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**Research Article** **Araştırma Makalesi**

# Seasonal and Reproductive Period Changes in Nutrient composition of *Nemipterus randalli* (Russell, 1986) and *Boops boops* (Linnaeus, 1758) from Northwest Mediterranean, Türkiye

## Türkiye Kuzeybatı Akdeniz'deki, *Nemipterus randalli* (Russell, 1986) ve *Boops boops* (Linnaeus, 1758) Balıklarının Besin Kompozisyonunda Mevsim ve Üreme Periyodundaki Değişiklikler

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**Abstract:** In recent years, Mediterranean fish species such as *Nemipterus randalli* and *Boops boops* have been increasingly preferred by consumers when commonly consumed species are expensive or not present. Furthermore, the commercialization of these species has been affected by their reaching large-scale populations and becoming a target species in the catch composition. Therefore, the purpose of this study was to determine changes in the proximate content and fatty acid levels during the seasonal and reproductive periods of *N. randalli* and *B. boops* caught from the Northwest Mediterranean. This study showed that the biochemical components of these fish varied significantly with season and maturity stage ($P < 0.05$). While the highest protein level was found to be 18.99% in winter out of the reproductive season, the highest lipid level was 3.85% in spring at the beginning of the reproductive season for *N. randalli*. The highest protein and lipid levels were 21.81% and 3.10% in summer at the end of the reproductive season for *B. boops*, respectively. As a result, the consistent presence of low eicosapentaenoic acid (EPA) levels, predominantly low ratios of polyunsaturated fatty acids to saturated fatty acids (PUFA/SFA), and the prevalence of saturated fatty acids (SFAs) throughout the year in the muscle composition of *N. randalli* and *B. boops* species has an adverse impact on the overall quality of the food derived from these species. However, low n6/n3 ratios, high protein, and a low lipid content are important for food quality.

**Keywords**
- *Nemipterus randalli*
- *Boops boops*
- Seasonal fatty acids
- Proximate composition
- Gonadosomatic index

**Özet:** Son yıllarda Kılkuyruk mercan, *Nemipterus randalli*, ve Kupez, *Boops boops* gibi Akdeniz balık türleri, yaygın olarak tüketilen türlerin pahalı olması veya bulunmaması nedeniyle tüketiciler tarafından giderek daha fazla tercih edilmektedir. Bu nedenle bu çalışmanın amacı, Kuzeybatı Akdeniz'den yakalanan *N. randalli* ve *B. boops*'un mevsimsel ve üreme dönemlerinde yaklaşık içerik ve yağ asidi düzeylerindeki değişimleri belirlemektir. Bu çalışma, bu balıkların biyokimyasal bileşenlerinin mevsim ve olgunluk aşamasına göre önemli ölçüde değiştiğini göstermektedir ($P < 0.05$). *N. randalli* de en yüksek protein düzeyi %18,99 ile üreme mevsimi dışında kışın, en yüksek lipit düzeyi ise üreme mevsimi başlangıcında %3,85 ile ilkbaharda tespit edilmiştir. *B. boops* ta en yüksek protein ve lipid düzeyleri sırasıyla %21,81 ve %3,10 ile üreme mevsimi sonunda yaz aylarında görülmüştür. Sonuç olarak, düşük eikosapentaenoik asit (EPA) seviyelerinin varlığı, çoklu doymamış yağ asitlerinin doymuş yağ asitlerine (PUFA/SFA) oranının düşük olması ve kas bileşiminde yıl boyunca doymuş yağ asitlerinin (SFA) yaygınlığı bu türlerin genel gıda kalitesi üzerinde olumsuz bir etki yaratmaktadır. Ancak gıda kalitesi açısından; düşük n6/n3 oranı, yüksek protein ve düşük lipit içeriğinin önemli olduğu tespit edilmiştir.

**Anahtar kelimeler**
- *Nemipterus randalli*
- *Boops boops*
- Mevsimsel yağ asitleri
- Besin bileşenleri
- Gonadosomatik indeks

## 1. INTRODUCTION

Fish play a crucial role as a vital food source, offering essential lipid, protein, vitamin, and mineral in the human food (Balami et al., 2019; Reale et al., 2006). The immunoglobulins found in fish proteins serve as a protective mechanism against both bacterial and viral infections. The lipids, especially long chain omega-3 polyunsaturated fatty acids such as EPA and DHA, which are not synthesized by the human body, play a crucial role in preventing cardiovascular diseases and coronary heart diseases. They also contribute to maintaining healthy blood pressure in humans and support neurodevelopment in children (Balami et al., 2019).

In Türkiye, a gradual decrease was observed in the production of prominent species such as anchovy, sardine and horse mackerel obtained through natural hunting between 2021 and 2023 (TÜİK, 2024). As a result of changes in these population dynamics, changes in the local ecosystem and fisheries management may occur in the future. The development of alien species such as *N. randalli* on native biota may cause some positive or negative situations on fisheries (Özen & Çetinkaya, 2020). Consumers tend to favor these species, especially when the more commonly consumed ones become either expensive or scarce according to obtained knowledge from the Antalya fisherman.

According to data from the Turkish Statistical Institute, *B. boops* catches reached a record high of 2 140 tons in 2023. There is no certain data on the number of *N. randalli* catches so far.

