RİBİAD Rizeli Bürokratlar, Yöneticiler ve İş İnsanları Sosyal Dayanışma Derneği

KÜÇÜK DEV BALIK: HAMSİ

ANCHOVIES:
Ecological, Economic and Social Evaluation

EDITED BY **Prof. Dr. Kadir SEYHAN**

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SUNUŞ...

Sivil toplum kuruluşları, devletin toplumla ilgili reel istek ve varsa çözüm önerilerinin oluşmasında önemli kuruluşlarıdır. RİBİAD, Rizeli Bürokratlar, Yöneticiler ve İş İnsanları Derneğimiz gönüllü çalışmaların esas alındığı vefakar hizmetlerle faaliyet alanını genişletip, memleket kültürüne duyulan hasretle yola çıkarak Rize ilimizin sorunlarına çözüm bulmak, gelişmesine katkı sağlamak ve ilimize ait örf, adet ve gelenekleri tanıtmak amacıyla kurulan bir sivil toplum kuruluşudur. Amacımız temsil ettiğimizşehrimizi ön plana çıkarırken bürokrasi, iş dünyası ve yöneticiler olarak birbirimizin çalışmalarını desteklemek ve katkıda bulunmaktır.

Demokratik toplumlardaki sivil toplum örgütleri, kendi üyelerinin görüşlerini topluma yansıtarak kamuoyu oluşturmaya çalışırlar. Sivil toplum örgütleri aracılığıyla kamuoyu oluşturma, hak ve özgürlüklerin korunmasında, çevre bilincinin yerleşmesinde çok önemlidir. Çünkü bunlar sivil toplum örgütlerinin yaptıkları çalışmalar olarak bireysel olarak yapılan etkinliklerden daha etkilidir. Bu bakımdan toplumsal anlamda yapılacak etkinlikler için sivil toplum kuruluşlarına katılım çok önemlidir.

Derneğimiz, herkesi kucaklayarak hiçbir siyasi parti ve görüş ayrımı yapmadan, daha güzel ve yaşanılır bir Rize/Rizeli için çalışmalarını sürdürmektedir. Attığımız her adım, ortak bir payda da buluşmak içindir. Herhangi bir amaca ulaştığımızda bununla yetinmek yerine, durmadan daha ileriye gitmek, için çalışmaya devam etmek en önemli amacımızdır.

Yaptığımız birçok etkinliğin yanında 2021 yılında tüm dünyayı sarsan COVİD-19 gölgesinde ancak online gerçekleştirebildiğimiz Hamsi konferansı ile sadece bölgemize değil dünya denizlerinde haklı bir üne sahip Hamsi' ye dikkatlerimizi çevirdik ve iki oturumda tam bir günde bitirdik. Konferansta sunulan tüm tebliğleri kitaplaştırmak bizim öncelikli görevlerimizdendi. Yerli yabancı emeği geçen tüm hocalarımıza teşekkür ediyorum. Bu çalışma dünya denizlerindeki Hamsi stoklarını ele alan ve Hamsi kültürünü dikkatlere sunan ilk eser olma özelliğini taşımaktadır. Dolayısı ile bu çalışmanın araştırmacılara, ilgi duyan tüm kesimlere ve hemşerilerimize yararlı olacağına inanıyorum. Özellikle bu konunun gündeme gelmesinde Prof. Dr. Kadir Seyhan, İlkay Gök ve Arif Ekşi'ye çok teşekkür ediyorum. Ayrıca Online toplantılarımıza katılım sağlayan, bilgi ve tecrübeleriyle çalışmamıza yön veren TÜMBİKON - TSTK Genel Başkanı Cevdet Akay'a, TÜMBİFED Genel Başkanı Mehmet Hüsrev'e, TÜMBİKON Genel Başkan Vekili Prof. Dr. M. Ertaç Ergüven'e, Moderatörümüz Arif Ekşi'ye, Ali Rıza Şişman'a, Murat Karali'ye, Kazım Ercihan'a, Osman Kan'a, İlknur Karlı'ya, Ayşe Çebi'ye, İshak Koçoğlu'na, Dokap Başkanı Hakan Gültekin'e, Prof. Dr. Ahmet Cemal Dinçer'e, Doç. Dr. Ülgen Aytan'a, Arş. Gör. Yahya Terzi'ye, Dr. Umar Khan'a, Dr. Kikhail Chesa¬lin'e, Dr. Violin Stoyanov Raykov'a sonsuz şükranlarımı sunarım.

Erol AYKUT

RİBİAD GENEL BAŞKANI

KARADENİZ’DEN DÜNYAYA BÜYÜK SERVET

Cevdet AKAY
TÜMBİKON Genel Başkanı

Her bir coğrafya bağrından yarattığı değerleriyle bilinir ve tanınır. Bizlerin de görevi o değerlere sahip çıkmak ve onları olabildiğince yüceltmektir. Bundan dolayıdır ki, bazen bir ürün, bir işaret bir söz bir memleketi anlatır ve çoğu zaman onunla özdeşleşir.

Karadeniz ve bölge insanı için tartışmasız bir önemi olan hamsinin ülkemiz açısından da önemini vurgulamak ana düşüncesiyle RİBİAD’ın öncülüğünde başlattığımız ve uzunca süren bir çalışmanın ardından nihayete erdirdiğimiz bu çalışmamızın bilim dünyamız açısından önemli bir başucu eser olacağı inancındayız.

TÜMBİKON olarak gerçekleştirdiğimiz tüm toplantılarımızda, etkinliklerimizde ve çalıştaylarımızda hamsinin tartışmasız önemine değindik. Karadeniz mutfağı, kültürü ve ekonomisi için vazgeçilmez bir balık türü olan hamsinin akademik düzlemde de tartışılmasını, değerlendirilmesini sağladık. Akademik camiadan birçok hocamızla bu meseleyi etraflıca ele aldık ve masaya yatırdık.”

Karadeniz’imizin bu milli değerini yüceltmek, bilim dünyasında yer edinmesini sağlamak ve en önemlisi ekonomiye katkısını somut hale dönüştürmek gayesiyle konfederasyonumuz olarak bütün çalışmaların yakın takipçisi olduk ve olmaya devam edeceğiz. Çünkü biliriz ki hamsi bir balıktan çok ötesidir.

Çalışmalarımıza destek veren tüm dostlarımıza, akademisyenlerimize ve dernek başkanlarımıza şükranlarımı sunarım.”
Saygılarımla

BÜYÜK KARADENİZ EKONOMİSİNİN KÜÇÜK KAHRAMANI : HAMSİ

KÜÇÜK KAHRAMANIN BÜYÜK ETKİSİ

MERHABA

Karadeniz denince akla gelen hamsinin hem Karadeniz'de hem de ülkemizin tamamında değerinin daha iyi anlaşılması, hak ettiği konuma ulaşması ve ülkemizin ekonomik döngüsüne katkıda bulunması düşüncesiyle Hamsi konusunu ele alan, onu her yönüyle inceleyen, irdeleyen ve bilimsel bir zeminde araştırılmasını sağlayan böylesi değerli bir çalışmayı tamamlamanın mutluluğu içindeyiz.

İklimsel ve çevresel faktörlerle birlikte ekonomi dünyasında da yaşanan değişim ve gelişmeler ışığında ele aldığımız hamsinin geleceğini somut adımlar atma koşuluyla kalıcı bir eser haline dönüştürme kararlılığımızın bir sonucu olarak, RİBİAD İş birliği ile hamsinin Türkiye'deki durumu, biyolojik yapısı, avlanma şekilleri ve ayrıca hamsinin tarihi, kültürü ve tüketimi gibi konuları uluslararası uzman konuşmacıların da katılımıyla bilimsel bir rehber niteliğine dönüştürdük.

Hamsinin yalnızca ekonomiye katma değer sağlamadığını ayrıca kültürel yönden de büyük değer kattığı bilinmektedir. Hamsinin Türkiye ve Dünya ölçeğinde pazarlanması ve bulunduğu konumdan çok daha üst bir konuma ulaşması için gerekli adımları atmaya devam edeceğiz.

Sevgi ve saygılarımla.

Arif EKŞİ
RİBİAD GENEL SEKRETERİ

ÖNSÖZ

"Balıkçılık, sadece dünya genelinde düşük gelire sahip 1 milyardan fazla insan için ucuz protein sağlayıcı sektör değil aynı zamanda muazzam sosyal, kültürel ve ekonomik öneme sahip bir aktivitedir. Bu nedenledir ki Birleşmiş Milletler (UN) 2030 yılını adaletsizlik ve eşitsizlikle birlikte deniz ve okyanus kaynaklarının korunması ve sürdürülebilir yönetimi için mücadele yılı olarak belirlemiştir. İstatistiksel verilere yansıyan son rakamlar alınan bu kararın ne kadar doğru olduğunu da gözler önüne sermektedir."

Bugün dünyada toplam balık üretimi 180 milyon ton civarındadır. Bunun yarısına yakını (80 milyon ton) yetiştiricilikten, geri kalan 100 milyon tonu ise avcılıktan sağlanmaktadır. Balık yetiştiriciliğindeki gözle görülür artış 1970'li yıllarda başlamış ve 1980'1i yılların sonlarına doğru artış net bir şekilde gözlemlenir olmuştur. Buna mukabil dünya balık stoklarından elde edilen av miktarında artış olmamış ve durağan pozisyona geçmiştir. Toplam avın %81,2 si, birinci sı- rada Çin olmak üzere, Endonezya, ABD ve Rusya'nın yer aldığı 25 ülke tarafından sağlanırken %18,8 ise dünyanın diğer 170 ülkesinden gelmektedir. İstatistiğe yansıyan toplam avın %88'i direkt insan gıdası olarak tüketilen kısımdır.

"Balıkçılık aktivitesi sadece denizlerle sınırlı olmayıp toplam avın %11'ini iç sulardan avlanan balıklar oluşturınaktadır. Toplam avın %80'i çoğu Asya ülkelerinden olmak üzere (16 ülkeden) sağlanmaktadır. Balıkçılık aktiviteleri ile en fazla avlanan balık türü Alaska mezgiti olup ikinci sırayı Türk kamuoyunun da yakından tanıdığı hamsi almaktadır. Tuna balığı ise üçüncü sıradan istatistiğe girmektedir. Kişi başına düşen balık tüketimi Dünyada 1960'lı yıllarda 9 kg iken yıllık

%1,5 artışla günümüzde 20 kg'a ulaşmıştır. AB, Japonya ve ABD, 1960'lı yıllarda toplam üreti- min %47'sini tüketirken bugün bu oran %20'lere düşmüştür. Asya ülkeleri ise kişi başı na 24 kg ile yarısından fazlasını tüketmektedir.”

“Güncel balıkçılık istatistiklerine göre dünyada 60 milyon insan balıkçılıkla geçimini sağlamakta- dır. Bunun 20 milyonu ise akuakültürde istihdam edilmektedir. Yine dünyada 4,6 milyon balıkçı teknesi mevcut olup bunun%75'i Asya ülkelerindedir. Balıkçılık endüstrisi dünyada 400 milyar doların sirküle edildiği bir pazardır. Bunun 250 milyar doları akuakültür ve 150 milyar doları ise avcılıktan elde edilmektedir. Bu pazarın değerinin 1976'larda 8 milyar dolar olduğu gerçeğinden hareket edilirse gelinen noktada rakamın 40 yılda 50 kat artmış olduğu görülür ki bu önemli bir değerdir. Çin dünya ülkeleri arasında hem en çok üreten hem de en çok satan ülke konumundadır. Norveç ise ikinci durumdadır.”

Türkiye'de de dünyada görülen trend benzer bir şekilde tezahür etmektedir. Yaklaşık 150-200 bin kişinin istihdam edildiği tahmin edilen Türkiye'de balıkçılık her geçen gün önemini arttır- mış, buna mukabil denizlerimizdeki balık çeşitliliği ve azalan av kamuoyu tarafından sıklıkla tartışılır olmuştur. Yıllar itibari ile denizlerimizde en fazla av veren balık hamsidir ancak av miktarı her geçen gün azalmaktadır. Özellikle 1980'li yılların sonunda gözlenen ve gemi balast suları ile Karadeniz'e taşındığı bilinen deniz anası (Mnemiopsis leidyi olarak bilinen tentaküllü ktenefor) istilası hem hamsi yumurtası ile beslenmiş hem de hamsinin besin kaynaklarına ortak olarak hamsi avının dramatik düşmesine neden olmuş, daha sonra da Karadeniz ekosistemine gelen Beroe ovata'nın (M. leidyi'nin doğal düşmanı) da etkisi ile eski seviyelerine hiç ulaşama- dan yıldan yıla dalgalanmış, pelajik balıklarda görülen genel dalgalanma eğilimi ile, son birkaç yılın dışında, hamsideki azalma devam etmiştir. Türkiye de kişi başına düşen balık tüketiminin yıllarca 6-9 kg arasında kaldığı dahası kıyı böl- gelerde yer alan yerleşim alanlarındaki tüketim miktarlarının Anadolu'nun diğer yer lerine göre mukayese götürmez şekilde açık ara önde olduğu bilinmektedir. Özellikle büyük kentlerde balık tüketiminin yaygın olması ucuz protein kaynağının tüketiciye taze olarak ulaşabildiği gerçeğini ortaya çıkarmaktadır. Bunun yanında son yıllarda ülkemizde akuakültür ürünlerinin bollaşması ve piyasa değerlerinin tercih edilebilir düzeylerde olması nedeni ile işlenmiş ve değerlendirilmiş yerli ürünler yaygınlaşmış hatta ihraç ürün olarak önemi her geçen gün artar olmuştur. Tatlı su balıklarından alabalık ve sazan, deniz balıklarından ise çipura ve levrek de tüketicinin her daim ilgisine mazhar olmaya devam etmektedir. Yetiştiricilik hem ekonomik girdi hem de sağladığı artı değer bakımından balıkçılıkta önemli bir sektör olmuş ve daha iyi pozisyon almaya aday konuma gelmiştir. Bunun en belirgin göstergesi Türkiye'nin AB ülkeleri arasındaki sırası ve kullanılan teknolojinin bu coğrafyadaki durumudur.

Türkiye' de istatistiğe yansıyan balıkçılık verilerine bakıldığında avcılık Karadeniz' de %70 oranı ile ilk sıradadır. Diğer bir deyişle toplam avın yarısından çoğu Karadeniz'den elde edilmektedir. Toplam istihsalin %60'ını ise hamsi oluşturmaktadır ve Karadeniz'de avlanan toplam hamsinin %90'dan fazlasını da sadece Türk balıkçılar avlamaktadır. Canlı kaynaklarının yönetiminde birçok problem vardır. Özellikle son yıllarda kamuoyunun hak lı olarak dikkatini çeken sorunlardan birisi iklim değişikliğidir. İklim değişikliğinin etkisini yok etmenin yolu CO2 salınımını azaltarak deniz ve okyanusların ısınmasının önüne geçmektir. Bu durum daha çok sanayileşmiş, gelişmiş ve gelişmekte olan ülkelerin tutumlarına bağlıdır ki bu büyük bir yekünü oluşturmakta ve sağduyunun hakim kılınmasının kolay olmayacağı aşikardır. Bir diğer önemli sorun ise deniz ve tatlısu canlıları habitatlarının yaşanamaz hale gelmesidir ki bu noktada da direkt sorumlu yine insanoğludur. Gerek kirlilik gerekse yaşam alanlarının tahrip edilmesinin önüne geçmek önem arz eden bir husustur. Aşırı avcılık bugün dünyada en önemli balıkçılık sorunu olarak bilinmektedir, bir bakıma da öyledir. Dünyada mevcut balık stoklarının biyolojik olarak sorunsuz olanlarının oranı yıldan yıla düşerken aşırı avcılığa maruz kalan balık stokların yüzdesi her geçen gün artmaktadır. Balık stoklarının %37'si tamamı ile bitme nokta- sındadır. Dünya stoklarının %60'ı ise maksimum düzeyde avcılığa maruz kalmış durum- dadır. Karadeniz ve Akdeniz üzülerek belirtmek gerekir ki %62 oran ile bu stokların en tepesindedir. Dünyada yasa dışı av, ıskarta vs'nin miktarı 25 milyon ton civarında olduğu tah- min edilmek- tedir. Bu da dünya av miktarının %15'ine teka- bül etmektedir ki bu durum hem ekonomik hem de biyolojik kayıp demektir. Aynı zamanda biyoçeşitliliğin azalmasına sebebiyet verebilecek tehlike olduğunu da göz ardı etme- mek lazımdır. Peki ne yapmalı, nasıl yapmalı da bu sorunun önüne geçilmelidir."

1) Alınan kararın balıkçılar tarafından uygulanması is- teniyorsa, kullanılan dil çok önemlidir. Deniz ve tatlı su canlı kaynakların yönetiminde arzu edilen düzeyde başarı sağlama "sının tek ve önkoşulsuz yolu balıkçılarla el-ele, gönül-gönüle çalışmaktan geçmektedir. Çünkü alınan kararların uygulanmasında iyi niyet ve hoşgörünün ön pla- na çıkması, duyarlı olunması ve sürdürülebilirliğin öne- mi kavranmış olmalıdır. Tüm bunların yapılabilmesi için av araç ve gereçlerinin daha fazla seçici olması, juve- nil alanlarının avlanmaya kapalı olması, ve etkili bir av- lanma zamanının hazırlanması ve takip edilmesi gerekir.

"2) Canlı kaynaklar yönetiminde kamuoyunun rolü önem- senmeli, göz ardı edilmemeli- dir. Kamuoyunun kendi kend- ini bilinçlendirmesi, haberdar etmesi (kulaktan kulağa me- saj, fis-kos) gerekmektedir. Olası sorunların çözülmesinde ve alınan kararların uygulanmasında uyum ve heves kararların" uygulanmasında olmazsa olmazdır. Ayrıca verilen kararların kaliteli olma- sına da kamuoyu katkı sağlar. Peki kamuoyu kimdir? Aslında doğal kaynakların yönetiminde kamuoyu dendiğinde kastedilen "herkes"dir. Günümüzde kamuoyu kendinin olduğuna inandığı doğal kaynakların yönetilmesinde "insan hakları" duyarlılığında taraf olmalıdır ve bu kamuoyunun en büyük hakkıdır."

3) Azalan kaynakların sürdürülebilirliği ve balıkçının sosyoekonomisini ve yaşam koşullarını da dikkate alarak geliştirilmesi gereken stratejilerin sürdürülebilmesi için yasal müeyyideler caydırıcı olmalıdır.

4) Balıkçı kaçak avladığı balığı satamamalıdır. Alıcıların yasal boyun altında ya da av- cılığı yasak türün satın alınmasının da satılmasının da cezai sorumluluklarının olduğunu bilmeli ve bu konuda otorite kararlı davranmalıdır. Davranmalıdır ki sürdürülebilirlik sağlanabilsin. Özellikle son yıllarda etkisini daha yoğun hissettiğimiz iklimsel ve çevresel faktörlerin değişimi balıkçılığı da önemli ölçüde etkilediği görülmektedir. Ayrıca hamsi avcılığı, yeterli boya ulaş- maması nedeni ile Karadeniz'de 2020 avlanma döneminde 10 gün süre ile durduruldu. İlk kez görülen bu uygulamanın görünürde olumlu sonuçlar doğurduğunu söylemek mümkün ise de akademik bir çalışmanın kamuoyu ile paylaşılması henüz mümkün olmamıştır. Ancak gözlem ve buna bağlı olarak avlanma stratejisini hızlı bir şekilde düzenlemenin Türk hamsi balıkçılığında görülen bir ilk olması nedeni ile taktirle karşılanmıştır. Kısaca hem ekonomik hem de bu denli sosyal değeri olan hamsinin bölgedeki kültüre yaptığı katkı da dikkate alındığında KÜÇÜK DEV balık olarak anılması ve haklı bir üne sahip olması boşuna değildir . "Bu kapsamda, hamsinin Dünyadaki dağılımı, Türkiye'deki durumu, biyolojik yapısı ve avcılı- ğı, ekonomisi ve kültürü üzerine uluslararası uzman katılımcılar RİBİAD çatısı altında bir ara- ya geldi. Online konferansta sunulan tüm tebliğler bu kitabın hazırlanmasında önemli girdileri

oluşturdu. Konferansın ilk bölümünde Dr. Öğr. Üyesi Umar Khan (DURRANI) ve Prof. Dr. Kadir SEYHAN, hamsiyi dünyadaki tüm türleri, dağılımı, biyolojik yapısı ve uygulanan yöne- tim stratejileri konusunda ilk kez bir bütün olarak ele aldı. Ardından Rusya Bilim Akademisi, Deniz Biyolojisi Araştırma Enstitüsü öğretim üyesi Dr. Mikhail Chesalin Karadeniz Bölgesi 'nde hamsinin yaygın bir popülasyona sahip olduğu, Karadeniz'e kıyısı olan ülkeler arasında avlanmanın en çok Türkiye 'de gerçekleştiğini, hamsinin Karadeniz kıyılarında üreme değil bekleme sürecine girdiğini ve bu sürede avlanıldıklarını açıkladı. Oturumun son konuşmasını gerçekleş"tiren Bulgar Bilimler Akademisi öğretim üyesi Dr. Violin Stoyanov Raykov ise Avrupa perspek- tifinden hamsi balıkçılığı yönetimi konusunda önemli açıklamalarda bulundu. İkinci oturumun açılışını gerçekleştiren KTÜ Sürmene Deniz Bilimleri Fakültesi'nden Dr. Yahya Terzi ise hamsinin biyolojisi ve ekolojisi hakkında bir sunum gerçekleştirdi. RTE Üniversitesi, Su Ürünleri Fakültesi öğretim üyesi Doç. Dr. Ülgen Aytan ise hamsi stoklarını etkileyen faktörler ve su kirliliği konularında açıklamalarda bulunarak, evlerde kullanılan ürünlerin su kanalları yoluyla denizlere ulaşması ve doğada yapılan tahribatların etkisiyle deniz canlılarının zarar gördüğünü ve bu durumun sofralara da yansıdığını belirtti. Özellikle toplumsal olarak bilinçlendirilme çalışmalarının yapılması gerektiğini vurgulayan Dr. Aytan, bu konuda dikkatli olunması gerektiğini söyledi. Kitabın hazırlanmasında ise balıkçılıkta önemli olan oşinografik parametrelerin hepsini dikkate alan geniş kapsamlı bir bölümü ise Doç. Dr. Ali Alkan ve Prof. Dr. Nigar Alkan kaleme aldı. KTÜ, Deniz Bilimleri ve Teknolojisi Enstitüsü Müdürü Prof. Dr. Ahmet Cemal Dinçer ise Türkiye'de hamsinin su ürünleri bakımından tüketimi ve avcılığı yüksek bir ürün olduğunu söyledi. Aynı zamanda hamsi avcılığının düşüş oranlarını yanlış avlanma teknikleri, tekne ve iş gücü, iklimsel farklılaşmalar ve çevre kirlilikleri nedeniyle olduğunu belirten Prof. Dr. Dinçer, su ürünleri üzerinde çalışmaların ve balıkçılık amenajmanının iyileştirici ve geliştirici işlemler vasıtasıyla denizlerin daha verimli olacağını belirtti. Konferans ta Okan Üniversiştesi öğretim üyesi Dr. İlkay Gök ise hamsinin besin değeri ile ilgili değerlendirınelerde bulunup hamsinin Omega 3 içeriği bakımından değerlendirildiğinde en yüksek balıklardan olduğunu ve bunun değerlendirilmesi gerektiğini vurguladı. Kitabın hazırlanmasında ise Karadeniz Teknik Üniversitesi Sürmene Deniz Bilimleri Fakültesi Balıkçılık Teknolojisi Bölümü Balık İşleme ve Değerlendirme Anabilim Dali Öğretim Üyesi Prof. Dr. Sevim Köse hamsinin besin değeri ile ilgili detaylı bir bölüm yazım omega 3 ün endüstriyel üretiminin gereçekleştirip insanların daha kolay ve ucuz bir şekilde omega 3 e ulaşabilmelerinin yolu açılmasını öne çıkardı. Trabzon Su Ürünleri Merkez Araştırma Müdürlüğünden Dr. Mustafa Zengin ise hamsi kültürünü tarihsel bir perspektifle ele aldı bölge insanının kimliğini başka hiç bir şey bu kadar doğru tanımlayamaz dedi ve ortaya bu çalışma çıktı. Hiçbir Balığın başka bir ülkede bu kadar fazla anlamı ve değeri olmadığına değinilen konferans bir tam gün sürdü. “Bu konferansı tertipleyip bu kitabın hazırlanmasını ve basılmasını sağlayan başta Sayın Genel Başkan Erol Aykut olmak üzere tüm RİBİAD gönüllülerine teşekkürü bir borç bilmekteyiz. Ayrı- ca yoğun işleri arasında hiçbir katkıdan çekinmeyip konferansa ve bu kitaba hayat veren değerli yazarlarımıza candan teşekkür ediyorum. İngilizce yayınlanması hamsinin dünyaya mal olmuş ekolojik ve ekonomik değeri olan bir canlı olmasından ve uzak diyarlara ulaşmak hevesimizden kaynaklanmaktadır. Yararlı olması en büyük dileğimizdir.”

Saygı ile,
Prof. Dr. Kadir SEYHAN
EDİTÖR
Ekim 2021, Trabzon.

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ANCHOVIES OF THE WORLD

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ÖZET

Hamsi, Engraulidae, familyasına ait subtropikal ve tropikal sularda dağılım gösteren ve 17 cinste 151 türü içeren pelajik küçük bir balık türüdür. Ticari, ekolojik ve besin değeri bakımından önemli bir yere sahip olması bakımından denizel ekonominin temel bileşenini teşkil etmektedir. Dünya Gıda örgütünün (FAO)'nün balıkçılık istatistikleri veri tabanına göre; dünya geneli deniz balıkçılık av toplamı bakımından ticari öneme sahip Engraulidae, familyasına ait 12 hamsi türünün 2018'de 85,6 milyon tonunun yaklaşık %11,1'i ve 2019'da 81,5 milyon tonunun %8,5'ini oluşturduğu kaydedilmektedir. Bu ticari açıdan önemli hamsi türlerinin yaklaşık yarısı, 2018 ve 2019 yıllarında tüm hamsi üretiminin sırasıyla ~%92,6'sına (~8,8 milyon ton) ve ~%86,9'una (~6,0 milyon ton) karşılık gelen Engraulis'e aittir. Günümüz bilimsel veriler ışığında Engraulis familyası dokuz tür içerdiği bilinmektedir. Bunlar sırasıyla; Peru hamsisi, Japon hamsisi, Pasifik hamsisi, Avrupa hamsisi, Güney Afrika hamsisi, Kaliforniya hamsisi, Avustralya hamsisi, Gümüş hamsi, Arjantin hamsisidir. 2021 FAO verilerine göre Peru hamsisi üretimi %71, Japon hamsisi %15, Avrupa hamsisi %10, Güney Afrika hamsisi üretimi %3 olmuştur. Hamsiler tipik olarak kısa ömürlü, ancak stokları öngörülemeyen sürekli değişiklikler gösteren hızlı büyüyen balıklardır. Ortalama yaşları, dört ile beş yıl olan Karadeniz hamsileri dışında, genellikle üç yıl kadardır. Karadeniz'de Avrupa hamsinin iki alt türü olduğu birçok bilimsel çalışma tarafından kanıtlanmıştır. Bunlar Azak hamsisi (Engraulis encrasicolus maeticus) ve Karadeniz hamsisi (E. encrasicolus ponticus), olup; taksonomik statüleri hala devam eden bir tartışma konusudur. Karadeniz hamsisi tüm yaşamını Karadeniz'de geçirirken, Azak hamsisi üreme ve beslenme amacıyla yaz aylarında Azak Denizi'nde bulunduktan sonra Ekim ve Kasım aylarında göç ederek Kerç Boğazı üzerinden Karadeniz'e ulaşır. 2019 yılında dünya genelinde avlanan Avrupa hamsisinin (E. encrasicolus) %80'e varan bölümü Akdeniz ve Karadeniz'den geldiği bilinmektedir.

Hamsi ölümlerinin başlıca nedenleri; Aşırı av baskısı, predasyon ve çevre-

sel koşullardaki ani değişikliklerdir. Bu nedenlerden ötürü hamsi stokları hassas ve aşırı kullanıma karşı özellikle savunmasızdır. Hamsi stoklarının aşırı kullanımını önlemek için Türkiye (ve diğer Karadeniz ülkeleri) tarafından minimum avlanabilir balık boyu, ağ boyutu ve ağ göz açıklıkları, kısıtlı alanlar ve avcılığa kapalı sezon gibi çeşitli yönetim stratejileri uygulanmaktadır.

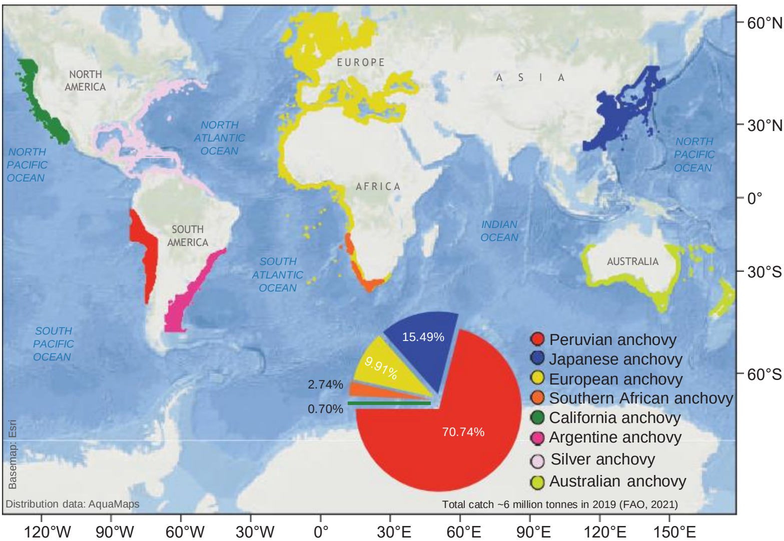
Introduction

The Engraulidae is a family of saltwater small pelagic fish, collectively called anchovies. This group includes 151 species in 17 genera widely distributed in subtropical and tropical waters (Whitehead, 1985; Froese & Pauly, 2020). These small oily fish are the best-known source of omega-3 fatty acids, well known to promote heart and brain health (Smith, 2020). They are also a good source of calcium, and many trace minerals such as selenium, which is a powerful antioxidant and may prevent the risk of some types of cancer if eaten regularly (Tinggi, 2008; Smith, 2020).

These nutrient-rich little fishes are the key component of the blue economy, providing substantial commercial, ecological, and culinary values and support tens of thousands of jobs (Potts, Wilkings, Lynch, & MacFatridge, 2016; Shively, 2018; European Commission, 2020). FAO's online fisheries statistics database has recorded up to 12 species of Engraulidae in commercial production that account for about 11.1% of the 85.6 million tonnes in 2018 and 8.5% of the 81.5 million tonnes in 2019 landed of the total global marine production (FAO, 2021). About half of these commercially important species belong to the genus *Engraulis* corresponding to ~92.6% (~8.8 million tonnes) and ~86.9% (~6.0 million tonnes) of total anchovies' production in 2018 and 2019, respectively (Table 1).

The genus *Engraulis* currently contains nine species *viz.*, European anchovy, Peruvian anchovy, Southern African anchovy, California anchovy, Japanese anchovy, Australian anchovy, Silver anchovy, Argentine anchovy (Froese & Pauly, 2020). They are globally distributed within 60° north to 43° south latitude, inhabiting marine coastal waters, estuaries, and lagoons of the major tropical and temperate sea basins (Silva, 2014; Kaschner et al., 2019; Figure 1). The rise or decline in marine fishes' global production mainly resulted from increased or decreased anchovies catch, especially Peruvian anchovy (FAO, 2020). The largest global catch of anchovies is presented by two countries, Peru, and Chile, which accounted for ~74.3% and ~61.5% of the 9.5 million tonnes and 6.9 million tonnes landed Engraulidae in 2018 and 2019, respectively (FAO, 2021). Their catches solely included Peruvian anchovy, and the rise in the total marine catches of these countries directly resulted from the increase in Peruvian anchovy fisheries.

Figure 1. The Distribution range of Anchovies Engraulis spp. (Map creator: Khan, U.)



Anchovies are typically short-lived but fast-growing fishes, whose stocks have displayed unpredictable variations (Gücü et al., 2017; FAO, 2020; Figure 2). Generally, their average life span is three years, except for the Black Sea anchovies that can live up to five years (Samsun, Samsun, & Karamollaoglu, 2004; Silva, 2014). The fluctuation in recruitment success, which itself is strongly regulated by environmental conditions, promptly resulted in anchovy's population size (Gücü et al., 2017). The male anchovy matures earlier than the female occurs after the first year (Parada, van der Lingen, Mullon, & Penven, 2003; Sinovčić & Zorica, 2006). Their spawning period shows a significant variation dependant on their geographical location (Silva, 2014). In the northern hemisphere, their spawning occurs during the late spring/early summer when the water temperature ranged between 11.5º C and 16.5º C (Whitehead, 1985; Lluch-Belda, Lluch-Cota, Hernández-Vázquez, Salinas-Zavala, & Schwartzlose, 1991). Contrary to northern, their spawning period in the southern hemisphere starts when the water temperature is between 16° C and 20° C (Richardson et al., 1998; Twatwa, van der Lingen, Drapeau, Moloney, & Field, 2005).

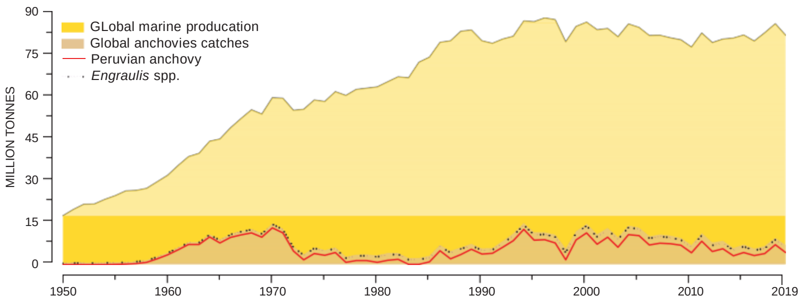


Figure 2. Trends in global captures of marine and anchovies. Here the Engraulis spp. represents six species of anchovies viz., European anchovy, Argentine anchovy, southern African anchovy, Californian anchovy, Japanese anchovy, and Peruvian anchovy.

The larvae of anchovies feed on the yok-sac which lasts for two days to a week, depending on the water temperature preventing starvation (O'Connell, 1981; ICES, 2014). The larvae then need to start feeding themselves to avoid starvation and ensure growth (Blaxter & Hunter, 1982; Morote, Olivar, Villate, & Uriarte, 2010). Generally, larvae of anchovies under 1.2 cm feed on nauplii and copepodites (Tudela, Palomera, & Quilez, 2002; Morote et al., 2010). The adult anchovies tend to feed on zooplankton, including copepods and crustacean larvae, and phytoplankton (Plounevez & Champalbert, 2000; Raab et al., 2011; Mazlum, Solak, & Bilgin, 2017). They feed intensively during late winter as well as early spring for the reservation of energy for gonad maturation and spawning activity (Silva, 2014). The feeding of anchovies is mostly diurnal below the thermocline, though some nocturnal and crepuscular activities have also been observed (Plounevez & Champalbert, 1999, 2000).

Table 1. World capture fisheries production of anchovies.

ENGLISH NAME	SCIENTIFIC NAME	1980	1990	2000	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Peruvian anchovy	*Engraulis ringens*	1.303	4.740	13.084	5.438	10.113	5.949	7.081	3.899	5.282	4.020	4.761	8.232	5.213
Japanese anchovy	*Engraulis japonicus*	0.507	0.674	1.814	1.551	1.607	1.638	1.653	1.733	1.638	1.421	1.287	1.120	1.141
European anchovy	*Engraulis encrasicolus*	1.124	0.679	0.740	0.760	0.738	0.623	0.513	0.350	0.544	0.449	0.642	0.560	0.731
Stolephorus anchovies nei	*Stolephorus spp.*	0.351	0.345	0.324	0.355	0.365	0.372	0.350	0.367	0.436	0.435	0.533	0.408	0.478
Anchovies, etc. nei		0.171	0.312	0.278	0.344	0.332	0.331	0.321	0.363	0.251	0.290	0.270	0.301	0.322
Pacific anchoveta	*Cetengraulis mysticetus*	0.272	0.127	0.156	0.078	0.183	0.443	0.336	0.157	0.168	0.110	0.173	0.107	0.298
Southern African anchovy	*Engraulis capensis*	0.837	0.252	0.311	0.281	0.146	0.390	0.098	0.298	0.291	0.328	0.262	0.296	0.202
Californian anchovy	*Engraulis mordax*	0.592	0.008	0.023	0.006	0.009	0.100	0.179	0.068	0.064	0.028	0.053	0.038	0.075
Buccaneer anchovy	*Encrasicholina punctifer*				0.005	0.002		0.004	0.004	0.004	0.004	0.004	0.004	0.008
Argentine anchovy	*Engraulis anchoita*	0.018	0.017	0.014	0.034	0.026	0.020	0.023	0.017	0.018	0.011	0.013	0.010	0.007
Longnose anchovy	*Anchoa nasus*			0.004	0.079	0.029	0.015			0.001	0.004	0.001	0.001	
Atlantic anchoveta	*Cetengraulis edentulus*	0.008												
Broad-striped anchovy	*Anchoa hepsetus*													
Marini's anchovy	*Anchoa marinii*													
Total contribution (%)		**5.183**	**7.154**	**16.748**	**8.931**	**13.55**	**9.881**	**10.558**	**7.256**	**8.697**	**7.100**	**7.999**	**11.077**	**8.475**
Global Marine Production, million tonnes		**63.1**	**79.6**	**86.2**	**77.3**	**82.3**	**78.9**	**80.1**	**80.5**	**81.6**	**79.4**	**82.4**	**85.6**	**81.5**

Sources: FAO (2021)

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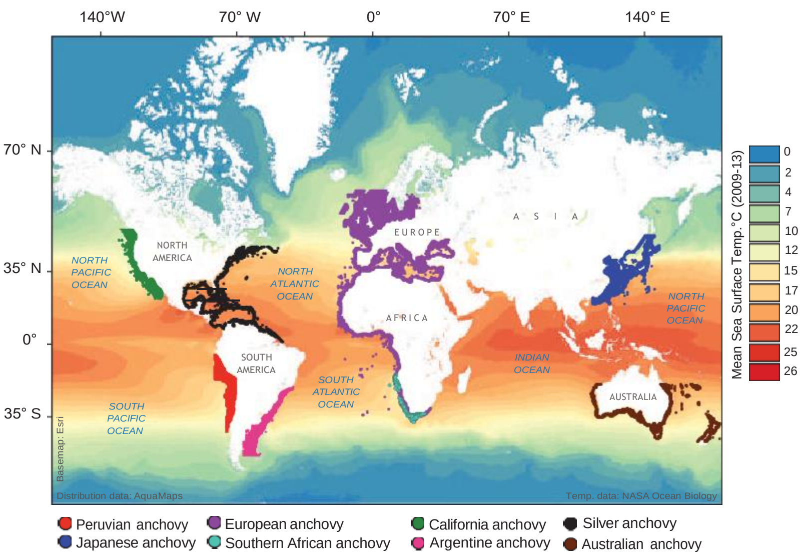


Figure 3. Distributions of species of Old-World anchovies: Genus **Engraulis** (Map creator: Khan, U.)

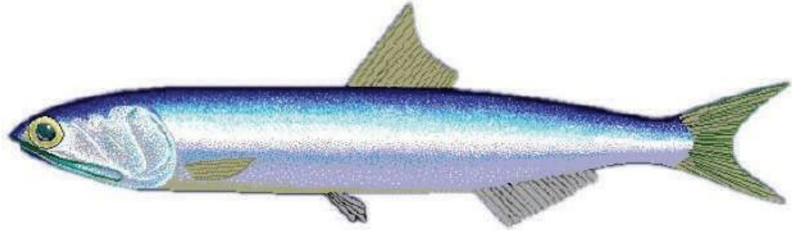
Fishing pressures, predation, and sudden change in environmental conditions are among the main external causes of anchovy mortality and hence they are particularly vulnerable to overexploitation (Pauly, Christensen, Dalsgaard, Froese, & Torres, 1998; Samsun et al., 2004). Anchovies are among the most exploited fish stocks, mainly captured by purse seine (Samsun et al., 2004; Silva, 2014). They travel in large schools of high densities, making them an easy target for commercial fishing (Azzali, De Felice, Luna, Cosimi, & Parmiggiani, 2002). Their population collapsed during 1987 in the Adriatic Sea, recovering slowly since then (Azzali et al., 2002; Silva, 2014). Fishing of anchovy was banned from 2005 to 2009 in the Bay of Biscay due to low recruitment with adults' reduced biomass (European Comission, 2013).

The anchovy can be classified as old world and new world anchovies (Silva, 2014). The old World *Engraulis* is monophyletic, but new world's are not. The old-world anchovies have similar habitat requirements inhibiting four coastal areas with contrasting physical features (Grant & Bowen, 2006; Figure 3). However, all these coastal areas have high productivity and are characterized by upwelling (Shannon, 1985; Agostini & Bakun, 2002).

Some detailed information on the biology, ecology and genetic variation of commercially important anchovy species is provided in the following sections.

a) Peruvian anchovy

The total length of Peruvian anchovy ranged from 10 cm to 14 cm and matured at a length of 12 cm (Whitehead, Nelson, & Wongratana, 1988). As mentioned above, they are the world's most abundant fish, excluding farmed fish, and have the highest contribution to the total world marine catches (Table 1). They are mainly distributed within the southeastern Pacific Ocean off Peru and Chile.



Peruvian anchovy, *Engraulis ringens* **(Froese & Pauly, 2020).**

They have a fast growth rate characterized by early maturity (1 year) with a standard length of 10–12 cm (Whitehead et al., 1988; Bertrand et al., 2008). They mainly feed on microzooplankton such as euphausiids and calanoid copepods (Espinoza & Bertrand, 2008). They are oviparous producing oval shape eggs of no more than 1 mm (Di Dario, Hüne, Pérez-Matus, & Vega, 2021), and are known to spawn in areas with high upwelling throughout the year along the entire coast to Chile and Peru (Lasker, 1985; Whitehead, 1985). Their peak spawning periods take place during winter/spring (July to September) in the off Peru and peaks in winter (May to July) and December in the off Chile (Whitehead et al., 1988). The female Peruvian anchovy with a length of >14 cm is known to have a major contribution to annual spawning with 60% to 80% potential egg proportion during times of less spawning activity (Perea, Peña, Oliveros-Ramos, Buitrón, & Mori, 2011; Di Dario et al., 2021).

Management regulations for Peruvian anchovy

Recent data suggest that the Peruvian anchovy stocks are at a sustainable level with the current population following an increasing trend (Di Dario et al., 2021), indicative of effective improving management strategies. The first management measures were set by establishing a minimum legal size of 12 cm Peruvian anchovy and a minimum mesh length in 1955 (CeDePesca, 2020). In the 1970s, additional management measures were drafted by establishing annual global fishing quotas (CeDePesca, 2020).

Currently, the Peruvian anchovy stock management (in Peru) includes several strict measurements concerning fishing juveniles (MCSUK, 2021). Each vessel is strictly obligated to report the percentage of juveniles in their catches and areas where the catches have a proportion of juveniles more than 10% of are closed for fishing for a minimum of three days (CeDePesca, 2020; MCSUK, 2021). Likewise, up to 85 zones were closed for fishing for 100 days in the first season of 2020 (MCSUK, 2021).

According to CeDePesca (2020) and MCSUK (2021), the management regulations and strategies for Peruvian anchovy fishing include:

a) seasonal quotas

b) closure of the fishery occurring in case the allowable quota is reached.

c) Maximum allowable catch per vessel (industrial fleet)

d) Minimum mesh size is 13 mm.

e) Minimum landing size of 12cm

f) Prohibited fishing within 5 miles of the coast

g) The bycatch of other species must not exceed 5% of the catch.

h) Vessels are obligated to have an operating satellite system

b) Japanese anchovy

Japanese anchovy has been commercially caught in China, Japan, and Korea, with a production of ~0.96 million tonnes in 2018 and ~0.93 million tonnes in 2019 (FAO, 2021). China has the highest yield of this fish species, corresponding to ~50%-72% of their total landed in the last decade (Figure 4). Like other anchovy species, they are schooling species that inhabit marine water mainly along the coast, but can occur over 1,000 km from the shore (Di Dario et al., 2021). The species moves northward and inshore into bays and inlets in spring and summer. They can reach a maximum standard length of 16 cm, but are more commonly found at sizes of 12 - 14 cm (Whitehead et al., 1988).

