J. Black Sea/Mediterranean Environment
Vol. 22, No. 1: 46-59 (2016)

RESEARCH ARTICLE

Demersal Lessepsian fish assemblage structure in the northern Levant and Aegean Seas

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Abstract

Spatial diversity and assemblage structure of Lessepsian fish were investigated, based on bottom trawlings carried out at the northern Levant and Aegean Sea coasts of Turkey. A total of 20 species were identified, with abundances gradually decreasing along the longitudinal gradient from east to west. Two species, *Saurida lessepsianus* and *Equulites klunzingeri*, made up 82.5% of the total Lessepsian fish catch, which were also responsible from the greatest portion of dissimilarity between Levant and Aegean Seas. The results of cluster and nMDS analyses based on a Bray-Curtis similarity value of 50% showed the presence of three different assemblages, revealing that the borders of Lessepsian province currently shows no sign of northwards expansion towards the northern Aegean Sea. Possible influence of six environmental variables on fish assemblage structure were tested; two (depth and water temperature) were found to be statistically significant by the Monte Carlo permutation test. Canonical correspondence analysis (CCA) showed that only *Nemipterus randalli* had a positive correlation with water temperature, while the remaining species either had a preference to shallow depths or cool waters.

Key words: Lessepsian province, fish assemblage, Levant Sea, Aegean Sea

Introduction

The idea of defining a new biogeographic subregion within the Mediterranean Sea was first expressed by Por (1978), who proposed the delimitation of the widely accepted "Lessepsian province" that covers an area ranging from the Levant Basin to Sicilo–Tunisian strait, but the Adriatic and northern Aegean Seas were excluded due to existence of 15°C isotherm of minimum winter surface temperature – a critical value claimed to be hindering successful establishment of thermophilic aliens. The eastern and northeastern Levant shores (from Port Said/Egypt to Mersin/Turkey) are the core areas for settlement of the migrants, while their importance gradually decreases westwards along the

Anatolian coast; but this dynamic province has a potential to expand or shrink in relation to climatic evolution of the region and should be considered as the first embryo of Neo–Tethys (Por 1990, 2009).

By the increased rate of alien species introductions at the eastern Levant and significant range expansions of several taxa beyond historic barriers such as the Sicilo-Tunisian channel and 38th parallel of the Aegean Sea (Bianchi 2007; Azzurro 2008; Lejeusne *et al*. 2010), some authors have started questioning the evolution of borders of the Lessepsian province, with a general approach on its possible expansion tendency due to winter sea surface temperature (SST) shifts as a result of sea warming (Corsini-Foka *et al*. 2010; Pancucci-Papadopoulou *et al*. 2012). Sicily Channel, as a major transitional sector separating the western and eastern basins of the Mediterranean, recently shows signs of losing its filtering strength, being ineffective to hinder the opposing spread of both Indo-Pacific and Atlantic originated fish species (Azzurro 2008). Likewise, tropical characteristic of the Aegean Sea ichthyofauna is also increasing. Only 14 alien fish was reported from the southern Aegean Sea coasts until the early 1990's and not even a single fish species was succeeded in reaching beyond the Psara-Chios-Izmir line, where the cold-water fauna characteristic of the Aegean Sea starts (Papaconstantinou 1990). The number of Lessepsian fish currently known from the Aegean Sea has increased to well over 30 species, several of which have penetrated to the northern basin (Corsini-Foka *et al*. 2010).

The proximity of Turkey to the Suez Canal has resulted in dense settlements of Lessepsian fish migrants (Çınar *et al*. 2011). Despite of the increased efforts to monitor effects of species introductions, majority of the studies hitherto conducted have focused on inventories (Bilecenoglu 2010), rather than analyzing changes in fish assemblage structures. Current available knowledge is restricted to a few temporal trend analyses of trawlable alien fish assemblages, all confined to the coastal strip between Iskenderun Bay and Mersin (Gücü and Bingel 1994; Gücü *et al*. 1994). In the present study, spatial variation of Lessepsian fish assemblages along the entire northern Levant and Aegean Sea coasts were examined together for the first time, to find out possible changes of the Lessepsian province borders, based on data obtained from bottom trawling excursions. Moreover, effects of some environmental variables on the distribution of species were also investigated using multivariate analysis.