*N. randalli* is one of the widespread Lessepsian species observed along the Türkiye coast. It has recently become abundant at the beginning of the catch and is a commercially important fish species in Türkiye (Yemişken et al., 2014; Akgun et al., 2023). After its first appearance in Haifa Bay in 2005 (Golani and Sonin, 2006), it has been observed around Lebanon (Lelli et al., 2008), Iskenderun Bay (Bilecenoglu 2008; Gurlek et al., 2010; Tartar and Yeldan, 2022; Yazici et al., 2024), Gökova Bay (Gülşahin and Kara, 2013), Izmir Bay (Aydın et al., 2016; Uyan et al., 2019) and Antalya marine region (Gökoğlu et al., 2009; Özen and Çetinkaya, 2020; Akgun et al., 2023). *N. randalli* is a species known to live on sandy and muddy surfaces between 22-450 m depths of tropical waters and generally feed on crustaceans, mollusks, and small fish (Ay et al., 2022). *B. boops* is a common sea bream (*Sparidae*), native to the Eastern Atlantic, found in Portuguese coastal waters and has a broad distribution, ranging from Norway to Angola in the Eastern Atlantic. Additionally, it is found throughout the Mediterranean Sea and the Black Sea. The bogue's presence extends to the Western Atlantic, including the Gulf of Mexico and the Caribbean Sea. This wide geographical distribution indicates the adaptability and habitat range of the species (Monteiro et al., 2006). The bogue is a gregarious semi pelagic species found as deep as 300 m on a variety of bottoms, but it is more common at depths <150 m, moving up to the surface during the night (Cunha et al., 2022; Monteiro et al., 2006).

There has been insufficient research on the food quality of *B. boops* and *N. randalli*. Most studies in literature have been conducted in the Northeast Mediterranean Sea on *N. randalli* (Bakan et al., 2020; Durmuş, 2019; Göçmen et al., 2018) and *B. boops* (Uçar, 2020). The current study differs from the literature which investigates the seasonal and reproductive period changes in the proximate and fatty acid composition of *N. randalli* and *B. boops*.

## 2. MATERIALS AND METHODS

### 2.1. Sample capture

*N. randalli* and *B. boops* samples were collected monthly from commercial trawl 84 catches in the Northwest Mediterranean between 2020 and 2021. In total, 392 *N. randalli* individuals and 641 *B. boops* individuals were caught (Table 1). The fish samples gathered were promptly transported to the laboratory in an ice cooler. The total length (TL) of each fish was measured to the nearest 0.01 mm, and the weight was determined with an accuracy of 0.01 g digital balance. The mean total length, weight, and sample numbers for both *N. randalli* and *B. boops* were provided in Table 1. The species identifications were carried out according to Özen (2021). The original photographs of *N. randalli* and *B. boops* species are given in Figure 1.


**Figure 1.** *Nemipterus randalli* (Russell, 1986) and *Boops boops (Linnaeus 1758)*

### 2.2. Gonadosomatic index (GSI)

The ventral of the fish samples was opened by cutting with a sharp scissor, and the muscle and digestive organs were removed. The left and right gonads were measured together as gonad weights with a digital balance to an accuracy of 0.01g. The spawning period was determined according to the monthly variation of the gonadosomatic index.

The gonadosomatic index (GSI) was determined through the following calculation: GSI = (GW/BW) × 100 (1)

Gonad weight GW (g), body weight BW (g) (Park & Jeong, 2020).

### 2.3. Proximate composition

The present study was conducted to determine proximate composition and fatty acid analyses during the following seasons: autumn in October 2020, winter in January 2021, spring in April 2021, and summer in July 2021. A total of 10 fish were randomly chosen as triplicates in every season. The fish were filleted by removing their skin, fin, skeleton, visceral, and head. Then, the 10 fish fillets in the replicate were minced and mixed for proximate and fatty acid analyses.

Proximate analysis, except crude lipid, was conducted in accordance with the methods of AOAC (1990) at 104°C. The ash content was determined by subjecting the sample to incineration in a muffle furnace at a temperature of 600°C for a duration of 2 hours. Crude protein content (calculated as N × 6.25) was analyzed using the Dumas method, employing a Dumas Nitrogen Analyzer (Velp NDA 701-Monza, Brianza-Italy). The device was calibrated using Ethylene Diamine Tetra-acetic Acid (EDTA). The lipid concentrations in the samples were analyzed through ether extraction, utilizing the ANKOMXT15 Extractor, an automated extraction system provided by composition ANKOM Technology in Macedon, USA.

### 2.4. Fatty acid composition

Determination of fatty acid composition, the lipids samples were extracted following the procedure outlined by Jakobsen et al. (2008). Wet tissue samples weighing between 50 to 100 mg were placed in a test tube with a secure screw cap and suspended in 0.7 mL of 0.1 M Tris HCl (pH 7.5 at 50°C). Two mL methanol and 1.0 mL chloroform were added to the tube, and the mixture was homogenized vigorously for 1 min

using a DATHANN HG-15A homogenizer (DAIHAN Scientific Co. Ltd.). Chloroform (1 mL) was introduced, and the mixture was homogenized for 20 seconds. Subsequently, 1.0 mL of distilled water was added, and the homogenization process continued for another 20 seconds. Following centrifugation (3,200 × g, 5 min, 4°C), a precisely measured quantity of the lower layer in the tube was extracted and subjected to drying through N2 flushing at 40°C. Fatty acid methyl esters (FAME) were synthesized in accordance with the procedures described by Ichihara et al. (1996). In a small glass tube, 20–40 mg of lipid, 2 mL of hexane, and 4 mL of 2 M methanolic KOH were placed. In a typical reaction, the tube was vortexed at room temperature for 2 min. After centrifugation (3,200 × g, 10 min, 4°C), an aliquot of the upper hexane layer was directly injected into gas chromatography (GC) (Focus GC, Thermo Electron, Waltham, MA). The fatty acid analysis was conducted using gas chromatography (GC) with an autosampler, flame ionization detector, and a fused silica capillary column (30 m × 0.32 mm, internal diameter × 0.25 μm film). The oven temperature commenced at 140°C for 5 minutes, then increased to 200°C at a rate of 4°C/min, followed by a further increase to 220°C at a rate of 1°C/min. The injector and detector temperatures were maintained at 220°C and 280°C, respectively. Fatty acid methyl esters (FAMEs) were identified by comparing retention times with those of the SUPELCO standard (Sigma-Aldrich). The outcomes were expressed as a percentage of the total lipid content.

