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COMPOSITION AND TEMPORAL FLUCTUATIONS OF ICHTHYOPLANKTON COMMUNITY IN THE KORNATI ARCHIPELAGO AND MURTER SEA, EASTERN ADRIATIC

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ICHTHYOPLANKTON
COMPOSITION
TEMPORAL FLUCTUATIONS
KORNATI ARCHIPELAGO
ADRIATIC

ICHTHYOPLANKTON
COMPOSITION
VARIATIONS TEMPORELLES
ARCHIPEL KORNATI
ADRIATIQUE

ABSTRACT. – Temporal fluctuations of species composition and abundance of fish larvae in the Kornati archipelago and Murter Sea were studied over 12 months from January to December 1990 from seven stations. A total of 2145 larvae, representing 28 families and 52 species, were collected using two types of plankton nets on each station, "Helgoland" and "Bongo". The community was dominated numerically by a few species: *Sardina pilchardus* (29.2 %), *Engraulis encrasicolus* (28.7 %), *Serranus hepatus* (7.5 %), *Sarpa salpa* (5.2 %), and *Cepola rubescens* (4.7 %), constituting 75.3 % of the total catch. Similarity between patterns in the abundance of the 11 most common species were examined using correlation matrix-based principal component analysis. Results were compared to the abiotic factors leading conclusion that only a low amount of variation in the abundance field can be explained by temperature and salinity.

RÉSUMÉ. – Les variations temporelles de la composition en espèces et de l'abondance des larves de Poissons de l'archipel de Kornati et de la Mer de Murter ont été étudiées pendant 12 mois (janvier-décembre 1990) sur 7 stations. Un total de 2145 larves représentant 28 familles et 52 espèces a été récolté à l'aide de 2 filets différents à chaque station « Helgoland » et « Bongo ». Les espèces dominantes sont *Sardina pilchardus* (29,2 %), *Engraulis encrasicolus* (28,7 %), *Serranus hepatus* (7,5 %), *Sarpa salpa* (5,2 %) and *Cepola rubescens* (4,7 %), soit 75 % du total. La similarité d'abondance des 11 espèces les plus communes a été étudiée à l'aide d'une matrice de corrélations (ACP). Les résultats analysés et l'étude des facteurs abiotiques permettent de conclure que la température et la salinité ne peuvent expliquer qu'une faible variation d'abondance.

INTRODUCTION

A number of studies and a variety of authors have studied the planktonic stages of individual fish species, particularly those of sardine (*Sardina pilchardus* Walb.) and anchovy (*Engraulis encrasicolus* L.) in the Adriatic. However, there is far less papers dealing with the composition and dynamics of individual groups or even of the ichthyoplankton community as a whole.

First joint data on the planktonic stages of the Adriatic fishes were given by Graeffe (1888), Steuer (1910), Stiasny (1910) and Vatova (1928) for the northern Adriatic. Karlovac (1953) provided the data on distribution, numerousness and the time of occurrence of planktonic stages of fish from the families Sternoptychidae, Stomatidae and Scopelidae for the whole Adriatic. Varangolo (1964) studied the period of the occurrence and

seasonal dynamics of the numerousness of larval stages of 21 fish species in the northern Adriatic in 1962-1963. In the course of investigations of the planktonic stages of sardine carried out in the central Adriatic in 1952-1953 period Karlovac (1967) recorded the larval stages of 68 fish species from the plankton. On that occasion this author studied their distribution and dynamics of abundance. Vucetic (1965, 1970, 1971) reported the seasonal and long-term distribution of the total numbers of the larval fish stages in the central Adriatic. The data on the qualitative and quantitative distribution of the larval fish stages in the central Adriatic in 1973 are also available (Regner 1976). Regner (1980, 1982) presented the results of the analysis of annual distribution and long-term fluctuations of the qualitative and quantitative composition of the larval fish stages in the plankton of the Kastela Bay and at the high sea of the central Adriatic for the period from 1970 to 1977, respectively.