Japanese anchovy, *Engraulis japonicus* **(Froese & Pauly, 2020)**

Near Sagami Bay, Japan, females spawn throughout the year with a peak from April to October (Xing et al., 2021). The Kuroshio-Oyashio transition region is apparently a nursery area for larvae (Takahashi et al. 2001). The Wakasa Bay and Osaka Bay in Japan are also nursery areas of Japanese anchovy (Funamoto, Aoki, & Wada, 2004). Other known spawning areas include Haizhou Bay, and China in the Yellow Sea (Hao, Jian, Ruijing, Lei, & Yi'an, 2003). The adults overwinter in the deep trench and migrate during spring to the northwest coastal area where their spawning season occurs between May to July (Hao et al., 2003). Furthermore, they migrate from the Eastern China Sea to spawn off northeastern and south-western Taiwan (Chiu, Young, & Chen, 1997).

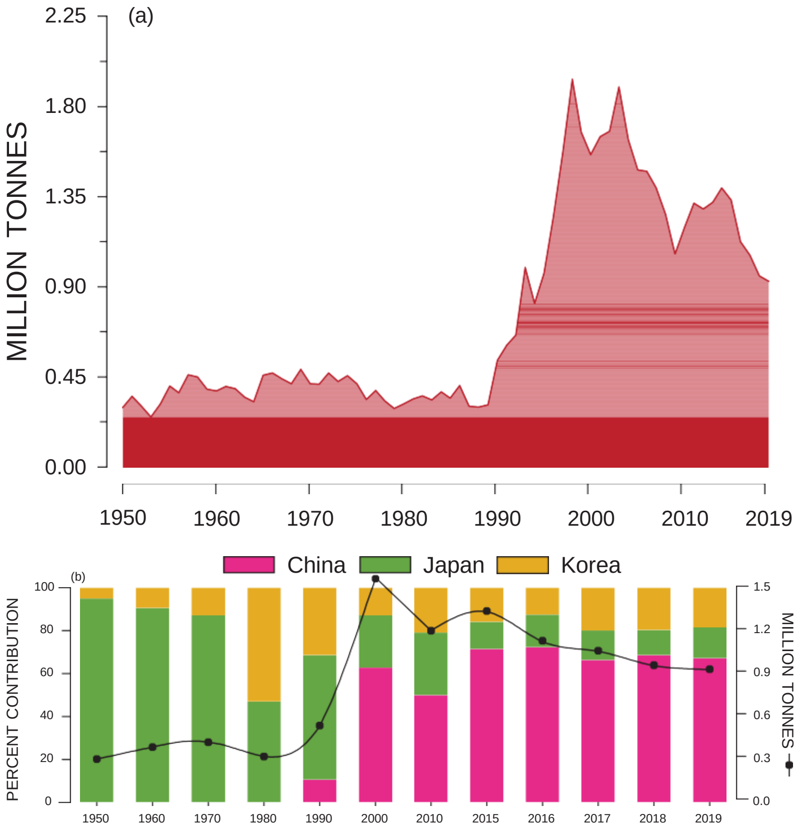


Figure 4. Trends in global captures of Japanese anchovy, **Engraulis japonicus** (FAO, 2021).

c) Southern African Anchovy

The southern African anchovy are widely distributed in the western Indian Ocean and southeastern Atlantic from the Angola/Namibia border south to South Africa and north to Maputo, Mozambique (Whitehead, 1985). Like other anchovies, they are a schooling species that inhabits coastal marine waters. They mainly feed on mesozooplankton and their spawning success and larval survival are strongly regulated by copepod biomass (James, 1987; Cochrane & Hutchings, 1995). They spawn during October and

April with a peak in February off Namibia and in November and December in South Africa (Whitehead, 1985). Their spawning grounds are located within 80 km offshore (Whitehead, 1985). The spawning grounds of southern African anchovy are located on the Agulhas Bank, while their nursery grounds are located off western South Africa In the Benguela Current region off Namibia (Hutchings et al., 1998; Parada et al., 2003).

Southern African Anchovy, *Engraulis capensis* **(source: www.tridge.com)**

The catches of the southern African anchovy display considerable fluctuations (Table 1) and their catches increase when the catches of sardine decrease (Whitehead, 1985; Whitehead et al., 1988). When abundant, they correspond to half of the total pelagic fish catch from South Africa (FAO, 2021). The highest catches of southern African anchovy are reported from Angola (~15,000 tonnes) between the years of 1970 and 1982, Namibia (~13,000 tonnes) between 1990 and 2013, and the U.S.S.R., (~6,400 tonnes) between 1978 and 1987 (FAO, 2020, 2021). While smaller catches of primarily less than ~500 tonnes are reported from Lithuania, Cuba, and Russia (FAO, 2020, 2021).

d) Californian anchovy

The California anchovy, also known as the northern anchovy, is widely distributed in the Pacific Ocean, ranging from Mexico to British Columbia and into the Gulf of California (Whitehead et al., 1988; Sydeman et al., 2020). The population of Californian anchovy can be classified into three subpopulations based on their morphometric characteristics, genetic analysis, and protein variation (Spratt, 1972; Díaz-Jaime, Uribe-Alcocer, & Ayala-Duval, 1999; Lecomte, Grant, Dodson, Rodriguez-Sanchez, & Bowen, 2004). They are often found in coastal waters within 30 km from the shore. However, they are sometimes found as far as up to 480 km from the shore (Di Dario et al., 2021). They can grow up to a size of 20.5 cm (standard length) though their size varies with latitude (Whitehead et al., 1988; Di Dario et al., 2021). They reach maturity at one year (Sydeman et al., 2020), while an earlier estimate showed maturity was reached at two years (Di Dario et al., 2021). Data indicates a substantial major life-history shift and their maximum longevity of eight years decreased to four years within the central subpopulation (Mais, 1981; MacCall, 2009; Sydeman et al., 2020). They feed on copepods, euphausiids, decapod larvae, and fish eggs by pecking at prey and by random filter-feeding (Chiappa-Carrara & Gallardo-Cabello, 1993; Sydeman et al., 2020).

Californian anchovy are epipelagic batch spawners depending on favorable ambient environmental conditions, preferring to spawn within offshore or inlets throughout the year (Roe & Goldberg, 1980; Watson & Sandknop, 1996). Their peak spawning occurs during the winter and early spring, though their spawning time substantially changed between years with the change more prominent in recent decades (Asch, 2015; Di Dario et al., 2021). Like the Peruvian anchovy, a positive correlation has been observed between Californian anchovy spawning and plankton productions (Contreras-Reyes, Canales, & Rojas, 2016). Female Californian anchovies of the central subpopulation produce up to ~14,000 egg annually s (Parrish, Mallicoate, & Klingbeil, 1986). The size of their eggs ranges from 1.23 mm to 1.55 mm in length and they lack oil globules (Therriault, McDiarmid, Wulff, & Hay, 2002). The embryo development is strongly regulated by temperature and their development accelerates at higher water temperature (Therriault et al., 2002). Their larvae are spread within the first 50 meters of the water column and spend most of their first year in the surface currents (Therriault et al., 2002; Sydeman et al., 2020).

Californian anchovy, *Engraulis mordax* **(**https://www.fisheries.noaa.gov/**)**

e) Argentine anchovy

The Argentine anchovy are found in coastal to the mid-continental shelf and widely distributed around waters of Argentina, Brazil to 48°S near southern San Jorge Gulf, and southwestern Atlantic from 20°S near Vitória (Whitehead et al., 1988; Di Dario et al., 2021). They can be categorized into three distinct stocks: 1) Brasilera stock, Bonaerense stock, and Patagonia stock, and among them, Brasilera stock is the largest of these three stocks (Carvalho & Castello, 2013). They are short-lived anchovy with an estimated generation length of two to four years (Castello & Castello, 2003). They reach maturity in the first year of age, with a length of 9.3 cm to 11.6 cm (CTMFM, 2020). The maximum standard length recorded for Argentine anchovy is 17 cm (Whitehead et al., 1988).

They are known to spawn throughout the year with a spawn synchronously at night which peaks between October and November (Pájaro, Macchi, Leonarduzzi, & Hansen, 2009; CTMFM, 2020). Their eggs are planktonic and ovoid in shape, lacking an oil drop (CTMFM, 2020). The larval growth of Argentine anchovy is strongly regulated by temperature and primary productivity (associated with food availability) and the growth rate is 0.41 mm day^{-1} to 0.51 mm day^{-1} (Leonarduzzi, Brown, & Sanchez, 2010).

Argentine anchovy, *Engraulis anchoita* **(**http://ctmfm.org/**)**

f) European Anchovy

European anchovy have been reported from up to 52 countries throughout the Black and Azov Seas, Mediterranean, and the Baltic Sea (Silva, 2014; FAO, 2021). European anchovy had a share of 0.7% of the global marine production, at 81.5 million tonnes in 2019 (FAO, 2021). The Mediterranean and the Black Sea have the highest shares in 2019, with a contribution of more than 80% to the total worldwide catches of European anchovy (Figure 5). Up to 76% of the total commercial European Anchovy catch worldwide (from 2015 to 2019) comes from Turkey, Georgia, Spain, Ghana, Russia, and Italy (Figure 6). Turkey was the main contributor, corresponding to 44% of the total yield of 0.60 million tonnes in 2019.

European Anchovy, *Engraulis encrasicolus* **from the Eastern Black Sea**

European anchovy can tolerate a wide range of temperatures (0+ to 30º C) and salinity (5 to 41 ppt), usually inhabiting coastal waters over the continental shelf, from the surface of the sea down to 400 meters (Whitehead et al., 1988; Silva, 2014). With such varying tolerance to salinity and temperature they can be found in coastal lagoons, inlets, estuaries, and with relatively higher abundance in upwelling zones (Froese & Pauly, 2020; Figure 3).

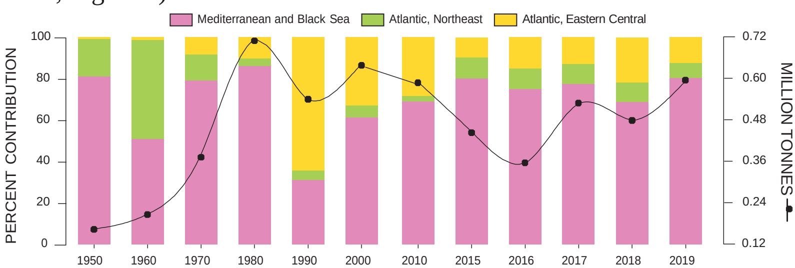


Figure 5. Trends in global captures of European anchovy, **Engraulis encrasicolus** in different seas (FAO, 2021).

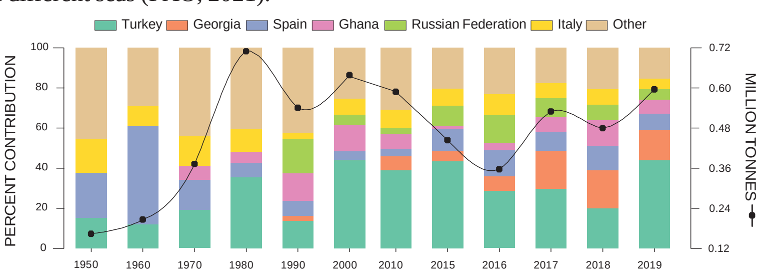


Figure 6. Trends in global captures of European anchovy, **Engraulis encrasicolus** in different countries (FAO, 2021).

There are two subspecies of European anchovy found in the Black Sea: Azov anchovy (*E. encrasicolus maeticus*) and Black Sea anchovy (*E. encrasicolus ponticus*). Though their taxonomic status is still an ongoing dispute (Gücü et al., 2017). According to Chesalin, Nikolsky, and Yuneva (2020), their stock assessment, recording to fisheries statistics as well as regulations for each subspecies are carried out separately. The Black Sea anchovy spend their whole life in the Black Sea whereas, the Azov anchovy feeds and spawns in the Sea of Azov during summer while migrating via Kerch Strait reaching the Black Sea in October-November (Chesalin et al., 2020).

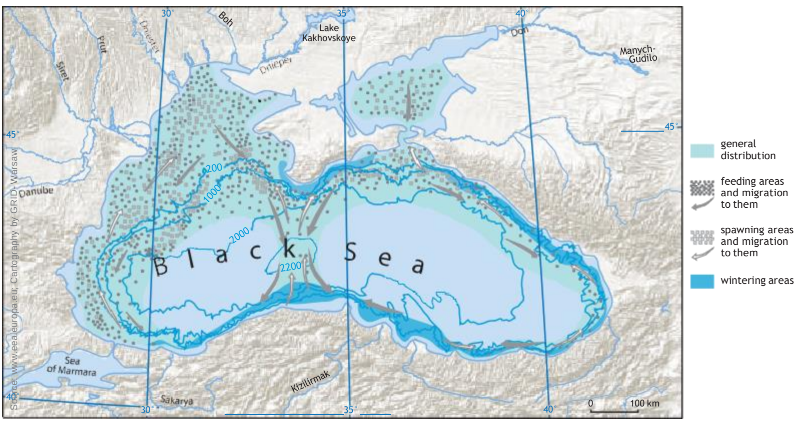


Figure 7. Distribution, feeding, spawning, and migration routes of European anchovy, **Engraulis encrasicolus** in the Black Sea (https://ec.europa.eu/).

European anchovy migrate for reproduction, feeding, and protection (Blaxter & Hunter, 1982; Guraslan, Fach, & Oguz, 2017). According to Guraslan et al. (2017), in the Black Sea, their migration is mainly regulated by ambient temperature and the adult as well as juvenile aggregate and form dense schools with the approach of cold temperature and begin wintering migration the southern Black Sea entering the warmer waters (Figure 7). The temperature thresholds for migration initiation in juveniles and adults European anchovy differ which 10.5–13.5°C for the former and

11.5–15.0°C for the latter group (Shulman et al., 2008). The adults tend to migrate first, then juveniles as the water temperature start decreasing, and thus when the water temperature drops further, the juveniles also migrate towards warm waters (Gücü et al., 2017). Along with the ambient environmental conditions, an internal stimulus e.g., the fat content of anchovy may also play a vital role in initiating the migrations (Gücü et al., 2017; Guraslan et al., 2017).

Management regulations for European anchovy in the Black Sea

Georgian, Ukrainian and Turkish vessels are known to exploit the south-eastern Black Sea anchovy fish stock in the Economic Exclusive Zone (EEZ) of Georgia resulting in a significant decrease of anchovy stock since 1999 (Castilla-Espino, Garcia-del-Hoyo, Metreveli, & Bilashvili, 2014). Several management regulations and strategies have been used to prevent overexploitation of anchovy stocks and/or rent dissipation of fishermen (Castilla-Espino et al., 2014). Anchovies in Bulgaria, Romania, Ukraine, Russia, and Turkey are generally regulated by i) minimum landing size, ii) mesh size regulations, iii) closed areas, and iv) closed seasons (Table 2). Turkey, having the largest fleet fishing the anchovy, Russia, and Ukraine have enforced several additional management strategies to control the size of the fishing fleet which are (GFCMs, 2016):

Additional management strategies of Turkey for anchovy stocks

1) Issuing licenses to new fishing boats have been stopped since 2002 in order to reduce fishing pressure on anchovy stocks and maintain sustainable fisheries. Consequently, the size of the main anchovy fishing fleet is stable since 2005.

2) A total of 1011 fishing vessels (37.7% of them were registered to the port on the Black Sea coast) have been removed (between 2012-2015) by the buyback program which was launched in 2012.

3) Several new regulations and methodological reforms have been enforced to get precise landing statistics.

4) The depth limit has been increased from 18 to 24 m for pelagic trawls and purse seine.

Additional management strategies of Russia and Ukraine

Based on Russian fishing regulations data, there are two stocks of anchovy: Azov anchovy and the Black Sea anchovy. Each year Russian-Ukrainian Commission on Fisheries in the Sea of Azov holds a meeting and makes a protocol. According to the agreement in 2021:

1) Fishing the Azov anchovy in the Sea of Azov and the Kerch Straight by purse-seine vessels is allowed, without limitation on the number and by mid-water trawl vessels (up to 7 on both sides, mesh size not less than 6.5 mm) from 1 September to 20 December.

2) Fishing is allowed, by bottom gill nets with a mesh size ≥ 6.5 mm in a 5 km coastal zone of the Sea of Azov (in the Kerch Strait to the outer boundaries of the navigable canal) from 20 September to 20 December. The total number of the bottom nets is not more than 30 units (15 units for each country).

3) According to the Russian-Ukrainian Commission data, the stock biomass of the Azov anchovy in 2021 is 100,000 tonnes, the total allowable catch (TAC) for the Russian Federation is 30,000 tonnes. However, there is no TAC for Ukraine. Also, there is no TAC on the fishing of the Black Sea anchovy. Present Ukrainian catches of Azov anchovy are very low, about 100 tonnes in 2019, and mainly come from the bottom nets.

Recommendation

Anchovies play a fundamental ecological role as a prey item for larger marine species resulting in transmitting energy and biomass from low trophic webs towards higher trophic levels. Furthermore, they are the key component of the blue economy supporting tens of thousands of jobs, and providing food security. History has shown that several times a collapse of anchovies stock has drastically affected global fisheries production. Therefore, these nutrient-rich little fish stocks need special consideration to ensure their sustainability. More research is needed to determine optimal timing for fishery closure, discovering new nursery areas including distribution and diet shifts that could be the consequence of global warming (Bunnell, Davis, Chriscinske, Keeler, & Mychek-Londer, 2015; Bal, Yanik, & Türker, 2021). A revision to close season has been suggested by Şahin and Düzgüneş (2019) which should be considered in future management

Table 2. Management and regulation measures of the European anchovy in the Black Sea and Sea of Marmara.

	Species	Area	Year	Category	Distance to coast/ Closed areas	Catch time	Mesh size	Gear dimensions/ Depth-based closed areas	Number of purse seiners vessels	Close season	Minimum legal size, TL	Reference
RUSSIA	Azov anchovy				5 km	No daytime limitation	≥ 6 mm	The number of vessels for fishing both anchovy subspecies with purse seine is not limited. However, mid-water trawl is up to 20		1 October - 15 March		
	Black Sea anchovy									October - 15 April		
TURKEY	Anchovies	Sea of Marmara	2008	Small-scale fishing/Purse seine	In the Gulf of Izmit, in the area east of the line joining Zeytin Cape (40° 44 ', 500 N - 29° 47, 068' E) and the opposite (40° 43 ', 416 N - 29° 46, 908' E) coordinate point.	16:00-8:00		Deep of Catch location must be>18 m	194			Republic of Turkey Ministry of Agriculture and Forestry (5/1 Regulating Fishing in Commercial Fisheries) TÜİK, 2021 https://biruni.tuik.gov.tr/medas/?kn=97&locale=tr
			2012	Small-scale fishing/Purse seine	In Izmit Bay; In the area east of the line connecting Dil Burnu Lighthouse (40° 44.430 'N - 29° 30.912' E), Dil wharf Kaba (40° 46.010 'N - 29 ° 31.082' E).	16:00-8:00		Deep of Catch location must be>22 m	124			
			2016	Small-scale fishing/Purse seine	In Gemlik Bay; The area to the east of the line joining Sarıburun (40° 28.390 'N - 29° 01.182' E) and Kurşunlu Fisher Shelter (40° 21.850 'N - 29° 02.099' E).	15:00-9:00		Deep of Catch location must be>24 m	128			

	Species	Area	Year	Category	Distance to coast/ Closed areas	Catch time	Mesh size	Gear dimensions/ Depth-based closed areas	Number of purse seiners vessels	Close season	Minimum legal size, TL	Reference
					'N - 29° 02.099' E)							
TURKEY	Anchovies		2020	Small-scale fishing/Purse seine	In Gemlik Bay; The area to the east of the line joining Sarıburun (40° 28.390 'N - 29° 01.182' E) and Kurşunlu Fisher Shelter (40° 21.850 'N - 29° 02.099' E) In Izmit Bay; In the area east of the line connecting Dil Burnu Lighthouse (40 ° 44.430 'N - 29° 30.912' E), Dil wharf Kaba (40° 46.010 'N - 29° 31.082' E).	15:00-9:00		Deep of Catch location must be>24 m	126			Republic of Turkey Ministry of Agriculture and Forestry (5/1 Regulating Fishing in Commercial Fisheries) TÜİK, 2021 https://biruni.tuik.gov.tr/medas/?kn=97&locale=tr
		Eastren and Western Black Sea	2008	Small-scale fishing/Purse seine	In the Black Sea; In Turkey territorial waters between Kastamonu province, Cide district, köpekkaya Cape and the Bulgarian border, it is prohibited less than 11 meters between September 1 and December 1. Artvin province, Hopa district, Kemalpaşa subdistrict, Sarp village, (41° 34 '48 "N - 41° 17' 13" E) and (41° 30 '42 "N - 41° 32' 12" E) on the part of the line up to the Georgian border	16:00-8:00		Deep of Catch location must be>18 m	192			
					Artvin province, Hopa district, Kemalpaşa subdistrict, Sarp							

	Species	Area	Year	Category	Distance to coast/ Closed areas	Catch time	Mesh size	Gear dimensions/ Depth-based closed areas	Number of purse seiners vessels	Close season	Minimum legal size, TL	Reference
TURKEY	Anchovies		2012	Small-scale fishing/Purse seine	village, (41° 34 '48 "N - 41° 17' 13" E) and (41° 30 '42 "N - 41° 32' 12" E) on the part of the line up to the Georgian border	16:00-8:00		Deep of Catch location must be>24 m	181		9 (cm)	
			2016	Small-scale fishing/Purse seine	Artvin province, Hopa district, Kemalpaşa subdistrict, Sarp village, (41° 34 '48 "N - 41° 17' 13" E) and (41° 30 '42 "N - 41° 32' 12" E) on the part of the line up to the Georgian border	16:00-8:00		Deep of Catch location must be>24 m	198			
			2020	Small-scale fishing/Purse seine	Artvin province, Hopa district, Kemalpaşa subdistrict, Sarp village, (41° 34 '48 "N - 41° 17' 13" E) and (41° 30 '42 "N - 41° 32' 12" E) on the part of the line up to the Georgian border	15:00-9:00		Deep of Catch location must be>24 m	154			
Bulgaria										May April to October/November	7 cm	GFCMs (2016)
Romania												

decisions. Since anchovy stocks have been drastically negatively affected by invader (alien) species (e.g., Mnemiopsis leidyi), new techniques such as eDNA should be applied to inform management decisions, including identifying the need for population control and/or eradication (Davison, Copp, Creach, Vilizzi, & Britton, 2017; Mychek-Londer, Chaganti, & Heath, 2020; Mychek-Londer, Balasingham, & Heath, 2020).

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Biology and ecology of European anchovy (*Engraulis encrasicolus* Linnaeus, 1758) in the Black Sea

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ÖZET

Küçük pelajik balıklar, dünyadaki toplam karaya çıkarılan av miktarının yaklaşık 3 / 4'ünü oluşturmaktadır (FAO, 2018). Küçük pelajik balıklar, yetişkin bireylerinin boyları 10-30 cm olan, epipelajik bölgede (200–0 m derinlik) bölgede sürüler oluşturan balıklar olarak tanımlanmaktadır (Bas ve diğerleri, 1995). Karakteristik olarak hızlı büyüyen ve kısa ömürlü balıklardır (Jacobson vd., 2001). Ekonomik önemlerinin yanında besin ağının alt ve üst seviyeleri arasında bağlantı kurmakta çok önemli rol oynamaktadırlar (Karachle ve Stergiou, 2017). Engraulis cinsi altındaki türler deniz ortamında en yaygın bulunan küçük pelajik balıklardır. Doğal yayılım alanında karayaçıkarılan hamsi miktarının %10'u bu cinse ait türlerden oluşmaktadır. Av miktarı olarak en bol ve ekonomik olarak değerli olan türleri, Avrupa hamsisi (Engraulis encrasicolus), Peru hamsisi (Engraulis ringes), Arjantin hamsisi (Engraulis anchoita), Japon hamsisi (Engraulis japonicus), Güney Afrika hamsi (Engraulis capensis) ve Kaliforniya hamsisi (Engraulis mordax) (Bingel ve Gücü, 2010).

Karadeniz'de Avrupa hamsisinin (Engraulis encrasicolus) beslenme, göç, büyüme, üreme biyolojisi ve ekolojisi kapsamlı bir şekilde incelenmiştir. Hamsi göçmen, planktivor ve kısa ömürlü (3-4 yaş) bir türdür. Karadeniz'de bildirilen iki alt türü mevcuttur Karadeniz hamsisi (Engraulis encrasicolus ponticus Alexandrov, 1927) ve Azak Denizi hamsisi (Engraulis encrasicolus maeoticus Pusanov, 1936). Türkiye'deki deniz balıkçılığının büyük kısmını küçük pelajik balık türleri oluşturmaktadır. Hamsi, Karadeniz'den avlanan en önemli stoku oluşturmaktadır. 2019 verilerine göre karaya çıkarılan toplam balık miktarı 374.725,7 ton olup bunun %70'ini hamsi oluşturmaktadır (TÜİK, 2020). Bu denli önemli bir stokun sürdürülebilirliğinin sağlanabilmesi için biyolojisinin anlaşılması son derece önemlidir.

Introduction

Small pelagic fish species constitute approximately 3/4 of the total landing in the world (FAO, 2018). They are commonly expressed as schooling epipelagic (depths of 0–200 m) species, which adults are generally 10–30 cm in terms of length (Bas et al, 1995). Small pelagics are characteristically short-lived and fast-growing species (Jacobson et al., 2001). Besides their economic value, they play an important role in the food web by linking the lower and upper levels (Karachle & Stergiou, 2017). The species included by the genus Engraulis are the most common small pelagic fish in the marine environment. The genus constitutes 10% of the total landing of anchovies in its native range. The most abundant and economically valuable species are European anchovy (*Engraulis encrasicolus*), Peruvian anchoveta (*Engraulis ringes*), Argentine anchoita (*Engraulis anchoita*), Japanese anchovy (*Engraulis japonicus*), Southern African anchovy (*Engraulis capensis*), and Northern anchovy (*Engraulis mordax*) (Bingel and Gücü, 2010).

The biology and ecology of the European anchovy (*Engraulis encrasicolus*) including feeding, migration, growth, reproduction was comprehensively studied in the Black Sea. Anchovy is a migratory, planktivorous, short-lived (3-4 years) species. Two subspecies of European anchovy reported in the Black Sea, namely, the Black Sea anchovy (*Engraulis encrasicolus ponticus* Alexandrov, 1927) and the Azov Sea anchovy (*Engraulis encrasicolus maeoticus* Pusanov, 1936).

The Turkish Black Sea fisheries are highly dependent on the small pelagic fish stocks. The Black Sea inhabits European anchovy (*Engraulis encrasicolus* Linnaeus, 1758), which is the most abundant small pelagic fish in terms of total landing. The total landing of marine fishes was reported as 374,725.7 tons in 2019, of which 70% is anchovy (TUIK, 2020). Understanding the biology and behavior of the species is crucial for sustainable fisheries.

Taxonomy and morphology

The Engraulidae family is known as anchovies consisting of 17 genera and 150 species (Agbayani, 2020). They are small-sized pelagic fishes (usually 10 to 20 cm in length). The most prominent characteristic of the family is the tip of the lower jaw behind the tip of the snout (Figure 8a). There are two supra-maxillae. Typically, small or minute jaw teeth. The dorsal fin is short and usually, near the midpoint of the body, the pelvic fins are before, under, or behind the dorsal fin base. The first anal-fin ray is located under or behind the base of the last dorsal fin ray (Figure 8b). The linea lateralis is not distinguishable.

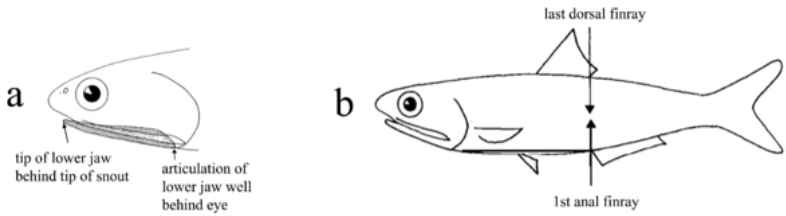

Figure 8. Morphological keys to family Engraulidae **(P. J. P. Whitehead, Nelson, & Wongratana, 1988)**.

The genus *Engraulis* consists of round-bodied individuals (up to 20 cm in length, generally 12–15 cm). The beginning of the anal fin is located under or behind the last dorsal fin ray (Figure 9a) The tip of the maxilla is blunt, reaching onto the front margin of the pre-operculum (Figure 9b). The maxilla tip is rounded and extending beyond the tip of the 2nd supra-maxilla (Figure 9c). Twenty-seven to 43 lower gill rakers. Short gill rakers on the hind face of the 3rd epibranchial (Figure 9d).

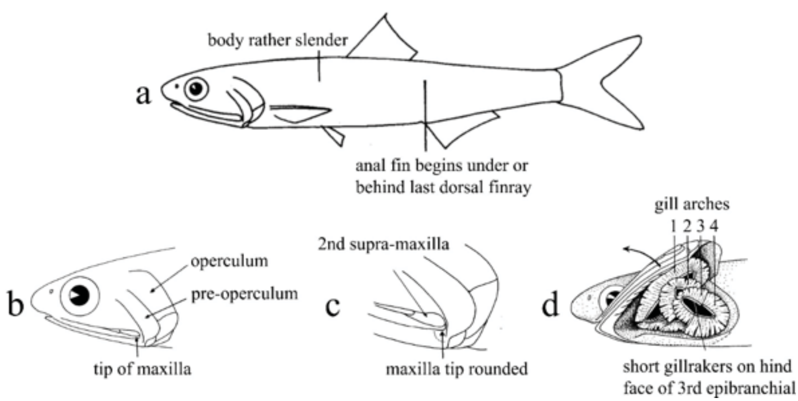

Figure 9. Some of the morphological keys to **E. encrasicolus** (P. J. P. Whitehead et al., 1988).

The taxonomy of the European anchovy (E. encrasicolus) is given below

Kingdom: Animalia
Subkingdom: Bilateria
Infrakingdom: Deuterostomia
Phylum: Chordata
Subphylum: Vertebrata
Infraphylum: Gnathostomata
Superclass: Actinopterygii
Class: Teleostei
Superorder: Clupeomorpha
Order: Clupeiformes
Suborder: Clupeoidei
Family: Engraulidae
Subfamily: Engraulinae
Genus: *Engraulis*
Species: *Engraulis encrasicolus* (Linnaeus, 1758)

Link to Fishbase

Distribution and migration

European anchovy is a marine species, however, in some cases enters the estuaries with down to 5‰ salinity. It is a pelagic species, distributed in coastal areas with a 0–400 m depth range in its native range. It is mainly distributed in the temperate and tropical waters. The native range of the European anchovy is all of the Mediterranean, Black, and Azov seas, with stray individuals in Suez Canal and the Gulf of Suez; Eastern Atlantic: Bergen, Norway to East London, South Africa (perhaps reaching Durban) (Carpenter, 1992). Also recorded from St. Helena (Peter J P Whitehead, 1985) (Figure 10).

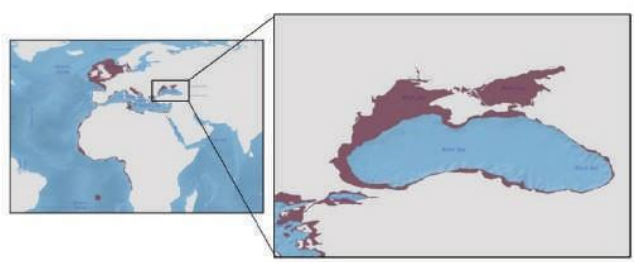

Figure 10. The distribution of European anchovy (**E. encrasicolus**) (FAO, 2020)

There are two populations of the European anchovy, namely, the Black Sea anchovy (*Engraulis encrasicolus ponticus* Alexandrov, 1927) and the Azov Sea anchovy (*Engraulis encrasicolus maeoticus* Pusanov, 1936) in the Black Sea. These two subspecies show different characteristics in morphology (Alexandrov, 1927), growth rate (Gubanov & Limansky, 1968), otolith shape (Skazkina, 1965), parasitism frequency (Terekhov, 1979), blood types (Yu P Altukhov, Limansky, Payusova, & Truveller, 1969), and genetical structure (Kalnin & Kalnina, 1984). Black Sea anchovy (*E.e. ponticus*) can grow up to 18–20 cm while the maximum length for Azov Sea anchovy (*E.e. maeoticus*) are 15 cm (Slastenenko, 1955). Azov Sea anchovy (*E.e. maeoticus*) feeds and reproduces in the Sea of Azov and form schools during the winter from the northern Caucasus to Sukumu and partially off the Crimea. Black Sea anchovy (*E.e. ponticus*) migrates between the southern and northern parts of the Black Sea for wintering and reproduction. The daily speed of the migrating schools is 10–20 miles. The density of the schools formed in the daytime is 200–800 individual/m^3 while 20–60 individual/m^3 in the night (Chashchin, 1996). The schools prefer relatively deep waters (70–90 m) in the daytime and shallow waters (10–40 m) during the night. The anchovy schools migrate from the wintering grounds to feeding and reproduction ground on the northern Black Sea in April and depending on the water temperature return in November (Chashchin, 1999; Ivanov & Beverton, 1985) (Figure 11).

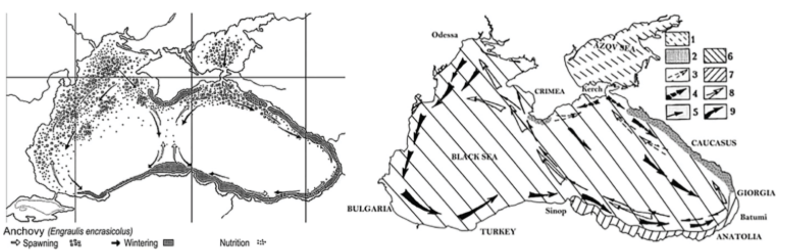

Figure 11. Feeding, reproduction, and wintering areas of anchovy (left) **(Ivanov & Beverton, 1985)**. The Azov Sea anchovy: 1 = spawning and foraging; 2 = wintering; 3 = spring migrations; 4 = autumnal migrations; 5 = periodical migrations of mixed populations. Black Sea anchovy: 6 = spawning and foraging region; 7 = wintering region; 8 = spring migrations; 9 = autumnal migrations (right) (Chashchin, 1999)

Although two subspecies of European anchovies exist in the Black Sea do-main, spatial overlap of the subspecies was reported by several researchers (Y.P. Altukhov, 1974; Danilevsky, 1960; Marty, 1980). The species coexist, in several fishing areas during the fishing activities (in the winter), in the Sea of Azov where juveniles of Black Sea anchovy enter for foraging in the summer, and low saline waters of the north-west the Black Sea.

Feeding

The European anchovy is an important fish species not only being a predator but also prey for highly commercial fish species at the top of the food pyramid. It establishes a link between the lower and upper trophic levels of the food chain (Coll, Santojanni, Palomera, & Arneri, 2009; Karachle & Stergiou, 2017). The species is a planktivorous fish mostly fed on zooplankton (Copepoda and Cladocera) (Brosset et al., 2016; Mazlum, Solak, & Bilgin, 2017; Zorica, Čikeš Keč, Vidjak, Mladineo, & Ezgeta Balić, 2016). In the early larval stages, the fish prey on phytoplankton (40–50 μ in diameter) due to the small mouth opening, as it develops it prefers zooplanktons. Anchovy may ingest zooplankton up to 13–55% of its body weight. From viewpoint, it is estimated that the anchovy populations in the Black Sea consume 80000 tons of zooplankton per day in the spawning season. This amount is approximately 20% of the daily plankton production in the Black Sea (Y. V. Bulgakova, 1996). Despite its importance in the pelagic ecosystem and economic value, data on the diet composition of the species distributed in the Black Sea are scarce. The first known studies were conducted in the 1900s by Bulgakova (1996, 1993; Yu V Bulgakova, 1993). A recent study reported that the diet of specimens collected from the Black Sea has mainly consisted of fish eggs-larvae, (30.89%), ctenophora (14.68%) and, copepods (12.95%) in numerical frequency (Mazlum et al., 2017) (Figure 12).

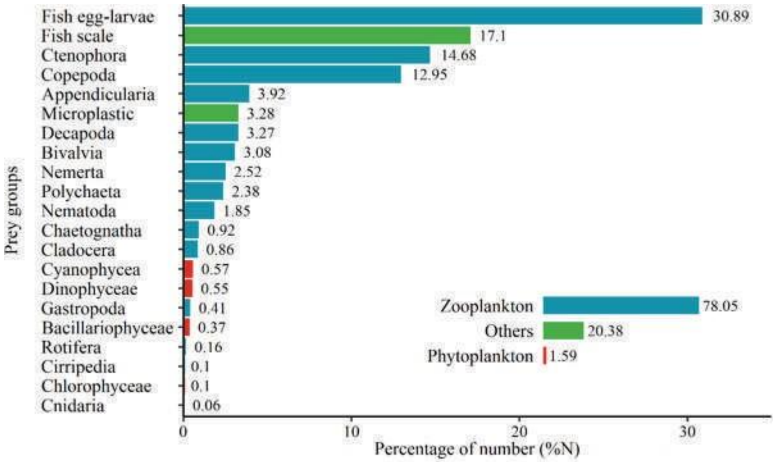

Figure 12. Prey composition of the E. encrasicolus specimens captured from the south-eastern Black Sea (Mazlum et al., 2017)

Reproduction

The European anchovy reaches maturity in the first year of its lifespan (11–12 months). The length at the first maturity for males and females is between 55 and 60 mm, and 60–65 mm respectively, and the weight is between 1.2–1.5 gr for males and 2.1–2.4 gr for females (Lisovenko & Andrianov, 1996). The difference between male and female individuals cannot be distinguished from their appearance. The sex determination of the species can be done by visual examination by dissecting out the gonads. The gonads are covered with capillaries in both sexes.

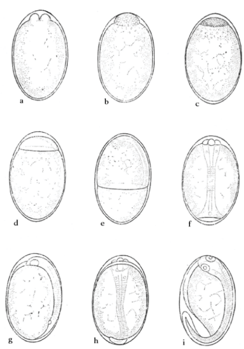

Figure 13. Egg development stages of **E. encrasicolus ponticus,** a,b- stage 1, c-stage 2, d,e,f – stage 3, g – stage 4, h,i – stage 5 (Dekhnik, 1973).

The individuals with red-colored gonads are females and white-colored gonads are males (Holden & Rait, 1974). The start of the spawning season is when the water temperature reaches 15–16°C, which is in middle of the May and it lasts until the water temperature is 25–26°C at the end of August (Lisovenko & Andrianov, 1996). Spawning reaches its peak when the water temperature is above 20°C (Niermann, Kideys, Kovalev, Melnikov, & Belokopytov, 1999; Şahin & Hacımurtazaoğlu, 2013). The spawning areas are brackish waters influenced by freshwater entrance (12–18‰ salinity) and relatively close to the coast with 5–10 meters in depth (Lisovenko & Andrianov, 1996). Water temperature is the key factor for gonad maturation, which is the minimum 13°C (Özdamar et al., 1995). A female spawns 13.000–40.000 eggs during the spawning season. The eggs are ellipse-shaped (1.5–1.9 mm in length and 0.2–1.2 mm in width), transparent, and pelagic (Error! Reference source not found.). There is no oil globule, the yolk is segmented. Depending on the water temperature larvae hatches within 24 h after fertilization (Slastenenko, 1955). The length of the larvae is 2–2.5mm (Figure 14).

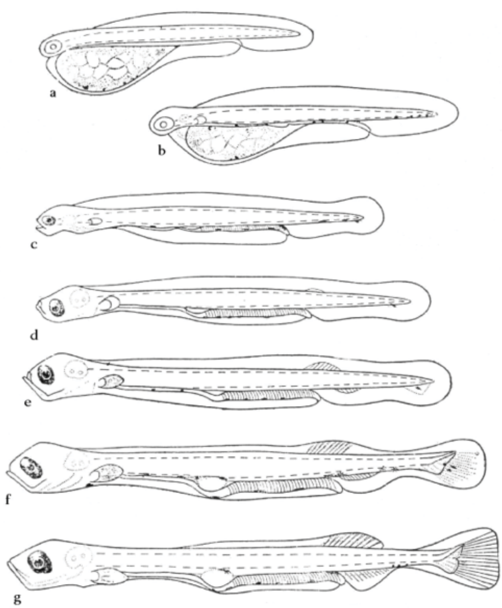

Figure 15. Development stages of **E. encrasicolus ponticus** larvae a) 2 mm; b) 3,5 mm; c) 4,5 mm, d) 5,3 mm; e) 6,5 mm; f) 8,5 mm; g) 10 mm (Dekhnik, 1973)

Conclusions

Understanding the biology and ecology (age, size, movement, and reproductive rates) of the exploited fish stocks is important for organizing the fishing season, determining the minimum catch size of the species, quota, and no-take zones. The fishing season for the anchovy in Turkey was regulated by considering the spawning season. The season starts on 1st September and ends on 15th April, which excludes the spawning period of the anchovy. The minimum catch size of anchovy is determined as 9 cm according to the regulations of the Ministry of Agriculture and Forestry of Turkey. These regulations allow individuals to spawn at least once in their lifespan to maintain recruitment into the stocks. However, stock management and assessment methods are usually relied on the landing data, so that biological data is usually ignored, underestimated, or assumed to be constant which leads to the mismanagement of the stock.

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AN OVERALL ASSESSMENT ON THE TURKISH FISHERY OVER THE LAST DECADE: The Black Sea and anchovy

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ÖZET

2007 yılında Türkiye'nin toplam su ürünleri üretimi 772.323 ton olup bunun 632.450 tonu avcılıktan ve geriye kalan 139.873 tonu ise yetiştiricilikten elde edilmiştir. Bundan sonra avcılık yoluyla elde edilen üretim azalmaya ve yetiştiricilik üretimi ise artmaya başlamıştır. 2018 yılında toplam su ürünleri üretimi 628.631 ton olup bunun 314.094 tonu avcılık üretimi ve kalan 314.537 tonu ise yetiştiricilik üretimi olarak gerçekleşmiştir. 2007-2018 arası dönemde avcılık üretimi yüzde yüz azalırken, su ürünleri üretimi yüzde 125 artmış ve ilk kez yetiştiricilik üretimi avcılık üretimini geçmiştir. 2019 yılında Türkiye'nin toplam su ürünleri üretimi bir önceki yıla göre % 33 artarak 836.524 tona ulaşmıştır. Yine 2019 yılında Türkiye'nin avcılık üretimi de bir önceki yıla göre yaklaşık % 48 ve yetiştiricilik üretimi ise yaklaşık % 19 arttı. Avcılık üretimindeki bu artış esas olarak Karadeniz'deki avcılıktan ve bilhassa bir önceki yıla göre yaklaşık üç kat artan hamsi av miktarından kaynaklanmıştır.
Bu makalenin amacı son on yılda Karadeniz balıkçılığına özel bir vurgu yaparak Türkiye'nin su ürünleri avcılık üretiminde meydana gelen değişikliklerin nedenlerini ve olası etkilerini tartışmak ve ayrıca, sürdürülebilir balıkçılık için hamsi avcılığının bir yıl süreyle yasaklanması gibi yapıcı önerilerde bulunmaktır. adan kaynaklandığını söylemek mümkündür. Yapılan değerlendirmeler sonucunda hamsi stoklarının sürdürülebilir balıkçılık açısından ciddi bir tehlike içinde olduğu anlaşılmaktadır. Bu nedenle; stokların iyileşmesine katkı sağlamak amacıyla tüm Karadeniz'de hamsi avcılığının en az bir yıl süreyle yasaklanması önerilmektedir

1. Introduction

Fisheries are one of the main sub-sectors of the agricultural sector of Turkey. It has a vital importance in contributing beneficial food for human beings. Providing raw material for the industrial sector, creating employment possibilities and high potential for export. Turkey, with its favourable geographic position between the Black Sea and the Mediterranean Sea, has access to fish resources of both of these water bodies. The country is also endowed with rich inland water and river systems with significant capture and aquaculture production.

Turkey is found at the seventh level among EU countries in total production and at the fourth level in aquaculture. Significant developments have been taken placed recently concerning aquaculture fishing in Turkey (Tas, 2007). Aquaculture now is one of the most rapidly developing sectors in Turkey because of decreasing fishing and suitable areas for aquaculture production, especially in the Black Sea for rainbow trout (Sener, E., 2002)
There are some 247 known marine fish species in the Black Sea, 200 in the Sea of Marmara and 500 in the Mediterranean. Despite its rich biological diversity, the Mediterranean is poor in the amount of fish productivity (Bilecenoglu et al., 2001; Unal and Goncuoglu, 2012).

