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Composition and diversity of ichthyoplankton in the Boka Kotorska Bay (South Adriatic Sea)

Milica MANDIĆ*[1], Slobodan REGNER[2], Zoran GAČIĆ[2], Mirko ĐUROVIĆ[1], Olivera MARKOVIĆ[1] and Zdravko IKICA[1]

[1] Institute of Marine Biology, University of Montenegro, Montenegro

[2] Institute for Multidisciplinary Research, University of Belgrade, Serbia

Corresponding author, e-mail: mamilica@ac.me

Variation in the diversity of ichthyoplankton was analyzed from samples collected during three-year cycle in Boka Kotorska Bay. Samples were collected using Calvet (modified PairOVET) plankton net at 18 stations, from July 2006 through January 2009. Families with most numerous species were Engraulidae, Sparidae and Labridae. Investigation shows dominance of anchovy (Engraulis encrasicolus), *Mediterranean rainbow wrasse* (Coris julis) *and annular sea bream* (Diplodus annularis) *during the summer. During the winter, dominant species were sardine* (Sardina pilchardus) *and Atlantic mackerel* (Scomber scombrus), *while during the spring dominant species were anchovy, annular sea bream and white sea bream* (Diplodus sargus). *Spawning of most pelagic fish species in Adriatic Sea starts in spring, and progress during spring and summer months. Therefore, the highest number of species was found in these months, while the lowest number of species was during autumn and winter surveys. Eggs and larval stages of 35 species was determined, while the diversity analysis showed a significant degree of diversity in certain stations where the sea currents were probably the strongest. Diversity of ichthyoplankton communities was analyzed applying two diversity indices: Shannon index (H') and Simpson index (D). Diversity analysis was performed for each of the 18 investigated stations during the tree-year research, while influence of environmental factors on presence of some ichthyoplankton species by seasons was tested with Canonical Correspondence Analyses (CCA).*

Key words: Fish eggs, Shannon diversity index, Simpson index, Canonical Correspondence Analyses, Adriatic Sea

INTRODUCTION

Surveys of fish eggs and larvae are increasingly being used to monitor the spawning areas and stock status of commercially important species. These surveys have contributed to improve our knowledge of the ecological relations among the communities, based on the analysis of the species composition and its time and space variability (FRANCO-GORDO *et al*., 2003).

Most marine teleost fishes produce pelagic eggs and larvae, while transport of ichthyoplankton affects the distribution and abundance of fishes, as well as the retention or dispersal of larval fishes (BOEHLERT & MUNDY, 1994). Both abiotic and biotic factors influence larval fish settlement, distribution, and abundance within an environment (KINGSFORD *et al.*, 2002).

First investigation of ichthyoplankton in Boka Kotorska Bay goes back to 1969, when spatial distribution of anchovy eggs was analyzed (MERKER & VUJOŠEVIĆ, 1972). Studies of the total ichthyoplankton in the Adriatic are relatively scarce, because most papers published so far refer to the one or two species, mostly to the anchovy and sardine. However, other investigations on demersal and pelagic fish species indicated that Boka Kotorska Bay could be one of the important spawning and nursery areas of pelagic species in south Adriatic Sea. After several decades of interruption, the aim of this research was to determine the main spawning and nursery areas of some economically important species.

Study area

The Boka Kotorska Bay (Fig. 1) is a large bay of the Adriatic Sea, situated in the southern part of its eastern coast, at the border between Montenegro and Croatia. Because of its deep indentation into the mainland, its size, and especially its historical, geographical and geo-strategic role and significance, it stands out among other bays of the Mediterranean Sea (MAGAŠ, 2002). Bay consists of four smaller sub-bays: the Bay of Kotor, the Bay of Risan, the Bay of Tivat, and the Bay of Herceg Novi. The Bay is influenced by great influx of fresh waters from numerous water streams and submarine springs.

Near the Bay of Kotor (Kotor-Risan Bay) is the area with the highest rainfall in Europe - Crkvice, from where in a variety of underwater sources and submarine springs, a large amount of fresh water entering the Bay. That water carries out large amount of suspended particles that affect the environmental conditions in the sea: colour, transparency, salinity, density. After abundant rainfalls sea currents intensify especially in the straits of the bay. In autumn emergent current can be so strong that, for example at Verige (Fig. 1, stations 8 and 9) flow from east to west straits can be seen with the bare eye (MAGAŠ, 2002).

Maritime zone of Boka Kotorska Bay, which has a total area of 87.3 km^2, is divided into three sections: inner, middle and outer part. The inner and middle parts are substantially influenced by freshwater inputs (submarine springs, rivers, streams, and precipitation), while the outer part of the Bay is under the influence of the open sea. Another feature of the Bay is relatively great depth in sub-bays and straits. The maximum depth is 64 m (DerMap Project Report, 2011), while the average depth is between 40 to 45 m in most parts of the Bay. The average depth of all four bays is 27.6 m (MANDIĆ *et al.*, 2001).

MATERIAL AND METHODS

This study was carried out between July 2006 and January 2009 (July 2006, December 2006, April 2007, August 2007, April 2008, July 2008, October 2008 and January 2009) at 18 stations in Boka Kotorska Bay. Sampling was not performed during the winter months in 2007 due to the problems with the research vessel.

Samplings were performed by vertical tows, using CalVet plankton net to the maximum depth of 60 m. Diameters of net cylinders were 25 cm each, and the total mouth area was 0.098 m^2, with mesh size of 0.160 mm. Net was towed vertically from the depth of 5 m above the bottom with the speed of 0.5 m/sec.

This type of net was primarily designed for anchovy eggs sampling and this is most likely the reason why very small number of larvae were obtained in the samples. Given that there have been no similar studies of total ichthyopankton composition in this area we decided to improve knowledge by publish the results of conducted ichtyoplankton investigations.

The samples were fixed immediately after sampling with 2.5% of buffered formaldehyde solution and later on analyses in the laboratory under the binocular NIKON SMZ 800. Temperature and salinity were measured on site from the sea surface to the maximum depth reached with a Marimatech HMS 1820 CTD probe at each station (July, December 2006 and April 2007).