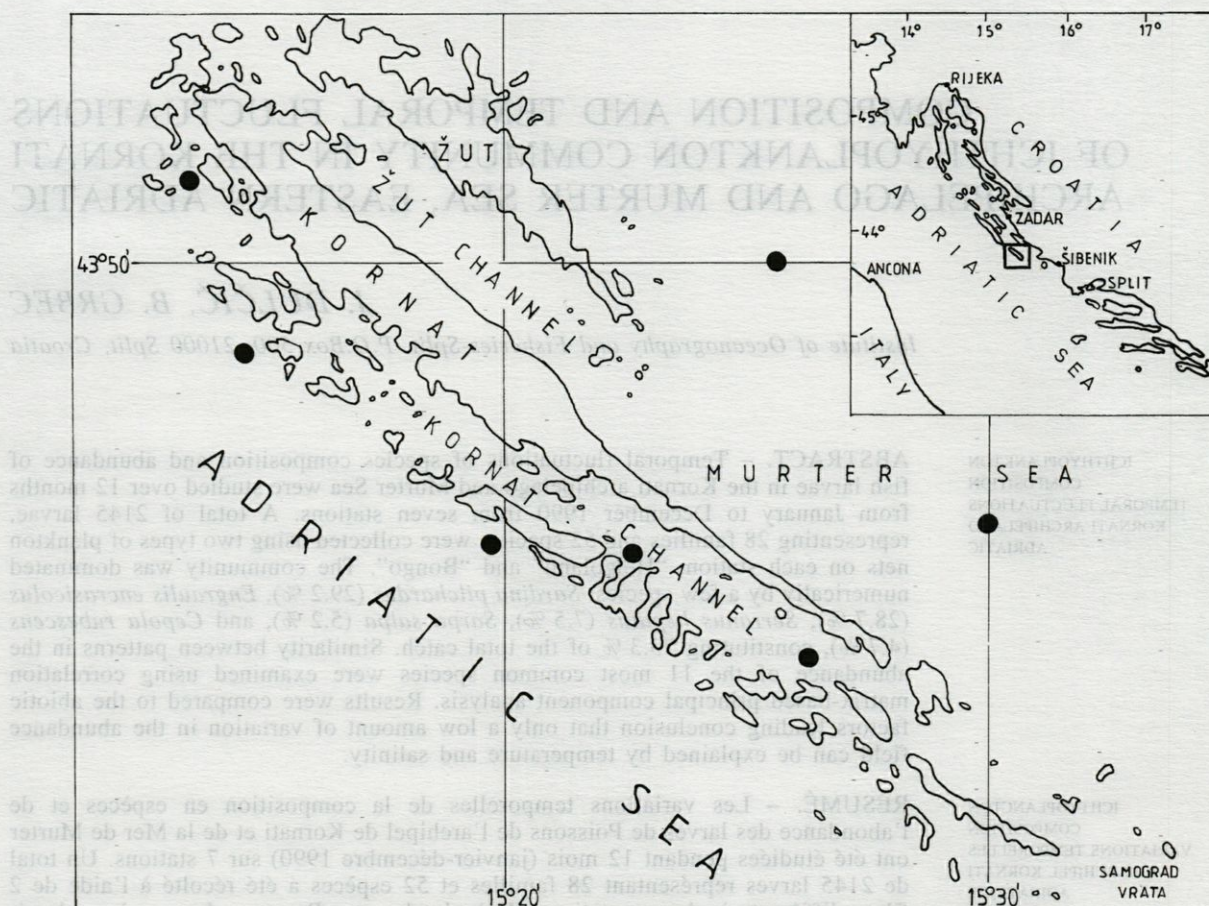


Fig. 1. – Locations of the sampling stations (•) in the Kornati Archipelago and Murter Sea, eastern middle Adriatic.

In the present study we present those data describing the composition and seasonal fluctuations of ichthyoplankton in the area of Kornati Archipelago and Murter Sea, eastern middle Adriatic. The relative importance of temperature and salinity on biotic factors was examined using multivariate techniques.

MATERIAL AND METHODS

The Kornati islands lie along the central part of the Croatian coast, between Zadar and Sibenik (Fig. 1). The Kornati Archipelago covers an area of approximately 224 km² and has 141 islands, islets and reefs (Rubić 1952). The Kornati Islands have the most irregular coastlines of any islands in the Mediterranean. Murter Sea covers an area of 210 km² (Friganovic 1981) and lies between islands Pasman, Vrgada & Murter on the north, and island Kornat on the south-west (Fig. 1). Stations in study area were located at depths ranging from 35 to 96 m.

