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RESEARCH ARTICLE

Keystone Porgy Species (Sparidae) Overcome the Alien Randall's Threadfin Bream (*Nemipterus randalli*) for Catch Balance in Space on An Oligotrophic Levant Shelf or *Vice Versa*?

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Abstract: Since 2008 spatiotemporal and ecological distributions of porgies (sparid, all indigenous fish) were examined in the presence or absence of Randall's threadfin bream, *Nemipterus randalli* in the present study area. Seasonal fish and environmental parameters samplings were conducted at three transects of the fishing (nMPA) or non-fishing (MPA) regions on an oligotrophic shelf (Levantine Sea) in 2014-2015 for understanding management and ecology of the porgies' catches. Of 13 sparid fish determined during the present study, five species are rarely found. There were no seasonal significant differences in densities of the sparid fish with or without the alien nemipterid fish. However, there were differences in the densities by the bottom depths, the regions, and soft and hard bottoms vegetated by *Caulerpa* spp and meadow, respectively. Ecologically, fish assemblages and faunistic characters of the sparid fish were highly variable when excluding the *N. randalli* as highlighted and follows; i) seasonal variation occurred and ii) the depthwise community assemblages became irregular. *N. randalli* seemed to balance the sparid catch attributed to the biomass-abundance ratio in the ecosystem or vice versa in this trophically sensitive gulf (ultra-oligotrophic) of the eastern Mediterranean Sea.

Besince Fakir Bir Levant Kıta Sahanlığında Sparid Balıklarının Anahtar Türleri Alandaki Av Dengesi İçin Yabancı Kılkuyruk Mercan Balığının Üstesinden Geliyor mu Yoksa Tam Tersi mi?

Öz: 2008 yılından beri çalışma alanında bulunan kılkuyruk mercan *Nemipterus randalli*'nın varlık ve yokluğu karşısında Sparid balıkların (tamamı yerli tür) alansal-zamansal dağılımları ve ekolojik davranışları incelendi. Avlanan Porgies türlerinin yönetimi ve ekolojisini anlamak için 2014-2015 yıllarında oligotrofik bir kıta sahanlığı içerisindeki (Levanten Denizi) balıkçılığa kapalı (nMPA) ve balıkçılığın serbest (MPA) olduğu bölgelerde üç ayrı hatta mevsimsel olarak balık ve çevresel parametre örneklemeleri yapıldı. Bu çalışma sırasında belirlenen 13 sparid türünden beşine nadiren rastlandı. Balıkların av yoğunluklarında kılkuyruk mercan var veya yok iken mevsimsel farklılık bulunmamıştır. Bununla birlikte derinlik, bölge ve *Caulerpa* spp ve deniz çayırı tarafından bitkilendirilen yumuşak ve sert zeminler bakımından Sparidlerin yoğunluklarda anlamlı farklılıklar bulundu. Ekolojik olarak, *N. randalli* türü hariç tutulduğunda Sparid toplulukları ve faunistik karakterleri oldukça değişkenlik göstermekte ve sonuç olarak; i) mevsimsel varyasyon (düzensizlik) ortaya çıkmakta ve ii) derinliğe bağlı balık toplulukları oluşumu bozulmaktadır. *N. randalli*, doğu Akdeniz'in bu trofik olarak hassas körfezinde (besince oldukça fakir) ekosistemdeki biyokütle-bolluk oranına atfedilen sparid avını dengeler gibi veya tam tersi olarak etkili olduğu görünmektedir.

Introduction

The porgies, the sparid fish are one (first or second order) of the dominant taxa overspreading on the shelf in the Mediterranean Sea (Biagi et al. 2002; Arechavala–López et al. 2008; Kalogirou et al. 2010, 2012) and the present study area (Özvarol 2016 a, b; de Meo et al. 2018), and all are indigenous species originated as Atlanto-Mediterranean (de Meo et al. 2018). They are commercially valuable. The first Mediterranean record of Randall's threadfin bream, *Nemipterus randalli* Russell, 1986 was reported in the eastern Levant Sea. (Golani and

Sonin 2006). *Nemipterus randalli* has inhabited the Turkish waters (Iskenderun Bay) since July 2007 (Bilecenoglu and Russell 2008), and the Antalya Gulf since February 2008 (Gökoglu et al. 2009). The nemipterid fish is also commercially valuable as much as the sparid fish in the eastern Mediterranean Sea.

The Mediterranean Sea hosts a rich and varied marine life that is comparatively well-studied (Vasilakopoulos et al. 2017). Although the Mediterranean Sea is considered to be a biodiversity hotspot (Coll et al. 2010), it is under increasing threat from pollution, over-exploitation and climate change (Cuttelod et al. 2009). Onset of change, the eastern Mediterranean Sea is well open to new records of plethora of marine organisms. In the Eastern Mediterranean, biodiversity is also threatened by invasive alien species including the gelatinous organisms (Galil 2007). Alien species span over most animal phyla and have created new communities altering the Mediterranean ecosystems (Coll et al. 2010). The easternmost Mediterranean coasts were invaded mostly by the Lessepsian fish (Galil 2007). Such non-indigenous fish affected the ecosystem and indigenous fish assemblages (Raitsos et al. 2010). Due to global warming and change in the architecture of Suez Canal, new introduction and establishment of the organisms have continued in time.

Local distribution and abundance patterns of fish assemblages are known to be influenced by many factors such as depth, which is often the main gradient along which faunal changes occur, bottom type and physical characteristics of the water column (Demestre et al. 2000; Kallianiotis et al. 2000; Araújo et al. 2002; Prista et al. 2003; Katsanevakis et al. 2009; Keskin et al. 2011a; de Meo et al. 2018). Therefore, the Levantine Sea, particularly the Turkish coasts have been oceanographically stressed by means of the Suez Canal and the Atlantic current from either sides of the Mediterranean Sea. Subsequently, assemblage patterns also mirrored changes in various oceanographic and geographic variables collected along with the fish samples, indicating that communities were responding to relatively small-scale spatial variability in the environment (de Meo et al. 2018).

Of the 70% alien fish species of the total in the Mediterranean Sea, 106 alien fish species (most of them recognized as the Indo-Pacific, IP) were reported in the eastern Mediterranean Sea (Zenetos et al. 2010; Galil and Goren 2013; Bilecenoğlu et al. 2014). A total of 74 alien fish species (66 IP and 8 Atlantic) was updated for the Turkish Mediterranean waters (Ergüden et al. 2016). Alien species such as *N. randalli,* were claimed to stabilize local fisheries catch in a highly invaded ecosystem (Stern et al. 2014; Rijn et al. 2020). Alien fish species may be a valuable resource and niche for marine fisheries, yet their contribution to the catch might be balanced by negative effects on indigenous species (Rijn et al. 2020). For instance, *N. randalli* which has made habitat selection and had trophic properties (Stern et al. 2014) were found to be very similar to those of the indigenous breams (Chessa et al. 2005; Gurlek et al. 2010). Catch per unit effort, CPUE

of *N. randalli* increased rapidly, while other ecologically comparable species from the family Sparidae showed generally stable catches (Raitsos et al. 2010). This striking ability of alien Lessepsian species to rapidly increase in population size, even when being commercially exploited, might be related to their pre-adaptation to warm climate conditions such as those occurring in the eastern Mediterranean (Raitsos et al. 2010). Furthermore, tropical fish generally grow faster (Henderson, 2005), which may lead to a higher percentage of individuals reaching maturity (Shapiro Goldberg et al. 2019) under the same fishing regime compared with species from a temperate origin (Yemişken et al. 2014; Stern et al. 2014; Rijn et al. 2020; Taylan and Yapıcı 2021).

Most of the studies on the sparid fish which were conducted in the eastern Turkish Mediterranean coasts focused on assessment of growth parameters or length-related parameters, followed by their diets as detailed in the discussion below. A few studies were attempted to outline their ecology with the limited abiotic variables such as bottom depths. In the western Mediterranean Sea, most studies focused on a variety of the detailed scopes of only sparid fish, owing to the lack of the non-indigenous nemipterid fish as referred in the discussion below.

The sparid species of the present study, the middle-sized specimens of commercially vulnerable fish species, have been hereby subjected for their spatiotemporal distribution of their biometry (density and morphometrics) for a sensitive area of the Turkish Mediterranean Sea, the Gulf of Antalya in the presence of the nemipterid fish. A total of 147 fish species were identified in the present study. 35 species were of Indo-Pacific origin and were assigned to the NIS group (de Meo et al. 2018). All the other species were assigned to the IS group, which consisted of 100 Atlanto-Mediterranean species, 8 cosmopolitan species, 3 species endemic to the Mediterranean and one to the Atlantic (Fig. 1, 2, Table 1). However, the porgies were ecologically located in the lower shelf and middle shelf (Fig. 1) while the nemipterid fish, *N. randalli* was ecologically separated from the lower shelf and located in the middle shelf where few NIS fishes were available (Fig. 2). Based on this separation, the present study was hypothesized to understand the crucial role of *N. randalli* in the keystone of porgies assemblages for its interaction in the middle shelf and for its restriction in the lower shelf. Their ecological importance and interactions, and recent historical comprehensive information on their distribution and ecology is lacking in the low-diversified and oligotrophic western Turkish Mediterranean water compared to the eastern waters (Coll et al. 2010; Sisma-Ventura et al. 2017). Subsequently, the aim of this study is to provide baseline information on bathymetric and seasonal ecological distribution in a variety of the abiotic variables (physical, chemical, optical parameters, and bottom types) and biometrical patterns (density, morphometric traits and sex composition) of the porgies interacted with the nemipterid fish, and to determine their biometrical dynamics and the species - environment, and –megafaunal benthos relationship.
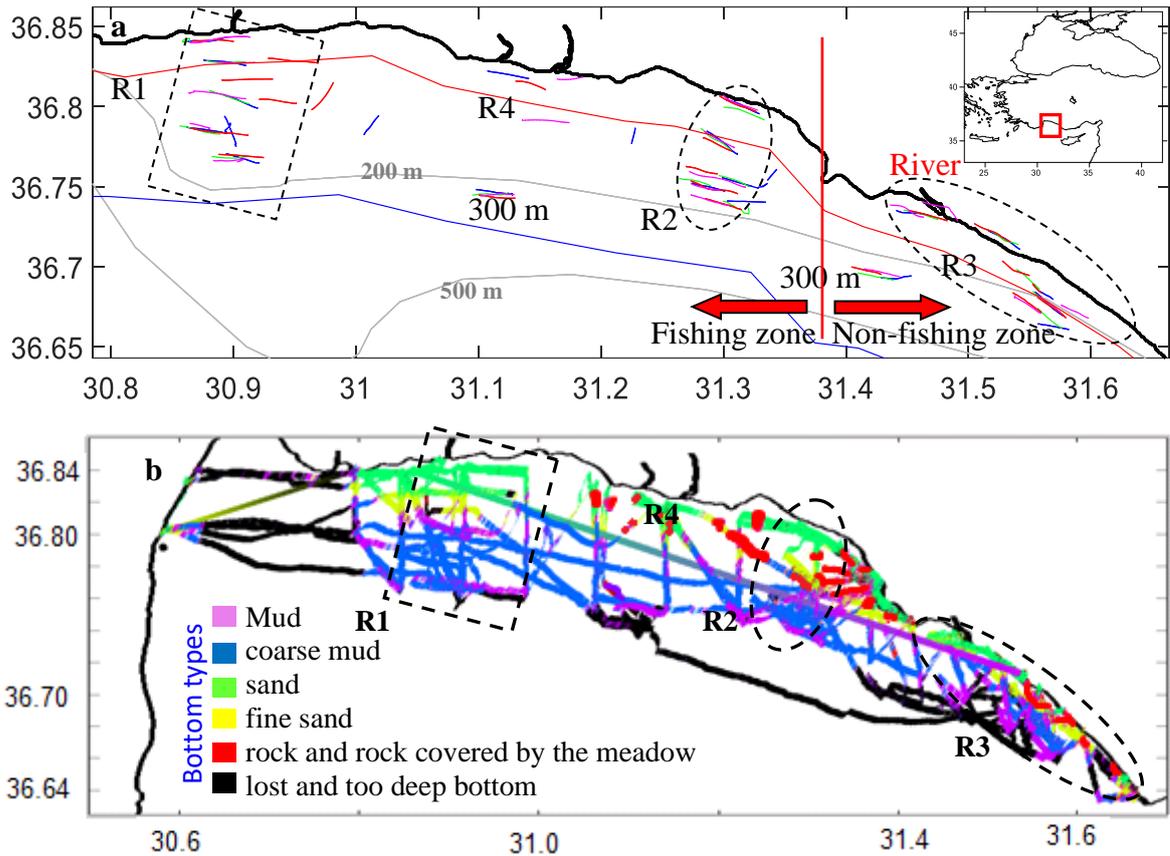
Figure 1. Seasonal trawl sampling tracklines during 2014-2015 (blue; May 2014, green; August 2014; red; October 2014 and magenta; February 2015), and two miles border for prohibition of the fishery, red line and 12 miles border, blue line, and fixed depths are in the order of the shallowest to the deepest bottom depths from the coast to open water seaward in each of regions (R1-R3) (a), and the study area showing the different bottom types from the acoustical tracklines by the echosounder during 2014-2015 (b).

Material and Methods

The present study was carried out by an official permission of the General Directorate of Fisheries and Aquaculture - Republic of Turkey Ministry of Agriculture and Forestry and was followed in compliance with ethical standards approved by the Akdeniz University (Protocol no: 2013.12.03).

Sample collection and studies, and data standardization

Study area and material and methods were well described for the present study in the papers by de Meo et al. (2018) and Mutlu et al. (2021). Briefly, fish samples were seasonally collected using the Otter trawl (wing mesh size; 88 mm in a diamond eye and the cod-end; 44 mm, and cover of codend; 22 mm) on the shelf and shelf break of Gulf of Antalya in May 2014, August, October and February 2015 including both fishery period (15 September–15 April) and non-fishery period (16 April–14 September) (Fig. 1). Materials and measurements of the biotic and abiotic environmental parameters were performed simultaneously (de Meo et al. 2018; Mutlu et al. 2021). The study area, one of the most oligotrophic areas in the Mediterranean Sea (Sisma-Ventura et al. 2017) was categorized to be the following sub-regions; R1; fishing zone and unvegetated soft bottoms, R2; the fishing zone and vegetated by *Posidonia oceanica* (Linnaeus) Delile, 1813, and R3; almost Marine Protected Area (MPA) exposed to little fishing effort of local fisheries using the longline nets and setline (log chip) (Fig. 1b). Each region had 5 fixed stations located at 10 m, 25 m, 75 m, 125 m and 200 m bottom depths. There were two further shelf break stations (300 m); one in R1-R2, and one in R3 (Fig. 1a). For riverine effects on the sparid species, a region R4, which was restricted coastally by a deepest bottom of 75 m, was added to the present study. On board of R/V "Akdeniz Su", the trawl was towed at a speed of 2.5-3 knots for about 30 minutes. Samples were then preserved in the 4-5% borax-buffered formaldehyde. The subsample of the total fish sample was taken if necessary (catch> 300 kg per trawl). Differential-Global Positioning System (D-GPS) recording data at every 1 s were converted to the swept area with estimations of the trawling distance multiplied with sweeping width calculated by multiplying the floatline length (35 m) with a multiplier of 0.5 (Pauly 1980).

All specimens of the porgies were individually measured for their total body length (mm) and weight (0.0001 g), and their gonads were dissected to determine individual sex of the species at the laboratory.

Statistical analyses

Spatiotemporal distribution of the porgies was evaluated by interpreting the results of the following statistical methods and analyses. Soyer's index based on dominance (*D%*), frequency of occurrence (*FO%*), and numerical occurrence (*NO%*) were evaluated to determine constancy of the species occurrence in the study area (Soyer, 1970). Thereafter, the present study focused mostly on ten common species assessed by Soyer Index for the following statistical analyses. These common species were given in Table 1.

