Belg. J. Zool., 130 (Supplement): 43-50 December 2000

Seasonal changes in distribution and abundance of the fish fauna in the two estuarine systems of Strymonikos gulf (Macedonia, Greece)

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ABSTRACT. Fifty-five fish species representing 20 families were recorded in the two estuarine systems of Strymonikos Gulf. Twelve of them were freshwater, while 43 were estuarine and near-shore marine species. Forty-three species were caught in the Strymon estuarine system, nine of which were freshwater (20.9%), and 29 in the Rihios estuarine system, five of which were freshwater species (17.5%). The euryhaline *Pomatoschistus marmoratus* was the dominant species throughout the whole sampling period in the Strymon system but the highest relative abundance was recorded for *Liza ramada* in May 1999 (4,738 ind./1,000 m^2). The highest species richness in the Strymon system was observed in September 1997 with 16 species and the lowest in January 1998 with only two species. In the Rihios system, the freshwater species *Rhodeus amarus* was the most abundant one during the months of its presence and exhibited the highest CPUE value (38,833 ind./1,000 m^2) recorded in this study. Species richness in the Rihios system peaked in July 1998 (18 species). Species richness and total abundance in the two sites were both found to increase during the warm seasons of the year (summer and autumn) following the water temperature fluctuations almost immediately. The seasonality of temperature changes was also found to determine the temporal changes of species composition of the overall fish community.

KEY WORDS: estuaries, euryhaline fish, CPUE, Strymonikos Gulf, Greece.

INTRODUCTION

Estuarine fish are mainly euryhaline forms that are able to exist in unstable surroundings surviving variable salinities, currents, and food supplies. Apart from these 'true' estuarine species, estuaries are also occasionally used by passage migrants or by marine and freshwater species for feeding and breeding or as nursery grounds (DANDO, 1984). Thus, estuarine fish communities are highly variable, and in some cases they experience large temporal changes in species composition and abundance (TREMAIN & ADAMS, 1995).

Although the estuarine fish communities have been extensively studied in other parts of the world (MARAIS & BAIRD, 1980; MARAIS, 1981; WHITFIELD, 1980; POTTER et al., 1983; WHITFIELD, 1983; LONERAGAN et al., 1986; TREMAIN & ADAMS, 1995 and others) literature concerning the distribution and abundance of fish fauna in European and Mediterranean estuarine systems is rather limited. Relevant information is available for River Po (VITALI & BRAGHIERI, 1981), Severn Estuary (CLARIDGE et al., 1986), Porto-Lagos lagoon (KOUTRAKIS et al., 2000), Gialova lagoon (DOUNAS & KOUTSOUBAS, 1996) and Mesolongi-Etolikon lagoons (LEONARDOS et al., 2000). Moreover, there are data referring to the distribution and abundance of commercially important fish species, mainly of Mugilidae (BOGRAD, 1961; ALBERTINI-BERHAUT, 1978; KATAVIC, 1980; TORRICELLI et al., 1982; VIDY & FRANC, 1992; KOUTRAKIS et al., 1994).

The two estuarine systems where the study was carried out are those of Strymon and Rihios, which are the two main rivers flowing into the Strymonikos Gulf. The Strymonikos Gulf is located at the northwestern part of the Aegean Sea occupying an area of 540 km^2. Strymon River, one of the three most important rivers in Northern Greece, originates from Bulgaria and flows to the northern part of the gulf. The river is embanked throughout its course, and

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towards its mouth it forms a small lagoon and a number of channels. Rihios is a small river with a steady flow throughout the year that drains the lake Volvi. It flows to the western part of the gulf, creating a small estuarine system. According to the Greek habitat project Natura 2000 both rivers are ecologically important sites and moreover, Rihios is part of the Lake Koronia-Volvi Ramsar site.

The aim of this study was to describe the seasonal patterns of distribution and abundance of the fish fauna in these estuarine systems. More specifically, the objectives were to provide a quantitative checklist of the fish species caught in the two areas and to detect the temporal changes in species richness and abundance and their relationship to the abiotic parameters of the water (temperature, salinity, oxygen and pH). The ecological importance of the two areas makes such data valuable for sustainable management.