Materials and Methods

The study was mainly based on materials collected during bottom trawlings carried out on board the R/V Beluga (22.8 m long, 580 HP) between 31 October – 21 November 2011 along the entire northern Levant and Aegean Sea coasts of Turkey. A total of 11 trawling hauls were conducted at the Levant shores, from Samandag/Hatay in the east to Dalaman Creek/Mugla in the west, while 14 hauls were made along the Aegean Sea coast from Marmaris/Mugla in the south

to Saroz Bay/Çanakkale in the north. Only the stations with alien fishsampled were included in the analysis, correspoding to a total of 16 localities (Figure 1). All trawlings were performed at shallow coasts (maximum 1 nautical mile off the coastal strip) with sandy/muddy bottoms, ranging between 9.0 and 46.3 m depth depending on the bottom topography and availability of the trawling grounds. The trawl net used was a conventional one with 25 m head rope and a cod-end of 44 mm. Samples were collected during day time with 2.0 – 2.4 knots trawling speed. Catch composition from each haul was identified to a species level, counted, weighed (to the nearest gram) and standardized to unit trawling hour (Catch per Unit Effort: CPUE, g/hr).

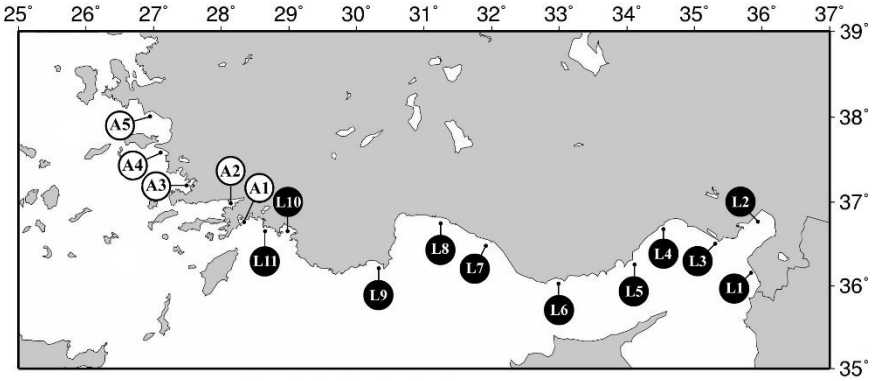

Figure 1. Bottom trawling stations along the Turkish coast (sampling stations located north of the 38th parallel not shown, since no alien fish were encountered). Northern Levant (full circles): 1) Samandag/Hatay, 2) Sugözü/Adana, 3) Karataş/Adana, 4) Tirtar/Mersin, 5) Göksu/Mersin, 6) Kızılliman/Mersin, 7) Lara/Antalya, 8) Finike/Antalya, 9) Finike/Antalya, 10) Fethiye/Mugla, 11) Dalaman/Mugla. Aegean Sea (open circles): 1) Marmaris/Mugla, 2) Gökova/Mugla, 3) Güllük/Mugla, 4) Kuşadasi/Aydin, 5) Seferihisar/Izmir

To assess patterns in assemblage structure across the spatial scales of the study, the obtained data of alien fish were analyzed using a non metric multi dimensional scaling (nMDS) and cluster analysis based on the Bray Curtis similarity index using fourth-root transformed data (to down weigh influences of extremely abundant and rare species); group average sorting was performed with the PRIMER 5.2 software (Clarke and Warwick 1994). To ascertain which species generate the most dissimilarity between groups (i.e. northern Levant and Aegean Seas), the SIMPER subroutine (in PRIMER 5.2) was used, where only species with more than 5% contribution to dissimilarity were taken into consideration. For statistical purposes, species those occurred only once (applies only for *Torquigener flavimaculosus*) were removed from analyses.

