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Volume: 10 Issue: 1 MARCH 2024 TURKISH JOURNAL OF MARITIME AND MARINE SCIENCES

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CONTENT

Research Article DOI: 10.52998/trjmms.1355596
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Modification of Gillnets and Their Effects on Catch Efficiency Used in Mediterranean Sand Smelt (*Atherina hepsetus* Linnaeus 1758) Fishing in the Sea of Marmara

Marmara Denizi'nde Gümüş Balığı (*Atherina hepsetus* Linnaeus 1758) Avcılığında Kullanılan Uzatma Ağlarının Modifikasyonu ve Av Verimi Üzerine Etkileri

Türk Denizcilik ve Deniz Bilimleri Dergisi Cilt: 10 Sayı: 1 (2024) 1-13

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ÖZET

Gümüş balığı; tüketim amaçlı kullanılmanın yanında, İstanbul Boğazı, Çanakkale Boğazı ve çevrelerinde olta ile lüfer avcılığında yem olarak kullanılmaktadır. Gümüş balığı, özellikle lüfer avcılığı döneminde ticari balıkçılar tarafından sade uzatma ağları ile yoğun olarak avlanmaktadır. Bu çalışmada Güney Marmara'da bir balıkçının 2014-2019 yılları arasındaki 2 yıllık periyotlarda gümüş balığı avcılığında kullandığı sade uzatma ağlarının teknik özellikleri ve yıllara göre ağlarında gerçekleştirdiği modifikasyonlar tespit edilmiştir. 2016-2017 yılında 2014-2015 yılına göre ağ göz açıklığı, ip kalınlığı, ağ rengi, ağ yüksekliği, mantar büyüklüğü, ağ uzunluğu; 2018-2019 yılında 2016-2017 yılına göre ip kalınlığı, ağ yüksekliği, ağ uzunluğunda modifikasyonlar yapıldığı belirlenmiştir. Ağlarda gerçekleştirilen modifikasyonlar sonucunda av veriminde 2017-2018 yılında 2016-2017 yılına göre av veriminde 5,79 kat artış olduğu tespit edilmiştir. En yüksek birim av miktarları (BAVM) 2016-2017 yılında 06:00 ile 08:59 saatleri (0.041 adet/m^2.operasyon^{-1}) arasında, 2017-2018 yılında ise 09:00 ile 11:59 saatleri (0.175 adet/m^2.operasyon^{-1}) arasında tespit edilmiştir. En yüksek BAVM kuş sürüsü avcılık yöntemi (1,309 adet/m^2.operasyon^{-1}) ile en düşük BAVM ise rastgele avcılık yöntemi (0.082 adet/m^2.operasyon^{-1}) ile belirlenmiştir. 2016-2017 ve 2017-2018 yılında avlanan uzatma ağları ile avlanan gümüş balıklarının ortalama boyları sırasıyla 12,7±0.09 cm, 12,7±0.07 cm; ortalama ağırlığı ise 12,6±0.21 gr, 13,1±0.17 gr olarak hesaplanmıştır. Bu çalışmada *Atherina hepsetus*'un uzatma ağları ile avcılığı ilk kez tanımlanmıştır. Hedeflenen bir türün avcılığında etkin bir şekilde kullanılan uzatma ağlarının ilk kez tanımlanması ile yıllara göre av veriminin, avlama yöntemlerinin ve av saatlerinin, av verimine etkilerinin tespit edilmesi balıkçılık yönetimi ve sürdürülebilir balıkçılık açısından önemlidir.

Anahtar sözcükler: Sürdürülebilir balıkçılık, Uzatma ağı, Lüfer avcılığı, *Pomatomus saltatrix*, Balıkçılık yönetimi
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ABSTRACT

Mediterranean sand smelt are intensively caught using gillnets by commercial fishermen. They are utilized for consumption purposes and also bait in line fishing to catch bluefish in the Canakkale Bosphorus, Istanbul Bosphorus and their surrounding areas. The technical characteristics of these gillnets were employed in South Marmara region over a 2-years period from 2014 to 2019 for catching *A.hepsetus*, and also modifications made to these nets during this time were identified. Chances in mesh size, twine thickness, color, floating size, height and length of gillnets occured from 2016-2017 to 2014-2015, while alterations in twine thickness, height, and length took place from 2018-2019 to 2016-2017. The impact of these modifications on the nets resulted in a 5.79 times increase in catch per unit in 2017-2018 compared to 2016-2017. The highest catch per unit effort (CPUE) was recorded between 06:00-08:59 hours (0.041 individuals/m^2.operation^{-1}) in 2016-2017, while observed the highest CPUE was between 09:00-11:59 hours (0.175 individuals/m^2.operation^{-1}) in 2017-2018. The sea-bird method yielded the highest CPUE (1.309 individuals/m^2.operation^{-1}), whereas the random method produced the lowest CPUE (0.082 individuals/m^2.operation^{-1}). The average length of *A.hepsetus* was calculated as 12.7±0.09 cm in 2016-2017 and 12.7±0.07 cm in 2017-2018, while the average weight was determined to be 12.6±0.21 grams and 13.1±0.17 grams, respectively. This study marks the first time definition of gillnets designed for catching *Atherina hepsetus*. It is of great importance for fisheries management and sustainable fisheries practices to identify effective gillnets for targeting specific species for the first time, and to assess their impact on catch efficiency, fishing methods, and catch time across different years.

Keywords: Sustainable fisheries, Gillnet, Bluefish fishing, *Pomatomus saltatrix*, Fisheries management

1. GİRİŞ

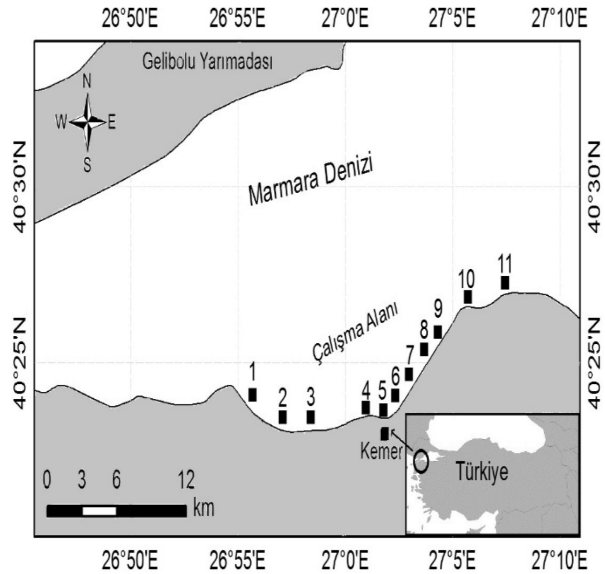
Ülkemiz denizlerinde dağılım gösteren Atherinidae ailesine ait gümüş türleri (*Atherina boyeri* Risso, 1810; *Atherina hepsetus* Risso, 1810*; Atherina presbyter* Cuvier, 1829) kıyısal alanlardan, nehir ağızlarına, lagünlerden, tuzlu bataklıklara ve iç sulara kadar dağılım gösteren, geniş adaptasyon yeteneğine sahip türlerdir (Leonardos, 2001; Çetinkaya *vd.,* 2011; İnnal ve Engin, 2020). Gümüş balıklarının ekolojik öneminin yanında ticari olarak da değerlendirilmesi, türlere ekonomik değer katması bakımından önemlidir (De Morais *vd.,* 2016). Bu türler dünyada kıyı sürütme ağları, kaldırma ağları, uzatma ağları, gırgır ve trol takımları ile avlanabilmektedir (Leonardos, 2001; Çetinkaya *vd.,* 2010). Türkiye'de ise kaldırma ağları ve olta takımları ile avlandığı bilinen türün, uzatma ağları ve gırgır tekneleri ile de avlandığı gözlemlenmektedir (Çetinkaya *vd.,* 2011; İnnal ve Engin, 2020).

Gümüş türleri, lüfer balığı (*Pomatomus saltatrix* Linnaeus, 1766) gibi predatör türlerin ana besinini oluşturan önemli yem balıklarıdır (De Morais *vd.,* 2016). Gümüş türleri, lüfer balığının olta ile avcılığında yem olarak kullanıldığı için, Ekim-Mart aylarındaki lüfer avcılığı döneminde özellikle Çanakkale ve İstanbul Boğazları çevrelerinde uzatma ağları ile yoğun olarak avlanılmaktadır (Ceyhan, 2005; Ceyhan ve Akyol, 2005). Fakat son yıllarda ekosistemde meydana gelen değişimler ve aşırı avcılık ile ilgili yapılan çalışmalar göz önüne alındığında; ülkemizde 2010 yılında 1142 ton avlanan gümüş türlerinin av miktarının, 2022 yılında %43 (494 ton) azalması, gümüş stoklarında bir sorun olduğunu göstermektedir (TÜİK, 2022). Bu azalmanın birçok sebebi olabilmekle birlikte (Hilborn *vd.,* 2020; Palomares *vd.,* 2020), 2021 yılında Marmara Denizi'nde meydana gelen müsilaj felaketindeki toplu balık ölümlerden en çok etkilenen türün *Atherina* sp. olduğu belirtilmiştir (Karadurmuş ve Sarı, 2021).

Dünyada ve Türkiye'de gümüş türlerinden *A.boyeri*'nin avcılığına ilişkin çalışmalar yoğunlaşmasına rağmen (Cilbiz *vd.,* 2020; Öztekin *vd.,* 2019; Rodríguez-Climent *vd.,* 2012; Yıldız *vd.,* 2013), *A.hepsetus*'un avcılığı, avcılık yöntemleri ve av verimleri ile ilgili veri bulunmamaktadır. Tüketim amaçlı kullanılan ve ekolojik önemi olan her bir türün avcılığından kullanılan av araçlarının teknik özelliklerinin tanımlanması ve bu av araçlarının av verimlerinin belirlenmesi sürdürülebilir bir balıkçılık yönetimi için oldukça önemlidir (De Morais *vd.,* 2016; Emirbuyuran ve Çalık, 2016; Öztekin *vd.,* 2019). Bu çalışma Marmara Denizi'nde gümüş balığı avcılığında kullanılan uzatma ağlarının özelliklerinin ve ağlarında gerçekleştirdiği modifikasyonlar ilk kez tanımlanması, gümüş balığının tespite etme yöntemlerinin ilk kez tanımlanması, av dönemi ve av saatlerinin av verimlerine etkilerinin belirlenmesi bakımından önem taşımaktadır.

2. MATERYAL VE YÖNTEM

Bu çalışma Marmara Denizi'nin güney bölümünde yer alan Kemer Bölgesi'nde gerçekleştirilmiştir (Şekil 1). Çalışmada 6.5 metre (m) uzunluğunda, 28 HP motor gücünde #M.Deniz 17# isimli balıkçı teknesi kullanılmıştır. Teknenin 2014-2019 arasındaki 2 yıllık periyotlarda gümüş balığı avcılığında kullandığı sade uzatma ağlarının teknik özellikleri ve yıllara göre ağlarında gerçekleştirdiği modifikasyonlar belirlenmiştir. Uzatma ağlarının teknik özellikleri yerinde ölçüm, sayım, inceleme ve Tokaç (2011)'den yararlanılarak hesaplamalar ile belirlenmiştir. Uzatma ağlarına ait teknik planlar ise MS Visio 10.0 programı yardımıyla FAO standartlarına göre ölçekli olarak çizilmiştir (Nedelec, 1975; Nomura ve Yamazaki, 1975; FAO, 1978).
Gümüş balığının tür tespiti Whitehead *vd.* (1986) referans alınarak yapılmıştır. Çalışma alanında bölge balıkçılarının gümüş balığı avladıkları 11 av sahasında voli yöntemiyle avcılık denemeleri gerçekleştirilmiştir. Kasım 2016-Nisan 2017 ayları arasında voli yöntemiyle 191 adet, Kasım 2017-Nisan 2018 ayları arasında ise 190 adet avcılık denemesine eşlik edilmiştir. Avlanan gümüş balıklarının birim av miktarları (BAVM) hesaplanarak av verimliliği hesaplanmıştır. Ayrıca belirtilen tarihlerde gerçekleştirilen operasyonlarda 06:00-24:00 saatleri arasındaki 3 saatlik periyotlarda BAVM'leri değerlendirilmiştir. Yine aynı tarihlerde ticari balıkçının 6 farklı, gümüş balığı sürülerini tespit etme yöntemleri tanımlanarak bu yöntemlerin toplam 82 adet operasyonda, operasyon başına BAVM'leri hesaplanmıştır.



Şekil 1. Çalışma alanı (■ Av sahalarını temsil eder)

Bir birim uzunluktaki ağın av miktarını gösteren (BAVM)'nin hesaplanmasında Balık ve Çubuk (2001)'de belirtilen formül modifiye edilerek kullanılmıştır.

$$BAVM = \Sigma(n/n')/N \qquad (1)$$

n: Bir seferde yakalanan av miktarı (birey sayısı (adet); n': Ağın sudaki kurşun yaka uzunluğu (m) x ağın sudaki yüksekliği (m); N: Deneme sayısı (operasyon))
Bu formüle göre avlanan gümüş balıklarının yıllara, av sahalarına ve av saatlerine göre BAVM'leri "adet/m^2.operasyon^{-1}" olarak hesaplanmıştır.
2016-2017 ve 2017-2018 yıllarında avlanan gümüş balıklarının toplam boyu 1 milimetre (mm) hassasiyetli ölçüm cetveli, ağırlığı ise 1 gram (gr) hassasiyetli elektronik terazi ile araştırma sahasında teknede ölçülmüştür. Avlanan gümüş balıklarından alt örnekleme yapılarak, örneklenen bireylerin minimum, maksimum ve ortalama boy ile ağırlık değerleri hesaplanmıştır.

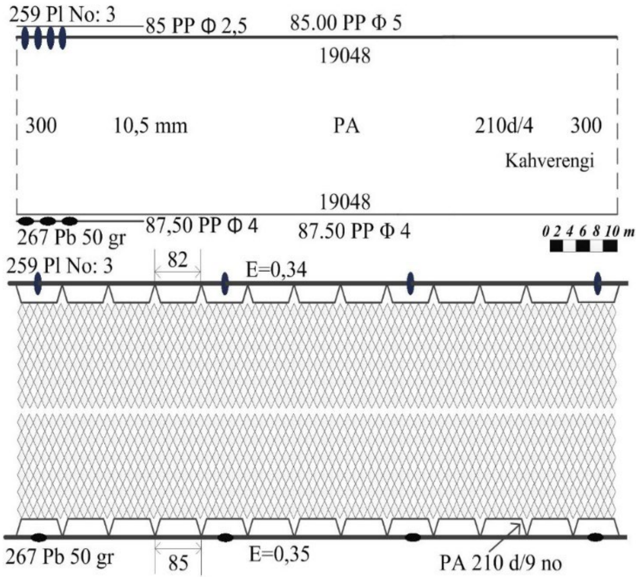
Denemelerde elde edilen veriler IBM, Corp (2017) istatistik programı ile istatistiksel olarak değerlendirilmiştir. 2016-2017 ve 2017-2018 yıllarındaki av sahalarında gerçekleştirilen operasyonlardaki birey sayıları; 2016-2017 yıllarında saatlik periyotlarda av sahalarında gerçekleştirilen operasyonlarda avlanan birey sayıları Kruskal Wallis H Testi ile test edilmiştir. Yıllar arasında, aynı av sahasında ve aynı saatlik dilimlerdeki birey sayıları Mann Whitney U Testi ile karşılaştırılmıştır. 2017-2018 yıllarında gümüş balığı sürülerini tespit etme yöntemleriyle yakalanan gümüş balıklarının birey sayıları Kruskal Wallis H Testi ile istatistiksel olarak değerlendirilmiştir. Karşılaştırılan iki farklı dönem arasındaki boy dağılımları ve ağırlık dağılımları Mann Whitney U Testi ile istatistiksel olarak analiz edilmiştir.

3. BULGULAR

Çalışmada gümüş balığı avcılığında kullanılan uzatma ağlarının teknik özellikleri ve yıllara göre ağlarda gerçekleştirilen modifikasyonlar Tablo 1'de gösterilmektedir. 2014-2015 yılında kullanılan gümüş uzatma ağı; 10.5 mm göz açıklığında, 210d/4 no (numara) ip kalınlığında, kahverengi renkte olup, ağı yaka ipine donatmakta ise 210d/9 no poliamid ip kullanılmıştır. Batırıcı olarak 50 gr kurşun, yüzdürücü olarak ise 3 no poliproplen mantar ile donatılmıştır. Kullanılan ağın uzunluğunun 85 m, yüksekliğinin 2,95 m olduğu tespit edilmiştir. Mantar ve kurşun yakalardaki, mantar ve kurşunların 3 boş 1 dolu tercih edildiği belirlenmiştir (Şekil 2).

Tablo 1. Gümüş balığı avcılığında kullanılan uzatma ağlarının yıllara göre teknik özellikleri (AGA:Ağ göz açıklığı, İp kal:İp kalınlığı, E:Donam faktörü, P:Pot oranı, YGS:Yükseklik göz sayısı, MY:Mantar yaka, KY:Kurşun yaka, Y:Yüzdürücü sayısı, B:Batırıcı sayısı, ÇB:Çako boyu)

Yıl	AGA (mm)	İp kal	Ağ rengi	E		P		YGS	Gergin ağ uzunluğu (m)	Gergin ağ yüksekliği (m)	Ağın sudaki uzunluğu (m)		Ağın sudaki yüksekliği (m)	Y	B	ÇB (mm)	
				MY	KY	MY	KY				MY	KY		(adet)		MY	KY
2014 2015	10.5	210d 4 no	Kahverengi	0.34	0.35	0.66	0.65	300	250	3,15	85	87,5	2,95	259	267	82	85
2016 2017	10.4	210d 3 no	Turuncu					400	300	4,16	102	105	3,90	311	412		
2018 2019		210d 2 no						450	350	4,68	119	122,5	4,38	363	480		

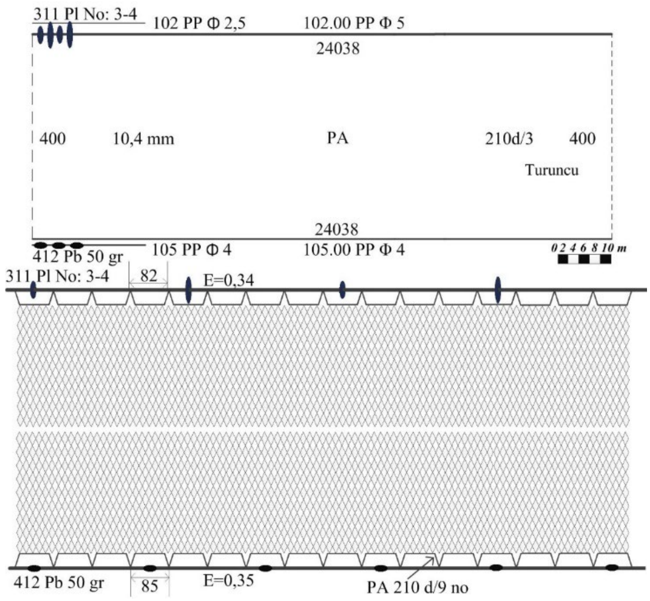


Şekil 2. 2014-2015 yılında gümüş balığı avcılığında uzatma ağının teknik özellikleri

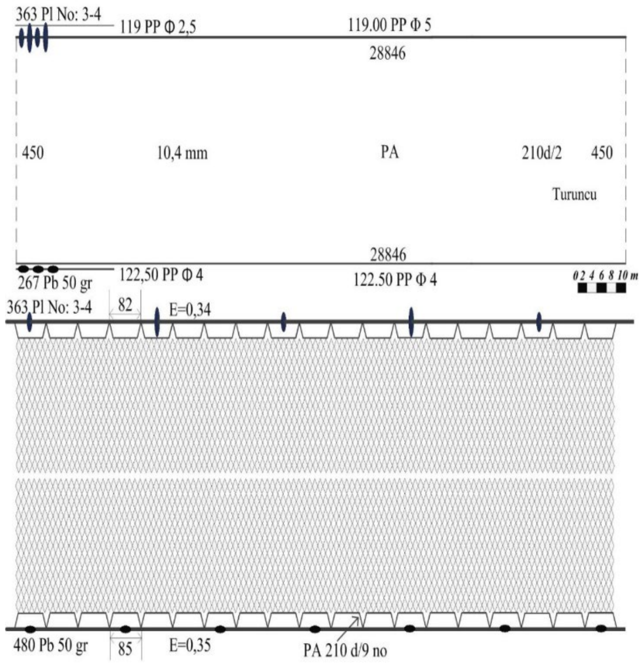
2016-2017 yılında kullanılan sade gümüş balığı uzatma ağında 2014-2015 yılında göre bazı değişiklikler gerçekleştirilerek yeni bir ağ kullanımına başlanılmıştır. Bu bağlamda oluşturulan yeni ağ; ağ göz açıklığı 10.5 mm yerine 10.4 mm, ip kalınlığı 210d/4 no yerine 210d/3 no, ağın rengi ise kahverengi yerine turuncu olacak şekilde hazırlanmıştır. Yine kullanılan ağın yüksekliği 2,95 metreden 3,90 metreye, ağın uzunluğu ise 85 metreden 102 metreye çıkarılmıştır. Mantar numarası olarak 3 ve 4 no mantarlar birlikte kullanılmaya başlanılmıştır. Kurşun yakalardaki kurşunlar ise 3 dolu 1 boştan, 2 dolu 1 boşa değiştirilmiştir (Şekil 3).