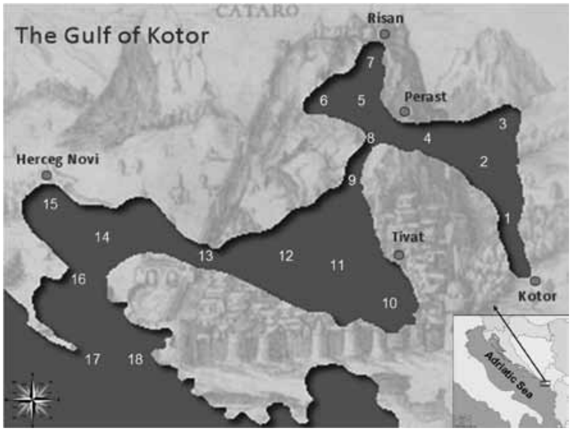

Fig. 1. Study area and the locations of sampling stations (1-18).

Diversity of ichthyoplankton communities was analyzed using two diversity indices: Shannon's diversity index (H ') and Simpson's index (D) for each station separately and total diversity was analyzed, too. Diversity indices are measures of specific attributes of the community; they are often used as indicators of ecological conditions in the environment (CLARKE & WARWICK, 1994). Species, which are in the same quadrant with environmental parameters (shown with arrows), are positively correlated, whereas those species, which are in opposite quadrants, are negatively correlated. Greater distance from the central point indicates higher correlation with the environmental factors analyzed.

Maps of horizontal distribution of temperature and salinity were done in the Surfer Golden Software 8 applying kriging method.

Relationship between the presence (occurrence) of certain types of ichthyoplankton species on the one hand, and locality on the other, as well as the influence of environmental factors (temperature and salinity) was tested using Canonical Correspondence Analyses (CCA) (TER BRAAK, 1986; TER BRAAK, 1994). This analysis were performed using software "Flora" (KARADŽIĆ *et al.*, 1998) for three seasons (July 2006, December 2006 and April 2007). This method is commonly used to identify environmental gradients in the series of data on environmental factors (BARKER, 1994), particularly those factors that are significant in determining community composition.

RESULTS

Total of 1116 eggs and 258 larvae was found during the period of investigation. Thirty five taxa representing 28 genera and 19 families were collected from 18 stations (Table 1).

Species composition in July 2006

Samples from July 2006 were represented with total of 19 different taxa. Of the total number of stations, only station number 1 was negative on ichthyoplankton. The most dominant were the following species - anchovy (*E. encrsicolus*), which was found at 14 stations (no. 2, 3, 4, 5, 6, 7, 8, 10, 11, 12, 13, 14, 16 and 18), Mediterranean rainbow wrasse (*C. julis*) whose planktonic stages were found at 11 stations (no. 2, 4, 7, 8, 9, 10, 11, 12, 13, 14 and 17), annular sea bream (*D. annularis*) at 9 station (no. 4, 6, 7, 8, 10, 13, 14, 15 and 17), Mediterranean scald fish (*A. lanterna*) at stations no. 13 and 14, and horse mackerel (*T. mediterraneus*) at 3 stations (no. 11, 13 and 14), as well as larvae belonging to the family Gobiidae, which were found in 7 stations (no. 2, 4, 5, 11, 12, 14, 16 and 18). Other species were present in small amounts at only one or two stations in the entire study area.

Species composition in December 2006

Samples from December 2006 were represented with total of 7 taxa, of which 5 was determined to species level and 2 to the genus. The most abundant species in all stations was sardine (*S. pilchardus*), whose eggs and larvae and/or postlarvae were found at 11 stations (no. 2, 3, 4, 5, 8, 9, 11, 12, 13, 14 and 16) and Atlantic mackerel (*S. scombrus*) whose planktonic stages were found at 7 stations (no. 4, 5, 12, 13, 14, 15 and 16). At two stations (station number 2 - in the central part of the Kotor bay and station number. 5 - in Risan bay) total of 5 anchovy eggs were found, which was the first record of anchovy eggs in the winter period in the Adriatic Sea (MANDIĆ *et al.*, 2012). Species *Callionymus maculatus* was found at 3 stations

Table 1. List of determined ichthyoplankton species and their presence by investigated months

Taxon	Common name	Month
Sparidae		
Diplodus puntazzo	Sharpsnout seabream	July 2006, August 2007, April 2008, July 2008, October 2008
Diplodus annularis	Annular seabream	July 2006, April 2007, August 2007, April 2008, July 2008
Diplodus sargus	White seabream	April 2007, August 2007, April 2008, july 2008
Pagellus acarne	Axillary seabream	July 2006
Boops boops	Bogue	April 2007, April 2008
Spondyliosoma cantharus	Black seabream	April 2007
Pagrus pagrus	Red porgy	August 2007
Lithognathus mormyrus	Sand steenbras	April 2007, october 2008
Engraulidae		
Engraulis encrasicolus	European anchovy	July 2006, December 2006, April 2007, August 2007, April 2008, July 2008, October 2008
Clupeidae		
Sardina pilchardus	European pilchard	December 2006, April 2007, April 2008, January 2009
Sardinella aurita	Round sardinella	July 2006, August 2007, july 2008
Labridae		
Coris julis	Mediterranean rainbow wrasse	July 2006, April 2007, August 2007, April 2008, July 2008
Labrus merula	Brown wrasse	April 2007
Bothidae		
Arnoglossus laterna	Mediterranean scaldfish	July 2006, July 2008
Arnoglossus thori	Thor's scaldfish	April 2007, January 2009
Carangidae		
Trachurus mediterraneus	Mediterranean horse mackerel	July 2006
Trachurus trachurus	Atlantic horse mackerel	April 2007, August 2007, April 2008
Seriola dumerili	Greater amberjack	August 2007
Serranidae		
Serranus hepatus	Brown comber	July 2006, April 2007, August 2007, July 2008
Serranus scriba	Painted comber	April 2007