Sampling was conducted on a monthly basis from January to December 1990 from seven stations (Fig. 1). Fish larvae were collected using two types of plankton

nets on each station "Helgoland" and "Bongo". The area of mouth aperture of "Helgoland" type is 1.6 m² and mesh size 0.516 mm. The net was towed from 35 m depth to surface at a speed of 0.5 m/sec. A plankton net type "Bongo" has mouth openings of 20 cm and 0.250 mm mesh size. Oblique hauls were performed, and net was towed up to the maximum depth of 5 m above the bottom, at the vessel speed between 1.5 and 2 knots. Wire angle and length of line were monitored during the tow. Note that oblique tows will underestimate the densities of organisms which are vertically stratified. Collected organisms were sorted and preserved in 5 % buffered formalin (pH from 8.5 to 9.0). Before being sorted, the material was sedimented for 24 hours in beakers. Fish larvae were afterwards extracted, identified and counted. Larvae and postlarvae were, as a rule, determined up to the species level. In cases when this was not possible they were determined up to the level of family. Temperature and salinity were measured by classical methods at every station before nets hauling. Measurements were taken of both surface and bottom waters.

Temporal fluctuations in community structure, abiotic factors and interactions between these variables were analysed using multivariate techniques: multiple linear regression and principal component analysis (Preisendorfer 1982). Community structure was specified by species richness (D), diversity (H), and evenness (J)

using formulae proposed by Margalef (1968), Shannon & Weaver (1949), and Pielou (1966), respectively. The degree of relationship existing between these variables and abiotic factors (temperature and salinity) was determined by R^2 , e.g. the coefficient of multiple determination.

Abundance in the species composition was subject to the correlation matrix-based principal component analysis (PCA) (Preisendorfer 1982) to examine a minimal number of groups (clusters) the variability of which describes the maximum amount of the total variability in the larval fish community. The PCA was performed on the correlation matrix of standardised variables (zero mean and unit standard deviation). We used Bartlett's test (Fulgosi 1988) for testing the significance of the correlation matrix. The significance of extracted principal components (eigenvalues) were tested with Rule N (Overland & Preisendorfer 1982), using Monte Carlo simulation of the random matrix of the same size as the original data matrix. To enhance the interpretation of the components, Varimax orthogonal rotation was applied (Richman 1986).

The relationship of species composition between seven stations was compared using Spearman's rank correlation test on the basis of the yearly catch in terms of number of each individual species. For comparing abiotic factors between seven sampling locations, an ANOVA model was used.

RESULTS AND DISCUSSION

Analysis of variance revealed significant correlations between temperature and salinity ($p < 0.01$) among the seven sampling stations, respectively. Mean monthly temperature ranged from 11.8°C (SD = 0.96) in February to 25.7°C (SD = 1.53) in August, with no significant difference in temperature between the seven stations. Mean monthly salinity values, however, were more stable (ranging from 37.42 ± 0.89 to 38.61 ± 0.51 psu) (Fig. 2). While sea water temperature shows typically Adriatic seasonal cycles, seasonal cycles in salinity typically for the Adriatic are not evident, mainly because the sampling stations are situated in the coastal area which is strongly influenced by precipitation and evaporation and which is different along the Adriatic from North to South (Grbec *et al.* 1997).

Spearman's rank correlation coefficients of species composition among the seven stations were highly significant ($p = 0.01$), indicating that the rank of species composition was similar among sampling stations. So, data for all seven stations were combined. Fifty-two species, representing 28 families, were caught between January and December 1990 (Table I), the number of species was most abundant in June (20) and lowest in February (8). A total of 2145 larvae were collected: the number of individual was higher in August (318), and the lowest in January (109). This finding agrees well with the data of Karlovac (1967) and