The following statistical analyses were applied to test for differences in the variables obtained from the species among the time (month or season) and space (depth and region). Three-way analysis of variance (3-way ANOVA) was subjected to each of species abundance among seasons, depths, and regions. The Post-hoc test (LSD, least significant difference) was applied then to each variable separately for each factor (way). Before the ANOVA application, the data (X) were tested to be normal distribution using one-sample Kolmogorov-Smirnov test. Consequently, non normal data were transformed to $\log_{10}(X+1)$. Faunistic characteristics of the nemipterid and sparid (porgies) fish were represented by mean number of species (*S*), abundance (*N*), biomass (*B*), Margalef's richness index (*d*), Pielou's evenness index (*J'*), and Shannon-Weiner diversity index (*H'*) estimated using PRIMER (PRIMER, vers.6+). Three-way analysis of variance (3-way ANOVA) was subjected to each of the faunistic characteristics among seasons, depths, and regions. Bray-Curtis similarities based on $\log_{10}$-transformed abundances and biomasses of the porgies with and without the nemipterid fish were applied to non-parametric Multidimensional Scaling (nMDS) and cluster to see the fish assemblages, and to PERMANOVA to test the differences among the clustered fish assemblages using PRIMER. A subroutine of the PRIMER, the Similarity of Percentage (SIMPER) analysis was applied to determine the contributor and discriminator species within and between the groups determined with the cluster truncation.

Abundance of the porgies and nemipterid fish was subjected to canonical correspondence analysis (CCA) to cluster the stations to estimate the sparid/nemipterid species-environment relationship and the sparid/nemipterid species-megabenthic fauna (Garuti and Mutlu 2021; Patania and Mutlu 2021) relationship using CANOCA (vers. 4.5).

The Generalized Additive Model (GAM) was used to estimate the regressive effect of the predicted variable (ten common sparid fish; abundance, biomass, and biomass/abundance) to the response variables (the nemipterid fish; abundance, biomass, and biomass/abundance) for seasonally pooled data. The univariate statistical analyses were performed using the statistical tools of the MatLab (vers. 2021a, Mathworks inc).

Table 1. Spatiotemporal distribution (X ± SD) of biomass (*B*; kg.km^{-2}), abundance (*A*; ind.km^{-2}), female:male ratio (F:M), individual total length (L; cm) and weight (W; g) of the Randall's threadfin bream and the common porgies. Bold *P* values denote significantly difference in variables among the factors at $P < 0.05$

Species/Factors	*B*	*A*	F:M	L	W
Nemipterus randalli					
Region	0.369	0.5561	0.6584	**0.0206**	**0.0319**
R1	4.2±1.2	94.6±27.0	6.8±3.3	14.0±0.2	41.3±2.4
R2	3.3±1.2	68.9±28.7	4.7±4.3	15.1±0.4	46.7±3.9
R3	1.3±1.2	46.0±27.6	0.4±4.3	13.3±0.4	33.2±3.7
R4	1.1±2.7	24.8±61.7	0.5±7.5	16.4±1.4	60.6±12.2
Season	0.9272	0.8604	0.3255	**2.1*10^{-7}**	**0.0011**
May	3.5±1.3	70.6±29.7	12.5±5.0	12.8±0.4	34.3±4.2
Aug	2.2±1.5	54.0±33.7	4.9±4.5	15.2±0.4	41.4±3.8
Oct	2.9±1.3	55.6±30.4	1.0±3.5	15.6±0.3±	52.5±3.4
Feb	2.6±1.4	88.4±31.9	2.4±3.8	13.1±0.3	35.7±2.9
Depth	**1.8*10^{-7}**	**5.6*10^{-7}**	0.8595	**0.0091**	**0.0075**
10	0.3±1.2	4.9±27.9	-	17.5±1.6	69.6±13.9
25	7.0±1.3	160.6±30.0	2.7±3.1	14.1±0.3	40.1±2.7
75	5.7±1.2	159.6±28.9	8.8± 4.1	13.4±0.3	35.8±2.8
125	0.1±1.7	2.8±38.2	1.0±11.0	14.2±2.8	41.2±24.1
200	-	-	-	-	-
300	-	-			

Table 1. Continued

Boops boops					
Region	0.8168	0.6758	0.7789	**$6.1*10^{-13}$**	**$1.1*10^{-14}$**
R1	44.4±16.1	1742±704.4	3.8±1.4	13.5±0.07	22.8±0.4
R2	43.6±17.1	2119±748.9	1.8±1.5	13.0±0.09	21.4±0.5
R3	24.6±16.4	913.0± 718.3	2.3±1.6	14.0±0.09	27.5±0.5
R4	33.3±36.7	1056±1606	2.0±2.5	13.7±0.2	25.4±1.3
Season	0.0628	0.0572	**0.0149**	**$5.6*10^{-40}$**	**$4.0*10^{-15}$**
May	2.9±16.8	126.5±736.0	0.5±1.4	13.3±0.1	23.5±1.0
Aug	55.7±19.1	1965±837.2	8.1±1.8	14.4±0.1	27.9±0.8
Oct	32.5±17.1	1302±753.3	1.5±1.3	14.0±0.07	25.4±0.4
Feb	65.5±18.0	3085±791.9	2.6±1.3	12.8±0.07	21.1±0.4
Depth	**0.0167**	**0.0214**	**0.0051**	**$1.1*10^{-44}$**	**$3.8*10^{-35}$**
10	11.1±19.5	376.4±860.8	1.4±1.7	12.7±0.1	20.1±1.0
25	11.3±20.9	526.3± 924.7	1.1±1.8	13.6±0.1	25.3±0.85
75	73.5±20.2	3518±891.1	1.2±1.4	12.8±0.1	20.6±0.5
125	100.6±20.9	3948±924.7	3.4±1.4	13.8±0.07	24.4±0.4
200	19.4±21.8	625.8±962.4	3.9±1.8	14.5±0.1	27.0±0.9
300	0.8±26.7	16.1±1178	25.0±4.8	17.3±0.6	50.2±4.1
Dentex macrophthalmus					
Region	0.1101	**0.0047**	0.2381	0.2430	0.2851
R1	0.6±0.7	41.3± 52.4	0.4±0.08	9.6±0.5	16.7±2.9
R2	1.0±0.7	50.2±55.3	0.2±0.1	10.9±1.1	20.2±6.5
R3	0.1±0.7	3.3±53.8	0±0.1	12.6±1.9	35.6±11.3
R4	5.2±1.9	552.0±135.4			
Season	0.4908	0.4119	0.8929	**0.0018**	**0.0072**
May	1.2±0.7	110.5±54.7	0.2±0.1	8.7±0.4	12.3±2.7
Aug	1.1±0.8	53.1±62.2	0.2±0.2	10.9±0.8	20.2±5.2
Oct	0.1±0.7	5.5±56.0	0.3±0.1	12.0±0.6	30.1±4.03
Feb					
Depth	0.2759	0.3926	0.3571	**0.0325**	0.0851
10	-	-	-	-	-
25	-	-	-	-	-
75	3.4±1.0	238.5±76.9	0.1±[0.1	11.3±0.8	24.0±5.2
125	1.1±1.0	79.2±80.7	0.3±0.1	9.2±0.4	14.5±2.9
200	0.1±1.1	3.8±85.0	0.5±0.1	12.2±1.2	30.9±7.4
300					
Dentex maroccanus					
Region	**0.0268**	0.0519	0.4725	**$7.4*10^{-37}$**	**$6.4*10^{-33}$**
R1	2.7±135.7	161.0±4273	2.8±3.1	10.3±0.1	18.7±1.5
R2	9.3±144.2	516.0±4543	8.1±3.4	10.6±0.1	20.0±1.3
R3	526.9±138.4	15283±4357	7.1±2.7	12.6±0.1	35.3±0.7
R4					
Season	0.5280	0.3907	0.8302	0.1385	**$9.2*10^{-7}$**
May	23.3±154.5	447.7±4792	2.1±6.1	11.9±0.4	37.9±3.4
Aug	352.8±175.7	12862±5452	4.9±3.2	11.7±0.1	27.6±0.8
Oct	118.7±158.1	3760±4905	8.0±3.2	11.9±0.1	29.5±1.2
Feb	234.5±166.2	4771±5157	6.3±3.5	12.3±0.1	36.5±1.5
Depth	0.1486	0.2902	0.4907	**$5.5*10^{-68}$**	**$2.9*10^{-64}$**
10	-	-	-	-	-
25	-	-	-	-	-
75	0.05±187.7	1.9±5945	0.5±8.3	11.6±1.4	26.7±11.7
125	383.3±194.8	16125±6169	9.2±2.7	10.8±0.09	21.6± 0.7
200	702.3±202.7	15649±6421	4.6±2.6	12.9±0.1	37.4± 0.8
300	6.2±248.3	86.7±7864	1.8±5.8	16.3±0.3	67.9±3.1

Table 1. Continued

Diplodus annularis					
Region	**$1.6*10^{-4}$**	**0.0016**	0.5266	**$1.2*10^{-5}$**	**0.0016**
R1	4.7±31.3	217.0±1571	3.8±1.7	10.6±0.1	21.4±1.05
R2	5.6±33.2	172.0±1671	1.4±1.9	12.1±0.3	29.3±2.08
R3	22.1±31.	878.4±1603	0.3±1.7	11.5±0.1	25.3±1.2
R4	362.4±71.3	15538±3584	0.4±2.7	11.2±0.1	25.3±0.7
Season	0.4887	0.4515	0.7670	**$1.6*10^{-24}$**	**$8.9*10^{-24}$**
May	34.9±38.2	1034±1857	1.2±2.3	12.0±0.1	29.3±1.2
Aug	1.0±43.5	30.9±2113	0.5±2.9	11.4±0.3	23.1±2.1
Oct	10.6±39.1	338.2±1901	0.5±2.0	12.0±0.1	30.8±0.8
Feb	84.7±41.1	4150±1998	2.9±1.5	10.4±0.09	19.5±0.6
Depth	0.5693	0.7256	0.7357	**$5.3*10^{-9}$**	**$1.0*10^{-5}$**
10	124.0±46.5	5396±2282	0.6±1.8	10.8±0.09	22.9± 0.6
25	58.2±49.9	2173±2451	2.3±1.2	11.8±0.1	28.0± 0.9
75	0.03±48.1	-		12.1±1.4	32.7±10.2
125	0.1± 49.9	1.8±2451			
200					
300					
Lithognathus mormyrus					
Region	**0.0305**	**0.0363**	0.5694	**$1.0*10^{-13}$**	**$1.0*10^{-4}$**
R1	36.4±11.9	1018±335.3	2.2±0.9	12.9±0.1	32.3±1.1
R2	0.8±12.7	22.8±356.5	0.5±1.3	14.2±0.5	34.3±3.7
R3	4.9±12.1	112.0±341.9	0.5±0.9	15.2±0.2	41.9±1.9
R4	73.0±27.2	1931±764.7	1.3±1.3	14.6±0.2	38.9±1.8
Season	0.3699	0.2620	0.7194	**$2.1*10^{-18}$**	**$8.7*10^{-8}$**
May	15.5±13.5	415.6±375.6	0.9±1.1	14.0±0.3	38.4±2.5
Aug	6.1±15.3	130.4±427.3	2.3±1.1	15.2±0.2	41.6±2.0
Oct	11.5±13.8	262.8±384.5	1.2±1.1	15.2±0.2	42.2±1.9
Feb	40.2±14.5	1188±404.2	0.7±0.9	12.8±0.1	30.9±1.1
Depth	0.0663	**0.0331**	0.2178	**$2.8*10^{-21}$**	**$2.3*10^{-18}$**
10	61.7±15.6	1969± 432.8	0.7±0.6	13.1±0.1	30.9±0.9
25	40.6±16.8	761.3± 464.9	2.0±0.8	15.6±0.2	47.2±1.4
75	0.07±16.2	1.3± 448.0			
125	-	-			
200					
300					
Pagellus acarne					
Region	0.3736	0.5992	0.5964	**$8.4*10^{-109}$**	**$5.2*10^{-97}$**
R1	33.8±60.1	2401±1634	0.5±0.2	11.2±0.1	16.6±0.7
R2	6.9±63.9	517.9±1737	0.002±0.3	10.6±0.1	14.2±0.8
R3	148.8±61.3	3503±1666	0.4±0.2	14.2±0.09	36.4±0.6
R4	0.3±137.1	11.8±3726		13.5±1.2	29.3±8.4
Season	0.5492	0.5732	0.5749	**$4.5*10^{-15}$**	**$2.0*10^{-14}$**
May	3.2±65.8	480.8±1774	0.1±0.3	12.7±0.7	27.0±4.8
Aug	62.8±74.8	3791±2019	0.7±0.3	11.4±0.1	18.8±0.8
Oct	136.8±67.3	3036±1816	0.1±0.2	12.7±0.1	28.1±0.8
Feb	39.4±70.8	1220±1909	0.3±0.3	13.1±0.1	27.7±1.1
Depth	**0.0014**	0.0867	**0.0166**	**$1.2*10^{-104}$**	**$1.0*10^{-118}$**
10	4.5±70.8	716.8±2056	0.12±0.5	11.0±0.3	15.8±1.9
25	0.3±76.0	17.8±2209	0.08±0.5	11.8±0.5	20.3±3.3
75	56.0±73.3	3621±2128	0.001±0.3	10.2±0.1	12.3±0.9
125	16.0±76.0	595.0±2209	0.2±0.2	12.1±0.1	22.9±0.8
200	93.6±79.1	3506±2299	0.1±0.2	12.3±0.1	22.9±0.6
300	4.5±96.9	91.8±2816	2.7±0.5	15.4±0.3	48.3±2.1

Table 1. Continued

Pagellus erythrinus					
Region	0.2185	0.7496	**0.0329**	**1.7*10⁻⁷⁵**	**1.9*10⁻⁵²**
R1	29.5±38.7	1221±856.6	87.8±55.6	11.7±0.1	24.4±1.3
R2	83.5±41.2	1889±910.8	56.6±49.0	14.5±0.1	44.5±1.3
R3	140.7±39.5	2394± 873.6	29.2±52.0	15.5±0.1	52.5±1.3
R4	19.1±88.4	739.8±1953	348.0±93.0	12.3±0.2	27.9±2.1
Season	0.1903	0.2088	0.5229	**2.1*10⁻⁶**	**6.4*10⁻⁴**
May	46.7±42.0	1049± 911.0	25.8±55.5	13.1±0.2	35.2±2.0
Aug	171.3±47.8	3714±1036	108.4±74.0	14.5±0.1	44.1±1.5
Oct	47.1±43.0	1176± 932.4	71.8±61.6	13.3±0.1	37.1±1.6
Feb	72.3±45.2	1465±980.3	142.2±57.3	13.6±0.1	37.2±1.4
Depth	0.0525	**0.0025**	0.9444	**1.2*10⁻⁴⁶**	**3.1*10⁻³⁸**
10	6.1± 49.1	289.9±1005	138.5±66.8	11.3±0.2	20.8±2.0
25	234.0±52.7	6398±1080	117.2±64.2	13.1±0.1	33.4±1.1
75	101.8±50.8	1385±1040	77.2±64.2	15.3±0.1	49.0±1.5
125	110.0±52.7	2005±1080	21.5±77.2	15.0±0.2	53.1±2.0
200	1.6±54.9	28.8±1124	5.0±231.7	16.3±0.7	56.4±6.7
300	0.2±67.2	2.8±1377		18.8±2.7	88.3±24.3
Pagrus caeruleostictus					
Region	0.7974	**0.0211**	0.0974	**9.8*10⁻⁴**	**0.0166**
R1	2.5±1.8	33.5±34.5	0.3±0.2	13.6±0.8	56.6±13.4
R2	2.7±1.9	34.3±36.7	0.03±0.2	16.2±0.8	93.1±13.7
R3	3.6±1.8	45.5±35.2	0.6±0.1	17.5±0.6	102.5±11.0
R4	6.9±4.2	298.2±78.7	0.02±0.2	12.6±1.4	41.1±22.8
Season	0.3534	0.2941	0.5328	**1.3*10⁻¹²**	**9.2*10⁻⁹**
May	3.0±1.9	107.5±39.0	0.2±0.2	12.1±0.5	35.8±9.6
Aug	6.1±2.2	73.5±44.4	0.7±0.3	16.3±0.5	85.2±9.6
Oct	3.5±2.0	24.2±39.9	0.2±0.2	20.1±0.6	144.9±11.7
Feb	0.5±2.1	8.7±42.0	0.3±0.2	15.2±1.5	91.5±26.9
Depth	**6.9*10⁻⁴**	0.0696	0.2025	**4.6*10⁻⁷**	**4.1*10⁻⁵**
10	5.1±2.1	168.3± 45.5	0.1±0.1	13.0±0.6	48.4±10.2
25	13.6±2.2	136.0±48.9	0.5±0.1	17.5±0.5	106.3±8.6
75	-	-			
125					
200					
300					
Pagrus pagrus			2.27		
Region	0.5510	0.5498	0.6249	0.0911	0.1873
R1	0.2±49.4	11.3±275.4	-	13.4±4.8	30.6±71.2
R2	2.9±52.5	45.9±292.9	1.5±3.6	16.0±0.7	85.7±11.7
R3	90.1±50.4	519.4±280.9	6.5±4.0	12.4±1.4	42.7±21.4
R4					
Season	0.4696	0.4810	0.8888	0.0819	0.0742
May	102.2±53.5	581.8±298.7	1.0±8.9	13.0±1.4	39.8±20.8
Aug	1.3±60.9	24.6±339.8	2.0±6.3	17.3±1.6	91.0±24.4
Oct	0.4±54.8	14.0±305.8	0.5±6.3	12.5±1.7	39.5±26.1
Feb	2.4±57.6	43.4±321.5	5.5±4.0	16.2±0.9	96.9±14.4
Depth	0.6588	0.6333	0.6593	0.7183	0.5937
10	0.04± 65.5	5.0± 364.8	-	-	-
25	0.4±70.4	16.8±391.8	-	-	-
75	3.8±67.8	63.0±377.6	1.2±4.1	15.6±0.9	82.3±13.1
125	173.5±70.4	999.0± 391.8	5.8±3.6	14.5±1.2	64.1±17.7
200	0.05±73.2	1.6±407.8	-	13.4±5.0	30.6±73.0
300	1.5±89.7	19.1± 499.5		-	

