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Biological aspects of two coexisting indigenous and non-indigenous fish species in the Aegean Sea: *Pagellus erythrinus* vs. *Nemipterus randalli*

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Abstract

Nowadays, the Mediterranean is a hotspot of biodiversity, characterized by changes in fish communities due to invasions. These invasions, mainly occurring through the entrance of species through the Suez Canal, a process called Lessepsian migration, has been increasing in the last 40 years. It is reported that, in Turkish seas, where 512 fish species are found, are 75 Lessepsian species. However, knowledge about the impact of Lessepsian species on native species is insufficient. This study aims to determine the bio-ecological characteristics and food interactions of a native *Pagellus erythrinus* and non-native *Nemipterus randalli* distributed in the Gökova Bay.

In the monthly sampling survey, carried out between January 2016 and December 2016, 1698 *N. randalli* and 945 *P. erythrinus* individuals were collected. Length, weight, age, sex distributions and ratios, length-age, weight-age, length-weight relationships, condition factors, stomach contents and reproduction periods were examined to determine the interaction between species. According to results, the life span of *P. erythrinus* is longer than *N. randalli* in the Gökova Bay. Nevertheless, *N. randalli* grows faster than *P. erythrinus*. Reproduction periods of both two species show similarities. Food competition between species is found to be significantly high. Results of condition factors exhibit that *N. randalli* shows an increased ability to exploit the available food sources. *Pagellus erythrinus* displays strategies such as: early maturation, short reproduction period, reproduction in the deeper waters and batch spawning, to compete with *N. randalli.* With the invasive characteristics of *N. randalli* established a successful population in the Gökova Bay.

Keywords: Biodiversity; *Pagellus erythrinus*; *Nemipterus randalli;* Gökova Bay.

Introduction

Biological invasion is one of the most important issues in today's World. Introduction of alien species to new ecosystems is considered a major threat to ecosystem biodiversity, and services (Katsanevakis *et al.,* 2014). However, the biological invasion has caused not only ecological but also economic damages (Ünal & Göncüoğlu Bodur, 2017; Öndes *et al.,* 2018). With the Suez Canal being completed in 1869, the geographical barrier between the Mediterranean and the Red Sea has been eliminated and therefore, the Mediterranean Sea, considered as a hotspot of species richness and endemism (Bianchi & Morri, 2000; Coll *et al.,* 2010), is affected dramatically by Indo-Pacific species (Zenetos *et al.,* 2012). In the Aegean Sea, alien biota includes 775 alien species of which 105 are exotic fish species consisting of more than 65 species of Indo-Pacific origin (Zenetos *et al.,* 2012). Filiz *et al.,* (2017) stated 75 Lessepsian species along the Turkish coasts while 39 Indo-Pacific fishes are reported in the Hellenic Seas (Zenetos *et al.,* 2018).

The common pandora, *Pagellus erythrinus* (Linnaeus, 1758), which belongs to the family of Sparidae, is found throughout the Black Sea, the Mediterranean Sea and the eastern Atlantic from Norway to Angola (Froese & Pauly, 2017), being distributed mainly on rocky and muddy–sandy bottoms, from 20 and to 300 m depth (Metin *et al.,* 2011). The common pandora is a commercially important, especially in fisheries, and has been captured by various fishing gears (gill or trammel nets, longline, and trawl) in Turkey. The production amount of the common pandora is 980 t, which corresponds to 0.37 % of the quantity of caught sea fish in the Turkish Seas (Turkstat, 2016).

Another species, Randall's threadfin bream, *Nemipterus randalli* Russell, 1986, is naturally distributed in the western Indian Ocean, including the east and west coasts of India, the Persian Gulf, and the Red Sea south to Madagascar (Russell, 1990). It was previously misreported as *Nemipterus japonicus* by Golani & Sonin (2006) in the Mediterranean. After that, its presence, initiated in the Levantine Sea (Golani & Sonin, 2006), has been continued to increase until the northern Aegean coasts in Turkey (Gülşahin & Kara, 2013; Aydın & Akyol, 2017). Although *N. randalli* is reported from the different parts of Mediterranean (Lebanon, Syria, Israel), it was able to become one of the dominant components of the demersal ichthyofauna in only Israeli and Turkish coasts.