In order to identify environmental influences on Lessepsian fish, a multivariate analysis was used. Decision on whether to use a linear or unimodal type of

ordination method was made by estimating the heterogeneity in the species data, using lengths of gradients, as calculated by detrended correspondence analysis (DCA) (Lepš and Šmilauer 2003). Species with rare occurrences (i.e. present at less than four sampling sites and form <1% of total biomass) were removed from the analysis; data of the remaining eight species were used. DCA (log transformed data; detrending by segments) estimated the length of gradient at the first axis as 3.75, indicating the unimodal species response (Ter Braak and Verdonschot 1995), thus a canonical correspondence analysis (CCA) was preferred. The null hypothesis that the abundances of Lessepsian fish species are independent of the environmental parameters was tested using 499 Monte Carlo permutations, where significance of environmental variables for determining the species composition was tested using a forward selection under full model conditions. Six environmental variables were included in the primary analysis (bottom water temperature, dissolved oxygen, salinity, depth, latitude and longitude). The CCA analysis was performed with the CANOCO version 4.5 software (Ter Braak and Smilauer 2002).

Results

Nine sampling stations in the north Aegean Sea yielded no alien fish (stations no A6 - A14, located above the 38th parallel), thus were excluded from further analyses (Figure 1). The list of species caught along the Turkish coastline and their corresponding CPUE (kg/hr) values are given in Table 1.

A total of 20 Lessepsian fish belonging to 13 families was identified, in which Tetraodontidae was the most diverse family represented by four species followed by Apogonidae with three species. *Saurida lessepsianus* occurred at 14 trawling hauls (out of 16) and was the most abundant species, constituting 43.71% of the total Lessepsian fish catch, followed by *Equulites klunzingeri* (38.82%) and *Nemipterus randalli* (6.30%). Proportion of alien fish within the gross catch composition was highest in Iskenderun Bay (means of stations no L1, L2, L3 and L4 was 68.90%) reaching to the most extreme biomass value ever recorded from the Mediterranean Sea (90.86% at station L2). The relatively lower proportion of Lessepsian fish at the closely located station no L1 (44.13% of all fish) is due to the masking effect of high abundances of two native chondrichtyans, namely *Gymnura altavela* and *Rhinobatos cemiculus*. Towards west from the Iskenderun Bay, impact of aliens gradually, but clearly decreases down to a proportion of ca. 30% at the northwestern Levant/Aegean Sea border. Alien fish was present only at five trawls hauled from the Aegean Sea, represented by ratios as low as 0.26% (station no A5) to 16.91% (station no A2).

Table 1. CPUE (kg/h) values of the Lessepsian fish among bottom trawl stations (Northern Levant: L1 – L9; Aegean Sea: A1 – A5). Framed data represent the highest abundance per sampling station. *: <0,05 kg/hr.

	Bottom Trawling Stations															
Species	**L1**	**L2**	**L3**	**L4**	**L5**	**L6**	**L7**	**L8**	**L9**	**L10**	**L11**	**A1**	**A2**	**A3**	**A4**	**A5**
Apogonichthyoides pharaonis			*													
Ostorinchus fasciatus				*	*	0,1	*	*	*			*				
Apogon smithi		0,3		0,1		*		*		*						
Callionymus filamentosus			*	*	0,1	*			*							
Cynoglossus sinusarabici						*										
Fistularia commersonii	0,6								0,4	0,1	0,1					
Oxyurichthys petersi		0,1								*						
Vanderhorstia mertensi	*					*										
Pteragogus trispilus						*	*									
Equulites klunzingeri	6,6	2,4	4,0	37,0	2,3	2,0	1,2	0,5	3,3	15,0	1,7	*				
Stephanolepis diaspros	0,1						0,1				0,1					
Upeneus moluccensis	*	0,2	0,1	*	0,6	0,1		0,1		1,5		*			0,2	*
Upeneus pori	1,1		0,5			0,2	0,7		0,1		0,7	0,2				
Nemipterus randalli	1,3	5,2	*	1,2	3,1	*	0,5	0,3	0,3	0,2						
Sphyraena chrysotaenia	0,2								0,7	2,1			0,2		0,2	0,1
Saurida lessepsianus	4,6	1,4	2,2	3,0	13,5	2,4	2,7	1,5	2,3	24,0	2,6	4,8	20,0	0,7		
Lagocephalus sceleratus							0,9		0,4		2,1					
Lagocephalus guentheri		0,1	1,5	0,8	0,1					0,1				*	0,3	0,1
Lagocephalus suezensis	*	0,1	1,9		0,4	0,2			0,2		0,1	0,2			0,1	
Torquigener flavimaculosus						*										
% Aliens in total fish catch	44,1	90,9	69,7	70,9	45,4	45,6	32,1	43,8	23,3	34,4	27,6	12,5	16,9	2,8	0,9	0,3