### 2.5. Statistical analysis

The proximate and fatty acid compositions were assessed based on analyzes using one-way analysis of variance (ANOVA) in the SPSS 13.0 computer program (SPSS Inc., Chicago, USA). Subsequently, the Duncan test was employed to identify significant differences between the samples at a significance level of P = 0.05. Additionally, the Pearson correlation test was utilized to explore potential correlations between GSI values and the seasonal protein-lipid, as well as certain fatty acid levels in *N. randalli* and *B. boops*.

## 3. RESULT AND DISCUSSION

### 3.1. The proximate composition

Length-weight parameters of fish are affected by several factors such as gonadal maturity, habitat, season, sex, diet, stomach fullness, health, water temperature, salinity and conservation techniques (Hossain et al., 2006). This study showed all total length and weight presented in Table 1 were highly significant (P<0.05). Kara & Bayhan (2008) investigated that monthly the length-weights of *B. boops* vary between 2.475 (January) and 3.194 (November) in males, between 2.304 (January) and 3.487 (October) in females and between 2.909 (October) and 3.298 (August) in hermaphrodites. Karakulak and Bilgin (2006) in their study, while the height-weight relations did not differ significantly according to the season for *B. boops* (P>0.05), they differed significantly for *Diplodus annularis*, *Mullus surmuletus* and *Spicara maena* (P<0.05). Significant variations were observed in the protein and lipid levels across different seasons for both species (P < 0.05) (Table 1). The highest protein level was identified in winter for *N. randalli* (18.99%), while for *B. boops*, the highest protein level was observed in the summer (21.81%). The lipid contents ranged from 0.52% to 3.85% for *N. randalli*, and from 0.52% to 3.10% for *B. boops* between seasons. The lipid content was found to be much higher in the spring for *N. randalli* (3.85%) and in the summer for *B. boops* (3.10%) than in the other seasons. It was interesting that the lipid difference between seasons was high in both species. The reason for the high seasonal difference in the lipid contents of species may be nutrient quality and diversity rather than the other known causes. The fish can be categorized based on total fat content into different classes, namely lean fish (<2%), low fat (2–4%), medium fat (4–8%), and high fat (>8%) as defined by Ackman 1990.

The muscles of the two species in the present study have a high protein and a low lipid content according to Martin et al. (2000).

**Table 1.** Seasonal, the numbers of sample, total length, weight and proximate composition of *N. randalli and B. boops* (Mean ± SE).

| | | | | | Proximate composition (N=3) | | | |
|---|---|---|---|---|---|---|---|---|
| | **Season** | **N** | **Total length (cm)** | **Weight (g)** | **Moisture (%)** | **Protein (%)** | **Lipid (%)** | **Ash (%)** |
| *N. randalli* | Autumn | 124 | 16.48±0.19$^{b}$ | 60.57±3.24$^{d}$ | 79.26±0.20$^{a}$ | 18.42±0.08$^{b}$ | 0.81±0.05$^{c}$ | 1.68±0.01$^{ab}$ |
| | Winter | 96 | 17.42±0.23$^{ab}$ | 71.62±3.26$^{c}$ | 78.71±0.10$^{ab}$ | 18.99±0.06$^{a}$ | 0.52±0.01$^{d}$ | 1.65±0.01$^{b}$ |
| | Spring | 74 | 18.46±0.27$^{a}$ | 92.10±4.82$^{a}$ | 76.75±0.38$^{c}$ | 16.97±0.10$^{c}$ | 3.85±0.12$^{a}$ | 1.49±0.04$^{c}$ |
| | Summer | 98 | 18.74±0.24$^{a}$ | 89.57±3.39$^{b}$ | 78.18±0.07$^{b}$ | 18.82±0.12$^{ab}$ | 1.18±0.02$^{b}$ | 1.72±0.01$^{a}$ |
| *B. boops* | Autumn | 237 | 15.89±0.10$^{d}$ | 37.27±0.79$^{d}$ | 76.09±0.26$^{b}$ | 21.16±0.07$^{b}$ | 0.52±0.02$^{bc}$ | 1.92±0.03$^{a}$ |
| | Winter | 171 | 22.26±0.91$^{a}$ | 58.00±2.72$^{a}$ | 77.88±0.06$^{a}$ | 19.53±0.09$^{c}$ | 0.71±0.09$^{b}$ | 1.61±0.01$^{b}$ |
| | Spring | 108 | 17.12±0.16$^{b}$ | 54.37±1.56$^{b}$ | 78.98±0.05$^{a}$ | 19.12±0.02$^{d}$ | 0.27±0.01$^{c}$ | 1.59±0.01$^{b}$ |
| | Summer | 125 | 16.49±0.12$^{c}$ | 50.94±3.43$^{c}$ | 73.19±0.43$^{c}$ | 21.81±0.09$^{a}$ | 3.10±0.14$^{a}$ | 0.91±0.45$^{c}$ |

N, numbers of sample; SE, standard error.
The results are presented as a percentage of dry matter. Intraspecific comparisons reveal that values in the same column with different letters are statistically significant in relation to seasonality.