In natural range, *N. randalli* is a target species and overexploited by trawl fisheries (Dineshbabu *et al.,* 2011; Naomi *et al.,* 2011). Following its Mediterranean introduction via Suez Canal, it has established successful populations and become dominant species of catch composition in artisanal fishery from the Levantine to Aegean coast of Turkey (Ergüden *et al.,* 2010; Mavruk *et al.,* 2016; Gülşahin & Soykan, 2017). *N. randalli* sold as common pandora (*P. erythrinus*) at the local fish market after becoming dominant in catch composition of the artisanal fishery (pers. obv.). Even though its range has been expanding throughout the Mediterranean and the Aegean coasts of Turkey, no detailed information on its biology and effect on the native species in the Aegean Sea is known. The goal of the present study represents some biological aspects and interactions between two coexisting species, *P. erythrinus* and *N. randalli* in the Aegean Sea.

Material and Methods

Samples of *P. erythrinus* and *N. randalli* were collected monthly via trammel nets (20 mm streched mesh size) from the Gökova Bay (37.0021° N, 28.1339° E), at the depths of 35 and 40 m from January to December 2016. Collected specimens were carried to the laboratory on ice. For all specimens, total length (TL, cm) to the nearest 0.1 cm and wet weight (W, g) to the nearest 0.01 were measured and recorded. The sagittal otoliths of all samples were removed, cleaned and dissected with Buehler-Isomet 1000 precision cutter for age estimation. Otoliths were read twice by two different readers (blind reading). A stereo microscope with reflected light against a dark background was used during age determination.

Fish growth was estimated according to the von Bertalanffy growth equation (VBGE) using the iterated least square method (Beverton & Holt, 1957): $L_t = L_\infty (1\text{-}e^{-k(t\text{-}t0)})$, where, L_∞ is the asymptotic total length, L_t the total length at age t, k the growth curvature parameter and t_0 is the theoretical age that fish would have been at zero length (Sparre & Venema, 1992). The von Bertalanffy growth curves were fitted to combined data and each sex separately .

Growth performance index (ϕ) that allows comparing the growth rates of populations spreading in different areas was calculated by the following formula (Pauly & Munro, 1984): $\phi = \log_{10} k + 2 \log_{10} L_\infty$

The length-weight relationship was established using $W = aL^b$, that is an allometric model, where W is total body weight (g), L is total length (cm), and a and b are coefficients (Ricker, 1975; Froese, 2006). The growth type was tested by use of Student's t-test with values of $p <$ 0.05 considered significant.

Sex was assessed by the existence of ovaries or testes. The spawning period was established following the monthly variations of the gonadosomatic index (GSI) based on from the formula GSI = [GW / (W – GW)] x 100, where GW is the gonad weight (g), and W is the total weight (g) of fish (Ricker, 1975). Maturity stages were determined macroscopically based on morphology and color of gonads. The maturity scale for partial spawners includes five steps as follows: stage I, immature; stage II maturing virgin and recovering spent; stage III, ripening; stage IV, ripe; stage V, spent (Holden & Raitt, 1974). The significance of the between female and male ratio was determined by chi-square (χ^2) test. The parameters, length (L_{50}) and age (A_{50}) at first maturity, for each sex, were obtained by fitting logistic ogives to the proportion of sexually mature individuals by non-linear least squares analysis (King, 1995).

Changes in nutritional condition of species were determined by the condition factor (K). K was estimated using the equation proposed by Ricker (1975): K = (W / L^3) × 100 where W= total weight of fish (g), L= total length of fish.

Feeding habits were determined based on the morphological identification of preserved stomach contents in 4% formaldehyde solution. Prey in the stomach contents belonging to all specimens was identified to the lowest possible taxonomic level. Since there were no statistically significant differences between the stomach contents data obtained according to the seasons, the data of all stomach contents are presented as general feeding compositions.

Feeding state of each species was characterized using the vacuity index: %VI= number of empty stomachs/total number of stomachs × 100 (Bayhan *et al.,* 2017).

The fractional trophic level (TROPH) values were estimated using TrophLab and the Pauly *et al.* (2000) equation: where DC_{ij} is the weight contribution of prey item j to the diet of species i; $TROPH_j$ is the trophic level of prey item j and G is the number of prey species included in the stomach of i.