The Cluster analysis, supported by the nMDS (stress=0.12), showed that fish assemblages were clearly separated into two groups at a Bray-Curtis similarity value of 19.98% (Figure 2), with further splits at 34.93% and 53.22% similarity. A single assemblage is observed at the northern Levant including 12 consecutive sampling localities, and two more in the Aegean Sea at the biologically significant 50% level. According to SIMPER analysis, the in-group similarity was higher in Levant (60.52%) than in Aegean Sea (33.89%), which revealed a relatively high level of overall dissimilarity (69.13%) between Lessepsian fishes of two regions. Species that contributed to the greatest amount of dissimilarity were *E. klunzingeri* (14.86%), *S. lessepsianus* (9.9%), *N. randalli* (8.99%) and *Upeneus pori* (5.00%).

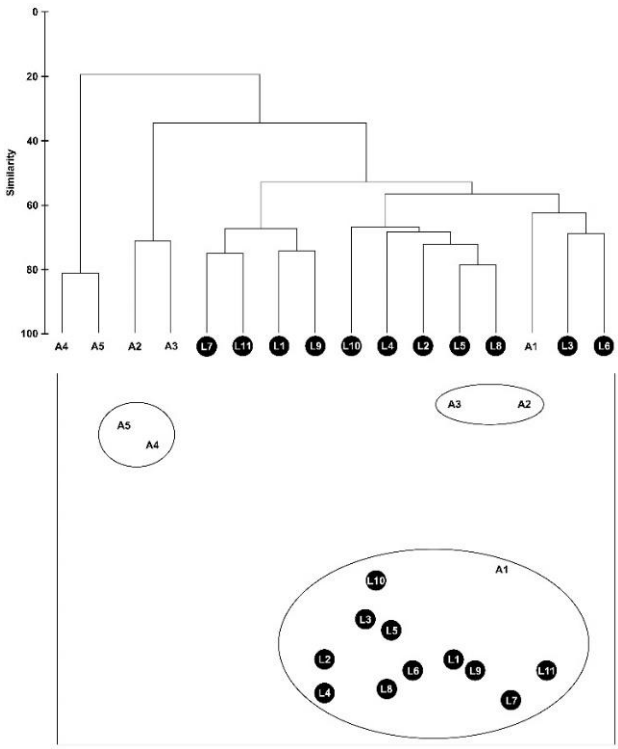

Figure 2. Group average sorting dendrogram and two dimensional nMDS ordination (stress=0.12) for the Lessepsian fish communities at each of the stations in the survey area. In nMDS plot, continuous lines represent 50% similarity.

The canonical correspondence analysis (Monte Carlo permutation test) was significant for the first axis ($F=2.714$, $p<0.05$) and all canonical axes combined ($F=2.340$, $p<0.05$), in which eigenvalues of axis 1 (49.43%) and axis 2 (14.75%) explained 64.18% of the cumulative variance of species data. Four

environmental parameters (dissolved oxygen, salinity, latitude and longitude) were removed from the analyses, since they were found to be statistically insignificant ($p>0.05$) following the forward selection routine of CCA. Despite of the few environmental variables analyzed (Figure 3), the picture drawn was enough to determine that only *N. randalli* was positively associated with temperature, while *Sphyraena chrysotaenia* preferred cooler waters and *S. lessepsianus* was mildly and negatively linked to water temperature. *E. klunzingeri* and *Lagocephalus guentheri* were located near the origin, indicating that they have little or no association with the environmental parameters tested. Depth drove most of the observed variation in assemblage structure and was associated with two Lessepsian fish with particular preference to shallow coasts, *La.suezensis* and *U. pori*, which appeared at upper left section of the ordination.