Similarly, Bakan et al. (2020) reported that the total lipid levels of *N. randalli* from Mersin Bay varied between 0.63% and 3.17%, and the highest lipid levels were found in the spring season. Göçmen et al. (2018) detected that the total lipid levels of *N. randalli* from Mersin Bay changed between 2.75% and 2.85% with different ages. Durmuş (2019) determined a lipid content of 1.12% in the muscles of *B. boops* from the Northeastern Mediterranean coast. Orban et al. (2011) reported total lipid levels of 2.54% and 1.02% and protein contents of 20.32% and 18.40% for *B. boops* caught from the Southern Adriatic Coast of Italy in September and March, respectively. Simat et al. (2015) revealed that lipid and protein contents were 2% and 18.8% in the muscles of *B. boops* from the Eastern Adriatic Sea. The variations observed in studies are likely due to a combination of factors, with the biochemical composition of fish being a key influencer. The reasons for the discrepancy between studies are likely multifaceted and could include the biochemical composition of fish, which is influenced by several factors such as biological variations (species, sex, size, and age), natural diet, geographical location of the catch, and seasonal changes (Chuang et al. 2012; Orban et al. 2011).

### 3.2. The relationship between GSI values with seasonal protein-lipid levels

Variability in growth and GSI of *N. randalli* and *B. boops* can be caused by a variety of factors, including differences in mortality, sexual maturity, genetic variations or environmental conditions (Dutka-gianelli and Murie 2001). In the present study, the monthly variation of gonadosomatic index (GSI) was given for the two species in Table 2.

**Table 2.** Correlation between seasonal fatty acids and protein, lipid with GSI of *N. randalli* and *B. boops*.

| | ***N.randalli*** | | | ***B.boops*** | | |
|---|---|---|---|---|---|---|
| | **Mean±SD** | **r** | **p** | **Mean±SD** | **r** | **p** |
| PROTEİN | 20.41±1.29 | -0.76 | 0.24 | 18.30±0.92 | 0.27 | 0.73 |
| LİPİD | 1.15±1.31 | -0.21 | 0.79 | 1.59±1.53 | -0.05 | 0.95 |
| SFA | 55.74±10.99 | 0.69 | 0.32 | 43.09±10.67 | 0.45 | 0.55 |
| MUFA | 15.69±10.81 | -0.79 | 0.21 | 20.42±8.62 | -0.45 | 0.55 |
| PUFA | 22.73±2.95 | 0.88 | 0.12 | 24.71±2.39 | -0.24 | 0.76 |
| PUFA/SFA | 0.42±0.07 | -0.28 | 0.72 | 0.61±0.20 | -0.44 | 0.56 |
| n6 | 5.89±3.18 | 0.31 | 0.69 | 9.63±4.19 | -0.54 | 0.45 |
| n3 | 16.84±4.49 | 0.36 | 0.64 | 15.05±2.11 | 0.82 | 0.18 |
| n6/n3 | 0.41±0.35 | 0.15 | 0.85 | 0.68±0.37 | -0.40 | 0.40 |
| DHA | 13.64±4.78 | 0.39 | 0.61 | 8.40±1.99 | 0.51 | 0.50 |
| EPA | 2.15±1.28 | -0.71 | 0.29 | 2.89±0.82 | 0.93 | 0.07 |
| DHA/EPA | 7.19±3.62 | 0.86 | 0.15 | 2.95±0.45 | -0.76 | 0.24 |

According to the GSI, *N. randalli* spawns in the period from April to October, with a peak in July, and *B. boops* spawns during the period from January to April, with a peak in March. However, for *N. randalli*, the lipid level in muscles was very high in April, the beginning of gonad development, but the lowest protein level was in this month. In other words, it could be said that

*N. randalli* stores lipid in muscles before entering the reproductive period. For *B. boops*, protein and lipid levels increased in muscles when the reproduction period finished in July (summer). It could be said that the species goes through a period of intense feeding between the end of the reproductive season and the beginning of summer. The lowest protein and lipid levels were observed in April, when reproduction was high (Figure 2).

Variability in growth and GSI of *N. randalli* and *B. boops* can be caused by a variety of factors, including differences in mortality, sexual maturity, genetic variations or environmental conditions. This may be because, during reproductive periods, there is a transfer of lipids and proteins from muscles to gonads, playing crucial roles in supporting embryonic development. The main source of ovarian protein is the muscle, while lipids may be sourced from both the liver and muscle. This process is essential for providing energy and fulfilling structural functions necessary for successful embryonic development (Tolussi et al., 2018). The results of the current study were similar to the results of previous studies (Soykan et al. 2015; Taylan and Bayhan 2015; Demirci et al. 2018; Özen 2021). In both species, no positive or negative correlation was detected between seasonal proximate composition and GSI levels in the present study ($P > 0.05$) (Table 2).