According to fishery statistics of the Turkish Statistical Institute, the total amount of fish production of Turkey was about 836.5 thousand tonnes in 2019, of which 55 percent was obtained by capture fishing (TSI, 2020). Concerning the capture production, Turkey is 45th producer of the word of 90.9 million tonnes (0.37%) (FAO, 2016). A large part of the catch obtained from the entire Black Sea basin is provided from Turkey’s Black Sea coasts. Turkey has historically been the primary producer in marine capture fishery among all Black Sea countries. According to catch data 1998–2016 Turkey meets averagely the 83% of this catch. (Zengin, 2019).

The Black Sea and its most abundant product, anchovy play a special and important role in Turkish Fishery. Anchovy is a type of fish, which is abundant in the Sea of Azov and especially in the Black Sea. This fish exists in the Black Sea as a two species, Engraulis encrasicolus ponticus and encrasicolus maeticus. Engraulis encrasicolus ponticus is known as the Black Sea anchovy and can grow up to 18–20 cm in length. Engraulis encrasicolus maeticus is known as the Azov anchovy and reaches up to 15 cm in length. It breeds and feeds in the Sea of Azov and winters from the north Caucasus to Sukumi and partly off the Crimea (Bingel and Orek, 2000).

Although the Black Sea anchovy goes to the south for wintering, it has recently proved that the northern Black Sea is not completely emptied and that an important part of anchovy biomass does not leave the region where they are located (Bingel and Gucu, 2010).

2. Material and Methods

This paper reviews and discusses the status of the Turkish fishery sector with the special emphasis on the Black Sea as it is the major contributor to the fishery in terms of the amount of catch. It then outlines some constructive proposals related to better management and sustainable fishing. The data used were mainly obtained from the official statistics of Turkey and the Food and Agriculture Organization of the United Nations (TSI, 2019; FAO, 2019).

2.1. Fish production of Turkey

Turkey's total fishery production, although has some fluctuations have an average level of 657 thousand tonnes during the last 12 years. It was 772 thousand tonnes in 2007 and reached nearly 837 thousand tonnes, of which 373 thousand tonnes were aquaculture production and 463 thousand tonnes was capture production, in 2019 (Table 1).

Years	Capture Production			Aquaculture Production			Total Production (tonnes)
	Sea (tonnes)	Freshwater (tonnes)	Total (tonnes)	Sea (tonnes)	Freshwater (tonnes)	Total (tonnes)	
2007	589 129	43 321	632 450	80 840	59 033	139 873	**772 323**
2008	453 113	41 011	494 124	85 629	66 557	152 186	**646 310**
2009	425 046	39 187	464 233	82 481	76 248	158 729	**622 962**
2010	445 680	40 259	485 939	88 573	78 568	167 141	**653 080**
2011	477 658	37 097	514 755	88 344	100 446	188 790	**703 545**
2012	396 322	36 120	432 442	100 853	111 557	212 410	**644 852**
2013	339 047	35 074	374 121	110 375	123 019	233 394	**607 515**
2014	266 078	36 134	302 212	126 894	108 239	235 133	**537 345**
2015	397 731	34 176	431 907	138 879	101 455	240 334	**672 241**
2016	301 464	33 856	335 320	151 794	101 601	253 395	**588 715**
2017	322 173	32 145	354 318	172 492	104 010	276 502	**630 820**
2018	283 955	30 139	314 094	209 370	105 167	314 537	**628 631**
2019	431 572	31 596	**463 168**	256 930	116426	**373 356**	**836 524**

Table 1. Total fisheries production of Turkey, 2007–2019

Source: For aquaculture production and freshwater products, Ministry of Agriculture and Forestry.

The total fishery product of Turkey has also presented according to type product for the same period in Figure1. As can be seen from Fig. 1, the amount of total production is characterized mainly by the nature of the capture fishery production. In year of 2007, capture production was about 632 thousand tonnes and it has dropped to about 314 thousand tonnes in 2018, presenting about 50% decrease. Although the decrease of capture production, the aquaculture production has reached almost 315 thousand tonnes from 140 thousand tonnes, with about 120% increase in the same period. As can be seen from Figure 1, the aquaculture production has caught capture production and even slightly passed it for the first time.

In 2019, the total fishery production has increased 33.1 percent compared to the previous year. 44.8% of the total production consisted of marine fish obtained from capture, 6.8% of other marine products obtained from capture, 3.8% of inland water products obtained from capture and the remaining of the 44.6% obtained from aquaculture products.

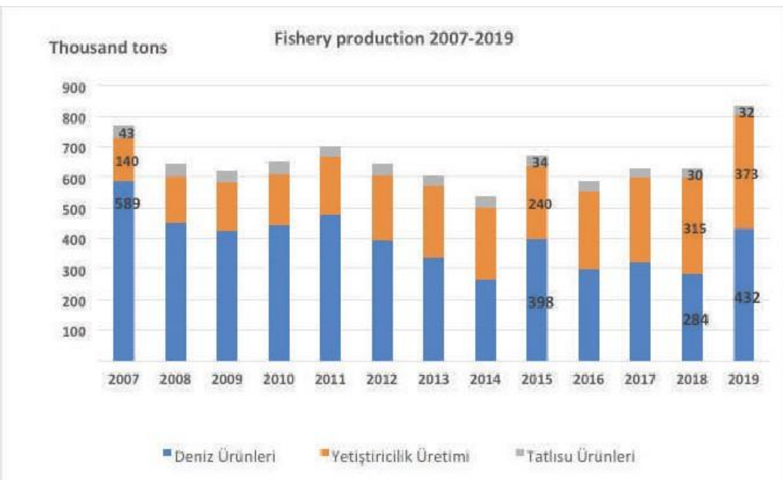


Fig. 1. Fishery production of Turkey (2000–2019) Source: TSI, 2019.

The main species and amounts for the aquaculture production of Turkey are shown in Table 2 (Anon., 2018).

Table 2. Aquaculture production of Turkey

Species	Amount (tonnes)	Percentage (%)
Rainbow trout (inland) (*Oncorhyncchus mykiss*)	101297	40
Sea bass (*Dicentrarchus labrax*)	80847	32
Sea bream (*Sparus aurata*)	58254	23
Rainbow trout (marine) (*Oncorhyncchus mykiss*)	5716	2
Others	7597	3

Marine capture fishery of Turkey by regions of product is presented in Fig. 2. According to the latest statistics (TSI, 2019), the total marine production of Turkey was about 375 thousand tonnes, of which 70% is from the Eastern Black Sea, 10% is from the Western Black Sea, 10% is from the Aegean Sea, 7% is from the Sea of Marmara, and 3% is from the Mediterranean. The Black Sea alone (the East the West) amounts to 80% of the total marine capture fishery because of the availability of anchovy catches in large quantities.

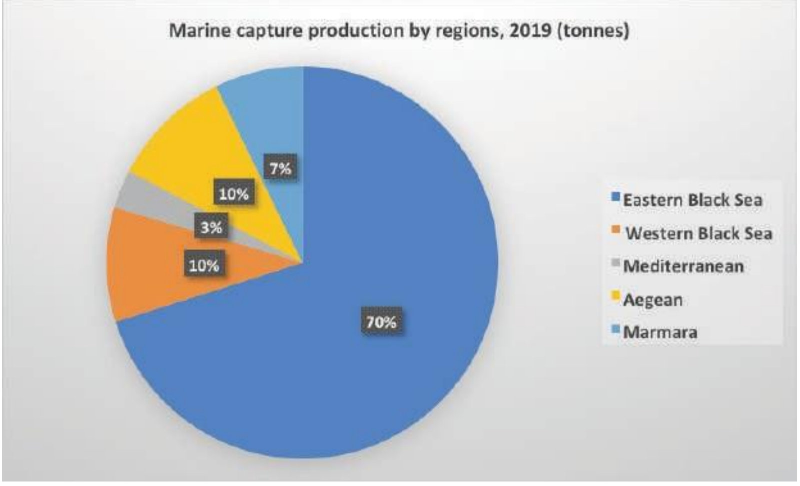


Fig. 2. Marine capture fishery of Turkey by regions of product, 2019. Source: TSI, 2017.

Main pelagic species of the Black Sea are anchovy, sprat, horse mackerel, sardine, bonito and bluefish. Their number of catches during the last decade have been shown in Fig. 3. The average values of these pelagius over this period are 196.3 thousand tonnes for anchovy, 40.9 thousand tonnes for sprat, 22.9 thousand tonnes for sardine, 22.7 for thousand tonnes for horse mackerel, 14.7 thousand tonnes for bonito and 5.3 thousand tonnes for bluefish. According to 2009-year data, the contributions of these six pelagic species to total Black Sea production were 88% for anchovy, 13% for sprat, 7% for horse mackerel, 6% for sardine, 1% for bonito and almost zero percent for bluefish. No doubt that the anchovy is the predominant species for the Black Sea fishing in terms of quantity.

Fig. 3. Main pelagic species of the Black Sea, 2007–2019. Source: TSI, 2019.
Fig. 4 represents the anchovy and total sea fish catch over the period 2010 to 2019. As can be seen from this figure, the anchovy is the most quantitate species of the Black Sea and indirectly Turkish capture fishery. It is therefore useful to examine the anchovy in a more detail.

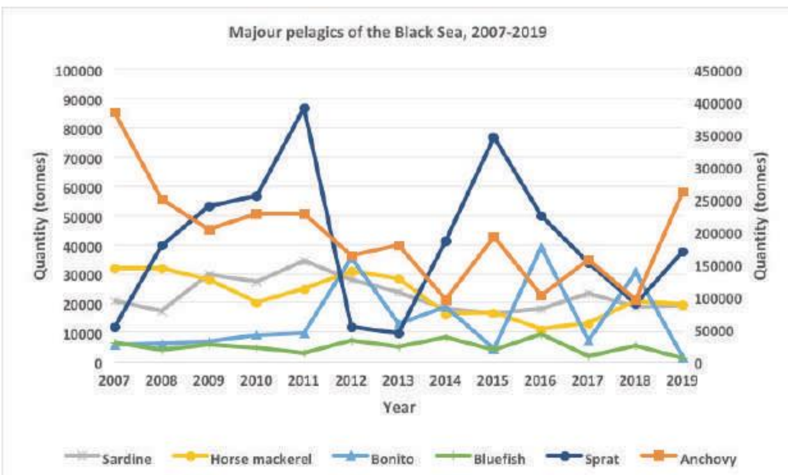
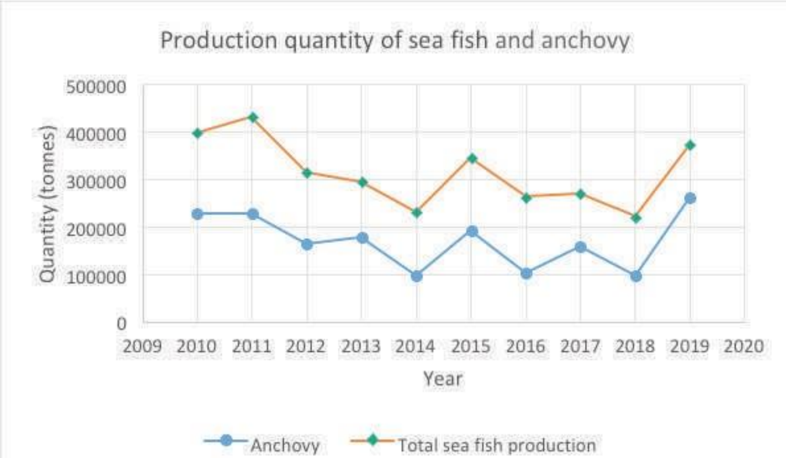


Fig. 4. Anchovies and total sea fish catch, 2010–2019.

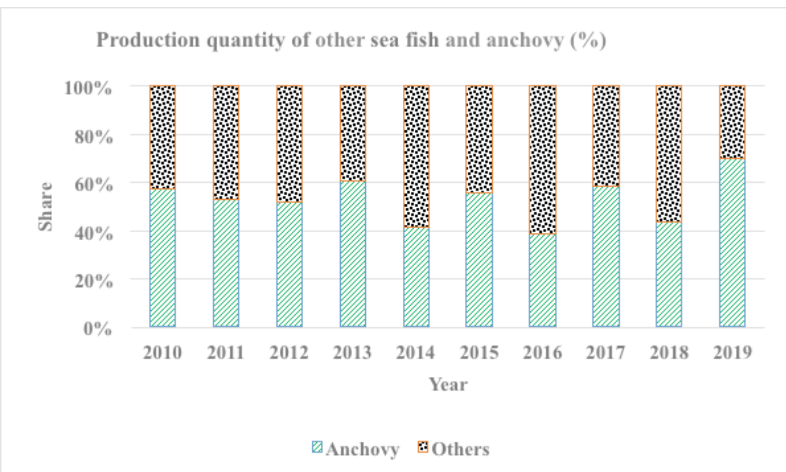
The contribution of anchovy catch to total sea fish production as a percentage value has shown in Fig. 5. As can be seen in this figure that the share of anchovy has always been more than half of the total marine fish product ex-



cept 2014, which was 42 percent. Its value was about 57% in 2010 and over the decade it fluctuated around 50% and reached its highest level of 70% in 2019. The average value of anchovy share over this period was about 53%.

Fig. 5. Percent share of anchovies among total fish capture of Turkey, 2010–2019.

Anchovy catch values (continues line) and its trend (dotted line) over the last twenty years has shown in Fig. 6. As can be seen from the figure that the anchovy catch has presented several dramatic decreases within this period. The one was in 2005, it dropped to nearly 140 thousand tons from 340



thousand tons, meaning a 59% decrease. The second one has taken place in 2014. The amount of anchovy catch dropped to below 100 thousand tons and this has been repeated in 2016 and 2018, which was the lowest value (96 thousand tons) ever seen. Although the catch quantity has risen to 260 thousand tons in 2019, the size of catch was generally under the allowable size of 9 cm, which was a clear indication of overfishing.

Fig. 6. Anchovy catches, 2000–2019. Source: TUIK, 2019.

2.2. Economy of fisheries in Turkey

According to the statistics released in 2019 the total value of anchovy

catches was approximately 10 billion TLY. The necessary statistics for 2019 are given in table 3.

Table 3. Anchovy unit price, consumption type and catches and its economic value in 2019 (TUIK, 2019)

A simple calculation shows that total anchovy income is around 9% of total fishery income taken place in 2019. If, of course, all catches in the same year were consumed by humans in Turkey without sending the undersized anchovy caught to the fish oil factories, this figure would have gone up to

Anchovy catch (tonnes)	Consumption type	Unit price (kg/TL)	Total (TL)
Eighty-three 031		7.31	606 957 000
Human cons.			
179 513	Fish meal and	1.44	258 499 000
oil			
262 544	Total		865 456 000

19 %. In other words, if undersized fish (less than 9 cm) were not caught an economic loses of 10% would have not been the case, resulting avoiding the overfishing in the Black Sea as well. Meanwhile, the total fisheries and aquaculture income accounts for only 0,23 % of the total Turkish economy, which may explain why the management of living natural resources is taken into consideration less seriously as discussed by some experts.

2.3. Fishing fleet of Turkey

The total number of fishing vessels in 2019 was 14092, of which 85% (11978) is under the length of 10 meters and the remaining 15% (2114) is more than 10 meters (Fig. 7). Fishing vessels over 20 meters are engaged in purse seining and trawling and are responsible for the major fish production of Turkey. Fishing of this type is therefore referred to as industrial fishing. Fishing vessels under 20 meters commonly practice other types of fishing, and take part in artisanal fishing.

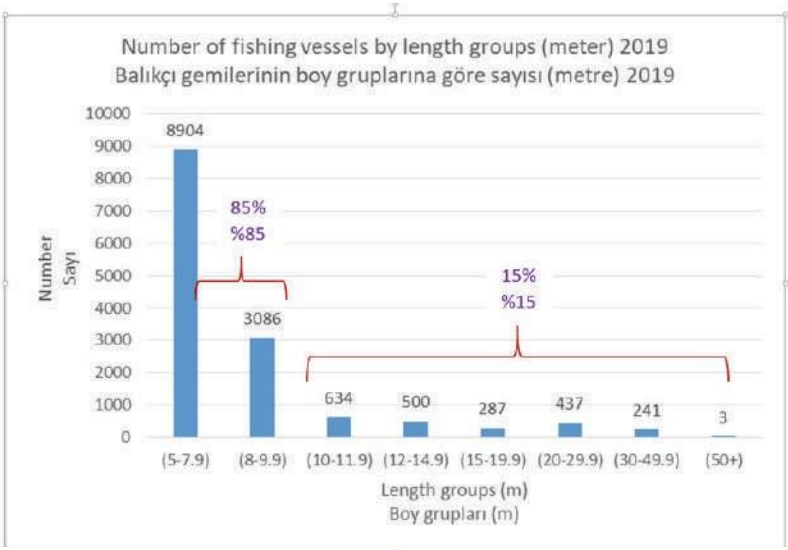


Fig. 7. Number of Turkish fishing vessels by length groups (2019). Source: TSI, 2019.

The fishing activity in Turkey is mainly costal. Dense fishing operations are conducted in the Black Sea and the Sea of Marmara, while small scale of fishery takes place in the Aegean Sea and the Mediterranean. However, a few number of industrial fishing vessels operate outside the Turkish waters such as Egypt, Algeria and Morocco (Saglam and Duzgunes, 2010). In addition to that some Turkish purse seiners have been fishing anchovy in the Black Sea of the Georgian's , exclusive economic zone (EEZ) with the Georgian and Ukrainian Vessels since 1991.

The total number of Turkish fishing vessels was 13381 in 2000 and tended to increase till 2003 and reached 18542, which was the value highest number ever seen. After this year, the number of vessels gradually decreased because of decreasing catch and some measures taken by the official authorities to reduce fishing effort. The number of fishing vessels according to fishing types for 2017 and 2019 is presented in Table 3. As can be seen from this table, there is a decrease of 387 in the total number of fishing vessels within two years. The decrease has taken place in almost every type of fishing, particularly in large scale of fishing vessels such as purse seining and trawling.

Table 3. Number of fishing vessels by type of use for 2017 and 2019.

Kullanım Şekli Type of usage	Gemi Sayısı Number of vessels	
Yıl Year	2017	2019
Trol Trawl	798	790
Gırgır Purse Seine	391	370
Taşıyıcı Gemi Carrier Vessel	98	93
Uzatma Ağları Gill Nets	7545	7349
Algarna ve Dreçler Dredges	525	634
Paraketa ve Oltalar Longline and Hooks	3845	3624
Çevirme ve Voli Ağları Encricling Gears	994	1010
Sürütme Ağları Towing Gears	23	15
Çökertme Ağları Droping Gears	16	12
Pinter	4	12
Diğer Other	240	183
Toplam Total	14479	14092

2.4. Number of fishers in Turkey

The variation in the number of people engaged in fishing activities directly and indirectly between the years of 2006 and 2019 is shown in Fig. 8. It can be seen from this figure that there is almost no change in the number of fishers between 2006- 2010, however, a considerable decrease has taken place after 2010, from about 47 thousands to 29 thousands (38%).

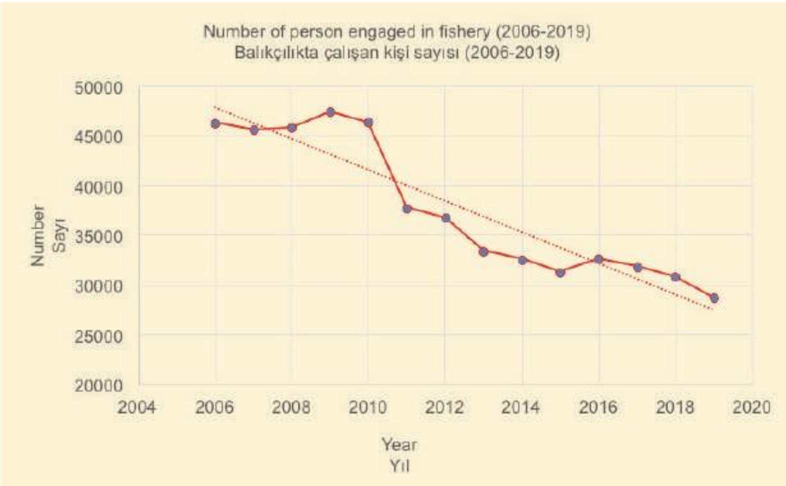


Fig. 8. Number of people working in fisheries sector in Turkey (2019). Source: TSI, 2019.

3. Conclusions and recommendations

The total fisheries production of Turkey was 772 thousand tons in 2007, it then reached 837 thousand tons in 2019 with slight fluctuations. Although there were no big fluctuations in total production, there was a serious decrease in the capture production over this period. The decrease in the capture production has been compensated by aquaculture production. The decrease in the capture production was mainly due to the decrease in the anchovy production.

With respect to the catch data, it can be said that there has been much fishing pressure on anchovy stocks, not only in Turkish waters but also in Georgian waters. It has been reported that this exploitation practice has caused a significant decrease in the anchovy fish stock (Castilla-Espino et al., 2014). The Ministry of Agriculture and Forestry has also implemented a new policy to reduce the capacity of the fishing fleet by using offering money to fishers to withdraw their vessels form operation since 2013 (Dincer, 2016). Unfortunately, this practice of the ministry, which reduces the number of fishing vessels has not produced the desired result in the last decade.

It has been determined that the anchovy-hunting period has changed significantly recently. It has been observed that the hunting period, which should normally be between November and March, has significantly shortened and the number of catches obtained has not showed a homogeneous distribution within the season. It is possible to say that this situation is primarily due to the recent climate change and the global warming.

Because of the discussion, anchovy stocks are in serious danger in terms of sustainable fisheries. To contribute to the recovery of the stocks, it is recommended that fishing for anchovy should be prohibited for at least one year in the entire Black Sea.

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Factors affecting fish schools with special reference to Anchovy in the Black Sea

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ÖZET

Dünya denizlerinden izole, yarıkapalı bir iç deniz olan Karadeniz ekosisteminde antropojenik aktivitelerin ve buna bağlı olarak iklim değişikliği etkilerinin anlaşılabilmesinde biyojeokimyasal döngülerin bilinmesi önemlidir. Havzanın genişliği ve çok sayıda tatlı su girdisi nedeniyle yüksek düzeyde karasal kirletici baskısına maruz kalan Karadeniz, yoğunluk farkına bağlı tabakalaşmanın bir sonucu olarak dünyadaki en büyük anoksik su kütlesini barındırmaktadır. Özellikle 1960'lı yıllarda başlayan besin elementleri ve ağır metaller gibi kirleticiler kaynaklı çevresel sorunlara sonraki dönemlerde petrol kökenli kirleticiler de dahil olmuştur. Bunun yanısıra *Mnemiopsis leidyi, Beroe ovata* gibi istilacı türlerin girişi ve aşırı avcılık Karadeniz ekosisteminde dramatik değişikliklere yol açmıştır. Karadeniz balıkçılığının başlıca ticari türü olan hamsi, besin (zooplankton), yumurta ve larvalarının istilacı türler tarafından tüketilmesi nedeniyle bu ekolojik çatışmanın ana kurbanı olmuştur.

INTRODUCTION

Determining fundamental processes affecting biogeochemical cycles in the water column is difficult in marine ecosystems. An understanding of foundational processes in aquatic ecosystems is required to delineate and mitigate the effects of climate change and other anthropogenic impacts upon their structure and function (Konovalov et al., 2005). Based on relative isolation from oceans, seas can be partially or fully located inland (Zaitsev, 2008). Among coastal and semi-enclosed European seas, the Sea of Azov and Black Sea have the largest enclosed catchment basins most isolated from any oceans (Rass, 1992).

Black Sea is characteristically and greatly affected by anthropogenic factors due to a relatively large drainage basin, geography, basin-wide morphometry, and because it is effectively isolated from any ocean. As a result, from 1950s through today, the Black Sea has periodically suffered from localised eutrophication, algal blooms, reduced water transparency, depleted oxygen levels in the benthos, and mass die-offs of bottom-dwelling organisms (Zaitsev, 2006).

In addition to many lakes and fjords, there are persistent anoxic conditions in some parts of world oceans (Yakushev, Pollehne, et al., 2007). The Black Sea exemplifies a marine anoxic basin with a surface layer harboring saturated levels of oxygen overlying an (anoxic) deep layer containing high levels of sulphide. Such dynamics have developed due to density-based water column stratification. Layering in the upper portions of the water column in the Black Sea exemplifies underlying connections between its physical regime, climate forcing, nutrient dynamics, and biotic responses (Murray et al., 2007).

In the 1960s, Black Sea ecology began to be dramatically impacted due to increasing pressures from varied anthropogenic factors. The most important changes that have taken place across large-scales have included reduced freshwater inputs from run-off, eutrophication, over-harvesting of fishes, and the proliferation of non-native and invasive species. Northern areas of the Black Sea have experienced the greatest effects from these changes as they receive the greatest relative contributions of freshwater from rivers and have a hydrological and hydrochemical regime dependent upon these inputs. Presently, inputs of phosphorous and nitrogen from rivers flowing into the northwestern Black Sea and Sea of Azov have substantially increased and caused coastal eutrophication (Shiganova, 2000).

Relatively unique ecological conditions exist among seas within the Black Sea. For example, low salinity and high primary productivity in the Black Sea have facilitated the establishment and subsequent proliferation of non-native and opportunistic predator species. Many such species have arrived through the release of ship ballast water and have carved their own ecological niches. One of the first documented non-native species that proliferated by such means was the snail Rapana, which was introduced from its native range in Japan in the late 1940s. Sea snails (*Rapana venosa*) are widely viewed as having caused the local and basin-wide extirpation of commercially harvested oyster species and reductions in biodiversity (Ragaini, 1999). Notable ecosystem-level changes likewise occurred in the Black Sea post-invasion of a ctenophore Sea walnut (*Mnemiopsis leidyi*), which itself facilitated another noteworthy invasion by becoming an important constituent prey species for a later arriving invasive species, *Beroe ovate* (Shiganova, 2000). With an invasive jellyfish, *Aurelia aurita*, *Beroe ovate* feeds upon and significantly impacts the dynamics of other Black Sea zooplankton, including fish larvae, and neither species appears to have natural predators. Consequently, many endemic Black Sea fishes are extinct and have become extirpated from the region. Due to anthropogenic impacts and these biological changes, the average yearly tonnage of fishes harvested of 850,000 in the 1980s has declined to only 250,000 in 1991 (Ragaini, 1999).

Thus, the aim of this manuscript summarizes all factors that have, and continue to affect the dynamics and harvests of Black Sea anchovy species, including natural and anthropogenic factors.

1. Black Sea characteristics

Environmental changes tend to be magnified in the Black Sea due to its relative geographic isolation from oceans of the world. The Black Sea has coastal areas that border six countries, links Southwestern Asia with Europe, is greatly influenced by inputs from Eurasian rivers, and is the world's largest anoxic basin. For these reasons, the dynamics of the Black Sea are an ongoing focus of detailed and precise oceanographic research (Murray et al., 2007).

1.1. Black Sea drainage basins

The Black Sea has a drainage area more than 5 times its own surface area (exceeds 2 million 300 thousand km^2). The Black Sea, which has a total length of coastline 4,340 km, has 6 riparian countries, namely Ukraine (1,829 km) in the north, Russia (379 km) in the northeast, Georgia (312 km) in the east, Turkey (1,695 km) in the south and Romania (245 km) and Bulgaria (378 km) in the west. In addition to these six countries, 17 countries (Albania, Austria, Belarus, Bosnia-Herzegovina, Croatia, the Czech Republic, Germany, Hungary, Italy, Macedonia, Moldova, Montenegro, Poland, Serbia, Slovakia, Slovenia and Switzerland) are entirely or partially within the Black Sea drainage basin. Thus, 23 Eurasian countries are located within the Black Sea Drainage basin (Borysova et al., 2005; Doussis, 2006; Ragaini, 1999; Zaitsev, 2008). However, proportional contributions to the Black Sea drainage area differ. For example, land area (in km^2) draining into the Black Sea in Italy, Poland, and Albania ranges only from 100-300, Switzerland 1,700, Moldova 33,700, Germany 58,000, Romania 226,000, Turkey 249,000, and one of the largest contributions is from Ukrainian lands 600,000 (Borysova et al., 2005; Langmead et al., 2009; Ragaini, 1999; Zaitsev, 2008).

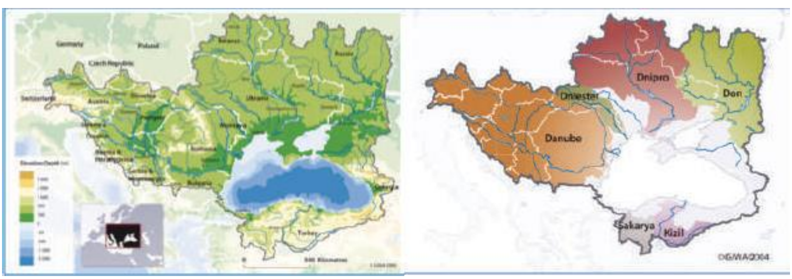

Figure 1. Drainage basin (A) and sub basin (B) map of the Black Sea (Borysova et al., 2005).

Geographically, Eurasian Black Sea waters originate from western and northern coastal areas of Bulgaria, Romania, Ukraine, and Russia. Asian waters originate in southern and eastern areas of coastal Turkey and Georgia (Zaitsev, 2008). The Eurasian-based catchment area drains three main river basins: the Danube, the Dnieper, and the Don and makes up a large proportion of the Black Sea and the entirety of Azov Sea (Borysova et al., 2005). In addition to the three major rivers, more than 300 other rivers varying from relatively large to small sizes drain its catchment basin and flow directly into the Black Sea. Because of its large catchment area and relative isolation from oceans, the Black Sea is geographically, ecologically, and biologically distinct. Important factors within the Black Sea catchment basin that impact its structure and function include vast intensively managed agricultural lands, large-scaled industry, and numerous densely populated cities including state and national capitals (Zaitsev, 2008).

1.2. Black Sea morphometry and bathymetry

Waters of the Black Sea fall between latitudes 40° 55'N and 46° 32'N, and longitudes 27° 27'E to 41° 42'E. Black Sea waters fill a topographic depression between two alpine fold belts delimited in the south by the Pontic Mountains and in the northeast by the Caucasus Mountains. The northwestern coast of the Black Sea (excluding the Crimean portion) is at a relatively low elevation and includes a large-scaled and shallow continental shelf. However, especially for a marginal sea, the majority and remainder of the Black Sea features relatively deep bathymetry (Murray et al., 2007).

The Black Sea has a surface area of 423,000 km^2, is 1,200 km across its widest stretch, fills a volume of 547,000 km^3, and its deepest point is at 2,212 m (Borysova et al., 2005; Özsoy & Ünlüata, 1997; Ragaini, 1999; Zaitsev, 2008; Zaitsev & Mamaev, 1997). A single outlet for the Black Sea is shallow (< 93 m) and narrow (0.76–3.60 km) and connects to the Mediterranean Turkish Straits System (i.e., the Bosphorus, Dardanelles Straits, and Marmara Sea). At the southern end, Bosphorus sill depths are 32-34 m, whereas depths are 60 m at the northern end (Doussis, 2006; Murray et al., 2007; Ragaini, 1999). The saline Mediterranean Sea derived inflows in this zone are outweighed by Black Sea freshwater outflows. These dynamics facilitate stratification of the water column with a resultant freshwater surface layer (salinity 17–19 parts per thousand (ppt)) and an underlying layer of denser saline water (approximate salinity 22 ppt). The results in a permanent halocline that is a distinguishing feature of the Black Sea. Density-based differences and non-existent vertical mixing limits oxygen penetration from surface waters to the benthos. The Kerch Strait connects the northern region of the Black Sea to the relatively shallow Sea of Azov with a mean depth of 8 m, maximum depth of 12 m, and a 39,000 km^2 surface area (Fulton et al., 2012; Ragaini, 1999).

The basin of the Black Sea has a relatively simple morphometrics such that main functional areas of deposition lie within clearly delineated intervals of depth. Consequently, Black Sea bathymetry can be divided into five zones: (1) a continental shelf less than 100 m deep with a width not exceeding 200 km, (2) a shelf break with depths up to 200 m, (3) steep upper continental slopes (200-1000 m), (4) lower slopes with gently sloping depth gradients (1000–1800 m), (5) and relatively large-scale basin portions with depths nearing 2000 m. The continental shelf constitutes 31.9% of the volume of the Black Sea and is typically characterized by waters saturated with oxygen. The shelf break (3.3 % of total volume) is situated near the oxycline and is influenced by suboxic conditions. The upper slope (8.4% of total volume), lower slope (15.1% of total volume), and the deep-sea basin (41.3% of total volume) of the Black Sea are exposed to anoxic waters (Teodoru et al., 2007). The Black Sea's northwestern continental shelf is less than 200 m deep, constitutes 25% of the its total volume, and receives discharge from three of Europe's largest rivers including the Danube, Dnieper, and Don, as well as receives considerable discharge from the Dniester and Kuban Rivers (Özsoy & Ünlüata, 1997; Ragaini, 1999).

Numerous gulfs, bays, peninsulas, and notable capes make up portions of Black Sea coastlines. The Burgas and Varna Bays in Bulgaria; Mamaia Bay in Romania; Odessa, Tendrovsky, Yagorliksky, Dzharylgachsky, Karkinitsky, Kalamitsky and Feodosia Gulfs and Sevastopol Bay in Ukraine; Novorossiysk and Gelendzhyk Bays in Russia; Batumi Bay in Georgia; Samsun and Sinop Bays in Turkey constitute the largest of such features in the Black Sea. The largest Black Sea peninsula is Crimea, and becomes limited to the west by the Tarkhankut peninsula and to the east by the Kerch peninsula (Zaitsev, 2008).

1.3. Hydrology and the water budget

1.3.1. Freshwater influxes

In the last century, contributions the balance of the water cycle in the Black Sea (in km^3) was constituted by river discharge (294 to 480), atmospheric precipitation (119 to 300), evaporation (54 to 402), inflows from the Bosphorus (175 to 312), inflows from the Kerch Strait (22 to 95), outflows through the Bosphorus (241 to 612 km^3), and outflows through the Kerch Strait (29 to 70). Substantial interannual changes to these values occur in relation to weather patterns and measurement accuracy (Zaitsev, 2008).

Freshwater contributions into the Black Sea are largely derived from its large catchment area, which includes a large proportion of Eastern and Central Europe, and Turkey (Doussis, 2006). The dynamics of freshwater runoff are influenced by urban conurbations, industry, and agriculture, all of which are all prevalent in the catchment area of the Black Sea. Consequently, significant pollution enters the Black Sea via river discharge having significant damaging environmental impacts. Furthermore, a relatively large portion of Asian and central European land- masses discharge to the Black Sea via several rivers (Table 1) Notably, the Danube, which is Europe's second longest river with a drainage basin including 16 countries (a number exceeding any other transboundary basin), discharges into the Black Sea and plays a major role in regional physicochemical and ecological dynamics (Doussis, 2006).

Table 1. Major rivers that discharge into the Black Sea (Zaitsev, 2008)

River	Discharge from	Catchment area, km^2	Length, km	Total runoff, km^{3}year	Sediment discharge, 10^6ton year
Danube	Romania	817000	2860	208	51.7
Dniester	Ukraine	71990	1328	10.2	2.5
Dnieper	Ukraine	505810	2285	51.2	2.12
Soutern Bug	Ukraine	68000	857	3	0.53
Rioni	Georgia	13300	228	12.8	7.08
Çoruh	Georgia	22000	500	8.69	15.13
Inguri	Georgia	4060	221	4.63	2.78
Kodori	Abkhazia	2030	84	4.08	1.01
Bzyb	Abkhazia	1410	110	3.07	0.6
Yeşilırmak	Turkey	36100	416	4.93	18
Kızılırmak	Turkey	78200	1151	5.02	16
Sakarya	Turkey	65000	790	6.38	-

Major rivers (Danube, Dnieper and Dniester) discharge into the north-western shelf in the region between the Crimea and Romania. The greatest contributor is the Danube, which accounts for approximately 50% of the total runoff from rivers into the Black Sea. Danube basin has a total area of 801,463km^2, out of which 29% (232,193 km^2) lies in Romania, 11.6% (93030 km^2) in Hungary, 11,1% (88,635 km^2) in Serbia and Montenegro, 10% (80,423 km^2) in Austria, 7% (56,184 km^2) in Germany, 5,9% (47,413 km^2) in Bulgaria, 5,9% (47,084 km^2) in Slovak Republic, 4,6% (36,636

km^2) in Bosnia Herzegovina, 4,4% (34,965 km^2) in Croatia, 3,8% (30,520 km^2) in Ukraine, 2,9% (21,688 km^2) in Czech Republic, 2% (16,422 km^2) in Slovenia, 1,6% (12,834 km^2) in Moldova, 0,2% (1,809 km^2) in Switzerland, < 0,1% (126 km^2) in Albania, < 0,1% (565 km^2) in Italy, < 0,1% (109 km^2) in Macedonia, and < 0,1% (430 km^2) in Poland (International Commission for the Protection of the Danube River, 2005).

The Dniester and Dnieper rivers contribute about three times less discharge than does the Danube. All remaining rivers account for less than 20% of the total river runoff into the Black Sea. The mean annual discharge of the Danube has been monitored for longer than a century and has exhibited a large variation due to natural factors (Özsoy & Ünlüata, 1997; Sur et al., 1996). Approximately 162 million people live in the catchment basin of the Black Sea and includes 80 million people within the basin of the Danube River. Coastal areas of the Black Sea are particularly important destinations for tourists, with about 40 million summer visitors compared to 10 million inhabitants of these regions (Ragaini, 1999).

Presently, annual Turkish river water discharge rates to the Black Sea by Turkish rivers is estimated to be 41 km^3. Annual Turkish river sediments discharge to the Black Sea is approximated at 28 x 10^6 tonnes. Pre-construction of hydroelectric dams, annual discharge of sediments approximated 70 x $l0^6$ tonnes. Decreased loads of sediments largely resulted due to newly constructed dams near the Yesilırmak and Kızılırmak river mouths. Before to the dam construction, Turkish rivers contributed approximately 33% of total sediments from all river discharge received by the Black Sea (Hay, 1994).

It was seen that the highest sediment transport is via Coruh and Inguri rivers according to the catchment area, Yeşilırmak, Kızılırmak and Çoruh according to total run off, and Yeşilırmak and Rioni rivers according to the river length.

1.3.2. Circulation

The dynamics of circulation in the Black Sea are strongly influenced by freshwater inputs from rivers, atmospheric forcing, a thermohaline, fluxes through straits, and pronounced changes in topography. An understanding of quickly changing jets and eddies is critical to determine the influence of circulation in the Black Sea and consequential properties of transport, realized the primary production, and the growth, migration and entrainment of pelagic marine organisms (Özsoy & Ünlüata, 1997).

The main current system in the Black Sea is cyclonic, in a circular anti-clockwise direction, and is called “Rim Currents”. Some of the water masses coming from the narrowest part of the Black Sea in the west are directed north from Kerempe Cape on the Anatolian coast and are directed the south coast of Crimea, whereby the sea becomes divided into two parts thus forming east and west cycles. These cyclonic current centers harbor halistatic zones with relatively stable salinities approximating 18.0‰ at surfaces. There is another cycle in the easternmost Black Sea that is in anti-cyclonic (clockwise) in nature and is called “Batumi Gyre” (Figure 2). In the coastal zone, local current speeds and directions can be influenced by winds, whereas basic currents remain relatively stable (Sur et al., 1996; Zaitsev, 2008). Coastal areas experiencing the Rim Current harbour several anticyclonic (clockwise currents) eddies. Some of these currents are permanently controlled by the influences of topography (e.g. the Sakarya Eddy spanning the Sakarya submarine canyon), whereas other currents (e.g. the Sevastopol Eddy) are more influenced by temporal and spatial factors (Murray et al., 2007).

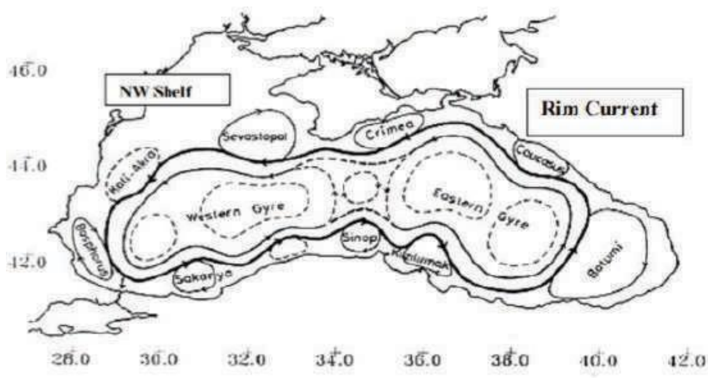

Figure 2. Main currents of the Black Sea (Murray et al., 2007)

Oceanographic dynamics in the Black Sea are strongly influenced by inputs of freshwater from numerous rivers, thermohaline influences, active atmospheric forcing, fluxes through straits, and pronounced topographic changes. Investigations of active Black Sea circulation have identified jets and eddies that rapidly change and that are crucial in determining its role in the basic dynamics of transport Likewise, such investigations have revealed the importance of circulation with respect to primary production, and the growth, migration, and entrainment of pelagic organisms (Özsoy & Ünlüata, 1997).

2. Vertical properties of Black Sea Water Column

Very few naturally hypoxic marine ecosystems characterised by low oxygen and massive upwelling are present worldwide. Some areas exist along the American and African coasts, and in the Arabian Sea. Even marine ecosystems with natural anoxic conditions exist, but include Framvaren and other fjords, the Cariaco Basin in the Gulf of Mexico, and Black Sea) (Konovalov et al., 2005).

Thus, the Black Sea is a unique marine environment as the largest land-locked basin in the world. Black Sea waters remain nearly completed isolated from any oceans due to limited exchanges with the Mediterranean Sea through the Turkish Straits System, including the Bosphorus, Dardanelles Straits, and the Sea of Marmara (Özsoy & Ünlüata, 1997).

Classification of Black Sea waters include oxygenated surface zones, suboxic zones, and anoxic (hydrogen sulfide-bearing) zones (Figure 3). The presence of pronounced chemical gradients in the water column extend from surface waters into suboxic and anoxic zones (Codispoti et al., 1991).

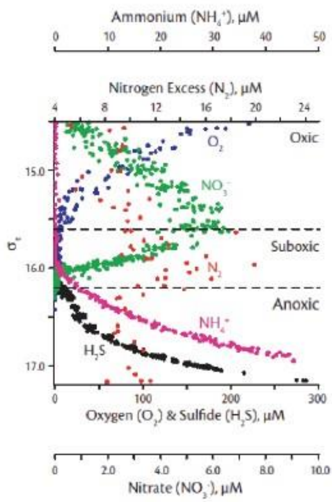

Figure 3. Black Sea water column layer (Konovalov et al., 2005)

The surface layer of the Black Sea is vertically stratified from about 0 to 50 m and is well oxygenated, whereas the deep layer (100 to 2000 m) is anoxic with high concentrations of sulphide. A suboxic zone from approximately 50 to 100 m depths exists at the boundary between the oxic surface zone and anoxic deep layers. The suboxic zone is an important biogeochemical transition zone and contains low levels of both O_2 and H_2S concentrations (Codispoti et al., 1991; Murray, 1991). Redox dynamics of nitrate-manganese-sulfur are important for element cycling in the lower suboxic zone (Murray et al., 2007; Oguz, 2002).

The Black Sea is a typical two-layered marine ecosystem with a strong permanent (main) pycnocline supported by fresh river water inflows in the upper layer and by salty Mediterranean waters in the lower layer. Whereas a seasonal pycnocline is located at the bottom of the surface-mixed layer in the Black Sea, the main pycnocline remains intact despite climate-induced mixing processes however the thickness varies regionally. Convective mixing during the winter in the upper layer transport cold surface waters deeper into the water column but is a process limited to the depth of the pycnocline where cold waters remain preserved. The resulting temperature of the Cold Intermediate Layer (CIL) is 8 ˚C at both the upper and lower boundaries (Konovalov et al., 2005; Lee et al., 2002).

The basin of the Black Sea is almost completely anoxic, containing oxygen in the upper 150 m depth (13% of the sea volume) and hydrogen sulphide in deeper waters. Separating the oxic and anoxic waters is a permanent halocline (Özsoy & Ünlüata, 1997). Consequently, the Black Sea is an excellent case study of oxic and anoxic biogeochemistry (Konovalov et al., 2005).

2.1. Salinity, temperature, density

Salinity classifications fall into eight categories for natural waters as follows: freshwater with salinity less than 0.5‰, mixohaline or brackish salinity from 0.5‰ to 30.0 ‰, oligohaline salinity from 0.5‰ to 5.0‰, mesohaline salinity from 5.1‰ to 18.0‰, polyhaline salinity from 18.1‰ to 30.0‰, euhaline or marine salinity from 30 ‰ to 40‰, and hyperhaline or ultrahaline waters with salinity exceeding 40‰. As a body of marine water, the Black Sea stands out from other seas because of its low salinity (Zaitsev, 2008).