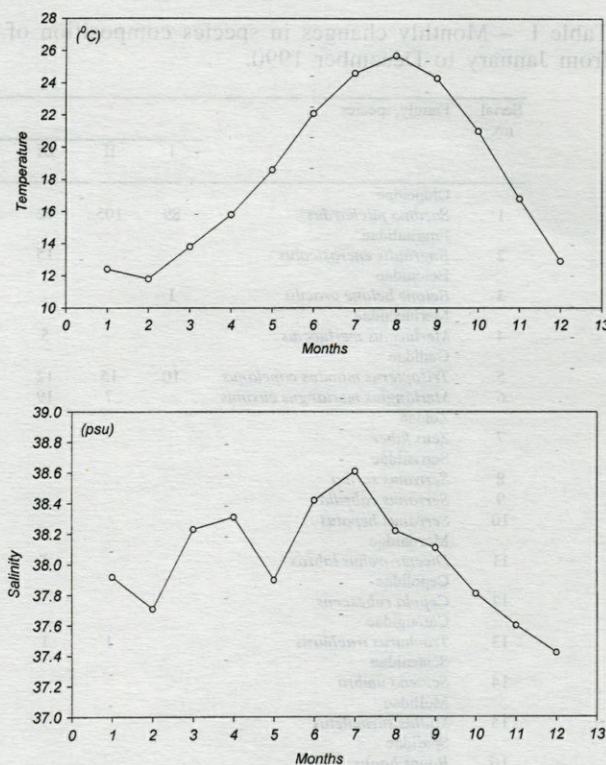


Fig. 2. – Monthly variations in the mean sea water temperature ($^\circ\text{C}$) and salinity (psu) in the Kornati Archipelago and Murter Sea between January and December 1990.

Regner (1980) for the Kastela Bay (eastern middle Adriatic) where the largest number of species of fish larvae may be found in the plankton during the warmer season of the year. *Sardina pilchardus* (29.2 %), *Engraulis encrasicolus* (28.7 %), *Serranus hepatus* (7.5 %), *Sarpa salpa* (5.2 %), and *Cepola rubescens* (4.7 %) comprised 75.3 % of the total catch abundance (Table I). *S. pilchardus* and *E. encrasicolus* were the two most dominant species. Therefore the seasonal succession of the occurrence of fish larvae may be divided into two seasons, i.e. sardine in the colder season (November–April), the anchovy in the warmer season (May–October). The similar seasonal succession was also found in the Kastela Bay – eastern central Adriatic (Regner 1980). *S. hepatus* has the highest abundance from April to August, while the *S. salpa* abundance was the highest from September to October. *C. rubescens* has the highest abundance from May to November. This could be correlated with the spawning periods (Jardas 1996) and duration of embryonic development of the mentioned species (Dulcic 1993). The remaining species comprised from 4.2 % to 0.05 % of the total catch. The occurrence time of fish larvae is also given in the Table I. To a certain extent this time is also an indicator of the approximate time of spawning of the adult fish (Regner 1980). Ecological separation of the dominant species by

Table I. – Monthly changes in species composition of fish larvae collected in Kornati Archipelago and Murter Sea from January to December 1990.