MATERIAL AND METHODS

Sampling was carried out on a monthly basis from September 1997 to May 1999. Four sampling stations were selected, two in the Strymon estuarine system and two in the Rihios one (Fig. 1). A bag seine net of 20 m length and 2 mm mesh size was used for the collection of freshwater, euryhaline and near-shore marine species. Moreover, a fyke-net of 2 mm mesh size was placed every month for a period of 24 hours in the Rihios river, in order to collect species difficult to catch with a bag seine, either due to the time of the regular sampling or to behavioural characteristics of the fish. After collection, samples were preserved in 6% formalin until total length and weight were measured in the laboratory. During sampling, water temperature, salinity, pH and dissolved oxygen were also measured *in situ.*

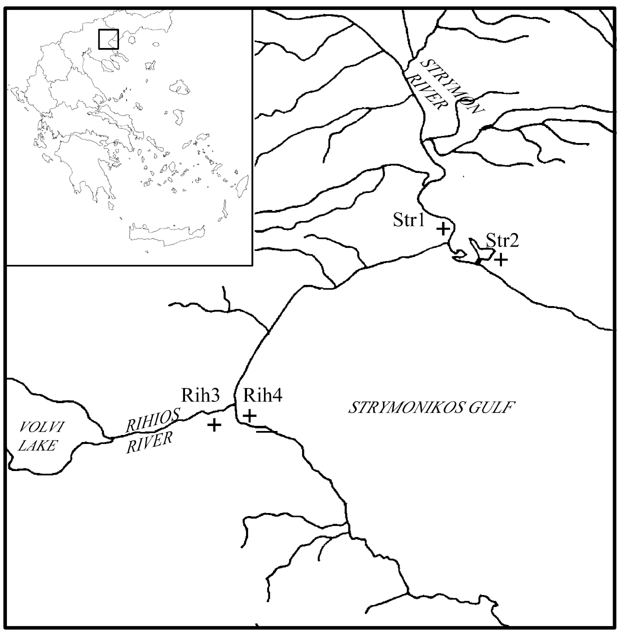

Fig. 1. – The Strymonikos Gulf (Macedonia, Greece) with the two rivers and their estuarine systems. The four sampling stations are indicated.

In order to estimate relative abundance, the catch per unit effort method (CPUE) was used (GULLAND, 1964; BANNEROT & AUSTIN, 1983). The unit of effort was defined as the area covered by hauling of the seine net (MARAIS & BAIRD, 1980; KOUTRAKIS, 1994; KOUTRAKIS et al., 1995) and was converted to 1,000 m^2. Abundance was not estimated for the species caught in the fyke-net.

Regarding data analysis, Pearson's correlation coefficient was used in order to detect relations of fish relative abundance and species richness with the water physico-chemical parameters, while in order to reveal any synchronisation in the monthly changes of the above biotic and abiotic parameters, cross-correlation analysis were used (CHATFIELD, 1975). The pattern of temporal changes in the structure of the overall fish community was explored by Correspondence Analysis, a multivariate method primarily introduced by BENZECRI (1969) and developed independently later by several other authors (e.g. 'Reciprocal averaging' by HILL, 1973). The computations used here are presented in GREENACRE (1984). For this analysis monthly samples from all experimental stations were treated together, while in order to avoid bias of the results, species that occurred only once or twice in the sampling period were excluded as outliers.

RESULTS

Fifty-five fish species, representing 20 families, were recorded in the two estuarine systems (Table 1 and 2). Twelve of them (21.8%) were freshwater, while 43 (78.1%) were estuarine and near-shore marine species. Forty-three species were caught in the Strymon estuarine system, nine of which (20.9%) were freshwater, and 29 were caught in the Rihios system, five of which (17.2%) were freshwater species. The freshwater species *Anguilla anguilla* and *Knipowitschia caucasica* were only caught in the fyke net.

With respect to the Strymon system (Table 1), members of the Mugilidae family were among the most abundant species, accounting for 43.4% of the total catch. The common goby *Pomatoschistus marmoratus* was the dominant species throughout the whole sampling period (31.2%), being present for 19 months. The second most frequently caught species was *Liza aurata* (14 months of presence), followed by *L. ramada* (13 months of presence). The highest relative abundance was recorded for *L. ramada* in May (4,738 ind./1,000m^2) and March 1999 (3,112 ind./1,000 m^2), followed by *P. marmoratus* in September 1998 (3,388 ind./1,000 m^2).