2018-2019 yılında ise 2016-2017 yılına göre ağın ip kalınlığı 210d/3 no yerine 210d/2 no ile değiştirilerek yeniden donatılmıştır. Ağın yüksekliğinin 4,38 metreye, ağın uzunluğunun ise 119 metreye çıkarılması dışında, ağın diğer özelliklerinde değişiklik gerçekleştirilmemiştir (Şekil 4).

Gümüş balığı avlamak için uzatma ağları ile 11 av sahasına 2016-2017 yılında gerçekleştirilen 191 operasyonda 1982 adet, 2017-2018 yılında gerçekleştirilen 190 operasyonda 13389 adet gümüş balığı avlanılmıştır. Gerçekleştirilen operasyonlarda 2016-2017 yılında birim av miktarı ortalama 0.025 adet/m^2.operasyon^{-1}, 2017-2018 yılında ise ortalama 0.131 adet/m^2.operasyon^{-1} olarak tespit edilmiştir (Tablo 2). Avlanan gümüş balıklarının tamamının, lüfer avcılığında yem olarak değerlendirilmek üzere avlanıldığı gözlemlenmiştir.



Şekil 3. 2016-2017 yılında gümüş balığı avcılığında uzatma ağının teknik özellikleri



Şekil 4. 2018-2019 yılında gümüş balığı avcılığında uzatma ağının teknik özellikleri

2016-2017 yılında en fazla operasyon 4 no'lu av sahasında gerçekleştirilmiş ve en çok birey 607 adet ile 4 no'lu av sahasında avlanmış, en yüksek BAVM (0.071 adet/m^2.operasyon^{-1}) ise 9 no'lu av sahasında) tespit edilmiştir. 2017-2018 yılında ise en fazla operasyon 5 no'lu av sahasına gerçekleştirilmiş ve en çok birey 4926 adet ile 5 no'lu av sahasından elde edilmiştir. En yüksek BAVM (0.283 adet/m^2.operasyon^{-1}) ise 10 no'lu av sahasında avlanırken, 9 no'lu istasyonda hiç avcılık denemesi gerçekleştirilmemiş ve hiç birey yakalanmamıştır (Tablo 2). 2017-2018 yılında 2016-2017 yılına göre BAVM olarak toplamda 5,79 kat daha fazla birey avlandığı tespit edilmiştir. 2016-2017 yıllarında av sahalarında gerçekleştirilen operasyonlarda yakalanan birey sayıları ve 2017-2018 yıllarında birey sayılarında istatistiksel olarak anlamlı bir fark bulunmuştur ($p<0.05$). Yıllar arasında aynı av sahasında, 10 numaralı av sahası hariç (p:0.116, $p>0.05$), birey sayılarında istatistiksel olarak anlamlı bir fark bulunmuştur ($p<0.05$).

Tablo 2. 2016-2017 ve 2017-2018 yıllarında av sahalarında uzatma ağları ile avlanan gümüş balığının BAVM'leri (n: Birey sayısı; N: Deneme sayısı)

Yıl	**2016-2017**			**2017-2018**		
Av Sahası	**N**	**n**	**BAVM**	**N**	**n**	**BAVM**
1	4	7	0.004	16	1696	0.198
2	3	2	0.002	9	976	0.202
3	16	136	0.021	26	1112	0.08
4	70	607	0.021	36	1396	0.072
5	36	551	0.037	50	4926	0.184
6	8	17	0.005	30	1797	0.112
7	17	77	0.011	8	309	0.072
8	15	106	0.017	6	686	0.213
9	9	260	0.071	0	0	0
10	9	191	0.052	1	152	0.283
11	4	28	0.017	8	339	0.079
Toplam	**191**	**1982**	**0.258**	**190**	**13389**	**1.494**
Ortalama	**17.4**	**180.2**	**0.025**	**17.3**	**1217.2**	**0.131**

Gümüş balığı avlamak için uzatma ağlarıyla 06:00-24:00 arasındaki 3 saatlik periyotlar arasında operasyonlar gerçekleştirilmiştir. 2016-2017 yılında en fazla operasyon 65 operasyon ile 18:00 ile 20:59 arasında gerçekleştirilmiş ve 652 adet gümüş yakalanmıştır. En yüksek BAVM (0.041 adet/m^2.operasyon^{-1}) ise 06:00 ile 08:59 saatleri arasında elde edilmiştir. 2017-2018 yılında ise 76 operasyon ile en fazla operasyon 15:00 ile 17:59 arasında saatleri gerçekleştirilmiş ve 6208 adet ile en çok birey avlanmış, 09:00 ile 11:59 saatleri arasında en yüksek BAVM (0.175 adet/m^2.operasyon^{-1}) elde edilmiştir (Tablo 3). 2016-2017 yıllarında saatlik periyotlarda avlanan birey sayılarında istatistiksel olarak anlamlı bir fark bulunmuştur ($p<0.05$). 2017-2018 yıllarında saatlik periyotlarda avlanan birey sayılarında anlamlı bir fark bulunmamıştır (p:0.291, $p>0.05$). Yıllar arasında aynı saat dilimlerinde birey sayılarında istatistiksel olarak anlamlı bir fark bulunmuştur ($p<0.05$).

Tablo 3. 2016-2017 ve 2017-2018 yıllarında 3 saatlik periyotlar arasında avlanan gümüş balığı BAVM'leri (n: Birey sayısı; N: Deneme sayısı)

Yıl	**2016-2017**			**2017-2018**		
Saat	**N**	**n**	**BAVM**	**N**	**n**	**BAVM**
06:00-08:59	18	300	0.041	7	448	0.119
09:00-11:59	17	72	0.01	28	2626	0.175
12:00-14:59	25	177	0.017	24	1016	0.079
15:00-17:59	28	211	0.018	76	6208	0.152
18:00-20:59	65	652	0.024	29	1726	0.111
21:00-23:59	38	570	0.037	26	1365	0.098

Güney Marmara'nın Kemer Bölgesi'nde ticari balıkçının 6 farklı yöntem ile gümüş balığı sürülerinin yerinin tespit ederek avcılık yaptığı belirlenmiştir. Bölgedeki gümüş balığı sürülerini tespit etme ve avlama yöntemlerinin tanımlamaları Tablo 4'te sunulmuştur. Çalışmada tekne sahibinin kendi isteği doğrultusunda gümüş balığı avlama ve avı tespit etme yöntemlerinden 29 operasyon ile en çok rastgele avcılık yöntemi denenmiş, 2 operasyon ile en az kuş sürüsü yönteminin tercih edildiği belirlenmiştir. En yüksek BAVM kuş sürüsü yöntemi (1.309 adet/m^2.operasyon^{-1}) ile en düşük BAVM ise rastgele avcılık yöntemi (0.082 adet/m^2.operasyon^{-1}) ile elde edilmiştir (Tablo 5). 2017-2018 yıllarında gümüş balığını tespit etme yöntemleri ile yakalanan gümüş balıklarının birey sayıları arasında istatistiksel olarak anlamlı bir fark bulunmuştur (p:0.001, $p<0.05$).

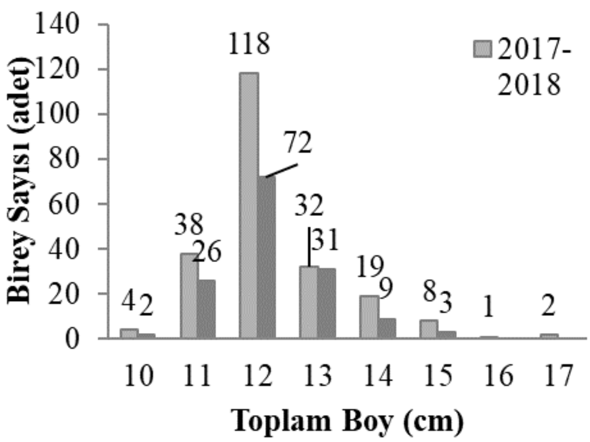
Tablo 4. Gümüş balığı sürülerini tespit etme ve avlama yöntemleri

Rastgele	Ayna	Balık Bulucu	Oynak	Üstten Görme	Kuş Sürüsü
Ticari balıkçıların, önceki yıllardaki tecrübelerine göre yüksek av verimi sağladığı bölgelere, öncelik vererek ağların rastgele atılması şeklinde yapılan avcılıktır.	Teknelerin baş kısmına yakın ve karina bölgesinde bulunan 15x25 cm genişliğinde camlı bölgeden, bir gözlemcinin denize bakarak balık sürüsünü tespit etmesi ile ağların atılması ile yapılan avcılıktır.	Genellikle daha derin bölgelerde ve kış aylarında, balık bulucu cihaz (echo-sounder) ile balık sürülerinin tespit edilerek yapılan avcılıktır.	Deniz yüzeyinin sakin olduğu günlerde, balıkçıların deniz yüzeyine bakarak balıkların su üstü hareketlerini fark etmesi ve izlemesi sonucu, balık sürüsünün tespit edilerek yapılan avcılıktır.	Deniz yüzeyinin sakin olduğu günlerde ve sığ sularda, teknenin baş kısmında bulunan bir gözlemcinin deniz yüzüne bakarak, balık sürüsü tespit ettiği anda, balık sürüsünün etrafının çevrilmesi ile gerçekleştirilen operasyondur.	Martı (*Larus* sp.), karabatak (*Phalacrocorax carbo*) gibi deniz su kuşlarının, suya dalıp çıktığı ve yoğunlaştığı bölgelere gerçekleştirilen operasyondur.

Tablo 5. 2017-2018 yıllarında gümüş balığını tespit etme yöntemleri ile avlanan gümüş balıklarının BAVM'leri (n: Birey sayısı; N: Deneme sayısı)

2017-2018	N	n	BAVM
Rastgele	29	1273	0.082
Ayna	26	4229	0.303
Balık bulucu	10	863	0.161
Oynak	11	984	0.167
Üstten görme	4	312	0.145
Kuş sürüsü	2	1405	1,309

2016-2017 ve 2017-2018 yıllarında avlanan uzatma ağları ile avlanan gümüş balıklarının ortalama boyları sırasıyla 12,7 ± 0.09 cm, 12,7 ± 0.07 cm; ortalama ağırlığı ise 12,6 ± 0.21 gr, 13,1 ± 0.17 gr olarak hesaplanmıştır. 2016-2017 yılında avlanan en küçük bireyin boyu 10.3 cm, en büyük bireyin ağırlığı 15,1 cm; 2017-2018 yılında avlanan en küçük bireyin boyu 10.6 cm, en büyük bireyin ağırlığı 17,8 cm olduğu tespit edilmiştir (Tablo 6, Şekil 5). Karşılaştırılan iki farklı dönem arasındaki boy dağılımlarında istatistiksel olarak anlamlı bir farklılık yokken (p:0.706, $p>0.05$), ağırlık dağılımlarında (p:0.014, $p<0.05$) anlamlı bir fark bulunmuştur.



Şekil 5. 2016-2017 ve 2017-2018 yıllarında avlanan gümüş balıklarının toplam boy-birey sayısı dağılımı

Tablo 6. 2016-2017 ve 2017-2018 yılında uzatma ağları ile avlanan gümüş balıklarının boy-ağırlık değerleri (n:Birey sayısı, Min:Minimum, Max: Maksimum, Ort: Ortalama, SH: Standart hata)

Yıl	n	Boy (cm)			Ağırlık (gr)		
		Min	Max	Ort ± SH	Min	Max	Ort ± SH
2016-2017	143	10.3	15,1	12,7 ± 0.09	9	21	12,6 ± 0.21
2017-2018	222	10.6	17,8	12,7 ± 0.07	9	21	13,1 ± 0.17
Toplam	365	10.3	17,8	12,7 ± 0.05	9	21	12,9 ± 0.14

4. TARTIŞMA

Gümüş balığı uzatma ağlarında gerçekleştirilen modifikasyonların temel sebebi, av verimini arttırma düşüncesidir. 2016-2017 yılında 2014-2015 yılına göre ağ göz açıklığı, ip kalınlığı, ağın rengi, mantar büyüklüğü, ağın yüksekliği, ağın uzunluğu; 2018-2019 yılında 2016-2017 yılına göre ip kalınlığı, ağın yüksekliği, ağın uzunluğunda değişiklikler meydana geldiği tespit edilmiştir. Literatürde de ağ göz büyüklüğünün ve ip kalınlığının (Acarli *vd.,* 2013; Brinkhof *vd.,* 2020; Kara, 2003; Petrakis ve Stergiou, 1996; Dereli *vd.,* 2022a; Dereli vd., 2022b); ağın renginin (Beğburs ve Kebapçıoğlu, 2009; Orsay ve Duman, 2012) av verimini etkilediğine dair çalışmalar bulunmaktadır. Ayrıca taranan alanın artması dolayısıyla ağ yüksekliğinin (Machiels *vd.,* 1994); ağ uzunluğunun (Hamley, 1975) av verimine etki ettiğini gösteren çalışmalar bulunmaktadır (Hamley, 1975; Yüksel ve Aydın, 2012). Bu çalışmada 2016-2017 yılı ile 2017-2018 yılları arasında av veriminde toplamda 5,79 kat farklılık görülmesinin sebebi, ağ yüksekliği ve ağ uzunluğu artmasına bağlı taranan alanın artması ile açıklanabilir. Yine ağda gerçekleştirilen diğer modifikasyonların av veriminin artmasında etkili olduğu düşünülmektedir.

Her iki avcılık döneminde de neredeyse aynı sayıda operasyon gerçekleştirilip, av verimleri arasında farklılıklar görülmesi balığın bulunurluğu ve bolluğu ile açıklanabilir. Nitekim Hamley, (1975) ve Özyurt *vd.,* (2019), balık bolluğu ve bulunurluğunun av veriminde etkili olduğunu belirtmiştir. Aynı zamanda Rahman *vd.,* (2022) tarafından belirtildiği üzere hava şartları, su sıcaklıkları gibi çevresel değişkenlerin av veriminde yıllara göre belirlenen değişikliğin sebebi olabileceği düşünülmektedir.

Bu çalışmanın gerçekleştirildiği dönemde TÜİK verilerine göre 2017 yılında 489 ton, 2018 yılında 591 ton gümüş türleri avlanması, gümüş balığının yıllar arasındaki av miktarındaki artış ile paralel olduğunu göstermektedir (TÜİK, 2022). Fakat balıkların dağılımlarının ve davranışlarının farklılıklarından dolayı, aynı ağla farklı sezon ve yerde yapılan avcılığın bile farklı sonuçlar ortaya koyabileceği unutulmamalıdır (Olin *vd.,* 2004). Yine aynı bölgede operasyon gerçekleştirilen farklı bir teknenin de av verimi farklılık gösterebilir. Bu çalışmada ağlarda tespit edilen modifikasyonların av verimini arttırırken, av baskısı oluşturabileceği göz ardı edilmemelidir. Nitekim Türkiye İstatistik Kurumu verilerine göre gümüş türlerinin av miktarlarının 2010 yılından 2022 yılına kadar azalma eğiliminde olması gümüş türlerinin stoklarında bir sorun olduğunu göstermektedir (TÜİK, 2022). Stoklardaki azalmanın birçok sebebi olabilmekle birlikte, müsilaj gibi felaketlerin gümüş stoklarının zarar görmesinde etkili olabileceği düşünülmektedir. Nitekim Karadurmuş ve Sarı (2021) çalışmasında müsilajdan en çok etkilenen türün *Atherina* sp. olduğu belirtilmişlerdir. Aynı zamanda uzatma ağları ile lüfer avcılığında yem olarak kullanılmak üzere yakalanan gümüş bireylerinin TÜİK kayıtlarına girmediği de göz ardı edilmemelidir.

Her iki dönemde de avcılık operasyonlarının Kemer limanına yakın bölgedeki 4 ve 5 no'lu av sahalarında yoğunlaştığı görülmektedir. Bu bölgelerin avcılık yapılan teknenin bağlama limanına yakın olması dolayısıyla yakıt maliyetinin azalması ve yine bu av sahalarının tatlısu girdisinin bulunduğu Kemer Çayı'na yakın olmasından kaynaklandığı düşünülmektedir. Çünkü geniş adaptasyon yeteneğine sahip olduğu bilinen gümüş balığı türlerinin (Çetinkaya *vd.,* 2010); tatlı su girdisi olan bölgelerde yoğunlaşması beklenmektedir. Yine balıkçıların daha önceki tecrübeleri ve bilgileri bu alanlarda daha yoğun avcılık yapmalarını tetiklemektedir. Fakat aynı bölgede diğer ticari teknelerin de yoğun avcılık gerçekleştirmesi 4 ve 5 no'lu istasyonlarda av baskısına sebep olabilmektedir. Bu durum ise av verimine etki etmektedir. Yine yoğun av yapılan av sahalarında bölgedeki 37 adet ticari balıkçının av operasyonu gerçekleştirdiği düşünülürse (ÇİTOM, 2021), operasyonların *Zostera* sp., *Posidonia oceanica* gibi deniz çayırları ile bentik habitatta bulunan hassas ve nesli tükenmekte olan *Pinna nobilis* gibi kıyısal ekosistemdeki hassas türler üzerindeki etkileri araştırılmalıdır. Kemer limanına uzak bölgelerdeki 1 ve 2 ile 9, 10. 11 no'lu av sahalarında daha az sayıda operasyon gerçekleştirilmesi, uzaklığın fazla dolayısıyla yakıt maliyetinin yüksek olması ile ilgili olduğu düşünülmektedir. Özellikle lüfer avcılığında kullanılan ve ticari olarak değerlendirilmeyen gümüş balığı için uzak av sahalarında gitmek oldukça maliyetlidir. Fakat uzak olduğu görülen 9 ve 10 no'lu sahalarında 2016-2017 yıllarında en yüksek BAVM görülürken, 2017-2018 yıllarında en yüksek BAVM 10. 8 ve 2 no'lu av sahalarında tespit edilmiştir. Fakat bu durumda lüfer avcılığının yoğun olduğu dönemlerde uzak av sahalarına yönelimi tetiklemektedir. Her iki dönemde de uzak av sahalarında daha yüksek BAVM görülmesi, av baskısının bu alanlarda daha az olması ile ilişkili olabileceği düşünülmektedir.

Bu çalışmada saatlik periyotlara göre bir türün av verimliliği üzerine ilk veriler elde edilmesi bakımından önemlidir. Farklı av saatlerinde yapılan gümüş balığı avcılığında, 2016-2017 yıllarında avcılık çabasının gün batımı (18:00-20:59) saatlerinde yoğunlaştığı, fakat av veriminin gün doğumu saatlerinde (06:00-08:59) daha yüksek olduğunu görülmektedir. 2017-2018 yıllarında ise avcılık çabasının 15:00-17:59 saatlerinde yoğunlaştığı, fakat av veriminin 09:00-11:59 saatlerinde daha yüksek olduğunu görülmektedir Av araçlarının gün batımı ve gün doğumu gibi operasyon zamanlarının av verimini etkilediği (Aydın ve Metin, 2008), bununda beslenme göçü (Mazeroll ve Montgomery, 1998), güneş ışığını takip etme (Daum ve Osborne, 1998), ağın görünürlüğü üzerinde ışığın etkisi (Wardle *vd.,* 1991) gibi faktörler ile ilgili olabileceğine dahil literatürde bilgiler bulunmaktadır. Bu çalışmada da av veriminin gün batımı ve gün doğumu saatlerinde yoğunlaşması literatür bilgileri ile benzerlik göstermektedir. Fakat av saatlerine göre belirlenen av verimi ve operasyon sayılarının; yem balığı olarak avlanan gümüş balığı ile ticari olarak avlanan lüfer balığı ile ilişkisi olduğu düşünülmektedir. Yani operasyon sayısının az olduğu saatlerde, lüfer balığı avcılığı için çaba harcanabilmektedir.