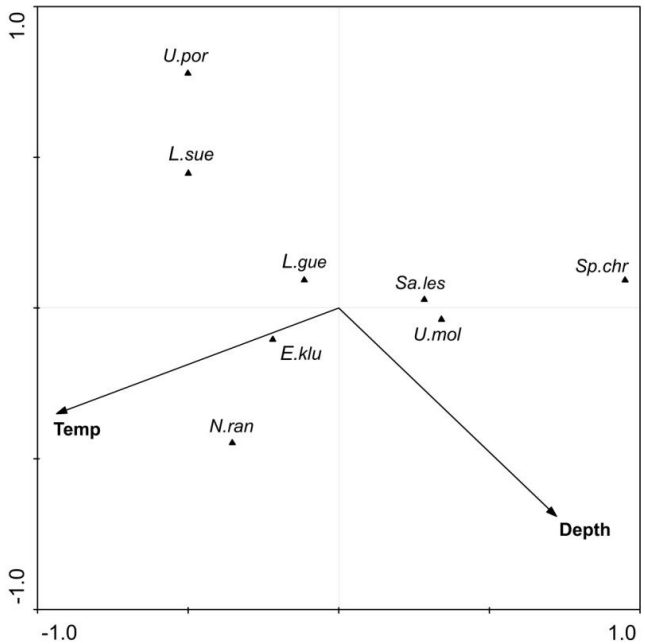

Figure 3. Ordination diagram showing the result of CCA analysis. The arrows indicate significant explanatory variables, with the arrowheads indicating the increase in gradient. Abbreviations: L.gue - *Lagocephalus guentheri*; L.sue - *Lagocephalus suezensis*; E.klu - *Equulites klunzingeri*; N.ran - *Nemipterus randalli*; U.mol - *Upeneus moluccensis*; U.por - *Upeneus pori*; Sp.chr - *Sphyraena chrysotaenia*; Sa.les - *Saurida lessepsianus*.

Discussion

Wealth of studies exist reporting results on the drastic biodiversity change and the tropicalization of the Mediterranean Sea (see Zenetos *et al*. 2012), which, unlike the prevalent statements, is also being considered as a normalization event from the viewpoint of biogeography and geology (Por 2009). While

increased sea surface temperature within the last century (especially since the early 1990's) is believed to be one of the major causes favoring establishment of alien species, combined effects of other drivers of the invasion such as the deepened and widened Suez Canal, damming of the Nile River, gradual extinction of physical barriers through the canal (i.e. salinity), faunal impoverishment of the Levant Basin and overfishing along the eastern Mediterranean coasts, should not also be neglected (Galil 2006; Edelist *et al*. 2013).

Present analyses of CPUE data (Figure 2) do not support the assumption of an expanding Lessepsian province towards the Aegean Sea. Indeed, relative importance of the areas of settlement of the migrants in the eastern Mediterranean (as indicated through four scales of shading by Por 1990) seems to remain unchanged, at least considering the northern Levant and the Aegean Sea. Ratio of Lessepsian fish in the trawl catch shows a peak at Iskenderun Bay (68.9%, means of stations L1 – L4), sharply decreasing 1/3 folds at Mersin coasts (45.5%, means of L5 and L6) and conspicuously losing much of its influence at Antalya coasts (33.1%, means of L7 – L9). This pattern is quite similar to the results of a previous study carried out three decades ago, where corresponding proportions were 62% and 34% for Iskenderun Bay and Mersin coasts, respectively (Gücü and Bingel 1994). Despite of the increased impact of aliens at the easternmost Levant, no sign of "biomass overflow" towards the Aegean Sea is evident, at least based on bottom trawling data. It is noteworthy to mention that, the two most abundant alien fish ranks (*S. lessepsianus* and *E. klunzingeri*) did not change since the 1980's (Gücü *et al*. 1994); and those species are also responsible from the greatest portion of dissimilarity between the Levant and Aegean Seas.