Regarding the Rihios system (Table 2), the most abundant species (56.5% of the total catch) were members of the Cyprinidae family. The thick lip mullet *Chelon labrosus* was present throughout the study period, but the freshwater species *Rhodeus amarus* was the most abundant one during the months of its presence (42.8% of the total catch), reaching its maximum relative abundance in September 1998

TABLE 1

The species caught in the Strymon estuarine system and their relative abundance. (Taxonomy of freshwater species is according to KOTTELAT, 1997)

Family	Species	S-97	O-97	N-97	D-97	J-98	F-98	M-98	A-98	M-98	J-98	J-98	A-98	S-98	O-98	N-98	D-98	J-99	F-99	M-99	A-99	M-99
Clupeidae	*Alosa fallax*				2																	
	Sardina pilchardus	3								493	112				13							51
Cyprinidae	*Alburnus alburnus*				147											43	24		7	37	24	53
	Barbus plebejus										10											
	Carassius auratus				2		8															
	Chodrostoma nasus																4					
	Leuciscus cephalus			2			49			7	2130	9										35
	Rhodeus sericeus										7											25
	Vimba melanops									3												
Belonidae	*Belone belone*	23		42							4			176	12							
Syngnathidae	*Hippocampus ramulosus*	3																				
	Syngnathus abaster						5		12				4	20	10							
	Syngnathus variegatis									4												
	Syngnathus typhle			5																		
Atherinidae	*Atherina boyeri*	613	46		48		6				8	206	371	336	23	626						2
	Atherina hepsetus	29								3												
Mugilidae	*Chelon labrosus*	13							5	99	245	31		24		17					120	134
	Liza aurata			275	96		6		1718	1190		3			212	1238	252	8	4	48	1388	127
	Liza ramada		6				3		210	265	579	3		4			392	112	135	3112	2260	4738
	Liza saliens	48										112	30	4	4	108	16	20			12	
	Mugil cephalus			150	15										16	439	548					
Moronidae	*Dicentrarchus labrax*								305	113	229	15								4		245
Percidae	*Perca fluviatilis*						3															
Sparidae	*Diplodus annularis*	5																			1708	
	Diplodus vulgaris	5																				
	Lithognathus mormyrus	8							170	152				8	3						1080	332
	Sparus aurata									7											124	
Mullidae	*Mullus barbatus*	19										29	3									
Callionymidae	*Callionymus maculatus*									4												
	Callionymus risso	30	13										117	12	7						4	
Centrarchidae	*Lepomis gibbosus*				2																	
Blennidae	*Parablennius sanguinolentus*	29	2									124	73	44								
Clinidae	*Clinitrarchus argentatus*		2																			
Gobiidae	*Gobius cobitis*	134	45	5	2							52	53	32								
	Gobius niger												3									
	Gobius paganellus															4						
	Pomatoschistus marmoratus	456	1225	361	309	3	130		667	82	475	2148	1805	3388	136	315	500	81		196	1680	840
Triglidae	*Lepidotrigla cavillone*								10													
Scophthalmidae	*Psetta maxima*					3														4		
	Scophtalmus rhombus	6																			24	
Soleidae	*Solea kleinii*		2													4				28	640	36
	Solea nasuta													4								
	Solea vulgaris								15													

TABLE 2

The species caught in the Rihios estuarine system and their relative abundance (*: species caught in the fyke-net)

Family	Species	S-97	O-97	N-97	D-97	J-98	F-98	M-98	A-98	M-98	J-98	J-98	A-98	S-98	O-98	N-98	D-98	J-99	F-99	M-99	A-99	M-99
Cyprinidae	*Alburnus alburnus**																67					
	*Barbus plebejus**	133	50								17	33	767	433	183	33						
	*Leuciscus cephalus**	1267	100							167	67	1033	9567	2800	1350							
	*Rhodeus sericeus**	6717	1017			17	100	17			17		4033	38833	7700	33						
	Vimba melanops														17							
Anguillidae	*Anguilla anguilla**																					
Poecilidae	*Gambusia affinis**	4383	517							117	167	17	567	8000	2017	500						
Atherinidae	*Atherina boyeri**			33	17					25	25	1375	525		50	25				1700	700	
	Atherina hepsetus															775						
Mugilidae	*Chelon labrosus**	67			50	50	17	167	17	92	100	675	200	100	50	500			50			
	Liza aurata	67		250		133	517	225	5142	2133	825	17			25	50		183	275		325	
	*Liza ramada**								2850	117	383	300					300	625		33	233	
	*Liza saliens**	58	25				17					333	10467	4375	1133	1200						
	*Mugil cephalus**			100	33		17	25					333	1867	633	2292	92	33			33	
Moronidae	*Dicentrarchus labrax**										900	200	25	25		25			25	50		
Sparidae	*Diplodus sargus*									25		25										
	Lithognathus mormyrus									25												
	Sarpa salpa										175	100										
	Sparus aurata									50												
Mullidae	*Mullus barbatus*											200										
Blennidae	*Aidablennius spynx*																				25	
	*Blennius fluviatilis**											100		67								
	Lipophrys pavo		100							17												
	Parablennius gattorugine											275	33					25				
	*Parablennius incognitus**	183	17	50																		
	*Parablennius sanguinolentus**	17	1175					33		25	67	500	275	500	133	25						
	Parablennius tentacularis									33												
Gobiidae	*Gobius cobitis*	50	225	33						25	75	225	75	150	275							
	Gobius cruentatus											25										
	*Knipowitschia caucasica**																					
	*Pomatoschistus marmoratus**										50			50	25				25	25	25	
Scophthalmidae	*Psetta maxima*											25										