In the Black Sea the total volume of river flow and atmospheric precipitation exceeds evaporation by more than one-third. Further, there is limited water exchange with the Mediterranean Sea, thus, salinity levels are considerably, respectively, lower in the Black Sea. In open sea areas surface salinity are nearly to 18‰ but in the northwestern region in the Black Sea, where the Danube, Dniester, and Dnieper empty salinity is reduced to 15‰ or lower, which corresponds to mesohaline conditions. Black Sea salinity increase with depth reaching as high as 20.5‰ at 200 m and 22.4‰ at 2000 m depths, which are levels that correspond to polyhaline conditions (Zaitsev, 2008).

Seawater entering via the Bosphorus Strait is the sole source of saline waters to the entire basin of the Black Sea. Depending on the dynamics of this source, salinity can increase to as high as 22 ‰ levels in areas with relatively great depth. Freshwater inflows from several European rivers, including the Danube, Dniester, Dnieper, Don, and Kuban particularly facilitate low levels of surface layer water salinity (S ≈ 18.0 to 18.5 in the central region). Consequently, there is a strong stratification in the water column with respect to salinity, and thus, density (Murray et al., 2007)

Due to the existence of a stable halocline, seasonal vertical mixing occurs only through depths of 60-80 m, where a Cold Intermediate Layer (CIL) forms. Restricted oxygen supplies at the CIL permit oxygen to become rapidly exhausted from the decomposition of organic-matter (OM), and anoxic OM mineralisation, ultimately facilitating the build-up of hydrogen sulphide in the water (Yakushev, Arkhipkin, et al., 2007).

In addition to salinity, water temperatures are an important ecological factor in the Black Sea. During summers and days lacking strong winds, warming of coastal waters up to 25- 26°C often occurs and temperatures sometimes exceed 28-30 °C in shallow bays and gulfs. In offshore regions of open seas, surficial summer water temperatures reach °24-23C. With increasing depths, water temperatures become colder and at 150 m depth water temperatures remain at 8.6-8.5 °C for the entire year. Water temperature is practically stable around 9 °C beyond this depth and to the benthos. Between depths of 70-50 m and 150-100 m in the water column, there is a “Cold Intermediate Layer” (CIL) with temperatures ranging from 7.2 to 7.5 °C (Zaitsev, 2008). Wide ranges of surface water temperatures are also noted and vary from as low as 0 °C in the northwestern coastal area during winters to as high as 25 °C in the western region of the Black Sea during summers. Waters at 1,000 ft depth remain at a constant temperature of 9 °C all year. Inputs of freshwater from large rivers on the northwestern shelf are transported by the actions of gyres throughout the Black Sea (Doussis, 2006). Surface water temperatures in the Southeastern Black Sea measured over ten years are given in Figure 4. Findings indicated that minimum water temperatures occurred in February-March whereas maximum temperatures occurred in August (Alkan et al., 2013).

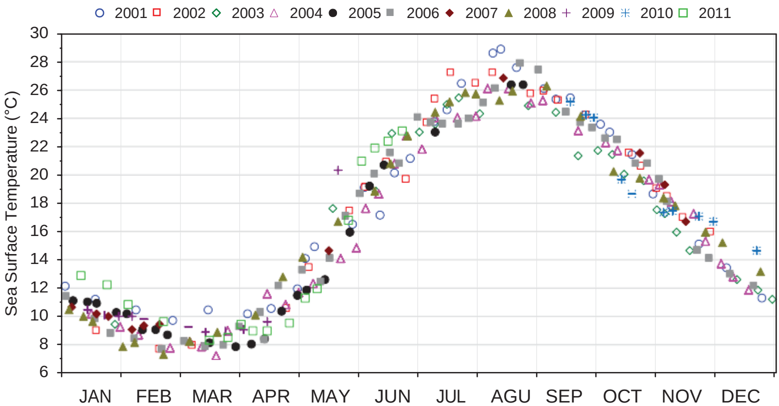

Figure 4. Monthly sea surface temperatures in the Southeastern Black Sea (Modified from (Alkan et al., 2013).

Water temperatures in the southern and south-eastern areas of the Black Sea during winters fall to 10-13 °C and, in northern areas to 4-5 °C or lower. During cold winters, as exemplified in 1954, 1963, 1985, 1996, 2002 and 2006, water temperatures in the Odessa Gulf fell to 0 °C and -1 °C. During such low temperatures, the surface of the Black Sea was covered with ice, especially in coastal regions. During such extremely cold winters ice-covered areas extend southward to Zmyiny Island. Post-March as the all the ice melts, sea water gradually warms (Zaitsev, 2008).

Density is another useful metric to help understand the dynamics of the Black Sea. The primary control of density is salinity, and they increase concomitantly. Shorthand notation for density is expressed as $\sigma = (\rho-1)x1000$ where ρ is density. For water with a density of ρ=1.016 kg m^{-3} the value of σ = 16.0. Density usually helps understand and delineate depth classifications the Black Sea. Characteristic features of density are that it tends to be deeper near the margins and shallower in the central gyres, but usually that it falls on specific density levels. Therefore, plotting density against depth produces scattered data for the Black Sea, however when the depth is plotted against the density, the same data show greatly reduced variability (Murray et al., 2007).

Four distinct layers with different physical and chemical characteristics are produced due to the effects of density and redox-based stratification in the Black Sea.

• The surface mixed layer (SML) from 0 to 40 m is fully oxygenated and contains only trace nutrient concentrations, which is resultant from phytoplankton growth and export of biomass to deeper depths during decomposition and remineralisation (Codispoti et al., 1991).

• The cold intermediate layer (CIL), which falls between 40 and 80 m depths is characterised by a pronounced density gradient, which forms the lower boundary of seasonal surface water mixing and this permits accumulation of remineralised nutrients at its bottom depth range.

• The chemocline is located within the suboxic layer (SOL) and is a water mass spanning depths between 80 and 100 m in the deep basin (Murray, 1991). Pronounced chemical gradients in the SOL enhance denitrification and anammox, thus fundamentally affecting nitrogen cycling in the basin by way of converting combined N to gaseous N_2 and N_2O.

• Combined-N deficits become annoyed in anoxic waters, whereby PO_4^{3-} is released from minerals and organic phases outpace NH_4^+ release from the decomposition of organic matter (OM), ultimately leading to PO_4^{3-} accumulation and low N:P ratios in the anoxic layer (AOL), at depths beyond 100 m (Fulton et al., 2012).

Metrics for salinity, temperature, and density are extremely uniform in water at great depths from about 1700 m to the benthos and form a homogeneous bottom boundary layer (Murray et al., 2007).

2.2. Dissolved oxygen and H_2S

Due to strong vertical stratification in the Black Sea, the replenishment of deep water too slow to replace the oxygen consumed by microbial respiration during the breakdown of organic matter (Murray et al., 2007). Over time, organic matter has sunk and decomposed, and depths greater than 150–200 m in the Black Sea are permanently anoxic. Because dissolved oxygen is not sufficiently available, the degradation of organic matter uses bound oxygen in nitrates, and especially in sulphates. Consequently, this results in a hydrogen sulphide production. As a result, ~90% of the water mass of this area of the Black Sea is anoxic and is the largest volume of anoxic water in the world (Ragaini, 1999).

Deeper layers of the Black Sea are contaminated with hydrogen sulphide (H_2S), which is toxic and allows only the existence of only anaerobic bacteria (Ragaini, 1999). Between the oxygen-rich upper layer and hydrogen sulfide-rich bottom layers of the Black Sea exists a thin intermediate layer spanning 10-20 m where there is a coexistence of both gases. Some organisms can exist in this intermediate layer and survive by using the available oxygen within this layer. However, approximately 87% of the volume of the Black Sea volume lacks oxygen and is contaminated with hydrogen sulphide (Zaitsev, 2008). The suboxic zone is a region where oxygen levels decrease to near zero (O_2<10 μM) and where sulphide first begins to appear (H_2S > 10 μM). The suboxic zone varies in thickness interannually mostly due to climate-driven variability affecting its formation at depths that are fully depleted of oxygen (Konovalov & Murray, 2001; Murray et al., 2007; Oguz et al., 2006). Data collected across seasons and from varied regions of the Black Sea in the 1990s (Bastürk et al., 1994; Saydam et al., 1993; Tugrul et al., 1992) consistently demonstrated the presence of an oxygen-deficient zone (known as the suboxic layer (SOL) with less than 1O μM of oxygen. The upper and lower boundaries of the SOL corresponded to constant density surfaces of σ_t 15.6 and σ_t 16.2 kg/m^3, respectively, regardless of the circulation characteristics of the basin (Oguz, 2002). Sulphide begins to occur at about 90 m or a σ_t=16.15 whereupon sulphide then continuously increases to maximum values of approximately 380 μM upon what place depths of 2,200 m are reached (Murray et al., 2007). An isopycnal uniformity was a concept that originated when composite profiles of oxygen, sulphide, and nutrients were plotted against density by combining all the casts conducted during the 1988 Knorr surveys (Oguz, 2002).

2.3.Nutrients

Nutrients and light are essential for the growth of marine plants and phytoplankton constituting the base of the marine food chain. However, anthropogenic sources contribute significant additional sources of nutrients via river runoff impacted by agriculture, managed forests, point source pollution, direct inputs, including municipal discharge, industry, and fish farming, and atmospheric deposition originating from agriculture, combustion of fuels, and roadway traffic. Such anthropogenic sources have facilitated increased nutrient flux into the Black Sea and consequently spurred eutrophication.

River runoff contributes to the main source of nutrients in the Black Sea. The watershed of the Black Sea is known as a region of moderate to high productivity and receives an abundant supply of nutrients compared with other seas and oceans. As in many waterbodies, in the Black Sea plants are more abundant in areas with higher nutrient availability. Particularly, high levels of nutrients correspond to high abundances of plants in coastal shallow waters, and especially in the northwestern Black Sea (NWBS) where large rivers contribute significant inputs (Sur et al., 1996; Tuğrul et al., 2014; Zaitsev, 2008).

Different processes control the formation and dynamics of oxic and anoxic layers of the Black Sea. Oxic and anoxic subsystems respond to anthropogenic influences and climate related inputs independently (Konovalov et al., 2005). Under oxic conditions, oxidisation of organic matter occurs and the consumption of oxygen ultimately produces nitrate. Under suboxic and anoxic conditions consumption of nitrate and nitrite occurs during denitrification and anammox processes (anaerobic ammonium oxidation) thus producing dinitrogen gases. Organic matter undergoes bacterially mediated respiration under anoxic conditions, consequently generating ammonium and sulphide. Organic matter that reaches the benthos is also respire and generates fluxes of ammonium and sulphide from sediments and into the water. Thus, an insignificant proportion of initial organic matter becomes buried in sediments and hence is eliminated from further contributing productivity to the system.

In the Black Sea, the depletion of nitrate occurs at the surface due to biological uptake. Nitrate levels begin to increase at 40 m and reach maximum concentrations at 65 m (σ_t = 15.5). Post-oxygen decreases to zero, the nitrification of ammonium released from organic matter stops. Nitrate levels then decrease to zero at 75 m (σ_t = 15.95). Then, ammonium levels begin increase at the same depth (density) and progressively increase in deeper waters. The disappearance of NO_3 and NH_4 at the same depth is consistent with downward fluxes of NO_3 and upward fluxes of NH_4 consumed over a narrow depth interval by the anammox reaction ($NO_2^- + NH_4^+ = N_2 + 2H_2O$). Notably, anammox reactions reduce NO_2^-, but do not reduce NO_3^-. Thus, some levels of denitrification also occur that subsequently reduces NO_3 - to NO_2 -in order for anammox to occur (Figure 3) (Murray et al., 2007).

Maximum levels of nitrate are located at a depth where the vertical oxygen gradient decreases (lower portion of the oxycline). Depths where the onset of ammonia and dissolved manganese correspond to positioning of the most pronounced phosphate minimum in the Black Sea. These depths mirror depths where oxygen depletion occurs, whereas depths where the onset of hydrogen sulphide occurs are 5–10 m deeper (Yakushev, Pollehne, et al., 2007). Maintenance of redox-stratification is facilitated by relatively high productivity in surface waters, which supports aerobic and anaerobic respiration in relatively deeper waters (Fulton et al., 2012).

3. Types and sources of pollution

Marine biodiversity, ecological balance, and natural resources are greatly impacted throughout the Black Sea ecosystem. Enclosed seas have higher degrees of sensitivity to anthropogenic impacts compared to open oceans, in particular as they have a relatively long retention period for several pollutants including such as petrochemicals, heavy metals, PCBs, pesticides, and radioactive waste. The landlocked nature and the limited size of the Black Sea and it make its ecosystem particularly sensitive to pollution and its accumulation (Doussis, 2006).

The Black Sea's marine environment has deteriorated extensively during recent decades such that certain areas are considered some of the most polluted of any seas on earth. Such impacts have arisen mainly due to increased anthropogenic impacts, but also have resulted because of natural and hydrographical conditions specific to the unique ecological dynamics of the Black Sea (Doussis, 2006).

Industry in the Black Sea watershed is flourishing and includes water-consuming ferrous and non-ferrous metallurgy (Ukraine, Bulgaria, etc.), chemical and petrochemical production (Bulgaria, Romania, Ukraine, Hungary, Austria, etc.), the generation of electrical power, including some nuclear facilities (all countries in the watershed but highest effects are from Bulgaria, Romania, Ukraine, Russia, Hungary, and Austria), machine-based engineering (all countries) and food-related industry (all countries) (Borysova et al., 2005).

Land-based pollution is the main type affecting the Black Sea and mostly originates from the Danube and 160 million inhabitants in its watershed. Multiple intensive uses of the river (e.g., drinking water, agriculture, industry, navigation, fishing, tourism, discharge of untreated sewage, etc.) cumulative impact water quality and biodiversity in the Danube and in the area where the Danube flows into the Black Sea. The impacts are especially noticeable in the Danube delta, which is one of Europe's most extensive wetland areas, and creates a great risk to public health. Similar issues arise on smaller scales from drainage into the Black Sea originating from the Dnieper, Dniester, and Don rivers (Doussis, 2006).

The largest single source of chemical and biological pollution in the Black Sea is the Danube River. Other rivers that discharge into the Black Sea Basin, which course through the former Soviet Union territory has also been seriously contaminated with industrial and mining wastes. Besides contaminant discharge from rivers, many coastal-based industries discharge unknown quantities of pollutants directly into the Black Sea with little or no prior mitigation or treatment (Ragaini, 1999).

Discharges of impurities entering the Black Sea from coastal areas and indirectly via rivers (i.e., untreated sewage, pesticide and fertilizers, etc.) are relatively prolific. These effects have caused eutrophication and significant disruption to ecosystems and coastal wetlands of the Black Sea and degraded standards related to human health and disruptions to food webs. Moreover, many fishes and their populations have been depleted through intense commercial fishing. Namely, drastic declines of as much as 80 per cent in the total number of fish caught have been noted in the Black Sea. For example, only six of 26 species of fishes once commercially harvested from the Black Sea in the 1960s presently remain sufficiently abundant in quantities facilitating similar efforts (Doussis, 2006).

Agriculture in the drainage basin is a major contributor to nutrient pollution and to a lesser degree chemical pollution in the Black Sea. In areas where intensive agriculture is practiced inevitably it leads to nutrient and chemical runoff. For example, the Russian Federation's Ministry of Natural Resources found that substantial damage to the Azov Sea was caused by runoff from rice growing operations in the Slavyansk district of Krasnodar. The Kuban River discharges this runoff, which contains significant nutrient and pesticide loads into the Black Sea. Although regional fertiliser use has decreased recently, mineral-based fertiliser storage and application remain impactful to the Black Sea. Inappropriate storage, i.e., open air storage, and excessive application of fertilizers leads to leach into rivers and groundwater pollution effecting both ecosystems and human health (Borysova et al., 2005).

The Black Sea Basin has a well-developed transportation system. The Danube, Dnieper, Dniester, and Don Rivers has transport to and from the Black and Azov Seas involving "river-sea" type ships. Sea ships include ocean-going ships that act as dry cargo ships, and transportation tankers that move petroleum products. Transportation in the Black Sea and its rivers adversely impacts regional water quality during normal operations and poses serious risk from potential accidents such as oil spills and organismal transport in ballast. Motor-based transport prevails in the western portion of the Black Sea Basin, where there is a highly developed road network, whereas railway transportation is used more and better developed in the eastern portion (Ukraine, Russia and Georgia). The network of extensive transportation and intense mobility of regional goods and population negatively impacts water quality through such of oil products and spills on roadways and the lack of use of adequate technologies to treat industrial wastewater servicing the transportation network (Borysova et al., 2005). Accidents and illegal discharges from ship-based pollution and spills constitute additional significant threats to water quality in the Black Sea and its tributaries. Ship derived pollution is expected to increase because the oil and gas production from the Caspian Sea is expected to increase significantly in coming years. Moreover, seabed and subsoil exploration and exploitation, such as offshore oil and gas exploration and exploitation, dumping, and air pollution (as exemplified in the Azov Sea) constitute significant inputs of pollution. Environmental assessments and reports have indicated that until the 1960s the Black Sea was a relatively 'clean' marine area with high measures of biodiversity and abundant fishing reserves. In contrast, from the 1970s increased industrial intensity, the introduction and establishment of non-native species via numerous vectors including aquaculture, ship ballast, illegal intentional releases, and factors such as uncontrolled discharge of untreated sewage, overharvesting of fishes, and transboundary pollution, along with the absence of adequate localized and regional preventive measures all have had severe impacts on the Black Sea's ecosystem (Doussis, 2006).

In 1995, the European Environmental Agency assessed occurrences and the relative importance of the most common problems among European Seas, including for the Mediterranean, Black, Caspian, White, Barents, Norwegian, Baltic, North Seas, and the North Atlantic Ocean. Of these, the Black Sea had the overall highest measures of negative impacts for five of seven categories including in relation to:

- Overexploited resources - highest concern
- Inadequate watershed management - highest concern
- Pollution in coastal zones- highest concern

- Eutrophication - highest concern
- Introduction and establishment of non-native species - highest concern
- Offshore activities - small or localised problem
- Coastal zone use conflicts- small, localised problem (Ragaini, 1999).

Over recent decades, water quality of the river runoff has substantially changed with increased inputs of controlled and highly impactful substances of both natural and articial origin (i.e., phenols, detergents, pesticides, and other xenobiotics). The latter do not naturally exist but have been increasingly produced by humans to fulfil certain needs. Such substances have induced vast changes in the ecosystem of the Black Sea, which is now sometimes designated (however, not fully objectively) as one of the most polluted seas globally. The entirety of the Black Sea has been impacted by anthropogenic influences but the northwestern portion and its contour (marginal) communities have been most effected (Zaitsev, 2008).

Research has recently revealed that interannual and interdecadal factors have influenced the inputs from major rivers and mainly affected the north-west region and its redox layer, such that phosphate and nitrate inputs, especially from the Danube, have decreased over the last 20 years (Yakushev, Arkhipkin, et al., 2007).

3.1. Eutrophication

Eutrophication is a complex process mainly caused by large nutrient inputs to both fresh and marine water. The main effect of eutrophication is food web imbalance that induces high levels of the biomass of phytoplankton in stratified aquatic ecosystems. Nutrient enrichment in water can occur naturally, but it is often dramatically increased by anthropogenic activity. Human induced eutrophication occurs almost everywhere in the world. There are three main sources of anthropogenic nutrient input: runoff, erosion, and from leaching originating from fertilised agricultural areas, sewage from cities and industrial wastewater. Atmospheric deposition of nitrogen (from animal breeding and combustion gases and coals) can also be important with respect to the dynamics of eutrophication (Borysova et al., 2005).

Anthropogenic induced eutrophication is becoming a major concern for many natural and human-made hypoxic and anoxic systems

(Özsoy & Ünlüata, 1997). The Black Sea is one of the marine ecosystems most affected by eutrophication globally (Borysova et al., 2005). Many significant ecological issues in the Black Sea result from the huge influx of nutrients and pollutants coupled with poor turnover and mixing in relatively deep waters (Ragaini, 1999). Some of the first noted and considerable changes in the Black Sea ecosystem were associated with articial or cultural eutrophication and characterised in the NWBS area in the late 1960s and early 1970s (Zaitsev, 2006). The main anthropogenic forces driving increased discharges of N and P to the Black Sea result from: (1) agriculture; (2) waste-water management (treatment of sewage and wastewater); and (3) combustion process-based air pollution (traffic, energy conversion, etc.) with NOx (Kroiss et al., 2006).

Globally, the use of nitrogen and phosphorus-based fertilisers has greatly increased over the last several decades. A drastic increase in fertilizer use occured in the 1960s, 1970s, and 1980s, after those levels of use of these fertilisers stabilized after 1990s (Zaitsev, 2006). For example, from 1950 through 2000, the use of mineral nitrogen in agricultural fertilizers has increased tenfold in the 15 EU member states, i.e., from only 1 to 9-10 million tonnes. The Transboundary Diagnostic Analysis (1995) indicated that annual nutrient inputs from human activity amounts to 647,000 tonnes of nitrogen, and 50,500 tonnes of phosphorus (Black Sea Pollution Assessment, 1998). The estimates also included river-based discharges (Borysova et al., 2005). Atmospheric deposition contributes only minor levels of nitrogen and phosphorous, 19%, and 8% of overall totals, respectively, where agriculture and domestic wastewater contributed the largest percentages.

Nutrient loading into the Black Sea has increased two- to three-fold increases with respect nitrates, and seven-fold with respect to phosphates from the period spanning 1970-1991 (Ragaini, 1999). The Black Sea is a sensitive ecosystem because of its extensive watershed, which receives massive nutrient loads from three countless and highly polluted rivers, namely, the Danube, Dnieper, and Dniester. For the Danube River annual loading of nitrate and phosphate into the Black Sea were respectively 2.5 and 4 times higher in the 1980s than were the levels in the 1950s. Similar trends have been reported for the Dnieper and Dniester rivers (Teodoru et al., 2007). The bathymetry of the northwestern Black Sea is largely below one hundred meters depth and has consistently received relative high inputs of nutrients from the Danube and Dnieper Rivers, which are Europe’s second and the third largest rivers (Borysova et al., 2005; Zaitsev, 2006). The 1970s and 1980s were some of the first periods during which the influx of river-borne nutrients into the NWBS considerably increased and became concerned for local residents, researchers, and management agencies (Tuğrul et al., 2014).

Of the major rivers flowing into the Black Sea, the Danube contributes the largest nutrient loads equaling about 60,000 tonnes of total phosphorus/year (66% of the total river-based inputs). Inorganic nitrogen contributed from Danube River discharge equals about 340,000 tons/year (53% of the total originating from river inputs), which is more than twice the amount contributed by the Rhine. Additionally, some settlements along coastal areas of Romania, Russia, and Turkey contribute high nutrient inflows as well as discharge their sewage and industrial waste directly to the Black Sea. While nutrient loads may be reduced in the future through mitigation, sediment-bound nutrients will be slowly released, and thus the dynamics of reducing eutrophication over time are complicated. Consequently, the major portion of the Black Sea, particularly, its northwestern (NW) shelf has become highly and consistently eutrophic (Ragaini, 1999).

The dam construction for irrigation and power generation on major rivers flowing into the Black Sea has resulted in substantial net decreases in the runoff to the NWBS and Sea of Azov. The consequential reduced freshwater and sediment inflows into these areas has resulted in coastal erosion and changes in salinity. Potential alterations in exchanges through the Bosphorus and thus has likely caused negative consequences for the Black Sea and even for the relatively distant Eastern Mediterranean (Ragaini, 1999).

Consequential to the 1989 economic breakdown in Eastern Europe, there were dramatic changes in agricultural practices (e.g., fertilizer application, management of manure), detergent uses, and industrial activity, including within the Black Sea watershed. The discharged N-load into the Black Sea (especially for dissolved species of nitrogen) is strongly influenced by the discharges of water from the Danube River, which can vary broadly (i.e, annually less than140 km^3 to almost 300 km^3, annual average 206 km^3) (Kroiss et al., 2006). Phosphorus loading from the Danube is however, 30%–50% lower than levels were in the 1980s, and dissolved P has been reduced to an even greater extent). Likewise to phosphorous, emissions of nitrogen have decreased considerably. Reduced discharges of nutrients from the Danube have facilitated significant improvements in the WBS ecosystem. Current low levels of N and P discharge to the WBS have resulted due to (1) improved removal of nutrients from wastewater in areas of the watershed in Germany, Austria, and the Czech Republic, (2) reduced discharges of P due to better designed and better managed discharges of detergents and (3) because of the consequences of the economic crisis in central and eastern European countries, which followed the political changes during 1989-1990 (Kroiss et al., 2006). Today, total loads of nutrient levels in the Danube River basin are significantly higher than they were in the 1960s, but are lower than in them were in the late 1980s.

Changes in phytoplankton communities, biodiversity, and species abundance and biomass directly relate to the dynamics of the composition and concentration of nutrient supplies. Typically, the most favoured species in eutrophic conditions are relatively small-sized planktonic algae such as dinoflagellates, coccolithophores, euglenoids, and other relatively small but productive species (Zaitsev, 2006). Concerning decreases have been noted in the total biomass and diversity of fish stocks, and many organisms have been extirpated from the Black Sea or localised regions. Furthermore, aspects of the food web have been impacted by opportunistic invasive and non-native species intentionally or unintentionally imported from beyond the Black Sea and its watershed (Zaitsev & Mamaev, 1997).

During periods of eutrophication, macroalgae, phytoplankton (diatoms, dinoflagellates, chlorophytes), and cyanobacteria that are depend upon nutrients, light, temperature, and water movement, experience excessive growth and proliferation. Where eutrophication occurs, fish and shellfish populations are the first species at higher trophic levels to exhibit consequential responses to changes in the lower food web (Borysova et al., 2005). Recent collapses of the Black Sea's fisheries have been closely linked with the above processes and likely have acted synergistically with increased fishing pressure (Özsoy & Ünlüata, 1997).

3.2.Metals

In the past, the primary contributors of direct and indirect metal-related pollution in the Danube basin were industry and mining-based discharges of hazardous materials. Industry and mining in the basin contribute heavy metals (extraction and processing, chemical industry), hazardous organic micro-pollutants (industrial organic chemicals, pharmaceuticals), petroleum products, and solvents (oil refineries).

In 2004 arsenic, cadmium, chromium, copper, mercury, nickel, lead, and zinc loading increased compared to 2001 and the amount of direct discharge reached 138 (t/a) for lead and 171 (t/a) for zinc. Furthermore, the levels of cadmium and lead were the most common of all heavy metals to have exceeded target values in many locales of the Lower Danube (International Commission for the Protection of the Danube River, 2005).

Typically, heavy metal and radionuclide concentrations are highly variable and are higher in coastal waters and lower in open seas. On average, heavy metal concentrations are usually close to normal acceptable levels on open seas. However, elevated levels of heavy metals occur in “hot spots” of the watershed of the Danube River and its delta (Ragaini, 1999). According to Mee (1992), the Danube basin annually discharges 1,000 tonnes of chromium, 900 tonnes of copper, 60 tonnes of mercury, 6,000 tonnes of zinc, 280 tonnes of cadmium, and 4,500 tonnes of lead (Mee, 1992).

Cadmium and lead are the most impactful inorganic microcontaminants in the Danube River Basin. The target values of these metals are exceeded in minor ways at several locations in the middle Danube and exceeded in a more serious manner through most of the lower Danube. There is a lack of sufficient and reliable data for mercury across the entirety of the Danube basin. High concentrations of metals are present in the main stem of the Danube and in its tributaries the flow into the Danube in its upper and middle sections. Mercury has been noted as the only heavy metal for which target limits were exceeded in the upper Danube section. Concentrations of copper, which is naturally abundant in the environment, have increased significantly in downstream portions of the Danube. The Danube River and its major tributaries are also polluted by nickel, zinc, and arsenic, which are typically at low levels excepting elevated concentrations in the lower section (International Commission for the Protection of the Danube River, 2005). The estimated annual loads of pollutants (in 1,000’s of tonnes) into the Black Sea basin were 0.082 for mercury, 12 for zinc, 1.5 for chromium, and 4.5 for lead (Ragaini, 1999).

The Black Sea Environmental Programme (BSEP) studies since the Chernobyl accident have indicated that the concentrations of variously compartmentalized artificial radionuclides has increased in the Black Sea. Since Chernobyl Cs-137 has doubled, and Sr-90 has increased by 20%. Mean concentrations of Cs-137 in the top 200 m layer of the Black Sea have been recently noted as 30 BQ/m^3, which equals a factor of 3-increase to measures before the accident. It has also been found that some radionuclide concentrations are ten times higher in the Black Sea than they are in the Mediterranean. However, levels of radiation in fishes (mainly from

Cs-137, Cs-134, and Sr-90) have been reported as within acceptable levels for human consumption. Relatively speaking though, little information has been gathered on alpha-emitting radionuclides, and more complete dose assessments are needed (Ragaini, 1999). Many studies have independently concluded that heavy metal levels in Black Sea biota are below those deemed to pose human health risks ((Alkan et al., 2016; Baltas et al., 2017; Bat et al., 2014; Karsli, 2021; Makedonski et al., 2017).

3.3.Oil and derivatives

The Black Sea is critical for shipping and fishing industries for its maritime routes. During the last decade, shipping and marine-oriented activity has increased in the maritime areas of the Black Sea, mainly due to the increasing demand for oil and gas and corresponding transport through pipelines and by tankers from the Caspian Sea to Western markets. Flows of oil and gas from the Caspian Sea are expected to increase significantly in the near future because the Black and Aegean Seas are considered as the most secure means of transportation of such goods. Thus, shipping-related pollution (e.g., incidental waste, oil spills, deballasting, waste dumping), is expected to increase in the Black Sea (Doussis, 2006).

Among polluting substances, oil and oil products are widespread and relatively dangerous components for the Black Sea. Oil spills and pollution from oil production and transport impacts marine living organisms, can break a natural hydrological cycle and, consequently, cause anthropogenic climate changes. When vast areas of ocean surfaces experience oil pollution and oil products in a considerable quantity, there are reductions of evaporation and simultaneously decreased salt fluxes to the atmosphere because of decreased effects of wind, waves, and splashes (Kordzadze & Demetrashvili, 2018).

Crude oil is a mixture of different fractions with main components including hydrocarbons (80- 90%). In marine environments, oil and oil products often pollute ecosystems as surface-based oil films, dissolved and emulsified petroleum products, and in other forms of oil aggregates. Significant concentrations of oil products in estuarine areas of large river mouths dumping into the Black Sea including for the Danube, Dnieper, and Dniester, as well as in major port-cities have been noted (Kordzadze & Demetrashvili, 2018).

In the 1970-1980s, researchers at the Novorossiysk Bay Biological Station found that oil-based pollutants caused significant changes in seaweed and animal species distributions. Further, once abundant macrophytes Zostera and Cystoseira, which previously developed rapidly in the shallow parts of the sea, retreated to a depth of 3 m. Mussel species, which were widely distributed in the middle of the bay pre-pollution impacts, now live only in open and deep areas of the Black Sea where pollution is reduced (Kordzadze & Demetrashvili, 2018).

The main sources of oil pollution in the Black Sea are river runoff, direct discharges of domestic and industrial wastewaters, atmospheric deposition, sea port operations, unintentional inflows and unregulated spills from oil ships. At present the Black and Azov Seas are the marine regions experiencing the largest impacts from anthropogenic pressures of all those in Europe. However, the Black Sea also plays a critical role as corridor for oil transportation from the East to the West and in the coming years use and production-related intensities are expected to increase. Thus, even greater impacts at the ecosystem level in the Black Sea could result in a result of ongoing, increased and potentially unintended catastrophic pollution events related to oil products (Kordzadze & Demetrashvili, 2018).

Annual oil emissions into the Black Sea for 2003 were estimated to be 110,000 tonnes. Particularly, large anthropogenic loads of oil-based pollutants have been noted in the shallow north-western Black Sea with most negative inputs in this having been contributed by the Danube River. In one of the documents prepared by the Parliamentary Assembly of the Council of Europe, only the Danube annual input greater than 50,000 tonnes of oil products into the Black Sea, whereas levels in other major rivers had notably lower contributions (Kordzadze & Demetrashvili, 2018).

Over the past 50 years in the Black Sea and especially in the Bosphorus Strait, and the Kerch Strait many oil spills have occurred. In October 1977 in the Bosphorus Strait because of damage to a Soviet tanker 20,000 tonnes of oil spilt into the Black Sea. In November 1979, Romanian and Greek tankers collided, and 64,000 tonnes of oil-based pollutants spilt into the Black Sea. The largest oil spill in the Black Sea that has occurred in the last 20 years (13 March 1994) occurred when the tanker Nassia and its shipbroker cargo vessel collided in the Bosphorus Strait. The shipbroker was completely burnt and most of Nassia’s cargo was spills over into the Black Sea with 20,000 tonnes of burnt oil. The Nassia spill caused severe marine and air pollution on the Bosphorus, and in the Black and Marmara Seas (Kordzadze & Demetrashvili, 2018).

In the Marmara Sea there have been nearly 450 differently scaled accidents reported over the last four decades. Over the last two decades, several accidents involving ships from the coasts of Bulgaria, Romania, Russia and Ukraine, have occurred. However, most ship-based accidents have only resulted in relatively small-scale oil spills or other relatively minor kinds of pollution affecting Black Sea biota and ecosystems only small scales or across short durations (Kordzadze & Demetrashvili, 2018).

Significant oil pollution is caused by tankers when they illegally clean their tanks while out at sea and when they dump dirtied water overboard. Approximately 72% of oil pollution caused by shipping is estimated to be deliberate and illegal, whereas only 28% is caused by tanker accidents. Obviously, a need for better organised environmental conservation related monitoring in the Black Sea and its watershed and stricter regulations and enforcement of owners of ships illegally cleaning their tanks at sea are required to limit related impacts. As more 100,000 tonnes of oil is dumped in the Black Sea by ships annually even if regulation only resulted in some declines in these loads, they could be substantial enough to greatly benefit the ecosystem (Biliavskiy & Golod, 2012).

Apart from navigation, commercial fishing, and oil and gas exploration amongst traditional uses of the Black Sea, tourism has also emerged as a major economic activity. Seasonal-based population increases (estimated 40 million tourists per year) in the already overpopulated coastal areas (10.6 million resident population), along with the lack of planning in urban and industrial areas of coastal cities, intensified agriculture, and overfishing has produced anthropogenic pressure on the ecosystem and species in the Black Sea that is thought to be levels never before recorded in human history (Doussis, 2006).

Vessels play an important role in contributing to levels of oil-based pollution in the Danube River by evacuating water wastes such as used oil, bilge oil, bilge water, oil-contaminated wash water, and fuel residues. Oil storage and transport in old tanks may produce accidental spills, that have been more frequently encountered in the Black Sea than is desirable. For example, in 2007, five pollution incidents occurred in the Romanian sector of the Danube, including from unidentified sources and bilge water, industrial operator negligence, and old technology. However, these spills and their respective vectors have low relative potential to induce severe pollution (International Commission for the Protection of the Danube River, 2005).

Oil-based pollution often contains a wide spectrum chemical component. Some components are toxic to aquatic microfauna and microflora and pose substantial threats to riverine ecosystems of Black Sea tributaries because once introduced into biological materials, substances may concentrate through the food chain (Gasparotti, 2010).

3.4.Pesticides

The Black Sea watershed experiences intensive agricultural activities, which contribute to pesticide-based pollutants. Although diffuse discharges from agriculture are important sources of nutrients, they also can input micro-pollutants. For example, approximately 300-500 different agent-based pesticides have been used in the Black Sea basin (International Commission for the Protection of the Danube River, 2005).

In the Black Sea, current assessments of organic micropollutants currently are lacking due to the unavailability of data (especially from the lower section), because high detection limits have failed to match with the environmental quality standards, and because of a high uncertainty and error in analytical results. All these factors must be accounted for when devising measures of existing and potential risk (International Commission for the Protection of the Danube River, 2005).

Two monitored persistent pesticides p, p'-DDT and Lindane occur in similarly relatively small amounts in the upper and middle sections of the Danube and elevated concentrations in the lower section are noted. However, relatively low target values for p, p'-DDT is often exceeded, which makes this substance a critical issue for ecosystem-based management approaches for the lower Danube and respective tributaries. Namely, the non-compliance factor in these areas reaches the order of two magnitudes. Thus, although there is a high level of uncertainty, the levels of pollution by p, p'-DDT is significant. From a community perspective, there is potential risk through the failure to achieve a good status considering the one-out all-out rule. An important fact is that p, p'-DDT is a pesticide banned in Europe and it is likely that the contamination stems from the past loads. However, a report from the Inventory of Agricultural Pesticide Use on uncontrolled and illegal trade of pesticide products identified widespread uses of banned pesticides (e.g. DDT) by farmers. Thus, such potential pollution sources should be thoroughly investigated (International Commission for the Protection of the Danube River, 2005).

4. Factors affecting food web

Approximately 160 species of fish of make up the ichthyofauna of the Black and Azov Seas. Black Sea ichthyofauna and other invertebrate species consist of marine fish species originating from the Mediterranean Sea (about 60%). Ichthyofauna also includes freshwater fish (more than 20%) and pontocaspian relicts (about 16 species). Because of its size, complex habitats, and dynamic ecology, is difficult to estimate the total number of aquatic and semi-aquatic species in the Black Sea, however, according to Zaitsev & Mamaev (1997), a total of 3,774 species has been identified (Borysova et al., 2005).

Until the mid-1970s, the Northern Black Sea has been noted as potentially having the most important spawning areas for all commercially harvested fishes, including for demersal species, planktivores, and predators that undergo migrations from the Mediterranean to spawn or feed (Shiganova, 2000).

The anchovy (*Engraulis encrasicholus ponticus*) is a pelagic Black Sea fish that belongs to a group of thermophilic species, starts spawning after the water temperatures have warmed to at least 17°C and, that in autumn, migrates for over-wintering into Caucasian and Asia Minor coastal waters (Zaitsev, 2008). Like most schooling-fish that occur at high densities, the anchovy is feeding fish for which migrations are orientated towards the coastal zone because these areas are richer in food for young of year and adults than ate comparatively deeper-water shelf and open sea zones. Such food-seeking behaviours are characteristic of not only benthic but also of pelagic species such as anchovy and horse-mackerel (Zaitsev, 2008).

Since the 1970s there has been an overall decrease in freshwater discharges into the Black Sea with corresponding reductions in the extent of fish migrations. Heavy fishing by all Black Sea coastal countries during the 1970-1980 contributed stock declines for all of these valuable species. Reduced pressure caused by predators resulted into the entire pelagic fish communities of the Black Sea to change to those dominated by small pelagic fish including anchovy, Black Sea horse mackerel, and sprat (Caddy & Griffiths, 1990). The decrease in Don and Kuban discharges in the 1970s caused an increased salinity in the Sea of Azov (Shiganova, 2000).

Anthropogenic activities have dramatically impacted the Black Sea ecosystem during recent decades. Eutrophication worsened due to increased nutrient levels at the end of the 1960s significant structural changes occurred in planktonic and benthic community compositions. Changes began in phytoplankton and indirectly in zooplankton communities. Consequently, there was a decrease in the abundance of key species for other species (Zaitsev & Mamaev, 1997).

In the early 1970s, phytoplankton blooms began to appear, then detritivorous and herbivorous zooplankton species became dominant. The abundances and diversity of fishes in the Black Sea then began to decline. Fish eggs and larvae consisted of predominantly plantivorous species, such as anchovy and horse mackerel in summer and sprat and whiting in winter. The eggs and larvae belonging to more valuable fishes such as *S. sarda*, *P. saltatrix*, and *P. flesus*, *P. maxima*, and *S. lascaris* were predominantly in the south and a small amount in the northwest. However, these taxa were extirpated in the northeast section of the Black Sea in the 1980s. Between 1970 and 1990, the dinoflagellate *Noctiluca miliaris* accounted for nearly 99% of the population.

In the early 1980s, with the triggering of eutrophication, an increase was observed in the biome of jellyfish *Aurelia aurita*, one of the invasive species. The zooplankton levels, which increased up to 5 times in the 1980s compared to the previous periods, started to decrease with the introduction of Aurelia. Also during these periods, ctenophore, Sea walnut, was seen in the Black Sea. In 1988, Sea walnut covered the entire Black Sea and peaked in the fall of 1989. Major changes began to be observed in the plankton community due to Sea walnut. Since zooplankton is the main food, a sharp decrease in its biomass has been observed. With the increase of Sea walnut, even anchovy egg larvae decreased. The amount of Sea walnut then showed variations annually. Sea walnut outcompeted small fishes, while also preying on their larvae and eggs, further altering pelagic food web structure and function (Shiganova, 2000). Sea walnut lacked natural predators until another gelatinous species, *Beroe ovata*, was introduced in 1997, which significantly decreased Sea walnut biomass (Kideys, 2002).

Anchovy eggs and larvae gradually increased from the early 1990s until 1992. When Sea walnut decreased in the period 1992-1993, zooplankton started to increase again. A significant increase was observed in Sea walnut in 1994-1995. It started to decline again in 1996-1997 due to the temperature and food. *Calanus euxinus* in particular increased significantly in 1996. There was an increase in anchovy eggs and larvae. After 1996, eggs belonging to the species that were destroyed in the previous periods (1992-1995) started to be seen again in the Northeastern Black Sea. Detected for the first time in the Black Sea in 1997, the ctenophore *B. ovata* spread to whole the Black Sea in 1999. Sea walnut has been greatly reduced as Beroe was a predator for Sea walnut. As a result, the rate of zooplankton started to increase again. There was a negative correlation between the abundance of ichthyoplankton and the abundance of Sea walnut (Shiganova, 2000).

As a result, Aurelia and Sea walnut have had important effects on the feeding of fish larvae. In the first years of Sea walnut blooms, the percentage of larvae that could not be fed increased and reached high rates. The larvae had to feed on larger organisms that were unsuitable for them and could lead to death due to the lack of small copepods in the environment. With the introduction of Beroe to the Black Sea, ichthyoplankton increased compared to previous years and anchovy became the most abundant species.

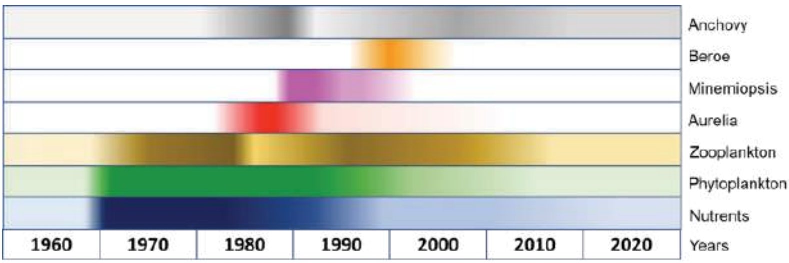

Figure 5. Schematic of connections among nutrients, plankton, invasive species, and anchovies of the Black Sea

Danube River rehabilitation efforts and the economic collapse of the surrounding socialist republics in the early 1990s resulted in decreased nutrient loading whereupon the Black Sea ecosystem. However, rapidly changing economic and political conditions makes potential future recovery uncertain (Langmead et al., 2009).

Intense fishing pressure has also induced stock depletion of several apex predators. Such an effect has contributed to increased planktivorous fish abundances and sea-wide biomass levels such that these fishes are now the focus of fishing efforts. Planktivorous pelagic fish stock abundances such as for sprat (*Sprattus sprattus* and *Clupeonella cultriventris*) and anchovy (*Engraulis encrasicolus*) have increased since the early 1990s and are now the focus of fishing efforts in the Black Sea (Daskalov, 2002). Demersal fisheries have also been increasingly targeted as the because of low levels of abundances of mullet (Muglidae), whiting (*Merlangius merlangus*), and turbot (*Scophthalmus maximus*) to the invasive sea snail

(Langmead et al., 2009).

5.Conclusion

The Black Sea is a unique basin with interesting hydrological and ecological features, an enclosed nature, a relatively large catchment, and relatively low taxonomic diversity. These and other factors contribute to a high level of sensitivity to ecosystems of the Black Sea to human induced disturbance (Langmead et al., 2009).

The Black Sea ecosystem is not only valuable and diverse, but also vulnerable due to ongoing, dynamic, and increasing anthropogenic pressures (Borysova et al., 2005). From the 1970s and into the 1990s, dramatic changes occurred in the Black Sea ecosystem, especially because of eutrophication triggered by the high amount of nutrient inflow from the Danube River. Eutrophication in the Black Sea Basin and associated challenges in managing this condition persist because of a lack of knowledge and information, insufficient management techniques, low economic incentives, and the difficulties faced when tackling long-term environmental problems (Borysova et al., 2005). Increased heavy anthropogenic impacts have brought about significant changes in phyto and zoo plankton species and abundance in the Black Sea. Such changes in the foundations and first steps of the food web have caused significant changes in food web dynamics in the Black Sea. Moreover, invasive species, especially since the mid-1980s invasive species have played significant roles in the environmental change in the Black Sea and its fisheries.