Results

Spatiotemporal distribution

Before ecological conception for the interaction between targeted IS and NIS, the quantitative and qualitative spatiotemporal distribution would help to better understand the ecosystem between the NIS and IS fish. A total of 13 porgies, all indigenous species were caught and one species belonging to nemipterid fish which is non-indigenous species (Lessepsian) to the eastern Mediterranean Sea. One species belonged to genus *Boops*, one to *Lithognathus,* 3 to *Dentex*, 2 to *Diplodus*, 2 to *Pagellus*, and 4 to *Pagrus*. According to Soyer index, *Pagellus erythrinus* and *Boops boops* were recognized as constant species, *Pagellus acarne, Nemipterus randalli, Dentex maroccanus* and *Diplodus annularis* were common species, and the rest of the species were rare species for the study area. The most abundantly occurred species was *Dentex maroccanus,* followed by *P. erythrinus, B. boops, P. acarne,* and *D. annularis* among all fish species caught during the present study. The rest of fish species had a *NO%* < 1%. Most of the NIS inhabited the lower shelf whilst *N. randalli* was present in the middle shelf (Fig. 2).

Abundance

The highest abundance was recorded for *D. annularis* and *P. acarne*, followed by *P. erythrinus*, *B. boops* and *D. maroccanus* (Fig. 2). There were significant differences in the abundances of some porgies among the regions at $P < 0.05$ (Table 1, Fig. 2). *Dentex macrophthalmus* had the maximum abundance in R4, followed R1 and R2, being rather high than that in R3, similar to *D. annularis* having maxima in R4, but minima in R1 and R2. *Lithognathus mormyrus* occurred abundantly in the unvegetated bottoms (R1 and R4). *Pagrus caeruleostictus* preferred the riverine region (R4) in numerous as compared to the other regions (Table 1, Fig. 2). However, abundances of all sparid and nemipterid fish were not significantly differentiated by the season (Table 1). Overall, the seafloor depth significantly affected abundances of some of the porgies excluding *D. macrophthalmus* (distributed in 75-125 m), *D. maroccanus* (75-300 m), *D. annularis* (10-25 m), *P. acarne* (10-300 m), *P. caeruleostictus* (10-25 m) and *Pagrus pagrus* (10-300 m, mostly 75-125 m). The abundance increased significantly by the bottom depth for *N. randalli* (10-75 m) preferring the 25-75 m, for *B. boops* (10-300 m) occurring abundantly at 75-125 m, for *P. erythrinus* (10-300 m) found abundantly at 25-125 m, and decreased significantly by the depth for *L. mormyrus* (10-75 m, mostly at 10-25 m) (Table 1, Fig. 2).

Biomass

Biomasses of the fish exhibited a similar distribution to the abundance among the regions, seasons, and bottom depth with a few exceptions (Table 1). *D. maroccanus* contributed to the biomass, most highly to the total biomass of the all fish, followed by *P. acarne, P. pagrus, D. annularis* and *P. erythrinus*. Regional differences in the biomass occurred significantly for *D. maroccanus* having higher biomass in R3, *D. annularis* in the riverine region

and *L. mormyrus* at the unvegetated bottoms (Table 1). Like the abundance distribution, seasonal difference in the biomass did not occur significantly for any of the fish (Table 1). Each of four fish species (*N. randalli, B. boops, P. acarne* and *P. caeruleostictus*) had different biomass significantly along the bottom depth gradient (Table 1). Their biomasses tended to increase from the shallow to deep waters in a range of their specific distributional depths (Table 1).

Faunistic characteristics

On contrary to the evenness index, the basic faunistic characters overall increased by the bottom depth in all seasons (Fig. 3a). Of the faunistic characteristics, number of species (*S*), abundance (*N*), biomass (*B*), and richness index (*d*) were significantly differentiated by all factors, and their interactions (Table 2). However, the evenness (*J'*) and biodiversity index (*H'*) were significantly different among none of the factors. Seasonal number of the species was highly variable in shallow waters (10-25 m), the variation decreased in intermediate depths (75-125 m), and then became stable at greater depths (Fig. 3a). The seasonal abundance showed a normal (bell-curve) distribution along the bottom depth gradient by having high abundance in August-October compared to the other seasons. The biomass had rather low values in May, and was more pronounced in a depth range of 75-200 m. The species richness index was similar to the trend of the number of species along the bottom depth, but was higher in all season along the shallow and intermediate waters with few exceptions, and was explicitly higher in February at the greater depths than the other seasons (Fig. 3a). The evenness index oscillated along the bottom depth for each of the seasons, but tended to increase by the bottom depths from 125 m to 300 m. The Shannon-Weiner biodiversity index had a bell-curve along the bottom depth of the shelf in August and October in contrast to a flipped-down curve occurred in February, and May (Fig. 3a).

Faunistic characteristics of the porgies were significantly differentiated by the nemipterid fish at $P < 0.05$ (Table 2, Fig. 3). Of the faunistic characters, the biomass between sparids with and without nemipterid fish was significantly different among each of the factors and their interactions excluding seasonal interaction (Table 2, Fig. 3). The depth and its interaction with the other factors changed significantly most of the faunistic characteristics between sparids with and without nemipterid fish (Table 2, Fig. 3). Seasonal faunistic characters of the porgies were highly variable (Fig. 3b) as compared to the faunistic characters with the nemipterid fish across the seafloor depth (Fig. 3a).
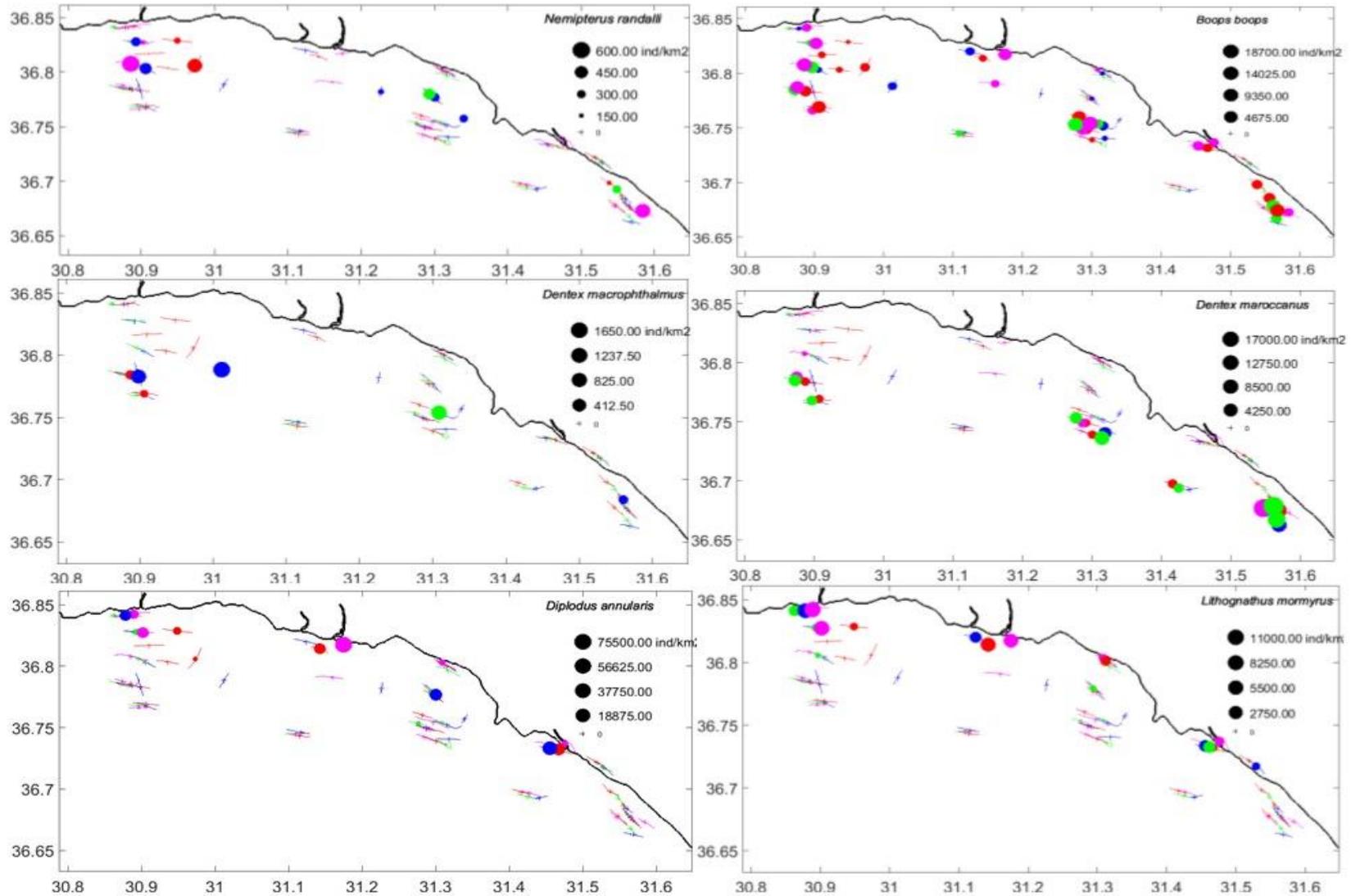
Figure 2. Spatiotemporal abundance (ind.km^{-2}) distribution (circles log$_{10}$-transfomed excluding the nemipterid fish) of constant and common nemipterid and sparid fish. Seasonal colors on the figures are: blue for May 2014, green for August 2014, red for October 2014, and magenta for February 2015
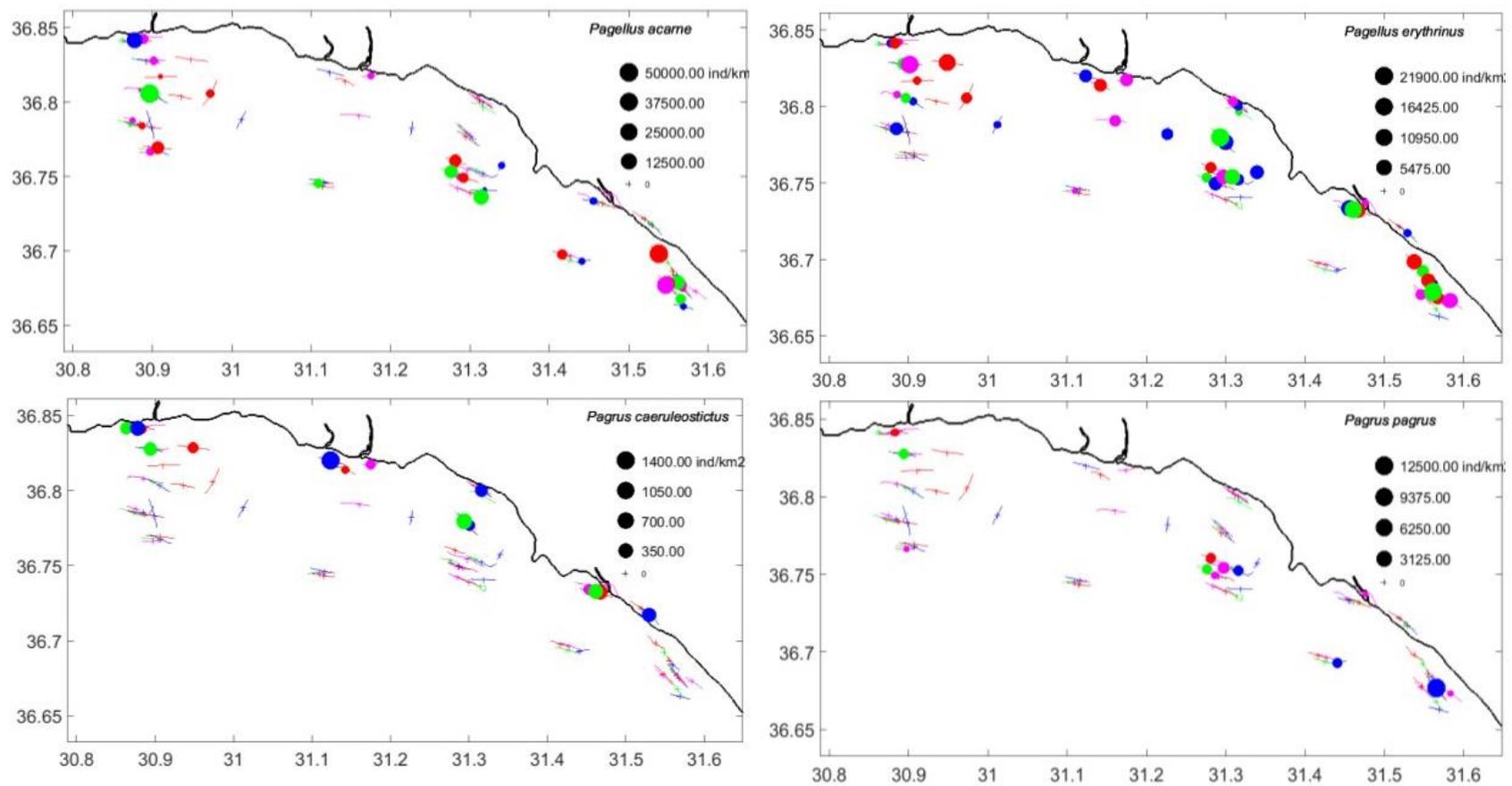
Figure 2. Continued

Table 2. Three-way ANOVA results (p value) of the faunistic characteristics of the sparid fish with the nemipterid fish (a), and nested ANOVA between with and without the nemipterid fish (b). Bold p values denote significant difference among the factors at $P < 0.05$