Serial no.	Family, species	No. Fish larvae												Total
		I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
1	Clupeidae <i>Sardina pilchardus</i>	89	105	72	37	30					44	59	191	627
2	Engraulidae <i>Engraulis encrasicolus</i>			15	8	10	15	100	215	188	65			616
3	Belonidae <i>Belone belone gracilis</i>	1											1	2
4	Merlucciidae <i>Merluccius merluccius</i>			5	12						10	19		46
5	Gadidae <i>Trisopterus minutus capelanus</i>	10	15	12	12								7	56
6	<i>Merlangius merlangus euxinus</i>		7	19										26
7	Zeidae <i>Zeus faber</i>											1	1	2
8	Serranidae <i>Serranus scriba</i>					4	1	2	3					10
9	<i>Serranus cabrilla</i>					2	2	1						3
10	<i>Serranus hepatus</i>				27	15	29	48	29	10	2			160
11	Moronidae <i>Dicentrarchus labrax</i>			1										1
12	Cepolidae <i>Cepola rubescens</i>					12	20	10	15	10	18	11	5	101
13	Carangidae <i>Trachurus trachurus</i>		1	1	2	1	2	3						10
14	Sciaenidae <i>Sciaena umbra</i>									1				1
15	Mullidae <i>Mullus surmuletus</i>							2	1					3
16	Sparidae <i>Boops boops</i>				5	1								6
17	<i>Dentex (Dentex) dentex</i>					1								1
18	<i>Diplodus annularis</i>						15	20	31	6				72
19	<i>Diplodus vulgaris</i>											2	1	3
20	<i>Diplodus sargus sargus</i>				1	1	2							4
21	<i>Diplodus puntazzo</i>										5	1		6
22	<i>Sparus aurata</i>	2											1	3
23	<i>Sarpa salpa</i>					18	10				24	48	12	112
24	<i>Pagellus erythrinus</i>					1	1							2
25	<i>Oblada melanura</i>			5	3	4								12
26	Centracanthidae <i>Spicara smaris</i>						7	2	5					14
27	<i>Spicara maena</i>										6	2	2	10
28	Labridae <i>Labrus merula</i>				1									1
29	<i>Symphodus tinca</i>						1							1
30	<i>Symphodus ocellatus</i>							1	1					1
31	<i>Symphodus cinereus</i>						1							1
32	<i>Coris julis</i>					2	1	4	1	1				9
33	Pomacentridae <i>Chromis chromis</i>					5	42	10	3					60
34	Scombridae <i>Scomber scombrus</i>	1		2										3
35	<i>Scomber japonicus</i>										1			1
36	<i>Thunnus thynnus thynnus</i>							1		2				3
37	Gobiidae <i>Gobius</i>	2	4	1	5	8	22	15	10	6	6	2	9	90
38	Callionymidae <i>Callionymus maculatus</i>		1	4	7									12
39	Bleminidae <i>Blemniidae</i>					11	3	4	2					20
40	Mugilidae <i>Chelon labrosus</i>												1	1
41	<i>Liza aurata</i>		1	2										3
42	Atherinidae <i>Atherina hepsetus</i>	1											1	2
43	Scorpaenidae <i>Scorpaena porcus</i>							1	1	1				

recruitment timing resulted in the fact that species did not compete one with the other for the same niche (Tzeng & Wang 1992). Temporal staggering of recruitment may be a mechanism for reducing possible interspecific competition, as has been observed in other fish communities (Doherty 1991). Segregation of some sparid species, for example, was seasonal in Kornati archipelago and Murter Sea since they recruit at different times of the year (*D. sargus sargus* in spring; *O. melanura* during summer; *S. salpa* during autumn; *D. puntazzo* at the beginning of autumn; *D. vulgaris* at the beginning of winter). Distribution of fish larvae is strongly affected by spawning seasonality, egg production variability, predation on eggs and larvae, larval starvation, duration of planktonic life, oceanographic features affecting plankton production, larval transport and competition (Richardson *et al.* 1980, Lasker 1985). The spawning strategies of fishes, the means of introducing the eggs or larvae to the plankton community, and the strategies for ensuring dispersal to new areas are quite numerous. The different combinations of spawning strategies in fish and the methods used to carry the eggs and larvae to the plankton give diverse but distinct patterns to plankton groups (Leiby 1986). These life-history strategies of fishes must be compatible with environmental features for species to persist, since the number of strategies meeting these requirements is finite, several species may converge on the same strategy; a consequence of these adaptive convergences is the formation of ichthyoplankton assemblages (McGowen 1993). Primary determinants of ichthyoplankton assemblage structure undoubtedly include mode, location, timing, duration and intensity of spawning by adults (Rakocinski *et al.* 1996). Aspects of larval biology, however, like planktonic stage duration (including stage duration, growth rates, and size at transformation) and transport mechanisms (including advection and mixing processes), also influence assemblage structure (Richardson *et al.* 1980). Recent studies that interpret ichthyoplankton community structure in terms of adult characteristics often find spatially heterogeneous distributions of larvae that are attributable to adult characteristics (Drake & Arias 1991a; Yoklavich *et al.* 1992). Some scientists even find interactions between adult reproductive models and larval biology may help explain spatial heterogeneity in ichthyoplankton community structure. For example, larval fish distribution in a small California estuary differed between inland and near-ocean stations in accordance with reproductive modes of constituent fishes and hydrographic conditions (Yoklavich *et al.* 1992). In another geographical region, Drake & Arias (1991) found that a shallow coastal inlet in southwestern Spain served primarily as a nursery for coastal pelagic spawners, and secondarily for benthic egg spawners and pouch brooder species.