Serranus cabrilla	Comber	April 2007
Callionymidae		
Callionymus risso	Risso's dragonet	July 2006, April 2007, August 2007, April 2008
Callionymus lyra	Common dragonet	July 2008
Callionymus maculatus	Spotted dragonet	December 2006
Gadidae		
Gadiculus argenteus	Silvery pout	July 2006, April 2007, August 2007, April 2008
Trisopterus minutus	Poor cod	July 2006, January 2009
Scombridae		
Scomber scombrus	Atlantic mackerel	December 2006, April 2007, January 2009
Scomber japonicus	Chub mackerel	August 2007
Sarda sarda	Atlantic bonito	August 2007
Trachinidae		
Trachinus draco	Greater weever	July 2006
Moronidae		
Dicentrarchus labrax	European seabass	December 2006, April 2008
Ophichthidae		
Ophisurus serpens	Serpent eel	April 2007
Lotidae		
Gaidropsaurus mediterraneus	Shore rockling	August 2007, April 2008, July 2008
Mugilidae		
Mugil cephalus	Striped mullet	July 2008
Scorpaenidae		
Scorpaena porcus	Black scorpionfish	July 2006
Gobiidae		
Gobius sp		July 2006, December 2006, April 2007, August 2007, April 2008, July 2008
Triglidae		
Trigla sp		December 2006
Soleidae		
Solea sp.		July 2008

(no. 5, 9, and 10). Of the total number of stations examined, in December 2006 four were negative on the planktonic stages of fishes (station no. 1, 6, 7 and 8).

Species composition in April 2007

Samples from April 2007 were represented with total of 17 taxa, of which 16 were determined to species level and one to the genus, while one larva remained undetermined. The dominant species in the plankton was anchovy, whose percentage contribution in the total ichthyoplankton composition was 61%. Planktonic stages of anchovy were found at 16 stations (negative were stations no. 1 and 7). White sea bream (*D. sargus*) was the most dominant species after anchovy with a total of 11 positive stations (station no. 2, 3, 4, 7, 8, 10, 11, 12, 13 15 and 17). Sardines were found at 6 stations (no. 8, 12, 13, 14, 17 and 18), Atlantic mackerel (*S. scombrus*) was found at 9 (no. 2, 4, 8, 9, 13, 14, 16, 17 and 18), bogue (*B. boops*) at 7 stations (no. 2, 3, 8, 11, 14, 16 and 17) and brown comber (*S. hepatus*) at stations (no. 4, 11, 14 and 17). Other species that were found in the samples were present in small numbers. April 2007 was characterized by a remarkable diversity of species and their abundance. All studied stations were positive, precisely early developmental stages of fish were obtained.

Species composition in August 2007

Samples from August 2007 were represented with total of 17 taxa, out of which 16 were determined to species and 1 to genus level, while one larva remained undetermined. The most numerous were planktonic stages of the anchovy, which planktonic stages were present in all surveyed stations. Annular seabream (*D. annularis*) were found in a number of stations (no. 1, 3, 4, 5, 6, 8, 9, 10, 11, 14, 16 and 17), then the Sharpsnout seabream (*D. puntazzo*) whose planktonic stages were found at 12 stations (no. 1, 2, 4, 6, 8, 9, 10, 12, 13, 14 and 17), brown comber (*S. hepatus*) at 8 (no. 9, 10, 11, 12, 13, 17 and 18), round sardinella (*S. aurita*) at 5 stations (no. 9, 10, 12, 13 and 17), red porgy (*P. pagrus*) at 4 stations (no. 2, 9, 14 and 17) and chub mackerel (*S. colias*) at the 4 stations (no. 4, 6 , 9 and 18). Larvae of Gobiidae were found at 12 stations.

Other species that have been identified in the plankton were present only at one surveyed station.

Species composition in April 2008

In the samples from April 2008 total of 13 taxa were present. Early developmental stages of anchovy were dominant in the total ichthyoplankton composition. After anchovy, most dominant were Atlantic horse mackerel eggs (*T. trachurus*), Gobius sp. larvae, sardine (*S. pilchardus*) eggs, then white seabream (*D. sargus*) and annular seabream (*D. annularis*).

Species composition in July 2008

July 2008 was represented with total of 13 taxa. Eggs and larvae/postlarvae of anchovy were dominant in the total ichthyoplankton (67%). Early developmental stages of anchovy were found at 14 stations (negative stations were no. 13, 15, 16 and 18). After anchovy, planktonic stages of Mediterranean rainbow wrasse (*C. julis*) were found at 12 stations (negative were stations no. 7, 9, 10, 12, 15 and 17). Eggs of *A. lanterna* were found at 5 stations (no. 4, 8, 10, 16 and 18), eggs of annular seabream (*D. annularis*) at 6 stations (no. 1, 2, 8, 9, 14 and 17), round sardinella (*S. aurita*) at 4 stations (no. 1, 2, 3 and 16), while the eggs of *G. mediterraneus* were found at 2 station in the bay (station no. 2 and 5). Larvae of Gobiidae were present at 5 stations (no. 1, 2, 5, 9 and 12), while all the eggs belonging to the genus *Solea* were found at the station no. 5, and that represents only finding of planktonic stages of *Solea* sp. during the entire sampling period. In July 2008 all surveyed stations were positive for ichthyoplankton.

Species composition in October 2008 and January 2009

Ichthyoplankton composition in October 2008 and January 2009 was characterized by a very few number of species. In October, from total number of stations examined, only 7 were positive for planktonic stages of fishes, with a total of 3 different taxa determined - anchovy (*E. encrasicolus*), which was found at the 3 stations (no. 2, 3 and 11), Sharpsnout seabream (*D. puntazzo*) at the 3 stations (no. 2, 4 and 8), and send Steenbras (*L. mormyrus*) whose eggs were found in two stations (no. 14 and 17).

In January 2009 total of 7 stations were positive for ichthyoplankton. Sardine (*S. pilchardus*) was found at 4 stations (no. 7, 11, 13 and 17), while Thor's skaldfish (*A.thori*), poor cod (*T. minutus*) and Atlantic mackerel (*S. scombrus*) were present at only one station in the Bay.

