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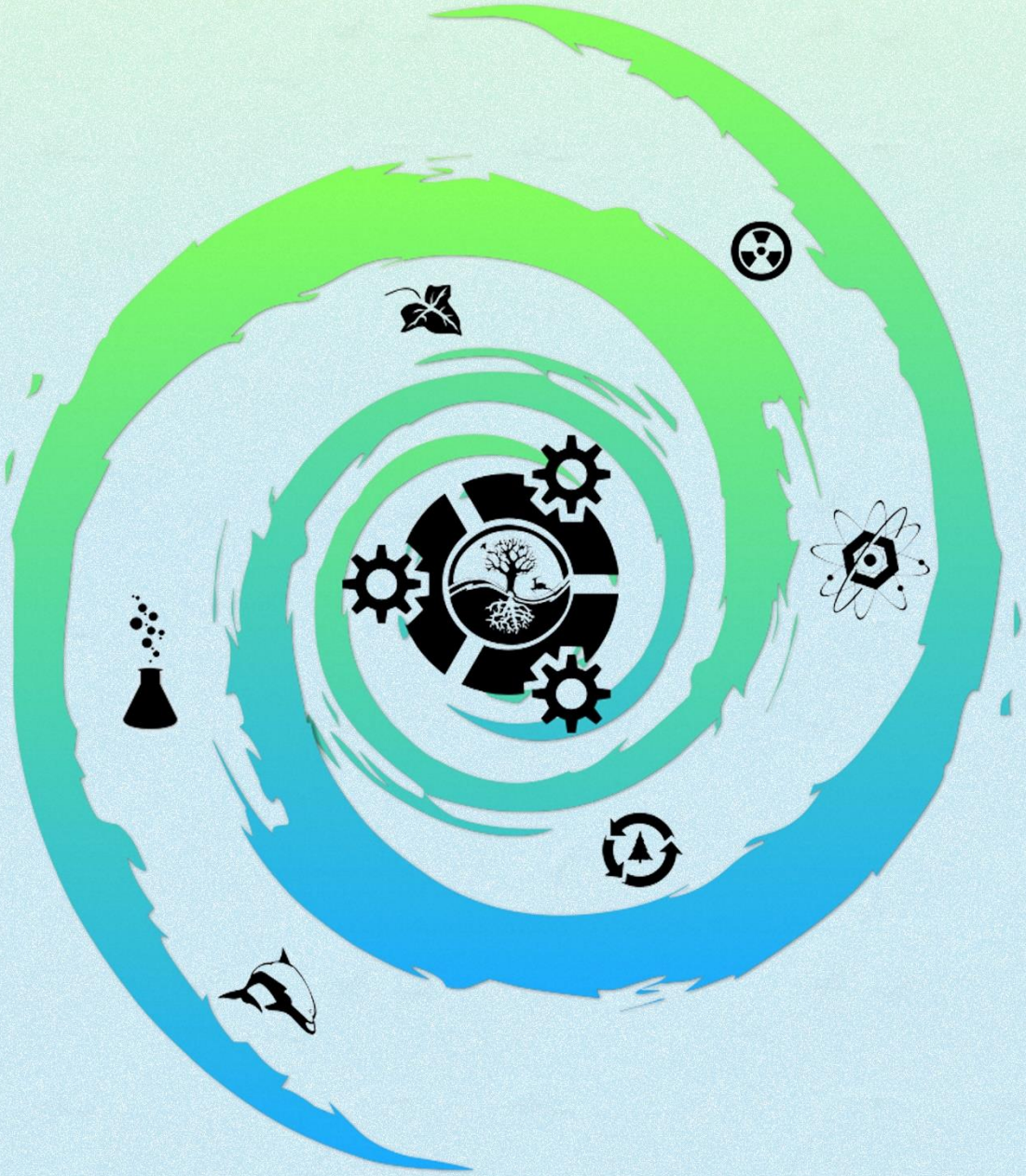