Knowing geographical locations of spawning adults can also help to explain spatial heterogeneity in ichthyoplankton community structure. Spatial and seasonal spawning behaviour of adults plays the key role in formation of ichthyoplankton communities. Mechanisms that may maintain ichthyoplankton community at islands include boundary layers, small scale frontal dynamics, tidal currents, topographically produced eddies, seasonally reduced on variable currents, and regions of no or returning flow. Behaviour of larvae particularly that affecting vertical distribution, can modify the influences of these mechanisms. The integrity of community can be disrupted by both biotic and abiotic factors (Boehlert & Mundy 1993). An abundant ichthyofauna was recorded from 141 localities of the areas of Kornati Islands and Murter Sea: 160 species and subspecies which make up 39.5 % of all known species and subspecies of the Adriatic Sea (Jardas *et al.* 1995). So, we collected larvae from 32.5 % of recorded adult species and subspecies in area of study. It is possible that sampling design (our choice in number of surveys, specific locations, type of net) could partially influence the results. The overall value of richness D was 6.65, ranging from 1.42 in February to 3.67 in June. H' values fluctuated from 0.74 in September to 2.31 in May and June, with an overall value of 2.25. J' ranged from 0.35 in December and January to 0.84 in May. Mean monthly variations in these biotic factors are presented in Fig. 3. These values could be comparable with values obtained in studies performed in similar areas bays and estuaries. Drake & Arias (1991) reported that mean H' value fluctuated from 0.77 to 1.08, and mean J' value from 0.29 to 0.46 for different sample fish groups in a shallow tidal channel of Cadiz Bay. The overall value of richness D fluctuated from 1.17 to 3.47, mean H' value from 1.19 to 2.36, while mean J' value from 0.57 to 0.80 for intertidal fish community in northwestern Arabian Gulf (Ali & Hussain 1990). Therefore, we can suppose that the overall high richness values of ichthyoplankton community in Kornati archipelago underline the possible importance of the area as a nursery and spawning ground for several local species.

The relationship between abiotic factors such as temperature and salinity (included in model as independent variables) and the biotic factors (number of species, number of individuals, diversity and abundances: dependent variables) was analysed using multiple linear regression models. The significance level for the variables included in the model was set at $p < 0.05$. Results indicated that variations in abiotic factors could predict more than 80 % of monthly variations in number of species mainly because of the interaction affect of temperature and salinity. Variation in number of individuals showed significant correlations with temperature ($R = 0.6722$; $p = 0.017$), while va-

Table II. – Coefficient of multiple determination (R^2) identifying the association according to rank of the 11 most dominant species (abbreviations in parentheses) with temperature and salinity.

Rank no.	Serial no.	Species	Temperature	Salinity	R^2	P
1	1	<i>Sardina pilchardus</i>	-0.78*	-0.64*	0.84	0.0001
2	2	<i>Engraulis encrasicolus</i>	0.78*	-0.17	0.66	0.01
3	4	<i>Merluccius merluccius</i>	-0.03	-0.17	0.05	0.789
4	5	<i>Trisopterus minutus capellanus</i>	-0.90*	0.66*	0.82	0.0001
5	6	<i>Merlangius merlangus euxinus</i>	-0.56	0.43	0.32	0.18
6	10	<i>Serranus hepatus</i>	0.46	0.71*	0.74	0.002
7	12	<i>Cepola rubescens</i>	0.84*	-0.53	0.71	0.004
8	18	<i>Diplodus annularis</i>	0.64*	0.31	0.62	0.01
9	23	<i>Sarpa salpa</i>	0.39	-0.63*	0.39	0.106
10	33	<i>Chromis chromis</i>	0.12	0.36	0.24	0.289
11	37	Gobiidae	0.42	0.25	0.38	0.114