Fig. 2 presents number of fish eggs and larvae (per m^2 of sea surface) of most abundant species find in plankton samples by seasons. October 2008 and January 2009 are not included in the Fig. 2 due to a very small number of species. Other taxa that are not presented graphically were found in a very small numbers (1-2 eggs / larvae per station).

Hydrography of the surveyed area

Figs 3 (A, B and C) and 4 (A, B and C) show spatial distribution of sea surface temperature and salinity on the 18 surveyed stations inside the Boka Kotorska Bay for July 2006, December 2006 and April 2007.

Average sea surface temperature in July 2006 was 22.9°C, and maximum was 25.8°C at station number 5 (Risan Bay). In August 2007 maximum sea surface temperature was measured in Kotor bay at station number 2 (25.2°C). Lowest value of sea surface temperature was measured in April 2007 at station number 8 (14.6 °C) while in December 2006 temperatures at all stations were around 1.5°C higher than in April 2007.

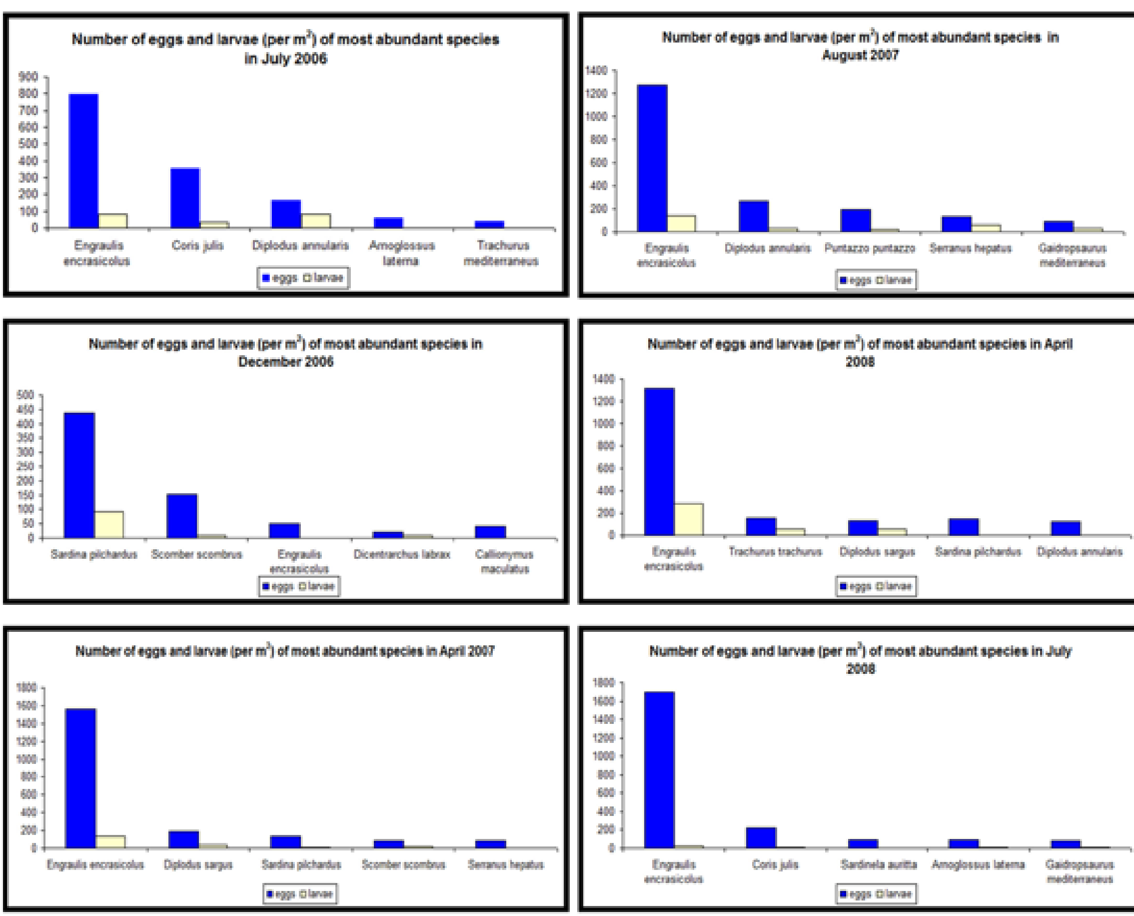

Fig. 2. Number of fish eggs and larvae (per m2 of sea surface) of most abundant species.