(38,833 ind./1,000 m^2), which was the highest CPUE value recorded in this study. *Liza saliens* and *Leuciscus cephalus* also exhibited high CPUE values in August 1998 (10,467 and 9,567 ind./1,000 m^2, respectively).

As far as the physicochemical parameters of the water are concerned (Figs 2-3), temperature displayed a strong seasonality in both areas, ranging from 7.9 to 29.4°C. Seasonal oscillations were also obvious in the case of dissolved oxygen, which ranged from 3.03 to 14.2 mg/l in Strymon and from 1.95 to 13.56 mg/l in Rihios. Salinity varied according to station location. Thus, at stations Str1 and Rih3, which were located in the mainstream, salinity ranged from 0 to 13 psu, while at stations Str2 and Rih4, which were located in the estuaries, it ranged from 4 to 35 psu. Finally, spatial and temporal variations of pH did not display any trend, ranging from 7.67 to 8.35.

The temporal changes in total relative abundance and species richness in the two areas are shown in Fig. 4. The highest species richness in the Strymon system was observed in September 1997 and May 1998, with 16 and 14 species respectively, and the lowest in January 1998 and February 1999, with 2 and 3 species respectively. Species richness in the Rihios system peaked in July 1998 (18 species). This was also the highest species richness observed in this study. The lowest values were observed in winter of both years (3 species).

In general, species richness at both sites was higher during the warm period of the year, i.e. summer and autumn. The same seasonal pattern was also displayed by the total relative abundance, being almost parallel to the one shown by the water temperature and dissolved oxygen fluctuations. Indeed, temperature was significantly correlated with species richness ($r=0.83$, $p<0.001$) and total abundance ($r=0.54$, $p<0.05$). In contrast dissolved oxygen and species richness were negatively correlated ($r=-0.52$, $p<0.05$). Further analysis of cross-correlations showed that species richness and abundance followed the changes of temperature and dissolved oxygen with a time lag of one month at most. No correlation of species richness with salinity ($r=0.25$, $p>0.05$) and pH ($r=-0.46$, $p>0.05$) was found, nor of total abundance with pH ($r=0.24$, $p>0.05$) and dissolved oxygen ($r=-0.28$, $p>0.05$).

The results of the correspondence analysis (Fig. 5) where the structure of the overall fish community is shown, indicated that species distribution in the monthly samples is generally determined by seasonality, since summer and autumn months together with most of the species were distributed in the right half of the two-dimensional plot, while the winter and spring months were placed towards the left end of the first axis together with *L. ramada, L. aurata, Lithognathus mormyrus* and *Sardina pilchardus*. The two most frequently caught species of the two estuarine systems, *P. marmoratus* and *C. labrosus*, were ordinated in the middle of the plot. Moreover, there was a partitioning of summer from autumn months along the second axis. The species com-