Source a	d.f.	S	N	B	d	J'	H'
Region	3	**0.000**	**0.022**	**0.024**	**0.004**	0.761	0.664
Season	3	**0.000**	**0.036**	0.069	**0.001**	0.723	0.504
Depth	5	**0.000**	**0.003**	**0.011**	**0.000**	0.613	0.133
Region*Season	8	**0.000**	**0.024**	0.086	**0.005**	0.722	0.357
Region*Depth	11	**0.000**	**0.013**	**0.031**	**0.002**	0.864	0.327
Season*Depth	15	**0.000**	**0.023**	0.084	**0.002**	0.829	0.286
Region*Season*Depth	27	**0.000**	**0.031**	0.088	**0.004**	0.749	0.374
Error	2						
Total	74						
b							
Species	1	0.687	0.749	**$2.4*10^{-5}$**	0.353	0.767	0.786
Region(Species)	5	0.314	0.094	**$4.6*10^{-8}$**	0.308	0.991	0.931
Season(Species)	6	0.778	**0.013**	**0.014**	0.406	0.485	0.486
Depth(Species)	12	**$5.7*10^{-9}$**	0.115	**$3.7*10^{-5}$**	**$3.3*10^{-7}$**	0.407	**0.002**
Region(Species)*Season(Species)	14	0.795	0.309	0.383	0.564	0.453	0.220
Region(Species)*Depth(Species)	21	**0.002**	**0.045**	**$1.9*10^{-6}$**	0.076	0.883	0.125
Season(Species)*Depth(Species)	31	**0.007**	0.898	0.552	**0.007**	0.590	0.057
Error	67						
Total	157						
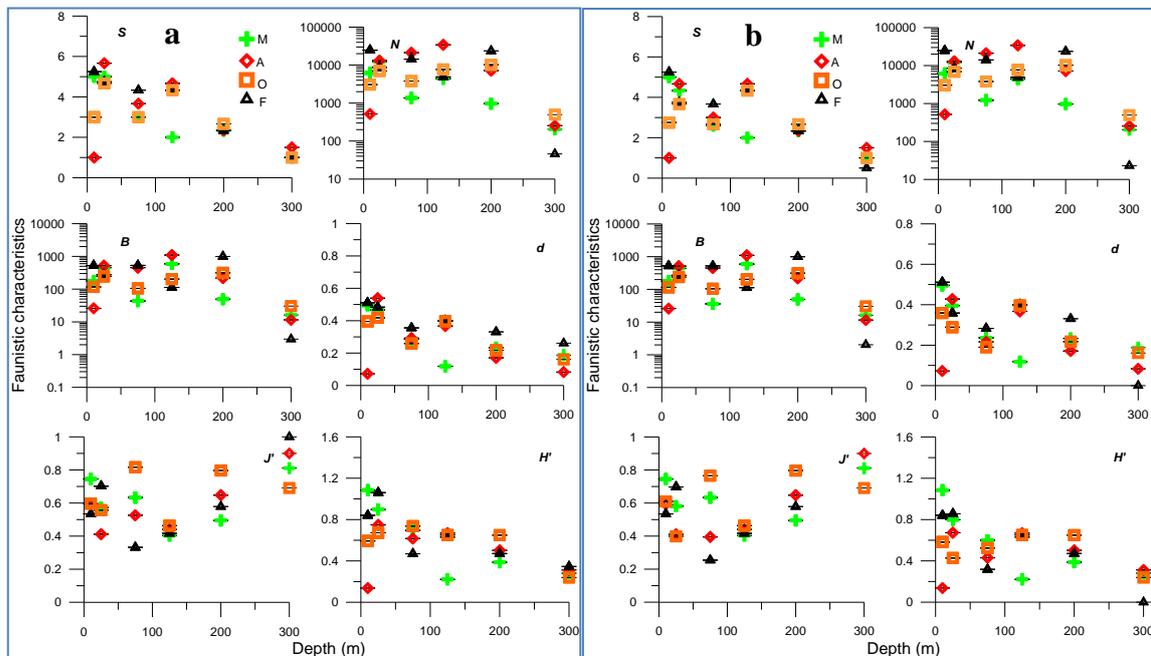
Figure 3. Seasonal distribution (M; May, A; August, O; October and F; February) of the average number of species (*S*), abundance (*N*, ind.km^{-2}), biomass (*B*, kg.km^{-2}), species richness (*d*), evenness (*J'*) and Shannon-Weiner (*H'*) indices on average based on the sparid fish with (a) and without (b) nemipterid fish along the bottom depth gradient

Table 3. Pearson product moment correlation among the abundance (black values), and biomass (red) between the common fish species (see Table A1 for the species abbreviations) subjected in the present study. Bold correlation coefficients denote significance in the correlations at *P* < 0.05.

	N ran	*B bop*	*D mac*	*D mar*	*D ann*	*L mor*	*P aca*	*P ery*	*P cae*	*P pag*
N ran		0.080	-0.097	-0.111	-0.057	-0.053	0.016	**0.250**	0.020	-0.063
B bop	-0.024		-0.054	0.128	0.072	-0.009	0.062	0.087	-0.110	-0.003
D mac	-0.100	-0.059		-0.044	-0.031	-0.056	-0.048	-0.013	-0.058	-0.026
D mar	-0.111	0.106	-0.051		-0.036	-0.064	0.164	**0.386**	-0.067	-0.025
D ann	-0.047	0.120	-0.040	-0.044		**0.267**	-0.035	0.038	0.016	-0.021
L mor	-0.036	0.002	-0.062	-0.069	**0.250**		0.001	0.156	0.110	-0.037
P aca	0.073	0.057	-0.042	0.200	-0.036	-0.045		0.015	-0.041	-0.032
P ery	**0.227**	0.129	0.024	**0.365**	0.031	0.090	0.090		0.220	-0.030
P cae	0.161	-0.130	-0.074	-0.082	0.076	-0.064	-0.064	**0.344**		-0.037
P pag	-0.055	-0.015	-0.025	-0.027	-0.022	-0.023	-0.023	-0.018	-0.040	

Community assemblage and ecology

Overall, there were no significant correlations in abundance, and biomass between the species with few exceptions which showed positive correlations (Table 3). *N. randalli* was correlated in both abundance and biomass with *P. erythrinus* which was correlated with *D. maroccanus*. Abundance and biomass of *D. annularis* increased significantly with that of *L. mormyrus* (Table 3). However, there was correlation in abundance and biomass between rare species.

Unlike the groups clustered in Fig. 4c, three-way PerMANOVA showed that the fish assemblages based on their abundance at the samples were not significantly different among the ungrouped regions, seasons, and bottom depths, and their factorial interactions at p< 0.05. The fish fauna was configured depending on groups of the bottom depths in the nMDS, regardless of regions and seasons (Fig. 4a). A similarity truncation of 37.5% at the cluster analysis discriminated three different and explicit faunal assemblages depending on the bottom depths; the shallow waters (S; 10-25 m), intermediate waters (I; 75-125 m) and the deep waters (D; 200-300 m) (Fig. 4c). All these groups were significantly different in the fish fauna (Table 4a), and their pairwise as well (Table 4b). Contributor species at S were *L. mormyrus* and *P. erythrinus*, *P. erythrinus* at I, and *D. maroccanus* and *P. acarne* at D (Table 5).

The discriminator species were *L. mormyrus* (abundantly found at S) between S and I, *L. mormyrus* (at S), *P. erythrinus* (at S), *D. maroccanus* (at D), *D. annularis* (at S), *P. acarne* (at D), *P. caeruleostictus* (at S) and *B. boops* (at S and D) between S and D, and *P. erythrinus* (at I), *D. maroccanus* (at D), *P. acarne* (at I and more at D), and *B. boops* (at I and D) between I and D. The rare species were discriminated from the other species

(Fig. 4d). A transition depth fish group occurred being contributed mostly by a single species, *D. macrophthalmus* abundantly found at 75 m (Fig. 4c, d). *N. randalli* co-existed with *B. boops* and *P. erythrinus* and was then linked with the shallow water fish (Table 4c). The nMDS of the sparid fish without the nemipterid fish showed the depthwise distribution was unassembled and there was not clear fish assemblages along the depth gradient (Fig. 4b) unlike the nMDS with nemipterid fish (Fig. 4a). *P. pagrus* only was replaced with the nemipterid fish when eliminating the nemipterid fish in the porgies assemblage.

However, the cluster based on biomass of the species showed two different depth groups for the faunal assemblages at a truncation of 18.5% similarity level; shallow, S constituting of two subentities (S1 mostly at 75 m and S2 at 10-25 m) and deep waters, D (mostly at 125-200 m) (Fig. 4e). More than half of total similarity at S was contributed by *P. erythrinus* whilst only three species (*B. boops, D. maroccanus* and *P. acarne*) were the contributor species accounting for 93% of the total similarity at the D. All four species were, at the same time, the discriminator species between S and D.

The nemipterid and sparid species-environment relation was highly correlated for their biomass and abundance data (Table A2, Figs. 5a-b). On CCA1 axis, the species biomass-environment relation was explained with a percent variance of 33.2% constituting mainly of the bottom depth, bottom type having positive correlation, and the finest sized bioseston having negative correlation (Table A2, Fig. 5b), and secondarily with water clarity and salinity positively correlated with CCA1, and water primary productivity negatively correlated with CCA1 (Fig. 5b). On CCA2, the suspended matter explained this relation with a cumulative variance of 45.6%, which was attributed mainly to correlation with the finest-sized seston and its fractions; tripton and bioseston.
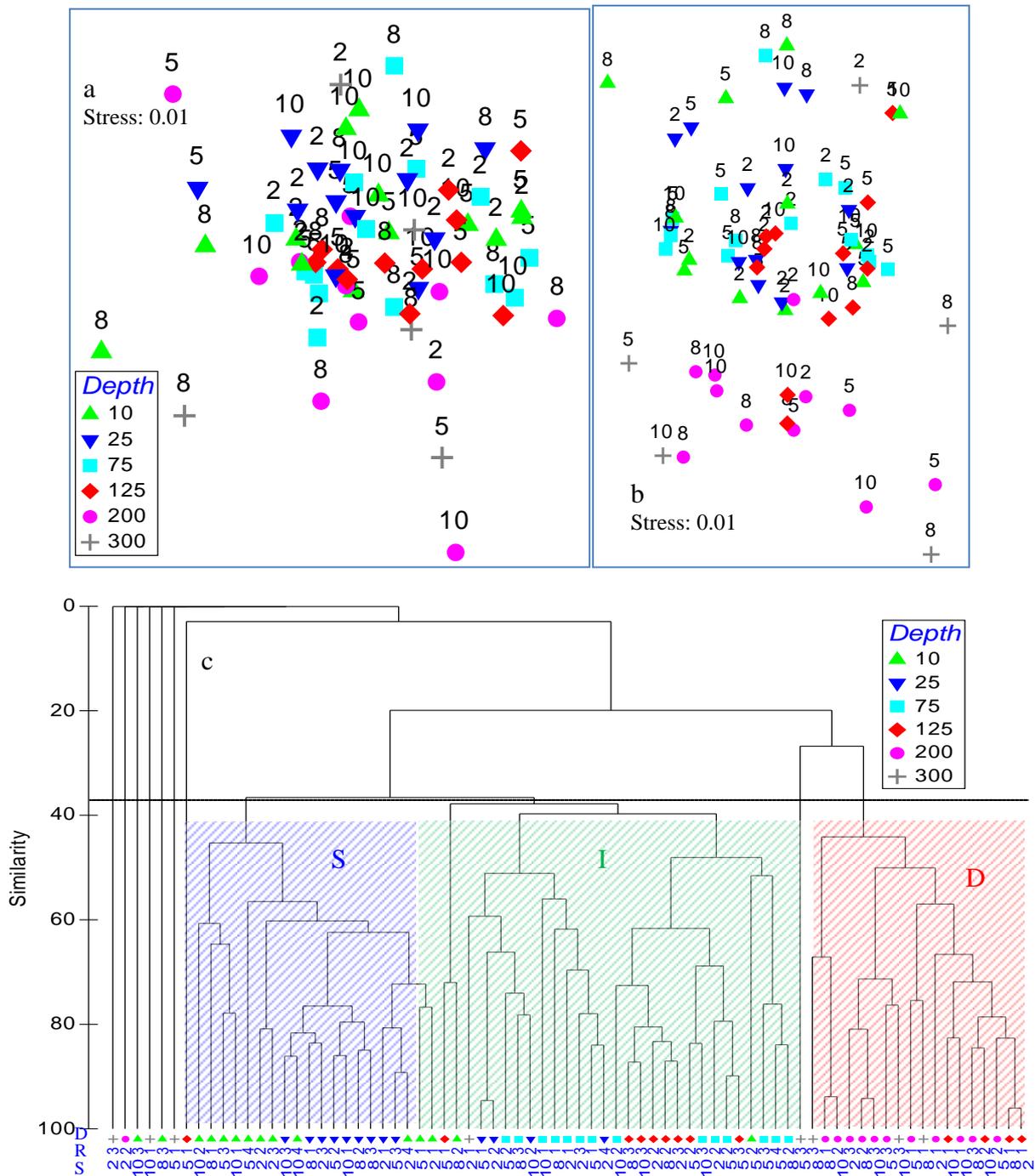
Figure 4. Non-parametric Multidimensional Scaling, nMDS (a and b) of log$_{10}$-transformed abundances of sparid species with (a) and without the nemipterid (b), and cluster analyses (c-e) among the samples (sampling stations) truncated at a similarity of 37%, and classified by bottom depths and seasons (2: February, 5; May, 8; August, and 10; October) (a-b), and by bottom depth, regions, and seasons, respectively (c), among the fish species (d), and of log$_{10}$-transformed biomasses among the samples, truncated at 15% (sampling stations classified by bottom depths and regions) (e).
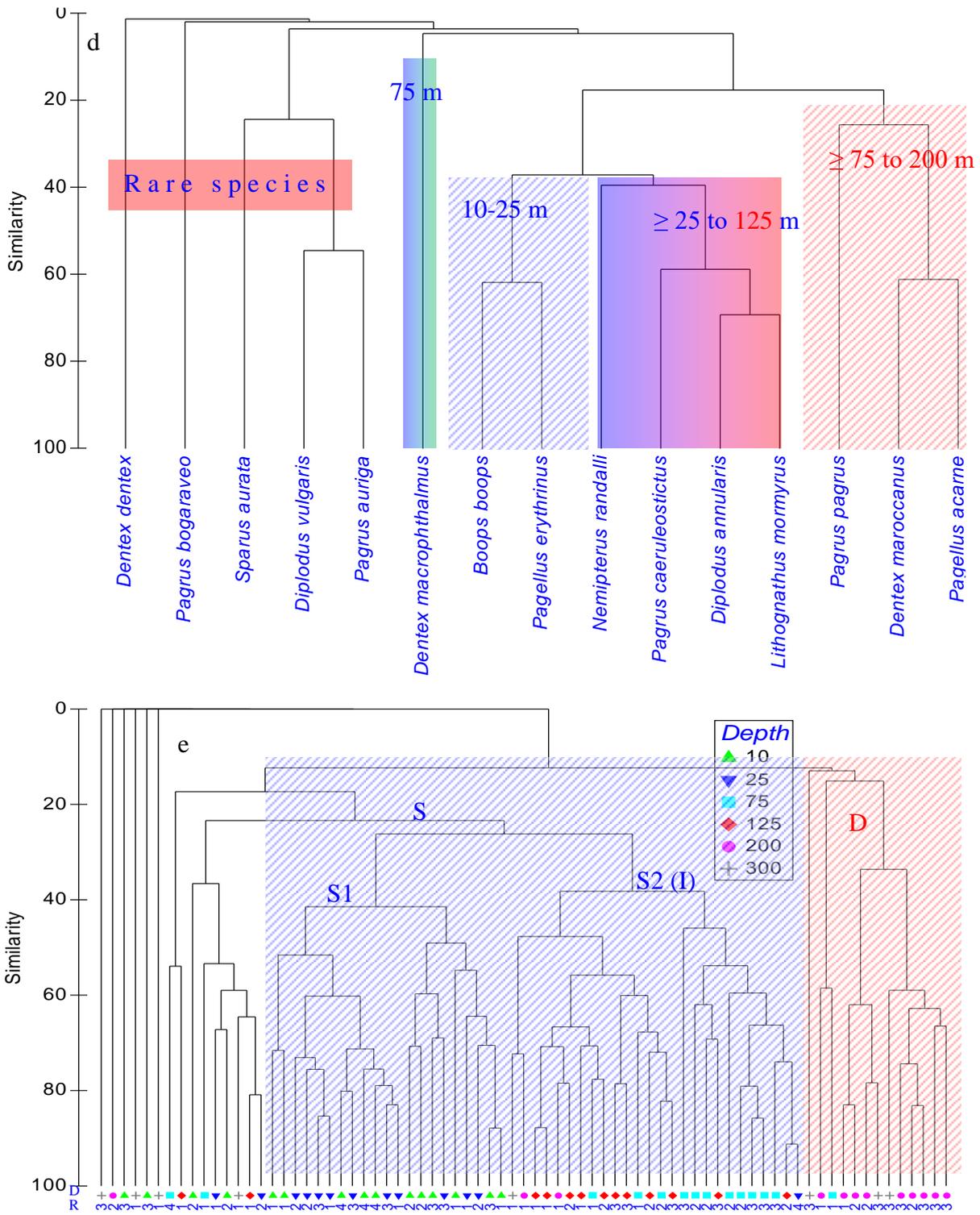
Figure 4. Continued

As an indication of the habitat, the bottom type was correlated with the two components on CCA 1-2 (Table A2, Fig. 5b). The species-environmental relation, and fish assemblages discrimination was significantly proofed with the Monte Carlo test ($F = 9.9$, $P = 0.002$ for the CCA1, and $F = 1.8$, $P = 0.002$ on all CCA for the biomass data) at $P < 0.05$. However, the CCA solved without the nemipterid species was found to be very similar in configuration on species-environment relation to that with the nemipterid species (Fig. 5a, c).