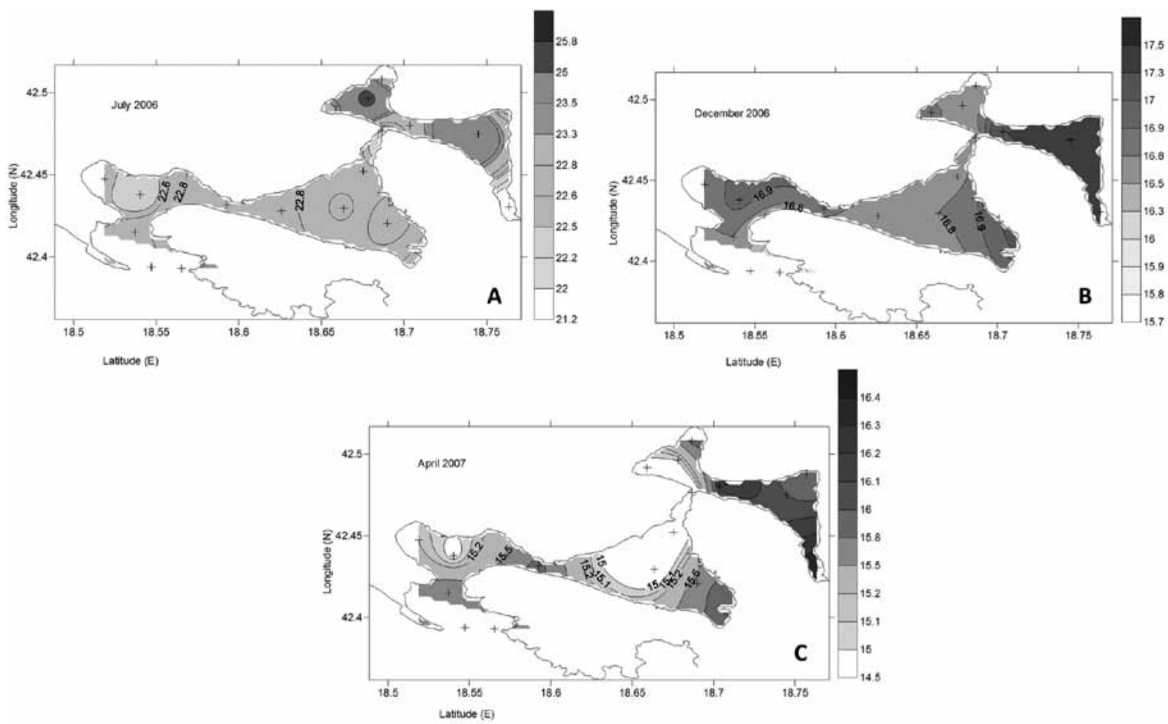

Fig. 3. Distribution of sea surface temperature (SST °C) in July 2006 (A). December 2006 (B) and April 2007 (C)

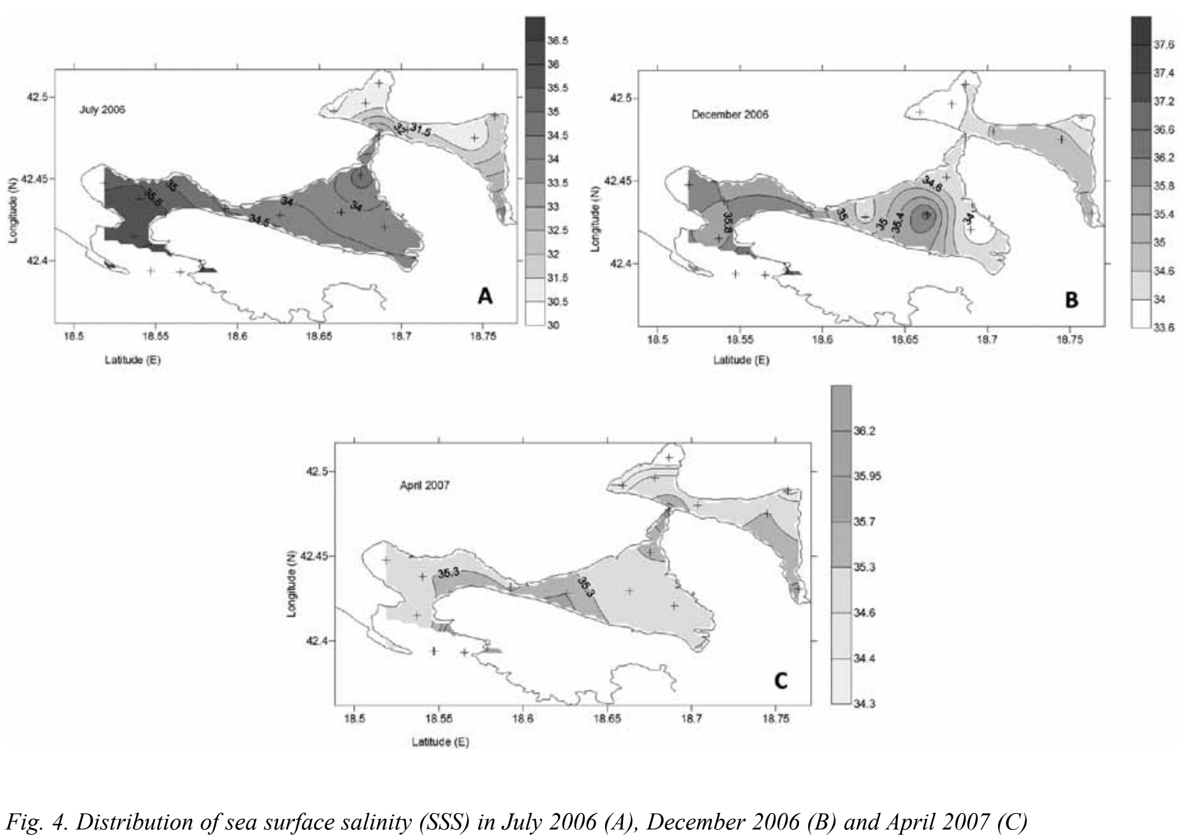

Fig. 4. Distribution of sea surface salinity (SSS) in July 2006 (A), December 2006 (B) and April 2007 (C)

Average value of sea surface salinity in July 2006 was 33.6‰. Minimum value of 30.4‰ was measured at station number 6 (Risan Bay), while maximum value of 36.7‰ was measured on the edge of the bay, at contact zone with open waters of Montenegrin coast, at station number 17.

In December 2006 average value of salinity was 34.9‰, minimum was 33.5‰ (station number 3), while maximum value was measured at station number 18 (33.5‰).

In April 2007 average value of salinity at all investigated stations was 35.2‰, minimum was 34.1‰ (station number 7) while maximum was 38.2‰ at station number 18.

Diversity indices

Shannon's diversity index (H') and Simpson's reciprocal index (D) were calculated at the species level for each season. Calculated values of Shannon's diversity index in July 2006 varied from 0 to 2.35, while Simpson's reciprocal index varied from 1 to 7.74 (Fig 5). July 2006 was characterized by the highest degree of diversity in relation to all investigated months. In December 2006 the value of Shannon's index ranged from 0 to 1.01, while the Simpson index varied from 1 to 2.57. April 2007 was characterized by significant diversity of species, although with slightly lower values compared to July 2006 (0 <H '<1.98, 1 <D <5.77). August 2007 (0.5 <H '<1.99, 1.47 <D <5.77) and April 2008 (0.2 <H '<1.83, 1.1 <D <5.76) were characterized with very similar values of the degree of diversity, while in July 2008, the calculated values for H' were from 0 to 1.33 and for D from 1 to 3.57.