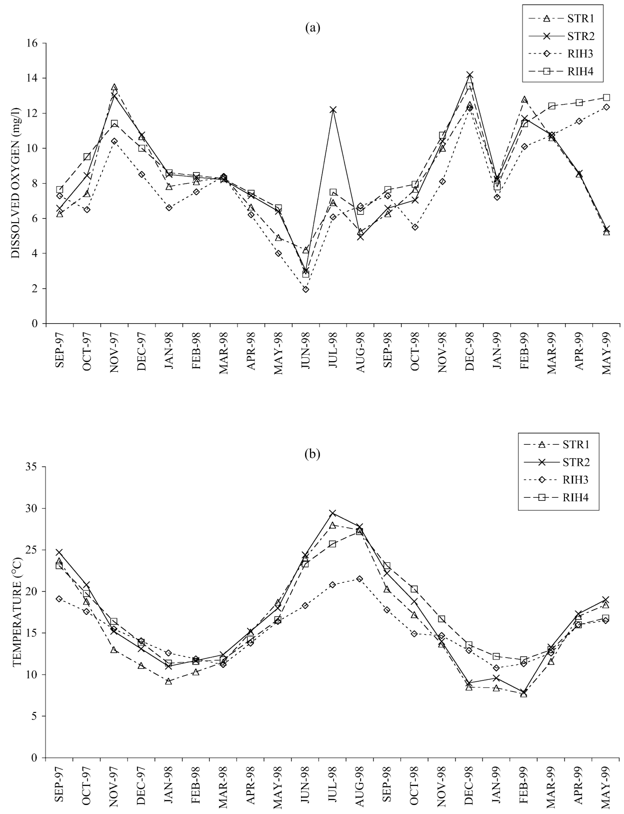

Fig. 2. – Monthly changes of dissolved oxygen (a) and temperature (b) in the sampling stations of Strymon (STR 1,2) and Rihios (RIH 3,4).

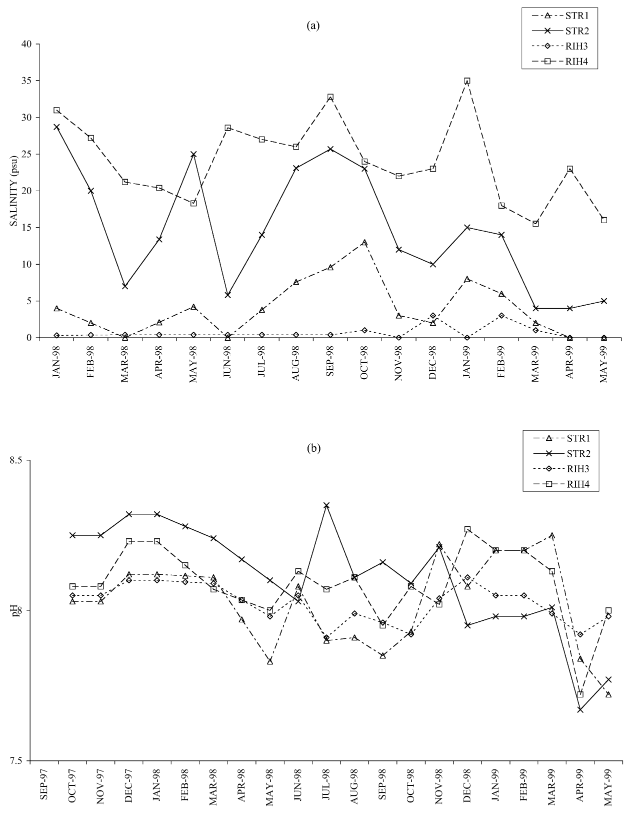

Fig. 3. – Monthly changes of salinity (a) and pH (b) in the sampling stations of Strymon (STR 1,2) and Rihios (RIH 3,4).