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Son Buzul Maksimum'dan Günümüze Kıyı Çizgisi Değişimlerine Örnek: Çanakkale Boğazı

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ÖZET

İklim değişikliği günümüzde yerküre için önemli bir sorun olarak karşımıza çıkmaktadır. Bu sorunun olumsuz etkileri yaşadığımız zamanda doğrudan yansımıyor olsa da önümüzdeki on yıllar/yüzyıllar içerisinde insan yaşamında gözlenecek ve binlerce/on binlerce yıl sonrasında ise olumsuz etkilerin yerküre üzerinde ayrıntılı olarak gözleneceği konu üzerinde çalışan bilim insanları tarafından ortaya konulmaktadır. Öngörülen bu iklim değişikliği yerkürenin oluşumundan günümüze kadar geçen yaklaşık 4,5 milyar yıllık zaman dikkate alındığında (geçmiş jeolojik zamanlardaki iklim değişikliği sebepleri ile öngörülen iklim değişikliği arasındaki farkın insan etkisi olduğu göz önüne alınmazsa) olağan bir durum olarak değerlendirilebilir. Kuvaterner iklim değişikliklerinin etkileri, yerküre üzerinde hem küresel ölçekte hem de bölgesel ölçekte gözlenebilmektedir. Küresel ölçekteki iklim değişikliğine örnek olarak deniz seviyesinin sürekli değişimi verilebilir ki bu değişimin en iyi göstergeleri kıyılarda gözlenen denizel taraçalar veya denizaltı kanyonları gibi jeolojik/jeomorfolojik yapılardır. Bölgesel ölçekte ise mağaralarda gözlenen sarkıt ve dikitler, göl çökelleri, derin deniz sedimanları, buzul karotları iklim değişimlerinin kaydedildiği en güzel örneklerdendir. Bu çalışmada son buzul maksimumdan günümüze kadar geçen zaman zarfında iklim değişikliğinin izlerini en iyi yansıtan deniz seviyesi değişimleri dikkate alınarak Türk Boğazlar Sistemi'nin güney kolu olan Çanakkale Boğazı kıyılarının kara-deniz sınırı (kıyı çizgisi) değişimleri incelenmiştir. Bu bağlamda, iklim değişikliklerini de gösteren farklı küresel ve bölgesel deniz seviyesi değişim grafikleri ele alınmış ve bunlara bağlı olarak Çanakkale Boğazı kıyılarının geç Pleyistosen'den günümüze kadar olan değişimleri, coğrafi bilgi sistemleri programları yardımıyla batimetri haritaları kullanılarak modellenmiştir. Bu üretilen yeni haritalardan en dikkati çekeni ise günümüzden yaklaşık 22 bin yıl öncesine ait olanıdır. Bu zamanda küresel deniz seviyesinin günümüze göre 120 metre daha alt seviyelerde olduğu bilinmektedir ve Çanakkale Boğazı'nın da bilinen en derin noktası günümüzde –113 metre civarıdır. Dolayısıyla, bu zamanlarda Çanakkale Boğazı aracılığıyla bir Akdeniz-Karadeniz su yolu bağlantısından bahsetmek mümkün değildir.

Example of Coastline Changes from the Last Glacier Maximum to the Present: Çanakkale Strait