The results of Canonical Correspondence Analysis of the species presence according to the three investigated seasons, sites and the

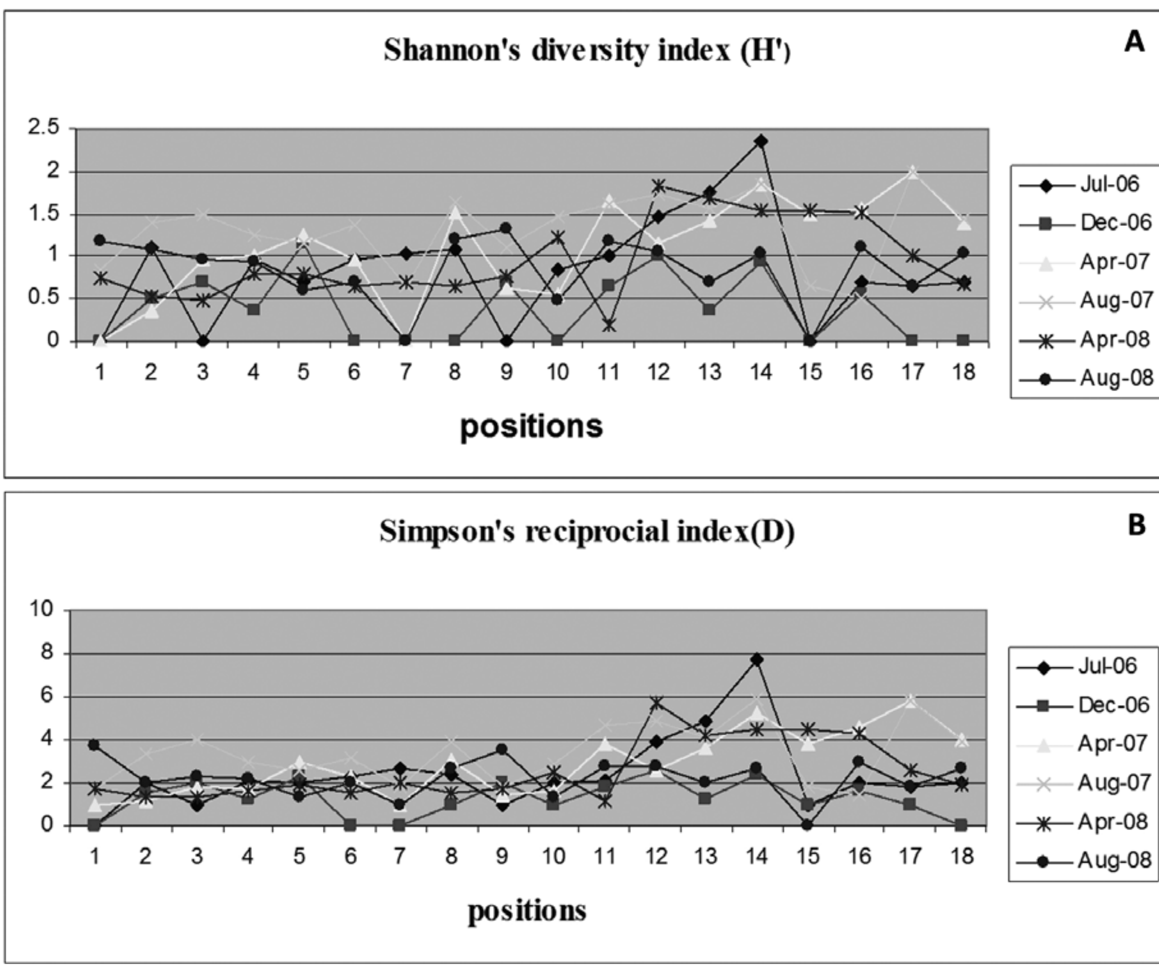

Fig. 5. Values of Shannon's diversity index (A) and Simpson's reciprocal index (B) by months

influence of environmental factors (temperature and salinity) are shown on the diagrams with the environmental variables as vectors. The analysis was done for the seasons for which hydrographical data were available.

CCA in July 2006 (Fig. 6) shows that the relationship between hydrographical factors (temperature and salinity) and the occurrence of planktonic stages of fish was positive, but very weak for the most of species. The strongest effect of temperature and salinity was found for species *T. draco* (Tra dra), *P. acarne* (Pag aca), *S. porcus* (Sco por), and *G. capelanus* (Gad cap). All four species were found at station 14, which is under the influence of the waters of the open sea. The temperature at this station was 22.2 °C, and salinity 35.81 ‰. The value of salinity was significantly higher than in the inner parts of the Bay.

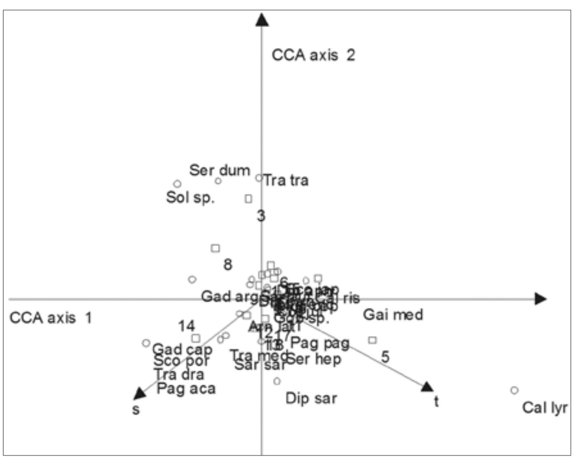

Fig 6. Canonical Correspondence Analysis explains the occurrence of species in relation to environmental factors (temperature and salinity) for July 2006

In December 2006 the negative influence of environmental factors was found to be important for species: *E. encrasicolus* (En enc), *A. thori* (Arn tho) and *Trigla* sp. (Tri sp), while the influence on the other species was very poor (Fig. 7).