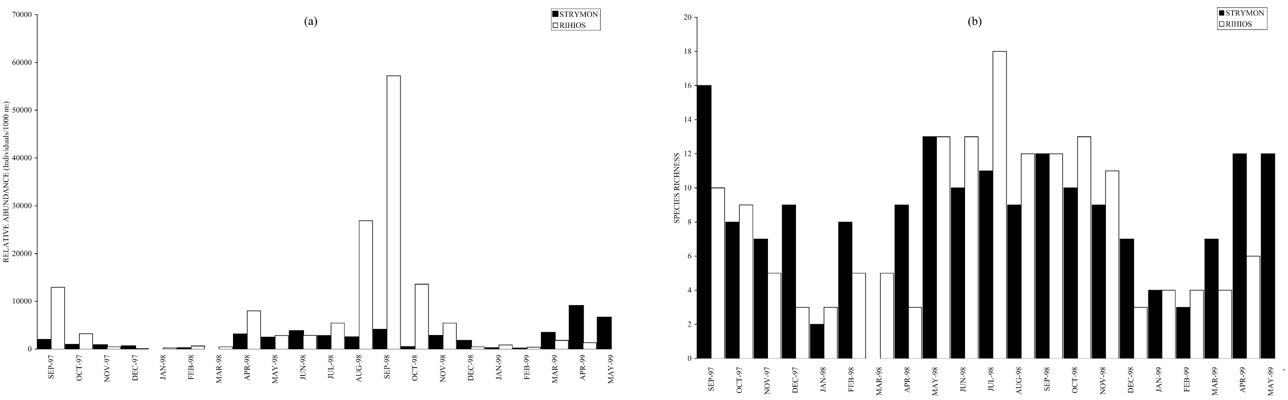

Fig. 4. – Monthly changes of total relative abundance (a) and species richness (b) in the estuarine systems of Strymon and Rihios.

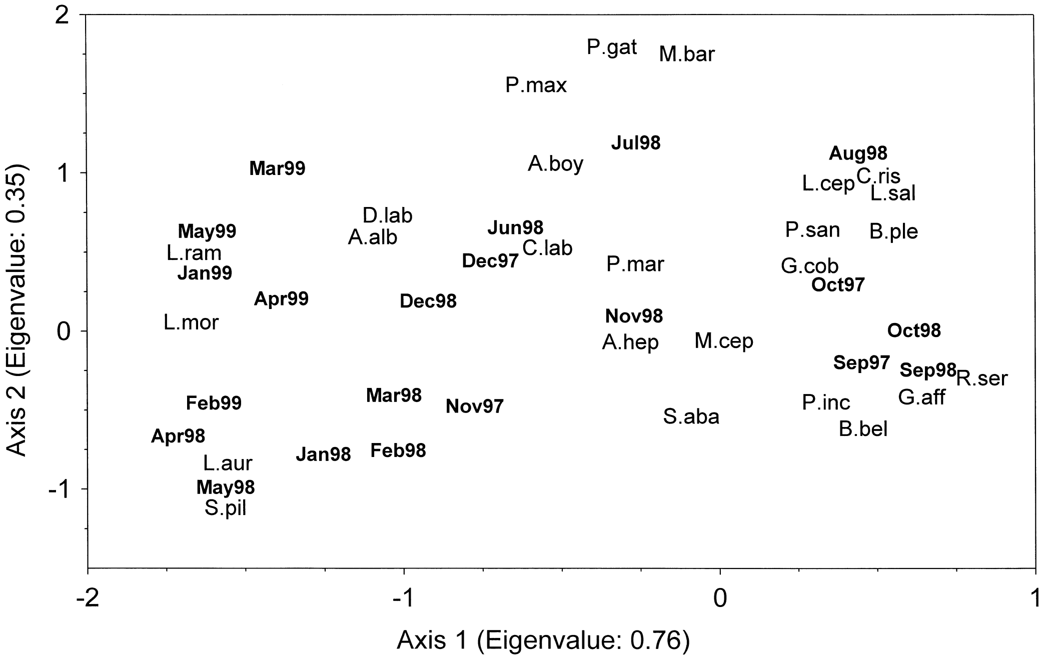

Fig. 5. – Ordination of monthly samples and fish species on the plane of the two first axes of Correspondence Analysis (A.alb: *Alburnus alburnus*, A.boy: *Atherina boyeri*, A.hep: *Atherina hepsetus*, B.ple: *Barbus cyclolepis*, B.bel: *Belone belone*, C.ris: *Callionymous risso*, C.lab: *Chelon labrosus*, D.lab: *Dicentrarchus labrax*, G.aff: *Gambusia affinis*, G.cob: *Gobius cobitis*, L.cep: *Leuciscus cephalus,* L.mor: *Lithognathus mormyrus,* L.aur: *Liza aurata,* L.ram: *Liza ramada,* L.sal: *Liza saliens,* M.cep: *Mugil cephalus,* M.bar: *Mullus barbatus,* P.gat: *Parablennius gattorugine,* P.san: *Parablennius sanguinolentus,* P.inc: *Parablennius incognitus,* P.mar: *Pomatoschistus marmoratus,* R.ser: *Rhodeus amarus,* S.pil: *Sardina pilhardus,* S.aba: *Syngnathus abaster,* P.max: *Psetta maxima*).

position changed evenly from autumn to winter and spring while there is a more abrupt transition from spring to summer. Indeed, the ordination of November and December of both years in the middle of the plot indicates that the community displays intermediate faunistic characteristics during these months, i.e. species composition is similar to that of both autumn and winter.