Gümüş balığı sürülerini tespit etmede ve avlamada kullanılan yöntemler belirlenerek, bu yöntemlerin kullanılma durumu ve av verimleri ortaya konulmuştur. Yöntemler balıkçılıkta bilinmesine rağmen (Çelikkale *vd.,* 1993), türe özgü değerlendirmeler ile literatüre katkı sağlayacağı düşünülmektedir. Bu yöntemlerden kuş sürüsü yöntemi ile kıyı balıkçılığı arasında bir ilişki olduğu Ceyhan ve Akyol (2020) tarafından bildirilmiştir. Kuş sürüsü yöntemi sadece su kuşlarının yoğunlaştığı ve dalıp çıktığı alanlarda kullanılmakta olup, bu çalışmada en az tercih edilen yöntem olmasına rağmen en yüksek av verimi elde edilmiştir. Az tercih edilmesi ise çalışma döneminde kuş sürülerinin tanımlanan davranışları göstermemesi ve avcılık alanında yoğunlaşmaması ile ilişkilidir. Rasgele yöntemin ise en çok tercih edilmesi balıkçıların önceki yıllarda yüksek av verimi sağladığı noktalara, öncelik vermesi ile ilgilidir. Fakat balıkçıların kullandıkları gümüş balığı tespit etme yöntemlerinin ve operasyon sayılarının; gümüş balığının bulunurluğu, hava şartları, teknenin donanımı, tekne büyüklüğü, tayfa sayısı gibi çeşitli faktörler ile ilişkili olduğu unutulmamalıdır.

Ülkemizde yapılan çalışmalarda yakalanan gümüş balığının boy-ağırlık değerleri arasında farklılıklar görülmesi (Tablo 7), gümüş balığının avcılık yöntemlerinin (gırgır, ığrıp, uzatma ağı, balık halinden örnekleme gibi) kullanılmasından kaynakladığı düşünülmektedir. Bu çalışmada 10.4 mm göz açıklığında uzatma ağı ile gümüş bireylerinin elde edilmesi, boy ve ağırlık gruplarının daha az değişiklik göstermesine sebep olmaktadır. İstatistiksel olarak da yıllara göre boy dağılımları anlamlı bir farklılık göstermez iken ($p>0.05$), ağırlık dağılımları arasında anlamlı bir farklılık belirlenmiştir ($p<0.05$). Aynı zamanda boy-ağırlık değerlerinin değişiklik göstermesinde birey sayılarının etkili olabildiği belirtilmiştir (Bostancı ve Coşkun, 2020). Aynı türde yıllar, farklı habitatlardaki popülasyonlar ve örneklemede midenin dolu ya da boş olması gibi faktörler boy-ağırlık değerlerinin farklılık göstermesinde etkili olabildiği belirtilmiştir (Ricker, 1975).

Tablo 7. Önceki çalışmalarda *A.hepsetus*'un boy-ağırlık değerleri (n:Birey sayısı, Min:Minimum, Max:Maksimum, Ort:Ortalama, SH:Standart hata)

Yazar	Çalışma dönemi	Örnekleme yöntemi	Bölge	Yer	n	Boy (cm) Min-Max (Ort ± SH)	Ağırlık (gr) Min-Max (Ort ± SH)
(Keskin ve Gaygusuz, 2010)	2000/2001	Iğrıp	Marmara Denizi	Erdek Körfezi	65	2,7-14,9	-
(Acarli *vd.,* 2014)	2009/2010	Iğrıp, Pinter Tuzak, Uzatma ağı	Ege Denizi	İzmir Körfezi	66	5,0-10.6 (6,61 ± 1,40)	0.79-8,1 (2,24 ± 1,72)
(Kara *vd.,* 2018)	2010/2014	Iğrıp, Pinter Uzatma ağı, Olta	Ege Denizi	İzmir Körfezi	83	4,3-9,0 (6,0 ± 0.16)	0.52-4,91 (1,56 ± 0.10)
(İnnal ve Engin, 2020)	2014/2017	Gırgır	Marmara Denizi	Mudanya Kıyıları	31	13,3-15,2	14,4-23,9
			Ege Denizi	Çanakkale Kıyıları	20	8,5-11,1	3,9-9
			Karadeniz	Rize Kıyıları	182	9,2-13,5	5,8-16,4
			Marmara Denizi	İzmit Kıyıları	32	10.5-15,4	8,7-22,4
(Bostancı ve Coşkun, 2020)	2017	Balıkçıdan	Ege Denizi	Gemlik Körfezi	213	9,9-14,5 (11,12 ± 0.52)	6,4-18
Bu çalışma	**2016/2017**	**Uzatma ağı**	**Marmara Denizi**	**Kemer Bölgesi**	143	10.3-15,1 (12,7 ± 0.09)	9-21 (12,6 ± 0.21)
	2017/2018				222	10.6-17,8 (12,7 ± 0.07)	9-21 (13,1 ± 0.17)
	Toplam				365	10.3-17,8 (12,7 ± 0.05)	9-21 (12,9 ± 0.14)

5. SONUÇ

Sonuç olarak; 2014-2019 yılları arasında kullanılan gümüş balığı uzatma ağlarının teknik özelliklerinde gerçekleştirilen modifikasyonlar türün avcılığının yönetimi açısından önemlidir. Bu değişimlerin uzatma ağları ile gümüş balığı avcılığının av verimi üzerinde etkilerinde gözlemlendiği üzere, diğer türlerin stokları üzerinde oluşturacağı etkiler üzerine çalışmalar yürütülmelidir. Unutulmalıdır ki; teknolojik gelişmeler ve modifikasyonlar ile av veriminin arttırması ticari balıkçılık açısından olumlu bir beklenti olarak gözükse de, kısa zaman içerisinde tüm balıkçıların benzer değişimlere gitmesi av sahalarında baskılar oluşturarak, sürdürülebilir balıkçılık açısından riskler ortaya çıkarabilir. Nitekim avlanabilir stoklar üzerindeki olumsuz göstergeler bu durumu desteklemektedir (Palkovacs, 2011; Pontecorvo, 2008; Hilborn *vd.,* 2020; Palomares *vd.,* 2020). Ayrıca ekolojik açıdan önemli bir tür olan gümüş balığının tamamının tüketim amacı ile, av kayıtlarına girmeden daha fazla katma değer sağlayan lüfer balığının avcılığında yem olarak kullanılması üzerinde durulması gereken bir konudur. Bu yüzden gümüş balığı ve lüfer balığı avcılığı arasındaki avcılık ilişkisini konu alan çalışmalar yürütülmelidir. Çünkü bu durum türün gerçek avlanma miktarının ve stok yapısının bilinmemesine sebep olmaktadır. Bu çalışmanın; gümüş balığı avcılığında kullanılan uzatma ağlarının teknik özelliklerinin ve av verimlerinin ilk kez belirlenmesi, türün avlama yöntemlerinin tanımlanması ve av verimine etkilerinin belirlenmesi ile literatüre katkı sağlayacağı düşünülmektedir.

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ESER SAHİPLİĞİ KATKI BEYANI

Yusuf ŞEN: Yazım- Orijinal Taslak, Görselleştirme, Şekilsel analiz, Kaynaklar.
Uğur ÖZEKİNCİ: Doğrulama, Yazım-Gözden Geçirme ve düzenleme, Veri iyileştirme, Denetleme.

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Renewable energy-based electrical microgrid of cold ironing energy supply for berthed ships

Gemiler için sahil elektriği tedarikinde yenilenebilir enerji tabanlı mikro şebeke uygulaması

Türk Denizcilik ve Deniz Bilimleri Dergisi

Cilt: 10 Sayı: 1 (2024) 14-26

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ABSTRACT

The importance of ports, which are the gateways between maritime transport and other modes of transport, is growing every day. In addition, the amount of cargo that ports can handle is increasing rapidly every year. At the same time, the need for energy is increasing. Ships hoteling at ports account for a large portion of the power demand at ports. Today, ships hoteling at ports meet their energy needs with their own auxiliary engines running on fossil fuels. In order to achieve decarbonization and zero emissions targets, it is essential to minimize the use of fossil fuels in ports and to increase the use of renewable energy. In this context, meeting the ship's power needs in port through a renewable energy-based microgrid will help reduce emissions. In this study, after determining the energy needs, the scenarios developed with the HOMER program were used to design electrically and economically suitable microgrid systems and to meet the electricity needs of the ships in port using renewable energy.

Keywords: Cold-ironing, HOMER, Port hoteling, Renewable Energy, Ship emission.

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ÖZET

Deniz taşımacılığı ile sanayi ve diğer taşımacılık yöntemlerini birbirine bağlayan bu sebeple de küresel lojistiğin en önemli bileşenlerinden olan limanlara artan ihtiyaçla birlikte liman tesislerinin önemi gün geçtikçe artmaktadır. Bununla birlikte, limanlarda elleçlenen yük miktarı da her yıl hızla artmaktadır. Artan liman kapasiteleri ile yük elleçleme operasyonlarının her aşamasında gerekli olan enerjiye bağımlılık da önemli oranda artmaktadır. Limanlardaki enerji ihtiyacını oluşturan en önemli unsurlardan birisi yük operasyonları amacıyla limanlarda konaklayan gemilerdir. Limanlardaki gemiler günümüzde enerji ihtiyaçlarını fosil yakıtlarla çalışan kendi yardımcı makineleriyle karşılamaktadır. Karbonsuzlaştırma ve sıfır emisyon hedeflerine ulaşabilmek için limanlarda fosil yakıt kullanımının en aza indirilmesi ve buna karşılık yenilenebilir enerji kullanımının artırılması hayati öneme sahiptir. Bu bağlamda, geminin limandaki güç ihtiyacının yenilenebilir enerji tabanlı bir mikro şebeke aracılığıyla karşılanması, emisyonların azaltılmasına yardımcı olacaktır. Bu çalışmada örnek bir liman sahası için enerji ihtiyaçları belirlendikten sonra HOMER programı ile geliştirilen senaryolar kullanılarak elektriksel ve ekonomik olarak uygun mikro şebeke sistemleri tasarlanmış ve limandaki gemilerin elektrik ihtiyaçlarının yenilenebilir enerji kullanılarak karşılanması hedeflenmiştir.

Anahtar sözcükler: Sahil elektriği kullanımı, HOMER, Gemi liman operasyonu, Yenilenebilir Enerji, Gemi emisyonu

1. INTRODUCTION

Ports are essential intermediaries that connect maritime transport with other forms of transportation, serving as pivotal hubs for global trade and economic activity. As the volume of cargo transported by ports continues to grow annually, so does the demand for energy (Buonomano *et al*., 2023; Sifakis and Tsoutsos, 2021). One major factor contributing to the energy demand at ports is the power required by ships during their berthed period, also known as "hoteling" (Canepa *et al*., 2023). Currently, ships meeting their energy needs at ports rely heavily on auxiliary engines powered by fossil fuels (Kumar *et al*., 2019). However, reducing the use of fossil fuels in ports and increasing the utilization of renewable energy sources has become imperative due to the growing emphasis on decarbonization and achieving zero emissions targets (Grzelakowski *et al*., 2022; Höhne *et al*., 2021). The maritime industry is actively engaged in implementing various regulations and measures to reduce greenhouse gas (GHG) emissions and improve the environmental performance of ships (Lu *et al*., 2023). Four key initiatives that play a crucial role in this regard are EEDI (Energy Efficiency Design Index), EEXI (Energy Efficiency Existing Ship Index), SEEMP (Ship Energy Efficiency Management Plan), and CII (Carbon Intensity Indicator) (Bayraktar and Yuksel, 2023). The EEDI is a regulatory measure that sets energy efficiency standards for new ships, aiming to promote the design and construction of more fuel-efficient vessels. It establishes a limit on the amount of CO_2 emissions allowed per ton-mile for different ship types and sizes (Lindstad and Bø, 2018). On the other hand, the EEXI focuses on existing ships and assesses their energy efficiency against the minimum requirements set by the International Maritime Organization (IMO). This index aims to encourage shipowners to adopt energy-saving measures, such as retrofitting, to improve the fuel efficiency of their fleet (Ivanova, 2021). SEEMP is a management plan that outlines specific energy-saving measures for ships to enhance their operational efficiency. Ship operators implement these measures as part of their overall strategy to reduce fuel consumption, improve energy management, and minimize GHG emissions. Lastly, the CII is a performance indicator under development by the IMO. It measures a ship's carbon emissions per transported cargo and determines its efficiency level. The CII will help identify areas for improvement and enable ships to track and reduce their carbon intensity over time (Wang *et al*., 2021).

In this context, the adoption of renewable energy-based microgrid systems to meet the power requirements of ships in port holds significant promise. Such systems offer an opportunity to decrease emissions and contribute to the overall decarbonization efforts. By utilizing renewable energy sources, ports can minimize their reliance on fossil fuels and make substantial progress towards sustainable and environmentally friendly operations (Sadek and Elgohary, 2020).

The research methodology involves determining the energy requirements of ships in port, followed by the development of scenarios using the Hybrid Optimization Model for Electric Renewable (HOMER) software. Through simulations and optimization, the study aims to identify the most suitable microgrid configurations that align with the specific electrical and economic requirements. Cold ironing, also known as shore power or alternative maritime power (AMP), refers to the practice of supplying electrical power to ships at port from onshore sources (Seyhan *et al*., 2022). The proposed microgrid system harnesses renewable energy sources such as solar, wind, and tidal power, along with energy storage systems, to provide a reliable and environmentally friendly alternative to conventional hotelling practices.

This study aims to address the energy needs of ships in port by designing electrically and economically suitable microgrid systems, powered by renewable energy sources. To achieve this, the HOMER program, a comprehensive software tool for renewable energy system analysis, is employed. These configurations would allow for the effective utilization of renewable energy sources to meet the power demands of ships in port.

2. LITERATURE REVIEW

The need to lower pollution emissions and meet the growing energy demand in port regions have prompted the development of renewable energy-based polygeneration systems, which can produce numerous energy types from sustainable sources (Elnajjar *et al*., 2021). A considerable amount of research has been done on the design, development, and operation of renewable energy-based systems and energy efficiency in port environments (Alamoush *et al*., 2020; Iris and Lam, 2019). Decarbonization of the maritime sector is heavily influenced by the interaction between ships and ports (Halim *et al*., 2018). Important services and infrastructure that facilitate the use of technology on ships can be provided in ports (Acciaro *et al*., 2020; Yau *et al*., 2020).

The ship-port interaction of the future will contribute to the decrease of other pollutants and greenhouse gas emissions from maritime activities (Hoang *et al*., 2022). Although the use of cold ironing in ports reduces emissions from auxiliary engines with help of grid electricity, it does not reduce emissions in all countries (Stolz *et al*., 2021) and is far from achieving the net-zero emissions target (Sifakis and Tsoutsos, 2021). Therefore, it is essential to use renewable energy technologies in ports to achieve the targets (Parhamfar *et al*., 2023; Sadiq *et al*., 2021).

When it comes to the environmental impact of berthing ships, ports may profit greatly from the combination of various renewable energy sources (Yigit and Acarkan, 2018). Studies involving renewable energy technologies have been carried out in many ports (Agostinelli *et al*., 2022; Philipp *et al*., 2021). In these studies, there are also examples benefiting from the HOMER program (Sifakis *et al*., 2022; Vichos *et al*., 2022). However, fully supplying cold ironing with renewable energy to meet its high electricity demand is a huge problem that requires further research (Bakar *et al*., 2023).

3. DATA COLLECTION

The Filyos Port, one of the largest ports in Turkey, is a national investment project located in the Filyos Investment Basin, which Turkey is emphasizing (URL-1, 2023). With the project, it is planned to create new transport corridors, reduce the traffic load of the Istanbul and Çanakkale Straits, increase qualified production, and develop national and international transport and trade. For this purpose, this port has been selected as a sample port since it is designed in accordance with today's technology. Since the port is at the design stage, it is possible to adapt it with cold ironing technology and to utilize renewable energy sources. The location of the port is shown in Figure 1.

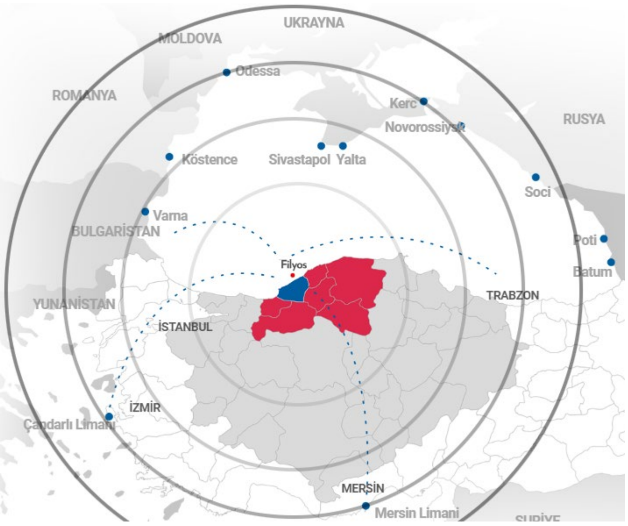

Figure 1. Filyos Port location

In order to produce the energy to meet the demands of the ships, the size of the ships that will stay at the port and the electricity demands of these ships are required. Ship types and sizes included in the port project and the electricity requirements of these sizes are given in the Table 1 (Faber *et al*., 2020; URL-1, 2023).

Table 1. Ship types, quantity and electric demand of port

Ship's Type	Number of Berth by Ship Type	kWh
Container	3	1100
Bulk Carrier	4	110
Ore (Bulk)	4	150
Liquid Cargo	2	800

While planning the energy requirement in this study, the scenario in which all ships are in service at the same time is taken into consideration. The decrease in the use of fossil fuels over the years and the increase in maritime trade require the amount of renewable energy to meet the energy demand. Therefore, it is taken into consideration that the port serves ships by 100% capacity. A bird's eye view of the port and the random berthing patterns of the ships are shown in Figure 2. The hourly distribution of the daily electricity demand of all ships in the port is shown in Figure 3. After the determination of the electrical load, the wind and solar energy potential of the port area gains importance. In this context, wind and solar energy potential is as shown in Figure 4 and Figure 5 respectively.