Canonical Correspondence Analysis for April 2007 (Fig. 8) shows that positive effect of temperature and salinity was found in 10 species, with the major significance for *D. puntazzo* (Dip pun) and *O. serpens* (Oph ser). Other species are scattered along the first CCA axis and to the third and fourth quadrant.

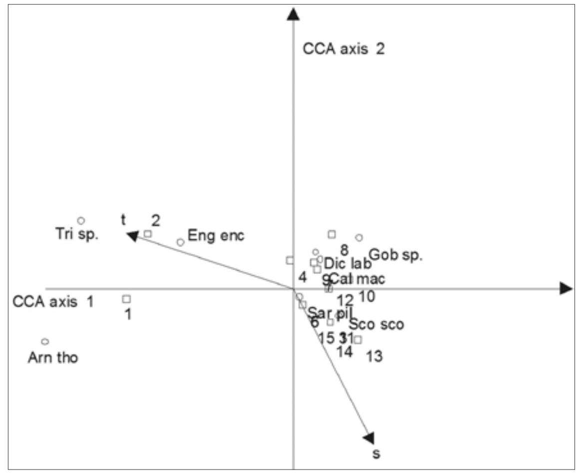

Fig. 7. Canonical Correspondence Analysis explains the occurrence of species in relation to environmental factors (temperature and salinity) for December 2006

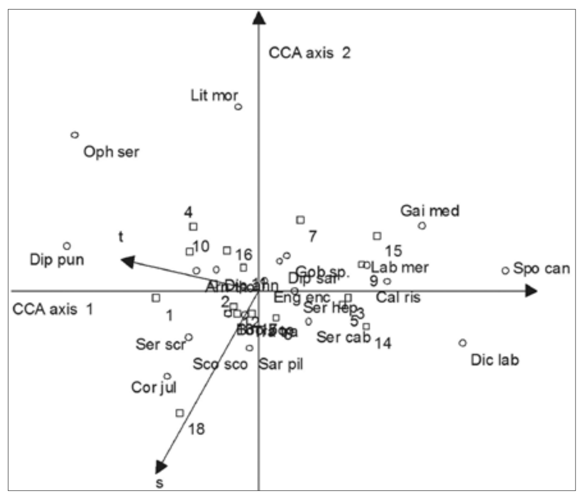

Fig 8. Canonical Correspondence Analysis explains the occurrence of species in relation to environmental factors (temperature and salinity) for April 2007

DISCUSSION

Study of composition and diversity of ichthyoplankton in the Boka Kotorska Bay showed a considerable diversity of fish eggs, larvae and postlarvae. This is the first study that refers to the species diversity of ichthyoplankton in this part of the south-eastern Adriatic Sea.

The highest diversity value was found during the summer, which implies that the greater number of species spawn in this time of year. This is consistent with previous studies of ichthyoplankton abundance and diversity, which showed that the late spring and early summer represent transitional period for the spawning of Mediterranean fish species, when species diversity and abundance are in maximum (SABATES, 1990; SABATES & MASO, 1992; SABATES & OLIVAR, 1996; SOMARAKIS *et al.*, 2002).

It was also found that the highest degree of species diversity was found at the stations where the flow of seawater seems to be fastest (Kumborski tijesnac and Verige – stations no. 8, 9 and 13), as well as in the area under the influence of the open waters (Mamula – stations no. 17 and 18). Although during this research there was no investigation of sea currents, it is well known that the specific conditions of each location (geographic location, currents, degree of enclosure, degree of anthropogenic influences, etc.) may strongly influence the ichthyoplankton abundance (GORDINA *et al.*, 2001; MARQUES *et al.*, 2006). Investigation on prediction of species diversity of benthic communities showed that stronger currents below 6-m depth might have resulted in greater species heterogeneity in deeper bottoms than that of the embayment (COLLIN *et al.*, 2011).

Relatively low values of diversity indices on majority of the studied stations are most likely the consequence of the dominance of few species, but they also may be the result of anthropogenic influence, which is especially pronounced during the summer months when the influx of tourists is intensified. Since diversity indices represent mathematical expression of relations of qualitative and quantitative composition of the community, their values will be significantly higher at the stations where there are no dominant species, although qualitative composition is the same (HOŞSUCU & YEŞSIM, 2002). In other words, maximum diversity indices do not need to coincide with the maximum species richness due to the dominance of some species (KARASIOVA & IVANOVICH, 2007).

Results of Canonical Correspondence Analysis, obtained for only three seasons (summer, winter and spring) for which hydrographical data were available, did not give a clear picture of the influence of abiotic factors (temperature and salinity) on the spawning of species. However, the analysis showed that during the summer months there was a significant positive correlation between these factors (especially salinity) and the spawning of following species: *T. draco, P. acarne, S. porcus,* and *G. capelanus*, which, as already stated, were found in the Bay of Herceg Novi, which is influenced by open sea. Taking into account that the egg density is well correlated to the sea water salinity, it can be concluded that the drifts of the eggs from their spawning location to their sampling location can be the consequences of spatial variation of the salinity (GOARANT *et al.*, 2007). This conclusion should be taken with caution because the drift and retention of fish eggs and larvae within habitats critical to their survival are among the most poorly understood elements of the early life history of many fish (REGNER *et al.*, 1987; SINCLAIR, 1988; HELBIG & PEPIN, 2002).

Indirect effect of salinity on development of fish eggs and larvae is reflected in the availability of oxygen, because at higher salinity concentration oxygen is lower, although other factors, such as temperature, may remain unchanged (REGNER *et al.*, 1987). Hence, relatively small difference in temperature and salinity values in the inner part of the Bay, where the number of species was highest, might be one of the reasons why CCA did not show a significant correlation between these factors and the spawning of fish species in the Bay. Since the optimum temperature for spawning of anchovy is 21.3°C (REGNER, 1996), this temperature (mean 22.6°C, range between 21.2 and 23.3 °C) may be probably close to the optimum for other fish species, which spawn during the summer, so it could be concluded that the temperature range found is among the broad limits of the optimum for most species found during the investigation. Thus, within such a small range of temperatures cannot be expected any significant correlation.