**3.3. Fatty acid composition**

In this study, a significant variation in fatty acids (FAs) was observed across seasons ($P < 0.05$), as indicated in Table 3. For both species, the predominant fatty acid composition consistently ranked as SFAs > PUFAs > MUFAs (monounsaturated fatty acids) throughout all seasons. The primary fatty acid in this category was stearic acid (C18:0), with palmitic acid (C16:0) following closely. Specifically, stearic acid (C18:0) exhibited peak levels, 29.77% during winter for *N. randalli* and 44.97% during summer for *B. boops*. Palmitic acid (C16:0) was found high at 19.63% in winter for *N. randalli* and 20.22% in autumn for *B. boops*. The high levels of saturated fatty acids (SFAs) in human foods are considered undesirable due to the potential health risks associated with SFAs. Increased consumption of SFAs has been linked to harmful effects, such as elevated total cholesterol levels, which can lead to the formation of arterial blockages in the heart and other parts of the body (Mensink, 2016). It is recommended that 5% to 6% of calories be derived from SFA, and the percent of calories from SFA be reduced (Kris-Etherton and Krauss 2020). Simat et al. (2015) pointed out that SFAs were dominant fatty acids for *B. boops*. According to Orban et al. (2011), SFAs were dominant in September while PUFAs were dominant in March for *B. boops*.

The n-3 long-chain polyunsaturated fatty acids (PUFAs), including C20:5 n-3 (eicosapentaenoic acid, EPA) and C22:6 n-3 (docosahexaenoic acid, DHA), play a crucial role in reducing the risk of cardiovascular diseases and other chronic non-communicable diseases (Merdzhanova et al., 2021). The European Food Safety Authority recommends that infants >6 months to 2 years should consume 100 mg/d of DHA, while the adult population should have a daily DHA and EPA intake of approximately 250 mg (Carlson et al., 2013). In the present study, PUFAs emerged as the predominant fatty acids, following SFAs. DHA was found to be a major PUFA for both species. The highest DHA content was detected in the winter for *N. randalli* (10.33%) and in the spring for *B. boops* (19.46%). Generally, EPAs were low for two species. EPA levels were high in the summer for *N. randalli* (4.00%) and in the autumn for *B. boops* (4.04%). Similarly, Bakan et al. (2020) determined that the highest DHA and EPA contents were 23.00% in autumn and 5.34% in the summer in the muscles of *N. randalli*, respectively. Göçmen (2018) determined DHA contents ranging from 20.16% to 22.02% and EPA contents varying from 3.75% to 5.49% in muscles of *N. randalli* specimens at different ages. The DHA ratio in total fatty acids was lower in both species in the present study. Diraman & Dibeklioğlu (2009) reported an EPA content of 4.53% and a DHA content of 20.66% in *B. boops* from the Aegean Sea in February.

In the current investigation, the DHA/EPA ratio reached the highest level 3.49 during the winter for *N. randalli* and 10.96 in the spring for *B. boops*. Bakan et al. (2020) reported that the highest DHA/EPA ratio was 5.30 in the autumn for *N. randalli*. Diraman & Dibeklioğlu (2009) and Simat et al. (2015) reported DHA/EPA ratios of 4.56 and 3.37 for *B. boops*, respectively.

PUFA/SFA ratio is recommended to be a minimum of 0.45 for human health (HMSO, 1994). In this study, generally the

PUFA/SFA ratios were below 0.45 for both fish species. The highest PUFA/SFA ratio was found to be 0.78 during both the autumn and spring seasons for *N. randalli*. Additionally, for *B. boops*, the highest ratio of 0.50 was observed specifically during the autumn season. Bakan et al. (2020) determined the highest PUFA/SFA ratio for *N. randalli* as 0.81 in the spring. The highest PUFA/SFA ratios for *B. boops* were detected in the winter as 1.51 (Uçar, 2020), 1.25 (Diraman & Dibeklioğlu, 2009), and 1.38 (Durmuş, 2019).

The UK Department of Health (HMSO, 1994) recommends 4.0 of maximum n6/n3 ratio. Exceeding this threshold is considered detrimental to health and may contribute to the promotion of cardiovascular diseases, as highlighted by Moreira et al., (2001). In the present study, the n6/n3 ratios were generally low for each of the two species. The highest of the n6/n3 ratio was observed at 1.02 in the autumn for *N. randalli* and 0.92 in the winter for *B. boops* in this study. In a previous study by Bakan et al. (2020), the highest n6/n3 ratio for *N. randalli* was reported as 0.18 in the spring.

### 3.4. The relationship between GSI values with seasonal fatty acid levels

No significant difference and correlation were detected between seasonal fatty acid and GSI values in both species. (P > 0.05) (Table 3).