Applied abundance data subjected to the CCA showed very similar configuration to that of the biomass data for the species-environment relation (Fig. 5a). The shallow water fish species which was correlated with the water primary and secondary productivity were discriminated from the deep water fish species correlated with the depth-related variables; Secchi disk depth and bottom type. This discrimination was more pronounced for the abundance data as compared to the biomass data (Table A2, Fig. 5a-b). *P. erythrinus* was co-configured with *N. randalli* on the CCA, and both correlated the total suspended mater and salinity in the near-bottom water. The species-environmental relation, and fish assemblages discrimination was significantly proofed with the Monte Carlo test ($F = 10.2$, $P = 0.002$, and $F = 1.6$, $P = 0.002$ for the abundance data) at $P < 0.05$. . Like the abundance data, The CCA without the nemipterid species did not change as compared to that with the nemipterid species (Fig. 5b, d).

The fish species-megabenthic fauna relation was significantly correlated for their abundance data at $P < 0.05$, but was lowly correlated in relative to the fish species-environment relation (Fig. 5 a, e). Some of the shallow water species were positively correlated mainly with class species of gastropods while the deep fish species was correlated with cephalopods and holoturids on CCA1 (Table A2, Fig. 5e). *N. randalli* and *P. erythrinus* were positively correlated with cnidarians, bivalves and annelids, and *D. macrophthalmus* and *Pagrus bogaraveo* was correlated with the class of the echinoderms on CCA2 (Table A2, Fig. 5e). However, the species-megabenthic fauna relation, and fish assemblage discrimination was not significantly proofed with the Monte Carlo test ($F = 4.8$, p = 0.248, and $F = 1.2$, $P = 0.262$ for the abundance data) at $P < 0.05$.

Table 4. One-way PerMANOVA test to test the difference in the fish assemblages among the truncated groups in Fig. 4c, and post-hoc test between each pair of the groups and their *P* values *p(MC)* of Monte Carlo test

a, Source	df	SS	MS	F	p	p(MC)
Truncated groups	2	74403	37201	29.78	0.001	0.001
Res	64	79948	1249.2			
Total	66	$1.5*10^5$				

b, Groups	t	p	p(MC)
S vs I	4.3262	0.001	0.001
S vs D	7.2105	0.001	0.001
I vs D	5.3592	0.001	0.001

Table 5. Contributor species, * within each season, determined from analyze of a similarity of percentages, SIMPER. (Avg. Sim.: Average similarity at each month, Avg. Abn: Average $\log_{10}$-abundance, Avg. Sim; average similarity, Sim/SD; correction term; Cum%; percent cumulative contribution of the similarities, and SD; standard deviation of the similarity)

S, 59.18	**Av.Abn**	**Av.Sim**	**Sim/SD**	**Cum%**
*Lithognathus mormyrus**	6.01	16.91	2.08	28.58
*Pagellus erythrinus**	6.54	16.69	2.29	56.78
Diplodus annularis	4.92	8.30	1.03	70.79
Pagrus caeruleostictus	3.75	8.04	0.98	84.39
Boops boops	3.76	5.97	0.87	94.48
I, 49.35				
*Pagellus erythrinus**	5.93	25.92	2.19	54.34
Boops boops	5.03	13.08	0.98	81.76
Nemipterus randalli	2.11	4.48	0.43	91.16
D, 55.85				
*Dentex maroccanus**	5.27	23.93	1.43	42.84
*Pagellus acarne**	4.70	18.10	1.28	75.24
Boops boops	4.04	13.66	0.84	99.69

Figure 5. Triplot of Canonical Correspondence Analyses (CCA) of the fishes' log₁₀-transfomed abundance (a, c), and biomass (b, d) with/without the nemipterid species, respectively at the trawls classified by the bottom depth with the environmental parameters and megafaunal abundance (e) (see Table A1 for the abbreviations of the fish species, and Table A2 for the environmental parameters, and the megafaunal species abbreviations)

The Generalized Additive Model (GAM) showed that abundance of *N. randalli* was negatively affected with that of *P. erythrinus* and *D. maroccanus*, and slight-positively by that of *L. mormyrus* based on abundance and log_{10}-transformed abundance (Fig. 6a, b). The biomass of *N. randalli* was influenced by different sparid species as compared with the abundance (Fig. 6). *N. randalli* was positively affected first by that of *P. caeruleostictus*, and negatively followed by *P. erythrinus*, *D. annularis* and *D. macrophthalmus* (Fig. 6a). The log_{10}-transformed biomass of *N. randalli* was, however, highly affected negatively with that of *D. maroccanus* (Fig. 6b). Therefore, the different predicted species suggested that catch (biomass) of *N. randalli* seemed to be relatively balanced with catch of small/middle-sized sparid species in numerous (such as *P. erythrinus* and *D. macrophthalmus*) or middle-sized sparid species in less numerous (such as *P. pagrus* for biomass/abundance of *N. randalli*, Fig. 6e, and *P. pagrus* and *L. mormyrus* for biomass of *N. randalli*) as compared to that of small-sized sparid species or *vice versa* along the seafloor depth gradient (Table 1, Fig. 6e).

As a consequence of all statistical evaluation, the nemipterid, *N. randalli* played crucial role as a barrier like a customs office in limiting the sparid fish distributions of the shallower and deeper shelf waters in space. The *N. randalli* which did not strongly influence the distribution of the shallowest- and deepest-shelf sparids (possitive effects on GAM) seemed to balance the sparid density (abundance and biomass) on the intermediate waters. Therefore, *N. randalli* controlled the distribution the sparid fish (negative effects on GAM) at the shallower and greater depths of locations which inhabited nearby *N. randalli*. Therefore, there was no significant correlation between the sparid and nemipterid fish excluding a correlation in low value with *P. erythrinus*, and unlike the GLM (Generalized Linear Model) the GAM which did not show linearity showed strong influence. Besides, the CCA showed low scores for *N. randalli* and *P. erythrinus* located around centre of the corresponding plot in correlation with the environmental variables.

Discussion

The sparid fish are of paramount importance for the ecosystem and commercial value in the Mediterranean Sea. Similar to the present study, the second most frequent family was the Sparidae represented by eight species (*B. boops*, *Dentex dentex*, *D. annularis*, *Diplodus vulgaris*, *P. acarne*, *P. erythrinus*, *P. pagrus* and *Spondyliosoma cantharus*) in the Balearic Islands (Cerdà et al. 2010) and the Egyptian waters (Akel, 2020). The 10 most dominant fish family was found to be sparid fish (*B. boops*, and *P. pagrus*) comprising 46% of the total biomass, and the second abundant family constituting of 31% of the total abundance in the waters of Rhodes Island (Kalogirou et al. 2010).

The nemipterid fish, *N. randalli* was common comprising of 8-30% of the total abundance in the eastern Mediterranean Sea, particularly east of the Levant Sea

(Keskin et al. 2011b; Yemişken et al. 2014; Özvarol 2016a; Gilaad et al. 2017; Ragheb et al. 2019; Akel 2020). The nemipterid species was overall determined in association with the sparid fish, especially *P. erythrinus*, and was related to their trophic linkage (Stern et al. 2014; Yemişken et al. 2014; Gilaad et al. 2017; Rijn et al. 2020; Taylan and Yapıcı 2021).

Spatiotemporal distribution

There were numerous NIS fish present in the lower shelf of the study area, but of the few NIS found at greater depth *N. randalli* inhabited a specific range of the bottom depth (de Meo et al. 2018). The spatiotemporal distribution of the fish varied among species depending on habitat-species heterogeneity during spawning and nursery (Lin et al. 2021). The sparid fish were unavoidable target species for small-scale fishery which was very effective for changing spatiotemporal distribution of the sparid fish (Tzanatos et al. 2005; Coll et al. 2007; Venturini et al. 2019).

Additionally, in the present study, the MPA, vegetated and unvegetated bottoms, and bottom types (hard and soft bottoms) changed fish spatiotemporal distribution similar to those reported by others (Arechavala–López et al. 2008; Seytre and Francour 2008; Giakoumi and Kokkoris 2013; Félix-Hackradt et al. 2018; Karachle et al. 2020).

Abundance and biomass

Abundance and biomass are important parameters to play a crucial role in the harmonization of their interaction in time and space. The density (abundance and biomass) did not show a seasonal difference, but showed regional and depth wise differences. Bottom depth and biological migration in space is one of the factors changing their spatiotemporal distribution as stated in some studies (e.g. Kallianiotis et al. 2000; Taylan and Yapıcı 2021).

Similar seasonal results were estimated previously in different regions of the Mediterranean Sea, particularly in Greek waters (Kalogirou et al. 2010, 2012). The sparid and nemipterid fish were inherently observed for peaks of their density specifically ascertained for seasons or months as reported in other studies conducted in the Mediterranean Sea. The density was maximized in different seasons depending on the habitats. In *P. oceanica* beds, abundance of *B. boops* which was composed mainly of small individuals in August increased from May through August-December to February. *P. pagrus* had a tendency with abundance increasing from February to August when smaller individuals predominated, followed by a decrease in December (Kalogirou et al. 2010). In the Egyptian Mediterranean waters (part of the Levant Sea), the nemipterid fish was among (8% in abundance and biomass peaked in spring) the abundantly caught fish species (Akel 2020). The nemipderid fish had a dominance value of 29% in the Turkish waters of the Levant Sea (Keskin et al. 2011b).
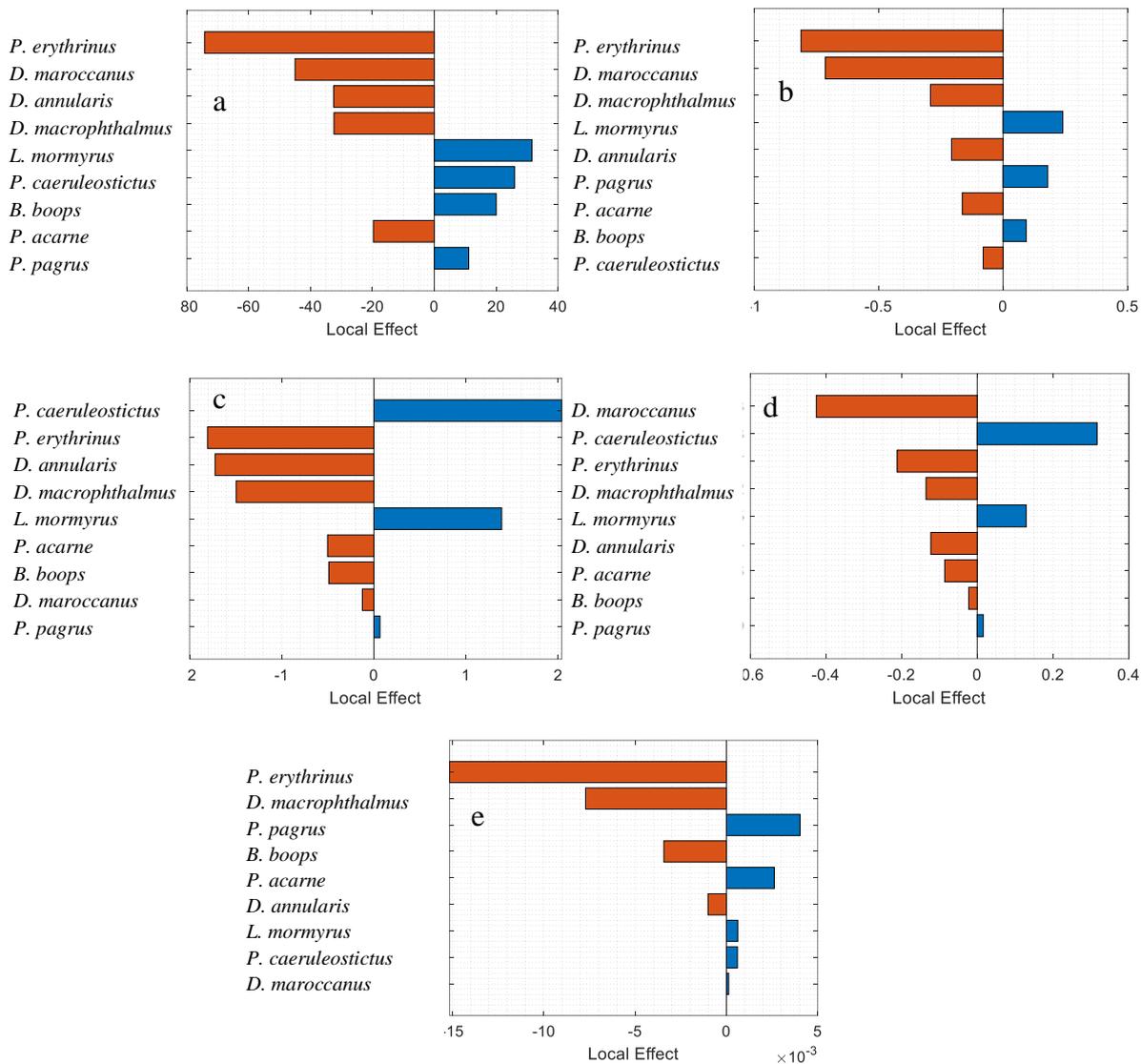
Figure 6. The GAM solution to estimate the effect of the predicted variables (dominant sparid fish) to the response variable (the nemipterid fish) for seasonally pooled data of the abundance (a) and log$_{10}$-trasnformed abundance (b), biomass (c) and log$_{10}$-trasnformed biomass (d), and biomass/abundance as a function of the fish size (e).

One of the factors changing their spatiotemporal distribution was the fishery considered for the present study area. Small scale fishery performed especially by fish nets and bottom longlines affected the large-sized sparid species, and the efficiency was very high in summer, and low in winter (Bousquet et al. 2022), and in Greek waters (Tzanatos et al. 2005). The present study area was influenced by small scale fishery year around and by the sportive fishery in the summer when domestic and foreign tourism was highly active. Large scale fishery conducted by the bottom trawls was low in the study area which was visited by around 16 trawl boats a year. The fishing was concentrated in the area between the two-mile border (25 m isobaths) and the isobaths of 200 m, and only in the fishing zone (Fig. 1). A specific fishing effort of 2.6 h/d/boat (a total of 9310 h) was performed during the fishing period. Monthly effort of the total boats varied

between 3.5 (December) - 5.8 (October) h/d and 119.7 (January) - 134.7 h/d (November) (Mutlu et al. 2022a), and was rather low as compared to the other Turkish marine regions (Gücü and Bingel 2022).

The MPAs affected the sparid distribution. The most representative family was Sparidae followed by Labridae, with 13 and 12 species respectively in MPA, but there were difference in the biomass between *P. oceanica* (low biomass) and rocky substrate (high biomass) (Tuya et al, 2014). Most of the sparid fish were classified as benthic-transient, but *Boops boops*, and *Diplodus annularis* as benthic-resident in the seagrass as occurred in the Gran Canary Islands (Tuya et al. 2014). In *P. oceanica* and rocky substrates as a function of MPA which affected occurrence and the density of the sparid species (Lizaso et al. 2000), *P. acarne* and *P. pagrus* were not observed

(Forcada et al. 2008). High abundance of the demersal fish having low biomass occurred in MPA areas because of dominance of small-sized fish (Félix-Hackradt et al. 2018). Sandy shorelines were abundantly dominated by sparids, mainly *Sparus aurata*, *L. mormyrus*, and *P. acarne* in the Ebro River delta (Gordoa 2009). As these species present different ecologies (Domanevskaya and Patokina 1984; Mariani et al. 2002; Pita et al. 2002) they may be descriptors of different types of soft bottoms. Such heterogeneity in the bottom types and specific area suggested better understanding their interaction and distribution in space and time. For instance, an overall significant decrease in total fish biomass and biomass were observed on *P. oceanica* and rocky substrates as MPA, but the distribution varied between size groups of the fish; biomass of larger size groups was higher in high than low protection area as contrasted to the smallest size groups (Arechavala–López et al. 2008). Nevertheless, fish biomass, abundance and species richness was low outside MPA, and inside MPA vegetated with *P. oceanica* (Seytre and Francour 2008). Faunistic characters had low values on sand, followed by seagrass compared to the rocks and boulders (Giakoumi and Kokkoris 2013). Their diet-substratum relation induced the spatiotemporal distribution in the northeastern Atlantic and Mediterranean (Hanel and Sturmbauer 2000).

