RESEARCH ARTICLE

Age and growth of *Nemipterus randalli* in the southern Aegean Sea, Turkey

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Abstract

In this study, the age and growth characteristics of Randall's threadfin bream (*Nemipterus randalli* Russell, 1986) in Gökova Bay (southern Aegean Sea) were examined. In total, 221 (varied between 10.8-21.9 cm in total length and 18.19-150.10 g in total weight) were examined on a monthly basis between May 2015 and April 2016. The sex ratio (male: female) was 1:0.51 and showed significant variation depending on age classes. The length-weight relationship parameters were estimated as follows; $a = 0.0171$, $b = 2.92$, $r^2 = 0.92$ (n = 221). Ages ranged from 1 to 5, and the 2-years group was dominant (42.53%) for both sexes. von Bertalanffy growth parameters and phi-prime growth performance index value calculated as $L_\infty = 27.57$ cm, $k = 0.183$ year^{-1}, $t_0 = -2.88$ and $\Phi = 2.14$ for all individuals. The results representing the first study on age and growth of *N. randalli* in the southern Aegean Sea.

Keywords: Randall's threadfin bream, Nemipteridae, Lessepsian fish, Gökova Bay

Introduction

Randall's threadfin bream (*Nemipterus randalli* Russell, 1986) naturally exists in all the western Indian Ocean including the east and west coasts of India, Pakistan, the Persian (Arabian) Gulf, Red Sea, including the Gulf of Aqaba, the Gulf of Aden, and the eastern African coast: the Seychelles and Madagascar (Russell 1990).

N. randalli entered the Mediterranean Sea via the Suez Canal and was mistakenly identified as *Nemipterus japonicus* by Golani and Sonin (2006) from

Haifa Bay (Israel) for the first time. Two years later, Lelli *et al*. (2008) recorded the species from the coasts of Lebanon with correct identification as *N. randalli*. At the same time, the species was recorded from Iskenderun Bay (Turkey) by Bilecenoğlu and Russell (2008). After one year, it passed to Antalya Bay (Gökoğlu *et al*. 2009), and rapidly reached to Ekincik (Bilecenoğlu and Yokeş 2013) and Gökova Bay (Gülşahin and Kara 2013) in the southern Aegean Sea, then appeared in the central Aegean Sea (Kuşadası region) (Bilecenoğlu and Yokeş 2013) and İzmir Bay (Aydın and Akyol 2017). The species was also recently reported from Syria (Ali *et al*. 2013) and Cyprus (Iglésias and Frotté 2015). Along with the very rapid increase in abundance and distribution rate, a risk screening tool so called Aquatic Species Invasiveness Screening Kit (AS-ISK) yielded that *N. randalli* is considered to have a high potential of being invasive in the Mediterranean Sea (Uyan *et al*. 2016; Bilge *et al*. 2019).

Although age and growth (Ergüden *et al*. 2010; Al-Kiyumi *et al*. 2014; Innal *et al*. 2015) and length-weight relationship (Ergüden *et al*. 2009, Dineshbabu 2013; Edelist 2014; Özvarol 2014; Ateş *et al*. 2017; Kalhoro *et al*. 2017) of *N. randalli* have been previously studied from some other regions in its native and non-native distributional ranges, the present study is the first one to provide the data on the age and growth of the species from the southern Aegean Sea (Gökova Bay, Turkey).

Materials and Methods

N. randalli specimens (Figure 1) were collected by trammel nets or long-lines of the Akyaka Fisheries Cooperative in Gökova Bay (Figrure 2) at monthly intervals between May 2015 and April 2016.

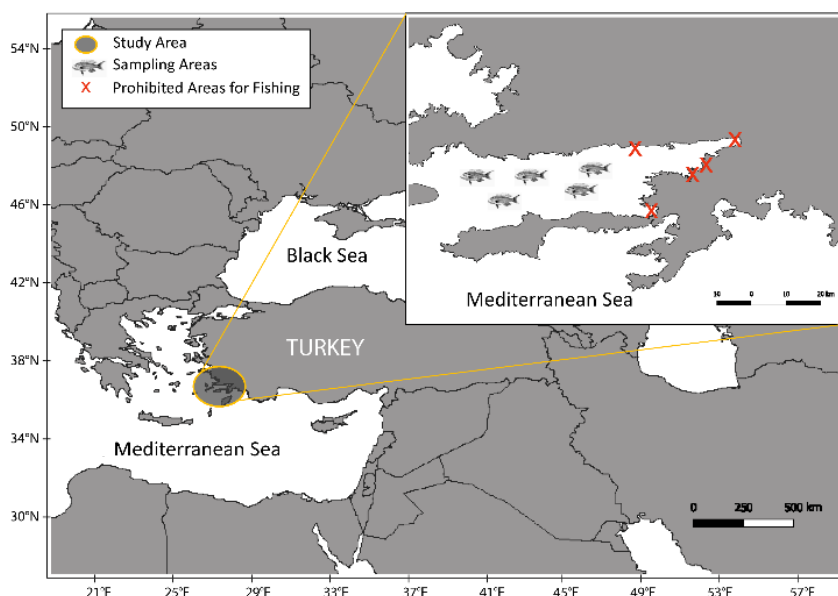**Figure 1.** A specimen of *Nemipterus randalli*