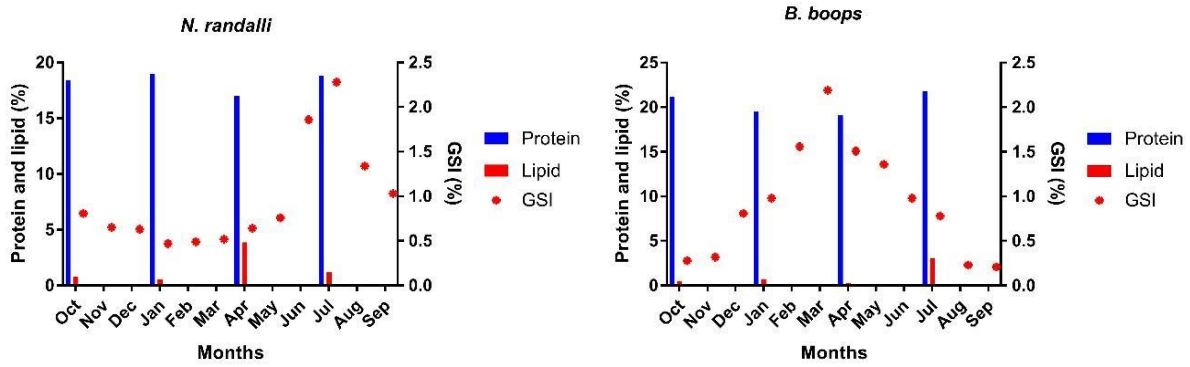


**Figure 2.** Relationship between GSI values with seasonal protein-lipid levels of *N. randalli* and *B. boops*.

**Table 3.** The seasonal changes in the fatty acid composition of *N. randalli and B. boops* (% of total lipid, N=3).

| **Fatty acid** | | ***N. randalli Mean ± SE*** | ***B. boops Mean ± SE*** |
|---|---|---|---|
| Myristic acid (C14:0) | Autumn | 2.15±0.00$^{b}$ | 5.22±0.03$^{a}$ |
| | Winter | 2.46±0.10$^{a}$ | 1.97±0.01$^{b}$ |
| | Spring | 1.67±0.00$^{c}$ | 1.44±0.02$^{c}$ |
| | Summer | 2.20±0.00$^{b}$ | 1.08±0.02$^{d}$ |
| Pentadecanoic acid (C15:0) | Autumn | 0.56±0.01$^{c}$ | 0.83±0.01$^{a}$ |
| | Winter | 0.96±0.01$^{a}$ | 0.35±0.01$^{c}$ |
| | Spring | 0.48±0.01$^{d}$ | 0.53±0.01$^{b}$ |
| | Summer | 0.65±0.01$^{b}$ | 0.36±0.01$^{c}$ |
| **Continuation of The Table 3.** | | | |
| **Fatty acid** | | ***N. randalli Mean ± SE*** | ***B. boops Mean ± SE*** |
| Palmitic acid (C16:0) | Autumn | 15.23±0.06$^{b}$ | 22.29±0.03$^{a}$ |
| | Winter | 19.63±0.09$^{a}$ | 16.82±0.08$^{d}$ |
| | Spring | 15.57±0.08$^{b}$ | 18.07±0.07$^{b}$ |
| | Summer | 19.11±0.08$^{a}$ | 17.36±0.08$^{c}$ |
| Heptadecanoic (margaric) acid (C17:0) | Autumn | 1.15±0.01$^{c}$ | 1.84±0.01$^{a}$ |
| | Winter | 2.24±0.01$^{a}$ | 0.86±0.01$^{d}$ |

| | | | |
|---|---|---|---|
| | Spring | 0.97±0.01$^{d}$ | 1.54±0.01$^{b}$ |
| | Summer | 1.65±0.01$^{b}$ | 1.21±0.01$^{c}$ |
| Stearic acid (C18:0) | Autumn | 14.14±0.10$^{d}$ | 11.12±0.06$^{d}$ |
| | Winter | 29.77±0.11$^{a}$ | 31.55±0.06$^{c}$ |
| | Spring | 14.74±0.06$^{c}$ | 40.28±0.09$^{b}$ |
| | Summer | 25.85±0.14$^{b}$ | 44.97±0.06$^{a}$ |
| Arachidic acid (C20:0) | Autumn | 0.66±0.00$^{c}$ | 0.42±0.01$^{c}$ |
| | Winter | 1.06±0.01$^{a}$ | 0.92±0.01$^{b}$ |
| | Spring | 0.58±0.00$^{d}$ | 0.93±0.01$^{b}$ |
| | Summer | 0.91±0.01$^{b}$ | 1.04±0.02$^{a}$ |
| ∑SFA | Autumn | 33.90±0.07$^{c}$ | 41.72±0.10$^{d}$ |
| | Winter | 56.12±0.13$^{a}$ | 52.47±0.15$^{c}$ |
| | Spring | 33.99±0.06$^{c}$ | 62.79±0.18$^{b}$ |
| | Summer | 50.36±0.22$^{b}$ | 66.01±0.11$^{a}$ |
| Palmitoleic acid (C16:1) | Autumn | 3.49±0.01$^{b}$ | 5.85±0.04$^{a}$ |
| | Winter | 2.46±0.01$^{d}$ | 1.67±0.02$^{b}$ |
| | Spring | 3.34±0.02$^{c}$ | 0.77±0.02$^{d}$ |
| | Summer | 3.70±0.01$^{a}$ | 1.11±0.02$^{c}$ |
| Cis-10-heptadecanoic acid (C17:1) | Autumn | 0.05±0.01$^{a}$ | 0.06±0.00$^{c}$ |
| | Winter | 0.05±0.01$^{a}$ | 0.09±0.00$^{a}$ |
| | Spring | 0.05±0.01$^{a}$ | 0.06±0.00$^{bc}$ |
| | Summer | 0.05±0.01$^{a}$ | 0.07±0.00$^{b}$ |
| Oleic acid (C18:1n9) | Autumn | 23.20±0.03$^{b}$ | 22.51±0.04$^{a}$ |
| | Winter | 8.54±0.01$^{d}$ | 18.00±0.07$^{b}$ |
| | Spring | 23.83±0.01$^{a}$ | 4.40±0.05$^{d}$ |
| | Summer | 10.25±0.04$^{c}$ | 6.84±0.02$^{c}$ |
| Erucic acid (C22:1n9) | Autumn | 0.53±0.01$^{a}$ | 0.07±0.00$^{d}$ |
| | Winter | 0.24±0.00$^{c}$ | 0.18±0.00$^{a}$ |
| | Spring | 0.52±0.01$^{a}$ | 0.11±0.00$^{b}$ |
| | Summer | 0.28±0.00$^{b}$ | 0.09±0.00$^{c}$ |
| Nervonic acid (C24:1) | Autumn | 0.35±0.01$^{a}$ | 0.27±0.01$^{b}$ |
| | Winter | 0.24±0.00$^{ab}$ | 0.34±0.09$^{a}$ |
| | Spring | 0.26±0.00$^{b}$ | 0.18±0.09$^{c}$ |
| | Summer | 0.24±0.00$^{ab}$ | 0.11±0.00$^{d}$ |