The analysis which was done in spring showed a strong positive correlation only for the species *L. mormyrus* and *O. serpens*, while for all other species correlation was non-significant. A possible reason for this is that in April sardines and other species that spawn during the winter end their spawning season, while anchovy and other species that follow them in spawning just begin to spawn. The values of temperature and salinity were beyond optimal values for both groups of fishes. Moreover, temperature range was relatively small, from 14.6 °C to 16.4 °C, while the mean value was 15.46 °C. This can be explained with the fact that ecological factors such as predation, competition, or food availability (quantity or quality), can influence the timing of spawning (JOHANNES, 1978; NORCROSS & SHAW, 1984). Spawning of fishes may coincide with favorable environmental conditions suitable for eggs, growth and survival of larvae, as well as for juveniles (NORCROSS & SHAW, 1984).

Analysis of samples from the winter season showed significant negative correlation between the salinity and the spawning of *E. encrasicolus* and *A.s thori*. On the other hand, anchovy was positively correlated with temperature. The mean temperature at the stations where anchovy eggs were found was 17.13°C, while the mean temperature of the whole area was 16.97°C (ranging from 15, 55 °C to 17.5 °C). Furthermore, Figure 12 shows that there is a positive but insignificant correlation between sardine spawning and abiotic factors. This is probably a consequence of the high temperature in December 2006, because the optimal temperature for spawning of sardine is 13.1°C (REGNER *et al*., 1987).

According to all the above, it can be concluded that the insignificant correlation obtained with the CCA method is most probably a consequence of relatively uniform temperature and salinity fields in the study area.

All determined species have pelagic eggs and the general pattern of ichthyoplankton assemblages of the area seems to be closely related to the adult fish assemblage and the spawning locations of adult populations (TSIKLIRAS & KOUTRAKIS, 2010).

Total number of determined species in a relatively small area of the Boka Kotorska Bay indicates significant species diversity, especially when compared to similar studies carried out in the northern Adriatic Sea and other parts of the Mediterranean. During the investigation carried out in northeast Adriatic, in the Kornati archipelago and Murter Sea during 12 month cycle, total of 28 families and 52 species were identified (DULČIĆ & GREBEC, 2000). Investigations of qualitative and quantitative composition of the larval fish stages in the plankton at the open sea of the central Adriatic Sea during six year cycle (1971-1977) showed presence of 56 different species and 14 genera (REGNER, 1982). In northern Ionian Sea, study of spatial distribution, abundance and composition of fish larvae carried in March 2000 showed presence of 46 different species of teleost early stages, belonging to 38 genera and 22 families (GRANATA *et al*., 2011). Survey carried out in the central Cantabrian Sea shelf (southern Bay of Biscay) showed presence of 34 taxa of fish larvae during the summer cruise (RODRIGUEZ *et al.,* 2011). Composition of ichthyoplankton from the Mar Menor lagoon (south East Spain) during the investigation carried out from February to December 1997, showed presence of 14 families, 22 genera and 36 different species (PEREZ-RUZAFA *et al*., 2004). Survey of larval fish assemblages in the coastal waters of central Greece (Ionian and Aegean Seas) during 1998 and 1999 showed presence of 74 larval taxa (SOMARAKIS *et al*., 2011).

The results of this study could have implications for management of marine resources as well as indications of the importance of Boka Kotorska Bay as a nursery and spawning ground for significant number of economically important fish species, due to the fact that this investigation confirmed our assumption that Boka Kotoska Bay is nursery and spawning ground for most pelagic fish species.

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Sastav i raznolikost ihtioplanktona u Bokokotorskom zaljevu (južni Jadran)

Milica MANDIĆ*[1], Slobodan REGNER[2], Zoran GAČIĆ[2], Mirko ĐUROVIĆ[1], Olivera MARKOVIĆ[1] i Zdravko IKICA[1]

[1] *Institut za biologiju mora, Univerzitet Crne Gore, p.p.69, Crna Gora*

[2] *Institut za multidisciplinarna istraživanja, Univerzitet u Beogradu, Srbija*

**Kontakt adresa, e-mail: mamilica@ac.me*

SAŽETAK

Kolebanja u raznolikosti ihtioplanktona analizirana su na uzorcima prikupljenim tijekom tri godine u Bokokotorskom zaljevu. Uzorci su prikupljeni pomoću Calvet (modificirani PairOVET) planktonske mreže na 18 postaja, od srpnja 2006. do siječnja 2009. Najbrojnije su bile obitelji vrsta Engraulidae, Sparidae i Labridae. Istraživanje pokazuje dominaciju inćuna (*Engraulis encrasicolus*), kneza (*Coris julis*) i špara (*Diplodus annularis*) tijekom ljeta. Tijekom zime, prevladavajuće vrste su bile srdela (*Sardina pilchardus*) i skuša (*Scomber scombrus*), dok su u proljeće prevladavajuće vrste bili inćun i šarag (*Diplodus sargus*).

Mrijest većine vrsta riba u Jadranu počinje u proljeće, a progresivni napredak se odvija tijekom proljetnih i ljetnih mjeseci. Dakle, najveći broj vrsta je pronađen u proljetnim i ljetnim mjesecima, dok je najmanji broj vrsta pronađen tijekom jesenskih i zimskih istraživanja. Tijekom istraživanja pronađeni su jaja i ličinke 35 vrsta, dok je analiza pokazala značajan stupanj raznolikosti na pojedinim postaja gdje su morske struje vjerojatno najjače.

Raznolikost ihtioplanktonske zajednice je analizirana primjenjujući dva indeksa raznolikosti: Shannon indeks (H') i Simpson indeks (D). Analiza raznolikosti je provedena za svaku od 18 istraživanih postaja tijekom trogodišnjih istraživanja, dok je utjecaj ekoloških čimbenika na prisutnost nekih vrsta po sezonama bio testirana primjenom CCA analize (Canonical Correspondence Analyses).

Ključne riječi: riblja jaja, Shannon indeks raznolikosti, Simpson indeks, CCA analiza, Jadransko more