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ABSTRACT

Climate change emerges as an important problem for the earth today. Although the negative effects of this problem are not directly reflected in the time we live in, it is revealed by the scientists working on the subject that it will be observed in human life for decades-centuries and will be observed in detail on the earth for thousands of tens of thousands of years later. This predicted climate change can be considered a normal situation when considering the time that has passed from the formation of the earth to the present, approximately 4.5 billion years (except that the difference between the reasons for climate changes in the past geological times and the predicted climate change is the human effect). The effects of Quaternary climate change can be observed on the earth both on a global scale and on a regional scale. As an example of global climate change, the continuous change of sea level can be given, and the best indicators of this change are geological/geomorphological structures such as marine terraces or submarine canyons observed on the coasts on the regional scale. On the local scale, stalactites and stalagmites observed in caves, lake sediments, deep sea sediments, glacial cores are among the best examples of climate change. In this study, the land-sea boundary (coastal line) changes of the coasts of the Çanakkale Strait, which is the southern branch of the Turkish Straits System, have been investigated, considering the sea level changes that show the climate change best in the last 25 thousand years. In this context, the coastal changes of the Çanakkale Strait coasts from the Late Pleistocene to the present are modeled using geographic information systems programs, by using different global and regional sea level change charts showing climate changes. The most striking of these new maps is the one from 20 thousand years ago. At this time, it is known that the global sea level is 120 meters lower than today and the deepest point of the Çanakkale Strait is around -113 meters today. Therefore, it is not possible to mention a Mediterranean-Black Sea waterway connection through the Çanakkale Strait at these times.

GİRİŞ

Günümüzde yaşanan iklim değişimleri dünyanın en önemli sorunudur. İklim değişimin olası etkileri de göz önüne alındığında dünyanın geleceği için şimdiden bazı önlemlerin alınması ve erklerin bu konu üzerinde acilen durması gerektiği bir öncelik içerisindedir. İklim değişikliğinin olası etkileri dikkate alındığında genellikle canlıların hayat ve yaşam ortamlarında meydana gelecek değişiklikler öncelikle konu edilirken bu değişimler ile birlikte yerküreyi oluşturan jeomorfolojik unsurlarda da önemli değişikliklerin meydana geleceği öngörülmektedir (IPCC, 2019a, 2019b; Oppenheimer vd., 2019).

Geleceğe dair bu öngörüler özellikle yer şekilleri üzerinde yapılırken Aktüalizm prensibine uygun olarak (Oldroyd, 1996'da J. Hutton ve C. Lyell'in teorileri) öncelikle günümüzdeki yeryüzü şekilleri değişimi takip edilerek, geçmişteki buna benzer olaylar incelenir ve ilerleyen zamanda hangi süreçlerin etkisi ile yer şekillerinde değişiklikler olabileceği açıklanmaya çalışılır. Geçmişte yaşanan yer yuvarı şekillerinin değişimlerini etki eden en önemli unsurlar tektonizma, izostasi sedimantolojik süreçler ve küresel deniz seviyesi (KDS) değişimleridir. KDS yerküre üzerinde bulunan suyun hareketliliğine bağlı olarak değişim göstermektedir. Bu değişim su döngüsü olarak bilinen sistemin kesintiye uğraması, döngünün unsurlarından olan okyanus sularının genleşmesi, buzulların eriyip tekrar buzul haline dönüşmesi tektonik ve sedimantasyon kökenli östatik hareketler ile yerküre genelindeki deniz seviyesi değişimleri şeklinde gözlenmektedir.

Deniz seviyesi değişimleri ayrıntılı incelendiğinde deniz seviyesinin uzun yıllık periyotların yanı sıra saatlik-günlük-haftalık-aylık olarak sürekli değişim gösterdiği görülür. Bu değişimler yerkürenin Güneş etrafındaki hareketi ve az da olsa Ay'ın kütle çekimi etkisinden dolayı gözlenen olağan bir durumdur. Bu etkenler dikkate alındığında küresel anlamda kalıcı bir deniz seviyesi değişimi söz konusu değildir ve bu değişim en iyi olarak yaz ve kış aylarındaki deniz seviyesi farklılıklarında hatta gel-git etkisinde dahi görülebilmektedir. Uzun vadeli deniz seviyesi