*significant

riation in number of species with salinity ($R = 0.5866$; $p = 0.045$). The positive and statistically significant correlation coefficient between the number of individuals and temperature showed that the numbers of larval stages is objectively high at higher temperatures. Namely, since the development and growth of the larval stages of fish as well as those of all the poikilotherms, are higher at higher temperature, their probability of occurrence at higher temperatures is lower than when their development lasts longer. Therefore their increased numerousness at higher temperatures in the Kornati archipelago and Murter Sea may be held to be a real consequence of the higher production of eggs and probably lower mortality rates. This was to be expected since it is known that the number of species of fish of Mediterranean-Atlantic and circumtropical zoogeographical origin exceeds to a considerable extent the number of Mediterranean-boreal and Arctic-boreal species in the Adriatic (Regner 1980). Results also suggests that about 70 % of the variability associated with monthly fluctuations in diversity could be predicted by the temperature. These results indicated that even if there is a temperature "controlling" monthly fluctuations of number of species and diversity, derivation of a non-zero association between these biotic factors and sea water temperature does not necessarily imply a causal relationship. In temperate seas such as the Adriatic, most species have internalised their biological cycles according to seasonal patterns. They spawn or settle in a quite short and well defined period of the year. So, abundances of many species were positively or negatively correlated with sea water temperature (Table II), because they settle during the hot or cold season. This is the reason why multilinear correlation coefficients between the number of individuals and water temperature are nonsignificant. Based on the multiple linear regression model it was found that five of 11 common species were positively (*E. encrasicolus*, *C. rubescens*, and *D. annularis*) or negatively (*S. pilchardus* and *T. m. capellanus*) correlated with temperature, indicating that timing

for settling of the individual species is different. Two species were correlated positively (*T. m. capellanus* and *S. hepatus*) and also two species (*S. pilchardus* and *S. salpa*) negatively with salinity.

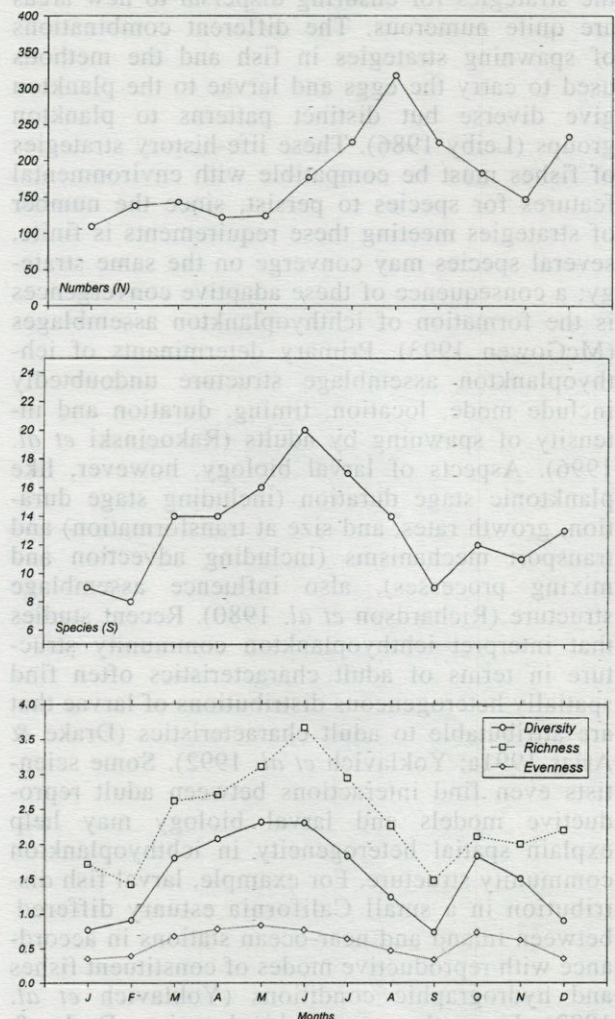


Fig. 3. – Monthly variations in the number of individuals (N), number of species (S), richness, diversity and evenness in the Kornati Archipelago and Murter Sea between January and December 1990.