Figure 2. The map showing study area in Gökova Bay (Turkey)

The specimens were brought to the laboratory on ice and their total length (TL) (upper caudal fin filament excluded) and total weight (TW) were measured with an accuracy of 0.1 cm and 0.01 g, respectively. The sex was determined by the examination of the gonads. Chi-Square (χ^2) and *t*-test were used to detect differences in sex ratio and sizes between the sexes.

A total of 221 otoliths was dissected out from the collected specimens, stored dry in Eppendorf tubes and used for age determination by the method of Chugunova (1963). For age determination, a stereo microscope with reflected light was used. To minimize misreading, three independent readers evaluated the otoliths; when differences were encountered, the decision of the majority was taken.

The parameters of the equation $W = aL^b$ were estimated on the log-transformed data: $\log W = \log a + b \log TL$. The 95% confidence intervals (CI), standard errors of the regression parameters *a* and *b* and the coefficient of regression (r^2) were determined by using the Past v3.21 (Paleontological Statistics). Regressions on log-transformed data were tested for differences in slopes and intercepts between sexes using ANCOVA (Zar 1999).

To examine the growth mathematically, von Bertalanffy growth equation (VBGF) $L_t = L_\infty [1 - e^{-k(t - t_0)}]$ was used where L_t is the total length at age *t*, L_∞ is asymptotic length, *k* is the body growth coefficient and t_0 is the theoretical age at zero length (Beverton and Holt 1959). The Growth performance index (Ø′)

was computed by formula $\emptyset' = \log(k) + 2\log(L_\infty)$ where k and L_∞ are VBGF growth parameters (Pauly and Munro 1984).

Results

A total of 221 *N. randalli* individuals [146 (66.06 %) males and 75 (33.94 %) females] were collected in Gökova Bay. Total length and total weight ranged from 10.8 to 21.9 cm and 18.19 to 150.10 g, respectively. There was no statistically significant difference between total length and weight of males and females (*t*-test, $p > 0.05$).

Table 1. Age-length key for *N. randalli* in Gökova Bay

Total Length (cm)	Age groups (in year)					Total
	1	**2**	**3**	**4**	**5**	
10.0-10.9	1					1
11.0-11.9	1					1
12.0-12.9	3					3
13.0-13.9	11					11
14.0-14.9	7	8				15
15.0-15.9	8	22				30
16.0-16.9		37	2			39
17.0-17.9		25	23			48
18.0-18.9		2	29	5		36
19.0-19.9			7	10		17
20.0-20.9				14	2	16
21.0-21.9					4	4
Total	31	94	61	29	6	221
%	14.03	42.53	27.60	13.12	2.72	100
Mean TL ± SD (cm)	14.02 ± 1.15	16.35 ± 0.90	18.09 ± 0.62	19.71 ± 0.70	21.05 ± 0.46	17.05 ± 1.96
Mean TW ± SD (g)	39.41 ± 9.76	62.80 ± 10.65	82.38 ± 9.98	106.22 ± 12.07	116.62 ± 12.92	72.36 ± 23.72
Males (%)	26 (11.76%)	47 (21.26%)	44 (19.90%)	23 (10.40%)	6 (2.71%)	146 (66.06%)
Females (%)	5 (2.62%)	47 (21.26%)	17 (7.69%)	6 (2.72%)	-	75 (33.94%)
M: F	1: 0.19	1: 1.00	1: 0.38	1: 0.26	-	1: 0.51

Ages ranged from 1 to 5 years, with the 2 year-class (n=94, 42.53%) being dominant in the population. The 0-age group individuals for both sexes and the 5-age group individuals of females were not found in the samples (Table 1). Male to female ratio (M:F) of the population was calculated as 1:0.51 ($\chi^2 = 22.8$; $p < 0.001$) (Table 1).