değişimlerinin en önemli sebeplerinden biri de yerkürenin sıcaklık değerlerinin değişmesidir. Bu değişime ait veriler geçmiş jeolojik zamanlardaki deniz seviyesi değişim grafiklerine yol gösterici olmaktadır. Sıcaklık değişim bilgileri genellikle Antarktika'daki buzulların CO_2, izotopik sıcaklık ve yaş analizlerinden elde edilen verilere dayalı hazırlanmaktadır (Reynolds vd., 2019). Son 130 bin yıl içindeki küresel sıcaklık değişim grafikleri incelendiğinde (Reynolds vd., 2019) yerküre, günümüzde en sıcak zamanları yaşamaktadır. Yine aynı zaman dilimi içerisinde en soğuk zamanların ise günümüze göre 8-11°C daha soğuk olan (Sarıkaya & Çiner, 2015; Osman vd., 2021) Son Buzul Maksimum (SBM) olarak tanımlanan zaman aralığında, günümüzden yaklaşık 22 bin yıl önce yaşandığı görülmektedir. SBM'nin çalışma alanını da kapsayan Türk Boğazlar Sistemi üzerine etkilerine bakıldığında ise Karadeniz–Akdeniz bağlantısının bu sistem üzerinden olmadığı (Smith vd., 2015) hatta Marmara Denizi'nin göl olarak varlığını sürdürdüğü jeolojik verilere dayanarak (Kırcı-Elmas, 2006; Çağatay, 2015) açıklanmaktadır.

Bu çalışmada Çanakkale Boğazı (Şekil 1) kıyılarının SBM'den günümüze kadarki zaman aralığında kıyı çizgisi dolayısıyla kara-deniz sınırının muhtemel yerlerinin gösterimi aktarılmaya çalışılmıştır. Bu amaçla küresel ve bölgesel anlamda deniz seviyesi değişiminin uzun süreli ve/veya kalıcı olduğu ve kendi zamanı için sabit bir değer olarak kabul edildiği (günümüzdeki seviye 0 metre olarak kabul edilmiştir) grafikler (Kayan, 1997; Lambeck vd., 2014; Benjamin vd., 2017) dikkate alınarak son 22 bin yıllık küresel-bölgesel deniz seviyesi (KBDS) değişim grafiği hazırlanmıştır. Ayrıca Akdeniz ile Karadeniz'i birbirine bağlayan Türk Boğazlar Sistemi'nin güney kolu olan Çanakkale Boğazı'nın (Şekil 1) küresel deniz seviyesi değişimlerine bağlı özellikle SBM'den itibaren gözlenen deniz seviyesi değişimleri dikkate alınmış ve KBDS grafiğinden faydalanılarak Çanakkale Boğazı'nın farklı zamanlara ait kıyı çizgileri haritalar üzerinde gösterilmiştir.

MATERYAL VE YÖNTEM

Yaklaşık 62 km uzanıma ve ortalama 55 metre derinliğe sahip olan Çanakkale Boğazı'nın (Şekil 1) öncelikle güncel kıyı çizgisi bilgileri ve batimetri haritaları temin edilmiş (SHODB, 1997; MTA, 2005) bu haritalardaki yükseklik/derinlik verileri ArcGIS 10.7 programında sayısallaştırılmıştır. Farklı zamanlardaki deniz seviyesi değişimlerini göstermek amacıyla KDS değişim eğrileri (Kayan, 1997; Lambeck vd., 2014; Benjamin vd., 2017) birleştirilmiş ve KBDS değişim grafiği hazırlanmıştır (Şekil 2). Bu grafikteki verilere bakılarak önemli geçişlerin gözlendiği zamanlara ait yükseklik değerleri alınmış ve bu değerlere bağlı olarak TIN to Raster yöntemi ile Sayısal Yükselti Modelleri (SYM) üretilmiş ve bu SYM'ler kullanılarak yükseklik/derinlik haritaları oluşturulmuştur. Elde edilen haritalarda yükseklikleri ayrıntılı gösterebilmek için 10 metre aralıklı 22 yükseklik sınıfı hazırlanmıştır. Elde edilen görüntülerin üzerine ek bilgiler eklenmesi ve görselliğin artırılması için CorelDRAW 2018 programı kullanılmıştır. Çalışmada amaç sadece kıyı çizgisi ve deniz derinliğini göstermek olduğundan kara bölgeleri ihmal edilmiştir.