The main food items were identified using the Index of Relative Importance (*IRI*) of Pinkas *et al.* (1971): $IRI = \%F \times (\%N + \%W)$ where F is the frequency of occurrence, N is the abundance of a food component, and W is the weight of a food item in a species diet (Hyslop, 1980). The index was expressed as: $\%IRI = (IRI / \Sigma\, IRI) \times 100$. Prey species were sorted in decreasing order according to IRI and then cumulative %IRI was calculated. Food items were grouped into categories of preference using the method proposed by Gomes *et al.* (1998). The categories were defined as follows: main important prey (MIP): $IRI \geq 30 \times (0.15 \times \Sigma\%F)$, secondary prey: $30 \times (0.15 \times \Sigma\%F) > IRI > 10 \times (0.05 \times \Sigma\%F)$ occasional prey (OP): $IRI \leq 10 \times (0.05 \times \Sigma\%F)$.

Diet overlap between fish species was determined by Schoener's index S (Schoener, 1974):

$$S = 100 \times [1 - 0{,}5\ (\sum_{i=1}^{n} |P_{xi} - P_{yi}|\,)]$$

Where P_{xi} and P_{yi} are the proportions (percent IRI) of food category 'i' in the diet of species x and y; n = the number of food categories. The values that S can range from 0 to 1 according to feed utilization from completely different or the same food resources. Diet overlap percentage higher than %60 could be considered biologically significant (Wallace, 1981; Wallace & Ramsey, 1983; Zaret & Rand, 1971).

Results

During the samplings conducted monthly between January 2016 and December 2016 in the Gökova Bay, 1698 *N. randalli* specimens and 945 *P. erythrinus* specimens were collected. Total length distribution was 6.9-23.0 cm for *N. randalli* (mean ± SD = 16.01 ± 2.35 cm) and 5.9-30.2 cm for *P. erythrinus* (mean ± SD = 17.56 ± 4.34 cm), while the weight distribution was 4.42-162.13 g for *N. randalli* (mean ± SD = 60.09 ± 26.05 g) and 3.03-368.35 g for *P. erythrinus* (mean ± SD = 77.68 ± 57.58 g).

Age determinations based on the sectioned otoliths, the maximum age was found to be 6 (six) for *N. randalli* and 8 (eight) for *P. erythrinus*. Age group ratio of population was found to be 0 (zero) (2%), 1 (one) (22.85%), 2 (two) (44.64%), 3 (three) (20.26%), 4 (four) (7.07%), 5 (five) (2.83%) and 6 (six) (0.35%) for *N. randalli*, and 0 (zero) (2.22%), I (one) (10.48%), 2 (two) (38.94%), 3 (three) (14.71%), 4 (four) (24.23%), 5 (five) (3.60%), 6 (six) (2.22%), 7 (seven) (1.9%) and 8 (eight) (1.69%) for *P. erythrinus*. According to the results, age 2 (two) group was the most dominant age group in the population for both species.

The estimated von Bertalanffy growth parameters and the growth performance index (ϕ**)** for each species were calculated and shown in Table 1.

The length-weight relationship parameters of *N. randalli* and *P. erythrinus* collected from the Gökova Bay are given in Tables 2 and 3, respectively. Based on the obtained length-weight data, the regression coefficient or *b* (slope of the line) value was calculated to show that the growth type of the individuals was isometric or allometric (Froese, 2006). *b* values were lower for males (3.01) and juveniles (3.08) and significantly different ($p < 0.05$) than those of females (3.12) in *N. randalli*. Similarly, in *P. erythrinus,* *b* values were lower for males (2.91) and juveniles (2.04) and significantly different ($p < 0.05$) than those of females (2.97). The high R^2 value for both species indicates a strong relationship between length and weight.

According to the results of dissection of collected individuals, it was determined that the number of female individuals belonging to both species were higher than those of the male individuals. Female: male ratio for *N. randalli* was 1:0.78 (χ^2= 145.505, $p < 0.05$), and 1: 0.43 for *P. erythrinus* (χ^2= 21.851, $p < 0.05$). The majority of females in *P. erythrinus* population is clearly associated with protogynous hermaphroditism.