DISCUSSION

Our results showed that the fish fauna of the Rihios system displayed higher values of relative abundance, compared with those of the Strymon system. This is partly due to the smaller sampling area in the Rihios River, a fact that may render the catch of certain species easier. Moreover, it is known that in estuarine systems, water temperature often reaches extreme values because of the shallow waters. This is true for the Strymon estuarine system, but it does not hold for the Rihios estuary, where the high and continuous freshwater flow is responsible for the absence of temperature extremes. However, species richness was generally higher in the Strymon especially during spring. Indeed, shallow waters, as is the case with the Strymon estuary and lagoon, warm up sooner in the season, thus attracting more species (Breber, 1996). The species richness observed in Strymon estuarine system (43 species) was, as far as we know, one of the highest recorded in the Mediterranean. Fifty-six species were recorded in the Mesolongi-Etolikon lagoons (Leonardos et al., 2000), 35 in the Porto-Lagos lagoon (Koutrakis et al., 2000), 29 in Rihios estuarine system (present study), 28 in Po estuary (Vitali & Braghieri, 1981) and 16 species in Gialova lagoon (Dounas & Koutsoubas, 1996). Only Severn Estuary in UK showed a remarkable species richness of 97 species (Claridge et al., 1986).

Species richness and total relative abundance at the two study sites depended strongly on water temperature fluctuations, increasing during the warm period of the year. Similar results were also reported by Whitfield (1980) and Loneragan et al. (1987). The negative correlation between species richness and dissolved oxygen found in this study is probably of no biological meaning and it can be attributed to the strong dependence of oxygen concentration on the water temperature. Thus, any positive effect of dissolved oxygen on species richness and abundance is masked by the stronger effect of water temperature.

According to the results of Correspondence Analysis, seasonality seemed also to determine the temporal distribution of the fish species. The abrupt change of species composition from spring to summer is probably because *L. ramada* and *L. aurata*, which are the dominant species in winter and spring, even though they are 'estuary-depended' species (Dando, 1984), disappear from early summer samples. As these species grow larger than 70-80 mm they become faster and hence their collection with a bag seine becomes very difficult. Moreover, during the same period, juveniles of *L. mormyrus* and *S. pilchardus* leave the estuary and migrate towards the sea. On the other hand, *P. marmoratus*, which dominates the community of the Strymon system, spends its entire life cycle in the estuary under euryhaline conditions and is characterised as a 'true' estuarine fish according to Dando (1984). *P. marmoratus* was also the second most abundant species in Porto-Lagos lagoon (12.7 % of the total catch) present in almost the whole study period (Koutrakis et al., 2000) and among the 15 most abundant fish species in the Severn Estuary (Claridge et al., 1986). Likewise *C. labrosus* individuals cannot live in wholly freshwater habitats for long periods but are better adapted in poly and mesohaline waters (Lasserre & Gallis, 1975), as is the case with stations Str2 and Rih4 (Fig. 1). Koutrakis et al. (2000) observed similar behaviour in the Porto-Lagos lagoon where *C. labrosus* was present during the whole study period (20 months of presence in a 21 month survey).

The importance of the studied estuarine systems as nursery grounds is supported by the presence of young individuals of several species such as *L. mormyrus*, *S. pilchardus* etc. Apart from the commercially important fish species that inhabit estuaries, the estuarine fish fauna has also a significant ecological value for the fish-eating birds that live and feed in estuarine systems. More specifically it has been reported (Goutner et al., 1997) that species of the families Gobiidae and Mugilidae were the dominant prey of the great cormorant (*Phalacrocorax carbo*). Moreover, some of the species found are either protected by the 92/43 EEC Directive and the Bern Convention (*R. sericeus*) or referred to the Red Data Book of Threatened Vertebrates of Greece (*Alburnus alburnus*, *L. cephalus*, *Vimba melanops*, *K. caucasica*). Therefore, it is necessary to obtain more information on their distribution and abundance in order to be able to provide more efficient means of protection.

ACKNOWLEDGEMENTS

The study is part of an EU co-funded LIFE project entitled "Concerted actions for the management of the Strymonikos coastal zone" and was carried out by the Fisheries Research Institute of Kavala, Greece.

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