Anchovy, the major commercial species of the Black Sea fisheries has experienced significant impacts from anthropogenic environmental impacts as its food (zooplankton), its eggs, and larvae are consumed by a now abundant and widespread invasive species - Sea walnut. As a result, in 1989-1990, the collapse of the anchovy fishery in the Black Sea occurred. Although anchovy stocks have since been freed from the effect of invasive species, today the abundance and biomass of Black Sea anchovy have dropped to around 150-200 thousand tonnes due to factors such as overfishing, global warming and pollution. These levels of catches are similar to catch levels between 1970 and 1980.

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FACTORS AFFECTING ANCHOVY STOCKS IN THE BLACK SEA: THE INVISIBLE MICROPLASTIC THREAT

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ÖZET

Son yarım yüzyılda Karadeniz ekosisteminin fiziksel, biyolojik ve kimyasal özelliklerinde kirlilik, habitat bozulması, istilacı türlerin girişi, aşırı avlanma ve iklim dalgalanmaları nedeniyle çarpıcı değişiklikler gözlenmiştir. Karadeniz'deki hamsi stokları da besin zincirinin diğer katılımcıları gibi değişen aradeniz ekosisteminde dramatic dalgalanmalar sergilemiştir. 1980'lerden sonra hamsi stoklarının azalmasında bu faktörlerden hangisinin daha güçlü rol oynadığı sorusu belirsizliğini korumakla beraber, doğal iklim değişikliği dışındaki tüm bu faktörlerin insan faaliyetleriyle yakından ilişkili olduğu iyi bilinmektedir. Son zamanlarda hızla büyüyen bir çevresel tehdit olan plastik kirliliği, 22 ülkenin drenaj alanını oluşturması dolayısyla kirliliğe karşı savunmasız olan Karadeniz ekosisteminde hızla büyen bir çevresel tehdit haline gelmiştir. Yakın zamanda yapılan çalışmalar ile Karadeniz'de hamsi ve hamsinin ana besinini oluşturan mikroskobik canlılarda mikroplastik tüketimi tespit edilmiş olması Karadeniz için kritik bir tür olan hamsi ve insan sağlığı bakımından endişe sebebidir. Önümüzdeki yıllarda artması beklenen plastik üretimi, bu kalıcı ve toksik malzemenin deniz ortamında birikmeye devam edeceği ve deniz yaşamını, insan sağlığını ve ekonomiyi olumsuz yönde etkileyeceği düşünülmektedir. Karadeniz'e giren plastik girdileri azaltmak için koordineli uluslararası ölçümlerin formüle edilmesine ve Karadeniz'deki plastiğin kaynakları, dağılımı ve etkilerine ilişkin düzenli bilimsel değerlendirmelere acilen ihtiyaç duyulmaktadır.

INTRODUCTION

The Black Sea is a special marine environment. It is characterized by a strong stratification with less saline waters in the upper 100 m and more saline waters from the Mediterranean Sea in deeper waters. As a result of the strong density stratification, the Black Sea evolved towards an oxygenated upper layer overlying an anoxic deep layer and is the largest anoxic basin the world. The continental shelf is particularly narrow, except in north-western part of Black Sea. The large-scale circulation is characterized by a permanent meandering cyclonic circulation around the basin, called the rim current. In summer, waters are thermally stratified and in winter the upper layers are vertically mixed by strong winds and lower air temperatures.

Figure 1. Drainage area of the Black Sea (Jelev and Jelev, 2012)

The Black Sea is surrounded by 6 industrialized countries; namely Bulgaria, Romania, Ukraine, Russia, Georgia and Turkey. Furthermore, the basin is characterized by a high river discharge from several countries (Figure 1). More than 171 million people, in 21 countries, live in the drainage basin of the Black Sea. For these reasons, the Black Sea has been highly vulnerable to anthropogenic pressures and is one of the most severely degraded and exploited ecosystems in the world (BSC, 2007).

During last decades the Black Sea as undergone dramatic changes in physical, biological and chemical properties, due to pollution, habitat degradation, non-indigenous species invasions, overfishing and climate fluctuations. Structural changes in the food web were observed. At the lower trophic levels, changes within phytoplankton communities, frequency and magnitude of phytoplankton blooms, and phytoplankton biomass have been reported (Daskalov, 2002; Kideys, 2002; Nesterova et al., 2008; Oguz and Gilbert, 2007; Oguz et al., 2012). Regarding zooplankton, pronounce changes on species composition, abundance and biomass of zooplankton have also been documented (BSC, 2007). At the upper trophic levels, there has been a depletion of large predatory fish stocks and anchovy is acting as the main top predator species.

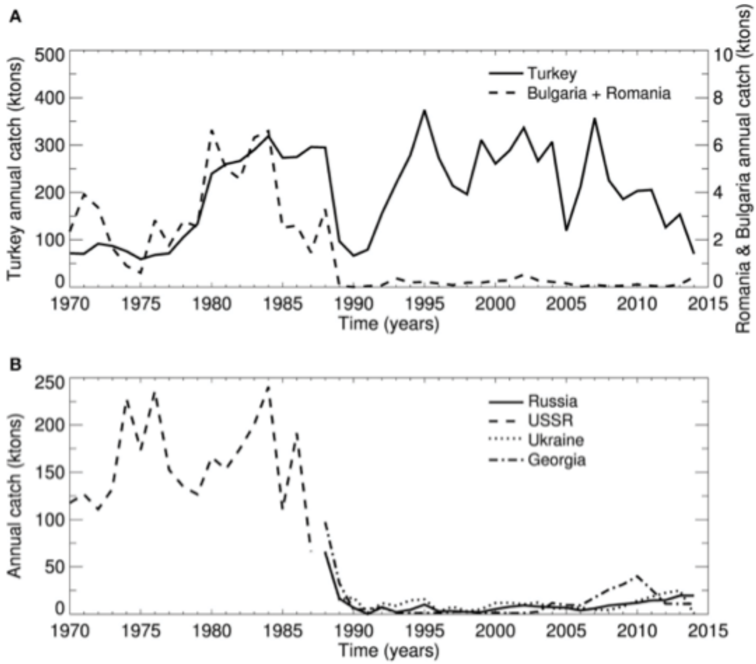

Figure 2. Total anchovy landings of Black Sea countries (Guraslan et al. 2017).

Black Sea anchovy is the most abundant pelagic fish that distributes throughout the Black Sea. This species has also commercial importance comprising the main fishing resource for all the Black Sea countries. Anchovy made up 50% of the total fish landings in Turkey (TUIK, 2019). They are used for human consumption, aquaculture feed, industrial oil and health supplements (Barange et al. 2014). The Black Sea anchovy landings fluctuated in last century (Figure 2) and multiple stressors may have cumulatively contributed for these changes (Guraslan et al., 2017). Below is provided a discussion on the possible factors affecting Black Sea anchovy stocks, namely climate variability, eutrophication, invasive species, overfishing, and a final emphasis on the microplastic pollution.

Climatic fluctuations

Long-term observations of sea surface temperature (SST) show a long-term centennial warming trend, as well as several decadal changes with alternative colder and warmer periods. In more recent decades, there has been a cold phase (1980-1990s) followed by a recent warming phase. Studies show relationships between regional climatic variations such as those influenced by the North Atlantic Oscillation (NAO) and anchovy stock fluctuations in the Black Sea (Niermann et al., 1999; Oguz et al., 2006; Oguz and Gilbert, 2007). Each fish species has a specific range of temperature, chemical and other physical tolerances. Any changes in the physical environment because of climate, can directly impact species physiology and fish behaviours such as spawning and migration. In the study where connection of climate variability with anchovy spawning and recruitment in the Black Sea were investigated, temperature was found to be the dominant factor influencing early life stages thus population dynamics of anchovy (Guraslan et al., 2014). Influences of climate on anchovy may also be indirect, through changes in circulation and vertical mixing regimes. In the interior of the basin, long-term time series of phytoplankton biomass suggest decadal changes following closely variations in temperature, with higher (lower) biomass occurring during cold (warm) years (Nesterova et al., 2008; Oguz et al., 2006). Previous reports of higher (lower) biomass occurring during cold (warm) years, could indirectly influence anchovy by altering their food supply. Other climate fluctuations could affect the lower trophic levels, from which anchovy stocks rely on food. Changes in nutrient enrichment from the rivers could alter phytoplankton productivity. Recent studies also indicate that the rim current is a major source of nutrients to upper layers through the frontogenesis mechanism (Oguz , 2017). Climate-driven changes in the rim current could then impact plankton production and consequently anchovy stocks.

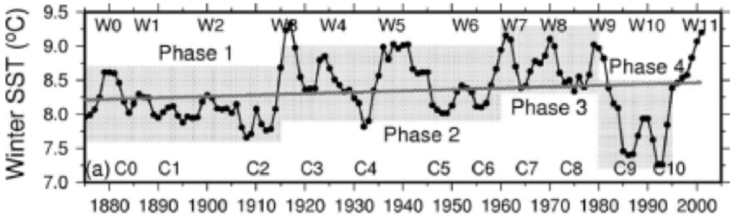

Figure 3. Long term variations of the winter mean sea surface temperature averaged over the interior basin with depths greater than 1500 m (Oguz et al. 2006).

Eutrophication and invasive species

Eutrophication is an excessive input of nutrients into the aquatic environment that leads to increase in the growth and production of algae, triggering chain reactions in ecosystems. In the 1970s, excessive nutrients input by large rivers (e.g. Danube) into the northwestern shelf of Black Sea led to marked changes in the ecosystem structure and functioning. Drastic changes in the composition of phytoplankton and zooplankton were observed in the northwestern-shelf, which was a spawning and nursery grounds of anchovy. A shift was observed on phytoplankton species composition and there was an increased in frequency, magnitude and duration of phytoplankton blooms (BSC, 2007). In this period, some zooplankton species almost disappeared while other opportunistic gelatinous species increase their abundance and the system shifted towards a gelatinous plankton dominated regime (Oguz, 2017). Following this period, in late 1980s, a second shift in the ecosystem was observed by an outburst of the non-indigenous carnivorous species Mnemiopsis leidyi. The most dramatic decrease of the Black Sea anchovy stock in the late 1980s were observed concomitantly with this massive increase in M. leidyi. This invasive ctenophore species competed with anchovy for food, by intense predation on zooplankton, and feeds on anchovy eggs and larvae. Notably, after the collapse of anchovy fisheries in 1980s, while the Turkish anchovy landings quickly recovered, the rest of the Black Sea countries never recovered their previous anchovy landings. In addition to the outburst of M. leidyi, other suggested factors causing the collapse of anchovy fisheries in 1980s include overfishing (exclusively or combine with M. leidyi outburst) or a change in fishing grounds (Gucu et al., 2017)

Overfishing

The fishery sector plays an important part of the Black Sea economy. It comprises industrial, semi-industrial and small-scale fisheries, and the fish stocks are shared among fleets from different countries. At present, the Black Sea is devoid of predatory fish species as a result of overfishing. Currently, around 85% of total fish catch comprises anchovy and is limited mostly to the southeastern region. Overfishing is a stressor on the anchovy stocks. Fleet overcapacity likely causes to catch fish faster than they can reproduce, leading to a gradual decline in stocks. Social and economic pressures limit measures to decrease quotas for long-term sustainability and the illegal or unreported catches exacerbate the problem. Furthermore, complex interactions and feedbacks as a result of overfishing may affect anchovy stocks. Overfishing can lead to the development of opportunistic species that then start competing for same food resources as anchovy or feeding on them and their larvae (BSC, 2007). The overfishing problem is especially challenge to address in the degraded Black Sea where multiple stressors (climate, invasive species, pollution, food-web shifts) affect anchovy populations and therefore a simple decrease in quotas would not guarantee a return of previous stocks.

Plastic Pollution

There are many types of pollution that might impact fisheries and potential implication on human health by contaminated sea food. Eutrophication in Black Sea in 1970s is one example, as the nutrient-laden runoff originated mainly from excess use of fertilizer in agriculture. This specific pollution problem seems to have been controlled as nutrients have decreased in recent decades. Recently, a growing threat on marine living resources of the Black Sea is marine litter, which is composed mainly of plastic.

There is a high risk of plastic pollution in the Black Sea because of the high river discharge of several industrialized countries into this semi-enclosed sea. The problem of marine litter is recognized as one of the most urgent and difficult environmental problems in the Black Sea (BSC, 2007). The large rivers, namely Danube, Dnieper, Bug, Dniester, Don, Kuban and Rioni, carry significant loads of pollutants (BSC, 2007; Lechner et al., 2014; González-Fernández et al., 2020). Recent study, estimates that, every day, 4.2 tonnes of plastic reach the Black Sea via the Danube (1533 tonnes every year) (Lechner et al., 2014). Because the Black Sea is a major fishing area (FAO, 2015), intense fishing activities can be considered as a source of plastic (e.g. fixed and floating fishing gear, discarded or abandoned nets) (BSC, 2007). Other sources of plastic pollution include coastal cities, shipping, coastal landfills and coastal uncontrolled dumping sites (BSC, 2007; Aytan et al. 2016). Plastic is usually the dominate debris and mainly from land-based sources (Topcu and Oztürk, 2010; Topcu et al., 2013; Aytan et al., 2020a). Plastic has been shown to be the dominant debris from the seabed (Topcu and Oztürk, 2010), sea surface (Suaria et al., 2015; Berov and Klayn, 2020; Pogojeva et al., 2020) and beaches (e.g. Topcu et al., 2013; Terzi and Seyhan, 2017; Simeonova and Chuturkova, 2020; Oztekin et al., 2020; Aytan et al., 2020b). Nonetheless, there is still limited data on plastic pollution in the Black Sea region and its effects on ecosystem.

One major problem of plastic is that once it enters the marine environment, it will not go away. It may take centuries to decompose and continue to breakdown into smaller particles called microplastic (< 5mm) (Figure 4) and nanoplastics (<100nm) that are extremely difficult to remove from the marine environment. Hence, the plastic will accumulate gradually. In addition to large plastics (e.g. plastic bags and bottles, fishing nets)that slowly fragment into MPs, a large majority of MPs enter the marine environment already in microscopic sizes including granulates used in cosmetics, washing powders, cleaning agents or pellets and fibres enters ocean directly from various pathways (Fendall and Sewell, 2009). These MPs are accumulating in marine environment and continue an invisible threat to humans and marine life.

Figure 4. Microplastics were collected from the marine environment (© Ülgen AYTAN)

The sizes of MPs are in the same range of plankton, therefore they may be ingested by many upper-trophic organisms (Wright *et al.* 2013). MPs can have potential ecotoxicological effects due to their adsorption of persistent and toxic pollutants (e.g. Martins and Sobral 2011). Recent studies have shown that MPs are ingested by zooplankton and filter feeders (Cole *et al.* 2013; Botterell *et al.* 2019) and that the MP-associated contaminants could transfer through food webs and into human diets. Experimental studies have shown that ingestion of MP by zooplankton affects their growth, reproduction, survival rates, nutritional behaviour, and life cycle (Botterell *et al.* 2019).

In many other regions of the world, ingestion of MPs by fishes has also been reported (e.g. Davison and Asch 2011; Boerger *et al.* 2010; Lusher et al. 2013; Compa *et al.* 2018), but this has only been recently quantified for the SE Black Sea, which is a major area for feeding, spawning and nursery grounds for anchovy (FAO 2015). Relatively high concentration of microplastics have been reported in SE Black Sea (Aytan *et al.* 2016; Öztekin and Bat 2017; Aytan et al., 2020a), as well as in NW Black Sea (Berov and Klayn 2020).

Black Sea anchovy is one of the most consumed species and is the most commercially important fish landed in Turkish Black Sea national ports (TUIK 2019). Anchovy feeds on plankton, from small phytoplankton to large crustaceans and fish eggs. Therefore, anchovy can directly feed on MPs or indirectly (through zooplankton), however, only recently it has been published a study on the presence of MPs in fish in the Black Sea (Aytan et al., 2020c).

Aytan et al. (2020c) showed that MPs were found in 20 % of the analysed Black Sea anchovy, resulting a microplastic ingestion of 0.25 particles per fish (considering all the fish analysed) and 1.21 particle per fish (considering the fish that ingested them). From the Gastrointestinal track of anchovy three types of MPs were found; fibre, film and fragment. The majority of ingested MPs were < 2 mm (75 %) and, overall, ranged between 0.07-4.94 m. The sizes of ingested MPs were in same range of previous studies size in Mediterranean Sea (Lefebvre et al., 2019; Renzi et al., 2019). Regarding the colours of ingested MPs, the most common colours were black, blue, transparent and red. This study provided evidence of MP ingestion by the important species Black Sea Anchovy. In same study, it was also shown evidence that copepods, which are a favourite prey of anchovy, also ingest MPs therefore could be acting as a vector for MPs transfer to anchovy. Black Sea anchovy has a high risk of ingesting MP by mistaken it by food or by ingesting it indirectly through zooplankton, and therefore can accumulate MP-associated contaminants. Effects of MP ingestion on anchovy growth, reproduction, survival rates, nutritional behaviour, and life cycle needs to be better understood and the public health risk should be evaluated.

Conclusion remarks

Anchovy stocks in the Black Sea have experienced dramatic fluctuation over last decades due to combined multitude of factors such as climate variations, eutrophication, invasive species and overfishing. The question of which of these factors played a stronger role on the decline of anchovy stocks after the 1980s remains unclear. Nevertheless, all these factors except natural climate variability are well known to be intimately related to human activities. Recently, a growing environmental threat is plastic pollution, but its effect on anchovy stocks are unknown. Since 1950s, when the mass production of plastic started, plastics have been accumulating in our seas. Although laboratory studies show that plastic affect vital function of marine biota, it is still unclear how it might be affecting anchovy in the Black Sea. Expected increased plastic production in next decades is a reason for concern that this persistent material will continue to accumulate in marine environment and negatively affect marine life, human health and economy. There is an urgent need for the formulation of coordinated international measurements to reduce the plastic inputs into the Black Sea and regular scientific assessments of the distribution, composition and fate of plastic in the Black Sea.

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APPLICATION OF IMAGE ANALYSIS TECHNIQUES IN FISH POPULATION STUDIES AND AGE ESTIMATION WITH EMPHASIS ON THE AZOV-BLACK SEA ANCHOVY

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ÖZET

Hamsi Karadeniz Ülkelerinde çokça tüketilen bir deniz balığıdır. Herne kadar daha çok Türkler tarafından avlanıp değerlendiriliyor ise de tüm Karadenizde çok bilinen ve tüketilen meşhur bir balıktır. Gerek dağılımı gerekse populasyon dinamiği çalışmaları ve dahi tüketimi ile ilgili bir çok çalışma yapılmış ve son yıllarda genetiği ile ilgili de yoğun çalımalar yapılmaktadır. Bilindiği gibi Karadeniz de hem Azak hamsisi hemde Karadeniz hamsisi olmak üzere iki alttür vardır ve bunların taksonomik durumları hala tartışma konusudur. Bu çalışmalarda kuşkusuz en önemli başlangıç deniz canlılarının yaşlarının tespit edilmesidir ve bunun için de çok yöntemler vardır. Özellikle son yıllarda dijital teknolojinin hızılı gelişmesi nedeni ile İmage analizi de balıkların yaş tayinlerinde kullanılmaya başladı. Bu balıkların yaşamsal parametrelerinin, yaş, doğru bir şekilde yapılması için çokça kullanılır bir yöntem oldu. Bu bölümdü Karadeniz deki hamsi için image tekniğinin kullanım detayları verilmiştir.

INTRODUCTION

Image analysis is a generic term used to refer to the digitization and manipulation of visual images, usually by a computer (Campana, 1987). Current developments in computers, electronic cameras and algorithms have contributed to progress in digital image processing by converting these images into sets of numbers and manipulating these numbers using various computer software. Thousands of images and videos can be saved, digitized, measured and analyzed in a computer environment. Digital image technology is commonly applied in various real-life applications such as industry, engineering design, medical diagnosis, robotics, communication, information systems, remote sensing, security, face finding, and others.

The image processing techniques in application to fisheries science include: fish identification and classification (Zion *et al*., 1999; Alsmadi *et al*., 2011; Hu *et al*., 2012; Ravanbakhsh *et al*., 2015; Allken *et al*., 2019; Kannan, 2020); counting and abundance estimation (Rooper *et al*., 2010; Raman *et al*., 2016; Aliyu *et al*., 2017); fish measuring (White *et al*., 2006; Rodriguez *et al*., 2015; Al-Jubouri *et al*., 2017); assessment of fish quality and freshness (Arnarson, 1991; Muhamad *et al*., 2009; Chakravorty *et al*., 2015; Dutta *et al*., 2016); fish diseases detection (Lyubchenko *et al*., 2016; Malik *et al*., 2017); population structure studies and stock identification based on fish body morphometry and landmarks (Strauss, Bookstein, 1982; Cadrin, Friedland, 1999; Cadrin, 2000; Maderbacher *et al*., 2008); stock discrimination using otolith shape analysis (Campana, Casselman, 1993; Tuset *et al*., 2006; Stransky *et al*., 2008; Farias *et al*., 2009; Treinen-Crespo *et al*., 2012; Vieira *et al*., 2014; Trojette *et al*., 2015); age estimation (Fawel, 1974; Campana, 1987; McGowen *et al*., 1987; Troadec *et al*., 2000; Panfili *et al*., 2002; Fablet *et al*., 2009; Mahé, 2009; Fisher, Hunter, 2018).

In recent years, the number of studies of the European anchovy (*Engraulis encrasicolus* L.) using the digital image technology has increased rapidly. In this paper, we would like to share knowledge from literature data and our researches about application of the image processing techniques to the population and age studies of the European anchovy in the Black Sea-Azov area.

Image analysis systems in morphometric studies

Traditional morphometric analysis plays a critical role in the identification of fish species and also uses for the differentiation of their populations and stock units. However traditional biometric measurements are typically limited to select body structures such as fins with poor or no ability to quantify body shape (Winas, 1984). The size-related morphometric measurements are mostly age dependent and as such fail to reveal the actual variation both within and between the populations (Cardin, Friedland, 1999). Another weakness of the manual method is that it is time consuming and some measurements can be inaccurate and not reproducible.

Strauss and Bookstein (1982) proposed a method of sampling linear distances from fish body by creating a box-truss network between landmarks as a more comprehensive representation of shape. The principle of truss networking stated that morphometric characters could be analysed by measuring any distances between predetermined landmarks, but the set of landmarks and distances must be homologous. Truss network system covers the entire fish in a uniform network, and theoretically, it should increase the likelihood of extracting differences between specimens (Strauss, 1985). Imaging data acquisition has become a tool for quick collection of many morphometric measures with better precision and accuracy than manual methods (MacLeod, 1990). The development of digital imaging systems and advances in analytical methods revolutionized the study of morphometric variation and has increased the power of morphometric analysis for stock identification (Bookstein, 1986).

Anchovy body truss network system in population studies

Several studies have been carried out on the population structure of the European anchovy in the Mediterranean Sea and the eastern Atlantic using the truss network system (Bembo *et al*., 1996; Caneco *et al*., 2004; Kristoffersen, Magoulas, 2008; Traina *et al*., 2011; Karahan *et al*., 2014). Similar studies based on the truss-morphometry for the anchovy were conducted in Turkish waters of the Black, Marmara, Aegean and northeastern Mediterranean seas (Turan *et al*., 2004; Erdoğan *et al*., 2009).

Turan *et al*. (2004) reported significant morphometric differences between four samples of anchovy (159 specimens) collected in the central (Sinop) and eastern (Trabzon) Black Sea, the Aegean Sea (Izmir) and the eastern Mediterranean (Iskenderun). Results of the study suggest a high level dissimilarity among the anchovy samples, indicating that the anchovies in each area may represent different aggregations or populations. The Mediterranean sample was most isolated from the Aegean and Black Sea samples, and the Black Sea samples were also clearly separated from the others, but were closer to each other in comparison. A correct classification of individuals into the studied samples by the discriminant analysis varied between 70% and 82%. In this study, main differences were found from posterior body measurements and measurements taken from the head.

Erdoğan *et al*. (2009) studied morphometric and genetic characteristics of the anchovy in six samples (300 spec.) collected from the Black Sea (Trabzon, Sinop, Istanbul), the Marmara Sea (Bandırma) and the Aegean Sea (Edremit, Izmir). The results of morphometric study indicated that the Aegean Sea samples were the most isolated from each other and from other samples. The western Black Sea sample was also clearly separated from the other Black Sea samples, but was closer to the Marmara Sea sample. The middle and eastern Black sea samples were overlapping together. The important discriminative characters in distinguishing between the samples were from the body height measurements. Based on discriminant analysis, each specimen was classified correctly to the original samples with an accuracy of 77%. The genetic differentiation between the samples was less expressed, however the eastern Black sea sample was the most isolated, so the authors suggested that there may be a self-recruiting population or Azov anchovy subspecies in the Turkish territorial waters.

However, the differences in the body shape of fish when studying such a small number of samples from different regions do not give a real representation about their population structure. Comprehensive studies, which include several methods, are needed to prove the existence of separate populations.

We performed a comparative analysis of anchovies using the box-truss method from 21 samples (840 spec.). The anchovies collected along the southern and western coasts of Crimea were presumably belonged to the Black Sea subspecies (*E. encrasicolus ponticus*), and the anchovies collected from the Sea of Azov, the Kerch Strait, and the North Caucasus were of the Azov subspecies (*E. encrasicolus maeoticus*). Location of the landmarks for constructing the truss network around the anchovy body and morphometric distance measures between the landmarks were the same as in Turan *et al*. (2004) and Erdoğan *et al*. (2009). Each landmark was obtained by piercing the acetate sheet with a dissecting needle, defining 12 landmarks. However, they measured distances between landmarks manually using calipers, while we scanned the sheet with the landmarks from 8 anchovies and coordinates of the landmarks were digitized the image processing program ImageJ (Abràmoff *et al*., 2004). The 22 interlandmark distances were calculated with macros in Excel, which we specially designed based on the Euclidean distance formula. The results of our study indicated that the body shape of anchovies varies greatly and the level of similarity between samples is very high. However visualizing the data with the Principal Component Analysis (PCA), we observed that centroids of the samples were concentrated according to the sampling areas. In addition, there was variability in the distribution of centroids of samples collected monthly from October 2016 to March 2017, which is probably associated with seasonal changes in the body height of fish during wintering. The results of our research showed that correct classification of the anchovies in the samples into two supposed subspecies as the Azov and Black Sea anchovy subspecies based on truss-body morphology using the Linear Discriminant Analysis (LDA) was 84%. However despite the good result, we do not recommend to use the body truss network system for differentiating of anchovy populations, especially in mixed catches, because on our opinion this method has many disadvantages.

Advantages and disadvantages of the truss network system

Advantages:

- Measurements more precise than in traditional morphometry and can be made automatically on numerous images.
- The set of measurements is not so limited.
- The measurements better describe differences in fish body shape.
- There are many landmark digitizing and analysis software (MorphoJ 1.07, TpsDIG 2.15, Morphologika2 v2.5, TMorphGen 6c, IMP8, GMTP 2.3, PAST 2.7, Grapher, SAGE, MACE, Coriandis, Lory, PAST, etc.).
- Easy combination with multivariate statistical programs (principal component analysis, cluster analysis, discriminant analysis, etc.);
- It is possible to share images, create image data bank, and measure the fish body shape by different ways.

Disadvantages:

- Results highly depend on the accuracy of placing landmarks around fish body, which is especially important for small-size specimens such as anchovy. This work with bulk material is time-consuming, and even small mistakes can lead to biases in the results. Thus, numerous images and measurements of the fish body shape can be practically useless.
- Measurements should be taken on fresh fish because the fish's body is soft and shape changes rapidly over time. Fish that that have lost turgor or were fixed long time in freezer, salt, formalin or alcohol give other meas-

urements and do not suitable for the study.
• Morphometric traits are closely related to the size, growth rate and age of fish, so only standardized measurements can be used in the analysis, but their comparison with other studies is rather difficult.
• Our results and those of several other authors show that main differences in anchovies were related to measurements of body height. The height of many fish species depends on its physiological condition such as fat content, gonad state, nutrition, which have a large seasonal variability and are very dependent on environmental factors.
• The truss network system can be considered as a modernized but simplified version of traditional morphometry, however, a lot of data may be lost, such as important measurements, all meristic counts, as well as data on fish sex, gonad stage, age, fatness, stomach fullness, etc.

Conclusion: This method has more negatives than positives, so it is not recommended for differentiating the anchovy populations, especially in mixed catches.

Analysis of otolith images in population studies

Otoliths (ear stones) are a hard calcium carbonate structure that does not change over time. Otoliths have unique qualities, including species and interspecies specificity and constant growth rate during a fish's life. Otolith is the most commonly used structure for determining the age of fish. Otolith is a useful structure for studying fossil fish fauna and determining the diet of fish-eating species from stomach contents. Recently, several methods have appeared for the fully-automated identification of fish species based on otolith contour analysis (Parisi-Baradad *et al*., 2010; Salimi *et al*., 2016).

Otolith shape and other otolith morphometric features are directly related to genotype but can also be affected by environmental conditions (Torres *et al*., 2000; Cardinale *et al*., 2004; Stransky *et al*., 2008). At present, the otolith shape analysis is one of the most popular approaches, which is widely and successfully used for stock identification and intraspecific population studies of various marine fish species. The greatest advantage of this method is its high correlation with results of genetic studies, but it less time consuming and less expensive compared to other methods of population studies (Jonsdottir *et al*., 2006; Abuanza *et al*., 2008; Orlov, Afanasiev, 2013).

Methodological approaches in the otolith shape analysis can be conventionally divided into three groups: 1) study of the entire otolith contour through Fourier or wavelet analysis (Iwata, Ukai, 2002; Libungan, Pálsson, 2015), which is considered as real otolith shape analysis; 2) otolith measurements (length, width, area, perimeter) and calculations of otolith shape indices (Messieh *et al*., 1989; Tuset *et al*., 2003; Ponton, 2006), 3) measuring distances and angles between homologous landmarks on otolith images (Monteiro *et al*., 2005; Turan, 2006; Carvalho *et al*., 2015).

Anchovy otolith shape analysis

The Fourier elliptical analysis was used as the main tool for the otolith shape analysis in the identification of stocks of the European anchovy in the Atlantic Ocean, Mediterranean, Marmara and Black Seas (Gonzalez-Salas, Lenfant, 2007; Kristoffersen, Magoulas, 2008; Bacha *et al*., 2014; Karahan *et al*., 2014; Jemaa *et al*., 2015; Akkus *et al*., 2018). Jemaa *et al*. (2015) examined the variability in the otolith shape of the European anchovy from 15 locations in the SW Mediterranean Sea and Atlantic Ocean using a combination of elliptic Fourier descriptors and otolith shape indices (1515 spec.). Within the studied area, four distinct anchovy groups were identified with an overall correct classification of 83%. Group A: North Sea and English Channel; group B: northwest Africa areas, north and south Cap Blanc; C) Mauritania and southeast Atlantic Morocco; group C: northeast Atlantic Morocco-Gulf of Cadiz-south Alboran-Algero-Provençal coasts; and group D: northern Mediterranean Sea. Previously, the Alboran stock was separated from the Algero-Provençal Basin (Bacha *et al*., 2014). Recently, Akkus *et al*. (2018) combined samples of Jemaa *et al*. (2015) with 10 new ones, which were collected along the Turkish coast of the Black Sea and the Tyrrhenian, Adriatic, Ionian Seas, and the northeast Atlantic Ocean (overall 2535 spec.). Based on the elliptical Fourier analysis, three different groups of anchovies were identified: Atlantic-Southwestern Mediterranean, Northwestern Mediterranean and Eastern Mediterranean-Black Sea with a classification success of 91%.

Many studies have revealed a complex population structure of the European anchovy in the Mediterranean basin and Northeast Atlantic

Ocean that only partially agrees with fishery stocks management (Jemaa *et al*., 2015). Overall, eight genetically distinct stocks were identified in the Mediterranean Seas (Aegian, Alboran, north and south Adriatic, NW Mediterranean, Algero-Provencal, Marmara, Black Sea) and five socks in the Eastern Atlantic (North Sea-English Channel, north and south Bay of Biscay, Moroccan, Canary Islands) (Magoulas *et al*., 2006; Bouchenak-Khelladi *et al*., 2008; Keskin, Atar, 2012; Viñas *et al*., 2014). However, the otolith shape analysis, as mentioned above, did not show such a complex population structure of the European anchovy, in particular, the differences between the Eastern Mediterranean, Marmara and Black Sea anchovies.

Further, recent genetic studies (Vodyasova, Abramson, 2017; Düzgüneş *et al*., 2018) did not reveal significant genetic differences between the Azov anchovy and the Black Sea anchovy. However, according to current international fisheries regulations, the Azov and Black Sea anchovies are considered as different subspecies and separate stock units (STECF, 2015). Therefore, we studied the shape variability of anchovy otoliths in Azov-Black Sea area to assess the differences between the Azov and Black Sea subspecies and the usefulness of using otoliths to separate these subspecies in catches. Anchovy otoliths (1502 spec.) were analysed in 18 samples collected from eight areas in the Sea of Azov, Kerch Strait, along the northern Caucasus, southern and western coast of Crimea and from the eastern, central and western Anatolian coast of the Black Sea from 2014 to 2020. The otolith images were digitized using the ShapeR package (Libungan, Pálsson, 2015). The program permits to automatically extract otolith contours from large number of images, and calculates 48 normalised Fourier coefficients and 64 discrete wavelet coefficients for each otolith. We found that the Fourier elliptic analysis and the study of wavelet coefficients give similar results. The Fourier coefficients were standardized allometrically to the fish length and those coefficients which depend on the fish length or each other were automatically removed. Overall, 22 Fourier descriptors were obtained as independent variables characterizing the features of an otolith shape for the study. The data on Fourier descriptors were imported into packages PAST 4.03 (Hammer *et al*., 2001) for the statistical analysis. Before studying the geographical differentiation, potentially confounding sources of variation (fish length, sex, sampling year and otolith side) were tested by the Permutational Multivariate Analysis of Variance (one-way PERMANOVA). We found only significant differences only between otolith shape of juveniles and adult fish. The young anchovies (< 9.0 cm TL) have more rounded otolith with more acute excisural notch angle than adults, therefore the small anchovies were excluded from the further comparative analysis. The spatial distribution of otolith shapes was visualized using PCA and grouping using Hierarchical Cluster Analysis (HCA). Based on results of PCA and HCA, all samples were divided into two groups: A) samples from the Sea of Azov, Kerch Strait and North Caucasus; B) samples from the Crimean coast and the Anatolian coast of the Black Sea. This grouping corresponds to the known spatial distribution of the Black Sea and Azov anchovy subspecies. Overall, the correct classification of two anchovy subspecies by the LDA was 80%. Thus, this study showed that the otolith shape analysis allows us to differentiate the Azov and Black Sea anchovies.

Advantages and disadvantages of the otolith shape analysis

Advantages:

• Basic field surveys include collection of otoliths, which are routinely processed with image analysis. Thus, this analysis does not require additional material, has simple preparation procedures and even there is no cost at all. Results can be obtained quickly on numerous images and the images can be easily re-analyzed.
• Currently, the otolith shape analysis is one of the most popular methods, which is widely and successfully used for stock identification and intraspecific population studies of various marine fish species.
• There are software specially designed to study variations in otolith shape among fish populations, based on automatic extraction and quantitative assessment of otolith contours from their images by transforming in Fourier and wavelet coefficients (SHAPE ver. 1.3, ShapeR package, scripts in MATLAB and R software). Recently, several methods have appeared for the fully-automated identification of fish species based on otolith contour analysis.
• Otolith image's database can be easily created and re-analyzed using multivariate statistics from the latest and advanced statistical methods.

Disadvantages:

• Fourier analysis and wavelet analysis characterize the otolith contour by many coefficients and do not permit to give its clear quantitative characteristic in understandable dimensional values.

• It is impossible to quantitatively characterize the “reference” shape of the otoliths for different populations, stocks or subspecies. Otoliths from new samples need to be compared with the existing database in order to determine their probabilistic relationship to a particular population.
• Fourier and wavelet coefficients or their standardized descriptors cannot be used to biologically interpret differences in otolith shape and explain effects of environmental factors on phenotypic discreteness of fish.

Conclusion: Contour based otolith shape analysis has more advantages than disadvantages. Our study supports the usefulness of the otolith shape analysis for the population and stock identification studies and we recommend using this method in the separation the Azov and Black Sea anchovies in catches.

Otolith morphometry and shape indices

Comparison of otolith morphometric characteristics and their shape indices was carried out in many studies with a view to separating fish stocks (Begg, Brown, 2000; Torres *et al*., 2000; Tuset *et al*., 2003), although this method is less powerful than otolith shape (contour) analysis.

Several studies were conducted to examine the geographical differentiation between otolith morphometric characteristics (length, width, area, perimeter, weight) and otolith shape indices (aspect ratio, form factor, circularity, rectangularity, roundness, ellipticity, etc.) of the European anchovy in different areas of the Mediterranean, Aegean, Marmara and Black Seas (Zorica *et al*., 2010; Bacha *et al*., 2014; Zengin *et al*., 2015; Erdogan *et al*., 2019; Başçınar, Atılgan, 2020).

Zengin *et al*. (2015) compared two samples of anchovy otoliths from the Marmara Sea and the south Black Sea (off Samsun) (263 spec.) based on five measurements (length, width, area, perimeter, weight) and four calculated indices (form factor, roundness, circularity, rectangularity). According to the results (ANOVA), there were no significant differences between right and left otoliths, as well as between otoliths of males and females. In respect the areas, the otoliths were similar in width between the Black Sea and Marmara Sea anchovy samples, but significantly different in length, weight and values of three otolith shape indices (form factor, roundness and circularity).

Erdogan *et al*., (2019) used only three otolith characteristics (length, width and weight) in discriminant function analysis (DFA) when comparing six samples of anchovies (300 spec.): three from the Black Sea (Trabzon, Sinop, Istanbul), one from the Marmara Sea (Bandırma Gulf) and two from the Aegean Sea (Edremit Gulf, Izmir Gulf). Only otoliths of anchovy from the Marmara Sea were clearly separated from other samples. Main differences were related to the otolith width and length. The authors suggested that the differences in otolith sizes may be attributed to geographic and environment conditions.

Başçınar and Atılgan (2020) described morphometric characteristics of otoliths of 102 anchovy specimens obtained from two different regions (Georgia region of the Black Sea and the Marmara Sea). Four morphometric measurements (length, width, area, perimeter) and three indices (form factor, roundness and aspect ratio) were used for the analysis. Differences were found in all size characteristics and two indices (aspect ratio and form factor), the authors suggested that the anchovy stocks in Georgia and Marmara can be different.

We compared otolith morphometric parameters and their shape indices in 18 samples (1502 otoliths), which we mentioned in the otolith shape analyses. Each otolith image was digitized using ImageJ by setting seven landmarks (top of rostrum, top antirostrum, top of posterior part, inside notch angle, top of ventral part, top of dorsal part, top of dorsal part without teeth). The coordinates of these landmarks were saved and distances between the dots were estimated using macros designed in Excel as: maximum otolith length, maximum width, rostrum length, dorsal teeth size, notch angle. Besides, the otolith perimeter and area were estimated in ImageJ. Actually, the package ShapeR permits automatically calculates length, width, perimeter and area of each otolith however we noticed that the values of the maximum (Feret) length and maximum (Feret) width depend on the orientation of the otolith, so the images should be positioned strictly on the x-axis to minimize the distortion of errors in the resulting calculations. The results of the otolith measurements in ImageJ and ShapeR did not differ significantly, so we used the data of the first program, since it has more parameters. The 10 otolith shape indices were calculated based on the otolith sizes (length, width, perimeter, area) using special formulas such as: aspect ratio, circularity, rectangularity, roundness, form factor, ellipticity, perimeter index, fractal index, Patton's diversity, ratio of the otolith length to fish length. We found that all otolith sizes depend on the fish length and all otolith shape indices have positive or negative allometric relationship with fish length, therefore they should be standardized for the comparative analysis. Almost all otolith shape indices were statistically significantly different between the Azov and Black Sea anchovies, but the average values in many cases differed only by one to two tenths or hundredths, and only the aspect ratio and the circularity differed markedly between the two subspecies.

Therefore, it is necessary to find the most distinctive features of otoliths to separate the anchovies. We have shown statistically that the Black Sea anchovy in comparison with the Azov anchovy differs in several otolith parameters. It has smaller values of the relative otolith length, notch angle, size of teeth, but larger values of the aspect ratio and the relative length of rostrum.

Advantages and disadvantages of using otolith shape indices in population studies

Advantages:

• At present, there are many publications about using otolith shape indices in studies of fish population structure and identification of stocks.
• Many image processing programs available to measure automatically various otolith dimensions (length, width, area, perimeter, etc.) such as Leica Application Suit, AxioVision, ImageJ, TNPC, NOESIS, etc.).
• Dimensionless otolith shape indices can be easily calculated using special formulas.
• Different indices help to provide a biological interpretation and explain differences in the otolith shape in relation to variability of environmental conditions.

Disadvantages:

• Different authors sometimes use different formulas to calculate otolith shape indices, so the results cannot be compared.
• Values of dimensionless otolith shape indices depend on fish length, so the differences in their average values may be caused not by geographical differences in the otolith sizes, but by different fish sizes in the samples. Therefore, the shape indices should be standardized to the average length of the fish in all samples.
• Geographical differences may be statistically significant for some shape indices and not significant or poorly expressed for others, which makes

difficulties in interpretation of the results.

Conclusion: Otolith shape indices can only be useful as additional information (not the main one) when studying the population structure of fish species or identifying stocks. It is necessary to find the most distinctive features of otoliths may be related to their morphology, size and weight, various angles etc. to solve the problem.

Image analysis systems in fish ageing

The feasibility of using digital imaging in studies of fish age has been investigated since Mina (1965, 1967), when studying the age of cod, first proposed the so-called photometric method based on measuring the optical density of the otolith from the center to the periphery. The otolith section was photographed under a microscope, the negative was placed in a microphotometer device, where the light passing through this negative excited a photocurrent in the galvanometer, and a wave-like curve was drawn on photographic paper, registering changes in optical density, then mathematical processing of digital data was carried out. Further use of computer assisted ageing techniques followed (Fawel, 1974; Methot, 1981; Campana, 1987; McGowen *et al*., 1987). Panfili *et al*. (1990) suggested the phrase 'Computer-assisted age and growth estimation' (CAAGE) to describe interactive imaging tools, and this name is still used to describe more recent systems that operate completely autonomously (Fisher, Hunter, 2018).

The first systems for semi-automatic otolith age determination were based on the analysis of light density distribution along 1D transect directed from the center to the edge of the otolith (Troadec, 1991; Macy, 1995; Welleman, Storbeck, 1995; Cailliet *et al*., 1996). Later, these systems advanced in the use of two-dimensional models when researchers transformed a selected segment or whole otolith into a rectangular coordinate system, and then analyzed the transmitted light profiles using Fourier or wavelet descriptors (Troadec *et al*., 2000; Palmer *et al*., 2005; Formella *et al*., 2007; Fablet *et al*., 2008). Recently several projects have been carried out on automatic age determination and growth analysis as AFISA (Automated FISh Aging) (Mahé, 2009) and FABOSA (Age determination based the otolith shape) (Arneri *et al*., 2002). As a result of AFISA project, the special TNPC software was designed for the automatic age determination from otoliths and fish scales (Mahé *et al*., 2011). Fisher and Hunter (2018) reported a comprehensive review on digital imaging techniques in otolith age analysis.

As was mentioned above, during the studies of the otolith shape, researchers used various image analysis software, mainly developed for microscopic techniques, including ImageJ (Abràmoff *et al*., 2004) and ImagePro (Whitman, Johnson, 2016). As an application to ImageJ, the plugin ObjectJ was developed, which describes a special technique for automatically counting and measuring annual rings on fish otoliths (Vischer, Nastase, 2015), as well as a method for measuring distances between annual rings and calculating interannual increments.

In 2018, the SmartDots software was designed under the guidance of the International Council for the Exploration of the Sea (ICES, 2019, 2020), to improve the quality and standardize the process of fish ageing in different European laboratories, as well as creating a common database of the otolith images (https://www.ices.dk/data/tools/Pages/smartdots.aspx). This program contains images of otoliths of several fishes, including the European anchovy, with estimated age by experts and provides a set of tools, particularly possibility to draw a density curves along any transect on the otolith image.

However, the automated fish aging have generally been found to be less precise than those obtained from experienced otolith readers (Robertson, Morison 1999; Fablet, Le Josse, 2005). It is a recognition of the complexity of the process that no age estimation laboratories have been able to replace their human readers' (Morison *et al*., 2005). Thus, the current method for determining ages of most fish species still relies on the visual observation of whole otoliths or otolith sections under a microscope by otolith readers. This process is expensive, time-consuming, and can be subject to biases such as differences in age estimations between readers and within readers over time.