By analyzing the GSI, it was found that female *N. randalli* and *P. erythrinus* individuals reproduced between April and October (Fig. 1). The first sexual maturity length and age values of both species were calculated according to the related formulas, and the results are given in Table 4.

Table 1. von Bertalanffy growth parameters of *N. randalli* and *P.erythrinus*.

			Growth parameters			
Species	**Sex**	**N**	**L_∞ (cm)**	***k***	**t_0**	**ϕ**
N. randalli	Total	1698	26.00	0.238	-1.89	2.21
	Female	940	23.39	0.290	-1.92	2.20
	Male	732	28.17	0.192	-2.26	2.18
P. erythrinus	Total	945	38.29	0.148	-1.42	2.34
	Female	650	35.41	0.170	-1.32	2.33
	Male	278	40.01	0.135	-1.54	2.34

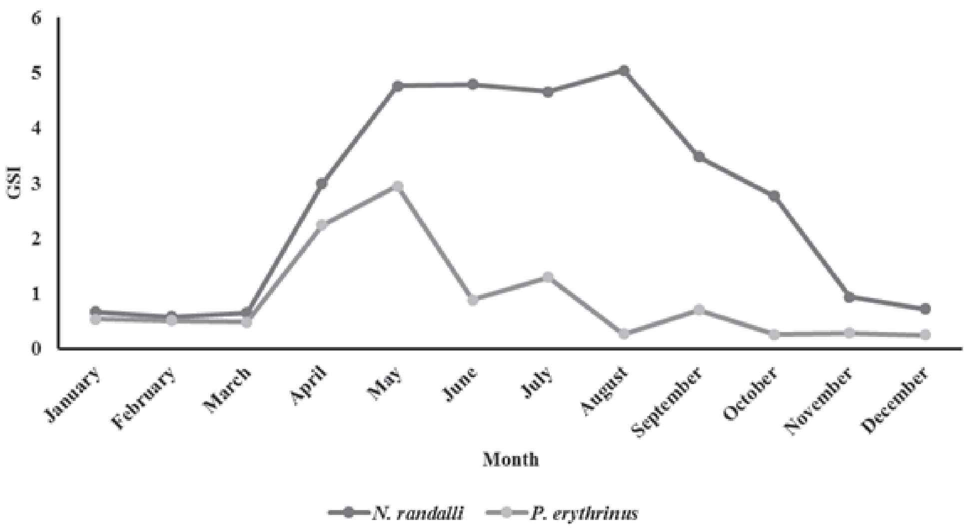

Fig. 1: Monthly change in the gonadosomatic index (GSI) for *N. randalli* and *P. erythrinus*

Table 2. Length-weight relationships of *N. randalli.*

Sex	N	L_{min}-L_{max} (cm)	W_{min}-W_{max} (g)	*W=a**L^b				
				a	*b*	R^2	%95 CI (*b*)	Growth type
Total	1698	6.9-23.0	4.42-162.13	0.0120	3.05	0.98	3.02-3.08	A(+)
Female	940	8.4-21.0	7.77-142.35	0.0099	3.12	0.97	3.07-3.18	A(+)
Male	732	10.6-23.0	13.95-162.13	0.0130	3.01	0.97	2.96-3.06	I
Juvenile	26	6.9-9.0	4.42-10.21	0.0113	3.08	0.92	2.48-3.68	I

Table 3. Length-weight relationships of *P. erythrinus.*

Sex	N	L_{min}-L_{max} (cm)	W_{min}-W_{max} (g)	*W=a**L^b				
				a	*b*	R^2	%95 CI (*b*)	Growth type
Total	945	5.9-30.2	3.03-368.35	0.0137	2.96	0.98	2.93-2.98	A(-)
Female	650	8.4-28.4	6.99-283.00	0.0134	2.97	0.97	2.93-3.00	I
Male	278	8.7-30.2	7.56-368.35	0.0130	2.91	0.98	2.85-2.96	A(-)
Juvenile	17	5.9-11.0	3.03-11.00	0.0887	2.04	0.80	1.45-2.62	A(-)