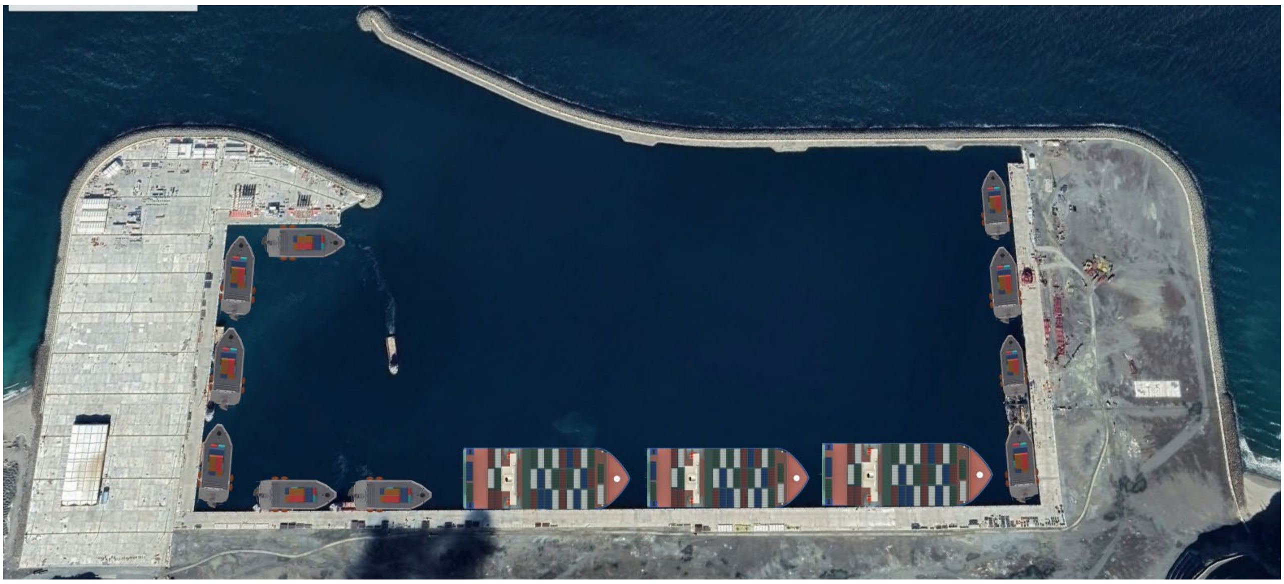

Figure 2. Port with planned ships

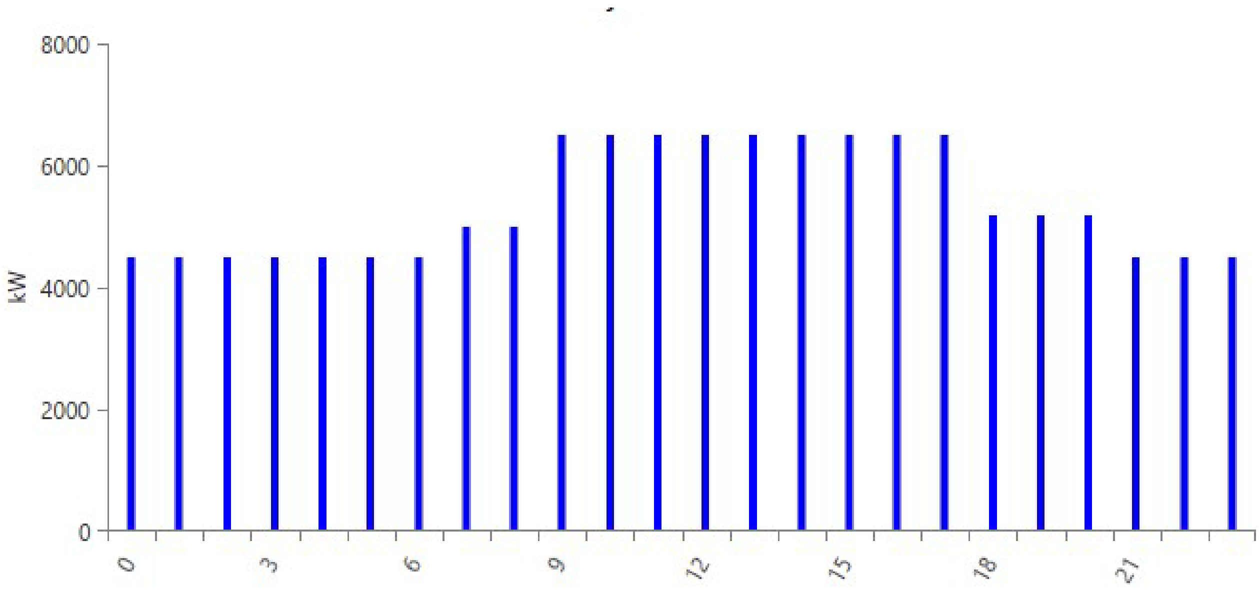

Figure 3. Daily electricity demand of all ships in the port

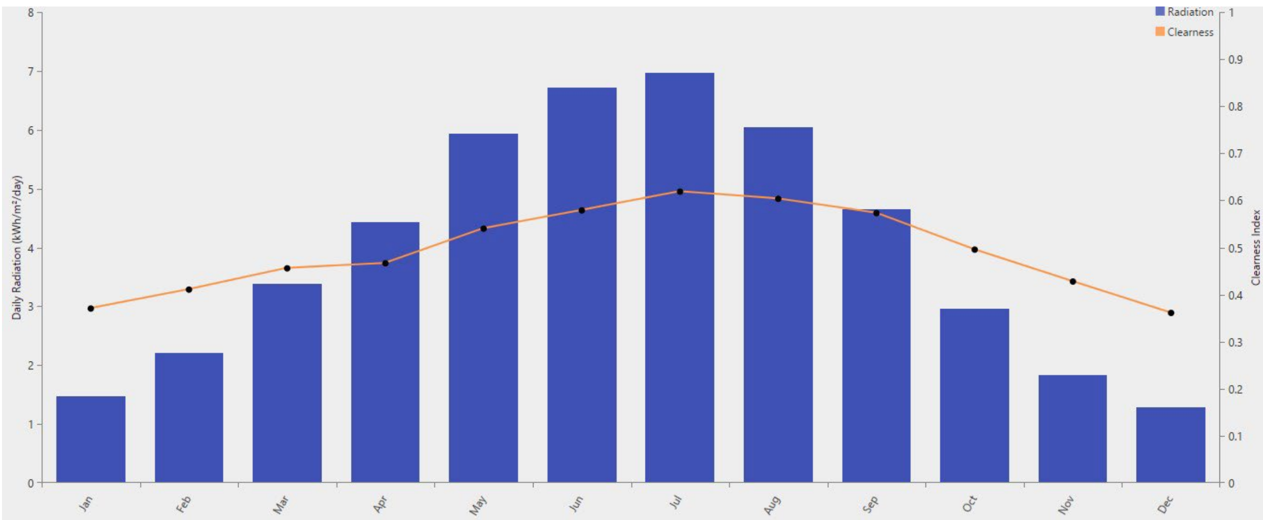

Figure 4. Solar resource of the year in the port

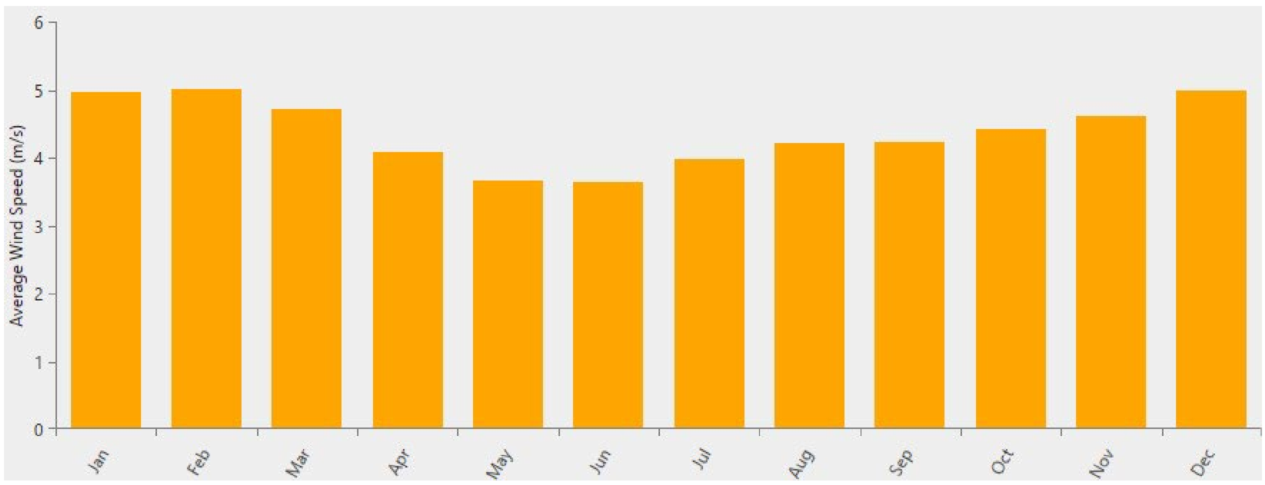

Figure 5. Wind resource of the year in the port

For the optimisation of the system, the costs of the components to be used are also included in the HOMER program. In this context, the cost inputs of the system are shown in Table 2.

Table 2. Costs of component

Component	Costs ($/kW)		
	Capital	Replacement	Operation and Maintenance
Wind	1515	1515	20
PV	830	0	8
Battery	220	200	2
Convertor	325	300	7

4. METHODOLOGY

The HOMER program, a widely used software tool for renewable energy system analysis, was utilized to model and simulate the renewable energy-based electrical microgrid (Baral *et al.*, 2022; Montuori *et al.*, 2014; Restrepo *et al.*, 2018; Shahinzadeh *et al.*, 2016). The program employs optimization algorithms to identify the optimal configuration and operation strategy for the microgrid based on user-defined inputs and constraints (Akarsu and Genç, 2022).
There are studies where the programme offers solutions to a wide variety of electrical needs. The programme can be used for micro-grid installation in areas far from the grid electricity (Amole *et al.*, 2023; Uwineza *et al.*, 2021; Vendoti *et al.*, 2021). In addition, the programme is also used in electrical infrastructure works in the health sector where power outages can have fatal consequences (Aisa *et al.*, 2022; Jahangir *et al.*, 2021). The programme also offers microgrid solutions to facilities that want to produce clean energy with renewable energy solutions (Çetinbaş *et al.*, 2019; Mehta and Basak, 2020). There are also studies in which the most suitable one for the region or facility is selected among the scenarios with multi-criteria decision-making methods (Jahangiri *et al.*, 2020; Odoi-Yorke *et al.*, 2022; Ullah *et al.*, 2021). In addition to all these studies, there are studies where the programme is used in ports as in our study (Bakar *et al.*, 2022; Buonomano *et al.*, 2023; Elnajjar *et al.*, 2021).
This section describes the methodology employed in the study on the renewable energy-based electrical microgrid of cold ironing energy supply for berthed ships. The primary objective of the study was to assess the feasibility and performance of such a microgrid system, with a specific focus on utilizing the HOMER program for system design and analysis.
HOMER calculates and compares different financial metrics, such as the levelized cost of energy (LCOE) and net present value (NPV), enabling users to evaluate the economic viability of the microgrid system. This comprehensive and user-friendly program empowers researchers, engineers, and policymakers to make informed decisions in achieving sustainable and renewable energy solutions for various applications, including meeting the electricity needs of ships in ports.
The working principle of the HOMER program is as shown in Figure 6.

Figure 6. HOMER framework

In the study, it is planned to meet the electricity demand with 3 different scenarios. These scenarios are as shown in Figures 7, 8 and 9 respectively.
While determining the scenarios, LCOE values, initial investment costs, renewable penetrations included in the systems were taken into consideration.
A. System Energy Production and Storage
When designing power generation from renewable energy sources in system design, the nature of available renewable resources affects the behaviour and economics of renewable energy systems, as it determines the amount of renewable energy generation.
Solar resource data show the amount of Global Solar Radiation (GCR) (the sum of beam radiation-beam radiation directly from the sun and diffuse radiation-diffuse radiation from all parts of the sky) that hits the Earth's surface in a typical year (Shilpa and Sridevi, 2019).

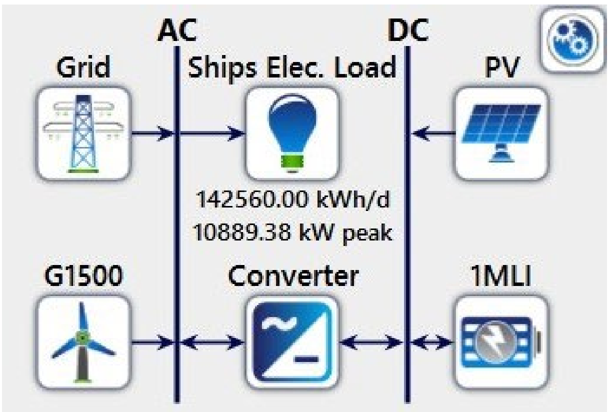

Figure 7. *Scenario 1* includes **wind turbine / photovoltaic (PV) / battery / converter / grid** systems.

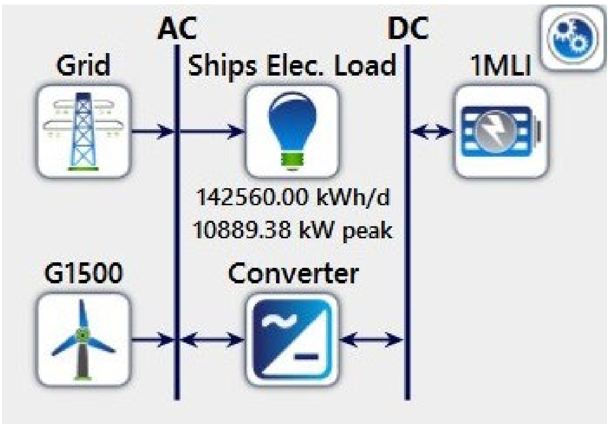

Figure 8. *Scenario 2* includes **wind turbine / battery / converter / grid** systems.

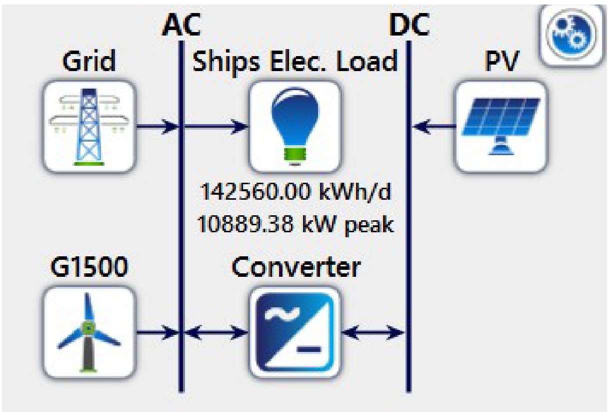

Figure 9. *Scenario 3* includes **wind turbine / PV / converter / grid** systems.

The data can take one of three forms: hourly average global solar radiation on the horizontal surface (kW/m^2), monthly average global solar radiation on the horizontal surface (kWh/m^2 day) or monthly average clearness index (Riayatsyah *et al*., 2022). The clearness index is the ratio of solar radiation hitting the Earth's surface to solar radiation hitting the top of the atmosphere. The clearness index is a measure of the openness of the atmosphere and is a number between zero (0) and one (1) (Islam *et al*., 2021). Wind resource to model a system with one or more wind turbines, the program user must provide wind resource data showing the wind speeds that will drive the turbines in a typical year. Whenever possible, wind resource data should be hourly. Otherwise, HOMER can generate synthetic hourly data from 12-month average wind speeds and four additional statistical parameters, such as the Weibull shape factor, the autocorrelation factor, the diurnal pattern strength and the hour of peak wind speed (Nasab and Kilby, 2022).

The program calculates the power output of the wind turbine for each hour in a four-step process. In the first step, it calculates the average wind speed for that hour based on wind speed source data and anemometer height. In the second step, it determines the wind speed corresponding to the centre of the turbine using the logarithmic law or power law. In the third step, it uses the power curve of the turbine to calculate the power output at the wind speed with reference to the standard air density. In the fourth step, this power output value is multiplied by the air density ratio to obtain the ratio of the actual air density to the standard air density. The program multiplies this power output value by the air density ratio, which is the ratio of actual air density to standard air density (Ahamed *et al*., 2021).

B. System Economic Background

Economic data is essential for the program to deliver accurate results. In this context, LCOE, one of the program outputs, is calculated with the formula below (Mostafa *et al*., 2020).

$$LCOE = \frac{C_{ann,tot}}{E_{base} + E_{sec} + E_{grid,sale}} \quad (1)$$

- EM, Levelised cost of energy
- $C_{ann.,tot}$, total cost (annual)
- E_{base} and $E_{sec.}$, base and secondary loads
- $E_{grid,sale}$, yearly sales to grid

The net present cost (NPC) of each proposed power system is calculated by the computer, which then ranks the systems by NPC in descending order. The NPC is the present value of all the expenses incurred over the life of the system, minus the income and the current value of the system. It is an important measure as it indicates whether or not the overall investment has been successful. The formula below gives the NPC.

$$C_{NPC} = \frac{C_{ann,tot}}{CRF(i, R_{proj})} \quad (2)$$

- C_{NPC}, Net Present Cost
- $C_{ann,top}$, total cost (annual)
- CRF, capital recovery factor
- i, real discount rate,
- R_{proj} project lifetime.

Scenario lifetime is determined by the lifetime of the component with the longest lifetime. For this reason, the scenario lifetime is 25 years, which is the lifetime of PVs. Component's capacity, number of components, capital cost, operating and replacement costs, salvage costs used in the scenarios are presented in tables. In addition, the renewable penetration of the scenarios and the cost per kW of electricity generation are also among the results.

5. RESULTS

Scenario lifetime is determined by the lifetime of the component with the longest lifetime. For this reason, the scenario lifetime is 25 years, which is the lifetime of PVs. Component's capacity, number of components, capital cost, operating and replacement costs, salvage costs used in the scenarios are presented in tables. In addition, the renewable penetration of the scenarios and the cost per kW of electricity generation are also among the results.

The costs of the scenario 1, 2 and 3 are given in Table 3, 4 and 5 respectively, where Table 6 shows economic and renewability penetration comparisons of the all scenarios.

Table 3. Costs of *Scenario 1*

Scenario 1	Size	Capital	Operating	Replacement	Salvage	**Total**
Wind	8 x 1.5 MW	$727,200	$240,000	$727,200	-$545,400	**$1.15M**
Battery	1MWh 78 pcs	$686,400	$156,000	$624,000	-$206,272	**$1.26M**
PV	23274 kW	$772,704	$186,194	$0.00	$0.00	**$958,898**
Grid	-	$0.00	$1.33M	$0.00	$0.00	**$1.33M**
Convertor	6401 kW	$83,215	$44,808	$76,814	-$25,605	**$179,233**
System		**$2.27M**	**$1.95M**	**$1.43M**	**-$777,277**	**$4.87M**

Table 4. Costs of *Scenario 2*

Scenario 2	Size	Capital	Operating	Replacement	Salvage	**Total**
Wind	12 x 1.5 MW	$1.09M	$360,000	$1.09M	-$818,100	**$1.72M**
Battery	1MWh 15 pcs	$132,000	$30,000	$120,000	-$40,000	**$242,000**
Grid	-	$0.00	$3.76M	$0.00	$0.00	**$3.76M**
Convertor	2862 kW	$37,200	$20,031	$34,339	-$11,446	**$80,124**
System		**$1.26M**	**$4.17M**	**$1.25M**	**-$869,546**	**$5.80M**

Table 5. Costs of *Scenario 3*

Scenario 3	Size	Capital	Operating	Replacement	Salvage	**Total**
Wind	8 x 1.5 MW	$727,200	$240,000	$727,200	-$545,400	**$1.15M**
PV	11885 kW	$394,588	$95,081	$0.00	$0.00	**$489,669**
Converter	5625 kW	$73,122	$39,373	$67,497	-$22,499	**$157,494**
Grid	-	$0.00	$3.68M	$0.00	$0.00	**$3.68M**
System		**$1.19M**	**$4.06M**	**$794,697**	**-$567,899**	**$5.48M**

Table 6. Economics and renewable fraction of Scenarios

Scenarios	CAPEX	OPEX	NPC	LCOE	Renewable Fraction
1 (W/B/C/G/PV)	$56.7M	$2.60M	$122M	$0.0855	%84
2 (W/B/G)	$31.5M	$4.54M	$145M	$0.0946	%57.7
3 (W/PV/G)	$29.9M	$4.28M	$137M	$0.0883	%59.1

Scenario 1, which has the highest initial investment cost with the highest number of components, has the highest percentage of renewability. Scenario 2 and Scenario 3 are scenarios with close renewability fractions and initial costs. In addition, LCOE values are close to each other.

6. DISCUSSION

In this study, it is aimed to meet the energy demand of ships while they are at the dock with cold ironing technology. In addition, as mentioned in the literature, it is also emphasised that electricity generation can be met by scenarios involving renewable resources and the national grid (Tawfik *et al*., 2023; Vakili and Ölçer, 2023). Filyos port, which is newly built, and its hinterland is open to innovation, has been chosen as the location, and it is foreseen that it can provide a place for renewable energies while reaching the port capacity.

When we analyse the scenarios economically, although the CAPEX values of *Scenario 2* and

Scenario 3 seem favourable, the OPEX values ensure that the LCOE values are close to each other in the long term in all scenarios. This situation requires decision makers to decide whether to make investments in the first place or to spread them over the long term. In addition, offering electricity service to ships for a charge will further reduce the cost of electricity generated.

Ports will be more motivated in this regard if they receive support from the government for this investment. In addition, the increase in the number of ships with shore power system will positively affect such investments.

As can be seen in Table 6, *Scenario 1* is superior to the other scenarios in terms of renewable fraction. The reason is that it includes both solar and wind energy and at the same time battery to use the generated energy more efficiently. Scenarios with higher renewability rates can be created, but this will both increase the cost and create problems in high energy needs (Bakar *et al*., 2023).

7. CONCLUSION

In conclusion, ports play a very important role in the global transport network but also contribute significantly to greenhouse gas emissions. To address this issue, the study presents suitable scenarios for renewable energy based microgrid systems in ports. While determining the scenarios, our study aims to accurately determine the energy needs of ships in ports. With the HOMER program, microgrid systems are designed to meet energy needs efficiently and economically.

However, this paper is not without limitations. The limitations of the study include the policy of selling electricity to the ship, not including the installation fee of shore power to the port in the system, and not including the areas where renewable energy systems will be installed in the port in the scenarios.

Scenario 1 is the most suitable scenario both economically and in terms of renewable fraction. As the rate of renewable fraction increases, emissions in the port area will also decrease. This will also contribute positively to the maritime industry, which needs emission reductions. The disadvantage of *Scenario 1* compared to other scenarios is the high initial investment cost.

Scenario 2 and *Scenario 3* have lower initial investment costs since they have fewer components. However, renewable fractions are also low compared to Scenario 1. Another disadvantage is the high operational costs as it is supplied more from the national grid.

The maritime industry adopts emission reduction as a priority strategy. In order to implement this strategy, ships are subjected to emission measures in a continuously tightening manner. Investments in ports are valuable to achieve the zero-emission target.

Future studies will include increasing the number of scenarios, ports selling electricity to ships or offering discounts in port fees so that ships using shore power in the competitive market will prefer such ports.

AUTHORSHIP CONTRIBUTION STATEMENT

Yunus Emre ŞENOL: Conceptualization, Writing - Original Draft, Writing-Review and Editing, Data Curation, Visualization.

Alper SEYHAN: Methodology, Validation, Formal Analysis, Resources, Software.

CONFLICT OF INTERESTS

The author declares that for this article they have no actual, potential or perceived conflict of interests.