In the last 3-4 years, there has been considerable progress in automating otolith age estimation due to improved algorithms and development of the micro-computed topography (Moen *et al*., 2018; Parsons *et al*., 2018). CT scanning technologies potentially offer a powerful approach to otolith imaging for ageing purposes. CT scanning uses X-ray technology to produce image slices through objects, which can be reconstructed into virtual, three-dimensional (3D) images that can be rotated and viewed in any orientation (Moore *et al*., 2019).

The age estimation of fish, including the European anchovy, is carried out in specialized fish ageing laboratories in many European countries. In the 1990s, otolith exchanges, workshops, and cross-validation of anchovy age determinations from different areas of the Eastern Atlantic began (Astudillo *et al.*, 1990; Villamor, Uriarte, 1996; Uriarte, 2002; Uriarte *et al*., 2006, 2007, 2014, 2016). In 2008-2009 and 2014-2016, exchanges of otoliths and their images continued, and workshops were held on methods of reading anchovy otoliths from the Atlantic and various regions of the Mediterranean Sea (ICES, 2010, 2017). As a result, a common protocol was adopted and criteria for the visual determination of the age of European anchovies were agreed in order to standardize the anchovy age assignments in the Atlantic and Mediterranean regions (ICES, 2017). Recommendations for determining the age of the main commercial and numerous fish species in European seas have been summarized in guidelines (Carbonara, Follesa, 2019; Vitale *et al.*, 2019).

In 2019, the first workshop on age reading of the Black Sea anchovy was held in Trabzon (Turkey) with participation of experts from all Black Sea countries (Bulgaria, Georgia, Russia, Romania, Turkey and Ukraine) (FAO-GFCM, 2019). The average agreement of the group with the 'reference reader's estimate was 53 %, ranged 36-76 %. Therefore, the experts agreed 'Age reading protocol for the Black Sea anchovy and Azov anchovy' to standardize the anchovies age estimations. According to the protocol, they recommended using whole otoliths immersed in glycerin under the reflected light of a binocular microscope and did not recommend using camera and screen for the age estimation, only for the morphological measurements. Further, they proposed to recognize the first completed hyaline ring as the "first age ring" without considering its distance from the core of the otolith. However, they noted that in order to avoid misinterpretation due to false rings, further research is recommended to determine the location of the first ring with respect to the center of the otolith. Such study is impossible without measuring the distances from the center of the otolith to annual or false rings using otolith images. According to study of Hernandez *et al*. (2009, 2013) based on microstructure analysis of anchovy otoliths from the NE Atlantic, the first hyaline check (not true winter hyaline ring) laid down at about 0.8 mm from the nucleus, corresponding to about 90 days old fish caught in autumn. Therefore, it was suggested that hyaline ring placed at a distance from the core of less than 0.85 mm (±0.10 mm) should be considered as a check. However, this rule was not adopted in the workshop in Spain held in 2016 (ICES, 2017), because for the protracted spawning seasons of anchovy populations (reaching September or even October) there might be some cohorts born in autumn, overpassing its first winter just at the age of 90 to 120 days. But, in a case the first hyaline ring on the otolith of juvenile (0+) is weakly formed, not observed all around the otolith and readers have serious doubts about its reliability as true winter ring it should be considered as a check (false) ring (FAO-GFCM, 2019). So, there is a need to validate and calibrate the currently age reading procedure on anchovy using image analysis technique.

We carried out preliminarily study on the age of the Azov anchovy, based on 300 specimens collected in the Sea of Azov and along cost of the north Caucasus in 2019 and 2020. The age estimations and otolith measurements were made using ImageJ, which is freely available on the website https://imagej.net. Each otolith image was calibrated and the length of otolith was measured. A transect line was drawn across the longer axis of the otolith and the data on density profile was saved in Excel. This approach is similar to that used by Gonçalves *et al.* (2017) in the age estimation of blue whiting. The core of the otolith was found and sharp declines in the anterior and posterior parts on the density plot were defined which characterize the position of hyaline zones (rings). Then distances between otolith edge, core and the rings were calculated. It was found that the distance from the core to the posterior edge of the otolith for juveniles (0+) with the mean length of 7.2 cm was on average 0.88 mm. The distance from the core to the first true hyaline ring posteriorly for the anchovies of 1+, 2+ and 3+ year old was about 0.92-0.94 mm. Approximately 30-50% of juveniles and 1-year old anchovies had a more or less distinct pronounced hyaline ring located at a distance of 0.31-0.80 mm (on average 0.51 and 0.60 mm), which we considered a false ring or a check.

Advantages and disadvantages of the automatic fish ageing

Advantages:

Computer-based systems are attractive because they seem to offer the possibility of moving from subjective age estimates to automated objective assessments. However, these approaches have proven very difficult to implement in practice (Fisher, Hunter, 2018). It is a recognition of the complexity of the process that no age estimation laboratories have been able to replace their human readers' (Morison *et al*., 2005).

Advantages:

• Otolith ageing represents an important application and an opportunity for integrating computer vision and machine learning in the design of robotic systems.

• Computer-based systems are attractive because they seem to offer the possibility of moving from subjective age estimates towards automated objective assessments. They have potential to provide more reliable, consistent, and rapid age estimations.

• Several image analysis programs had been adapted in order to allow automatic counts of annual and daily increments and fish age estimation from otoliths such as TNPC, CAF, RATOC, Image • Pro Plus and ImageJ with plug-in ObjectJ.

• The automating fish ageing will significantly reduce cost of acquiring age data in future.

Disadvantages:

• The best results for automatic fish ageing can be obtained from digitized otolith images which exhibit clear annual growth rings as a sectioned otolith. Images recovered from whole otoliths suffer from instability due to lighting inconsistencies.

• Many otoliths are difficult to age. A simple count of the number of rings can lead to an incorrect estimate of the fish age, because some otoliths have additional checks or stress marks (spawning, false, incomplete, double, etc.) in addition to opaque and translucent bands.

• Computer vision still performs relatively poorly and have generally been found to be less precise than those obtained from experienced otolith readers. Therefore, Fish Ageing laboratories have been reluctant to adopt image-based computer-assisted age and growth estimation systems.

Conclusion: Currently, the automated age and growth estimation systems should not be seen as being able to fully substitute the expert readers, but it can help the experts with additional information in the age estimations. They can be a useful tool for improving data acquisi-

tion, standardization between laboratories, creating integrated image databases and tracking analysis results, while reducing the cost of this work. There is considerable potential for the development of fully automated fish age estimation systems in the nearest future.

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ANCHOVY AS A FOOD

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ÖZET

Su ürünlerinin sağlığa yararları, türlerin çeşitli etkenlerle değişen besin içeriklerine önemli ölçüde bağlıdır. Hamsi antik çağlardan beri insan gıdası olarak kullanılmaktadır. Bu bölümde, hamsi türlerinin besin değeri ile ilgili geçmişte yapılan araştırmalar, kimyasal kompozisyonunda varyasyonlara neden olan faktörlere bağlı olarak değerlendirilmiş ve insan tüketimi için sağlık yararları açısından tartışılmıştır. Farklı denizlerden avlanan farklı hamsi türlerinin yağ asidi, amino asit, mineral ve vitamin içerikleri üzerinde kapsamlı çalışmalar yapılmıştır. Yapılan çalışmalarda hamsinin bildirilen besin içeriklerini üzerinde avlama mevsimi, yaşadığı ortam, pişirme ve işleme teknikleri ve depolama koşullarının büyük ölçüde etki ettiği ortaya koyulmuştur. Hamsinin besin bileşimi insan sağlığı açısından değerlendirildiğinde geniş bir varyasyon olmasına rağmen, hamsi, özellikle beyin ve kalp sağlığı için gerekli olan eikosapentaenoik asit (EPA) ve dokosaheksaenoik asit (DHA) olmak üzere zengin omega-3 yağ asitleri kaynağıdır. Ayrıca protein eksikliği bozukluklarını hafifletebilen dengeli ve yüksek miktarda esansiyel ve esansiyel olmayan amino asitleri ve sağlıklı beslenmeye katkı sağlayacak çeşitli mineral ve vitaminleri içerdiği görülmektedir.

Omega-3 yağ asitlerinin, özellikle EPA+DHA'nın, başta kardiyovasküler hastalıklar olmak üzere birçok hastalığın önlenmesi ile ilişkilendirilmiştir. Ancak yapılan araştırmalar her balıkta olduğu gibi hamsinin bu yağ asitleri açısında içeriği yukarıdaki faktörlere bağlı olarak değiştiğini kanıtlamıştır. Bu nedenle, haftada bir kez hamsi tüketimi yılın belirli aylarında önerilen haftalık EPA+DHA ihtiyacını karşılamaya yeterli olurken, diğer zamanlarda daha yüksek değerler gerekebilir. Benzer şekilde, pişirme ve işleme teknikleri de yağ asitleri ve diğer besin bileşimlerinde varyasyonlara yol açacağından hamsi ile ilgili gıda veri tabanı son bulgulara, pişirme ve işleme yöntemlerine göre güncellenmelidir.

Özellikle su ürünleri sektöründe hamsi üretiminin önemli bir kısmı hayvan yemi için de kullanılmaktadır. Hayvan diyeti için hamsi kullanımının sınırlandırılması ve alternatif kaynakların yetiştiricilikte artırılması konusunda tartışmalar/öneriler devam etmektedir. Hamsinin farklı kısımları aynı zamanda yüksek besin bileşenleri içerdiğinden, gelecekteki sürdürülebilir balıkçılık için hamsinin yan ürünlerinin daha iyi kullanılması yararlı olacaktır.

Küçük boyutu nedeniyle hamsinin otomatik işleme teknikleriyle işlenmesi sınırlandırılmış olup çok azdır. Bu nedenle bu balık manuel işleme teknikleriyle beraber çoğunlukla taze olarak tüketilir. Hamsinin balık yağı kapsülleri gibi fonksiyonel gıdalara işlenmesi gibi ileri teknikler kullanılarak değerlendirilmesi bu ürünün değerini de artıracaktır. Sonuç olarak, hamsi yüksek besin değerine sahip sağlıklı ve dengeli beslenmede önemli katkı sağlayacak bir balıktır.

Introduction

According to FAO statistics (2021), the highest fisheries catch was accounted for anchovies, which the production of anchoveta (Peruvian Anchovy: *Engraulis ringens*) made it the top species, at more than 7.0 million tons per year, followed by Alaska pollock was as the second, at 3.4 million tons, while skipjack tuna ranked third for the ninth consecutive year, at 3.2 million tons. Considerably high production amounts were also reported for other anchovy species, making it a large quantity available for human and animal consumption in the world (FAO, 2021). Therefore, anchovy deserves considerable attention from the seafood industry, nutritionists, scientists, and government authorities due to its high contribution to the economy as well as to human consumption. For this reason, the nutritional value of various anchovy species has been discussed in this chapter.

Seafood is accepted as an essential food for humans due to its abundance of high-quality proteins, n-3 polyunsaturated fatty acids (PUFAs), and other nutrients, such as minerals, trace elements, and vitamins (FAO, 2010). These nutrients are essential for bodily functions and are beneficial to growth, the brain, and the nervous system; they also have anti-cancer properties (Liao and Chao 2009; Hosomi et al., 2012). Consumption of fish provides energy, protein, and a range of other vital nutrients, including the long-chain n-3 polyunsaturated fatty acids (LCn-3PUFAs), specifically eicosapentaenoic (EPA) and docosahexaenoic acids (DHA). FAO (2010) pointed out that the consumption of fish, particularly fatty fish, lowers the risk of mortality from coronary heart disease among the general adult population. Moreover, studies on risk and health benefits assessments indicated that fish consumption could reduce or prevent coronary heart disease as well as preventing some other health risks (FAO, 2010). Therefore, several health agencies and professional organizations such as the American Heart Association, the European Society for Cardiology, the Scientific Advisory Committee on Nutrition (UK), the European Food Safety Authority, the Australian Health and Medical Research Council have issued recommendations for increased intakes of n-3 fatty acids (De Backer et al., 2003; FAO/WHO, 2010; EFSA, 2010; Merdzhanova et al., 2013. These recommendations are based on solid evidence derived from various scientific approaches linking dietary deficiency of long-chain n-3 fatty acids with the risk of cardiovascular events, notably sudden death. Fish lipids are the richest in valuable n-3 LCPUFA decreasing the cardiovascular risk. Thus, more frequent consumption of fish is recommended. Few randomized controlled trials on fish in relation to coronary and all-cause mortality have been conducted in cardiac patients (De Backer et al., 2003; FAO/WHO, 2010; EFSA, 2010; Merdzhanova et al., 2013). He et al. (2004) estimated in a meta-analysis of prospective cohort studies that eating fish once per week was associated with a 15% lower risk of coronary death than a fish intake of less than once per month. Some health authorities recommend that people eat two to three servings of various fish and shellfish each week (Merdzhanova et al., 2013; TÜBER, 2015). Amongst these n-3 (omega 3) fatty acids, EPA and DHA are assumed to be primarily responsible for these health effects of fish. The fundamental mechanism by which n-3 FA appears to mitigate risk of coronary heart diseases begins with enriching membrane phospholipids with EPA and DHA. It was also reported that modest fish consumption (1–2 servings/week, which is 100–200 g fish/week) was associated with a 36% lower risk of coronary death. They suggested that an intake of 250 mg/d of EPA+DHA (1 serving of fatty fish/wk) for the general population would be sufficient. Others have recommended target intakes of about 500 mg/d (Merdzhanova et al., 2013). However, the contents of EPA and DHA in different fish and fisheries products high vary. Therefore, some other health authorities made a more specific recommendation in relation to the consumption of total n-3 and total EPA+DHA intake per day/week that was discussed later in this chapter. Therefore, it is imperative to evaluate the contents of n-3, EPA+DHA in various foods, particularly fish species, since most studies have mainly reported fish as the main source of EPA and DHA (Merdzhanova et al., 2013). However, the nutritional composition of seafood is affected by various factors such as species, season, age, spawning period, feeding habits and living environment, and the handling and processing techniques (Gogus and Smith, 2010; Tufan et al., 2011; Abraha et al., 2018). Therefore, such variations in nutritional compounds can directly lead to variations in the health benefits of seafood (FAO, 2010). The main reasons for the nutritional variations in fish arise from the living habitat, which contributes to the feed inputs, and environmental effects can alter the chemical composition of these organisms. Moreover, cooking methods also impact the nutritional composition of fish (Kocatepe et al., 2011; Abraha et al., 2018). Therefore, the type of cooking and processing methods of seafood are highly concerned by the health authorities in their dietary guidelines.

Anchovy is one of the most studied seafood so far for its variation in the chemical composition, functional properties, and nutritional values. The past research demonstrated that variation could occur due to different factors, such as season, differences in the living habitats, cooking and processing methods, differences in the species (**Özden**, 2005; Kaya and Turan, 2010; Tufan et al., 2011; **Šimat** and Bogdanović, 2012; Sankar et al., 2013; Kumar et al., 2014; Czerner et al., 2015; Gencbay and Turhan, 2016; Tufan et al., 2016; Kocatepe et al., 2019; Biton-Porsmoguer et al., 2020; Reksten et al., 2020).

Anchovy is marketed mainly as fresh or frozen in many countries, and few processing techniques are also applied (Dewi, 2002; Varlık, 2004; Zaitsev et al., 2004; Köse, 2013; Kocatepe et al., 2011; Savitri et al., 2021; FAO, 2021). Due to its small size, it is difficult to use automatic processing equipment; therefore, limited processing techniques are applied to small pelagic fish species such as anchovies worldwide. Although several handling and processing equipment are available in the current market (URL-1-3), manual processing techniques are still commonly used for a better yield in the anchovy-processing sector (Köse, 2013).

The main processing methods of anchovies are known as the traditional techniques, namely, salting, drying, marinating, smoking, and fermenting

(Dewi, 2002; Zaitsev et al., 2004; Köse, 2013; Ahmad et al., 2018; Kocatepe et al., 2011; Savitri et al., 2021). Fermenting methods are usually applied in Asian and African countries, such as fish sauce and similar products, while canning and other modern processing methods are more common in developing and developed countries. However, some of the traditional techniques (e.g., salting and marinating) are also used in developed countries due to their distinct taste and aroma (Dewi, 2002; Varlık, 2004; Zaitsev et al., 2004; Ahmad et al., 2018; Kocatepe et al., 2011; Savitri et al., 2021). In Turkey, salting, drying and marinating methods are commonly applied, although marinating is mainly used at the processing plants while salting is more common at the household production (Karacam et al., 2002; Varlık, 2004; Köse et al., 2012; Koral et al., 2013; Köse, 2013; Kocatepe et al., 2011). Figure 1 shows some processed anchovies in Turkey. New product developments using anchovies have also been studied, although only a few are accepted in the commercial market (Köse and Uzuncan, 2000; Köse et al., 2001; Koral and Köse, 2005; Yerlikaya et al., 2005; Inanlı et al., 2011; Ordonez Ramos et al., 2012; Piotrowicz and Mellado, 2015; **İzci** et al., 2016; Gomma et al., 2020; Hendrayati et al., 2020). In this chapter, the nutritional value of anchovy was evaluated in terms of the major affecting factors and their contribution to human health.

A B C

Figure 1. Anchovy (Engraulis encrasicolus) products from Turkish seafood companies (Pictured by S. Köse). *A. Marinated anchovy (by MezzeMarin), B. Marinated and Smoked anchovy, C. Salted-dried anchovy* **(Çiroz**, *by Nevzat)*

Proximate Composition of Anchovy

It was reported that factors affecting fish composition could be either endogenous or exogenous. The endogenous factors are genetically controlled and are associated with the life cycle of fish. Various exogenous factors such as environmental changes and fluctuations in the availability and composition of feed are reported to affect proximate muscle composition of fish (Olsson et al., 2002; Tufan et al., 2011). Proteins and lipids are mobilized from muscle and transferred to the gonads in the reproductive period (Shearer, 1994; Tufan et al., 2011). Moreover, other factors such as temperature and salinity may also affect the proximate and fatty acid compositions in fish (Wodtke, 1981; Gökçe et al., 2004). Thus, variations in the proximate composition of anchovy from various seas have also been expected and demonstrated by past research.

Table 1 represents the proximate composition reported in various studies for anchovy compared to other fish species. although many reports for the nutritional value of seafood, many studies used single sampling in their methodology. Therefore, high variations in these studies were observed. In fact, the past research has demonstrated seasonal variations in the proximate composition, particularly on the lipid contents of anchovies, muscle, and other parts of the fish (liver and gonads). In our previous study (Tufan et al., 2011), we investigated fat content and fatty acid values of different parts of European anchovy during the fishing season of 2008–2009. We obtained the fat content of the muscle, gonads, and liver of European anchovy varied among the months and sample groups. The lowest and highest fat contents corresponded to liver sample in January as 6.52% and muscle in November as 14.98%, respectively. However, Boran et al. (2008) found the lower fat content in this month as 9.6%, while the highest value was obtained in December as 15.3% indicating the variation can also occur at different years. The differences may have been attributed to the environmental factors affecting the sea habitat, such as temperature and feed availability over the years. In their study for this species, seasonal changes were also reported for other compounds such as protein and ash levels.

Deficient levels of carbohydrates were reported for several studies in a range of 0.1%-2.2%, and the values greatly depend on the processing and cooking methods (Boran et al., 2008; Palani Kumar et al., 2014; Vijayakumar et al., 2014). Boran et al. (2008) investigated the proximate composition of European anchovy from the Black Sea. They obtained carbohydrate values in a range of 0.1%-0.7%. The values of two anchovy species (*S. commersonii* and *E. devisi*) caught from the Thoothukudi Coast of India were 0.1% (Palani Kumar et al., 2014). However, Vijayakumar et al. (2014) reported higher carbohydrate contents for *S. indicus* and *S. commersonii* as 1.1 and 0.8%, respectively, caught from S. East India's coast. The energy values were also different depending on the months in a range of 587–848 KJ/100g for European anchovy (Boran et al., 2008).

Table 1. Proximate composition of anchovy caught from different seas and some other fish species

Anchovy Species	Moisture %	Protein %	Lipid %	Ash %	References
European Anchovy (*E. encrasicolus*)	64.4-78.2	12.8-22.1	0.7-18.6	1.1-2.6	Krzynowek & Murphy (1987); Güner et al., 1998; Özden (2005); Boran et al. (2008); Kaya & Turan (2010); Öksüz & Özyılmazer (2010); Tufan et al. (2011); Şimat & Bogdanović (2012); Gencbay & Turhan (2016)
Indian Anchovy (*S. indicus*)	71.4-78.4	15.9-20.0	1.3-2.4	3.3-3.9	Edirisinghe et al. (2000); Vijayakumar et al. (2014); Reksten et al. (2020)
Longljaw (*Thryssa setirostris*)	74.7	15.9	3.6	5.0	Edirisinghe et al. (2000)
Commerson's anchovy (*Stolephorous commersoni)*	70.0-80.7	14.7-18.8	1.2-2.9	2.3-6.6	Edirisinghe et al. (2000); Sankar et al. (2013); Vijayakumar_et al., (2014); Sumi et al. (2016); Palani Kumar et al. (2014)
Japanese Anchovy *(E. japonicas)*	82.1	11.6	1.3-10.7	1.3	Krzynowek & Murphy (1987); Dewi, 2002.
Devis'anchovy *(Stolephorous devisi)*	76.2-79.7	12.0-19.0	1.1-2.4	1.0	Palani Kumar et al. (2014); Reksten et al. (2020)
Peruvian anchoveta *(E. ringens)*	79.2	17.3	1.9	1.2	Pariona-Velarde et al. (2020)
Anchovy Fishmeal (*E. enrasicolus*)	4.8-6.9	73.9-74.2	6.6-7.2	10.4-12.2	Turan et al. (2009)
Marinated anchovy (*E. enrasicolus*)	69.4-69.9	21.5-23.4	1.7	4.2-4.5	Şimat et al. (2019)
Dried ancovy (*S. commersoni*)	20.3-20.9	63.8-64.9	3.2-3.7	10.9-12.2	Ahmad et al. (2018)
Dried anchovy (*Steloporus sp.)*	11.2	59.3	2.6	11.9	Savitri et al. (2021)
Dried-salted anchovy (*Steloporus sp.*)	31.7	49.6	4.3	11.6	Dewi (2002)
Protein concentrate (*E. ringens*)	8.0	76.4	5.2	10.6	Pariona-Velarde et al. (2020)
Anchovy flour (*Steloporus sp.)*	6.4	83.0	6.0	7.8	Hendrayati et al. (2020)
Anchovy surimi (*E. anchoita*)	81.9	63.6	0.9	4.0	Piotrowicz & Mellado (2015)
Farmed A. Salmon (*Salmo salar*)	62.2	20.4	16.5		Colombo & Mazal (2020(
Boiled-Dried (*E. japoniccus*)	23.2-25.2	51.5-52.5	7.1-7.2	0.3-0.5	Kim & Heu, 2002
Sardine (*Sardinella longiceps*)	70.6	21.3	3.7	3.5	Sumi et al. (2016)
Mackerel (*Rastrelliger kanagurta*)	75.2	16.8	5.0	4.6	Sumi et al. (2016)
Horse mackerel (*Trachurus mediterraneus*)- wild	67.1-77.3	16.7-22.0	3.4-9.5	1.2-1.5	Tufan et al. (2016)
Horse mackerel- cultured	63.5-71.2	13.7-18.0	12.2-16.3	1.1-1.5	Tufan et al. (2016)
Pacific mullet (*Mugil so-iuy*)	75.4-83.7	6.5-10.5	1.2-2.8	0.6-0.8	Köse et al. (2010)
Gilthead seabream (*Sparus aurata*)	69.1	21.1	7.9	1.5	Pateiro et al. (2020)
Skipjack tuna (*Katsuwonus pelamis*)	69.0-72.6	16.0-24.5	0.7-2.6	0.6-2.4	Balogun & Talabi (1985); Karunarathna & Attygalle (2010)
Bluefin tuna (wild) (*Thunnus thynnus*)	63.3	21.0	11.0		Popovic et al. (2012)
Yellowfin tuna (*T. albacares*)	70.8-72.4	16.9-21.4	0.9-1.0	0.7-1.1	Karunarathna & Attygalle (2010)
Frigate tuna (*Auxis thazard*)	71.4-73.4	19.7-25.4	0.8-1.5	0.4-1.0	Karunarathna & Attygalle (2010)
Kawakawa tuna (*Euthynnus affinis*)	71.0-73.7	16.9-21.5	0.6-1.3	0.7-1.0	Karunarathna & Attygalle (2010)
Bullet tuna (*Auxis rochei*)	69.9-71.1	17.5-25.6	0.7-1.2	0.7-1.2	Karunarathna & Attygalle (2010)

Table 2 represents the seasonal variations in the fat content of different parts of several fish species caught from the Black Sea. A great variation was observed among species, body parts and during the seasons (Tufan, 2008; Tufan et al., Tufan et al., 2011; Balçik Misir et al., 2014; 2016). The seasonal variations were usually attributed to the fish's spawning season and feed availability in the living habitat (Llorett et al., 2007). Therefore, lower fat contents were obtained in the fish muscle during spawning seasons (Kandemir and Polat, 2007). Moreover, differences in the proximate values have been reported amongst the other parts of various fish species (Tufan et al., 2013; Gencbay and Turhan, 2016). The effect of size, age, and sex differences has also been other factors that cause differences in the proximate values of fish species, particularly the content of lipids (Köse et al., 2010).

A fish protein, which is a significant micronutrient in fish, plays a vital role in human nutrition worldwide (FAO, 2010) and has been used as the main ingredient in processed seafood, such as kamaboko (Japanese fish paste) and fish sausage (Hosomi et al., 2021). In 2017, global per capita consumption of fish was estimated at 20.3 kg, with fish accounting for about 17.3% of the global population's intake of animal proteins and 6.8 percent of all proteins consumed. Therefore, globally, fish provides about 3.3 billion people with almost 20% of their average per capita intake of animal protein and 5.6 billion people with 10% of such protein (FAO, 2021). Very high protein values have been reported for anchovy species caught from various seas, and the highest was corresponded to the European anchovy up to 22.1% (wet weight bases) caught from the Adriatic Sea (**Šimat** and Bogdanović, 2012). However, the values varied according to the studies from different seas and the seasonal changes that occurred (Boran et al., 2008; Palani Kumar et al., 2014; Sumi et al., 2016; Kocatepe et al., 2019; Reksten et al., 2020).

It is well reported that processing and cooking methods highly influence the nutritional compounds of foods. Therefore, various studies have also demonstrated the variation in the proximate composition of different anchovies and other fish species in relation to processed fish products (**Özden**, 2005; Inanlı et al., 2011). One of those effects is reducing the moisture in the fish products by salting, drying, smoking and cooking. Since the proximate composition is usually present as wet weight bases, the reduction in the moisture contents will increase the percentages of other compounds as also occurs in the values calculated as dry weight bases. However, it is a known fact that the fundamental changes can be obtained by adding other ingredients in the fish products during processing and/or cooking, such as adding the fat during cooking will increase the amount of fat and change the fatty acid contents. Inanlı et al. (2011) demonstrated that the fat content of E. anchovy in fish fillets has first decreased from 5.49% down to 2.58% after the preparation of fish cake, then increased to 6.66% after cooking in oil. They also reported that the protein content of the anchovy cake decreased from 20.87% to 5.80%. Therefore, cooking and processing methods of anchovy must be taken into account when calculating their nutritional value and health benefits for consumers.

Fatty Acid Contents of Anchovy

The fish lipids' contents and quality are critical for nutritional points since fish lipids contain long-chain polyunsaturated fatty acids (PUFAs), especially omega 3 fatty acids. These fatty acids are apparently widely accepted as part of modern nutrition because of their beneficial effects on metabolism. Most significantly, the reported protective effect of n-3 omega fatty acids in relation to cardiovascular and inflammatory diseases, cancer, and several other illnesses has led people to consider these fatty acids more beneficial than other dietary supplements (Gogus & Smith, 2010). Some of the essential PUFAs as ARA (arachidonic acid, C20:4n-6), EPA (eicosapentaenoic acid, n-3), and DHA (Docosahexaenoic acid, n-3) cannot be synthesized by mammals, and it must be provided as a food supplement. ARA and DHA are the major PUFAs that constitute the brain membrane phospholipid. n-3 PUFAs are contained in fish oil and animal sources, while the n-6 PUFAs are mainly provided by vegetable oils (Shanab et al., 2018). Therefore, beneficial effects of fish consumption on human health have been mainly related, among other factors, to their high contents of n-3 fatty acids, especially eicosapentaenoic acid (EPA: C20:5n-3) and docosahexaenoic acid (DHA: C22:6n-3) (Zlatanos Laskaridis, 2007). They are also crucial for neural development in the infant in the uterus and during the first few years after birth. Moreover, these fatty acids have a promising impact on preventing cognitive decline and dementia in older people (Strobel et al., 2012). The other health benefits of omega-3 fatty acids have been discussed in detail in various studies and reviewed by several publications (Kris-Etherton et al., 2002; Simopoulos, 2003; Gogus & Smith, 2010; Candela et al., 2011; Lee and Hiramatsu, 2011). Studies have indicated that the health benefits of these acids are mainly related to specific omega-3 fatty acids (DHA and EPA) and the ratio of omega-3/omega-6 or vice versa. Gogus & Smith (2010) pointed out that only lower ratios between 2.5:1(n-6:n-3) and 5:1(n-6:n-3) are beneficial. A daily intake of 2.5:1(n-6:n-3) has been proven to act beneficially in cases of colorectal cancer, 2-3:1(n-6:n-3) on rheumatoid arthritis, and 5:1(n-6:n-3) on asthma (Simopoulos, 2008; Gogus & Smith, 2010).

There has been a disagreement in the recommended average daily intake of n-3 omega PUFA by different health organizations, depending on the amount of other fatty acids such as linoleic, α-linolenic, and arachidonic acids. Their recommendations varied in a range of 0.2–0.45 and 0.5–1.0 g for n-3 PUFA and EPA + DHA intake, respectively (Gogus and Smith, 2010; Candela et al., 2011). However, it was suggested that 4,550 mg EPA + DHA should satisfy the weekly requirement of an adult on a 2,000-kcal diet (Simopoulos, 2003). However, epidemiological/observational studies, as well as past clinical trials, have demonstrated that higher values of n-3 PUFA, EPA, and DHA are usually needed for the treatment and/or preventive effect of various illnesses such as cardiovascular and inflammatory diseases, and neurological disorders (Kris-Etherton et al., 2002; Gogus & Smith, 2010; Candela et al., 2011). Lee and Hiramatsu (2011) revised the recommended values given by different health organizations in terms of the health benefits. They reported that healthy adults should consume 0.5 g daily EPA + DHA, while patients with coronary heart disease should consume 1.0 g.

Table 3 represents the amounts of fatty acids in various fresh and processed anchovy species caught from different seas compared with other fish species. As seen in the table, anchovy and other fatty fish species contain high omega-3, EPA, and DHA levels in their muscle and the extracted oil samples. The levels of total saturated fatty acids (SFAs) were usually found lower than total PUFAs (with some exceptions). More than half of the fatty acid methyl esters (%FAME) in the muscle oil has corresponded to PUFA in various anchovy species as well as other fish muscle samples investigated in the past studies. The higher PUFA values (over 50 % FAME) were estimated for European anchovy (*E. encrasicolus*) caught from the Catalan Sea by Biton-Porsmoguer et al. (2020) up to 50.9%, for Commerson's anchovy (*S. commersoni*) from the Arabian Sea by Sankar et al. (2013) up to 51.9%, for Peruvian anchoveta (*E. ringens*) from the Pacific Ocean by Albrecht-Ruiz and Salas-Maldonado (2015) as 56%, and Osbeck's grenadier anchovy (*Coilia mystus*) from the Yellow Sea by Cui et al. (2014) up to 56.3%. Similarly, high contents of PUFA were also found in some other fish species, namely, sardine and frigate tuna from the Atlantic and Indian oceans, respectively (Table 3).

Table 2. Seasonal variations in the fat contents of fish species caught in the Black (2008-2016)

Fish Species		January	February	March	April	August	September	October	November	December	References
A. bonito	Muscle	13.1		8.1		4.0	4.6	6.9	8.4	13.5	Balçık Mısır et al., 2014
	Liver	34.5		28.3		18.9	20.2	23.2	23.2	27.5	
Spotles Shad	Muscle	16.3	21.2	15.8						15.8	Balçık Mısır et al. 2016
	Liver	17.0	12.8	8.5						16.9	
	Gonad	6.6	4.1	5.3						8.5	
E. anchovy	Muscle	8.5	12.8	8.1	7.7		8.3	12.4	15.0	12.7	Tufan et al., 2011
	Liver	6.5	12.7	10.3	8.1		15.0	12.9	13.3	13.1	
	Gonad			10.5	8.7		14.1				
Horse mackerel	Muscle	9.0	7.7	6.6				7.3	8.4	10.6	Tufan, 2008
	Liver	27.1	35.3	32.2				27.0	28.7	30.4	
	Gonad	13.7	12.7	13.0				11.4	12.7	13.2	
Whiting	Muscle	0.7	0.7	0.7				0.9	1.0	1.1	Tufan, 2008
	Liver	44.8	44.6	38.0				38.7	39.3	64.5	
	Gonad	1.4	1.2	0.8				1.3	1.4	1.7	

Fatty acid contents of fish species as %FAME must be converted into an edible portion of the fish to evaluate its health benefits. Most past studies have investigated fatty acid content of fish as the percentage of fatty acid methyl esters (% FAME) in the analyzed extracted oil. The levels must be calculated using the fat contents in the portion of fish muscle or other parts of fish. This was calculated using the specific formulae given by different publications (Exler, 1975; Weihrauch et al. 1977; Greenfield and Southgate, 2003; Tufan and Köse, 2014). The formulae are;

FA content (g FA per 100 g edible fish muscle/gonad/liver) = [FAME% x FACF x lipid
Content % (g lipid/100g food)] = 100,
where FAME is fatty acid methyl esters, FACF: the lipid conversion factor (fatty acid conversion factor, g FA g^{-1} lipid).

FACF is reported as 0.899 for fish gonads/caviare/roes and 0.919 for fish liver (J. Exler, 2013, Personal Communication). FACF for fish muscle was calculated for each month separately from the formulae as suggested by Exler (2013, Personal Communication) and Weihrauch et al. (1977); Factor (finfish) = 0.933 – (0.143/TL); where TL refers to the total lipid of fish muscle. The reason of using such formulae was explained in the relating references.

Table 4 represents fatty acid contents of several fish species, including anchovy as g/100 g of fish portion (muscle, liver and gonad). The given data highlight the importance of total fat in the fish in calculating the actual amount of the related fatty acids in the edible fish portion. Although high percentages of PUFA, EPA and DHA have been observed in several fish species such as the Black Sea whiting (*Merlangius merlangus euxinus*), the actual values in the edible portion were accounted for very low, such as muscle samples due to meager contents of fat in this fish species (Tufan and Köse, 2014). However, high values were found for species with high-fat contents and high percentages of FAME in their extracted oil.

Anchovy species usually have high-fat contents (%) as well as higher omega-3 fatty acids, particularly EPA and DHA (%FAME) during their catching seasons. The actual levels of these fatty acids in the muscle of fish increase with the increasing fat contents based on the seasonal changes. For example, Tufan et al. (2011) has demonstrated that the amounts of total PUFA, n-3, and EPA+ DHA have almost increased twice as much with doubling the fat contents during the catching season. Anchovy in the Turkish Black Sea is caught between September until the end of March. The higher fat contents were obtained between October and February (except for January when a lower value was obtained by Tufan et al., 2011). A similar trend also occurred for the levels of %FAME in relation to total PUFA and EPA+DHA except April. The amounts of these fatty acids in the edible portion of anchovy muscle (mg/100 g) also showed the same trend as the levels first increased from September to December (which was the highest), then decreased in January, followed by a fluctuation with increase and decreasing levels. Although the changes can also occur depending on the years due to environmental factors, it is recommended that the anchovy be consumed during the catching season, usually colder seasons. However, further studies are advised to confirm these findings in relation to the sea temperature. According to the results obtained by Tufan et al. (2011), in November, about 130 g of anchovy edible meat is found to be in the satisfactory level for EPA + DHA according to the recommended weekly requirement while almost twice the higher amount needed to cover the same requirement in September. Gogus and Smith (2010) also reported high variation in the amounts (g) of some fish species which should be consumed to provide 1 g EPA and DHA. The lowest value was reported for herring (as 45-60 g), which is a fatty fish, and the highest was cod (as 375-750 g) that is a lean fish. The fat content of herring was reported as 18%, while cod had 0.6% (Gogus an Smith, 2010). Therefore, these findings also support the relationship between the fat contents of fish and their omega-3 fatty acids, with some exceptions. The disagreement with the fat contents of fish and their levels of omega-3 fatty acids can usually occur with the species being freshwater or being cultured since they usually are fed with oils of plant origin. Justi et al. (2003) reported that the fatty acid composition of freshwater fish is characterized by high contents of n-6 PUFA and mainly of linoleic and arachidonic acids. It was also reported that there is usually a reduction in the n-3/n-6 ratio in the farmed fish resulting from fish feeds rich in terrestrial plant oils (Lenas et al., 2011). Various studies comparing wild and aquaculture fish species confirmed this finding (Nettleton and Elmhurst, 2000; Afkhami et al., 2012; Trbović et al., 2012; Yeşilayer and Genç, 201; Tufan et al., 2016). Although α-linolenic acid (ALA; 18:3n-3), a precursor of the n-3 family of fatty acids, is found in appreciable amounts in green leaves, stems, and roots, the major sources of EPA and DHA are algal, fish, and other marine oils. Marine fish obtains EPA and DHA contents, usually from marine algae (Shahidi and Senanayake, 2006). Therefore, high levels of n-3 fatty acids, particularly EPA+DHA are expected in marine fish compared to freshwater fish. High levels of n-6 fatty acids have been reported for the oils of terrestrial plants (Strobel et al., 2012). Thus, the diet of fish , which is either freshwater or cultured fed these plants/their oils, can lead to high levels of n-6 fatty acids. However, feed used for aquaculture usually contains high amounts of fish meal and fish oil, particularly anchovy origin. Therefore, high levels of omega-3 fatty acids, particularly EPA and DHA are also expected in the cultured species since cultured fish is highly affected by its diet (Trbović et al., 2012).

Tocher (2010) demonstrated that essential fatty acid (EFA) requirements vary qualitatively and quantitatively with both species and during fish ontogeny, with early developmental stages and broodstock being critical periods. Environment and/or trophic levels are major factors, with freshwater/diadromous species requiring C18 PUFA whereas marine fish have a strict requirement for long-chain PUFA, eicosapentaenoic, docosahexaenoic and arachidonic acids. Therefore, they specified the importance of considering the physiological requirements of the fish when planning changes in feed formulations being forced upon the aquaculture industry by the pressing need for sustainable development, namely, the replacement of marine fish meal and oils with plant-derived products. Anchovy is a pelagic fish species whose high percentages are used to produce fish meal and oil due to its small size and high catch at a limited time to be consumed for human consumption. Although its use in aquaculture helps increase the nutritional compounds, particularly the levels of omega-3, of the farmed species, the current attempts for the anchovy oils for human consumption are rather promising for the better use of this species for human health purposes. In Turkey, over the past 5 years, one fish meal and oil company has started to change their processing unit suitable for human consumption for the oil production from anchovy (URL-4). This will lead to future companies to market their fish oil at a better price while helping to use anchovy as a more beneficial way for human consumption (Köse, 2014; Köse, 2015; Köse, 2017). Kaya and Turhan (2008) obtained 17.8%-19.0% n-3 PUFA, with 6.3%-9.4% representing EPA and 8.8%-10.3% for DHA. Only 3.15%-4.1% was accounted as n-6 PUFA. In later years, we found the total EPA+DHA levels of anchovy oil were accounted for over 25% (Tufan et al., 2009). In the related study, we have obtained fish meal and fish oil samples from three different processing companies, one from Georgia and two from Trabzon, Turkey. High protein content up to 74.2% was obtained, while the lower value was found for the samples of one company as 58%. In the samples containing the lowest protein content, the moisture content was also high, over 16% which was not up to the standards given for fishmeal. The other parameters were found within the permitted level. Fatty acid contents of fishmeal also varied in a range of 4.13%-6.60% for EPA, 14.52%-19.45% for DHA. The values of fish oil were also close to the levels obtained for fish meal as 5.04%-6.72% and 14.6%-19.72%, respectively. Therefore, anchovy meal and oil from the processing companies of Turkey are highly acceptable by the international market (Tufan et al., 2009). Thus, anchovy also provides high nutritional value for animal feed usage, particularly for aquaculture.

The changes in the fatty acid profile of processed fish have also been investigated for different fish species, including anchovy. Czerner et al. (2015) demonstrated that n-3 PUFA was higher than n-6 PUFA in salted, salted-ripened anchovy (*E. anchoita*) while the opposite situation has occurred for marinated anchovy. However, n-3 values, particularly DHA levels, were accounted relatively high after the calculation of the data in g/100 g of the edible portion as the fat content of marinated anchovies were higher than the other samples (Table 3 and 4). The lowest EPA and DHA corresponded to the salted samples in oil. Several other scientists investigated the effect of different processing and cooking methods on the changes of nutritional compounds of fish species, including anchovy (Kocatepe et al., 2011; Abraha et al., 2018). They observed a great variation in the fat content and fatty acid profile of fish, mainly additional fat during cooking such as frying. The moisture content of raw anchovy decrease after these cooking methods, while fat contents increase as percentage of the expected wet weight bases. Therefore, the nutritional value of anchovies also depends on the cooking and processing methods.