During the study period, a total of 300 stomachs of the *N. randalli* and 240 stomachs of the *P. erythrinus* were examined, and it was found that 254 and 181 stomachs of that total number were full for *N. randalli* and *P. erythrinus* respectively. Vacuity index (VI) was estimated as lower for females (11.3%) and clearly different than those of males (27.8%) in *N. randalli*. Likewise, VI was lower for females (22.3%) and highly different than those of males 48.4%) in *P. erythrinus*. Following the examination of the contents of full stomachs, it was determined that *N. randalli* feed on Crustacea and Teleostei species as the main important prey and Polychaeta and Mollusca species as the occasional prey (Table 5), while *P. erythrinus* consumed *G. rhomboides* (Crustacea) as the main important prey and Mysida, Stomatopods and *Dentalium* sp. as the occasional prey (Table 6).

The Schoener's diet-overlap (1974) conducted to determine the food competition was found to be 80%, indicating a strong overlap in the feeding habits of the two species. Trophic level was estimated as 3.76±0.61 for *N. randalli* and as 3.39±0.52 for *P. erythrinus*.

Age-related condition factor values of *N. randalli* and *P. erythrinus* were compared in Table 7. According to results, it was seen that the values of *N. randalli* for each age group were higher than those of *P. erythrinus* and condition factor decreases after 3 years old.

Table 4. First maturity length and age of *N. randalli* and *P. erythrinus.*

Sex	*N. randalli*		*P. erythrinus*	
	L_{50} (cm)	A_{50} (year^{-1})	L_{50} (cm)	A_{50} (year^{-1})
Female	12.86	1.4	11.90	1.3
Male	15.35	2.2	14.52	2.2

Table 5. Diet composition of *N. randalli.*

Species or higher taxa	%N	%W	%F	%IRI
POLYCHAETA	**3.41**	**0.86**	**6.52**	**0.59**
CRUSTACEA	**80.11**	**81.70**	**110.88**	**83.33**
Copepoda	2.27	0.07	2.17	0.11
Mysida	2.27	0.39	4.35	0.24
Alpheus sp.	15.34	19.52	25.00	18.33
Bathynectes sp.	3.98	4.96	7.61	1.43
Goneplax rhomboides	9.66	19.93	15.22	9.47
Stomatopoda	2.27	0.48	4.35	0.25
Brachyura	9.66	10.47	15.22	6.44
Processa sp.	34.66	25.88	36.96	47.06
MOLLUSCA	**2.84**	**0.88**	**5.44**	**0.19**
Bivalvia	0.57	0.22	1.09	0.02
Gastropoda	1.70	0.64	3.26	0.16
Dentalium sp.	0.57	0.02	1.09	0.01
TELEOSTEI	**13.64**	**16.58**	**25.00**	**15.89**

Discussion

Today, biodiversity conservation studies in aquatic ecosystems carried out by monitoring, planning, management and inspection based on scientific infrastructure are of vital importance. This is possible by examining the biological properties of the alien species entering the ecosystem and their interaction with the indigenous species.

Gökova Bay is a region rich in biodiversity due to being a transition between the Aegean Sea and the Mediterranean Sea. For the last 20 years, the Gökova Bay has become the hotspot for the organisms that introduced the Mediterranean Sea, called the Lessepsian species (Çoker & Akyol, 2014). Although some of the species in the region appear to contribute to commercial fishing

Table 6. Diet composition of *P. erythrinus.*

Species or higher taxa	%N	%W	%F	%IRI
POLYCHAETA	**13.16**	**3.22**	**22.00**	**10.68**
CRUSTACEA	**40.79**	**77.30**	**90.00**	**56.40**
Mysida	2,63	0.53	8.00	0.75
Alpheus sp.	6,58	21.29	12.00	9.91
Bathynectes sp.	3,29	5.99	10.00	2.75
Goneplax rhomboides	12,50	29.51	18.00	22.42
Stomatopoda	1,32	0.80	2.00	0.13
Brachyura	9,21	9.65	24.00	13.42
Processa sp.	5,26	9.53	16.00	7.02
MOLLUSCA	**41.44**	**4.91**	**42.00**	**24.97**
Bivalvia	19,08	2.53	26.00	16.66
Gastropoda	20,39	2.26	12.00	8.06
Dentalium sp.	1,97	0.12	4.00	0.25
TELEOSTEI	**4.61**	**14.55**	**14.00**	**7.95**