ETHICS COMMITTEE PERMISSION

Author declares that this study was conducted in accordance with Ethics Committee of Social Sciences, Science and Engineering Sciences Research.

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Early-Life Population Parameters and Hatch-Date Analysis of Sharpsnout Seabream (*Diplodus puntazzo* Walbaum, 1792) Juveniles in the Sea of Marmara, Türkiye

Marmara Denizi'nde Sivriburun Karagöz (*Diplodus puntazzo* Walbaum, 1792) Juvenillerinin Erken Yaşam Populasyon Parametreleri ve Yumurtadan Çıkış Analizi

Türk Denizcilik ve Deniz Bilimleri Dergisi Cilt: 10 Sayı: 1 (2024) 27-38

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ABSTRACT

This research aims to determine early-life population parameters and hatch date of sharpsnout seabream (*Diplodus puntazzo* Walbaum, 1792) juveniles using microstructure analyses of sagittal otoliths collected from the Sea of Marmara, Türkiye. Specimens were collected using an experimental beach seine at 12 stations from November 2021 to March 2022. The mean catch per unit effort (CPUE) was 1.1 individuals per haul, with 44.4% of the total *D. puntazzo* specimens collected at the Erdek Station. A negative allometric growth was calculated from the length-weight relationship equation ($W=0.0178L^{2.698}$). The daily age ranged between 39 $days^{-1}$ and 141 $days^{-1}$, with a mean of 78.9 ± 2.29 $days^{-1}$. The daily growth rate and mortality ratio were calculated as 0.213 mm/day and 4.38%, respectively. The hatching mainly occurred in September and October.

Keywords: Microstructure, Sagittal otoliths, Spawning season, Population, Early-life

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ÖZET

Bu çalışmada Marmara Denizi'nde dağılım gösteren sivriburun karagöz (*Diplodus puntazzo* Walbaum, 1792*)* türüne ait juvenillerin otolit mikro-yapısı kullanılarak yumurtadan çıkış analizi ve erken yaşam popülasyon parametrelerinin belirlenmesi amaçlanmıştır. Bireyler Kasım 2021 ile Mart 2022 tarihleri arasında deneysel ığrıp ağı ile 12 istasyondan örneklenmiştir. Çekim başına ortalama bolluk 1.1 adet/çekim olup, toplam bireylerin %44.4'ü Erdek istasyonundan elde edilmiştir. Boy-ağırlık ilişkisi denkleminden ($W=0.0178L^{2.698}$) negatif allometrik büyüme tespit edilmiştir. Bireylerin günlük yaşları 78.9 ± 2.29 gün ortalama ile, 39 gün ile 141 gün arasında değişmiştir. Bireylerin ortalama günlük büyüme oranları ve ölüm oranları sırasıyla 0.213 mm/gün ve %4.38 olarak hesaplanmıştır. Yumurtadan çıkış yoğun olarak Eylül ve Ekim aylarında gerçekleşmiştir.

Anahtar sözcükler: Mikroyapı, Sagittal otolitler, Üreme sezonu, Popülasyon, Erken yaşam

1. INTRODUCTION

Sharpsnout seabream (*Diplodus puntazzo* Walbaum, 1792) is a subtropical fish species belonging to the family Sparidae, which is mostly distributed in coastal areas (Bauchot and Hureau, 1990) of Eastern Atlantic, Mediterranean, (Bauchot and Hureau, 1986) and Black Sea (Aydın, 2019). Also, Bauchot and Hureau (1986) stated that younger individuals are distributed around estuarine areas. It has great economic importance, mainly small-scale fisheries such as gillnet fishery, longline and handline fishery. As with many members of the Sparidae family, hermaphroditism is common, and fertilization and egg development take place in the pelagic environment. Spawning generally occurs in autumn season and after pelagic larval duration (32.7 days), postlarvae settle from the pelagic environment to the demersal habitat (Macpherson and Raventós, 2006).

Although sharpsnout seabream is a well-known fish species around the Mediterranean Sea and worldwide, published scientific knowledge is very scarce in both adults and early life stages. For wild stocks of adults, Palma and Andrade, (2002) studied stock discrimination of adults using morphological differences, Mouine *et al.,* (2012) investigated reproduction biology, Pajuelo *et al.,* (2008) presented gonad development and spawning cycle, Kouttouki *et al.,* (2006) revealed shape variation of wild and reared stocks, Bostancı *et al.,* (2016) investigated otolith morphology, Kraljevic *et al.,* (2007) and Domínguez-Seoane *et al.,* (2006) estimated age and growth. In contrast, the scientific papers related to juveniles remain limited to feeding, enzyme and rearing protocols of reared fish. According to our knowledge, no study has yet been found on the biology of wild stocks, such as daily growth, mortality, hatch-date distribution etc.

Considering the lack of knowledge on population parameters of juvenile sharpsnout seabream, the main aim of this study was to estimate the length-frequency distribution, length-weight relationship, daily growth and daily mortality rates, and hatch date frequency of the *D. puntazzo* stock distributed in the Sea of Marmara, Türkiye.

2. MATERIALS AND METHODS

Experimental beach seine samplings were realised at 12 sampling stations between November 2021 and March 2022. The beach seine used in the scientific samplings had a 30 m wing length, 1.8 m wing height and, 2x2x2 m bag dimensions. The 4 mm nominal bar length was used in the bag net, and the 6.5 mm nominal bar length was used in the wings.

To prohibit bias-related miscalculation, samplings were realised as 2 replications from all 12 stations (Figure 1). While preserving cold-chain, specimens were transferred from the field to the laboratory, immediately. Total length (*TL*) of the individuals was measured with the Digital Caliper (Mitutoyo CD-15 APX) and measured values were converted to 0.01 cm TL units. All individuals were weighed to the nearest 0.001 g total weight (*W*) with a precision scale. The mean abundance of each location was given with Catch per Unit Effort (CPUE) with the unit of fish number per haul. The CPUE was calculated with a given formula:

$$\text{CPUE}\,(\text{n/haul}) = \text{N}_i / \text{H}_i \quad (1)$$

where N*i* is the total individual number of *D. puntazzo* obtained from *i* station in the study period, and H*i* is the total haul number from the *i* station. The total haul number was detected as multiplication of replication number (two) with the total monthly survey number (four).

To determine daily age, growth, mortality and hatch date frequency, sagittal otoliths of *D. puntazzo* juveniles were grounded and polished with abrasive papers (12 µ, 9 µ, 6 µ, and 3 µ). Otoliths were removed with forceps and pin vises. The right sagittal otoliths were affixed on a glass slide with thermoplastic glue for all examined individuals. After grounding and polishing, daily increment rings were counted from the first visible checkmark succeeding the primordium to the outer edge along the maximum diameter axis, as stated by Brothers, (1984).

Simple linear regressions by least squares between the daily age (A), larval lengths (SL) and juvenile lengths (TL) were used to estimate the daily growth rate (GR). The daily mortality rates were estimated using the slope coefficient in the regression relationship of the ln values of the abundance per length groups. Hatching time was determined by subtracting the daily age of the individual from the sampling date, and the hatch peak and hatch interval were determined for applying the calculation for all sampling months.

3. RESULTS

3.1. Abundance and Spatial Variation

A total of 102 individuals of *D. puntazzo* was obtained from two replicated experimental beach seine sampling from 12 station between December and March. Between all catches from total beach seine sampling, 1.5% of the abundance arose from *D. puntazzo*. The mean CPUE of *D. puntazzo* was calculated as 1.1 n/haul in the Marmara Sea. Between all areas, none of individuals was obtained from S3 (Kumbağ) and S8 (Bursa Ayazma Beach). A 44.4% of the total *D. puntazzo* catch was revealed from S4 (Erdek). Comparatively, S12 (Yalova TİGEM) and S1 (Şarköy) were the other abundant areas, with 10.2% and 8.3% of the total catch, respectively (Figure 1). A 50% of the total *D. puntazzo* catch was sampled in January. December was the second abundant month by 29.2% of frequency. In February and March, the abundance frequency was calculated as 10.4%.

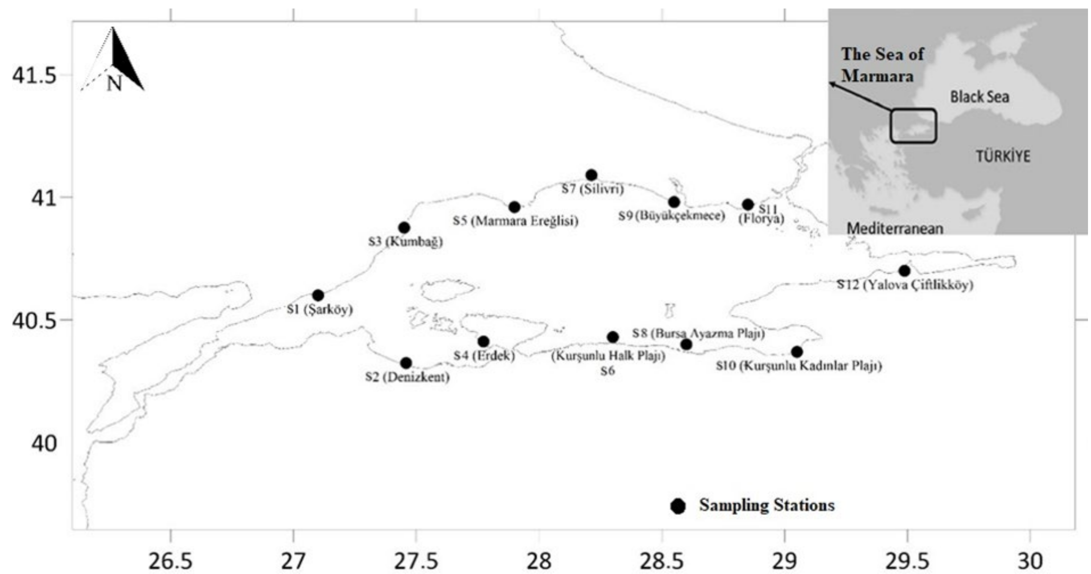

Figure 1. The study area and the beach seine sampling stations located in the Sea of Marmara, Türkiye

3.2. Population Parameters

The mean values of total length (TL), fork length (FL), and total weight (TW) were 36.22 ± 0.45 mm, 33.13 ± 0.42 mm and 0.603 ± 0.024 g, respectively (Table 1). According to length-frequency distribution, a 46.1% of the total *D. puntazzo* individuals consisted of 34 – 38 mm length group. In addition, a 73.6% of the individuals originated in 29 – 38 mm length intervals. A strong linear relationship (r^2: 0.94) was detected between the TL and FL, with a given equation: FL= 0.8962 X TL + 0.6095. An exponential distribution between length – weight relationship (Figure 2) showed that the b value (2.698) statistically differed from 3, and the growth type was estimated as negative allometry.

Table 1. The population parameters of *D. puntazzo* juveniles in the Sea of Marmara, Türkiye (N: Number of fish)

		Total Length (TL, mm)			Fork Length (FL, mm)			Total Weight (g)		
Months	N	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
December 22	30	27.25	50.87	35.50 ± 0.90	23.6	47.08	32.24 ± 0.91	0.295	1.575	0.585 ± 0.048
January 23	52	29.05	46.89	36.92 ± 0.57	26.33	41.89	33.74 ± 0.49	0.2442	1.249	0.609 ± 0.032
February 23	10	31.64	45.72	37.76 ± 1.43	29.07	41.35	34.86 ± 1.36	0.3866	1.264	0.737 ± 0.101
March 23	10	24.52	39.34	33.25 ± 1.31	22.52	36.32	30.80 ± 1.25	0.3156	0.752	0.500 ± 0.043
Total	102	24.52	50.87	36.22 ± 0.45	22.52	47.08	33.13 ± 0.42	0.2442	1.575	0.603 ± 0.024

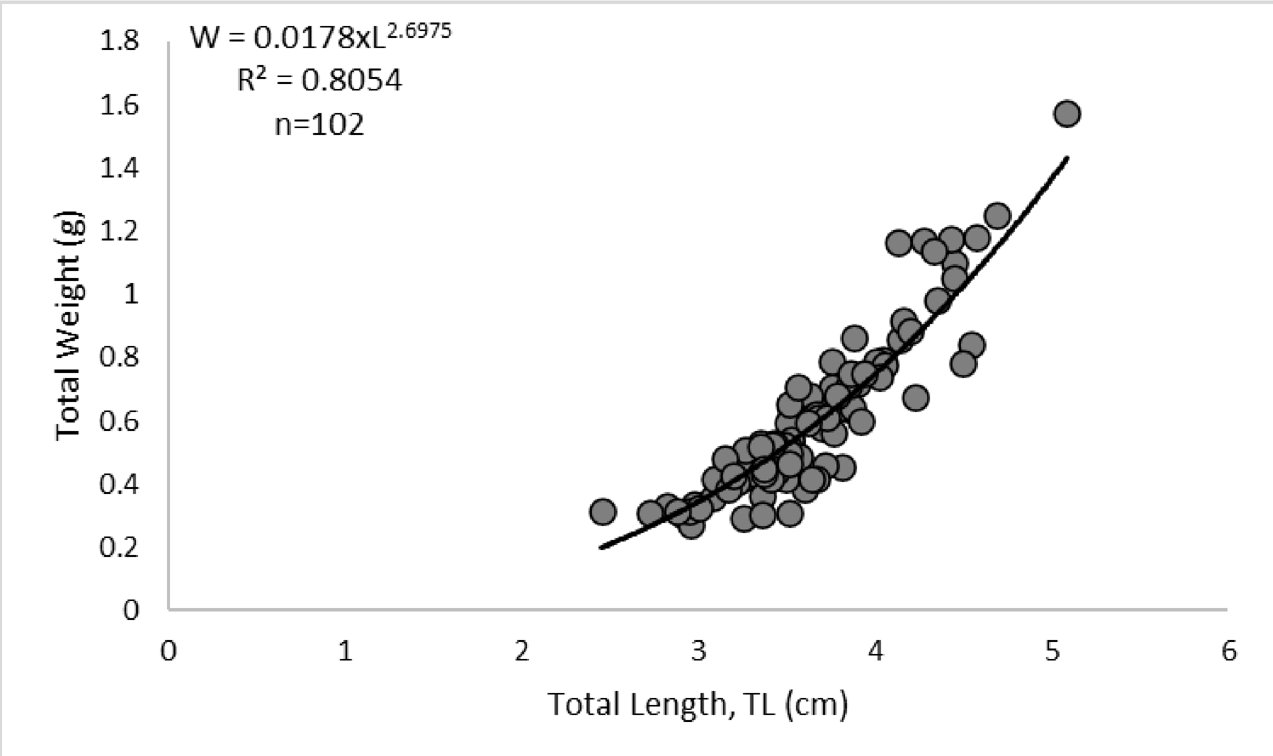

Figure 2. The length – weight relationship of *D. puntazzo* juveniles in the Sea of Marmara, Türkiye

The sagittal otolith lengths (OL) of *D. puntazzo* individuals ranged between 1.377 mm and 2.319 mm, with a mean length of 1.7834 ± 0.019 mm. Otolith width (OWi) of individuals were ranged from 0.819 to 1.842, with a mean value of 1.1487 ± 0.014 mm. A weak linear relationship was found between OL and OWi with a given equation, OWi = 0.5462 X OL + 0.1665

(r^2=0.74). Otolith weights (OW) were distributed between 0.0001 g and 0.0020 g, with a mean of OW= 0.0007 ± 0.000038 g. The relationship between OL and OW was linear (r^2= 0.97), with a given equation: OW= 0.0202 x OL - 0.0028. A weak linear relationship was detected between TL and OL (r^2= 0.65) (Figure 3). Similarly, a very weak relationship was found between individual total weight (TW) and otolith weight (OW) (r^2=0.34).

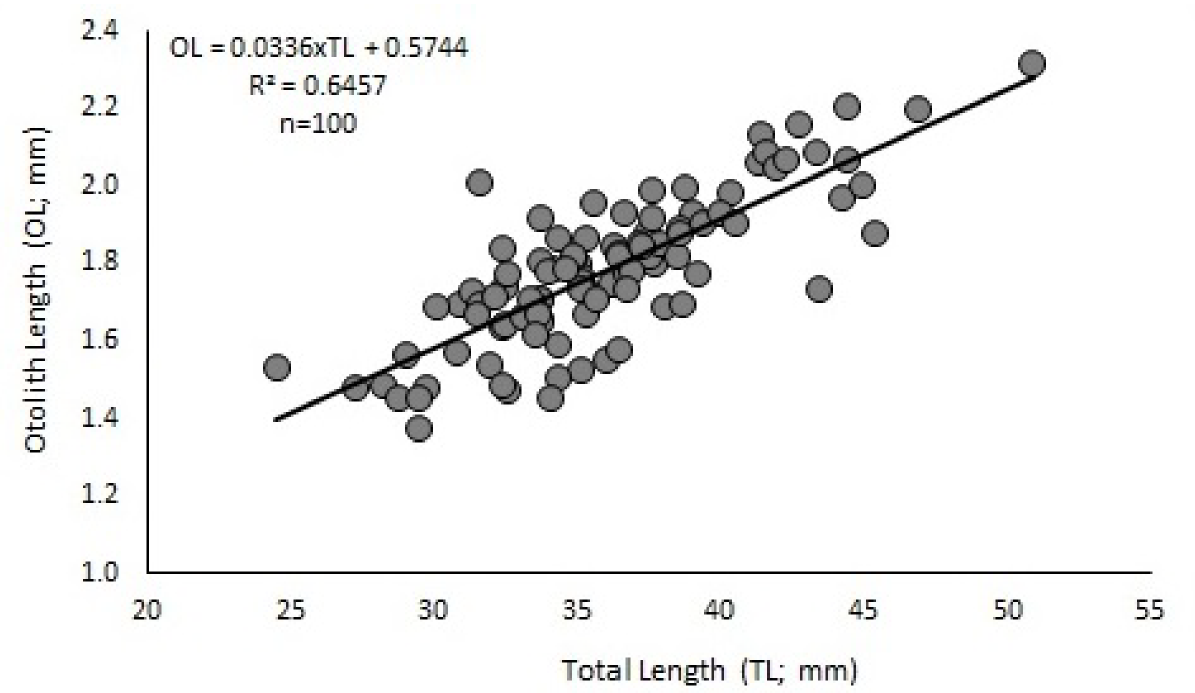

Figure 3. The fish total length (TL) – sagittal otolith length (OL) relationship of *D. puntazzo* juveniles in the Sea of Marmara, Türkiye

3.3. Daily Age, Growth, Mortality and Hatch Date

According to examination of the daily rings of 86 individuals, age ranged between 39 days^{-1} and 141 days^{-1}, with a mean of 78.9 ± 2.29 days^{-1}. The oldest individual was caught on 22.12.2021, whereas the youngest was collected on 15.03.2022. The mean age at the abundant stations, S4 (35 ind.) and S12 (25 ind.) were determined as 83.3 days^{-1} and 73 days^{-1}, respectively (Table 2).

The mean daily growth rate was estimated at 0.213 mm/day (Figure 4). The mean daily growth rate at the abundant stations, S4 (35 ind.) and S12 (25 ind.) were estimated to be relatively the same as 0.211 mm/day. The instantaneous mortality coefficient and daily mortality rate were determined as 4.447 and 4.38%, respectively (Figure 5).

