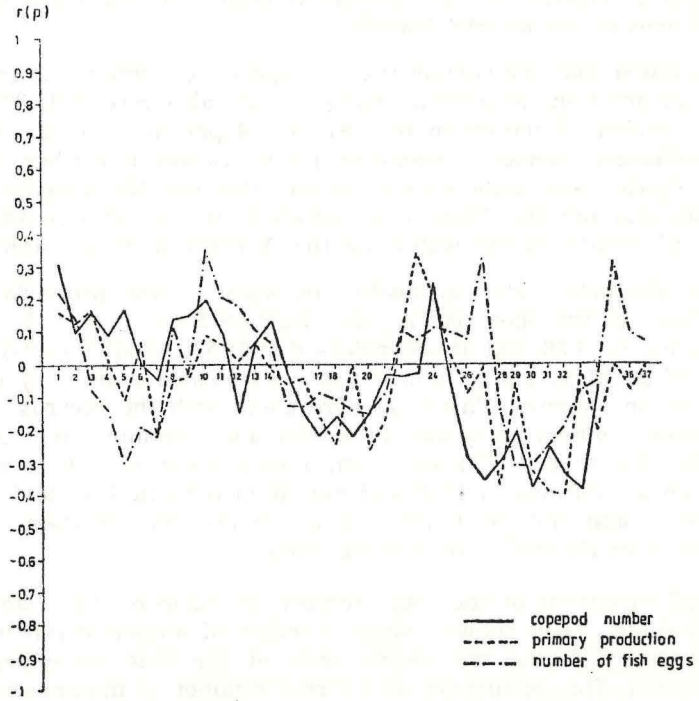

Fig. 27. Autocorrelation function of copepod number, primary production and fish egg number at »Stončica« station

CONCLUSIONS

1. A total of 98 copepod species were recorded from the mid-Dalmatian coastal area during the five year studies: 53 from the Kaštela Bay, 91 from »Pelegrin« and 90 from »Stončica«.

2. Horizontal distribution showed the following: markedly neritic species dominated in the Bay, neritic and open sea species were most frequent in the channel area and open sea species at »Stončica«.

3. The occurrence of open-sea species at »Pelegrin« and »Kaštela Bay« stations is suggested to be related to the current system, where NE direction carries open-sea water masses towards the coast most frequently in winter-spring period. On the other hand, temporary occurrence of neritic species at »Pelegrin« and »Stončica« may partly be due to the stronger outgoing Adriatic current which facilitates the dispersion of neritic species from the northern Adriatic. It may also be related to the W direction which carries surface water masses offshore.

4. Seasonal maximum numbers of species were recorded from all the stations in winter, and minimum ones in spring and summer. It is also suggested

that this is related to the intensified effects of the open sea on the coastal area of the middle Adriatic.

5. It was found that the composition of copepod community changed seasonally. In addition, long-term changes were also recorded. The increase in the number of species in the 1970—1974 period coincided with occurrence of larger number of open-sea species. However, neither the changes in the species composition were considerable nor the variations of temperature and salinity. Thus, it is assumed that in all five years annual effects of Mediterranean waters on the Adriatic were not significant.

6. Species diversity index gradually increases if one proceeds from the coast towards the open sea. At the »Kaštela Bay« station $d = 2.682$, at »Pelegrin« $d = 4.86$ and at »Stončica« $d = 6.252$. At all the stations maximum values of diversity indices were established mainly in winter and minimum in summer. This is in agreement with the records of seasonal maximum numbers of species in winter and minimum ones in summer. Over the five-year period maximum annual diversity indices were recorded from all stations in 1970 and minimum ones in 1972 and 1973. This, however, could not be related to the long-term variations of species numbers over the period of investigations.

7. Seasonal variations of the total number of copepods were similar at all three stations. They showed larger number of annual maxima occurring predominantly during the warmer part of the year: in spring, summer and autumn. This occurrence of a larger number of maxima may be due either to natural fluctuations or to the enrichment of coastal area by nutrients (eutrophication) as well as to the sufficent food available over a larger part of the year.

8. Positive correlation between the total number of copepods and sea salinity ($r = 0.312$, $p < 0.05$) and between the total number of copepods and temperature ($r = 0.413$, $p < 0.01$) were established as well as negative nonsignificant correlation between copepods and sea water density ($r = -0.139$).

   Total number of copepods showed positive correlation with temperature only at »Pelegrin« and »Stončica« stations.

9. The observations of the total number of copepods over the 1970—1974 period showed only slightly differences from one year to another. This is indicative of the fact that no significant qualitative changes of hydrographic properties took place in the coastal area of the middle Adriatic.