Descriptive statistics of length-weight relationships are presented in Table 2. All relationships were statistically significant ($p < 0.01$) and r^2 values were found to be close to 1 (Table 2). The *b* values of length-weight regressions were significantly different between sexes (ANCOVA; $F = 6.257$, $p = 0.013$).

The von Bertalanffy growth model for female, male and all individuals were L_t = 25.50 [1- $e^{-0.238(t+2.293)}$], L_t = 24.12 [1- $e^{-0.210(t+3.389)}$] and L_t = 27.57[1- $e^{-0.183(t+2.88)}$], respectively. The growth performance index $(\varnothing')$ was higher in males $(\varnothing' = 2.19)$ than females $(\varnothing' = 2.09)$. Notably, the males reached their asymptotic length at a faster rate. The parameters of equations and the grow performance indexes were presented separately for male, female and all individuals in Table 4.

Table 2. Relationships between total length and total weight of *N. randalli* in Gökova Bay (n: sample size; *L*: length (cm); *W*: weight (g); SE: standard error; CI: confidence interval; *a*: intercept of the relationship; *b*: slope of the relationship; r^2: coefficient of correlation)

Sex	n	L_{min} - L_{max} (cm)	W_{min} - W_{max} (g)	a	± SE (*a*)	*a* CI 95 %	b	± SE (*b*)	*b* CI 95 %	r^2
♀	75	13.8-19.8	13.63-116.57	0.0144	0.090	0.0092-0.0208	3.00	0.073	2.87-3.16	0.957
♂	146	10.8-21.9	18.19-150.10	0.0161	0.045	0.0132-0.0195	2.94	0.036	2.87-3.01	0.978
♂ + ♀	221	10.8-21.9	18.19-150.10	0.0171	0.044	0.0140-0.0206	2.92	0.035	2.86-2.99	0.968

Discussion

We found the maximum ages as 4 (19.8 cm) and 5 years (21.9 cm) for female and male, respectively. In the Mediterranean Sea, Ergüden *et al*. (2010) and Innal *et al*. (2015) reported the maximum ages as 3 and 4, respectively. However, Al-Kiyumi *et al*. (2014) determined the maximum age as 2 both sexes in Gulf of Oman (within native range). Differences in the age distribution of the population may be due to factors such as species' ecology, sampling methods, fishing activity, trophic status and specific ecological characteristics of the marine system (Innal *et al*. 2015).

The sex ratio may vary from year to year in the same population, indicating that it is either determined genetically or environmentally (Bohlen *et al.* 2008). This variation may arise due to many factors, such as season, feeding and maturation periods, sexual differences in growth rate and mortality, and perhaps, size-selectivity effects of the fishing gear (Innal *et al*. 2015). This change in sex ratios (male:female) was also observed in previous studies as 1:0.88 (Ergüden *et al*. 2010), 1:1.11 (Al-Kiyumi *et al*. 2014; Innal *et al*. 2015) and 1:0.51 (this study). Generally observed male dominant populations could be attributed to time of the sampling e.g. spawning where males are usually represented more abundant than females (Bohlen *et al*. 2008).

The *b* value typically is close to 3, but varies between 2 and 4. A value of 3 indicates that the fish grows symmetrically or isometrically; values other than 3

indicate allometric growth (Tesch 1971). In the previous studies, *b* varied between 2.74 to 3.08 for this species (Table 3). In the present study, however, *b* value of all individuals showed negative allometry and this is in agreement with Ateş *et al.* (2017) who studied on *N. randalli* in the same region. Several factors are considered to affect the length–weight relationship in fish, including growth phase, season, degree of stomach fullness, gonad maturity, sex, size range, health and general fish condition and preservation techniques (Tesch 1971; Moutopoulos and Stergiou 2002). These factors were, however, not accounted for in the present study.