Faunistic characteristics in the interaction

The faunistic characters of the sparid fish with and without the nemipterid fish, *N. randalli* which was recorded for the first time for the Turkish waters (Iskenderun Bay) in July 2007 (Bilecenoglu and Russell 2008), and for the Antalya Gulf in February 2008 (Gökoglu et al. 2009), were assessed depending on the factors as discussed for their densities. Seasonal faunistic characters of the porgies without *N. randalli* were highly unstable as compared to that with *N. randalli* across the seafloor depth. Alien species such as *N. randalli,* were claimed to stabilize local fisheries catch in a highly invaded ecosystem (Stern et al. 2014; Rijn et al. 2020). Alien species may be a valuable resource for marine fisheries, yet their contribution to the catch might be balanced by negative effects on indigenous species (Rijn et al. 2020). The time-series data captured the establishment of the relatively new arrival *N. randalli* (Stern et al. 2014) for which habitat selection and trophic properties were found to be very similar to those of the indigenous breams (Chessa et al. 2005; Gurlek et al. 2010). Catch per unit effort, CPUE of *N. randalli* increased rapidly, while other ecologically comparable species from the family Sparidae showed generally stable catches (Raitsos et al. 2010). This striking ability of alien Lessepsian species to rapidly increase in population size, even when being commercially exploited, might be related to their pre-adaptation to warm climate conditions such as those occurring in the eastern Mediterranean (Raitsos et al. 2010). Furthermore, tropical fish generally grow faster (Henderson, 2005), which may lead to a higher percentage of individuals reaching maturity (Shapiro et al. 2019) under the same fishing regime compared with species from a temperate origin

(Yemişken et al. 2014; Stern et al. 2014; Rijn et al. 2020; Taylan and Yapıcı 2021). Besides, total biomass, fish abundance and species richness was low outside MPA, and inside MPA vegetated with *P. oceanica* (Seytre and Francour 2008). Faunistic characters of the fish varied with the bottom types and substrata, the characters had low values on sand, followed by seagrass compared to the rocks and boulders, i.e. *B. boops* and *Diplodus* spp tended to occur in soft bottoms and seagrass (Giakoumi and Kokkoris 2013).

Community assemblage and ecology in the interaction

Life style and habitat of the sparid fishes were recognized depending on main food type in the Northeastern Atlantic and the Mediterranean (Hanel and Sturmbauer 2000). Porgies were ecologically distributed along the depth gradient similar to that in the northwestern Mediterranean shelf as follows; 12-47 m, 62-123/131 m, and 131-195/218 m. Of the sparid fish *D. annularis* and *P. erythrinus* only contributed to a total similarity only at the shallowest waters (Biagi et al. 2002). This distribution varied between data of abundance and biomass (de Meo et al. 2018), was specific to autoecology of the fish at family level (Mutlu et al. 2021; 2022a, b, c), and depended on zonal occurrence of their diets (Hanel and Sturmbauer 2000; Karachle and Stergiou 2008; Taylan and Yapıcı 2021).

In the present study, regular depth wise zonal distribution of porgies was well organized on the shelf as *N. randalli* was involved to the porgies community. *N. randalli* seemed to fill the gap of empty zonal niche occurred in the present study area. Such ordination could be attributed to mouth morphology specific to their diet between alien and indigenous fish, as reported in earlier studies (Linde et al. 2004; Gilaad et al. 2017; Rijn et al. 2020; Taylan and Yapıcı 2021). For instance, the aliens *Jaydia smithii* and the two natives *B. boops* and *Caranx rhonchus*, which feed mainly on amphipods, overlapped by 50–70%, and in another instance, the diets of three native sparids *P. erythrinus*, *L. mormyrus* and *P. caeruleostictus* and the alien *N. randalli*, overlapped by 40–60% (Stern et al. 2014; Gilaad et al. 2017; Rijn et al. 2020; Taylan and Yapıcı 2021), similar to the GAM solution estimated in the present study. Porgies congeneric species were related to mouth and oral morphometry and diet (Day 2002; Linde et al. 2004) as clustered for their abundance in the present study. The phylogeny supports multiple independent origins of trophic types and it is suggested that the evolutionary plasticity of the oral teeth of sparids has been fundamental to the adaptive radiation of this family compared to their closest allies including Nemipteridae (Day 2002).

As a function of trophic group, most of porgies and the nemipterid fish were categorized as omnivore with a preference for animal material, but *P. pagrus* and *P. bogaraveo* were carnivore with a preference for decapods and fish (Karachle and Stergiou 2017). Of the sparid fish, *P. pagrus*, *P. erythrinus* and *D. vulgaris* were assembled

on diet composition (main food was Polychaeta). Excluded *P. acarne* (crustaceans), the rest (fishes) of sparid fish were clustered together (Karachle and Stergiou 2008).

Furthermore, their diet-substratum relation induced the fish assemblage in Northeastern Atlantic and Mediterranean (Hanel and Sturmbauer 2000). *N. randalli* whose habitat selection and trophic properties were found to be very similar to those of the indigenous breams (Chessa et al. 2005; Gurlek et al. 2010; Raitsos et al. 2010) stabilized local fisheries catch in a highly invaded ecosystem (Stern et al. 2014; Rijn et al. 2020). The present study area included MPA (R3) and nonMPA (R1-R2) areas, and hard bottoms vegetated by *P. oceanica* (Fig. 1) and soft bottoms vegetated by *Caulerpa prolifera* and *Caulerpa taxifolia* var. *distichophylla* overspreading the coastal waters abundantly between regions of R4 and R2, extending to R3 (Mutlu et al. 2022d). Habitat structure can drive a large part of spatial variability in the distribution and abundance of organisms, either reinforcing or buffering the effects of management measures, especially when fishing effects are relatively slight or when species abundance is assessed at a small spatial scale (de Meo et al. 2018). The qualitative and quantitative faunistic characters were low outside MPA, and inside MPA vegetated with *P. oceanica* (Seytre and Francour 2008), and had low values on sand, followed by seagrass compared to the rocks and boulders, i.e. *B. boops* and *Diplodus* spp tended to occur in soft bottoms and seagrass (Giakoumi and Kokkoris 2013). Some sparid species were attracted by *Caulerpa taxifolia* in Ligurian waters (Relini et al. 2000).

Conclusion

The porgies were ecologically spanned by the alien nemipterid fish species in space. There were no seasonal significant differences in densities of the sparid fish with or without the alien nemipterid fish. However, the seasonal faunistic characters of porgies were highly variable without the alien. There were differences in the densities by the bottom depths, the regions, and soft and hard bottoms vegetated by *Caulerpa* spp and meadow, respectively. The nemipterid alien fish was strongly interacted with two porgies. Unlike sparid assemblages including alien nemipterid fish, depthwise sparid community was unassembled when excluding the alien. Ecologically, fish assemblages and faunistic characters of the sparid fish were highly variable when excluding the nemipterid fish as highlighted with the following main conclusions; seasonal variation occurred, the depthwise community assemblages were broken, the nemipterid fish seemed to balance the sparid catch attributed to the biomass-abundance equilibrium in the ecosystem of the food chain or vice versa as management in their fisheries in trophically sensitive gulf (ultra-oligotrophic) of the eastern Mediterranean Sea, and the alien seemed to stabilize catch of indigenous porgies.

Conflict of Interest

On behalf of all authors, the corresponding author states that there is no conflict of interest.

Author Contributions

Erhan Mutlu: Onboard works, Project administration, Supervision, Software, Data analyzes, Writing, Funding acquisition. Ilaria de Meo: Onboard works, Laboratorial works, Measurements, Data entry. Claudia Miglietta: Onboard works, Laboratorial works, Measurements, Data entry. Mehmet Cengiz Deval: Onboard works, Laboratorial works, Measurements, Data entry.

Ethics Approval

The authors declare that all applicable guidelines for sampling, care and experimental use of animals in the study have been followed in compliance with ethical standards approved by the Akdeniz University (Protocol no: 2013.12.03).

References

Akel ElSHKh (2020) Fisheries status of the trawlers by-catch from Alexandria, Egypt. Egyptian J Aquat Biol Fish 24(2):83–106. http://dx.doi.org/10.21608/ejabf.2020.78754

Araújo FG, de Azevedo MC, de Araújo SM, Pessanha ALM, Gomes ID, da Cruz-Filho AG (2002) Environmental influences on the demersal fish assemblages in the Sepetiba Bay, Brazil. Estuaries 25:441–450. http://dx.doi.org/10.1007/BF02695986

Arechavala–López P, Bayle–Sempere JT, Sánchez–Jerez P, Valle C, Forcada A, Fernández–Jover D, Ojeda–Martínez C, Vázquez–Luis M, Luna–Pérez B (2008) Biodiversity and structure of rocky reef fish assemblages in the Sierra Helada Natural Park (South–western Mediterranean Sea). Arxius de Miscel·lània Zoològica 6:232–254.

Biagi F, Sartor P, Ardizzone GD, Belcari P, Belluscio A, Serena F (2002) Analysis of demersal assemblages off Tuscany and Latium coasts (north-western Mediterranean). Sci Mar 66:233-242. http://dx.doi.org/10.3989/scimar.2002.66s2233

Bilecenoğlu M, Kaya M, Cihangir B, Çiçek E (2014) An updated checklist of the marine fishes of Turkey. Turk J Zool 38:901–929. http://dx.doi.org/10.3906/zoo-1405-60

Bilecenoglu M, Russell BC (2008) Record of *Nemipterus randalli* Russell, 1986 (Nemipteridae) from Iskenderun Bay, Turkey. Cybium 32(3):279-280.

Bousquet C, Bouet M, Patrissi M, Cesari F, Lanfranchi J-B, Susini S, Massey J-L, Aiello A, Culioli J-M, Marengo M, Lejeune P, Dijoux J, Duchaud C, Santoni M-C, Durieux EDH (2022) Assessment of catch composition, production and fishing effort of small-scale fisheries: The case study of Corsica Island (Mediterranean Sea). Ocean Coastal Manag 218:105998. http://dx.doi.org/10.1016/j.ocecoaman.2021.105998

Cerdà M, Alós J, Palmer M, Grau AM, Riera F (2010) Managing recreational fisheries through gear restrictions: The case of limiting hook size in the recreational fishery from the Balearic Islands (NW Mediterranean). Fish Res 101:146–155. http://dx.doi.org/10.1016/j.fishres.2009.09.016

Chessa LA, Lanera P, Pais A, Plastina N, Scardi M, Serra S, et al. (2005). Observations on feeding habitus of *Lithognathus mormyrus* (Linnaeus, 1758) in the Calich Lagoon (north western Sardinia). Biol Mar Medit 12(1):492–495.

Coll M, Piroddi C, Steenbeek J, Kaschner K, Ben Rais Lasram F, Nike Bianchi C, Corbera J, Dailianis T, Danovaro R, Estrada M, Froglia C, Galil BS, Gasol JM, Gertwagen R, Gil J, Guilhaumon F, Kesner-Reyes K, Kitsos MS, Koukouras A, Lampadariou N, Laxamana E, Lopez-Fe de la Cuadra CM, Lotze HK, Martin D, Mouillot D, Oro D, Raicevich S, Rius-Barile J, Saiz-Salinas JI, San Vicente C, Somot S, Templado J, Turon X, Vafidis D, Villanueva R, Voultsiadou E (2010) The biodiversity of the Mediterranean Sea: estimates, patterns, and threats. PLoS One 5(8):e11842. https://doi.org/10.1371/journal. pone.0011842.

Coll M, Santojanni A, Palomera I, Tudela S, Arneri E (2007) An ecological model of the Northern and Central Adriatic Sea: Analysis of ecosystem structure and fishing impacts. J Mar Syst 67:119–154. http://dx.doi.org/10.1016/j.jmarsys.2006.10.002

Cuttelod A, García N, Malak DA, Temple HJ, Katariya V (2009) The Mediterranean: a biodiversity hotspot under threat. Wildlife in a Changing World–an analysis of the 2008 IUCN Red List of Threatened Species 89:1-2.

Day JJ (2002) Phylogenetic relationships of the Sparidae (Teleostei: Percoidei) and implications for convergent trophic evolution. Biol J Linnean Soc 76:269-301. https://doi.org/10.1111/J.1095-8312.2002.TB02088.X

de Meo I, Miglietta C, Mutlu E, Deval MC, Balaban C, Olguner TM (2018) Ecological distribution of demersal fish species in space and time on the shelf of Antalya

Gulf, Turkey. Mar Biodiv 48:2105–2118. https://doi.org/10.1007/s12526-017-0739-7

Demestre M, Sanchez P, Abello P (2000) Demersal fish assemblages and habitat characteristics on the continental shelf and upper slope of the north-western Mediterranean. J Mar Biol Assoc UK 80:981–988. http://dx.doi.org/10.1017/S0025315400003040

Domanevskaya MV, Patokina FA (1984) Feeding of the large-eyed dogtooth, *Dentex macrophthalmus*, and Spanish bream, *Pagellus acarne*, from the central-Eastern Atlantic Ocean J Ichthyol 24(5):107-112.

Ergüden D, Gürlek M, Öztürk B, Turan C (2016) Alien species of the Turkish part of the Mediterranean, In Turan C, Salihoğlu B, Özbek EÖ, Öztürk B (Eds.). The Turkish Part of the Mediterranean Sea; Marine Biodiversity, Fisheries, Conservation and Governance. Turkish Marine Research Foundation (TUDAV), Publication No: 43, Istanbul, TURKEY. pp. 462-479.

Félix-Hackradt FC, Hackradt CW, Treviño-Otón J, Pérez-Ruzafa Á, García-Charton JA (2018) Effect of marine protected areas on distinct fish life-history stages. Mar Environ Res 140:200–209

Forcada A, Bayle-Sempere JT, Valle C, Sánchez-Jere P (2008) Habitat continuity effects on gradients of fish biomass across marine protected area boundaries. Mar Environ Res 66:536–547

Galil B (2007) Seeing Red: Alien species along the Mediterranean coast of Israel. Aquat Invasions 2(4):281-312. http://doi.org/10.3391/ai.2007.2.4.2

Galil BS, Goren M (2013) Metamorphoses: bioinvasions in the Mediterranean Sea. In: Goffredo S, Dubinsky Z (eds) The Mediterranean Sea: its history and present challenges. Springer, Dordrecht, pp 463–478

Garuti A, Mutlu E (2021) Spatiotemporal and ecological distribution of megistobentic non-crustacean invertebrates in an ultra-oligotrophic gulf, the eastern Mediterranean Sea. J Mar Sys 224:103644. https://doi.org/10.1016/j.jmarsys.2021.

Giakoumi S, Kokkoris GD (2013) Effects of habitat and substrate complexity on shallow sublittoral fish assemblages in the Cyclades Archipelago, North-eastern Mediterranean Sea. Medit Mar Sci 14/1:58-68. http://dx.doi.org/10.12681/mms.v0i0.318

Gilaad R-L., Galil BS, Diamant A, Goren M (2017) The diet of native and invasive fish species along the eastern Mediterranean coast (Osteichthyes). Zool Mid East 63(4):325–335. http://dx.doi.org/10.1080/09397140.2017.1375196

Gökoglu M, Güven O, Balci BA, Çolak H, Golani D (2009) First records of *Nemichthys scolopaceus* and *Nemipterus randalli* and second record of *Apterichthus caecus* from Antalya Bay, southern Turkey. Mar Biodiv Rec 2:e29. http://dx.doi.org/10.1017/S175526720800033X

Golani D, Sonin O (2006) The Japanese threadfin bream *Nemipterus japonicus*, a new Indo-Pacific fish in the Mediterranean. J Fish Biol 68(3):940-943. http://dx.doi.org/10.1111/j.0022-1112.2006.00961.x

Gordoa A (2009) Characterization of the infralittoral system along the north-east Spanish coast based on sport shore-based fishing tournament catches. Estuar Coast Shelf Sci 82:41–49. http://dx.doi.org/10.1016/j.ecss.2008.11.024

Gücü AC, Bingel F (2022) Identification of critical demersal fish habitats in the northeast Mediterranean - with an emphasis on *Mullus barbatus*. Acta Biol Turcica 35(3):A1:1-12.

Gurlek M, Erguden S, Yaglioglu D, Turan F, Demırhan SA, Gungor M et al. (2010) Feeding habits of Indo-Pacific species *Nemipterus randalli* Russel, 1986 (Nemipteridae) in Iskenderun Bay, Eastern Mediterranean Sea. Rapp Comm Int Mer Medit 39.