If the one way relationship between sea water temperature and number/abundance of Lessepsian fish is to be examined, the same pattern will constantly be obtained - both variables are strongly correlated, and either spatially decrease from east to west (Figure 4), or temporally increase within a long period for a particular region (Pancucci-Papadopoulou *et al*. 2012). On the other hand, among the environmental variables tested herein by the multivariate analysis, only a single species (*N. randalli*) was positively influenced by high water temperatures while several others were negatively correlated with depth and/or temperature (Figure 3). Shallow water preference of Lessepsian fish was previously documented (Golani and Ben-Tuvia 1989; Golani 1996), and such habitats seem to be the most prone to invasions, even resulting in remarkable declines of some indigenous species (Edelist *et al*. 2013). The present finding on ambiguous effect of water temperature on fish communities may be explained by the biological history of the species analysed – except for the recent invader *N. randalli*, all others tested by CCA are early colonizers of the Mediterranean that have completed their thermal adaptation to the environment, thus likely to be governed by other environmental factors providing abiotic resistance, or

indirect effects of water temperature should be suspected. Azzurro *et al*. (2013) have found a similar result for *Fistularia commersonii*, whose response to temperature was minor and the main environmental parameter influencing its distribution was depth. The massive proliferation of *N. randalli* is recent and even though it also succeeded in rapidly reaching to the central Aegean Sea (Bilecenoglu *et al*. 2013), the species is experiencing the integration phase of an invasion, where water temperature currently acts as a limiting factor as evidenced from the multivariate analysis.

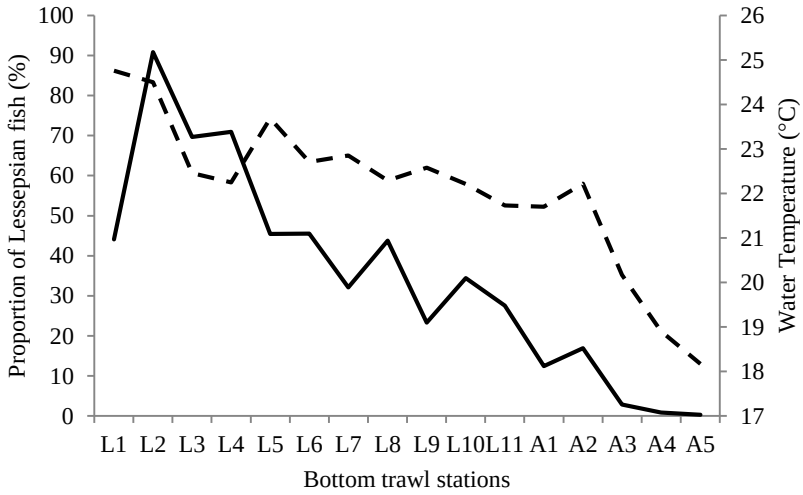

Figure 4. Proportion of Lessepsian fish (solid line) versus corresponding sea surface temperature (dashed line) at each trawling station
(L: Levant Sea; A: Aegean Sea).

Increased SST at the Aegean Sea (Theocharis 2008; Pancucci-Papadopoulou *et al*. 2012) may result with a northwards shift of the winter gradient, but does not essentially indicate an expansion of the Lessepsian province, even though a taxonomical richness of the alien biota above the 38th parallel is evident. Several efforts to examine spatial distribution of tropical originated species led us to discriminate eurytherm and stenothermic aliens, thus the existing prevalent argument that the increasing SST will accelerate Lessepsian species influx (Lasram and Mouillot 2009; Lejeusne *et al*. 2010; Hiddink *et al*. 2012) still needs to be discussed. Considering the fact that summer - winter difference in SST varies from 6°C in the Red Sea and Gulf of Elat to 12°C in the eastern Mediterranean and Aegean Sea (Berman *et al*. 2003; Skliris *et al*. 2011), establishment success of thermophilic species cannot be explained only by the global warming influence. Abiotic factors may not be a limiting factor for the survival and establishment of *r*-selected species especially under conditions where a natural predation pressure does not exist (Cebrian and Rodriguez-Prieto