Table 3. Fatty acid levels of fresh and processed anchovy species compared to some other fish species

Species	ΣSFA	ΣMUFA	ΣPUFA	ΣEPA	ΣDHA	Σn3	Σn6	Origin	References
European Anchovy (*Engraulis encrasicolus*)	33.5-43.5	17.2-15.6	39.3-50.9	9.0-14.1	25.2-32.0	35.3-47.5	3.4-4.0	Catalan Sea	Biton-Porsmoguer et al. (2020)
	41.3	11.2	48.1	10.1	29.5	40.3	6.0	Aegean Sea	Kocatepe et al. (2019)
	32.4	31.4	36.2	8.3	12.3	22.7	9.6	Black Sea	Kocatepe et al. (2019)
	32.9	32.2	34.8	4.4	12.1	16.5	13.0	Marmara Sea	Kocatepe et al. (2019)
	36.6	23.8	39.6	11.1	20.7	33.4	6.1	Black Sea	Gencbay & Turhan (2016)
	42.6	19.4	38.6	12.0	15.6	29.2	9.4	Mediterranean Sea	Küçükgülmez et al. (2013)
	29.8-37.6	18.8-22.5	32.0-38.5	10.7-14.1	13.0-18.8	25.4-32.6	3.2-6.5	Black Sea	Tufan et al. (2011)
	36.8	27.6	24.6	8.6	12.0	21.5	2.2	Black Sea	Turhan et al. (2011)
	33.4-37.9	25.9-30.9	34.0-36.2	9.5-11.6	14.0-19.0	29.4-31.2	3.7-5.2	Black Sea	Öksüz & Özyılmaz (2009)
	29.1-46.6	11.90-23.0	24.7-48.0	2.5-12.4	12.2-32.5	20.8-42.7	1.6-3.4	Mediterranean Sea	Zlatanos et al. (2007)
	31.2	21.0	36.2	10.0	18.5	29.4	5.9	Marmara Sea	Özden (2005)
Anchovy (*S. commersoni*)	51.0	16.6	24.5	2.9	13.8	18.9	1.2	Arabian Sea	Sumi et al. (2016)
	24.0-57.3	17.2-36.6	23.4-51.9	2.9-5.0	9.9-22.5	13.0-29.8	4.3-15.9	Arabian Sea	Sankar et al. (2013)
Anchovy (*S. indicus*)	37.6	10.6	46.6	7.1	28.6	38.8	7.5	Indian Ocean	Reksten, et al. (2020)
Devis' Anchovy (*E. devisi*)	37.3	12.4	43.9	8.3	25.3	36.6	7.0	Indian Ocean	Reksten, et al. (2020)
Anchovy (*E. anchoita*)	18.2	36.8	44.9	4.5	22.6	31.8	8.7	S. Atlantic Ocean	Czerner et al. (2015)
Anchovy (*E. ringens*)	30.0-46.0	12.0-26.8	26.0-56.0	8.9-14.7	13.0-35.6	25.3-55.7	0.5-1.0	Pacific Ocean	Albrecht-Ruiz & Salas-Maldonado (2015)

Table 3 continue…

Anchovy (*E. japonicus*)	37.2	21.2	23.9	5.2	9.2	18.8	5.1	Yellow Sea	Wan et al. (2010)
Anchovy (*Coilia mystus*)	28.8-36.5	9.5-19.2	49.7-56.3	10.4-11.5	30.8-39.6	45.8-53.1	3.20-9.1	Yellow Sea	Cui et al. (2014)
Anchovy Fish Meal (E. encrasicolus)	33.0-56.1	11.0-19.9	22.6-38.4	4.1-6.6	14.5-9.5	18.7-26.0	4.9-18.9	Black Sea	Tufan et al. (2009)
Anchovy Fish Oil (*E. encrasicolus*)	33.6-42.8	5.5-29.5	21.5-45.6	5.0-9.4	8.8-19.7	17.8-26.4	3.15-18.5	Black Sea	Kaya & Turan (2008); Tufan et al. (2009)
Marinated (*E. anchoita*)	17.8	30.5	65.9	1.5	4.8	10.2	41.6	S. Atlantic	Czerner et al. (2015)
Brined (*E. anchoita*)	26.9	39.5	33.7	5.2	25.2	30.5	3.2	S. Atlantic Ocean	Czerner et al. (2015)
Salted-ripened (*E. anchoita*)	25.6	49.9	24.2	3.8	14.2	21.4	2.2	S. Atlantic Ocean	Czerner et al. (2015)
Sardine(*S. pilchardus*)	25.6-28.8	18.2-24.7	39.8-50.2	10.7-26.0	9.6-22.2	31.5-36.4	1.5-1.9	Atlantic Ocean	Bandarra et al. (1997)
Sardine (*S. lalongiceps*)	41.7	20.8	35.0	20.1	5.4	26.6	1.3	Arabian Sea	Sumi et al. (2016)
Canned Sardine (in olive oil) (*S. pilchardus*)	18.1	70.8	9.7	1.7	1.6	4.1	5.6	Mediterranean Sea	Mesias et al. (2015)
Trenched sardinella (*Amblygaster sirm*)	36.8	11.6	47.0	8.0	28.9	40.3	6.4	Indian Ocean	Reksten, et al. (2020)

Species	Total Fat %	ΣPUFA g/100g	ΣEPA g/100g	ΣDHA g/100g	Σn3 g/100g	Σn6 g/100g	Origin	References
E. Anchovy *(E. encrasicolus)* muscle	7.7-15.0	2.40- 4.63	0.75- 1.38	1.02- 2.21	2.01- 3.76	0.23- 0.75	Black Sea	Tufan et al. (2011)
Anchovy (*E. anchoita*)- fresh	4.3	1.91	0.19	0.96	1.35	0.36	South Atlantic Ocean	Czerner et al. (2015)
Salted-ripened	4.6	2.31	0.37	1.36	2.05	0.10		
Fillets in oil	5.7	2.95	0.08	0.27	0.58	2.37		
Canned	6.2	3.44	0.27	1.17	1.67	1.77		
Marinated	6.8	3.37	0.37	2.14	2.50	0.87		
Horse mackerel (*T.mediterraneus*)-Wild	3.4-9.5	0.84- 2.36	0.28-1.35	0.41- 1.51	0.44- 2.21	0.07- 0.33	Black Sea	Tufan et al. (2016); Tufan et al. (2018)
Cultered	12.2-19.7	3.22- 4.12	0.33-0.62	0.80- 1.40	1.67- 2.70	1.38- 1.91		
A. bonito (*Sarda sarda*)- mMuscle	4.0-13.5	1.45-5.30	0.25-1.17	0.71-3.32	1.12-4.42	0.28-0.80	Black Sea	Balçik-Misir et al. (2014)
Liver	18.9-34.5	3.22-13.47	0.97-3.23	0.16-6.99	1.35-11.76	1.00-1.89		
Red Mullet (*Mullus barbatus*)	3.5-7.5	1.10-2.27	0.22-0.40	0.26-0.66	0.64-1.35	0.30-0.67	Black Sea	Tufan et al. (2018)
Garfish *(Belone belone euxini)*	8.3-11.5	3.46-4.18	0.34-0.49	2.18-2.26	2.88-3.45	0.43-0.51		
Whiting (*Merlangius merlangus euxinus*)- muscle	0.9-1.6	0.37 -0.77	0.05-0.11	0.23-0.50	0.34-0.70	0.02-0.07	Black Sea	Tufan & Köse (2014)
Liver	33.1-64.5	17.0 -27.7	10.0-18.1*		14.6-24.9	1.5-3.2		
Gonads (Roe)	0.9-1.4	0.40- 0.57	0.26-0.45*		0.32-0.52	0.07-0.17		

Table 4. Variations of fatty acid contents in the g/100 g of the edible portion of various fish species, including anchovy
*** The data was given as åEPA+DHA**

Amino Acid Contents of Anchovy

Several studies have reported the amino acid values of anchovy species in the Black Sea and other seas (**Özden**, 2005; Gencbay and Turhan, 2016; Kocatepe et al., 2019). However, there have been some differences in the presentation of the values as some reported the percentages of individual amino acids in total amino acid contents, while others presented the values in mg/100 g of the edible portion of the fish. Therefore, it is not easy to compare the relating values. In fish, amino acids are the main components of non-protein nitrogen, accounting for 50%–85%, and the most important amino acids from a quantitative viewpoint are reported as proline, arginine, glycine, alanine, histidine, glutamic acid, and taurine. In cooked fish, amino acids are directly responsible for flavour and taste and can be precursors of aromatic components (**Özden**, 2005).

Kocatepe et al. (2019) compared the amino acid values of anchovy species caught from three different seas of Turkey. They found the highest essential amino acid corresponded to the samples obtained from the Aegean Sea as 13.86 mg/kg and the lowest to the Marmara Sea as 10.64 mg/kg. The essential and non-essential amino ratio was found the highest for the anchovy caught from the Black Sea as 1.31.

Free amino acids give the fish meat a characteristic taste. Although the level of total sweet amino acid components was higher in the Aegean Sea anchovy than the anchovy caught from other seas, the total bitter amino acid was also higher than the other groups. Amongst the amino acids, free glutamate has an umami taste; however, glutamate in proteins has no taste. This might explain why the consumer preferred the Black Sea anchovy compared to the Aegean anchovy despite its higher glutamate values than the Black Sea anchovy.

The World Health Organization's (2007) reported the adult daily requirement of protein and amino acid for human nutrition as 0.83g/kg for protein and the essential amino acids; leucine as 59 mg/g, lysine as 45 mg/g, isoleucine as 30 mg/g, threonine as 23 mg/g and methionine as 16 mg/g. According to the findings of Kocatepe et al., (2019), about 80 g of European anchovy meat meets the daily consumption of leucine, lysine, isoleucine, threonine, and methionine requirements. Additionally, 320 g anchovy consumption is enough for daily protein requirements.

Gencbay and Turhan (2016) reported a variation among the amino acid levels in different parts of the anchovy caught from the Black Sea. They obtained the most abundant amino acid in all anchovy sections was glutamic acid (14.61–19.11%), followed by aspartic acid (12.52–15.10%), and the least abundant amino acid was threonine (0.49–1.67%). Their results explain the contribution of glutamic acid to the taste of anchovy from this sea. Similar results were also reported for other studies in relation to different fish species, such as yelloweye rockfish (Oliveira et al., 2009) and the Pacific Ocean perch (Bechtel et al., 2010). The total content of essential amino acids in anchovy whole fish, fillets, and by-products varied from 27.38 to 39.55%, and the most abundant essential amino acid was lysine (6.19–9.34%) (Gencbay and Turhan, 2016). Sankar et al. (2013) reported variations in the amino acid levels in the different sizes of anchovy (*S. commersonii*). Sumi et al. (2016) investigated the amino acid composition of sardine (*Sardinella longiceps*), mackerel (*Rastrelliger kanagurta*) and anchovy (*S. commersoni*). The most abundant essential amino acids in the three species were leucine followed by lysine, isoleucine, and phenylalanine. In the relating study, mineral contents were also compared within the species. Calcium and potassium contents were higher than other species as 0.93 and 1.89%, while the amount of sodium was lower than 0.4%.

Mineral Contents of Anchovy

Recently, Reksten et al. (2020) investigated the mineral contents of 19 fish species, including two anchovy species (*S. indicus* and *E. devisi*). They demonstrated that the mean calcium values for small and large species showed significant variations with a mean content of 960 mg/100 g for small species and 100 mg/100 g for large species. They reported that calcium presented in the anchovy potentially contributes at least 500-mg calcium when a portion of 100 g is consumed, thus accounting for ≥50% of the recommended nutrient intake (RNI). However, lower contributions to daily the RNI for zinc and iron were reported for these anchovy species. Sankar et al. (2013) demonstrated the mineral contents of the anchovy can significantly differ in different sizes. Gencbay and Turhan (2016) investigated the mineral contents of European anchovy from the Black Sea. Their results showed that anchovy from the Black Sea is a prosperous source of iron, phosphorus, potassium, and zinc (Table 5).

Vitamin Contents of Anchovy

Few studies have also investigated the vitamin contents of anchovies. Aakre et al. (2020) reported that about 100-g anchovy (whole fish) (*E. enrasicolus*) in the diet would contribute substantially to the RNI for vitamin B12, vitamin D, and vitamin A. However, further studies are required for this species caught from the Black Sea.

Table 5. Variations in the mineral contents of different anchovy species

Minerals/Ref.	*E. encrasicolus* (Gencbay & Turhan, 2016)	Encrasicholina (S.) devisi (Palani Kumar et al., 2014; Reksten et al., 2020)	S. indicus (Reksten et al., 2020)	*S. commersonii* (Sankar et al., 2013; Kumar et al., 2014)
Calcium (mg/100 g)	415	550-715	620	440-730
Iron (mg/100 g)	7964	0.6-1.7	2.0	2.8
Iodine (µg/100 g)		177	20	
Magnesium (mg/100 g)	112	83	51	10-30
Phosphorus (mg/100 g)	955	15-510	590	34
Potassium (mg/100 g)	1070	300	440	1220-1890
Selenium (µg/100 g)		56	44	
Sodium (mg/100 g)	325	460	160	
Zinc (mg/100 g)	8647	2.4	2.2	10

Conclusion

The health benefits of seafood greatly depend on their nutritional contents, which highly vary amongst the species affected by various factors. Anchovy is used as human food since ancient times. Its popularity as food recently has increased since it has an excellent source of metabolically essential proteins, vitamins, trace elements, and polyunsaturated fatty acids associated with various health benefits. Therefore, in this chapter, the past research on the nutritional value of anchovy species has been evaluated depending on the different factors causing the variations and discussed in terms of their health benefits for human consumption. Extensive studies have been conducted on the proximate composition and the contents of fatty acids, amino acids, minerals, and vitamins in different anchovy species caught from different seas. The effects of seasonal changes, living habitat, differences in the body parts, cooking and processing techniques, and storage conditions have been reported on the nutritional composition of anchovies. Despite high variations in the values, anchovies are rich sources of omega-3 fatty acids, particularly eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA), which are essential for developing brain and heart tissues. Anchovy also contains high amounts of essential and non-essential amino acids in a balanced proportion capable of easing protein deficiency disorders. Moreover, it provides a good contribution of various minerals and vitamins to a healthy diet.

The consumption of omega-3 fatty acids, particularly EPA+DHA has been associated with the prevention of many diseases, particularly cardiovascular diseases. However, the studies proved that the contents of these acids in fish species, including anchovy, vary depending on the above factors, particularly the seasonal effects. Thus, while the consumption of anchovy once a week can be enough to cover the recommended weekly requirement of EPA+DHA during certain months of the year, higher values may be needed for other times. Similarly, the amounts of cooked or processed anchovy will contribute different amounts to recommended fatty acids, leading to the variations in the required servings of anchovy per day/week in the human diet. Although the catch season of anchovy seems to provide the right contribution of omega-3 fatty acids as well as the other nutritional compounds for a healthy diet in human consumption, the catching seasons should be revised at least every 5 years according to the environmental changes and the past studies on the nutritional compounds. Moreover, the nutritional database concerning anchovy should be updated according to the recent findings, and to the cooking and processing methods.

A great proportion of anchovy production is also used for animal feed, particularly in the aquaculture sector. There have been disputes on limiting the use of anchovies for animal diet. However, further studies should be conducted on evaluating the advantages and disadvantages of replacing fishmeal and oils with plant-derived products in relation to the economic issues and nutritional points of view. Moreover, the fish's physiological requirements should also be taken into account when planning the changes in the feed formulations being forced upon the aquaculture industry. Since different parts of anchovy also contain high nutritional compounds, better use of anchovy by-products is advised for future sustainable fisheries.

Due to its small size, processing methods of anchovies are minimal, and they are mainly used as fresh for human consumption. Therefore, more advanced processing methods should be applied to the production of functional foods or nutraceuticals from this species, e.g., fish oil capsules. In conclusion, anchovy has high nutritional value, and therefore, it can help alleviate food crises in many developing countries, providing a valuable supplement to a diverse and nutritious diet.

In summary of summary, the health benefits of seafood, particularly fatty fish such as anchovies, are commonly known. Since the highest world fish production comes from anchovy, its consumption as human food is highly important to get the highest benefit from its nutritional value as well as preventing various diseases such as cardiovascular diseases. Since it has a high value of omega 3, therefore, making an omega 3 Supplemented medicine derived from anchovies would be an affordable and budget-friendly choice.

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Anchovy's long history

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ÖZET

Karadenizlinin hayatında ve kültüründe hamsinin olduğu yere sahip olan dünya denizlerinde başka bir balık türü var mıdır bilinmez ama ülkemizde diğer balıkların hamsinin saltanatını ele geçirmesi çok zordur. Bu gerçek balıkçılık tarihimiz boyunca hiç değişmemiştir. Karadeniz'in incisi hamsi, ticarette, sanatta ve edebiyatta o kadar hayatın içine girmiştir ki adeta kültürün bir parçası olmuştur. Hamsi hiçbir yerde Karadeniz'de olduğu gibi yerel halkın yaşamıyla bütünleşmiş ve iç içe geçmiş ve hatta günlük yaşamın vazgeçilmez bir parçası, bir yaşam tarzı haline gelmemiştir. Karadeniz insanının sosyal, kültürel ve ekonomik hayatının bir parçası olan hamsi, yüzyıllardır onunla kimliğini tamamlamıştır. Onlar için hamsi bir yaşam tarzıdır. Belki de var olmak için önemli bir motivasyondur.

Geçmişten günümüze Karadeniz balıkçılığın gelişmesinde, tabiatın sunduğu sonsuz imkânların yanısıra tarihin derinliklerinden gelen bazı konjektürel ve siyasi şartlar da etkili olmuştur. Ticaretin modernleşmeye başladığı 16. 17. ve 18. yüzyıllarda; yeni üretim ve tüketim alışkanlıklarından transit ticaret merkezi olarak kar sağlamışsa da; artan nüfus yerli tarımsal üretimle karşılanamamıştır. Osmanlının son dönemlerinde tütün, Cumhuriyet döneminde ise fındık ve çayın bölgede nam kazanması ahalinin denize, balıkçılığa, hamsiye karşı olan ilgisini hiçbir zaman azaltmamıştır. Bölgedeki tarımsal üretimin yetersizliği tarıma dayalı ekonominin gelişimini engellemiştir. Geçimlik/köy ekonomisinin geleneksel ürünü hep mısır olmuştur. Bu nedenledir ki; hamsi mısır ile birlikte sahil insanlarının birincil gıdası olmuştur yüzyıllar boyunca. Seksenli yılların öncesine kadar hamsi Karadenizli haneler için vazgeçilmez bir nimetti. Av sezonu boyunca taze tüketildiği gibi, av sezonun dışında tuzlu/salamura olarak saklanırdı. O yıllarda fazla avlanan hamsinin tütün tarlalarına, fındık bahçelerine gübre niyetine verilmesi alışkanlık haline gelmişti. Osmanlı dış borçlarının ödenmesi için kurulan '*Duyun-i Umumiye*'nin bir kuruluşu olan '*Reji İdaresi*' faaliyete başladıktan sonra Doğu Karadeniz'de, özellikle Trabzon'da tütün alımının artması ile birlikte avlanan hamsi de gübre niyetine tütün

tarlalarına dökülmeye başlamıştır. Bölgedeki tarımsal üretimin yetersizliği, tarıma dayalı ekonominin gelişmesini engellemiş ve kırsal ekonominin genel ürünü olan hamsi ve mısır, kıyılarda yaşayan insanların yüzlerce yıldır temel gıda maddesi olmuştur. Zorlu iklim ve çevre koşullarıyla mücadele eden Karadeniz insanının balıktan daha fazla anlam ifade ettiği hamsi, yöre mutfağının da en önemli protein kaynağıdır. Karadeniz mutfağına nereden bakılırsa bakılsın bütün yollar hamsiye çıkar. Kuşkusuz bu kavram, Karadeniz kıyılarında başlayan hızlı kentleşme ve beraberinde getirdiği kültürel değişim ve beslenme seçenekleri ile 21. yüzyıldan itibaren değişmeye başlamıştır. Ekmekten pilava, buğulamadan ızgaraya, undan yağa kadar geniş bir yelpazeye sahip olan ve fıkralara konu olan hamsi, Karadeniz bölgesinin ve kültürünün en önemli simgesidir. Kış mevsiminin yaklaşmasıyla birlikte yolları izlenir ve yılın üç dört ayı sofraların en önemli yemeğidir. Hamsi balıkçılığının yanı sıra pazarlama, ulaşım ve lokanta gibi alt sektörleri ile yerel ekonominin önemli faaliyet alanlarından biridir ve birçok insanın 'ekmek kapısı' konumundadır.

Bu çalışmada Karadeniz'deki balıkçılığın temelini oluşturan hamsinin tarihsel, kültürel, sosyolojik ve ekonomik serüveni uzun bir geçmiş perspektifi ile ele alınmış ve bütüncül bir metin ile ortaya konulmaya çalışılmıştır. Hamsi ne salt denizde balıkçıların avladığı ticari bir meta, ne toplumdaki her ekonomik sınıfın tükettiği bir besin türü, ne de tarihini tamamlamış bir deniz canlısıdır. Bu metinde hamsinin geçmişten günümüze kadar ve halen devam eden yolculuğu geleneksel ve otantik kültürel ögelerle renklendirilerek okuyucuya aktarılmaya çalışılmıştır.

Important events related to anchovy in historical periods

Fishing in the Black Sea has an important place both in terms of nutrition and trade. Black Sea fishermen have gained a lot of knowledge about fishing with the experiences passed down from generation to generation. It is known that the city of Trabzon, which had an important position in the Black Sea in the XV and XVI centuries, was very developed in terms of fishing. As a matter of fact, taxation of every fish type caught in the '*Trabzon Legislation*' should be a sign that fisheries have developed (Konan, 2006). Again, it is recorded in the law code that fish oil is produced from surplus fish and that this oil is sold in Christian neighbourhoods and the acquisition official is taken from this fish oil. **Âşık** Mehmed in his book *'Menâzırü'l-avâlim (1598)*' (Hegan, 1998) stated that delicious fish were caught in the sea of Trabzon, Evliya **Çelebi** recorded in *'Seyahatname'*

(Dağlı and Kahraman, 2005) that one of the seven business lines that Trabzon people deal with is fishing, and It shows that the number of people engaged in fishing has reached a significant number. Again, **Âşık** Mehmed and Evliya **Çelebi** noted that there were plenty of anchovies, haddock, turbot, sea bass and mullet, red mullet, mackerel, horse mackerel fish in the Trabzon Sea (Picture 1).

Picture 1. A castle in the Kemerkaya district of Trabzon from the Roman period; Frenk Hisar (Venice) Castle. The castle was used by Venetian merchants between 1150 and 1660 AD.

Sources of fishing activity in the Black Sea are not limited to these. **Şâkir Şevket** notes that '*The inhabitants of the seaside are fishermen and they hunt large amounts of dolphins*'. Darüşşafaka Director Major Hüseyin Bey stated in his textbook that he wrote in 1885 that turbot was fished in the Black Sea and anchovy was hunted mostly on the shores of Trabzon and Samsun provinces; Tüccarzâde İbrahim Hilmi states that there are petroleum gas vessels and sources on the beaches called Old Trabzon and Kemer, flowing from the open to the sea, and therefore the fishes smelled their meat (Yüksel, 2007).

According to the '*Salname*' dated 1888 (Emiroğlu, 1999), which contains valuable information about Trabzon province, anchovy, turbot, coral, haddock, bonito, mullet, pike, garfish are the leading fishes that are caught and sold in the sea. Anchovies were sold very cheaply when the season came. Because it was cheap, the poor were taken by the peasant in sufficient quantities and salted, thus providing food for the children. Anchovy, which is less than a little smaller than ordinary sardines, is delicious and oily, but is too salty, after being eaten by those who are not used to it, it was a great boon for the people of the coast. Each batman of anchovy, which was produced in abundance in 1893, was sold from two kuruş to twenty-thirty money.

Trabzon Governor Kadri Bey, in a telegram dated 13 November 1892, which he sent to the Mabeyn-i Hümayun Chief Inscription, stated that many families working in trades such as boating and fishing in Trabzon suffered damage due to quarantine and cordoning, and they were in need. Stating that they fell, asked these people for help. On this supply of Kadri Bey, there is a record that a hundred lira was sent to the fishermen and fishermen who became victims in Trabzon province 27 February 1893 (Emiroğlu, 1999).

There were fishermen from the Ottoman country, especially from the Black Sea coast, as well as fishermen from Russia, who went to Russia every August to fish. These fishermen who went to Russia to earn a living would also have fought with the Russian fishermen. Such a fight was fought between Russian fishermen and fishermen who went from Lâzistan (Rize) and Sürmene County in the city of Kerch in Crimea during the 1909 fish season. Upon this development, the Ministry of Foreign Affairs asked the Ministry of Internal Affairs in 1910 to warn the fishermen who will go to Kerch for fishing in season, to follow the advice of the shahbenders by the local administrators (Emiroğlu, 1999).

Karekin Deveciyan, one of the directors of Istanbul Fish Market, is among the fish species that are caught and sold between **İnebolu-Hopa** fishing ports on the Black Sea coast, mainly anchovy, red mullet, horse mackerel, butts, turbot, black bream, rock, gray mullet, swordfish, sea bass, bluefish, sturgeon, whiting, states that there are species such as tuna, bonito, flounder, shad, torik (big bonito), dolphin, garfish (Deveciyan, 2006). Again, according to the author, fish weighing 3,393,300 kg and valued at 6,211,500 kuruş were sold in Black Sea ports in one year. These fish sold are worth 1.200.000 kuruş (19.3%) in Trabzon port, 350.000 kuruş (5.6%) in Sürmene port, 300.000 kuruş (4.8%) in Rize port, 150.000 kuruş (2.4%) in Pazar port, 450.000 kuruş in Giresun port. (7.2%), 140.000 kuruş (2.3%) in Tirebolu port, 180.000 kuruş (2.9%) in Ordu port, 350.000 kuruş (5.6%) in Samsun and Terme port, 1.200.000 kuruş (19.3%) in Sinop port, **Çatalzeytin** It has been traded over 7.000 kuruş (0.1%) at its port (Deveciyan, 2006).

It is noteworthy that the Russian navy, which surrounded the Black Sea coast during the First World War, was harassed by the was

Black Sea fishermen. As a matter of fact, it was reported that Russian torpedoes caught especially young children among the fishermen who were opened from the beach and tried to get intelligence from them. As a precaution, it was decided that the fishermen under the age of 18 should not sail on the Zonguldak beaches, while the others should not go more than 2 miles from the coast and return immediately when they see a ship on the horizon. The same was true for the eastern coasts of the Black Sea. Orders were sent to these places, and they were asked to take measures. As a matter of fact, Kastamonu Governor Reşid Bey stated that, except Zonguldak, children were not allowed to wander and fish on the piers 10 February 1915; The governor of Trabzon, Cemâl Azmi Bey, stated that fishing in the Lazistan completely prohibited, that those under the age of twenty in the central and affiliated provinces strictly required to obtain a certificate from the port offices to fish, and that all fishermen were warned not to sail more than a mile from the coast February 10, 1915. Despite the measures taken, it was also happening that Russian torpedoes caught some fishermen and took them with them. As a matter of fact, a Russian torpedo coming from Batumi on the January 8, 1916, landed a boat off Mahrikale and left the fishermen and children that he had caught before to the beach. Of those released, there were about twenty people, seven of whom were elderly and 13 were children between the ages of twelve and thirteen. These fishermen left by the enemy torpedo were from Civra village of Sürmene and there were 27 more people waiting to be released. Although measures were taken to protect the fishermen against Russian torpedoes, it was also possible that some Greek and Armenian origin people, who were officially allowed to fish, crossed over to the enemy side (Yüksel, 2007).

It is known that Black Sea fishing, which entered a period of stagnation during the war years, continued in the traditional manner after the war and in the first years of the Republic, before the coastal road was built (1964-1966) and in the years when trawling technique was not yet available. Küçüklü, Eriklimanı, Burunucu villages of Bulancak in Giresun-Ordu province in the 1940s; Zefre (Gülburnu) village of Espiye; Keşab's Kulak location; Kaleyka, Mersin and **Çınar** villages of Vona (Perşembe); Yeniköy district of Tirebolu; Ordu's Bozukkale were mainly fishing villages. Espiye, Zefre-Kulak, Keşap in front and Giresun Island, Batlama and Güre stream mouths, Ayvasıl-Burunucu in front, the mouth of Pazarsuyu stream and around Yason Cape were the main fishing areas (Yüksel, 2007).

Anchovy: Traces of the Black Sea's socio-cultural life

While the anchovy and Black Sea life began to be included in the Ottoman "public knowledge" relatively, it is witnessed that an interest in anchovies started to revive in the educated class in Trabzon. As seen in Hamamizade İhsan's book '*Hamsiname*' under the title of '*Anchovies in Literature and Humour*', (Hamamizade, 1928) poems describing anchovies have now become fashionable and an anchovy literature has developed with the ministers written by poets. Hamamizade '*it can be said that the anchovies for Trabzon and its surroundings, have taken its place, whatever some invariable mythological stories of oriental literature and our classical literature were chanted by separate poets*'. There are literally thousands of myths about anchovies in folk literature, especially in the form of '*mani*' (a local lyric poem). With the economic and social modernization of Trabzon that started in the 1830s and triggered especially by commercial relations with Europe, it is seen that the educated class of the city was also revived and local subjects and especially the local icon anchovy were included by producing poetry (Emiroğlu et al, 2008.).
Hamamizade with its own Anchovy Kasidesi; Hafız Mehmet Zühdi, Bayburtlu Zihni (1795-185), Mehmet Ziver (1821-1879), Çizmecizade Hodja Hüseyin Hüsnü Efendi (1840-1908), Kayseri Mehmet İzzet Pasha (1843-1914), Hasan Tahsin Tıfli Efendi (1849-1908) , Ahmet Sarım Doğru (1884-1966), Baba Salim Öğütçen (1888-1956), Esat Ömer Eyyübi (1893-1921), Mustafa Sıdkı Cansızoğlu (1895-1975), Süleyman Mahir Durukan (1895-1953) has taken (Yüksel, 1989). Bayburtlu Zihni states the following in an ode about anchovy:

'Its geda is anchovy, its raw agniya is for pleasure.

This is the city's vitality, anchovy representation-i evail.' **(Emiroğlu et al, 2008).**

In the development of anchovy literature; a parallel development confirming that the recognition of anchovy outside the Eastern Black Sea region and the fact that the Black Sea people establish a relationship with the outside through anchovy is the reinforcement of the legend that forty kinds of dishes are made, including baklava. The fact that the anchovy defines the Black Sea people living abroad has created an environment in which they adopt anchovy as their identity / belonging. They read from Trabzon, who despised the poor people by saying '*hapsi*' at the time, and now they have adopted being called '*hamsi*' as a distinctive feature (Emiroğlu et al, 2008).

Although the use of anchovy as a fertilizer is an interesting subject in the literature; As an establishment of 'Duyun-i Umumiye', the 'Regie Administration' started its activities, and with the increase in tobacco cultivation in the Eastern Black Sea, anchovy started to be poured especially on the fields. In 1913/14, Abdülvahab Hayri, evaluating the economy of Trabzon with his book 'İktisadi *Trabzon,* İktisadi *Nokta-i Nazardan Trabzon'un Vaziyet-i Hazurası ve* İstklali', states that fertilization of tobacco fields with anchovies increases the yield and is reflected even in the prices of anchovies (Gürsoy, 1984; Yerasimos, 1997. Tiryak and, Özlü, 2019).

The first information about anchovy is given in Mehmet El-Âşık›s work named "Manazirü'l-Avalim" written in 1589. In this work, in which various in formations is given about the anchovy, the abundance of anchovy and its importance for the region are emphasized as follows: "*When fishermen fished anchovies with small boats, they blow a pipe to make it known to the public that its sound reaches a distance of two or three' fersah' (1 fersah 5685 meters) and this sound. The dead of the hearers get on the alive and run to the beach because the "habsi" fish has come out "* (Ak, 1997; Hegen, 1998).

Evliya Çelebi came to Trabzon in 1634 and mentioned anchovy in his "*Seyahatname*". Just like Mehmet El-Âşık, Çelebi mentions that when the anchovies come to the pier, the horn is blown by the clerks' shouting (Ak, 1997). Referring to the jokes made among the public on this issue, he writes in a humorous language that everyone who hears the sound of the trumpet quits their work, and that those who are prayed and who are in the baths come out and rush to the pier (Dağlı and Kahraman, 2005).

Karekin Deveciyan also gave various in formations about anchovy and anchovy fishing in his work titled "*Fish and Fisheries*", which was written in 1915, which includes biological, ecological and hunting information of fish in our country and which is a first in its matter. Undoubtedly, the main work in which anchovy is the crowning crown is Hamamizade İhsan Bey's work named '*Hamsiname*'. This is a book that deals with anchovy from beginning to end, which does not have any other fish and makes them jealous. Hamamizade has gathered everything about anchovy, from its name to its fishing, from its biology to its trade, from its food to its folk songs, in '*Hamsiname*'. According to the sources, there used to be so many anchovies in the Black Sea that it almost came ashore without fishing. The following expressions in folk language are not exaggerated:

Anchovy struck land; ‘*Okkası*’ (an old weight unit) was five coins. Since he landed on the shore, he has five moneys this time, and he has his own interest ashore so as not to bother the people. It is certain that anchovy was more in the past than it is today. However, it can be said that the size reduction seen in other fish today is not much in anchovy. This may be due to the short life span of anchovy and its reproduction after one year of age. He states that the length of the Hamamizade anchovy varies between 3 and 12 cm and makes the following criticism to Evliya Çelebi regarding the size of the anchovy: It is exaggerated that Evliya Çelebi says that it is more than one inch in his book of travels. Either the anchovies of that time were large or Evliya Çelebi›s mix was small. Karakin Deveciyan gives the figure of 10-12 cm about the size of the anchovy (Hamamizade, 1928; Dağlı and Kahraman, 2005; Deveciyan, 2006) (Picture 2).

Although it has partially changed due to the developing fishing methods and changing climatic conditions, anchovy used to be seen in Trabzon in November and sometimes later. However, most of its fishing was done between January and April. Deveciyan states that anchovy is very abundant in Sürmene, Trabzon and Sinop coasts in the Black Sea and that it fished in this region with spinning nets, anchovy pellets and manyat from 8 November to April. Hamamizade, on the other hand, tells at length how this fishing is done in his work. In the years when it appeared in abundance, anchovies were used instead of fertilizers in fields and gardens, mostly in tobacco fields. According to the information given in Hamsiname, 100 kg of chemical fertilizer, which was imported at that time and bought for 11-12 lira, can fertilize a half acre of field. When the same land is fertilized with anchovies, it costs 5-10 lira depending on the price of the fish (Deveciyan, 2006). Moreover, tobacco fertilized with anchovies is very good. There are so many anchovies in the sea that, according to Hamamizade, even one percent of the anchovy coming to the Trabzon coast cannot be caught.

Picture 2. The first editions of Karekin Deveciyan and Hamamizade İhsan Bey's books deemed important for Turkey's fishing history

One million '*okka*' are caught on the coast of Trabzon and several million '*okka*'s on the entire Black Sea coast. These figures '*are like the ears of a camel'* as well as the presence of fish in the sea. In order for our economy to benefit more from this resource, Hamamizade recommends bringing fishing techniques used in developed countries to our country, increasing fishing and improving its conservation in terms of marketing. Referring to canned fish, '*hile our homeland is an anchovy country, we eat thousands of kilos of Italian and Norwegian anchovies every year! And we eat so expensive!'* he says (Üstündağ, 2010).

The mystery of taste, the richness of the tables: anchovy

Anchovy; with its production and consumption, it continues to be the primary meat product both in the fishing sector and in our kitchen, as it was in the past. Anchovy, the symbolic seafood of the Black Sea, is perceived as a different species from fish in its own geography. The delicious fish species of the Black Sea are haddock, horse mackerel, turbot, red mullet, garfish, bonito fishes are '*fish*'. However, anchovy is an anchovy. Anchovy means far beyond being a seasonal food product for Black Sea people. It provides a year-round nutritional security with various conservation techniques such as salting-drying in the past, salting and deep-freezing preservation. A fisherman from Hopa seems to summarize what anchovy means to the Black Sea person when he says '*Our bones are strengthening with corn bread and anchovies'* (Köknar, 1996). It is necessary to add the '*black cabbage'* to these.

The most important food source symbolizing the abundance and fertility of the Black Sea table is anchovy. '*As soon as the anchovies appear in the sea, the news is spread. They would go down to the beach that took the tin, the basket, the barrel on his back… Wherever you go home, everybody had a tin, a ceramic cube of salted anchovies… Especially the anchovies are poured on the dried chestnut leaf and fried on fire… We make bread with anchovy in 'pileki'* (a kind of ceramic cookware). In the past, the vital importance of anchovy for the Black Sea people is emphasized with the words (Köknar, 1996).

Anchovy, which the Black Sea people, who struggle with difficult climate and environmental conditions, have more, meaning than fish, is also the most important protein source of the local cuisine. No matter where one looks at the Black Sea cuisine, all roads lead to anchovy. Undoubtedly, this concept has begun to change since the 21st century with the rapid urbanization that started along the Black Sea coast and the cultural change and nutrition options it brought about. Anchovy sometimes turns into a bread if it is made plain, as in the example of '*hamsikoli*' (with corn flour, leek, chard, etc.), and a bun when it is with vegetables. There are many seasonal dishes such as *pan-fried, grilled, steamed, pilaf, wraps, meatballs and even 'anchovy bird', 'corn pita*'. When a meal with olive oil is desired, it offers different options such as anchovy with vegetables (with leek, carrot and potato) and '*anchovy pileki'* (Duman, 2003; Al, 2004).

It is possible to establish a one-to-one relationship between anchovy and the lifestyle of the Black Sea people. The climate, which makes it necessary to use the time well, has made it necessary for the meals to be prepared quickly. Cultivating, hoeing, and fertilizing the fields opened between steep slopes, doing all these works under a nearly continuous rain require quicker and more practical in all areas of life. This situation is reflected in the speech, games and all daily practices of the Black Sea people. Anchovy is an ideal food in this respect. The anchovies, which are cleaned quickly, can be placed on a grill or in a pan and served immediately with some greens, especially onions. Salted anchovy is a food source that will keep this practicality alive in the summer (Emiroğlu et al, 2008).

A fisherman made sense of this situation in a very meaningful way: '*The henchmen of the Black Sea play horon very fast… As we play horon quickly, our works are fast. Because of the anchovies are running. You will quickly go after the anchovy so that you will be fed. The running and fast travel of that anchovy is the same as ours. So is our horon… We play quickly…'* (Emiroğlu et al, 2008).

In addition to the abundance and cheapness of anchovy, its adaptability too many dishes with different mixtures is an important factor that increases its prevalence in consumption. The season of the anchovy, more precisely the fat level and size of the anchovy, determine that any kind of food will be made. It is grilled abundantly in November-December-January. Especially in these months, the large anchovies are cleaned and salted, then grilled and cooked. Pan and steaming is preferred when it is lean. Undoubtedly, anchovy is also an indispensable blessing for the poor. Because of it is the cheapest sustenance among all fish and it is a product accessible to people of all socio-economic classes.

Cleaning one kilo of anchovy is a five to ten minute process for hands that are skilled in cleaning anchovies (the term 'weeding' is used more in the region). It does not require a knife. With a sudden hand movement, the head and internal organs are cleaned. In cases where it is necessary to remove the bone, the same practicality and convenience are available. As Hamamizade İhsan Bey stated; '*Eaten without tools and difficulties such as anchovies, forks and knives; but there are procedures to be followed in its defeat*'. He expressed this with an ode (Hamamizade, 1926).

'*Observe your table manners; keep this pendent in your chest*

Take your knees and become a besmelkesh, good luck, hope

Take a sip of water and then take a bite of lazut

Hold your tail firmly in one hand and swallow it like that

There is a way to add anchovies.'

In the traditional settlement of the Black Sea, the kitchen, which is called '*aşana*', '*domestic*', is a functional place in the centre of life, where the fire is burning, and the daily work is carried out. Cooker, which are among the common household appliances, are practical utensils where several dishes can be cooked at the same time, with copper kettles with constant hot water on them. A peculiar pot-leak has also developed within the cultural pattern of the anchovy. Such as pileki, anchovy pan, anchovy strainer, corrugated tile. The anchovy pan, which is made of copper and takes names such as *'turning pan'*, has a single handle, made of copper, and has a lid with a handle to turn the anchovy with knees during frying anchovies. The special cover of the anchovy pan functions as a unique means of use in the preparation of pan or slippery type dishes. Before some women cook anything inside the pan they just bought, they rub it thoroughly with corn flour over a hot fire to prevent it from '*sticking*' (Picture 3).

Picture 3. Specific to the Black Sea; strainer and traditional copper grill pan for cleaning anchovies

'*Pileki*', which is among the examples of stone work in the Black Sea, is a soft stone and is quarried from a specific quarry. It is not found everywhere. After the stone mass is removed, it is first carved inward and then its outer surface is cut round. This particular stone is made into a kind of shallow, spreading ceramic casserole. Corn bread is usually baked on the *to fish. They say that I send fifty cratesof anchovies to the neighbourhood grant…*fire-resistant pileki. It is also used to bake anchovy bread, or simply anchovy. Some pleats have a hole for the anchovy juice to flow while cooking. Cooking is provided with the help of embers, with a suitable hair or leaving it opens (Emiroğlu et al, 2008) (Picture 4).

Picture 4. Pileki used to cook Black Sea anchovy

Irresistible taste of pickled anchovy

Anchovies in brine; it is a storage method prepared as consumption in the summer months when anchovy is not available. In fact, salted anchovy is an important food security for poor households. As a very old and traditional preservation method; pickled anchovies still main tain their importance. In Trabzon Faroz, it is seen that salting anchovy based on a deep-rooted tradition has turned into a social sharing, almost a ritual. Brine was made by the women in the household and the daughters of the family. This traditional phenomenon, which has completely disappeared today, was expressed as follows by an inhabitant from Faroz. '*During the anchovy hunting season, anchovies used to come to the neighbourhood with a crate. For example, who are the rich people of the neighbourhood…? They used Everyone takes their safe in turn. Neighbours gather in an open field. Anchovies are cleaned by helping each other. Then the cut anchovies are* *taken home and washed with plenty of water. The anchovies are washed many times and repeatedly with clean and plenty of water. It is kept in a copper strainer for a day in light salt. Blood water is expected to come out thoroughly. The next day, it is mixed with thick salt. Salt is laid at the bottom of the ceramic cube or tin can. My mother would also put a bay leaf at the bottom. Also, no water is put into the container. Its own juice released by the anchovy in the bowl was enough. The top of the container was covered with a row of bay leaves so that it would not rust. When we took the anchovy from the container in the summer, we boiled it with fig leaves* ... (Sezer, 2007).

The best season for salting anchovies is the middle of the season. The perception that '*anchovies are salted after hitting snow water*' is common among the public during this period. It is possible to say that this is related to the fattening of anchovy. It is known that salty anchovy, which reaches the desired consistency and taste a few months after salting, was stored for up to 3-4 years in the past, and even pickled anchovy prepared in large barrels with bay leaves in between is exported (Sezer, 2007).

Anchovy was an indispensable benediction for the households at the Black Sea…

Besides the unlimited opportunities offered by nature, the development of Black Sea fishery has also been influenced by some conjectural conditions which are rooted in history. As the heart of the Black Sea, the city of Trabzon has been the most important harbour since antiquity. There was a time when Trabzon was the door for the trade between the Ottomans and the Europeans for a long time. The increasing population could not be met by the local agricultural production although it secured profit by being a transit trade centre due to new production and consumption habits during the 16th, 17th and 18th century when trade was being modernized (Emiroglu et al., 2008). In spite of the increasing popularity of tobacco in this region during the last periods of the Ottoman Empire and of hazelnut and tea during the period of the Republic, the local people's interest for the sea, for fishing and for anchovies could never be reduced. The insufficiency of the agricultural production in the region prevented the development of the economy which was based on agriculture and, as the general product of the rural economy, anchovy and corn were the primary food for hundreds of years of the people living at the coast…

This relation, this conventional bond between the agricultural produc tion and anchovies, was interpreted by the then Regional Trade Director of Trabzon, *Said Bilal* Çakiroglu, in 1964 as follows: *"As the sea is very close to the mountains, the land is formed like a narrow strip. Although main products in Turkey such as hazelnut and tobacco are being planted on these narrow strips, they cannot provide a stable salary for the people of Trabzon. Those who know about the life at these coasts know that the people here carry on their back the soil they have lost to the sea in the winter months from other places in summer in order to make up their fields again. For that reason, the producers and citizens were forced to turn their faces to the sea and made fishing a custom and an art. Fishing can be found in all the places of the eastern part of the Black Sea. In times when husbandry was possible, villagers who owned a small ship went to the sea in order to provide their subsistence. In this respect, each Trabzon man is interested in fishing. The number of those who contributed to fishing becoming an art and spent their lifetime on this matter is not inconsiderable…"* (Çakıroğlu, 1964).

Before the 1980s, when corn was a product of subsistence and reinforced the kitchen of the people living at the coast, anchovy was an indispensable benediction for the households at the Black Sea. While anchovies were being consumed fresh during the fishing season, it was salted and conserved out of the fishing season. In these years, people used to use anchovies which had been fished too much as fertilizer for their tobacco fields and hazelnut gardens. *Hamamizade Ihsan Bey*, one of the gentry in Trabzon, wrote in his book entitled '*Hamsiname'* (1928): "*In Trabzon and its environment, anchovy is also used as a fertilizer on the tobacco fields in the years when the fishermen had fished too many anchovies.*" (Sayılır and Babuçoğlu, 2007). There is a close relation between the use of anchovies as a fertilizer on tobacco fields and *'Duyun-i Umumiye'*, which was one of the most important institutions in the last years of the Ottoman Empire. After *'Rej Idaresi'* of *Duyun-i Umumiye* was founded to pay the foreign debts of the Ottomans, it can be understood that together with the increase of tobacco sales especially in Trabzon, anchovy was used as a fertilizer on tobacco fields (Emiroglu et al., 2008).

"Moloz, Faroz, Yoroz… Everywhere beyond is abroad…"

There was a time when Faroz was the centre of fishery at the Black Sea. The northwest autumn winds were the sign for the coming of pare themselves in the shelters of those rocks days before and gathered all kinds of needs, all their stuff and their nets on the dams here. The small ships along the shore were replaced by hook ships, square sterned ships and sailing vessels. By stormy weather, the fishermen living away from home took shelter and spent their nights here. The anchovy captains used Faroz as a shelter. After taking the anchovies which they had fished during the season to the landing site in Moloz, they turned back for completion. To be a fisher meant to be at sea, to live away from home and to feel longing. It meant to be away from home and family, not to have a warm soup and to lack tenderness. It meant to collect the fishing net in the middle of the sea, between giant waves, it meant elbow grease, and sometimes pain and tears. Captains who went out fishing did not turn back home for six months. They suffered from being away from home and to be at sea. They put out to sea until the West of İnebolu, Eregli at the Black Sea, Sile and the Bosporus mouth. At these times, being further than Yoroz meant to the fishers of Moloz and Faroz to be away from home…

An old fishing district: Faroz

In these times, the sea provided the livelihood for impoverished people living at the coast. The poor fishers coming from Hopa, Arhavi, Rize, Fatsa, Ayvasil (Giresun), and Tirebolu, worked as seamen for the captains of Faroz. The '*Han Cafés*' were a popular hangout. The fishers slept on the benches at the beachside of those cafés, they drank, ate, and took shelter there. The owners of those cafés were at the same time captains. The most famous of those captains, whose names are forgotten today, were *'Incenin Sali', 'Baranlarin Salih Ağa',* 'Şemsiler*', 'Emin Reis', 'Kalafat Temel', 'HisimaĔa Teel Reis', 'Vanlioğlu Recep (Denizer)', 'Mucoğlu'* and honey suckles, all of which are hanging down from the garden walls onto the cobbled streets, Faroz takes its viewers back to these old happy days. In fact, Faroz is the district where the warm and friendly neighbourhood culture is lived out in its deepest and most sincere way.