in economic terms, it is likely that they may prompt to ecological losses. Because, in the ecosystem services of the study area, significant changes may occur due to biotic factors (prey-predator relationships, food competition, etc.) that occur between the Lessepsian species entering the Mediterranean and the indigenous fish species (Ateş *et al.,* 2017; Gülşahin & Soykan, 2017). Most of the studies conducted on invasive species in the region has been limited to the reports on the "first record" or checklist. Although such reports include valuable findings concerning the" detection of the non-indigenous species," which is the first step of the invasion processes, there is a need for regular data on invasion and competition to fully monitor the change in the ecosystem. In the literature, it has been seen that *N. randalli* quickly expanded its distribution area although it has recently entered the Mediterranean (Gülşahin & Kara, 2013, Stern *et al.,* 2014). Even so, there are limited studies on the biology of the this species in the Mediterranean (Ergüden *et al.,* 2010; İnnal *et al.,* 2015; Uyan, 2017). The present study aims towards setting baselines for monitoring and assessing the effects that *N. randalli*, an invasive species that increase its distribution area and population densities in the Turkish coasts, will have on an indigenous fish species as there are no comparative studies on *N. randalli* and *P. erythrinus* found in the literature.

In the Gökova Bay, *N. randalli* was found to reach until age 6 (six) while *P. erythrinus* reach until age 8 (eight). As a known, invasive species tend to have a shorter life span than indigenous species (Karachle *et al.,* 2018). In the collected samples, it was seen that the individuals belonging to the early age groups (ages 1 and 2) were in the majority for both species. In fish populations, the number of individuals in the younger age groups and the low number of individuals in the older age groups indicate excessive overfishing or predation (Bennett, 1970). On the other hand, it is stated that the majority of invasive fishes in the Mediterranean have short life spans (Karachle *et al.,* 2018). Considering that *N. randalli* was reported from the study area in 2013, it is expected that the population of this species is represented by young individuals, though, in the population, individuals aged 5 (five) and 6 (six) were also determined. This shows that invasive species such as *N. randalli* remains unnoticed (hidden/quiet invader) in the areas that they recently entered for years and, following the adaptation period (lag phase), can become a dense population that has a sudden effect (Tarkan, 2013; Azzurro *et al.,* 2016). It is known that there is a positive relationship between body size and distribution depth in *P. erythrinus* (Somarakis & Machias, 2001). Although the sampling depth in the study was limited to 30-40 m, large individuals were not adequately found. Even so, it should not be forgotten that variation in the length, maximum age, and longevity of collected individuals may be influenced by, especially, gear selectivity, sampling depth, and sea bottom characteristics. Despite the possibilities which may affect the size distributions aforementioned, it was thought that overfishing has a negative effect on older age groups in *P. erythrinus* population because it is one of the target species for the small scale fisheries in the region.

Table 7. Comparison of length, weight and condition factor per age groups of *N. randalli* and *P. erythrinus.*

	Total Length (cm)				Weight (g)		Condition factor	
	N. randalli		*P. erythrinus*		*N. randalli*	*P. erythrinus*	*N. randalli*	*P. erythrinus*
Age	**N**	**Mean±S.D.**	**N**	**Mean±S.D.**	**Mean±S.D.**	**Mean±S.D.**	**Mean±S.D.**	**Mean±S.D.**
0	34	8.52±0.59	21	8.46±0.92	8.15±1.51	7.73±1.86	1.31±0.09	1.20±0.21
I	388	13.05±1.01	99	11.66±0.91	34.51±7.07	20.14±4.77	1.37±0.09	1.26±0.18
II	758	15.86±0.65	368	15.27±1.39	54.90±7.92	44.42±13.03	1.37±0.10	1.22±0.16
III	344	17.73±0.65	139	18.19±0.59	78.39±11.20	73.97±10.90	1.40±0.12	1.23±0.13
IV	120	19.7±0.66	229	20.96±1.37	105.36±12.72	113.21±26.35	1.38±0.11	1.21±0.11
V	48	21.19±0.54	34	24.07±0.87	132.09±14.32	168.59±23.60	1.39±0.15	1.20±0.10
VI	6	22.33±1.15	21	25.89±0.43	138.27±20.10	205.85±15.86	1.24±0.04	1.19±0.10
VII		-	18	27.19±0.91	-	235.16±29.99	-	1.18±0.09
VIII		-	16	28.81±0.94	-	275.78±36.08	-	1.14±0.10

The effect of overfishing on *P. erythrinus* might be more devastating than thought. Overfishing could impair sex transformation in the stock of the hermaphrodite species and so the sustainability of reproduction and population may collapse.