Table 3. Length-weight parameters of *N. randalli* in different areas

Reference	Area	n	$W=aL^b$		
			a	*b*	r^2
Ergüden *et al.* (2010)	Iskenderun Bay	379	0.011	3.06	0.98
Edelist (2014)	Israel	168	0.0101	3.08	0.97
Al-Kiyumi *et al.* (2014)	Gulf of Oman	1749	0.0135	3.06	0.94
Özvarol (2014)	Antalya Bay	143	0.012	2.97	0.93
Innal *et al.* (2015)	Antalya Bay	175	0.0105	3.04	0.98
Ateş *et al.* (2017)	Gökova Bay	1273	0.0201	2.98	0.96
Kalhoro *et al.* (2017)	Pakistani waters	1141	0.035	2.74	0.97
This study	Gökova Bay	221	0.0171	2.92	0.96

In this study, the average asymptotic length (L_∞) values indicated that male individuals had a higher length growth rate (Table 4). The differences of asymptotic length (L_∞) can be explained with productivity (Mann *et al.* 1984) or environmental conditions such as temperature and salinity (Ricker 1975). Basilone *et al.* (2006) also reported that values of L_∞ increased in length with the decline of temperature. This result can justify that most values of L_∞ in the Mediterranean Sea are higher than those in native areas of *N. randalli* (Table 5). The body growth coefficients ($k = 0.2384$ for male, $k = 0.2104$ for female) suggest that males approach their asymptotic length at a faster rate than females. Absence of 5 years old female in the dataset caused a higher L_∞ value than that of males and females (Table 4).

Table 4. von Bertalanffy growth parameters and phi-prime grow performance index of *N. randalli* in Gökova Bay

Sex	L_∞ (cm)	k (year^{-1})	t_0	Φ'
Male	25.50	0.238	-2.29	2.19
Female	24.12	0.210	-3.38	2.09
Combined	27.57	0.183	-2.88	2.14

The growth performance index (∅) values calculated for *N. randalli* in Gökova Bay were lower than values presented by other researchers (Table 5). The reason for these differences may be a disproportional count of males (n=146) and females (n=75). This parameter can also be influenced by ecological factors (Deriso 1987).

Table 5. Comparison of von Bertalanffy growth parameters of *N. randalli* from different areas (M: male, F: female, A: all)

Reference	Sex	L_∞ (cm)	k (year^{-1})	t_0	$Φ'$	Area
Murty (1982)	A	21.9	0.83	-	2.6	Kakinada
	M	35.58	0.219	-1.255	-	
Ergüden *et al*. (2010)	F	34.2	0.22	-1.365	-	Iskenderun Bay
	A	34.96	0.214	-1.244	2.42	
Al-Kiyumi *et al*. (2014)	A	22.12	0.64	-	2.48	Gulf of Oman
Innal *et al*. (2015)	A	33.2	0.22	-0.22	2.38	Antalya Bay
Kalhoro *et al.* (2017)	A	26.25	0.32	-0.538	-	Pakistani waters
	M	25.50	0.238	-2.29	2.19	
This study	F	24.12	0.210	-3.38	2.07	Gökova Bay
	A	27.57	0.182	-2.88	2.16	

The results obtained by the present study provide the information on the age and growth of *N. randalli* from the Aegean Sea (Gökova Bay) for the first time and are expected to be useful for future studies.

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Türkiye, Güney Ege Denizi'ndeki *Nemipterus randalli*'nin yaş ve büyümesi

Öz

Bu çalışmada Gökova Körfezi'ndeki (Güney Ege Denizi) kılkuyruk mercan balığının (*Nemipterus randalli* Russell, 1986) yaş ve büyüme özellikleri incelenmiştir. Mayıs 2015 ile Nisan 2016 tarihleri arasında aylık olarak elde edilen toplam 221 örnek (10.8-21.9 cm total boy ve 18.19-150.10 g) incelenmiştir. Cinsiyet oranı (erkek:dişi), 1:0.51 ve yaş

sınıflarına bağlı önemli farklılıklar göstermiştir. Boy-ağırlık ilişki parametreleri şu şekilde tahmin edilmiştir. n = 221; a = 0.0171; b = 2.92; r^2= 0.92. Yaşları 1-5 arasıda değişmekte olup her iki cinsiyette de 2 yaş grubu (%42.53) baskındır. von Bertalanffy büyüme parametreleri ve phi- prime büyüme performans index değeri tüm bireyler için L_∞= 27.57 cm, k= 0.183 year^{-1}, t_0= -2.88 ve Φ= 2.14 olarak hesaplanmıştır. Güney Ege Denizi'nden elde edilen *N. randalli*'nin yaş ve büyümesi ile ilgili ilk çalışmayı temsil eden bu sonuçlar diğer çalışmalar ile karşılaştırılmıştır.

Anahtar Kelimeler: Kılkuyruk mercan, Nemipteridae, lesepsiyen balık, Gökova Körfezi

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