Hanel R, Sturmbauer C (2000) Multiple recurrent evolution of trophic types in Northeastern Atlantic and Mediterranean Sea breams (Sparidae, Percoidei). J Mol Evol 50:276–283. https://doi.org/10.1007/s002399910032

Henderson PA (2005) The growth of tropical fishes. Fish Physiol 21:85-100. https://doi.org/10.1016/S1546-5098(05)21003-8.

Kallianiotis A, Sophronidis K, Vidoris P, Tselepides A (2000) Demersal fish and megafaunal assemblages on the Cretan continental shelf and slope (NE Mediterranean): seasonal variation in species density, biomass and diversity. Prog Oceanogr 46:429–455. http://dx.doi.org/10.1016/S0079-6611(00)00028-8

Kalogirou S, Corsini-Foka M, Sioulas A, Wennhage H, Pihl L (2010) Diversity, structure and function of fish assemblages associated with *Posidonia oceanica* beds in an area of the eastern Mediterranean Sea and the role of non-indigenous species. J Fish Biol 77:2338–2357. http://dx.doi.org/10.1111/j.1095-8649.2010.02817.x

Kalogirou S, Wennhage H, Pihl L (2012) Non-indigenous species in Mediterranean fish assemblages: Contrasting feeding guilds of *Posidonia oceanica* meadows and sandy habitats. Estuar Coast Shelf Sci 96:209-218. https://doi.org/10.1016/J.ECSS.2011.11.008

Karachle PK, Dimarchopoulou D, Tsikliras AC (2020) Is shore-based recreational fishing in Greece an unregulated activity that increases catch uncertainty? Region Stud Mar Sci 36:101273. http://dx.doi.org/10.1016/j.rsma.2020.101273

Karachle PK, Stergiou KI (2017) An update on the feeding habits of fish in the Mediterranean Sea (2002-2015). Medit Mar Sci 18/1:43-52. http://dx.doi.org/http://dx.doi.org/10.12681/mms.1968

Karachle PK, Stergiou KI (2008) The effect of season and sex on trophic levels of marine fishes. J Fish Biol 72:1463–1487. http://dx.doi.org/10.1111/j.1095-8649.2008.01809.x,

Karachle PK, Stergiou KI (2011) Mouth allometry and feeding habits of some Mediterranean fishes. Acta Ichthyol Piscat 41(4):265–275. http://dx.doi.org/10.3750/AIP2011.41.4.02

Katsanevakis S, Maravelias CD, Damalas D, Karageorgis AP, Tsitsika EV, Anagnostou C, Papaconstantinou C (2009) Spatiotemporal distribution and habitat use of commercial demersal species in the eastern Mediterranean Sea. Fish Oceanogr 18:439–457. http://dx.doi.org/10.1111/j.1365-2419.2009.00523.x

Keskin Ç, Ordines F, Guijarro B, Massutí E (2011a) Comparison of fish assemblages between the Sea of Marmara and the Aegean Sea (north-eastern Mediterranean). J Mar Biol Assoc UK 91:1307–1318. http://dx.doi.org/10.1017/S0025315410002213

Keskin Ç, Turan C, Ergüden D (2011b) Distribution of the demersal fishes on the continental shelves of the Levantine and North Aegean Seas (eastern Mediterranean). TrJFAS 11:413-423. http://dx.doi.org/10.4194/trjfas.2011.0311

Lin Yu-J, Roa-Ureta RH, Pulikkoden ARK, Premlal P, Nazeer Z, Qurban MA, Rabaoui L (2021) Essential fish habitats of demersal fish in the western Arabian Gulf. Mar Pollut Bull 173:113013. http://dx.doi.org/10.1016/j.marpolbul.2021.113013

Linde M, Palmer M, Mez-Zurita JG (2004) Differential correlates of diet and phylogeny on the shape of the premaxilla and anterior tooth in sparid fishes (Perciformes: Sparidae). J Evol Biol 17:941–952. http://dx.doi.org/10.1111/j.1420-9101.2004.00763.x

Lizaso JLS, Goñi R, Reñones O, García CJA, Galzin R, Bayle JT, Jerez PS, Ruzafa AP, Ramos AA (2000) Density dependence in marine protected populations: a review. Environ Conserv 27(2):144–158. https://doi.org/10.1017/S0376892900000187

Mariani S, Maccaroni A, Massa F, Rampacci M, Tancioni L (2002) Lack of consistency between the trophic interrelationships of five sparid species in two adjacent central Mediterranean coastal lagoons. J Fish Biol 61:138-147. http://dx.doi.org/10.1006/jfbi.2002.2073

Mutlu E, Claudia M, de Meo I, Deval MC (2022b) Length-weight relationships of 107 osseous and 9 cartilaginous fish species on a shelf/break zone of the eastern Mediterranean Sea. Cah Biol Mar 63(1):19-27. http://dx.doi.org/10.21411/CBM.A.DEBDACF1

Mutlu E, de Meo I, Miglietta C (2021) Spatio-temporal distribution of pufferfish (Tetraodontidae) along the Turkish coast of the Mediterranean Sea. Mediter Mar Sci 22(1):1-19. http://dx.doi.org/10.12681/mms.23481

Mutlu E, Deval MC, de Meo I, Saygu İ, Miglietta C (2022a) Spatiotemporal density and ecology of Batoids (Elasmobranchii) along a Turkish shelf/upper slope of the Mediterranean Sea during years 2009–2015.

Thalassas: Int J Mar Sci 38:57–69. https://doi.org/10.1007/s41208-021-00391-4

Mutlu E, Deval MC, Miglietta C, Saygu I, de Meo I (2022c) Biometrical distribution of sharks in alow Elasmobranchs-diversified shelf, the eastern Mediterranean Sea. Acta Biol Turcica 35(2):A2:1-22.

Mutlu E, Olguner C, Gökoğlu M, Özvarol Y (2022d) Population dynamics and ecology of *Caulerpa prolifera* vs *Caulerpa taxifolia* var. *distichophylla* within a Levantine Gulf. Thalassas: Int J Mar Sci. 38:1311-1325. https://doi.org/10.1007/s41208-022-00477-7

Özvarol Y (2016a) Selectivity of Lessepsian fish, Randall's threadfin bream (*Nemipterus randalli* Russell, 1986) in the gulf of Antalya, eastern Mediterranean. Scientific Papers Series D Animal Science LIX:330-335.

Özvarol Y (2016b) Size selectivity of sorting grid for common Pandora (*Pagellus erythrinus* (Linnaeus, 1758)) in the gulf of Antalya, eastern Mediterranean. Scientific Papers Series D Animal Science LIX:336-341.

Patania A, Mutlu E (2021) Spatiotemporal and ecological distribution of megabenthic crustaceans on the shelf-shelf break of Antalya Gulf, the eastern Mediterranean Sea. Mediter Mar Sci 22(3):446-465. https://doi.org/10.12681/mms.26142.

Pauly D (1980) On the interactionships between natural mortality, growth parameters and mean environmental temperature in 175 fish stocks. Conseil Permanent International pour l'Exploration de la Mer 39(3), 175–192.

Pita C, Gamito S, Erzini K (2002) Feeding habits of the gilthead seabream (*Sparus aurata*) from the Ria Formosa (southern Portugal) as compared to the black seabream (*Spondyliosoma cantharus*) and the annular seabream (*Diplodus annularis*). J App Ichthyol 18(2):81-86. http://dx.doi.org/10.1046/j.1439-0426.2002.00336.x

Prista N, Vasconcelos RP, Costa MJ, Cabral H (2003) The demersal fish assemblage of the coastal area adjacent to the Tagus estuary (Portugal): relationships with environmental conditions. Oceanol Acta 26:525–536. http://dx.doi.org/10.1016/S0399-1784(03)00047-1

Ragheb E, Akel ElSHK, Rizkalla SI (2019) Analyses of the non-target catch from the Egyptian Mediterranean trawlers, off Port Said. Egyptian J Aquat Res 45:239–246. http://dx.doi.org/10.1016/j.ejar.2019.07.003

Raitsos DE, Beaugrand G, Georgopoulos D, Zenetos A, Pancucci-Papadopoulou AM, Theocharis A, Papathanassiou E (2010) Global climate change amplifies the entry of tropical species into the eastern Mediterranean Sea. Limnol Oceanogr 55(4):1478–1484. https://doi.org/10.4319/lo.2010.55.4.1478

Relini G, Relini M, Torchia G (2000) The role of fishing gear in the spreading of allochthonous species: the case of *Caulerpa taxifolia* in the Ligurian Sea. ICES J Mar Sci 57:1421–1427. https://doi.org/10.1006/jmsc.2000.0913.

Rijn Ivan, Kiflawi M, Belmaker J (2020) Alien species stabilize local fisheries catch in a highly invaded ecosystem. Can J Fish Aquat Sci 77:752–761. https://doi.org/10.1139/cjfas-2019-0065

Seytre C, Francour P (2008) Is the Cape Roux marine protected area (Saint-Raphaël, Mediterranean Sea) an efficient tool to sustain artisanal fisheries? First indications from visual censuses and trammel net sampling. Aquat Living Resour 21:297–305. http://dx.doi.org/10.1051/alr:2008043

Shapiro G, Rijn Dvan, Kiflawi IM, Belmaker J (2019) Decreases in length at maturation of Mediterranean fishes associated with higher sea temperatures. ICES J Mar Sci 76:946–959. https://doi.org/10.1093/icesjms/fsz011.

Sisma-Ventura G, Bialik OM, Yam R, Herut B, Silverman J (2017) pCO_2 variability in the surface waters of the ultra-oligotrophic Levantine Sea: Exploring the air–sea CO_2 fluxes in a fast warming region. Mar Chem 196:13-23. http://dx.doi.org/10.1016/j.marchem.2017.06.006

Soyer J (1970) Bionomie benthique du plateau continental de la côte catalane française Volume III - Les peuplements de Copepodes harpacticoides (Crustacea). Vie et Milieu 21(2B):337-551

Stern N, Levitt Y, Galil B, Diamant A, Yokeş M, Goren M (2014) Distribution and population structure of the alien Indo-Pacific Randall's threadfin bream *Nemipterus randalli* in the eastern Mediterranean Sea. J Fish Biol 85:394-406. http://dx.doi.org/10.1111/jfb.12421

Taylan B, Yapici S (2021) Reproductive biology of non-native *Nemipterus randalli* Russell, 1986 and native *Pagellus erythrinus* (Linnaeus, 1758) from the Aegean Sea. North-Western J Zool 17(2):180-186.

Tuya F, Haroun R, Espino F (2014) Economic assessment of ecosystem services: Monetary value of seagrass meadows for coastal fisheries. Ocean Coast Manag 96:181.187. http://dx.doi.org/10.1016/j.ocecoaman.2014.04.032

Tzanatos E, Dimitriou E, Katselis G, Georgiadis M, Koutsikopoulos C (2005) Composition, temporal dynamics and regional characteristics of small-scale fisheries in Greece. Fish Res 73:147–158. https://doi.org/10.1016/j.fishres.2004.12.006

Vasilakopoulos P, Raitsos DE, Tzanatos E, Maravelias CD (2017) Resilience and regime shifts in a marine biodiversity hotspot. Scientific Report 7:13647. http://doi.org/10.1038/s41598-017-13852-9

Venturini S, Merotto L, Campodonico P, Cappanera V, Fanciulli G, Cattaneo-Viet R (2019) Recreational fisheries within the Portofino MPA and surrounding

areas (Ligurian Sea, Western Mediterranean Sea). Medit Mar Sci 20/1:142-150. http://dx.doi.org/10.12681/mms.18043

Yemisken E, Dalyan C, Eryilmaz L (2014) Catch and discard fish species of trawl fisheries in the Iskenderun Bay(North-eastern Mediterranean) with emphasis on Lessepsian and chondricthyan species. Medit Mar Sci 15/2:380-389. http://dx.doi.org/10.12681/mms.538

Zenetos A, Gofas S, Verlaque M, Cinar ME, Garcia RJ, Bianchi C, Morri C, Azzurro E, Bilecenoglu M, Froglia C, Siokou I, Violanti D, Sfriso A, San Martin G, Giangrande A, Katanga T, Ballesteros E, Ramos-Espla A, Mastrototaro F, Ocana O, Zingone A, Gambi M, Streftaris N (2010) Alien species in the Mediterranean Sea by 2010. A contribution to the application of European Union's Marine Strategy Framework Directive (MSFD). Part I. Spatial distribution. Mediter Mar Sci 11(2):381. http://doi.org/10.12681/mms.8