Based on age-related growth data of *N. randalli* and *P. erythrinus*, it was seen that in growth in the age groups 0 (zero), 1 (one) and 2 (two), *N. randalli* have higher length values whereas *P. erythrinus* individuals reach higher length values at the further age groups (Table 7). It is known that some economically important invasive fish species have large body size in the environment that they entered compared to indigenous species (Polat *et al.,* 2011). In the present study, it was found that the average weight values in *N. randalli* between ages 0 (zero) and 4 (four) age were higher than those of *P. erythrinus* individuals (Table 7).

The sex ratio of both species was biased towards females, however, explicitly was more for *P. erythrinus*. The most important reason for these differences was that *P. erythrinus* is a protogenic hermaphroditic species. The expected situation in the stocks of the protogenic hermaphroditic species, which is defined as the species that have the ability of transformation of a female-first individual to male, is that of a small male and large male individuals. Unlike this situation, in the present study, small male (8.7 cm) and large female (28.4 cm) individuals occurred. This is an indication that the sex-change in the *P. erythrinus* does not occur in all length groups. Also, it can be argued that since the large females in the population indicate higher fecundity, *P. erythrinus* waives sex transformation in the population due to the reproduction competition with *N. randalli*. In the present study, it was found out that *P. erythrinus* reduced the growth performance to increase the reproductive effort to compete with *N. randalli*.

Based on GSI results, it was observed that female *N. randalli* and *P. erythrinus* reproduce between April and October. Furthermore, both species are partial spawners (Fig. 1). The findings for the spawning strategies of species found in the present study have also been reported in other studies (Murty, 1981; Hossucu & Turker Cakir, 2003). Partial spawning is a strategy applied to increase recruitment success under unsuitable environmental conditions. This strategy is also used by invasive fish species to increase settlement success in the new environment. Although there is found the difference in GSI values between male and female of both species, the monthly oscillations in GSI values show similarities for both sexes. Therefore, it may be the clue that *N. randalli* and *P. erythrinus* are group spawners. In group spawners, large amounts of sperm enable advantages for successfully fertilizing eggs and broadcast spawning which groups of fish congregate together with the potential for sperm from one male to fertilize the eggs of many females and the eggs from one female to be fertilized by many males (Karleskint *et al.,* 2010). The overlap of the reproduction periods of both species will bring competition to the reproduction areas. Considering the number of individuals obtained at the time of reproduction, it was determined that the individuals of *N. randalli* were more *than P. erythrinus*. To increase the reproductive success of *P. erythrinus*, it was thought that *N. randalli* spawns eggs at narrower time intervals and deeper waters.

According to first maturity length and age values, male and female individuals of *N. randalli* had total lengths of 12.86 cm and 15.35 cm, respectively, and reached sexual maturity at ages 1 (1.4) and 2 (2.2). For male and female *P. erythrinus* individuals, these values were 11.90 cm and 14.52 cm, respectively and it was seen that the species reached sexual maturity at ages 1 (1.3) and 2 (2.2). It is known that invasive species tend to become dominant in the environment by reaching sexual maturity in the early stages of their lives (Rilov, 2009). According to the findings obtained in the present study, *P. erythrinus* individuals reached sexual maturity at early length values and ages for competing with *N. randalli*. However, reaching sexual maturity in early life stages especially in indigenous species is not always resulted in success on competition against non-indigenous species. Larval recruitment will be delayed in that the survival rate of the eggs spawned by young individuals is lower than the eggs left by individuals in older age groups. Consequently, the recuitment of *P. erythrinus* should be monitored in the study area.