Table 2. Age-length key of *D. puntazzo* juveniles in the Sea of Marmara, Türkiye

	Daily Age							
Length (mm)	20-39	40-59	60-79	80-99	100-119	120-139	140-159	Total
20-24	1							1
25-29		6	1					7
30-34		3	19	2				24
35-39		1	19	10	5			35
40-44			1	4	8	2		15
45-49					1	2		3
50-54							1	1
Total	1	10	40	16	14	4	1	86

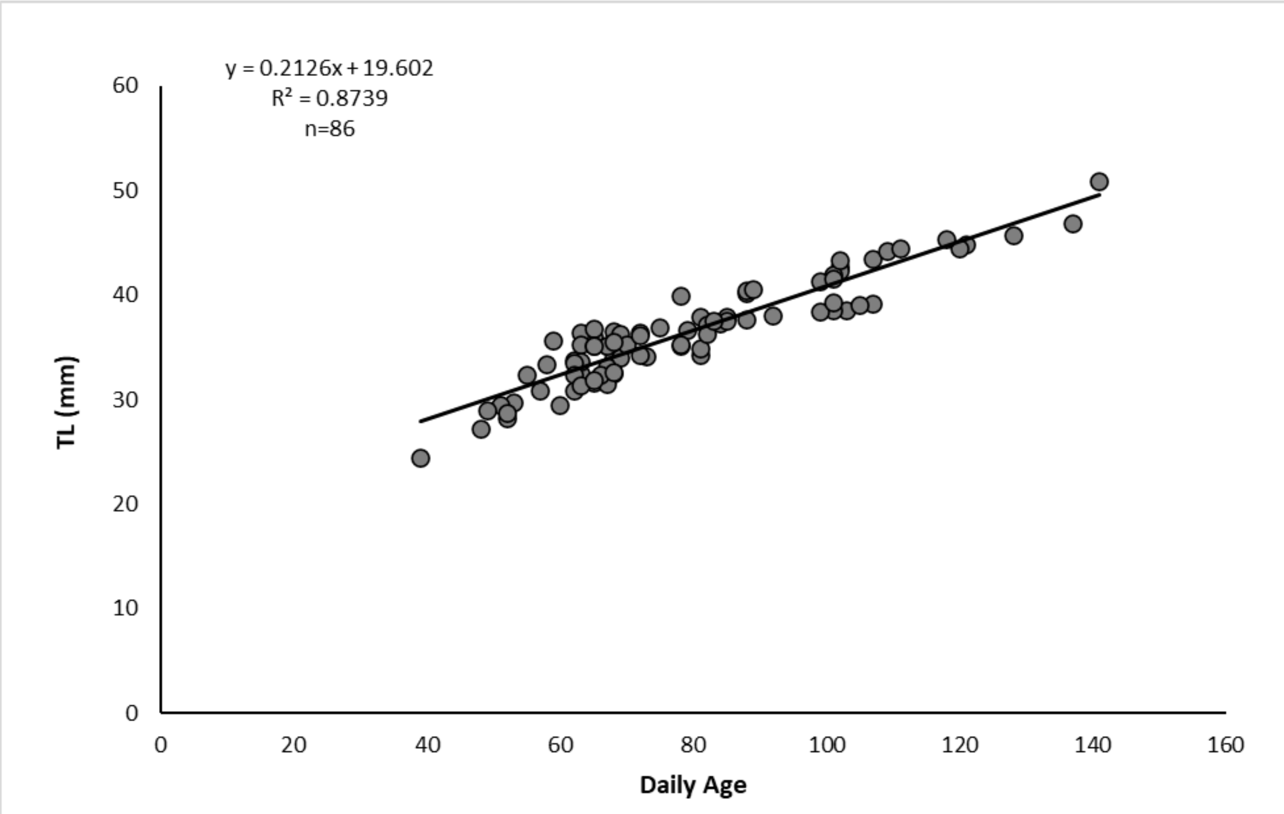

Figure 4. Daily age – total length (TL) relationship of *D. puntazzo* juveniles in the Sea of Marmara, Türkiye

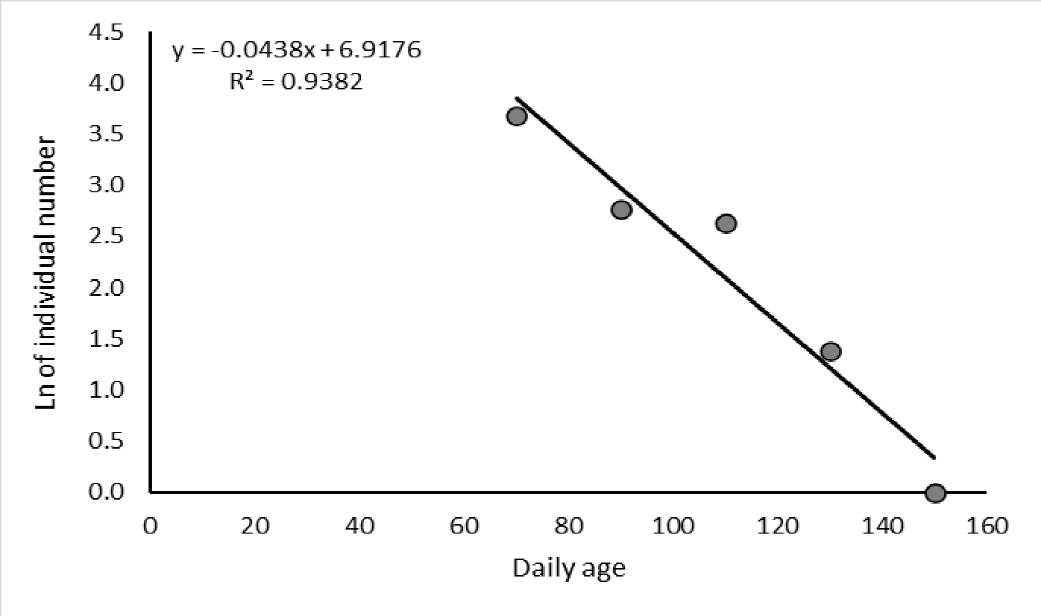

Figure 5. Mortality curve of *D. puntazzo* juveniles in the Sea of Marmara, Türkiye

The hatch date frequency distribution is shown in Figure 6. The hatching times of *D. puntazzo* took place between August 2022 and February 2023, and hatching peaked in October 2022, with 41% of the total individuals. In contrast, 83% of the individuals were hatched between September 2022 and November 2022.

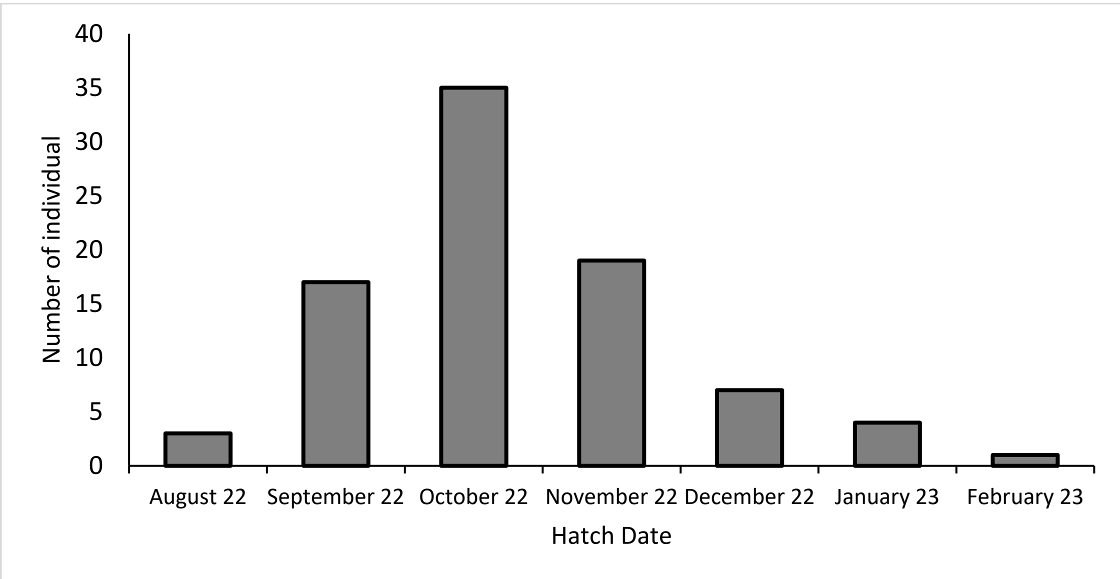

Figure 6. Hatch date frequency of *D. puntazzo* juveniles in the Sea of Marmara, Türkiye

4. DISCUSSIONS

According to ichthyoplankton and adult fish biodiversity results of previous studies (Demirel *et al.,* 2007; Daban *et al*., 2023; Kara, 2015), Erdek Bay was defined as an area that had the highest biodiversity in the Sea of Marmara. Although *D. puntazzo* juveniles were observed at 10 of the 12 sites, most individuals were found in Erdek Bay (44.4%). The southwestern part of the

Sea of Marmara is under the effect of the more saline Aegean Sea deep water flow, one of the possible factors increasing the biodiversity of Erdek Bay. Also, the geo-morphological structure, which mostly arose from small islands and rocky shelves, may be another factor that increased biodiversity. Besides, Meinesz *et al*., (2009) and Karadurmuş and Sarı, (2022) emphasized that the dense seagrass beds in the coastal areas, may originate growth areas for the newly-settlers. In addition, the nutrient flow by the Gönen Stream may be the other possible factor related to high biodiversity. These factors should explain the high abundance of *D. puntazzo* around Erdek Bay.

As it is known, all other Sparidae family species except *Spondliosoma cantharus* (Linnaeus, 1758) have a pelagic early phase, in which eggs, pre-larvae and post-larvae are distributed in the plankton. Thus, the early development of *D. puntazzo* takes place in the pelagic environment until settlement from the pelagic to the demersal environment. Macpherson and Raventós, (2006) examined the pelagic larval duration (PLD) of *D. puntazzo* around Spain coasts and Gibraltar. They estimated that the PLD of *D. puntazzo* ranged between 19 and 48 days, with a mean of 32.7±4.8 days from the settlement mark on the otoliths of new settlers. The daily age of the youngest individual found in this study (39 days^{-1}) was consistent with the PLD result of the previous study. Besides, the settlement mark observed at this individual was 30 days in this study, supporting the findings of Macpherson and Raventós, (2006).

When compared with the other Sparidae species distributed in the Mediterranean, scientific data on adult fish biology related *D. puntazzo* remain limited to only a few studies (Domínguez-Seoane *et al.,* 2006; Kraljevic *et al.,* 2007). Kraljevic *et al.,* (2007) detected isometric growth type (b: 3.001) and low growth (K: 0.191) rate and long-life span (18 years). Also, similar findings were found by Domínguez-Seoane *et al.,* (2006) in the Canary Islands. Similar slow growth and negative allometry also was detected by Aydın and Özdemir, (2021) in low-saline Black Sea waters. However, the growth trajectories of younger individuals are defined inconsistently with the adults (Froese, 2006; Gordoa and Moli, 1997; Petrakis and Stergiou, 1995). Although knowledge of population parameters is common for lots of adult Mediterranean fish, reported data on the juvenile phase is limited. However, when compared to other species, there are more studies in the literature on juvenile stocks of the Sparidae family and *Diplodus* genus (Ayyıldız *et al.,* 2014; Ayyıldız *et al.,* 2015; Ayyıldız and Altın, 2021; Daban and İşmen, 2022; Di Franco *et al.,* 2011; Matic-Skoko *et al.,* 2004; Matic-Skoko *et al.,* 2007; Planes *et al.,* 1999). This relevance result from this family's economic importance and easy cultural adaptation of this family members. According to our knowledge, the daily growth rate of juvenile *D. puntazzo* was only estimated by Planes *et al.,* (1999) as a 0.160 mm day^{-1} in the Northwestern Mediterranean, which was lower than our finding as 0.213 mm/day. Planes *et al.,* (1999) stated that the low daily growth rate of *D. puntazzo* stemmed from the low sea surface temperature and limited zooplankton abundance in the winter period, when the settlement occurred. Thus, a slight variation in daily growth rate result from higher zooplankton availability in the Sea of Marmara against in the Western Mediterranean. The daily growth rate of *D. vulgaris* was detected as 0.202 mm day^{-1} in the Western Mediterranean (Planes *et al.,* 1999), 0.276 mm day^{-1} in the North Aegean Sea (Ayyıldız *et al*., 2014), and daily growth rate of *Sarpa salpa* was estimated as 0.203 mm day^{-1} in the Adriatic Sea (Matic-Skoko *et al*., 2004). Due to *D. vulgaris* and *S. salpa* also settling in the winter period, similar low daily growth rates supported the hypothesis of Planes *et al.,* (1999). This situation is explained by the low metabolism rate from lower sea water temperatures in winter. Conversely, a higher daily growth rates were found for summer settlers such as *D. sargus* at 0.567 mm day^{-1} (Planes *et al.,* 1999) and 0.460 mm day^{-1} (Ayyıldız and Altın, 2020), and *D. annularis* as 0.369 mm day^{-1} (Ayyıldız *et al*., 2014), and *Lithognathus mormyrus* as 0.325 mm day^{-1} (Ayyıldız *et al*., 2014). According to adult morphometric characteristics, the daily growth rate should reach relatively higher ratios for other family members such as 2.37 mm/day for *Thunnus thynnus* (La Mesa *et al*., 2005) and 23 mm/day for *Xiphias gladius* (Megalofonou *et al.,* 1995).

Mortality rates reveal crucial information related to coming up with next-generation stock capacity. In previous studies, mortality rates were found as 1.8-2.0% for *Alosa sapidissima* (Crecco *et al*., 1983), 22-39% for *Anchoa mitchilli* (Leak and Houde, 1987), 3.6-6.3% *Leiostomus xanthurus* 0.8-3.7% and for *Micropogonias undulatus* (Ross, 2003), 2.9% for *D. annularis* (Ayyıldız and Altın, 2020), 4.6% for *L. mormyrus* (Ayyıldız and Altın, 2021), 1.9% for *D. vulgaris* (Ayyıldız *et al.,* 2015). In this study, the calculated daily mortality (4.3%) rate of *D. puntazzo* showed a similar pattern against other juvenile species. Conversely, no clear relationship pattern between settlement season and mortality rate was shown from the comparison of previous studies. However, Macpherson *et al.,* (1997) found that the Daily mortality of *D. sargus* was higher than *D. puntazzo* and *D. vulgaris* and stated that the mortality possibility may be higher in the warmer settlement period. Leak and Houde, (1987) stated that predation and starvation were the biggest reasons for daily mortality in early life stages. Also, the food competition immediately after the settlement should play an important mortality for demersal juveniles.

The hatch date frequency distribution showed that relatively half of the individuals were hatched in October. Macpherson *et al.,* (1997) and Vigliola *et al.,* (1998) also found that most individuals of *D. puntazzo* hatched in October and November in the Northwestern Mediterranean Sea. Also, the results of adult reproduction biology studies of *D. puntazzo* showed that the spawning period occurred between September and December in the Gulf of Tunis (Mouine *et al.,* 2012), and was detected from September to February in the Canary Islands (Pajuelo *et al*., 2008), and found as September in the Eastern Black Sea (Aydın and Özdemir, 2021), where relatively lower temperate and saline waters against Western Mediterranean. Thus, the adult reproductive characteristics also supported the first hatch date timing of *D. puntazzo*.

5. CONCLUSIONS

Under high fishing pressure and without proper inspection, as in Mediterranean coastal fisheries, the late maturation pattern of the *D. puntazzo* may cause problems in ensuring the sustainability of the species. Thus, the knowledge of fish biology from egg to adult should be clearly examined, and detailed stock situations should be revealed to sustain proper management policy, especially in Turkish waters and Mediterranean coastal areas.

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AUTHORSHIP CONTRIBUTION STATEMENT

İsmail Burak DABAN: Writing-Original draft, data analyses, sampling. **Yusuf ŞEN:** Sampling, laboratuary works, visualization, investigation. **Alkan ÖZTEKİN:** Sampling, laboratuary works. **Adnan AYAZ:** Sampling, laboratuary works. **Uğur ALTINAĞAÇ:** Sampling, laboratuary works. **Ali İŞMEN:** Supervision, data-analyses. **Ahsen YÜKSEK:** Supervision, data-analyses. **Uğur ÖZEKİNCİ:** Laboratuary works, visualization, investigation, **Fikret ÇAKIR:** Laboratuary works, visualization, investigation. **Tekin DEMİRKIRAN:** Sampling, laboratuary works. **Gençtan Erman UĞUR:** Sampling, laboratuary works. **Oğuzhan AYAZ:** Sampling, laboratuary works. **Buminhan Burkay SELÇUK:** Sampling, laboratuary works.

CONFLICT OF INTERESTS

The author(s) declare that for this article they have no actual, potential or perceived conflict of interests.

ETHICS COMMITTEE PERMISSION

No ethics committee permission is required for this study.

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Fatty Acid Composition of Commercial Smoked Salmon Products

Ticari Somon Füme Ürünlerinin Yağ Asidi Kompozisyonu

Türk Denizcilik ve Deniz Bilimleri Dergisi

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ABSTRACT

In this study, the fatty acid composition of smoked salmon fillets sold in grocery stores in Türkiye was investigated. Gas chromatography (GC) was used to determine fatty acid composition from extracted lipid. The main saturated fatty acids observed in smoked salmon samples were myristic acid (C14:0), palmitic acid (C16:0) and stearic acid (C18:0); monounsaturated fatty acids were palmitoleic acid (C16:1), oleic acid (C18:1n9), and vaccenic acid (C18:1n7); polyunsaturated fatty acids (PUFA) were linoleic acid (C18:2n6), eicosapentaenoic acid (EPA, C20:5n3) and decosahexaenoic acid (DHA, C22:6n3). Among the monounsaturated fatty acids, oleic acid was found to be the fatty acid with the highest value. Oleic acid amounts were found to vary between 27.22% and 35.52%. PUFA values in smoked salmon fillet groups were determined as 27.77%, 27.49%, 32.94% and 30.62%. The highest EPA value was determined in F1 group with 4.29% and the lowest value was determined in F2 group with 2.07%. DHA amounts were between 11.74% and 6.22%. The ratio of $\Sigma n6/\Sigma n3$ was between 0.80 (F4 group) and 1.16 (F2 group). As a result, it was concluded that the smoked fish fillets examined had high nutritional quality in terms of fatty acids. Among the groups, especially F3 and F4 groups were found to have rich content in terms of PUFA and $\Sigma n3$ values.

Keywords: Smoked, Fatty acid profile, PUFA, Gas chromatography

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ÖZET

Bu çalışmada, Türkiye'de marketlerde satışa sunulan tütsülenmiş somon filetolarının yağ asidi kompozisyonları araştırılmıştır. Ekstrakte edilmiş lipitten yağ asidi kompozisyonunu belirlemek için gaz kromotografisi (GC) kullanılmıştır. Füme somon örneklerinde gözlenen başlıca doymuş yağ asitleri miristik asit (C14:0), palmitik asit (C16:0) ve stearik asittir (C18:0); tekli doymamış yağ asitleri palmitoleik asit (C16:1), oleik asit (C18:1n9) ve vaksenik asittir (C18:1n7); çoklu doymamış yağ asitleri (PUFA), linoleik asit (C18:2n6), eikosapentaenoik asit (EPA, C20:5n3) ve dekosaheksaenoik asittir (DHA, C22:6n3). Tekli doymamış yağ asitlerinden en yüksek değere sahip olan yağ asidi oleik asit olarak tespit edilmiştir. Oleik asit miktarları %27.22 ile %35.52 arasında değişim gösterdiği tespit edilmiştir. Tütsülenmiş somon fileto gruplarındaki PUFA değerleri %27.77, %27.49, % 32.94 ve %30.62 olarak belirlenmiştir. En yüksek EPA değeri %4.29 ile F1 grubunda, en düşük değer ise %2.07 ile F2 grubunda tespit edilmiştir. DHA miktarlarının ise %11.74 ile %6.22 aralığında olduğu belirlenmiştir. Σn6/Σn3 oranının en az 0.80 (F4 grubu) ve en yüksek 1.16 (F2 grubu) arasında olduğu belirlenmiştir. Sonuç olarak incelenen füme balık filetolarının yağ asitleri açısından besinsel kalitesinin yüksek olduğu kanaatine varılmıştır. Gruplar arasında ise özellikle F3 ve F4 gruplarının PUFA ve Σn3 değerleri açısından zengin içeriğe sahip oldukları belirlenmiştir.

Anahtar sözcükler: Tütsüleme, Yağ asidi profili, PUFA, Gaz kromatografisi

1. INTRODUCTION

Climate change and environmental degradation have negative impacts on the world's natural resources. On the other hand, the human population will exceed 9 billion by the middle of the twenty-first century, making it even more difficult to provide healthy food (FAO, 2018). The food industry, which is already growing day by day, is growing even more as the demand for healthy food increases. Consumers, on the other hand, tend to prefer natural foods that are more beneficial in order to minimize increasing health risks. With this increasing demand for healthy nutrition in recent years, the consumption of seafood is also increasing. The digestible protein content, mineral substances and polyunsaturated fatty acids are the three main topics that come to mind in the nutritional composition of seafood. The most prominent feature in the nutritional composition of seafood is the polyunsaturated fatty acids (PUFA) they contain. It is widely acknowledged and frequently advised by experts that fish oil is essential for human health and nutrition. The primary cause of this is that fish oil contains long-chain polyunsaturated fatty acids like EPA and DHA. Fish oils have been found as a way to lower mortality risks, especially in cardiovascular disorders, due to their high content of essential fatty acids, which have been connected to brain development and cardiovascular health (Durmus, 2018; Raatz and Bibus, 2016; Fung *et al*., 2009; Mol, 2008). Due to their rich fatty acid content, health organizations recommend regular consumption of seafood; for example, the American Heart Association Nutrition Committee recommends fish consumption 2 or 3 times a week (Mnari *et al.*, 2007). Consumption of polyunsaturated fatty acids, particularly EPA and DHA from the omega-3 fatty acid series, can reduce risk factors like heart rhythm, blood pressure, triglyceride levels, and platelet aggregation, which in turn can prevent many diseases in humans, particularly cardiovascular disorders (Fung *et al*., 2009; EFSA, 2012; Durmus, 2018). However, with this increase in demand for seafood, there have been problems in product supply and these problems have led to growth in the aquaculture and processed seafood industries.