10. Copepods constituted from 18.72 to 99.43% of the total zooplankton counts at the »Kaštela Bay«, from 7.75 to 77.66% at »Pelegrin« and from 9.11 to 92% at »Stončica«. These high percentages show the significance of copepods as quantitatively dominant zooplankton group. This was proved also by the high value of the coefficent of correlation between the number of copepods and the total zooplankton number ($r = 0.673$; $p < 0.001$).

Copepods were most abundant in the coastal area in autumn and winter, in the channel area in spring-summer and in the open sea in summer. This group numerically dominated the zooplankton population of the Kaštela Bay in 1974, at »Pelegrin« in 1973 and at »Stončica« in 1971.

11. The following species dominated the zooplankton population in the Kaštela Bay: *Ctenocalanus vanus, Centropages typicus, Centropages kröyeri, Temora stylifera* and *Acartia clausi* and accounted for 76.29% of the total number of copepods; *Ctenocalanus vanus, Centropages typicus, Temora stylifera* and *Clausocalanus jobei* were the dominant species at »Pelegrin« constituting 50.65% of the total number of copepods; the species that were predominant at »Stončica« were *Mecynocera clausi, Clausocalanus jobei, Clausocalanus furcatus, Ctenocalanus vanus, Centropages typicus,* and *Temora stylifera* making up 42.05% of the total copepod counts.

12. The dependence of each of the dominant species on sea temperature and salinity was statistically observed. Positive correlation coefficients were established for copepods which preferred higher temperatures and salinites and negative ones for copepods which occurred in higher numbers during the colder part of the year and at longer salinities. In this connexion a seasonal alternative occurrence of dominant copepods was established.

    Thus, *Acartia clausi* numerically dominated in winter-spring, *Ctenocalanus vanus* in spring-summer *Clausocalanus jobei, Clausocalanus furcatus* and *Centropages typicus* in summer-autumn and *Centropages kröyeri, Temora stylifera* and *Mecynocera clausi* in autumn.

13. Positive correlation between the number of copepods and phytoplankton as their principal food was also established with the significant correlation coefficient for the Kaštela Bay ($r = 0.670$; $p < 0.01$) and not significant coefficients for Pelegrin ($r = 0.10$) and Stončica ($r = 0.12$).

14. Positive correlation was also established between the number of copepods and fish eggs however with not significant correlation coefficient for both the Kaštela Bay ($r = 0.07$) and Stončica ($r = 0.145$)

15. Observations of the pattern of variations of copepods and some of the abiotic (temperature, salinity) and biotic environmental factors (primary production, number of fish eggs) by the autocorrelation method showed maximum values of autocorrelation coefficient for the periods of 12, 24, and 36 months at all three stations.

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SEZONSKA I VIŠEGODIŠNJA DINAMIKA POPULACIJA KOPEPODA SREDNJEG JADRANA

Dubravka Regner

Institut za oceanografiju i ribarstvo, Split, Jugoslavija

KRATAK SADRŽAJ

U ovom radu iznose se rezultati petogodišnjih istraživanja kopepoda iz obalnog područja, kanalnog dijela, te otvorenog mora srednjeg Jadrana.

U radu je po prvi put razmotrena na osnovu višegodišnjih mjesečnih podataka, horizontalna raspodjela kopepoda u srednjem Jadrana. Za svaku od 98 nađenih vrsta izneseni su podaci o kvantitativnoj zastupljenosti kroz

godinu i kroz cijelo razdoblje, što predstavlja doprinos poznavanju njihove sezonske i višegodišnje dinamike.

Praćene su sezonske i višegodišnje promjene kvalitativnog i kvantitativnog sastava kopepoda. Na osnovu višegodišnjih podataka izračunat je indeks raznolikosti vrsta kao numerički izraz strukture ove skupine.

U radu su statistički razmotrene sezonske i višegodišnje promjene brojnosti kopepoda u odnosu na temperaturu, salinitet i gustoću mora od abiotskih faktora sredine, te broj fitoplanktonskih i ihtioplanktonskih organizama od biotskih faktora.

Posebno je još praćeno učešće kopepoda među ostalim zooplanktonskim organizmima, kroz godinu i kroz petogodišnji period.

Statistički su obrađeni podaci o kvantitatvno dominantnim vrstama kopepoda i njihovoj zastupljenosti u odnosu na temperaturu mora i salinitet, kao i periodičnost kolebanja ukupnog broja kopepoda u odnosu na temperaturu, salinitet, primarnu produkciju i broj ribljih jaja.