As a result of the vacuity index (VI), in both species, the VI of females was lower than that of males. These results are related to females of both species that are partial spawner. Females of *N. randalli* and *P. erythrinus* have a higher feeding intensity than males, as they need to consume more energy for the maturation of their gonads all the year round. Following the examination of the stomach contents, it was found that *N. randalli* and *P. erythrinus* species mostly feed on benthic organisms. The most important prey group was *Processa* sp. (Crustacea) for *N. randalli* and *G. rhomboides* (Crustacea) for *P. erythrinus*. Gilaad *et al.* (2017) have reported that *N. randalli* species mostly feed on benthic decapods and fish. Gürlek *et al.* (2010) have reported that *N. randalli* species may have a negative effect on the Crustacea fauna in the Mediterranean Sea since it mostly feeds on benthic decapods. The stomach contents of *P. erythrinus* obtained in the present study and the results of the studies on the feeding of the species in the Mediterranean Sea show similarities (Stergiou & Karpouzi, 2002; Karachle & Stergiou, 2017). As a result, the findings obtained in the present study and the findings obtained in the studies on the feeding biology of the species show compatibility.

The Schoener's diet-overlap (niche overlap) index value of the obtained to determine the food competition was found to be %80. This indicates that there is a high rate of food competition between the two species. Gilaad *et al.* (2017) found that the stomach contents of *N. randalli* included individuals belonging to genus *Pagellus*. Based on the results of the study by Gilaad *et al.* (2017) and the present study, it was seen that *N. randalli* prefer to feed the teleosts at a high rate. In the present study, although the species determination could not be performed to the high digestibility of fish species in the stomach, it was found that *N. randalli* prefers the teleosts as well as

Table 8. Comparison of condition factor values of *P. erythrinus* in different areas (allopatry/sympatry).

References	Location	Sex		
		Female+Male	Female	Male
Vassilopoulou *et al.* (1986)	Saronikos Gulf	1.936	-	-
	Ionian Sea	1.875	-	-
Özaydın (1997)	Aegean Sea	1.822	1.807	1.836
Can (2000)	Iskenderun Bay	1.373	1.370	1.385
Hossucu & Turker Cakir (2003)	Edremit Bay	1.82	1.79	1.84
This study	Gökova Bay	1.224	1.235	1.213

decapod crustaceans. In addition, according to results of calculated trophic level in this study, *N. randalli* (TROPH 3.76±0.61) was classified as carnivores with a preference for decapods and fish (3.7<TROPH<4.0). These results may prove the possibility of *N. randalli* to prey on *P. erythrinus* individuals in the Gökova Bay. Successful invasive predators that are more specialists, as *N. randalli*, in their diet are expected to have stronger direct effects on a single or a few species and possible wider indirect effects. Given the fact that predation of *N. randalli* on decapods and teleosts, using molecular and stable isotope analyses will help to better understand these feeding relationships.

The condition factor values obtained in the studies conducted in the habitats where *P. erythrinus* populations are not cohabited with *N. randalli* individuals (Vassilopoulou, 1986; Özaydın, 1997; Can, 2000; Hossucu & Turker Cakir, 2003) were higher than the results obtained in the present study (Table 8). Furthermore, considering the high diet-overlap between these two species, it may suggest that *P. erythrinus* is unsuccessful in the food competition with *N. randalli*. Factors such as resource partitioning, competition, ecological niche are the main processes responsible for the structuring of populations and communities (Gerking, 1994). If non-indigenous species prevail in food competition which can be seen among the indigenous / non-indigenous species in the similar position within the food chain, there may be changes in the abundance of the indigenous species, leading to possible negativity in the functioning of the ecosystem (Mooney, 1996). In light of these data, it is possible to argue that *N. randalli* has a negative effect on *P. erythrinus* and food chain of study area.

Considering both the distribution reports and the results of Aquatic Species Invasiveness Screening Kit (AS-ISK), *N. randalli* has been reported to be one of the most invasive species in the Mediterranean Sea (Bilge *et al.,* 2017). In conclusion, the management of biodiversity in the Mediterranean basin should be carried out by monitoring the Lessepsian species such as *N. randalli* entering through various vectors and determining the effects they have on indigenous species.

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