Especially with the Covid-19 pandemic, consumers have tended to pay more attention to their nutrition and the place of fish in the consumer diet has increased. During this period, processed and packaged products were preferred over fresh or chilled products worldwide (Chenarides *et al*., 2021; Fernández-González *et al.*, 2021; Kitz *et al*., 2022; Knorr and Khoo, 2020; Li *et al*., 2021; Oliveira *et al*., 2021; White *et al*., 2021). The consumption of processed products in Europe increased from 424 thousand tons to 511 thousand tons from 2019 to 2020 with the pandemic (EUMOFA, 2021). The increase in consumers' preference for processed and packaged products over fresh or chilled products has also increased production. For example, canned food consumption increased in Portugal (21%), Italy (14%) and Luxembourg (13%) during the pandemic (European Commission, 2021). The increase in consumer preference for processed products led to a significant increase in imports of raw and processed fish in Europe in 2020 (EUMOFA, 2021). Imported seafood products are processed with different processing techniques and offered to consumers. Although methods such as marinating, canning, salting, salting, drying, smoking are traditionally used in many parts of the world, smoking is a processing technology for which demand has increased in recent years due to the different taste and aroma in the final product (Kose and Erdem 2004, Ayas 2006, Atar and Alçiçek 2009; Düzarduç, 2021). In this context, smoked products have an important market share among the processed seafood products offered to consumers in Europe (EUMOFA, 2021).

Smoking is a complicated process technique. Factors such as the wood material used in the application, temperature and humidity inside the oven should be taken into consideration (Ünal and Çelik, 1995; Ceylan and Şengör, 2015). During the application of this technology to seafood, the compounds in the smoke content come into contact with the food and these compounds add flavor and color to the product. If smoking technology is not applied consciously and in a controlled manner, it is inevitable that undesirable compounds will appear in the food to be consumed. Therefore, it is important to investigate the nutritional content of this technique in order not to adversely affect the nutritional content of the smoked product and consumer health. It is also especially important to determine the effect of the smoking process on the fatty acids in seafood products. However, research on the contents of smoked seafood products in our country is limited. Therefore, in this study, fatty acid compositions of processed salmon fillets offered for sale in grocery stores were investigated.

2. MATERIALS AND METHODS

2.1. Smoked fish

The smoked salmon used in the study was obtained from an international hypermarket in Adana. Then they were delivered to Çukurova University, Faculty of Fisheries, Processing Technologies Laboratory. The samples were stored in the refrigerator until the day of analysis. The analyzed samples were coded as F1, F2, F3 and F4 (Table 1).

Table 1. Characteristics of sampled smoked fish.

Code	Content	Weight	Origin	Date of production
F1	Salmon meat, salt, sugar, wood smoke	250 g	Norway	7 Nov 2022
F2	Turkish salmon, salt, preservative (sodium benzoate), natural wood smoke	100 g	Türkiye	15 Nov 2022
F3	*Salmo trutta labrax*, salt, natural wood smoke	100 g	Türkiye	8 Nov 2022
F4	Salmon (*Salmo salar* 98%), salt, sugar, spice mixture (mustard, onion, etc.)	200 g	Norway	19 Oct 2021

2.2. Lipid Analysis

Lipid analysis was performed according to the method of Bligh and Dyer (1959). 15 g of homogenized sample was mixed in a homogenizer after adding 120 mL of methanol/chloroform (1/2, v/v). Then 20 mL of 0.4% $CaCl_2$ solution was added to these samples and the samples were filtered through filter paper (Scleicher and Schuell, 5951/2 185 mm) and placed in an oven at 105 °C for 1 hour and filtered into tared balloon jugs. These flasks were sealed airtight and kept in a dark place for 1 night and the next day the top layer of methanol-water was removed with the help of a separating funnel.

From the chloroform-lipid portion remaining in the balloons, chloroform was evaporated using a rotary evaporator in a water bath at 60 °C. The flasks were then placed in an oven at 60 °C for half hour to evaporate all the chloroform, cooled to room temperature in a desiccator and weighed on a 0.1 mg sensitive precision balance.

2.3. Fatty acids analysis

The method of Ichihara *et al.* (1996) was used to create fatty acid methyl esters from extracted lipid. 4 mL of 2M KOH and 2 mL of n-heptane were added to 25 mg of the isolated lipid sample. After being centrifuged for 10 minutes at 4000 rpm and vortex-mixed for 2 minutes at room temperature, the heptane layer was analyzed using gas chromatography (GC).

2.4. Gas chromatography conditions

Fatty acid analysis was performed using a GC Clarous 500 instrument (Perkin-Elmer, USA), a flame ionization detector and an acid silicide salt tube SGE (30 m x 0.32 mm ID x 0.25 lm BP20 0.25 UM, USA). Injector and detector temperatures were set to 220 °C and 280 °C, respectively. Meanwhile, the oven temperature was kept at 140 °C for 5 minutes. Then it was increased by 4 °C every minute up to 200 °C and from 200 °C to 220 °C by 1 °C every minute. The sample size was 1 mL and the carrier gas was controlled at 16 ps. A split ratio of 1:100 was used. Fatty acids are identified by comparing the standard 37-component FAME mixture based on arrival times.

2.5. Statistical analyses

SPSS 22.0 was used to determine for statistical analysis. All collected data were analyzed by one-way ANOVA ($p<0.05$) confidence level using the Duncan multiple range test (Duncan, 1955). The level of significance was taken as $p<0.05$.

3. RESULTS AND DISCUSSION

3.1. Fatty acid changes

The main saturated fatty acids observed in smoked salmon samples were myristic acid (C14:0), palmitic acid (C16:0) and stearic acid (C18:0); monounsaturated fatty acids were palmitoleic acid (C16: 1), oleic acid (C18:1n9) and vaccenic acid (C18:1n7); polyunsaturated fatty acids were linoleic acid (C18:2n6), eicosapentaenoic acid (EPA, C20:5n3) and decosahexaenoic acid (DHA, C22:6n3). The saturated fatty acid composition of smoked salmon fillets is given in Table 1.

According to the findings of present study, it was determined that the total SFA amounts of the smoked salmon fillets examined varied between 16.84% and 25.01%. In addition, it was determined that there was a statistical difference between smoked salmon fillets in terms of the results ($P < 0.05$). Espe *et al.* (2004) investigated the quality of smoked salmon from 3 different origins (Norwegian, Scottish, and Irish) collected in a French hypermarket. The researchers determined the SFA value of Norwegian, Scottish and Irish smoked salmon as 24.5, 23.2 and 23.7 g $100g^{-1}$ lipid, respectively. In the study conducted by Keskin *et al.* (2022), SFA amounts similar to our study were reported. Among the saturated fatty acids, the fatty acids with the highest values were myristic acid (C14:0), palmitic acid (C16:0) and stearic acid (C18:0) in all smoked salmon samples. The highest myristic acid value was determined in the F1 group (2.40%), while the lowest value was determined in the F2 group (1.92%). Although there was no statistical difference between F1 and F4 groups, it was determined that there was a statistical difference between the other groups. It was determined that the fatty acid with the highest value among saturated fatty acids was palmitic acid. Many researchers have reported that palmitic acid has the highest amount among saturated fatty acids (Keskin *et al.*, 2022; Erdem et *al.*, 2020). The amount of palmitic acid in smoked salmon samples was determined as F3 (16.29%), F2 (15.08%), F4 (10.73%) and F1 (10.25%) groups in order from highest to lowest. Regarding the amount of stearic acid, the highest value was found in the F3 group (5.31%) and the lowest value was found in the F1 group (3.01%). Erdem *et al*. (2020) reported the myristic acid content of Atlantic salmon as 3.24% in their study.

It has been reported by many researchers that fish oils are a very important nutritional source especially in terms of unsaturated fatty acids in their structure (Durmus, 2018; Hrebień-Filisińska, 2021). Among these unsaturated fatty acids, monounsaturated fatty acids (MUFA) are known to reduce the risk of high blood pressure and protect against cardiovascular diseases by balancing cholesterol. Monounsaturated fatty acid compositions of smoked salmon fillets are given in Table 2.

Table 1. Composition and amount of saturated fatty acids in smoked salmon fillets

Fatty acids	Groups			
	F1	F2	F3	F4
C14:0	2.40±0.02[a]	1.92±0.01[c]	2.02±0.01[b]	1.94±0.02[c]
C16:0	10.25±0.07[c]	15.08±0.41[b]	16.29±0.05[a]	10.73±0.18[c]
C17:0	0.12±0.01[b]	0.15±0.00[a]	0.14±0.00[a]	0.13±0.01[b]
C18:0	3.01±0.01[c]	4.68±0.13[b]	5.31±0.06[a]	3.20±0.02[c]
C20:0	0.69±0.03[a]	0.43±0.01[b]	0.32±0.02[c]	0.27±0.00[c]
C24:0	0.38±0.01[c]	0.18±0.00[d]	0.94±0.03[b]	1.62±0.06[a]
∑SFA	16.84±0.11[d]	22.44±0.57[b]	25.01±0.07[a]	17.87±0.23[c]

Means sharing the same letter in the same row (a–d) is not significantly different ($p < .05$) using Duncan's multiple range test. The values are expressed as mean ± standard deviation, n = 3. C14:0 (Myristic Acid), C16:0 (Palmitic Acid), C17:0 (Heptadecanoic Acid), C18:0 (Stearic Acid), C20:0 (Arachidic Acid), C24:0 (Lignoceric Acid), ∑SFA (Total Saturated Fatty Acids).

Table 2. Composition and amount of monounsaturated fatty acids in smoked salmon fillets

Fatty acids	Groups			
	F1	F2	F3	F4
C14:1	0.13±0.00a	0.14±0.00[a]	0.12±0.07[a]	0.14±0.00[a]
C16:1	2.80±0.24b	4.04±0.09[a]	3.22±0.25[b]	2.22±0.08[c]
C17:1	0.10±0.01a	0.07±0.01[c]	0.08±0.00[b]	0.04±0.00[d]
C18:1n9	34.47±0.51a	32.13±0.74[b]	27.22±0.49[c]	35.52±0.72[a]
C18:1n7	4.08±0.05a	3.60±0.15[b]	3.16±0.05[c]	3.44±0.05[b]
C20:1n9	4.41±0.05a	2.62±0.01[b]	1.84±0.04[c]	2.74±0.16[b]
C22:1n9	0.56±0.01b	0.52±0.00[c]	0.43±0.01[d]	0.64±0.01[a]
∑MUFA	46.55±0.49a	43.11±0.67[b]	36.05±0.81[c]	44.74±0.61[ab]

Means sharing the same letter in the same row (a–d) is not significantly different ($p < .05$) using Duncan's multiple range test. The values are expressed as mean ± standard deviation, n = 3. C14:1 (Myristoleic acid), C16:1 (Palmiteloic acid), C17:1 (Heptadecanoic acid), C18:1n9 (Oleic acid), C18:1n7 (Vaxenic acid), C20:1n9 (Eicosenoic acid), C22:1n9 (Erusic acid), ∑MUFA (Total monounsaturated fatty acids)

The total MUFA amounts of smoked salmon fillets were found to vary between 36.05% and 46.55%. Similar to our study, Erdem *et al.* (2020) determined the MUFA values of natural and cultured trout and Atlantic salmon as 40.86%, 34.53% and 46.19%, respectively. In the present study, palmitoleic acid (C16:1), oleic acid (C18:1n9) and vaccenic acid (C18:1n7) had the highest values among total monounsaturated fatty acids. Oz (2019) reported similar monosaturated fatty acids in his study on trout. The highest amounts of palmitoleic acid and vaccenic acid were determined in F2 (4.04%) and F1 (4.08%) groups, while lower values were determined in F4 (2.22%) and F3 (3.16%) groups, respectively. Among the monounsaturated fatty acids, oleic acid was the fatty acid with the highest value. The amount of oleic acid, which is one of the most important MUFAs, was found to vary between 27.22% and 35.52%. The highest oleic acid was determined in F4 group, followed by F1 and F2 groups. Keskin *et al.* (2022) reported the oleic acid content of Turkish salmon and Atlantic salmon sold in the central Black Sea region as 28.58% and 43.99%, respectively, similar to the present study.

Unsaturated fatty acids, which are among the most important determinants of the nutritional quality of seafood, are mostly in the form of omega-3 and omega-6 fatty acids. Omega fatty acids have an important role in the development of the brain and immune system. In addition, omega fatty acids have been reported to play an important role in the prevention of cardiovascular diseases, hypertension, immune, allergy and nervous disorders (Kinsella 1987; Leaf *et al.* 1988; Simopoulos 1991). The polyunsaturated fatty acid composition of smoked salmon fillets is given in Table 3.

Table 3 Composition and amount of polyunsaturated fatty acids in smoked salmon fillets.

Fatty acids	Groups			
	F1	F2	F3	F4
C18:2n6	12.37±0.04^{c}	13.56±0.13^{b}	15.41±0.20^{a}	12.64±0.07^{c}
C18:3n6	0.14±0.00^{a}	0.13±0.00^{a}	0.13±0.00^{a}	0.15±0.00^{a}
C18:3n3	3.99±0.06^{b}	2.67±0.04^{c}	2.33±0.15^{d}	4.99±0.03^{a}
C20:4n6	0.77±0.07^{c}	1.05±0.02^{b}	1.18±0.01^{a}	0.82±0.05^{c}
C20:5n3	4.29±0.22^{a}	2.07±0.11^{b}	2.16±0.04^{b}	4.24±0.27^{a}
C22:6n3	6.22±0.28^{c}	8.03±0.81^{b}	11.74±0.11^{a}	7.79±0.47^{b}
∑PUFA	27.77±0.41^{c}	27.49±0.78^{c}	32.94±0.21^{a}	30.62±0.59^{b}

Means sharing the same letter in the same row (a–d) is not significantly different ($p < .05$) using Duncan's multiple range test. The values are expressed as mean ± standard deviation, n = 3. C18:2n6 (Linoleic acid), C18:3n6 (γ-linolenic acid), C18:3n3 (Linolenic acid), C20:4 n6 (Arachidonic acid), C20:5n3 (Eicosapentaenoic acid) (EPA)), C22:6n3 (Docosahexaenoic acid (DHA)), ΣPUFA (Total polyunsaturated fatty acids).

Total polyunsaturated fatty acids (∑PUFA) are one of the most important indicators of food quality. In the present study, the PUFA values of smoked salmon fillets were determined as 27.77%, 27.49%, 32.94% and 30.62% and statistical differences were found between the groups except F1 and F2 groups. The most important fatty acids among PUFAs were linoleic acid (C18:2n6), eicosapentaenoic acid (EPA, C20:5n3) and decosahexaenoic acid (DHA, C22:6n3) in all groups. Among the smoked salmon samples, the highest value of linoleic acid was determined in F3 group with 15.41%, followed by F2 (13.56%) and F4 (12.64%) groups. Eicosapentaenoic acid (EPA) is one of the polyunsaturated fatty acids which has a very important value for human health. In the present study, the highest EPA value was found in the F1 group with 4.29% and the lowest value was found in the F2 group with 2.07%. DHA is another important polyunsaturated fatty acid. DHA amounts were found to vary between 11.74% and 6.22% and the highest DHA was found in the F3 group. It was determined that there was a statistical difference between the groups except F2 and F4 groups in terms of DHA ($p<0.05$). Pekcan (2016) reported the amounts of total PUFA, EPA and DHA in smoked salmon as 32.01, 3.63 and 6.68, respectively. Erdem *et al.* (2020) investigated the fatty acid content of Atlantic salmon and reported total PUFA and EPA values in similar ranges with the current study, while DHA value was reported as 5.00. The ΣPUFA/ΣSFA, Σn3, Σn6, n6/n3 and DHA/EPA changes of smoked salmon fillets are given in Table 4.

Table 4. Fatty acid index changes in smoked salmon fillets

Fatty acids	Groups			
	F1	F2	F3	F4
ΣPUFA/ΣSFA	1.65±0.01^{a}	1.22±0.00^{b}	1.28±0.05^{b}	1.71±0.01^{a}
Σn3	14.49±0.44^{ab}	12.76±0.89^{b}	15.23±1.41^{ab}	17.02±0.71^{a}
Σn6	13.28±0.03^{c}	14.73±0.11^{b}	16.72±0.21^{a}	13.61±0.12^{c}
Σn6/Σn3	0.92±0.03^{bc}	1.16±0.09^{a}	1.10±0.12^{ab}	0.80±0.04^{c}
DHA	6.22±0.28^{c}	8.03±0.81^{b}	11.74±0.11^{a}	7.79±0.47^{b}
EPA	4.29±0.22^{a}	2.07±0.11^{b}	2.16±0.04^{b}	4.24±0.27^{a}
DHA/EPA	1.45±0.01^{d}	3.87±0.18^{b}	5.44±0.05^{a}	1.84±0.00^{c}

Means sharing the same letter in the same row (a–c)) is not significantly different ($p < .05$) using Duncan's multiple range test. ∑n3 (Total omega 3 fatty acids), ∑n6 (Total omega 6 fatty acids).

In the present study, the lowest ΣPUFA/ΣSFA ratio was determined in the F2 group (1.22) and the highest ratio was determined in the F4 group (1.71). HMSO (1994) reported that the ΣPUFA/ΣSFA ratio should be at least 0.45. According to the findings of the present study, all groups had ΣPUFA/ΣSFA ratio above the minimum limit value recommended by HMSO (1994). In terms of Σn3 and Σn6, the highest values were found in F4 group with 17.02 and F3 group with 16.72, respectively. It was determined that there was a statistical difference between F2 and F4 groups in terms of Σn3. The lowest amount of Σn6 was determined in the F1 group with 13.28. The n6/n3 ratio of unsaturated fatty acids is associated with the causes of mortality from cancer and cardiovascular diseases (Hoz *et al.*, 2004). This ratio has also been reported to be an important indicator used to compare the nutritional value of fish oil (Pigott and Tucker, 1990; Cengiz *et al.*, 2010) and should be kept as low as 1:1 or 2:1 in diets (Granados *et al*., 2006). According to HMSO (1994), it was suggested that this ratio could be maximum 4. In the present study, the Σn6/Σn3 ratio was found to be between a minimum of 0.80 (F4 group) and a maximum of 1.16 (F2 group). Statistical differences were found between the groups ($p<0.05$). The results obtained in our study did not exceed the limit value of Σn6/n3 ratio recommended by HMSO (1994). The DHA/EPA ratio was found to vary between 1.45 and 5.44. A statistical difference was found between all groups. Erdem *et al.* (2020) calculated the DHA/EPA ratio of wild caught, farmed trout and Atlantic salmon as 3.22, 3.42 and 2.01, respectively. Aslan *et al.* (2007) reported the DHA/EPA ratio of wild-caught and farmed trout as 1.55 and 5.00, respectively. Similarly, Oz and Dikel (2015) found the DHA/EPA ratios of wild-caught and farmed trout to be 1.31 and 5.32. Pekcan (2016) investigated the effects of different salt concentrations on the quality of hot smoked salmon (*Salmo salar*), trout (*Snchorhynchus mykiss*) and mackerel (*Scomber scombrus*) fillets. They reported the Σn3, Σn6, Σn3/Σn6 and DHA⁄EPA values of salmon as 11.11%, 19.47%, 0.57% and 1.84%, respectively. While DHA ⁄ EPA values reported by Aslan *et al.* (2007) and Pekcan (2016) were similar to the present study, differences were observed in terms of Σn6, Σn3/Σn6 values. It is thought that these differences may be due to the quality, physico-chemical structure, technical differences in processing technology conditions or environmental conditions, as well as the feeding regime of the fish.

As a result, it was concluded that the smoked fish fillets examined had high nutritional quality in terms of fatty acids. Among the groups, especially F3 and F4 groups were found to have rich content in terms of PUFA and Σn3 values.

4. CONCLUSION

In this study, the fatty acid composition of processed salmon fillets sold in grocery stores was investigated. All of the smoked fish fillets investigated were found to be rich in unsaturated fatty acids, which are important for human health. However, it can be concluded that there were significant differences in fatty acid compositions between the groups, especially in total MUFA and PUFA. The highest and lowest EPA values were detected in the F1 and F2 groups, respectively. Additionally, the highest amount of DHA was found in the F3 group. The Σn6/Σn3 ratio in all groups is compatible with the recommended values for human health. With this study, it was concluded that smoked fillets contain a particularly good fatty acid composition in terms of nutrition and can be classified as beneficial to human health. With the increasing demand for processed seafood products, it is recommended that the nutritional content of other processed seafood products should be regularly examined in order to provide healthy products to consumers and sustainability.

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AUTHORSHIP CONTRIBUTION STATEMENT

All authors contributed to the conception and design of the experiments, their performance, interpretation of the obtained results, writing of the article.