The brave Argonaut seamen

Located outside the provincial centre and between the quarters of St. Sophia Church (*Hagia Sophia*) and *Sotka* (*Hızırbey*), Faroz is one of the oldest and most famous districts of Trabzon. It was founded right next to St. Sophia, one of the holiest and most attractive sites of the Pontic byzan tine. The holiness dedicated to these shores had been maintained since hundreds of years ago. At the time of the *Megarali Colonies*, the first settlers at the Black Sea dedicated this sanctuary to the sea gods and goddesses. The famous implacable voyage of the Argonauts who went out to search for the '*golden fleece*' also took place at these shores. The '*Argo'*, the name of which means '*fast'* and which had been constructed by a shipmaster called '*Argos'*, was made in *Colchis* (today Georgia) for the heroes who set off to find the 'golden fleece'. On this ship with 50 oars, a group of brave and strong seamen with *Jason (Iason)* as their leader set out on a challenging journey in the treacherous waters of the Black Sea… (Özbay, 2002).

Baker Dimitri of Sotka

At the beach from Faroz to Pazarkapı, and from there until Moloz and Kemerkaya, a high number of rowboats were waiting at the capstans to go to sea. Before the mobilization and exchange, Muslims, Pontians and Armenians lived together in Faroz as it was the case in other villages at the coast. There was a good neighbourhood relationship between Pontic and Muslim fishermen. These were the years when there still was peace and order. They went to sea, cast their nets together and helped each other in bad times. Before dawn, they snatched the bread of 'Baker *Dimitri of Sotka'*, which had just been baked, and went to sea. The sea was bountiful. After fishing, the quay in Moloz was full of anchovy barges. There were so many fish that anchovy schools were washed ashore. All the children took their loincloth (peştemal), basket, can, and ran to the quay to gather around the small sailing boats…

The captains, who spent their nights in Faroz and went to sea from there, delivered their fished anchovies from the quays of Pazarkapı and Moloz. During the Second Constitutionalist Period of Istanbul, Moloz and Pazarkapı were the most dynamic districts of the province of Trabzon and of the regional economy. A lot of factories, shipbuilding yards, offices and commercial buildings, especially hazelnut factories, carried on their activities in this surrounding. The goods were disembarked by the ships approaching the shore and were transported to the quays by rowing boats. After that, these boats were bound on the boatyard of the Tabakhane stream. Until the 1950s and 1960s, there were no big, well organized, modern harbours at the coast of the Black Sea, which had a pier, and whose backyard was available. There were quays in the sheltering bays of important centres such as Istanbul, Samsun, Trabzon, İnebolu, Rize, Hopa, which were the

[1]Horon is a folk dance of the eastern Black Sea coastal region.

most important harbour cities. Big freighters did not approach to the shore, but cast their anchor far from it. People and loads were transported to the quays at the shore by barges and boats, and there, they were embarked on and disembarked from the ships. These quays were named differently in different cities, e.g. passenger, gas, flour, and customs quay.

Salih Ağa[2] of the Barans

At that period, sea transport was mainly under the control of *'Salih Aga of the Barans in Faroz'*. The sailing boats of Sâlih Aga cruised from Batum until inner Russia and from there until the Sea of Azov, and fished *'Loloğlu'*.Most of those captains also stayed in these cafés and had an eye on their crew. Those captains had been powerful in their times. Each of them had their men in Moloz/ Pazarkapı doing shipment. When the anchovy season started, the shore of Faroz was bursting at the seas and everywhere became cheerful. The fishers gathering in the cafés made merriments every evening and danced and sang to the melody of the kemençe. Those fearless and hook-nosed fishermen, who had dedicated themselves to the sea, danced horon[1] and made merry all night long.

Faroz, where only very few traces of its past can still be seen today and which is more than only a district of its city, still functions as a bridge between the past and the future. Although it has lost most of its distinctive features, it has maintained some traces of its own distinctive life style. With its fishery, weaving, coppersmiths, which belong to its long history, with its famous footballers since the 1960s and its '*kolbastı*' of modern times, Faroz has become more than just a district and is a class of its own as it has developed its own lifestyle. With its narrow side streets, flowing fountains, its masonry constructed, half wooden, two stored, tiled roofed houses and large gardens, grape vineyards, ivies, pink and white wild roses, fragrant seine and fish there. On their way back, they also took goods which were not available in Trabzon. The captains fished anchovies in winter, and during the summer months when there were no anchovies, they made trade. In the harbours of Batum and Samsun, they loaded corn, wheat, tobacco and salt on their ships. Besides, Sâlih Ağa also imported yarn. He sold the yarn which he had imported from England to the captains in Faroz. At that time, the captains in Faroz where the only one in these coasts who had seine net for anchovies. The seine nets were hand-knitted at home by women who lived in the villages near the coast. The most famous seine weavers at the coast of Trabzon were from *Zavena* (Salacık) and İskefiye (Çarşıbaşı). At that time, only the chieftains from Faroz used to have 'hamsi ığrıbı' on these beaches. The seine net has maintained its size and shape since the Byzantine period. While seine net was used to fish one level above the seafloor, the beach seine was used for fishing fish on the seafloor. The size of the seine net and the equipment for fishing differed according to the size of the group of fish to be hunted and according to the depth and streams of the fishing site (Zengin, 2013).

The Bugler Kalfa Ağa

With the start of the anchovy season, the fishermen of Faroz returned to their usual working routine. The ships returning from fishing were full of anchovies. The '*Bugler Kalfa Aga*' bowled his bugle in Faroz in the direction of Kavakmeydan and this sound could be heard in near districts, distant villages, and even at the Karlık Tepe (a local hill). This was the job of Kalfa Aga. In the dawn, he announced with his bugle the coming of the boats, which were loaded with anchovies, to the shore. The sound of his bugle could be heard from the seaside until 2 to 3 leagues in distance. All the people, "*old and young, ran bareheaded and barefoot to see the fish (anchovies)*" (Kayaoğlu vd, 2007). In spite of his old age, Kalfa Aga fulfilled his job with great passion. He was the bugler of the union. Moloz, Pazarkapı, and Faroz became overcrowded by those who had heard the sound of his bugle. The shore was bursting at the seams with people who had come from districts and villages near or far. But this tumult did not last for long. After that, the captains and seamen enjoyed their fishing. First of all, they warmed their freezing hands and tired bodies at the fire made by woods of oaks. After that, the fresh and living anchovies were cut, salted and arranged quickly on the barbecue. The smell of grilled anchovies spread all over the beach. The first man to come near to the barbecue was '*Mucoğlu Reis* [3]' (Bostan, 2008). Actually, Mucoğlu was a typical Trabzon man. The blood of a real seaman was running through his veins. He was born and grew up here, and when he was a child, he ate what the sea gave to his family and so, later, when he was an adult, he also earned his livelihood at the sea. He was one of the most famous and skilful captains in Faroz. With his impatience and impetuosity, and his inner energy he had all the qualities typical of a '*Black Sea Child*'. Sometimes, he burst like the waves at the sea with joy and happiness, and sometimes, he suddenly got angry and burst with anger. Patience and calmness were alien to him. If

[2]The Turkish word„aga" means „landlord, landowner".

something went wrong, he began to curse and used all the swearwords he knew. But he was a man of such credulity and gracefulness, that after a few words of excuse, he became soft and calmed down again. His nature was an exact mirror of the nature of the Black Sea.

This way of life of the people living at the sea, which had continued for hundreds of years, was put to an end when in 1916 the Russian attacked the coast of Trabzon… From that day on, peace and order were destroyed. During the years of mobilisation, there was no peace anywhere. The Pontians, Armenian and Turkish people, who had breathed the same air and had filled their jugs from the same fountains for hundreds of years, were now fighting against each other…

The first fishery shelter and the construction of the first coast road

Today, there is only very little left of that old fishery past in Faroz (Picture 5). The fishermen are craving for those old blessed days! Neither the mystic rocks along the shore, nor the natural shelters at the seaside can be found anymore. None of them could adapt to the new living conditions, which changed during a long time period, and gave in to the ravages and were destroyed. The seaside, which was enlarged through filling again and again, was changed into roads, lodgings and settlements, parks, restaurants, and wholesale market halls, and succumbed to the merciless trade economy, which developed especially after the 1980s. During this time, the old great captains kept their hands off the sea one after another. Only very few of them continued their profession. The majority departed this life and got lost in eternity. Leaving so much pain behind them… Those who remained remembered Faroz as it was like in the past and their good old fishermen days and took a trip down memory lane.

Picture 5. Historical Faroz fishing shelter; Beginning of the 1920s (from Muzaffer Bozali Albums)

[3]reis = engl.captain

Muzaffer Bozali has outlived this long past of Faroz and his fishermen days and is one of its oldest citizens. Today at the age of 85, captain Muzaffer still feels those deep traces within his heart and longs for those old times: *"Our family was one of the oldest households in Faroz. In the time we settled here, there were no more than 20 Muslim households in Faroz. Almost all of them earned their living by fishing. My ancestors had learned fishing from the Pontic captains. The Armenians earned their living usually as tradesmen. The business of coppersmiths, smithereens', weaving, the construction business, and bakeries were in their hands. Most of the coppersmiths, boiler smiths and thinners working in Kemeraltı and in the ateliers at the coppersmith market were people from Faroz. The craftsman working in those ateliers produced oven vessels which had a handle on the top, copper buckets, kettles, copper vessels, cups for milk and compote, dough basins, frying pans with caps for anchovies, metal drinking cups, shallow frying pans with a cap, pots, and braziers, all in a style characteristic of this region'* (Picture 6).

Picture 6. 1900's. The Çömlekçi›s side of the current big harbor in Trabzon. Yelkenli aynakıç boats ...

‘No matter if Pontians, Armenians or Turks, a weaving loom could be found in every household. A wide array of ornate linen, towels, peştemal, undershirts, and socks were woven with them. The dowry of girls who were going to marry was always ordered from the households of this district. After being expelled from this region, Turkish families continued to practice hand weaving until the 1950s and 1960s. But when modern weaving looms were produced for factories, weaving at home also became history. Until the foundation of the “National Unity Government” in 1960, there were no roads at the seaside. There was a pathway between Faroz and Sotka-Pazarkapı. The transport between the harbour of Faroz and Pazarkapı and between the quays of Moloz was carried out by transporter barges at that time. The Fishery Association in Faroz was founded in 1952. In the year when I became head of this association, I went to Ankara in order to make a petition to the National Unity Government. Then the first thing made in Faroz was a shelter. Until then, the boats were pulled ashore near the rocks. In fact, the first asphalt road was completed in these years, at the beginning of the 1960s. Until then, there was no city road at the seaside. The road starting in the provincial centre at the Maras Cadde, Tabakhane and the Zağanos bridges and reached Kavakmeydan, and from here St. Sophia Church. At the right time, our three storied fishing house which was used as headquarters during the occupation of Trabzon by Urusun fell down during the first road constructions. This house had been built by my maternal grandfather. My grandfather captain Emin was a sailor. He transported goods from Istanbul to Batum…’

The white foam of wild waves washed the stone walls of tile roofed houses…

Until the early 1960s when the asphalt road was built, the houses in Faroz were seafront. The white foam of wild waves, whose speed was broken by the rocks, washed the stone walls of tile roofed houses. It was a time when technology had not been sufficiently developed yet. Until the end of the 1950s, the sea was very profitable for the fishers. The people of Faroz sampled the fish such as anchovies, skipjack tuna, and horse mackerel, which were washed to the shore, with their hands. Unfortunately, these were not the only changes to come! After the 1960s with an interval of almost 10 years each, the road enlargement constructions at the seaside destroyed the unique natural beauty of Faroz until nothing was left. Even worse, the ‘*Black Sea Seaside Road Project*’ during the first years after

2000 caused the biggest destruction and the historical traces of Faroz were lost forever. The land reclamation towards the sea destroyed the old face of this area forever and shaped a new geography. Apart from this, the settlement structure of this district, its houses, buildings, gardens and streets became object of the merciless rules of the trade economy after the 1980s. This district, which had a high migration from outside, distant villages and small towns, had lost its original characteristics to a great extent.

Captain Temel

Captain Temel, who had the nickname '*Hisimağa'*, was of the oldest and most famous fishery families in Faroz. There was no captain above him. He knew the sea very well and was always careful. Looking from Faroz at the horizon of Yoroz, he could tell the weather of the following day. He knew that the south wind was immediately followed by the northwest wind. According to this, he took his precautions and put out to sea… He had two brothers. When the immigrants came and came up against, they also left Faroz as all the other Muslim families did. The three brothers gathered and sailed until they reached Samsun.

While other families were troubled with hunger, poverty and illnesses, they had better luck. As they knew the sea inside out, their journey did not last very long. Also after leaving Faroz, captain Temel spent his whole life at the sea. Like others, he had also dedicated himself to this painful way of life. The life of the people at the Black Sea went on like this from generation to generation. They were born into this profession which they regarded as their honour and pride and as a holy heritage. It was their inevitable destiny. And this was exactly the case with the family of Hisimağa.

The descendants of Hisimağa are one of the very few old fisher families of Faroz who are still alive today. Today, there is only very little left of the magnificent old fishery times of Faroz but the profession is still continued in the third generation…One of Captain Temel's sons, Captain Murat, who was born in 1931 and is still alive today, regrets that there is unfortunately nothing left today of the old good fishing times, of the fishing shelter in Faroz and the copper coloured coasts. *"I was born in Samsun. My father returned to Faroz when I was five years old. After he had returned, he tried to earn his living by fishing. Later, he was captain on big ships, and on "capital ships" of 10-15 metres size, 10-12 tons. He did not know the meaning of the word "stop". He had always been working. In winter,* *he was a fisher, in summer; he worked as a captain on transporter ships. He suffered a lot. When he died in 1956, he left only a lot of hardship and connoisseurship of this profession as heritage for us. He never stopped being an honourable man. Then he passed his flag on to us. These shores are not the ones we remember from our childhood. They have filled the sea and at the same time there are ships everywhere. Since we did not learn another profession, being a fisher was the only way for us to earn our living and we continued this job. In remembrance of him, we have named our ship after him. The day came when even captain Temel had to defer to the new technology. At the end of the 1990s, the old fishermen of Faroz finally gave up and moved away. They either moved to bigger cities or gave up their profession. We are the last of the old fishermen of Faroz. But since the beginning of the 1980s, villagers have left their homes and sold their animals and moved to Faroz. Since then, peace has been completely disturbed. The rules of the sea have been flouted. There is no respect of and love for the sea, the fish and the captains…and those who leave us don't come back again. Now, we comfort ourselves by remembering the old days… We have no expectations for the future… I grieve about the times when we went fishing dolphins, enormous cods, Atlantic bonitos, turbots which were as big as a tray without calculating…"*

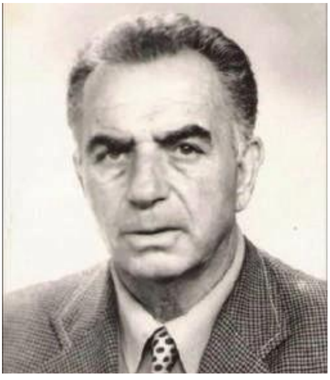
In spite of all these misfortunes, the people of these coasts, who have dedicated their lives to the sea, those tall and slim, sharp nosed people with sea blue eyes, have never lost their endless hopes and love for the sea, the Black Sea, and anchovies and have always carried them in their hearts…

A mighty fisherman family: Denizerler

'*Denizerler*' was one of the most famous, established and wealthiest fishery families that have survived from those magnificent fishing years of Faroz. Even though the glory of that old days does not last enough today, '*Denizerler*' has been known as the leading and leading family of the Trabzon, Black Sea and even Istanbul fish market for many years ... Yahya Reis started from the end of the 1940s until the mid-eighties, until his death in 1986 He was a leading leader in the fishing market, who has always been mentioned, listened to. He always led the fishing movements in the Black Sea. His name was always mentioned until the support of the Hasan Saka Government in 1948 for the first time for dolphin fishing (Zengin, 2009), the use of the first modern purse seiners in the Black Sea, and the establishment of the first modern fish market / brokerage system in the country.

Yahya Reis's father was born in Vanlıoğlu Recep Reis Ayvasıl (Giresun). There is no clear information about when Vanlıoğlu came and settled in Faroz. But he, like the other chiefs, worked as a puller on these coasts in his time and was carrying the wheat, corn and flour he loaded to his ten meters tall '*aynakıç*' (old vessel) from Samsun pier to Trabzon. In those years, he started to grow from small to small and fished anchovies during the fishing season. He used to take shelter in the natural shelter in Akçakale in bad weather. Vanlıoğlu Reis passed away this mortal world in the early fifties… Vanlıoğlu Recep Reis; He was on the team of '*Yahya Kâhya'*, one of the important men of the Committee of Union and Progress in the 1915s and was influential in many domestic and foreign national political events of the period (Üçüncü, 2015), and they were close friends. He gave his son the name of the murdered '*Boatmen Steward Yahya. This Yahya Captain was so powerful that he used to take a man from the rope*'.

These days, in the fish market sector, especially in the domestic market; As the company that directs anchovy trade for processing, canned food and fresh consumption, there are fishing stories from the grandfathers of '*Denizer Fishery*' dating back to the very old years, the end of the 1880s. First Vehbi Ağa opened the Black Sea with a small crew team and his crew, then his children, then his grandchildren… They were attached to the sea with such passion; when the surname law was passed, their surnames immediately became Denizer. After Vanlıoğlu Recep Reis, his two sons Abdullah and Yahya (Picture 7) took up the fishing business. After them, their children ... Then their children ... As you can see, the passion for the sea and fish passed down from generation to generation...



Picture 7. Yahya Denizer: Two generations of fishermen who made an important effort in the development of anchovy fishing in the Black Sea

Past fishing times in the Sinop peninsula

At the beginning of the 20th century, fishing was done under very primitive conditions compared to today. Fishing boats were towed by sail-boats or two or three pairs of oars. Fishing was mainly based on dolphin hunting, diving, fishing and pickling. Fishing was done in coastal waters with weeping (ığrıp). In anchovy fishing, coastal '*voli'* nets and a kind of router network traps called 'pie' were used. The anchovies that entered the trap were transported to the deck with the help of a bucket, and from there to baskets made of straw, wood, baskets or cubes made of clay. In those years, bonito and '*torikçilik'* were famous. With the '*alamana*' nets, starting from June, first the torik, and following the "*chestnut black*" storm (*kestane karası*) in September, acorn farming started. The oldest traditional fishing left from the Greeks was dalyan. Until the 1980s, fish were caught along the Black Sea coast, as well as perch, mullet, torik, and even tuna. In these years, when money was not used as an important commercial commodity, instead of the exchange of goods in marketing, the anchovies that were hunted were exchanged in the villages for eggs and for corn. Maybe the people were poor, maybe poor, in need of a bowl and a straw roof, but the seas were not so spoiled (Zengin, 2019a).

American traveller David Robinson describes Sinop, which was very famous for fishing along the Black Sea coast, in 1903 as follows; *"... Bonito is the most important fish. Schools of fish spread to the north and south of the coast to spawn. It was made from acorn in brine and shipped to Greece. The price of fish was increasing enormously from Greece to Rome. A small jar of Sinop brine was sold for 400 drachmas. In addition, many fish such as mackerel, turbot, red mullet and dolphin were caught and shipped. The dolphin, on the other hand, was kept not for food, but mostly for its oil and the medicinal value of its lungs*" (Robinson, 1906). The building of "*Mumyakmaz Nikola*" in the shipyard, which existed in Sinop until the last period of the Ottoman Empire, was a fish salting plant. These pickled fish, which Armenian and Greek women worked on, were imported to Crimea, Italy, and from there to France, and into Europe through the Danube and Volga. In this facility, the pickled fish obtained from the fish of 'dalyan' Kırımizade İsmail Hakkı Bey, were stacked in oak barrels of different sizes and loaded onto the ships. '*Vasil Usta'*, son of Yorgi from '*Varoş District'*, the last craftsman who made barrels of pickled fish in Sinop, has devoted himself to teaching this profession to Turkish subjects. He even opened a course for inmates at a midterm prison. He also donated

43 pieces of his tools here. This period is the years of turmoil in which the country fell into war and poverty. The last salted fish export to appear in the records was the Kosovo Ferry and 100 barrels of bonito from September, 1922 (Deniz, 2012).

Another person pointing to Sinop's reputation for fishing in the past is; the famous writer and intellectual Refi Cevat Ulunay was exiled to Sinop Prison in 1913 and spent two years there. Refi Cevat Ulunay made the following determinations about the fishing of Sinop, where he came with the "*Bahri Cedid Ferry*". "*Essentially, fishing in Sinop is very primitive. However, the city makes great use of fish, especially anchovy, every year. I also saw a strange situation there; they consider the fish that do not play as dead and do not eat it as dead fish! Turbot fish will surely jump in the scales. Especially the Christian people of Sinop are extremely fond of fish. For this reason, all of them have red faces, and at least six children's heads appear on the door of each house. Fertility is extremely high*" (Ulunay, 1999). This abundance mentioned by Ulunay continued until the end of the 1980s. Especially the news that anchovy flocks have entered Sinop bays; He grabbed his net from the house and cheered on the houses of the people who gathered on the seaside for free. When the ladies weeded the anchovy for cooking at noon, when they saw the boats full of anchovy coming to the pier from the window, they threw the anchovies in front of them as fertilizers and rushed back to the port to grab free anchovies (Deniz, 2012).

The first fishing activity of the Turks in Sinop

The first fishing activity of the Turks in Sinop; It was started by the first generation Dangaz, Osman Reis, who worked alongside the Greeks. In those difficult years, he reached Sinop Port two days after departing from Istanbul on May 16, 1919 on the *'Bandırma Ferry'* to implement Mustafa Kemal's '*National Liberation Plan*', and he landed here and met with the notables of Sinop. In this meeting, one of the two heroes from Sinop who guided Pasha with his horses was the son of Osman Reis; Mehmet Reis is from the second generation and the other is Çerkez Ali. Basically, after Osman Reis emigrated to Sinop from Crimea, he started to be a shepherd in this poor state on the Peninsula. On the western side of the island, he would help Greek fishermen to pull their ewes into the sea when the weather was good… Osman Ağa improved his friendship with the Greek fishermen in this way and also he has gotten the profession of weeping. He learned the skills and subtleties of this work from his friendly neighbours… Equipping nets, throwing nets, the time of fishing… Today, the brothers Niyazi and Hikmet Kuruoğlu from the third generation continue their fishing activities with their fourth generation sons, although they are 87 and 91 years old (Picture 8). It is the end of the 1980s (Zengin, 2019).

The seas had not gotten worse yet ...

In the first half of the 1900s, both the ecosystem and the fish populations in the seas of Turkey have not deteriorated yet compared to the 1980s, 90s and 2000s. And especially the residential areas of the coastal fishermen are small villages and towns in terms of population, industry and tourism. Nature, sea and coasts have not been contaminated yet; fish populations have not been decreased. Industrial fishing has not reached its current dimensions, aquaculture activities have not started in the near coasts, the coasts have not been filled, sea areas have not been closed for different infrastructure activities such as energy, transportation, blood-bridge, highway, and fishing areas have not been narrowed. Along the Black Sea coast, the problems of intensive urbanization, urban discharges and pollution caused by industrial

Picture 8. The year is the end of the 1940s ... Dangaz are sharing their food with their crew after an anchovy fished in Sinop's Daşbağı region, during a break ...

wastes have not started since the 2000s. In this process, the populations of tuna, torik (big bonito), swordfish, mackerel, horse mackerel and even dolphin, which were hunted in abundance in the Black Sea, have also entered the process of extinction. These are the years when our fishing has not yet transitioned to the stage of capital accumulation, fishing is still self-sufficient, and there is an inadequate and limited subsistence economy. This period is also the years when there was no capital accumulation and technological development in fishing (Zengin et al., 2010; Zengin, 2019b).

In this period, traditional fishing activities were also carried on in many fishing settlements along the Black Sea coast outside Istanbul. In the pre-industrialization period of the fishing industry in Turkey, fisherman-sea relations were traditionally made with local resources and physical labour, and indeed, being a fisherman required a great deal of experience. This structure continued until the 1980s. Since 1980, radical changes in the national economy have gradually reflected sea and fisheries While one end of these changes is technologically based on fishing, on the other hand, human relations of the capitalizing profession have also been affected (Zengin, 2019b; Ulman et al., 2020). With the market economy, a capitalization process has been entered in the fishing sector. The people involved in the fishing profession, especially the local coastal fishermen, were poor, and the most important motivation for them was their passion for sea.

Technological developments in anchovy fishing

In our country, 'purse seiners', which were first used in fishing of pelagic fish such as anchovy, horse mackerel, bluefish and bonito, started to become widespread after the First World War. The first examples of these nets were 110 fathoms long and 15 fathoms deep, and the anchovies that came to the mouths of the bay and dalyan were hunted with these nets. Over time, these nets were replaced by purse seiners made of cotton yarn, which were enlarged to a length of 300-400 fathoms and a depth of 30-40 fathoms. These purse seiners were named as '*anchovies*' in the Eastern Black Sea Region (Yalıngün, 1967). However, these purse seine nets, which were completely knitted from cotton yarn and whose ropes were made of hemp called '*oktun*' in the region, had to be dried every day and the processes of throwing these purse seiners into the sea and withdrawing them to the sea should be done completely with human power. The boats used in fishing with these nets were wooden boats of 10-15 meters, called three or four pairs, and fish shoals were detected using the sparkle at night and the rash during the day, and 4-5 tons of anchovies were caught each

[4] This period is a period in which the greatest radical transformations have been achieved historically in the socio-political and socio-economic structure of Turkey. Turkey left the mixed / semi-statist economic model on January 24, 1980 and switched to a liberal / market economy.

time. Fishing was also affected by the rapid development of technology after the Second World War. First of all, by importing nylon nets and using them in making anchovy purse, the problem of drying the nets every day is eliminated. At the same time, because of the high bearing power of nylon nets, the splitting and explosion problem of the nets is also reduced. Since there are redundant networks, it has been possible to easily replace the torn parts of the networks (Düzgüneş, 2010; Düzgüneş et al, 2015).

On the other hand, the size of both the boats and the nets has increased, as the engine power enters the fishing boats. The boats were made of wood, 18-20 meters tall, called ‘kancabaş’ (Picture 9). Pressing (pulling and shrinking) of the gold of the used nets with cranes based on engine power has introduced “steel ropes”. The “echo-sounder” (fish finder), which detects schools vertically next to a synthetic (nylon) net and machine, has started to be imported. With the import of fish finders, the problem of day and night fishing of anchovy schools has been eliminated. With fish finders, the amount of catch has increased rapidly. Therefore, carrier boats were needed. Therefore, one or two carrier boats started to travel behind each fishing boat. However, the carrier boats doing the same course while the fishing boat was looking for the fish shoals caused huge fuel costs. Therefore, it would be more appropriate for the carrier boats to go to the vessel after the catch is wrapped. The problem of providing communication between carrier boats and the fishing boat, determination of the port where the catch will go, communication of the fishing boats or carrier boats with the marketers or organizations, on the other hand, the problem of a fishing boat informing other fishing boats when it found dense schools arose. This problem has been solved by the introduction of “wireless” communication into fishing (Çelikkale et al, 1993).

Picture 9. Kancabaşlar… The years of 1950's when the fishing fleet was not technologically developed yet… tekneler…

Anchovy (Engraulis encrasicolus); It is the most important commercial species in both Black Sea and Turkish fisheries. Fishing in the Black Sea is characterized by anchovies and the fishing industry is largely dependent on anchovy fishing. Why anchovy is so important in Black Sea fishing. (1) First of all, it constitutes the largest prey among all fish species that are caught. Black Sea, even Turkey fishing is characterized by anchovies. (2) It has a high trophic level in the food chain. (3) It is a very important food source for people living in the coastal zone and (4) it is a very important source of economic employment for work and business life. Although the anchovy landing constitutes 70-75% of the total catches landed according to the averages of many years, it has shown a decreasing fishing trend for the last 10 years. It is likely that the oceanographic conditions are decisive. Total anchovy production reached from 60 thousand tons in the early 1970s to 375 thousand tons with an increase of approximately 300% in the mid-1990s (1995). However, as a result of both overfishing, increased fishing power and overfishing, and irrational administrative practices in anchovy fishing, the amount of catches landed in the second half of the 2010s (2016) decreased to 70 thousand tons.

Autumn-winter migration on the Southern Black Sea coasts begins in early November and lasts shortly until mid-December and the anchovy schools migrates to the Caucasus coasts from the end of December. In this process, anchovies in about a month; it is fished by Turkish fishermen with bilateral agreements with the Georgian government. The history of anchovy fishing by Turkish fishermen in the Caucasus coasts dates back to the mid-1990s. Anchovy fishing in the waters of Georgia was carried out with the personal relations of local entrepreneurs in both countries and largely illegal. The catch amount of Turkish fishing boats during this period is unknown. Since 2000, the Georgian Government has unilaterally tried to regulate fishing activities in its national waters. In this new process, it has given the fishing right in its national waters to private companies. Approximately 46 thousand tons of anchovy were caught in the waters of Abkhazia and Georgia in the 2011/12 fishing period. Approximately 10 thousand tons of this catch was shipped to Turkey for fresh consumption. The remaining 34.4 thousand tons were given as raw material to the fish meal-oil factory operated by Turkish entrepreneurs in Abkhazia and 2.8 thousand tons in Georgia (Zengin et al, 2012). In order for Turkish fishermen to make a profitable and efficient fishing in the Eastern Black Sea, cross-border fishing conditions with neighbouring countries should be addressed in terms of legal and commercial legislation. On the other hand, in order to monitor the biological sustainability of the anchovy stock, it is necessary to implement a "regional monitoring program" together with the countries bordering the Black Sea. It is important for our national interests to expand this national program to include cross-border and to establish political, technical and economic cooperation with the countries in the region.

Since the end of the 20th century, significant changes have been observed in the migration of anchovy to the coasts of Turkey. The fishing season has started to narrow gradually. School of anchovy leave the South-eastern Black Sea coasts earlier than in the past. Many scientific studies have been conducted to support this phenomenon (Gücü et al, 2017). It is claimed that global climate changes are effective in this strategic change in the migration of anchovy population. About 90 years ago; news in the local newspaper published in Trabzon in 1932 reveals this situation in a striking way. The following information was included in the news titled '*Beautiful Trabzon Morning and Abril Five Storm'. 'The strong 'kıble' wind tonight, the warm weather this morning, the burning sun, the half-covered sky are nothing but preparation for the five storm of Abril (April)… Indeed, the fog spreading from the smoky mountains to the vast valleys shows this. Because of in Trabzon, it may be after the five storms of Abril, in the words of the commons who did not care about the full spring and then the storms and weather disruptions. This morning I made a walk around the city in this weather. I went to Mumhane beach, passing through narrowly spaced streets of the city backing to the sea. Here, the people surrounding the anchovy boats buy anchovies, the various sounds (sedas) of the vendors shouting from the anchovy boats (for five kuruş), the porter (hamal), donkeys, horses, mules being loaded with anchovies in the baskets, cooking anchovies on tin barbecues, large sliced bread in front of them, a head onion or radish, You should see these places and this view, which resembles a fair in general, where porters eat anchovies around wooden tables and the delegation to the general public, although there are pan anchovies on the floor! "How vividly is depicted this state and this landscape in Hamamizade's Hamsiname'* (Akşam Newspaper, 1932).

Difficult working conditions at sea, on the vessel and expatriate for months

Working and living conditions in purse seiners, which constitute the basic fishing tool of anchovy fishing, are quite difficult. Crews, who have to live and work on the sea for about four to five months, can visit their families only twice during a fishing season, using leave periods ranging from one week to ten days. On the other hand, working hours are uncertain and long. Since the fishery season mostly involves the winter months, the workers struggle not only with the difficulties of the work but also against the difficult weather conditions (Picture 10). The uncertain working hours, sleep and rest periods during the hunt further aggravate the working conditions. The crew working in a purse seiners express these conditions as follows: *'The heaviest work after mining is ours. There are no working hours; we are vigilant for 24 hours, sleep time according to the flow of the fish. Especially in the first three months bonito, horse mackerel hunting is very difficult. We work under all of them cold, rain, snow, storm and frosty. When the fish is dense, we cannot rest at all and cannot be fed regularly. This is not making money, not working, it's war! The day and night are not clear on the boat. Boots on our feet, linoleum on our backs, cold rain, we work non-stop day and night. It happens that you don't feel your hand from the cold. I know that I never took that linoleum off my back for three days; I was sleepless for three days. We work for 30 days, but we have been working day and night for 60 days a month because'* (Can, 2013).

Picture 10. The early 1980s… The crew team working at the port during the anchovy fishing season (Can, 2013)

In addition to working conditions, the difficulty of staying away from home for months is frequently expressed by crews who are married and have children: '*You always think about home in expat fishing, how they will end this month. They say that he uses cigarettes and alcohol a lot, how about the fisherman, how not to drink. His family comes to mind, light a cigarette. You travel with your child on the shore; I look at you from the sea, and light another cigarette…'* (Can, 2013).

During the fishing season, which lasts for months, the boats, which have working environments for crews whose numbers vary between 20 and 30 depending on the size of the purse-seiners, are also living spaces. Therefore, in addition to the working conditions of the boats, the accommodation and living conditions are also important for the safety and health of the crew. In this context, the intertwining of working environment, social environment and living space often causes the distinction between work and leisure / rest to be blurred. '*There is no rest, no social life, in this profession, you work 18-20 hours a day, 8 months a year. Especially when the prey is intense, you cannot even sleep, let alone rest. We even pray for the weather to blow and the storm to break out, so that the boat should move to the shore so that we can rest. But that doesn't happen; we fix the nets when we're not fished…'* (Picture 11) (Can, 2013).

Picture 11. The *'misery convoy'* **from pursuing the fleet in the sea from the land ... The early 1980s… (Can, 2013).**

For these reasons, it is extremely important to make the working relations, labour and labour process of the fishing sector visible first. Because the fishing industry are continues its existence as an invisible area in terms of labour relations, organization, worker health and safety, and social security. The capitalist relations and labour process in the fishing industry have not been understood or questioned even today. Both by those within the sector and by bureaucrats… It is that fish workers, who work with or without salary in purse seiners, which make up the largest part of employment in fisheries, have a wide range of precariousness that affects their daily practices. This broad insecurity begins with the establishment of informal relations at the beginning of the work process. This process, which started with no formal agreement of any crew, continues with the lack of a healthy working environment and social insecurity in terms of worker health and safety. These working conditions, which lack social security, unregistered and unorganized work in the fishing sector, which is seen as the most dangerous sector in the international literature, undoubtedly place the workers working here next to those who are in the category of the most insecure, whose number is increasing day by day (Ulukan, 2016).

In 1980, with the decisions of January 24, 1980, with the transition to the 'market / capitalist economy', the purse-seine fishing fleet has developed a lot both technologically and numerically with the cheap loans provided by the state. In parallel with this, a rapid increase has been achieved in fish meal and oil factories with the government support. However, there has been a gradual decline in anchovy stocks since the 2000s due to excessive fishing pressure and other factors (Zengin, 2019b).

Anchovy is the bread money of the Black Sea people, a folk song that spills from the head and lips of the table. The anchovies, which are hunted 4-5 months a year from September to April, are also processed as fish meal and oil in factories while decorating the tables with various dishes. In every purse seine that catch anchovies; approximately 50-60 people work both on board and at the discharge ports. Besides the shares paid to diesel, food and crew members, loan debts are an important burden for fishermen chiefs (reis) (Ersin, 1967). Factories that cannot get enough anchovies operate at low capacity. One of the pioneers of fish meal-oil enterprises and the first private business owner in Trabzon, Orhan Çakır (over 100 years) was producing only one fourth of the anchovy processing capacity, which was 300 tons / day. Çakır in this regard; He stated that anchovy fishing has come to these days unconsciously and by being encouraged by daily political decisions (September, 2000, Personal Interview).

Tens of tons of fish caught overnight, unloaded and loaded onto trucks in ports where they are sent require a large workforce on its own. There is a never-ending race between fishing boats and anchovy flocks. For example, when a stream sailing from Ordu finds and catches a fish off Giresun, it fills it with a spare engine and sends it to the nearest port. In order to unload this prey from boats and load it onto trucks, human labour is needed on land as well as on the boat. However, it is not easy to find crew members during the anchovy hunting season. It is hard to find a person who can endure this hardship. In this respect, the most important source of income for the coastal fishermen living in coastal villages such as Ordu, Perşembe, Vona, Ünye and Fatsa in their small boats out of season is expatriation in anchovy purse seiners.

Yusuf Kaya, the head of the boat 'Can Kardeşler', who was hunted in Hopa harbour; He complains about the intensity of operations in the fishing area, saying '*I am afraid that at least ten boats will be followed by me on my way back to Samsun*'. Heads of the purse-seine team find permanent carriers who will transfer the anchovies they fished from boats to trucks through subcontractors / great captain, who call them '*sergeant*'. The people of the Black Sea called the '*misery convoy*' to the community of mobile hotels in which the carriers who had to follow the fleet in the sea from land used to sleep and leave. They follow the anchovy flocks by sailing every evening with 2 or 3 carrier boats that will carry the anchovies to the shore with their purse-seiners. Wherever the sea fleet moves, the '*misery convoy*' will follow them by land. While some of the carriers sit in cafes and spend time, others rest by cooking and drinking tea in mobile shelters consisting of vehicles such as buses, trucks and caravans. One of the crew members on land; '15-20 people sleep together in a tarpaulin truck bed. We cannot even find water to wash our faces in the ports. He reproached, saying, "*We are working in misery in these places that are better than the grave and worse than prison*" (Hopa, November, 1984). Some of the crews who had to lead a miserable life in mobile convoys had to leave the university due to financial problems. Some of them chose seasonal workers / crews because they could not find a job after finishing high school. Actually they had three options; they will work seasonally in constructions, woods in the forest or sea (Can, 2013).

Development of fish meal-oil industry based on anchovy fishing

With the transition to the market economy in 1980, especially the anchovy fishing fleet / purse-seine fishing showed improvement in terms of numerical and technical capacity, and also caused an increase in the amount of catches landed. In the previous period; the annual anchovy catches landed in the early 1970s were around 60-70 thousand tons; Anchovy hunting increased to 300 thousand tons in the mid-1980s, and 375 thousand tons in the mid-1990s. In this period of approximately 20-25 years, anchovy catch has increased four or five times. Despite this increase in anchovy hunting in the Black Sea; Due to the lack of interest in the marketing network and consumption habits, it faced the problem of evaluating the hunted product. More interestingly, the large amount of anchovy hunts in these years, which are mentioned due to the inadequate marketing network, were used as fertilizer in the hazelnut orchards in the region (Zengin, 2010)

Fish meal-oil industry in Turkey started to be established in the second half of the 1970s based on the existing anchovy fishing potential in the Black Sea and developed only in this region. Until 1972, EBK's existing 100 tons / day capacity fish meal-oil factory in Trabzon was the first and only investment of the sector, with the introduction of the private sector, as of 1980, the number of factories was 23 and the processing capacity of the sector was 7855 tons / day (DPT, 1989), It has reached the day. Since the early 1980s in the Black Sea, due to the increase in anchovy catches, the use of surplus anchovy outside of fresh consumption has come to the fore and entrepreneurs have been provided with various investment facilities for this purpose. In addition to the incentives provided, this sector has become attractive in parallel with the cheapness of raw material / anchovy and the developments in fish oil exports (Özdamar ve Aral, 1995). However, due to the short duration of the anchovy hunting season, factories could not reach their installed capacity in terms of productivity and their capacity utilization could not exceed 25% (Zengin et al, 1992).

Orhan Çakır is one of the first entrepreneurs and pioneers of the fish meal-oil sector in the Black Sea. Until the establishment of the Meat and Fish Institution by the state in 1952; before 1952, there was only a '*işlekhane*' (small local business) belonging to Vessel Çakıroğlu in Trabzon. This facility was established jointly with the support of the Germans before the Second World War (Figure 12) (Çakıroğlu, 1969). In 1927-1928, for the first time, a joint facility that processes dolphin oil was established by Veysel Çakır and Mr. Ernest Hegler (Swedish citizen) called 'Delphin' (Veysel and Ernest Collective Comp) (Köse, 2014).

Picture 12. The first dolphin oil factory established by the 'EBK Fisheries Organization' in Değirmendere, Trabzon in the early 1950s (Çakıroğlu, 1969)

In 1976, KARSUSAN was established as a publicly traded company in Trabzon. This company covered two processing units: one is fish processing for human consumption and the other fish meal and oil processing unit. Ten months after the establishment, the company started to produce fish meal and oil. About the same year as KARSUSAN established, another firm called BALIKSAN has also opened to public trade in 1976. The company produced fish meal and oil using anchovy as raw material (Köse, 2014).

KARSUSAN firstly gained capital from processing and marketing fish meal and oil from anchovy. In 1980s, the company started to produce salted fish using support from Türk Sanayi ve Kalkınma Bakanlığı (Turkish Ministry of Industry and Development) using the World Bank funds under a project that uses local raw material and high local labour. The project aim was to process salting anchovy packed in oil in cans, and then marketing. It was also aimed to use fish waste from salting process as in the fish meal and oil factory unit. The owner of the company hired a foreign expert on fish salting according to criteria of consumers in the some European markets (Köse, 2014).

Although anchovy has the largest share in the production of marine fish in the Black Sea, the processing and evaluation technology in our country could not develop and become widespread until the 1980s, ancho vy hunting intensified in a certain period of the year and the fishing period lasted as short as three months; This has led to the use of the amount of the landed catch, other than the portion that can be offered for fresh consumption in the market, as the basic raw material in fish meal-oil factories (Zengin, 2000). In addition to the anchovy, horse mackerel, stingray, shark and whiting were also given to factories in the first years (seventies and eighties), albeit in small quantities, from time to time Özdamar, 1988). However, the majority of the raw material input of these enterprises (93%) was anchovy, and thus the dependence on anchovy resulted in overfishing of anchovy stocks (Zengin, 2000).

Today, there are important operational problems caused by working at low capacity in fish-meal oil factories operating in the Black Sea Region. Profitability in such industrial enterprises; Capacity utilization in enterprises significantly affects the availability of input prices as well as. It is not possible to work profitably and efficiently by working at low capacity. This situation has brought up the constant raw material problem for these enterprises. These enterprises have a significant share in the collapse of anchovy stocks since the early 2000s.

An endless song sung for centuries…

Anchovy, which has a wide range from bread to pilaf, steamed to grilled, flour to oil and is the subject of anecdotes, is the most important symbol of the Black Sea region and culture. With the approach of the winter season, its paths are observed and it is the most important food of the tables for three to four months a year. It is one of the important activities of the local economy with its sub-sectors such as anchovy fishing as well as marketing, transportation, and restaurant and it is the “bread gate” of many people.

The definition of ‘*anchovy is fish’* is not valid for Black Sea people. “Anchovy is an anchovy”. For its hunter, seller, restaurateur, and consumer, anchovy is not a fish; it is as if it is another creature. The fish transcended its identity centuries ago. He is small, his culture is big. Anchovy is not only unique to the Black Sea; it has spread too many seas. However, nowhere like in the Black Sea, it has become integrated and intertwined with the life of the local people and even has become an indispensable part of daily life, a lifestyle. For example, in the traditional Black Sea horon, the calmness of the sea is replaced by the rough sea in the finale, while the white metals on the waist of the male dancers revive the reflections of the anchovy in the water.

Anchovy is a part of the social, cultural and economic life of the Black Sea people and has completed its identity with it for centuries. For them, anchovy is a lifestyle… Maybe it's an important motivation to exist. Just like in the lines of the great poet Nazım Hikmet… (Hikmet, 1987).

"*There were people at the helm and under their heads that*

These;

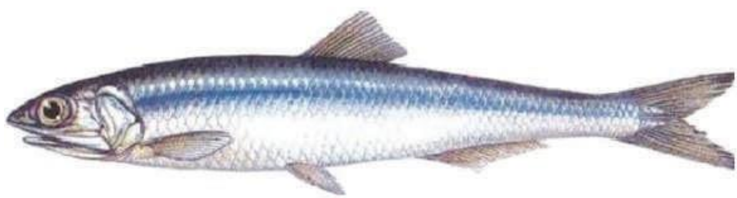
Long crooked nose

And people who lustfully loved to talk

For the glory of navy blue anchovies and cornbread on the back

Without expecting anything from anyone

They could die like singing a song… "



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