**Continuation of The Table 3.**

| **Fatty acid** | | ***N. randalli Mean ± SE*** | ***B. boops Mean ± SE*** |
|---|---|---|---|
| ∑MUFA | Autumn | 27.63±0.03$^{b}$ | 28.76±0.06$^{a}$ |
| | Winter | 11.53±0.02$^{d}$ | 20.28±0.09$^{b}$ |
| | Spring | 27.99±0.02$^{a}$ | 5.53±0.05$^{d}$ |
| | Summer | 14.52±0.03$^{c}$ | 8.22±0.01$^{c}$ |
| Linoleic acid (C18:2n6) | Autumn | 7.59±0.02$^{a}$ | 0.83±0.01$^{b}$ |
| | Winter | 0.67±0.01$^{b}$ | 7.28±0.02$^{a}$ |

| | | | |
|---|---|---|---|
| | Spring | 7.64±0.02[a] | 0.69±0.01[c] |
| | Summer | 0.63±0.00[b] | 0.69±0.01[c] |
| (alfa) linolenic acid (ALA)(C18:3n3) | Autumn | 2.19±0.01[a] | 0.63±0.01[b] |
| | Winter | 0.86±0.01[c] | 1.26±0.01[a] |
| | Spring | 2.17±0.01[a] | 0.32±0.01[d] |
| | Summer | 1.32±0.01[b] | 0.47±0.01[c] |
| Stearidonic acid (C18:4n3) | Autumn | 0.13±0.00[c] | 0.72±0.01[a] |
| | Winter | 0.16±0.01[b] | 0.16±0.01[c] |
| | Spring | 0.13±0.00[c] | 0.11±0.01[d] |
| | Summer | 0.18±0.01[a] | 0.28±0.01[b] |
| Cis-11,14-eicosadienoic acid (C20:2n6) | Autumn | 2.24±0.01[a] | 0.15±0.03[d] |
| | Winter | 0.45±0.01[c] | 0.47±0.07[a] |
| | Spring | 2.24±0.01[a] | 0.22±0.08[b] |
| | Summer | 0.58±0.01[b] | 0.18±0.06[c] |
| Eicosatrienoic acid (C20:3n6) | Autumn | 0.48±0.01[c] | 0.19±0.01[d] |
| | Winter | 0.62±0.01[a] | 0.39±0.01[a] |
| | Spring | 0.47±0.01[c] | 0.25±0.01[c] |
| | Summer | 0.53±0.01[b] | 0.29±0.01[b] |
| Arachidonic acid (C20:4n6) | Autumn | 2.24±0.04[c] | 1.46±0.02[c] |
| | Winter | 2.70±0.01[b] | 1.32±0.01[d] |
| | Spring | 2.11±0.01[d] | 1.62±0.01[b] |
| | Summer | 3.22±0.06[a] | 2.03±0.01[a] |
| cis-13,16-docosadienoic acid (C22:2n6) | Autumn | 0.19±0.00[a] | 0.06±0.00[d] |
| | Winter | 0.14±0.00[b] | 0.23±0.01[a] |
| | Spring | 0.15±0.00[b] | 0.15±0.00[b] |
| | Summer | 0.10±0.01[c] | 0.11±0.00[c] |
| Eicosapentaenoic acid (EPA) (C20:5n3) | Autumn | 2.10±0.01[d] | 4.04±0.04[a] |
| | Winter | 2.96±0.05[b] | 1.32±0.01[d] |
| | Spring | 2.52±0.04[c] | 1.78±0.02[b] |
| | Summer | 4.00±0.07[a] | 1.44±0.02[c] |
| Docosatetraenoic acid (C22:4n6) | Autumn | 0.63±0.01[c] | 0.54±0.01[d] |
| | Winter | 1.24±0.01[a] | 0.82±0.01[c] |
| | Spring | 0.55±0.01[d] | 1.92±0.01[a] |
| | Summer | 1.15±0.01[b] | 1.64±0.01[b] |

**Continuation of The Table 3.**

| **Fatty acid** | | ***N. randalli* Mean ± SE** | ***B. boops* Mean ± SE** |
|---|---|---|---|
| Docosapentaenoic acid (C22:5n3) | Autumn | 2.16±0.02[b] | 1.12±0.01[a] |
| | Winter | 1.57±0.02[d] | 0.82±0.01[b] |
| | Spring | 1.89±0.02[c] | 0.59±0.01[d] |
| | Summer | 2.26±0.01[a] | 0.76±0.01[c] |
| Docosahexanoic acid (DHA) (C22:6n3) | Autumn | 6.57±0.05[d] | 11.13±0.05[c] |
| | Winter | 10.33±0.05[a] | 7.80±0.02[d] |