2012). Therefore, the existence of seven Lessepsian fish signaled at the north Aegean Sea overcoming the winter isotherm of 14-15°C (Corsini-Foka *et al*. 2010) possibly reveals the spreading phase of species that have eventually completed their biological integrity, rather than an increased SST triggered dispersal. One good example is the recent advance of *Stephanolepis diaspros* to the Sea of Marmara (with summer to winter SST difference of 16°C), in which an established population survives at 14°C (Bilecenoglu *et al*. 2013). Penetration of the same species to Bizerte Lagoon of Tunisia (Bdioui *et al*. 2004), characterized by a low winter SST of 11.5°C (Béjaoui *et al*. 2008) and sustained survival of three *S. diaspros* juveniles at Rhodes aquarium during a sudden accidental decrease of water temperature from 20°C to 12°C (Corsini-Foka 2010) are indications of the cryophilic nature of the species, controlled no more directly by the high temperature gradient. The recent conjecture drawn by Belmaker *et al*. (2013) that the elevated water temperatures in the Mediterranean will likely to decrease the proportion of Red Sea species, especially for those unable to cope with warm Levant summers, presents a clear evolution of interactions between alien fish with environmental factors.

The present study have focused on demersal assemblages of Lessepsian fish, where several abundant pelagic species and those inhabiting particular habitats such as sea grass meadows and rocky substrates could not be sampled. Although available data neither supports the expansion of Lessepsian province by quantitative means, nor reveals a clear correlation between water temperature and sampled fish, further studies are clearly required with reference to the virtual rapid evolution of the region. Since each alien species has a unique evolutionary history, genetic structure and ecological plasticity, shifts in biological needs in the new environment should be monitored meticulously. It is suggested that, the rapidly raised number of Lessepsian fish in the cold north Aegean waters should be currently regarded as an initial endeavor of breaking the historical barrier, likely to be achieved in the near future.

Acknowledgements

Special thanks to Betil Ergev, D. Kemal Özyurt (Derinsu Underwater Engineering Inc.) and crew of R/V Beluga for their help during bottom trawl surveys. Dr. Ernesto Azzurro has kindly commented on a previous draft of the manuscript. The study was partly financed by the Ministry of Environment and Urbanism within the framework of the project titled Integrated Pollution Monitoring at Aegean and Mediterranean coasts.

Kuzey Levant ve Ege Denizlerinde demersal Lessepsli balık topluluklarının yapısı

Özet

Lessepsli balıkların uzaysal çeşitlilik ve topluluk yapısı, Türkiye'nin kuzey Levant ve Ege Denizi kıyılarında gerçekleştirilen dip trolü çekimleri ile incelenmiştir. Toplam 20

tür saptanmış olup, bollukları doğu batı gradyanı boyunca tedricen azalmaktadır. Toplam Lessepsli balık avının %82.5'ini iki tür, *Saurida lessepsianus* ve *Equulites klunzingeri*, oluşturmaktadır ve söz konusu türler Levant ve Ege Denizi kıyılarındaki kompozisyon farklılığının sorumlularıdır. Bray-Curtis (%50 benzerlik seviyesi) değerlerine dayanılarak hesaplanan kümelendirme ve nMDS analizleri üç farklı topluluğun varlığını işaret etmekte ve Lessepsli sahasının kuzey yönünde genişleme göstermediğini ortaya koymaktadır. Balık toplulukları üzerinde muhtemel etkileri bulunan altı çevresel değişken test edilmiş, bunlardan sadece derinlik ve su sıcaklığı Monte Carlo permütasyon testine göre istatistik açıdan anlamlı bulunmuştur. Kanonik Uygunluk Analizi (CCA) sadece *Nemipterus randalli* türünün su sıcaklığı ile pozitif korelasyon sergilediğini, diğer türlerin ise sığ veya soğuk sulara eğilimlerinin olduğunu göstermiştir.

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Received: 05.01.2016
Accepted: 20.01.2016