Supplementary
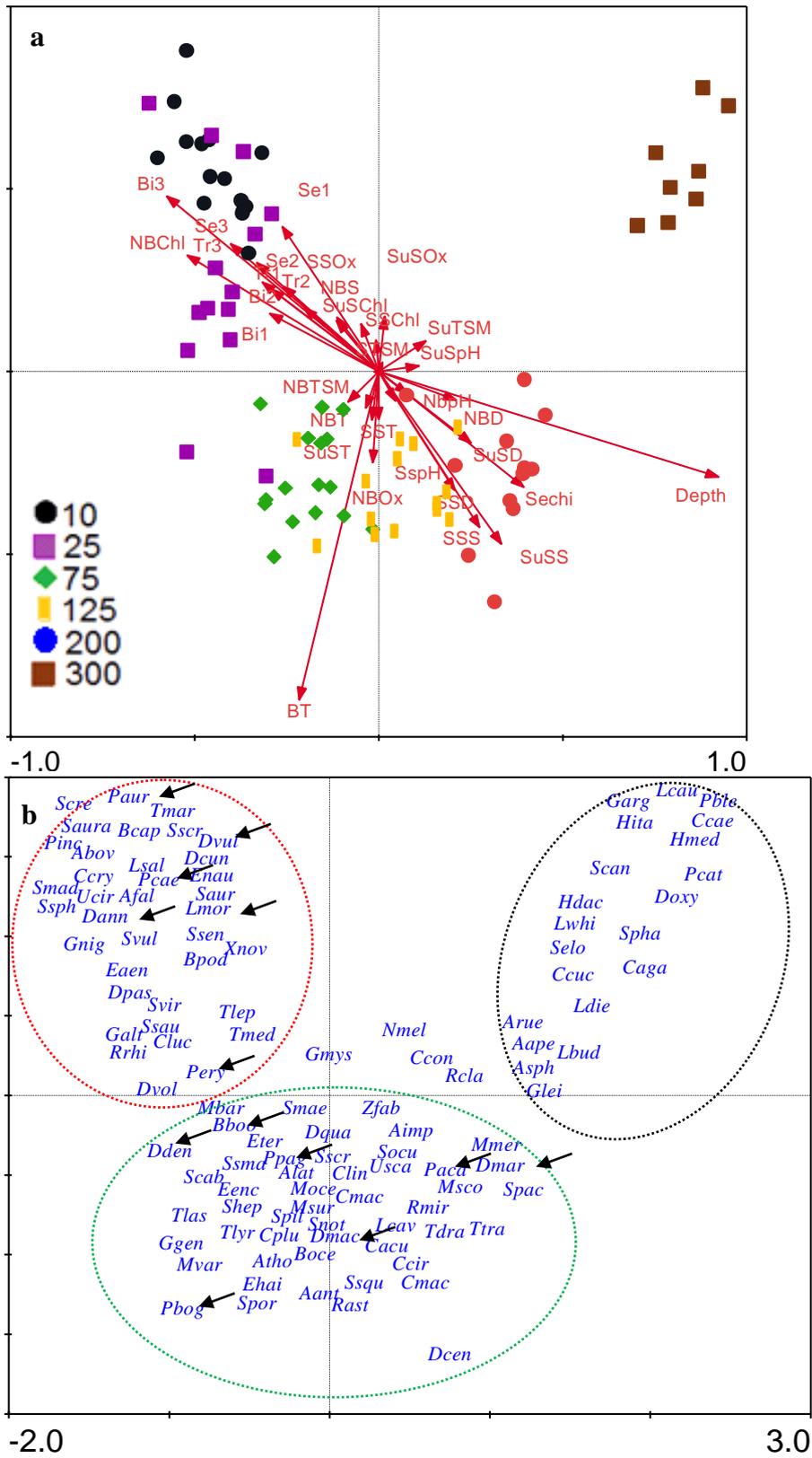
Fig A1. Biplot of Canonical Correspondence Analyses, CCA, for sample (symbols classified by the bottom depths in meters)-species-environmental variables (arrow) relation and scatter plot of the IS fish (a and b, respectively). Arrowed species denote porgies subjected among the IS fish species in the present study.
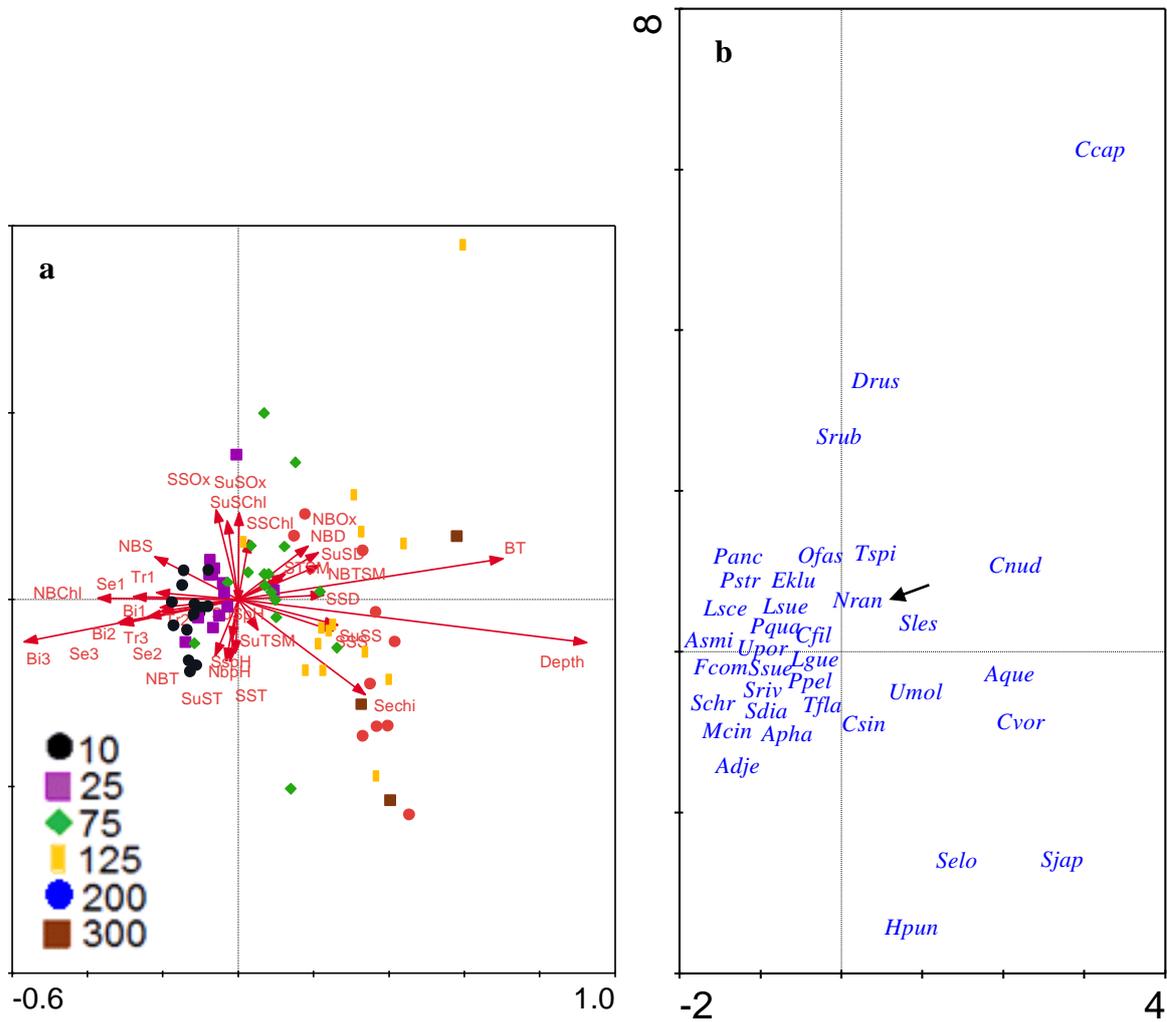
Fig A2. Biplot of Canonical Correspondence Analyses, CCA, for sample (symbols classified by the bottom depths in meters)-species-environmental variables (arrow) relation and scatter plot of the NIS fish (a and b, respectively). Arrowed species denote the fish species subjected among the NIS fish species in the present study.

Table A1. Indegeous fish species (IS) of Mediterranean Sea and non-indegenous species (NIS). Abb denotes abbreavation of fish species used in the statistrical analyses in Appendices 1, 2.

Species	Abb	Species	Abb	Species	Abb
Aetomylaeus bovinus	*Abov*	*Peristedion cataphractum*	*Pcat*	*Solea elongata*	*Selo*
Alosa fallax	*Afal*	*Phycis blennoides*	*Pble*	*Sphyraena chrysotaenia*	*Schr*
Anthias anthias	*Aant*	*Pomadasys incisus*	*Pinc*	*Stephanolepis diaspros*	*Sdia*
Argentina sphyraena	*Asph*	*Raja asterias*	*Rast*	*Torquigener flavimaculosus*	*Tfla*
Arnoglossus imperialis	*Aimp*	*Raja clavata*	*Rcla*	*Tylerius spinosissimus*	*Tspi*
Arnoglossus laterna	*Alat*	*Raja miraletus*	*Rmir*	*Upeneus moluccensis*	*Umol*
Arnoglossus rueppelii	*Arue*	*Rhinobatos rhinobatos*	*Rrhi*	*Upeneus pori*	*Upor*
Arnoglossus thori	*Atho*	*Sardina pilchardus*	*Spil*		
Balistes capriscus	*Bcap*	*Sardinella aurita*	*Saur*		
Blennius ocellaris	*Boce*	*Sardinella maderensis*	*Smad*		
Boops boops	*Bboo*	*Scorpaena elongata*	*Selo*		
Bothus podas	*Bpod*	*Scorpaena porcus*	*Spor*		
Callionymus maculatus	*Cmac*	*Scorpaena scrofa*	*Sscr*		
Capros aper	*Aape*	*Scorpana notata*	*Snot*		
Caranx crysos	*Ccry*	*Scyliorhinus canicula*	*Scan*		
Carapus acus	*Cacu*	*Serranus cabrilla*	*Scab*		
Carcharhinus plumbeus	*Cplu*	*Serranus hepatus*	*Shep*		
Centracanthus cirrus	*Ccir*	*Serranus scriba*	*Sscr*		
Cepola macrophtalma	*Cmac*	*Solea senegalensis*	*Ssen*		
Chelidonichthys cuculus	*Ccuc*	*Solea vulgaris*	*Svul*		
Chelidonichthys lucerna	*Cluc*	*Sparisoma cretense*	*Scre*		
Chlorophthalmus agassizi	*Caga*	*Sparus aurata*	*Saura*		
Citharus linguatula	*Clin*	*Sphoeroides pachygaster*	*Spac*		
Coelorinchus caelorhincus	*Ccae*	*Sphyraena sphyraena*	*Ssph*		
Conger conger	*Ccon*	*Sphyraena viridensis*	*Svir*		
Dactylopterus volitans	*Dvol*	*Spicara maena*	*Smae*		
Dasyatis centroura	*Dcen*	*Spicara smaris*	*Ssma*		
Dasyatis pastinaca	*Dpas*	*Squatina oculata*	*Socu*		
Deltentosteus quadrimaculatus	*Dqua*	*Squatina squatina*	*Ssqu*		
Dentex dentex	*Dden*	*Synchiropus phaeton*	*Spha*		
Dentex macrophthalmus	*Dmac*	*Synodus saurus*	*Ssau*		
Dentex maroccanus	*Dmar*	*Torpedo marmorata*	*Tmar*		
Dicologlossa cuneata	*Dcun*	*Trachinus draco*	*Tdra*		
Diplodus annularis	*Dann*	*Trachurus mediterraneus*	*Tmed*		
Diplodus vulgaris	*Dvul*	*Trachurus trachurus*	*Ttra*		
Dipturus oxyrinchus	*Doxy*	*Trichiurus lepturus*	*Tlep*		
Echeneis naucrates	*Enau*	*Trigla lyra*	*Tlyr*		
Engraulis encrasicolus	*Eenc*	*Trigloporus lastoviza*	*Tlas*		
Epinephelus aeneus	*Eaen*	*Umbrina cirrosa*	*Ucir*		
Epinephelus haifensis	*Ehai*	*Uranoscopus scaber*	*Usca*		
Etrumeus teres	*Eter*	*Xyrichthys novacula*	*Xnov*		
Gadiculus argenteus	*Garg*	*Zeus faber*	*Zfab*		
Glossanodon leioglossus	*Glei*	*Alepes djedaba*	*Adje*		
Gnathophis mystax	*Gmys*	*Apogonichthyoides pharaonis*	*Apha*		
Gobius geniporus	*Ggen*	*Callionymus filamentosus*	*Cfil*		
Gobius niger	*Gnig*	*Champsodon capensis*	*Ccap*		
Gymnura altavela	*Galt*	*Champsodon nudivittis*	*Cnud*		
Helicolenus dactylopterus	*Hdac*	*Champsodon vorax*	*Cvor*		
Hoplostethus mediterraneus	*Hmed*	*Cynoglossus sinusarabici*	*Csin*		
Hymenocephalus italicus	*Hita*	*Decapterus russelli*	*Drus*		
Lepidopus caudatus	*Lcau*	*Equulites klunzingeri*	*Eklu*		
Lepidorhombus whiffiagonis	*Lwhi*	*Fistularia commersonii*	*Fcom*		
Lepidotrigla cavillone	*Lcav*	*Herklotsichthys punctatus*	*Hpun*		
Lepidotrigla dieuzeidei	*Ldie*	*Jaydia queketti*	*Aque*		
Lithognathus mormyrus	*Lmor*	*Jaydia smithii*	*Asmi*		
Liza saliens	*Lsal*	*Lagocephalus guentheri*	*Lgue*		
Lophius budegassa	*Lbud*	*Lagocephalus sceleratus*	*Lsce*		
Macroramphosus scolopax	*Msco*	*Lagocephalus suezensis*	*Lsue*		
Merluccius merluccius	*Mmer*	*Muraenesox cinereus*	*Mcin*		
Microchirus ocellatus	*Moce*	*Nemipterus randalli*	*Nran*		
Microchirus variegatus	*Mvar*	*Ostorhinchus fasciatus*	*Ofas*		
Mullus barbatus	*Mbar*	*Pelates quadrilineatus*	*Pqua*		
Mullus surmuletus	*Msur*	*Petroscirtes ancylodon*	*Panc*		
Nettastoma melanurum	*Nmel*	*Pomadasys stridens*	*Pstr*		
Pagellus acarne	*Paca*	*Pteragogus trispilus*	*Ppel,*		
Pagellus erythrinus	*Pery*	*Sargocentron rubrum*	*Srub*		
Pagrus auriga	*Paur*	*Saurida lessepsianus*	*Sles*		
Pagrus bogaraveo	*Pbog*	*Scomber japonicus*	*Sjap*		
Pagrus caeruleostictus	*Pcae*	*Siganus rivulatus*	*Sriv*		
Pagrus pagrus	*Ppag*	*Sillago suezensis*	*Ssue*		

Table A2 Summary of statistical measures of the characteristics of fish species abundance and biomass in relation to the environmental variables for the CCA. Environmental parameters with the abbreviations used in statistical analyses (Prefixes for the abbreviations: SS, sea surface, Su; Sub-surface and NB; Near-bottom water) and summary of statistical measures of the characteristics of fish species biomass and abundance in relation to the megabenthic fauna (Mega) abundances (Garuti and Mutlu, 2021; Patania and Mutlu, 2021) for the CCA.

Environmental parameters	Variables abbreviated	Biomass CCA1	CCA2	Abundance CCA1	CCA2	Taxa	Mega	Abundance CCA1	CCA2
Bottom depth (m)	Depth	**0.8904**	0.0097	**0.8720**	-0.0410	Crustacea, Decapoda	Dec	-0.0402	-0.0161
Total Suspended Matter (g/m³)	STSM	0.0096	0.0887	0.0194	0.0420	Annelida	Ann	-0.0244	**-0.2004**
Total Suspended Matter (g/m³)	SuTSM	0.1007	-0.0168	0.0619	-0.0707	Cnidaria	Cni	-0.0679	**-0.2182**
Total Suspended Matter (g/m³)	NBTSM	-0.0003	-0.2535	-0.0224	-0.1231	Echinodermata, Asteroidea	Ast	0.1645	**-0.2761**
Secchi disk depth (m)	Sechi	0.5539	0.0014	**0.5352**	0.0938	Echinodermata, Crinoidea	Cri	-0.0014	**-0.2757**
Oxygen (mg/l)	SSOx	-0.2601	0.0176	-0.2322	-0.0188	Echinodermata, Echinoidea	Ech	0.1308	**-0.1716**
Oxygen (mg/l)	SuSOx	-0.1854	0.0155	-0.1580	-0.0085	Echinodermata, Holoturidea	Hol	**0.2422**	**0.1541**
Oxygen (mg/l)	NBOx	0.1810	-0.0068	0.1650	-0.0959	Echinodermata, Ophiuridea	Oph	**0.2613**	**-0.1821**
Temperature (°C)	SST	0.1638	-0.0366	0.1322	0.0019	Echiura	Ech	-0.0471	**-0.1757**
Temperature (°C)	SuST	0.1514	-0.0368	0.1210	-0.0008	Mollusca, Bivalvia	Biv	-0.0884	**-0.1698**
Temperature (°C)	NBT	0.1095	-0.0425	0.0806	-0.0042	Mollusca, Cephalopoda	Cep	**0.4422**	**0.2071**
Salinity (PSU)	SSS	0.4547	-0.1346	0.4282	-0.0452	Mollusca, Gastropoda	Gas	**-0.2301**	0.0891
Salinity (PSU)	SuSS	0.5152	-0.1915	**0.5076**	-0.1101	Porifera	Por	-0.1196	-0.0193
Salinity (PSU)	NBS	-0.2050	-0.1582	-0.2247	-0.1229	Sipunculida	Sip	-0.0854	**0.2078**
pH	SspH	0.1313	-0.0934	0.1273	-0.1289	Tunicata	Tun	0.0706	**-0.1379**
pH	SuSpH	0.1348	-0.0303	0.1283	-0.1669				
pH	NbpH	0.1613	-0.1238	0.1396	-0.1906				
Density, σ_t	SSD	0.3192	-0.1285	0.3137	-0.0560				
Density, σ_t	SuSD	0.2726	-0.1380	0.2739	-0.0870				
Density, σ_t	NBD	0.1852	-0.0239	0.1868	-0.0416				
Chl-*a* (mg/l)	SSChl	-0.1067	0.0571	-0.1146	0.1126				
Chl-*a* (mg/l)	SuSChl	-0.2411	0.0396	-0.2107	0.1241				
Chl-*a* (mg/l)	NBChl	-0.5584	0.0183	**-0.5437**	-0.0740				
Seston - 1 mm (g/m³)	Se1	-0.4277	0.1861	-0.4092	0.0927				
Seston – 0.5 mm (g/m³)	Se2	-0.3954	-0.0097	-0.3673	-0.0427				
Seston – 0.063 mm (g/m³)	Se3	-0.4247	**0.2568**	-0.4216	0.1269				
Bioseston - 1 mm (g/m³)	Bi1	-0.3461	0.0164	-0.3279	-0.0094				
Bioseston – 0.5 mm (g/m³)	Bi2	-0.3544	0.1262	-0.3285	-0.0267				
Bioseston – 0.063 mm (g/m³)	Bi3	**-0.6733**	0.2373	**-0.6474**	0.1101				
Tripton – 1 mm (g/m³)	Tr1	-0.2809	-0.0027	-0.3243	0.0109				
Tripton – 0.5 mm (g/m³)	Tr2	-0.2877	-0.0595	-0.2775	0.0172				
Tripton – 0.063 mm (g/m³)	Tr3	-0.3515	**0.2501**	-0.3545	0.1257				
Bottom types	BT	**0.6808**	**-0.2749**	**0.6430**	-0.1359				
Eigen values		0.562	0.209	0.504	0.177			0.191	0.101
Species-environment correlations		0.972	0.766	0.955	0.708			0.598	0.576
Cumulative percentage variance									
of species data		20.2	27.7	20.3	27.4			7.7	11.7
of species-environment relation		33.2	45.6	36.2	48.8			33.2	50.7