| | | | |
|---|---|---|---|
| | Spring | 6.81±0.01[c] | 19.46±0.03[a] |
| | Summer | 9.89±0.04[b] | 13.15±0.05[b] |
| ∑PUFA | Autumn | 26.52±0.10[a] | 20.88±0.07[c] |
| | Winter | 21.71±0.14[c] | 21.87±0.04[b] |
| | Spring | 26.66±0.09[a] | 27.11±0.05[a] |
| | Summer | 23.86±0.14[b] | 21.05±0.06[c] |
| Total | Autumn | 88.05±0.09[b] | 91.37±0.10[c] |
| | Winter | 89.36±0.32[a] | 94.63±0.26[b] |
| | Spring | 88.65±0.08[ab] | 95.43±0.23[a] |
| | Summer | 88.74±0.38[ab] | 95.29±0.17[a] |
| PUFA/SFA | Autumn | 0.78±0.00[a] | 0.50±0.49[a] |
| | Winter | 0.39±0.00[c] | 0.42±0.40[c] |
| | Spring | 0.78±0.00[a] | 0.43±0.43[b] |
| | Summer | 0.47±0.00[b] | 0.32±0.32[d] |
| ∑n6 | Autumn | 13.37±0.06[a] | 3.24±0.03[d] |
| | Winter | 5.82±0.02[d] | 10.51±0.02[a] |
| | Spring | 13.15±0.06[b] | 4.85±0.02[c] |
| | Summer | 6.21±0.09[c] | 4.95±0.03[b] |
| ∑n3 | Autumn | 13.15±0.05[d] | 17.64±0.08[b] |
| | Winter | 15.88±0.12[b] | 11.36±0.04[d] |
| | Spring | 13.51±0.05[c] | 22.26±0.03[a] |
| | Summer | 17.65±0.08[a] | 16.10±0.04[c] |
| n6/n3 | Autumn | 1.02±0.00[a] | 0.18±0.00[d] |
| | Winter | 0.37±0.00[c] | 0.92±0.00[a] |
| | Spring | 0.97±0.01[b] | 0.22±0.00[c] |
| | Summer | 0.35±0.00[d] | 0.31±0.00[b] |
| DHA/EPA | Autumn | 3.14±0.03[a] | 2.75±0.02[d] |
| | Winter | 3.49±0.06[b] | 5.92±0.09[c] |
| | Spring | 2.71±0.04[c] | 10.96±0.15[a] |
| | Summer | 2.47±0.04[d] | 9.12±0.16[b] |
| Others | Autumn | 11.95±0.09[a] | 8.63±0.10[a] |
| | Winter | 10.64±0.32[b] | 5.37±0.26[b] |
| | Spring | 11.35±0.08[ab] | 4.57±0.23[c] |
| | Summer | 11.26±0.38[ab] | 4.71±0.17[c] |

Seasonal differences in fatty acids of the same species are indicated by vertical lettering.

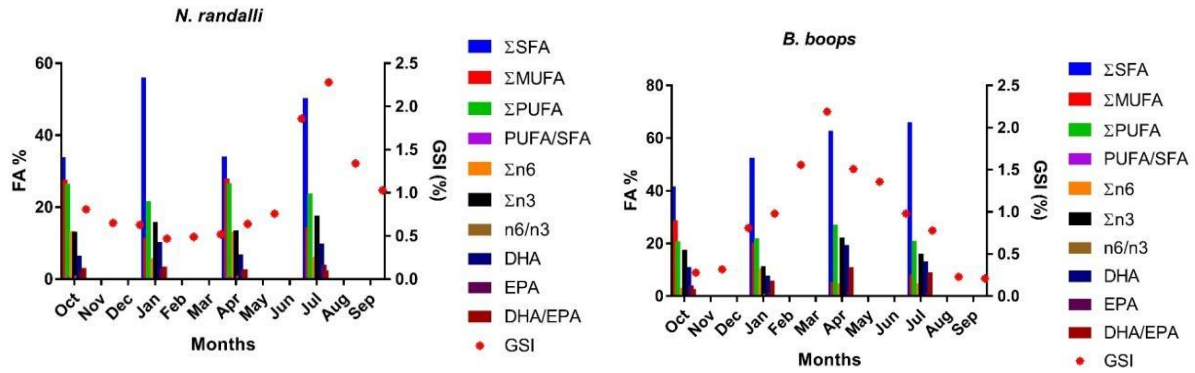


**Figure 3.** Relationship between GSI values with seasonal fatty acid levels of *N. randalli* and *B. boops*.

However, PUFA, MUFA, PUFA/SFA, and lipid levels increased in April at the beginning of gonad development for *N. randalli*. The lipid levels in the muscles of *B. boops* increased in July when the reproduction period finished, but the highest PUFA, DHA, and DHA/EPA ratios were observed in April when reproduction was high for *B. boops* (Figure 3).

Dobroslavić et al. (2017) reported that the gonadosomatic index and histological examination indicated the spawning season of the Bogue in the Adriatic region occurs from January to May, with the peak observed in February.

## CONCLUSIONS

Fish, an important source of PUFA, has the unique advantage that many seafood species are available, and consumers have a wide choice. Because Turkiye is surrounded by sea with different characteristics on three sides, it hosts a rich biodiversity of fish, which differ significantly in their nutritional composition. In the present study, SFAs were high in *N. randalli* and *B. boops* in all seasons. Therefore, excessive consumption is not recommended in the spring for *N. randalli* and in the summer for *B. boops* when their lipid contents are high. Consumption is recommended when protein and DHA content is high in winter for *N. randalli* and in the autumn and spring for *B. boops*. In addition, introducing these species as DHA-rich species would increase their nutritional benefits in terms of public health.

## AUTHOR CONTRIBUTIONS

All authors contributed to this research. The idea for the experiments came from H.U Koca. H.U Koca gathered the raw material and set up the plans for experiments. Ö. Aktaş and F. Pak performed the analyses of the samples. S. Bahadır Koca and G. Sürengil analyzed the data and wrote the article. G. Sürengil researched the literature, participated in drafting of the article and critical revision. All authors approved the final version of the manuscript.

## CONFLICT OF INTERESTS

The authors declare no conflict of interests.

## ETHICS STATEMENT

The paper is not requiring ethics committee approval.

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