CONFLICT OF INTERESTS

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

ETHICS COMMITTEE PERMISSION

No ethics committee permissions are required for this study

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Comparison of ANN and SVR based models in sea level prediction for the Black Sea coast of Sinop

Sinop'un Karadeniz kıyısı için deniz seviyesi tahmininde YSA ve SVR tabanlı modellerin karşılaştırılması

Türk Denizcilik ve Deniz Bilimleri Dergisi

Cilt: 10 Sayı: 1 (2024) 49-56

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ABSTRACT

Seawater level oscillations are very critical to coastal construction, flood prevention and human living conditions. However, it is difficult to accurately project the daily future for seawater level due to the effects of wind, precipitation and other atmospheric conditions. For this reason, in this paper, artificial intelligence (AI) based Artificial Neural Networks (ANN) and Support Vector Regression (SVR) methods are applied for the estimation of seawater level in Sinop Coast. In addition, Multiple Linear Regression (MLR) is used as a benchmarking model. In this study, coefficient of determination (R^2) and root mean square error (RMSE) were applied as model evaluation criteria. Besides, 15 minutes (approximately 22 months) sea water level data of Sinop Station were collected and used as is. The findings revealed that the ANN model can predict the water level for 1st, 2nd, 3rd, 4th days with correlation coefficients (R^2) of 0.84, 0.67, 0.64, 0.63, respectively, and the SVR model can predict for 1st, 2nd days with correlation coefficients (R^2) of 0.86, 0.66, respectively.

Keywords: ANN, SVR, Artificial Intelligence, Black Sea, Sinop coast

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ÖZET

Deniz suyu seviyesi salınımları, kıyı inşaatı, taşkın önleme ve insan yaşam koşulları için çok büyük önem arz etmektedir. Ancak rüzgar, yağış ve diğer atmosferik koşulların etkileri nedeniyle deniz suyu seviyesinin günlük hareketini doğru bir şekilde tahmin etmek zordur. Bu nedenle bu çalışma bünyesinde Sinop Sahili'nde deniz suyu seviyesi tahmini için yapay zeka (AI) tabanlı Yapay Sinir Ağları (YSA) ve Destek Vektör Regresyon (DVR) yöntemleri uygulanmaktadır. Bunların yanında kıyaslama modeli olarak Çoklu Doğrusal Regresyon (ÇDR) kullanılmaktadır. Model değerlendirme kriteri olarak ise determinasyon katsayısı (R^2) ve ortalama karesel hata (RMSE) yöntemleri kullanılmıştır. Bunlarla beraber, Sinop İstasyonu'nun 15 dakikalık (toplamda yaklaşık 22 aylık) deniz suyu seviyesi verileri toplanmış ve olduğu gibi kullanılmıştır. Sonuç olarak bulgular, YSA modelinin sırasıyla 0.84, 0.67, 0.64, 0.63 korelasyon katsayıları (R^2) değerleri ile 1., 2., 3. ve 4. günler için su seviyesini tahmin edebildiğini ve DVR modelinin 1., 2. günler için sırasıyla 0.86, 0.66 korelasyon katsayıları (R^2) değerleri ile tahmin edebildiğini ortaya koymuştur.

Anahtar sözcükler: YSA, DVR, Yapay zeka, Karadeniz, Sinop sahili

1. INTRODUCTION

Sea level has increased greatly in recent times due to human activities. (Woodworth *et al.*, 2021; Yesudian and Dawson, 2021; Jin *et al.*, 2023). The social economy and ecological habitat of coastal areas has been catastrophically affected by sea level rise (Bernstein *et al.*, 2019; Meilianda *et al.*, 2019). Thus, accurate estimation of sea level change has great importance for coastal zones with growing population (Primo de Siqueira and Paiva, 2021; Zhao *et al.*, 2021; Jin *et al.*, 2023).

The Black Sea is an inland sea that receives Europe's largest discharge from the Danube River (Karsavran *et al.*, 2020). It also exchanges water from the Mediterranean through the Bosphorus and the Dardanelles (Karsavran and Erdik, 2021). Accordingly, the daily forecast of the Black Sea level change has great importance.

Artificial Intelligence (AI) methods are commonly utilized in navigation safety, agricultural processes etc. Compared to traditional engineering, AI analysis techniques offer outstanding learning performance and noise tolerance. Therefore, AI methods are more preferred in the analysis of coastal processes and their importance is strengthened by an increasing number of observational datasets (Beuzen and Splinter, 2020; Guillou and Chapalain, 2021).

Röske (1997) was the first to use ANN to estimate sea water level. Also, it has been reported that neural networks for sea level prediction has been successfully applied in studies conducted in recent years (Song *et al.*, 2022). For instance, Imani *et al.* (2017) employed machine learning to estimate the water level projections in the Coast of Chiayi. Zhao *et al.* (2019) applied a neural network approach to predict the sea level of the Yellow Sea. Similarly, the water level of Bosphorus Strait was predicted by using ANN and SVR (Karsavran and Erdik, 2021). Balagun *et al.* (2021) applied SVR and neural network systems to predict sea level fluctuations in the western Peninsular Malaysia. Lastly, Jin *et al.* (2023) used neural network methods to predict sea level in the coastal area of China.

Although there is a great deal of research in this area, there is a lack of comparison of the prediction performances of artificial intelligence methods for the Black Sea coast of Sinop. Our study applies SVR and ANN models to predict sea level of Sinop coast. Based on the performances, we evaluate prediction performance for future projection. In addition, MLR is used as a benchmarking model in this study.

2. METHODOLOGY

2.1. Artificial Neural Network

An ANN is a small group of separately related processing units that transmit information to interconnects. The multilayer perceptron (MLP) technique, that has been used for predictions in many fields of engineering and science since the 1990s, consists of at least three interconnected layers of neurons (Chau and Cheng, 2002). The input layer is the first layer accepting external data, and the output layer is the last layer producing the results of the MLP. The hidden layer is the layer, where weighted inputs are received by artificial neurons and add a bias value (Karsavran and Erdik, 2021).

Back propagation algorithm performs two stages of data flow. Firstly, the inputs travel to the network from the input layer to the output layer. Lastly, the network generates an output vector that is confronted with the desired target vector and an error is estimated using predetermined error function. At this point, the error signals are propagated back from the output layer to the previous layers to update their weights based on the Equation 1:

$$\Delta w_{ij}(n) = \alpha^{'} \Delta w_{ij}(n-1) - \varepsilon \left(\frac{\partial E}{\partial w_{ij}} \right) \quad (1)$$

$\Delta w_{ij}(n)$ and $\Delta w_{ij}(n-1)$ are the weight gains among the input and hidden layers during the nth and $(n-1)^{th}$ steps, α' is the momentum factor that accelerates the training and aids blocking oscillations, and ε is the learning rate that rises the possibility of preventing the training process from being ambushed in a local minimum instead of a global minimum (ASCE Task Committee, 2000; Karsavran and Erdik, 2021).

2.2. Support Vector Regression

SVR is a neural network based on statistical learning which is used for a variety of engineering regression problems (Patil *et al.*, 2012). The SVR has a machine learning algorithm that works with hyperplane for splitting data from one dimension to high dimensional space (Alshouny *et al.*, 2022). It solves the regression problems with Equation 2:

$$f(x) = \sum_{i=1}^{n} w.\phi_i(X) + b \quad (2)$$

where w=weight, $\emptyset_i$(X)= Kernel function and b=bias. The optimal objective function is depicted in Equation 3:

$$\min R = \frac{1}{2} w^2 + C \sum_{i=1}^{n} (\xi_i + \xi_i^*) \quad (3)$$

The constraint conditions are shown in Equation 4:

$$Subject\_to \begin{Bmatrix} f(x_i) - y_i \le \varepsilon + \xi_i \\ y_i - f(x_i) \le \varepsilon + \xi_i^* \\ \xi_i \ge 0, \xi_i^* \ge 0, i = 1, 2, ..., n \end{Bmatrix} \quad (4)$$

where C= cost factor, ε= allowable error, ξ_i and ξ_i^* are relaxation numbers. Both will be greater than zero if there are some prediction errors, otherwise both will be zero (Lin *et al.*, 2020; Karsavran and Erdik, 2021).

2.3. Multiple Linear Regression

For models with more than one independent variable, the Multiple Linear Regression (MLR) model is applied and it makes the regression model highly flexible. The general MLR is depicted in Equation 5:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_n X_n \quad (5)$$

where X_i=independent variable, β_i= regression coefficient, Y= dependent variable. The aim of MLR is to find an approximation function for estimating system outputs (Karsavran and Erdik, 2021).

2.4. Model Evaluation Criteria

The model performances were obtained in terms of two different numerical error statistics. These are coefficient of determination (R^2) and the root mean square error (RMSE) given in Equation 6 and Equation 7, respectively.

$$R^2 = \left[\frac{\frac{1}{n} \sum_{i=1}^{n} (WL_0(i) - WL_0^{'})(WL_f(i) - WL_f^{'})}{\sqrt{\frac{1}{n} \sum_{i=1}^{n} (WL_0(i) - WL_0^{'})^2} \cdot \sqrt{\frac{1}{n} \sum_{i=1}^{n} (WL_f(i) - WL_f^{'})^2}} \right]^2 \quad (6)$$

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(WL_f(i) - WL_0(i))^2} \quad (7)$$

where $WL_o(i)$ and $WL_f(i)$ are observed and forecasted sea water level, respectively. WL_0' and WL_f' depicts their averages, and n is the number of data.

3. DATA AND STUDY AREA

This study is based on the measurements of the Sinop tide gauge station (Lat:42.02, Lon:35.14) on the southern Black Sea coast (Figure 1). The sea level data are acquired from the Turkish Sea Level Monitoring System (TUDES, https://tudes.harita.gov.tr/), provided at 15-minute time intervals.

The Sinop Station started recording in June 2005. The sea level data used in this study were measured at 15-minute time intervals for 22 months, from July 2016 to May 2018, and were used as is (Figure 2). Missing data were estimated by applying linear interpolation method. In this study, 70% of the total data was used for training and the remaining 30% for testing all models (Karsavran and Erdik, 2021). Data splitting was done randomly and the same training and test data were used for each model run.

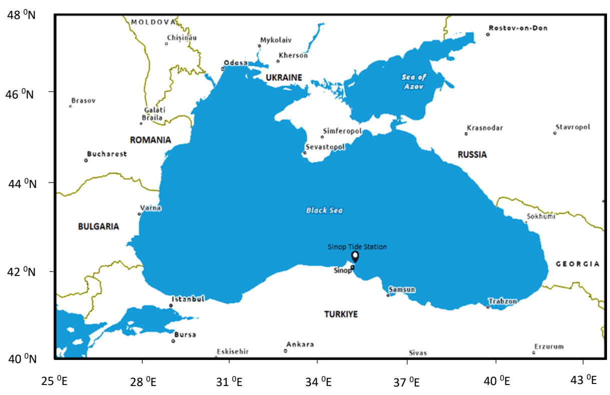

Figure 1. The location of the Sinop Tide Gauge Station

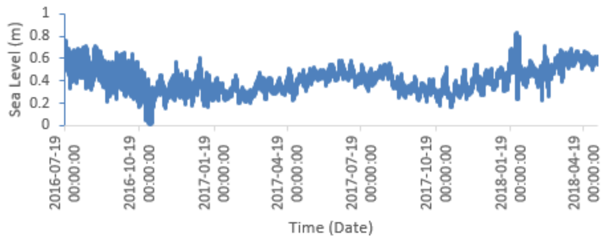

Figure 2. Time series of sea water level in Sinop station

4. RESULTS AND DISCUSSIONS

In this article, ANN and SVR model performances for sea level prediction of Sinop coast are compared for the next 4 days. The code of all models in this study has been written in Python. Firstly, ANN is used to decide on the input set combination of the models. Table 1 shows the benchmark of the input sets on the prediction results of the ANN model for the next day (t+1) in Sinop Station. The use of three values WL(t), WL(t-1) and WL(t-2) increases the model performance with R^2 values of 0.84, while the use of subsequent four values WL(t), WL(t-1), WL(t-2) and WL(t-3) decreases the performance of the ANN model. Finally, the previous variables (WL(t), WL(t-1) and WL(t-2)) were applied as inputs for all models that produced the highest performance.

After the decision on input set, the ANN model including Vanilla-Standart backpropogation algorithm is used to predict the seawater level for lead times of 1, 2, 3 and 4 days. Activation functions logsig, tansig and purelin of hidden and output neurons are applied. As a result, R^2 is 0.84 and 0.65 for lead times 1 (Figure 3) and 2 days, respectively (Table 2).

The Radial Basis Function (RBF) Kernel SVR is applied to predict the water level with specified lead times (Table 2). Most of the studies on the use of SVR in coastal modeling and forecasting have shown positive performance of the RBF (Wang *et al.*, 2009; Karsavran and Erdik, 2021). Therefore, RBF as a Kernel function has been applied and Kernel's C parameter is 1000 in this study. The best performance of SVR is found with R^2 = 0.86 and RMSE = 0.07 for 1 day the lead time (Figure 4).

The results of MLR model for the designated lead times are given in Table 2. The best performance of MLR model is R^2 = 0.68 and RMSE = 0.12 (Figure 5). The underlying residues are normally distributed in MLR models.

In general, ANN and SVR models provide similar prediction results and better prediction performance than MLR model. The SVR predicts the water level with the highest R^2 = 0.86, 0.66 and RMSE = 0.07, 0.12, while ANN is with the highest R^2 = 0.84, 0.65 and RMSE= 0.09, 0.12 in Sinop Station for lead times 1 and 2 days, respectively. Therefore, SVR seems to be the best model to forecast next 1 and 2 days water level in Sinop. However, SVR prediction performance decreases drematically with R^2 = 0.53, 0.49, while ANN predicts with R^2= 0.64, 063 for lead times 3 and 4 days, respectively. Accordingly, ANN is more ideal than the SVR model in Sinop for forecasting the next 3, 4 days and for long-term forecasting.

This study can be used for long-term projections of the water levels in the coastal region of Sinop. The results of this article and the approach proposed and applied in this study can be used for the analysis of such phenomena.

Table 1. ANN model performance for t+1 sea level according to input sets

Input Set	Output Set	RMSE (m)	R^2
WL(t)	WL(t+1)	0.13	0.63
WL(t)WL(t-1)	WL(t+1)	0.09	0.80
WL(t)WL(t-1)WL(t-2)	WL(t+1)	0.08	0.84
WL(t)WL(t-1)WL(t-2)WL(t-3)	WL(t+1)	0.08	0.83
WL(t)WL(t-1)WL(t-2)WL(t-3)WL(t-4)	WL(t+1)	0.08	0.83

Table 2. Model performances with respect to lead time prediction WL(t+L)

Inputs (t = day)	Prediction (t = day)	ANN		SVM		MLR	
		RMSE (m)	R^2	RMSE (m)	R^2	RMSE (m)	R^2
WL(t)WL(t-1)WL(t-2)	WL(t+1)	0.08	0.84	0.07	0.86	0.12	0.68
WL(t)WL(t-1)WL(t-2)	WL(t+2)	0.12	0.65	0.12	0.66	0.18	0.25
WL(t)WL(t-1)WL(t-2)	WL(t+3)	0.13	0.64	0.15	0.53	0.20	0.10
WL(t)WL(t-1)WL(t-2)	WL(t+4)	0.13	0.63	0.15	0.49	0.21	0.07

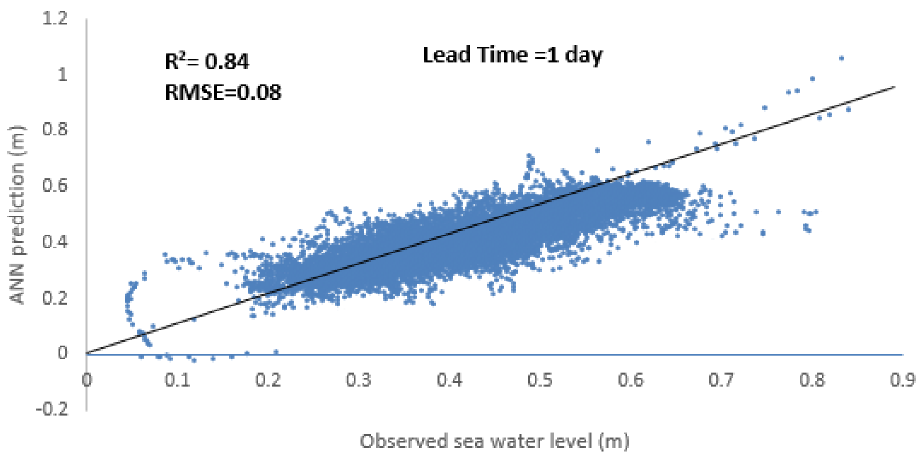

Figure 3. Scatter plot of observed and predicted sea water level for ANN

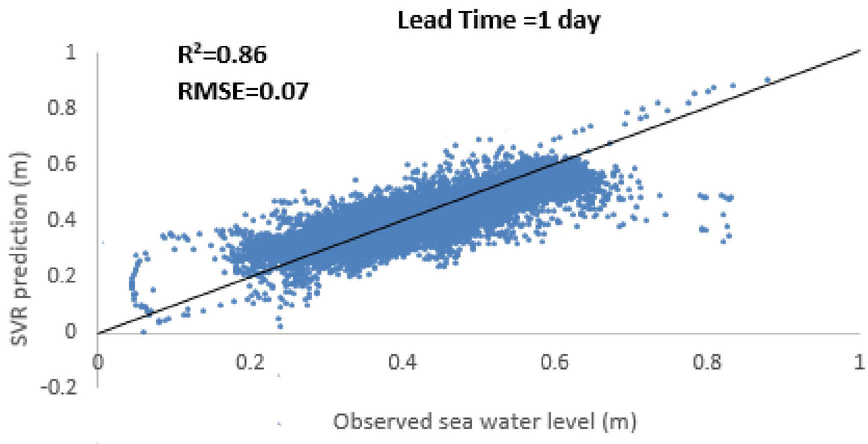

Figure 4. Scatter plot of observed and predicted sea water level for SVR

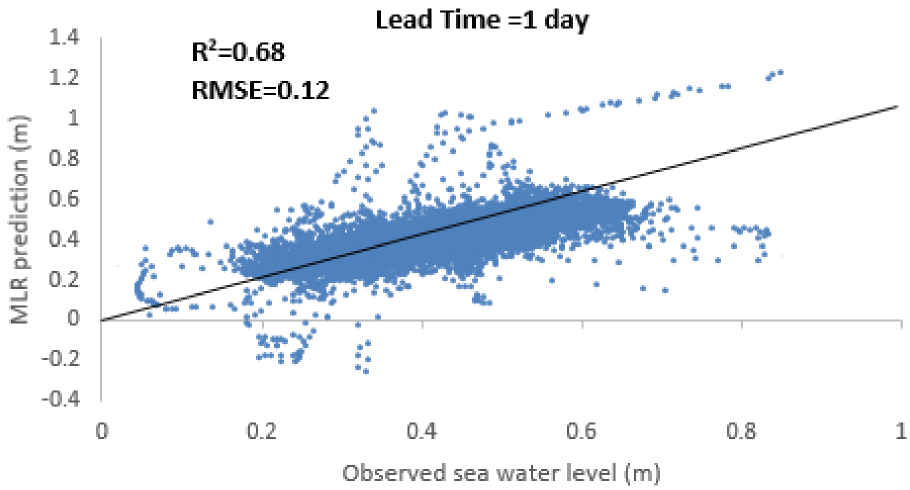

Figure 5. Scatter plot of observed and predicted sea water level for MLR

5. CONCLUSION

In this study, a higher coefficient of determination R^2 was obtained by applying ANN and SVR models to predict the daily water level of the Sinop for next 1, 2, 3 and 4 days. The results depict that SVR has the best performance in prediction of the seawater level in Sinop, while ANN comes close to its prediction performance for the lead times 1 and 2 days. However, ANN produces higher scores than SVR for the lead times of 3 and 4 days for the prediction of seawater level in Sinop. As a result, while the SVR model is more advantageous to be applied for the next 1 and 2 days for water level prediction in Sinop, ANN is more advantageous to be applied for the next 3-4 days and for long-term forecasting.

The SVM model is the main AI method to be used for the sea level surge warning system in Sinop for future studies. I believe that the results presented here may open up new insights in modeling the sea level. More specifically, the methods applied in this study can be used for other coasts of the Black Sea region, including but not limited to Igneada, Istanbul, Amasra, Trabzon.

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AUTHORSHIP CONTRIBUTION STATEMENT

Yavuz KARSAVRAN: Conceptualization, Methodology, Formal Analysis, Writing-Original Draft, Writing-Review and Editing, Data Curation, Software, Visualization, Supervision.

CONFLICT OF INTERESTS

The author declares that for this article they have no actual, potential or perceived conflict of interests.

ETHICS COMMITTEE PERMISSION

No ethics committee permissions is required for this study

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