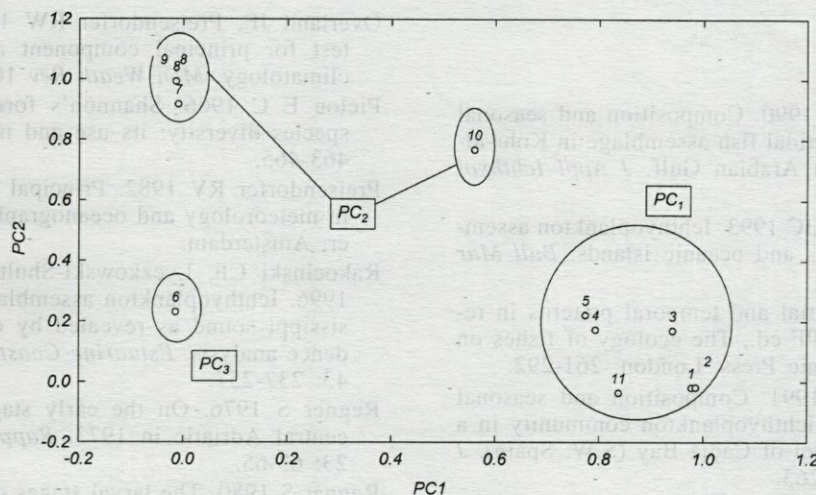


Fig. 4. – Scatter plot of the loadings along PC₁ versus PC₂ of 11 most common species. Letter coding, see Table II.

The number of species, abundances and indices of species richness and diversity of the community of fish larvae and juveniles in the Tanshui river estuary were positively correlated with temperature and salinity (Tzeng & Wang 1992).

To consider which species, or group of species, contributes significantly to the community structure, principal component analyses were performed. According to nonsignificance of the correlation matrix (Bartlett's test) for 11 common species, PC analysis was done. Correlation matrix was significant for $p = 0.05$. Three principal components together describe 91.12 % of the total abundance variance: PC₁ contributes with 52.56 %, PC₂ with 29.59 %, and PC₃ with 8.96 %. When using only percentages of total variances it is difficult to choose the number of PCs with significant meanings. Therefore, Rule N was applied. The first three PCs are significant because the eigenvalues of the real data matrix are smaller than those of the random data matrix. On the basis of the distribution of rotated loadings it was possible to distinguish three groups (Fig. 4). PC₁ has the highest loadings for *Sardina pilchardus*, *Engraulis encrasicolus*, *Merluccius merluccius*, *Trisopterus minutus capelanus*, *Merlangius merlangus euxinus* and family Gobiidae. In the case of PC₂, four species were grouped: *Cepola rubescens*, *Diplodus annularis*, *Sarpa salpa* and *Chromis chromis*. PC₃ has the highest loading just for *Serranus hepatus*. It is difficult to explain species arrangement according to PC loadings. However, species in the case of PC₁ are species which were generally abundant and all of them (except Gobiidae) are offshore spawners and temporary residents. PC₂ has the highest loadings for species

which are benthic species and permanent residents (mostly in coastal region, except *C. rubescens*) and characterised by a similar reproduction time (Jardas 1996). Most of the temporary resident species caught in this study, could be classified into two main groups: autumn-winter egg spawners and pouch-broader species. The main exception was a small group of early summer planktonic egg-spawners (for example, *E. encrasicolus*).

Scores of the first three principal components were compared with sea water temperature and salinity showing that significant linear correlation was found between temperature and PC₁ and salinity and PC₁ scores ($p < 0.0001$, $r = 0.91$; $p < 0.037$, $r = 0.61$).

Unfortunately, we don't have any data about the primary production and zooplankton volume for this area even though some correlation between both number of species and individuals with mentioned parameters could probably exist. This correlation was confirmed for the area of Kastela Bay and station Stoncica (high sea in the eastern middle Adriatic) (Regner 1980, 1982).

Preliminary results of the present study provide a basis for establishing the temporal and spatial patterns of recruitment in various fish species. Following this study, we recommended long-term research to establish whether the correlation between biotic factors and temperature really exists. This should be done after estimating seasonal patterns from both data sets. Further work is needed to elucidate which additional aspects (primary production, zooplankton volume, dissolved oxygen, currents) may influence the distribution and abundance of ichthyoplankton community in the Kornati archipelago and Murter Sea.

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