Figure 1. Study area (Satellite image of 08.07.2021 obtained from Google Earth on 27.06.2022). The star in the northwest of Nara Cape indicates the deepest point of the Çanakkale Strait (Gökaşan et al., 2007).

Şekil 1. *Çalışma alanı (27.06.2022 tarihinde Google Earth'ten alınan 08.07.2021 tarihli uydu görüntüsü). Nara Burnu kuzeybatısındaki yıldız Çanakkale Boğazı'nın en derin noktasını (Gökaşan vd., 2007) göstermektedir.*

BULGULAR

KBDS (Şekil 2) grafikleri kullanılarak elde edilen verilerin coğrafi bilgi sistemleri yöntemleri ile değerlendirilmesi sonucunda öncelikle Çanakkale Boğazı'nın günümüzdeki batimetri/derinlik durumunu gösterir harita hazırlanmıştır (Şekil 3a). Ortalama derinliği 55 metre olan Çanakkale Boğazı'ndan elde edilen batimetrik ve jeofizik verilere göre en derin alanlar günümüzde Nara Burnu–Kilye Koyu arası ile Nara Burnu kuzeybatısındaki bölgelerdir (SHODB, 1997) ve bu bölgelerdeki bazı noktalar 113 metre (Şekil 1'de yıldız ile gösterilmiş nokta; Gökaşan vd., 2007) derinliğe ulaşmaktadır.

Kayan (1997) çalışmasında son 7 bin yıllık zaman içerisindeki en düşük deniz seviyesinin günümüzden yaklaşık 3300 yıl önce –3 metre seviyelerinde olduğunu belirtmiştir. Bu çalışmada KBDS grafiğindeki değer dikkate alınmış ve bu değerden dolayı ortaya çıkan batimetri haritasının günümüz kıyı çizgisi ile paralellik gösterdiği belirlenmiştir (Şekil 3b). Ancak, haritada yaklaşık bir paralellik gözlense de o zamanki kıyı çizgisinin az da olsa deniz tarafında olduğu görülmektedir.

KDS'nin hızla yükseldiği ve Holosen'de ivmelenmenin azalmaya başladığı dönemlere karşılık gelen günümüzden yaklaşık 9 bin yıl önceki durum, çalışmamızda 3. seviye olarak ele alınmıştır. Bu zaman aralığındaki seviye günümüze göre –20 metre daha aşağıda olarak değerlendirilmiştir (Lambeck vd., 2014; Benjamin vd., 2017). Bu dönemde Çanakkale Boğazı'nın hala Türk Boğazlar Sistemi'nin bir parçası olduğu ve Marmara Denizi ile Ege Denizi'ni birbirine bağlayan bir kol olarak yer aldığı SYM'den hazırlanmış olan haritada da (Şekil 3c) ayrıntılı bir şekilde görülmektedir.

Pleyistosen–Holosen geçişinde (günümüzden 11.700 yıl önce) ise KDS günümüze göre yaklaşık –60 metreden daha alt seviyelerdedir (Lambeck vd., 2014; Benjamin vd., 2017). Eldeki veriler ile hazırlanan haritada Çanakkale Boğazı'nın her iki girişinden de deniz sularının girmiş olabileceği değerlendirilmiştir. Ancak, doğrudan bir bağlantının varlığı kesin olarak harita bilgilerinden anlaşılamamaktadır (Şekil 3d). Burada günümüzdeki batimetriyi gösteren haritalar ve çalışmalar (SHODB, 1997; Gökaşan vd., 2007) incelendiğinde çok dar bir geçişin olabileceği düşünülmektedir. Bu deniz bağlantısını ortaya çıkarabilmek için bahsi geçen zamana ait kıyı çizgisi yakınında oluşan yalıtaşı gibi jeolojik/jeomorfolojik unsurların varlığı aranarak bu unsurlar üzerinden yapılacak çalışmalar ile bağlantının varlığı hakkında daha ayrıntılı bilgiler ortaya konulabilir.

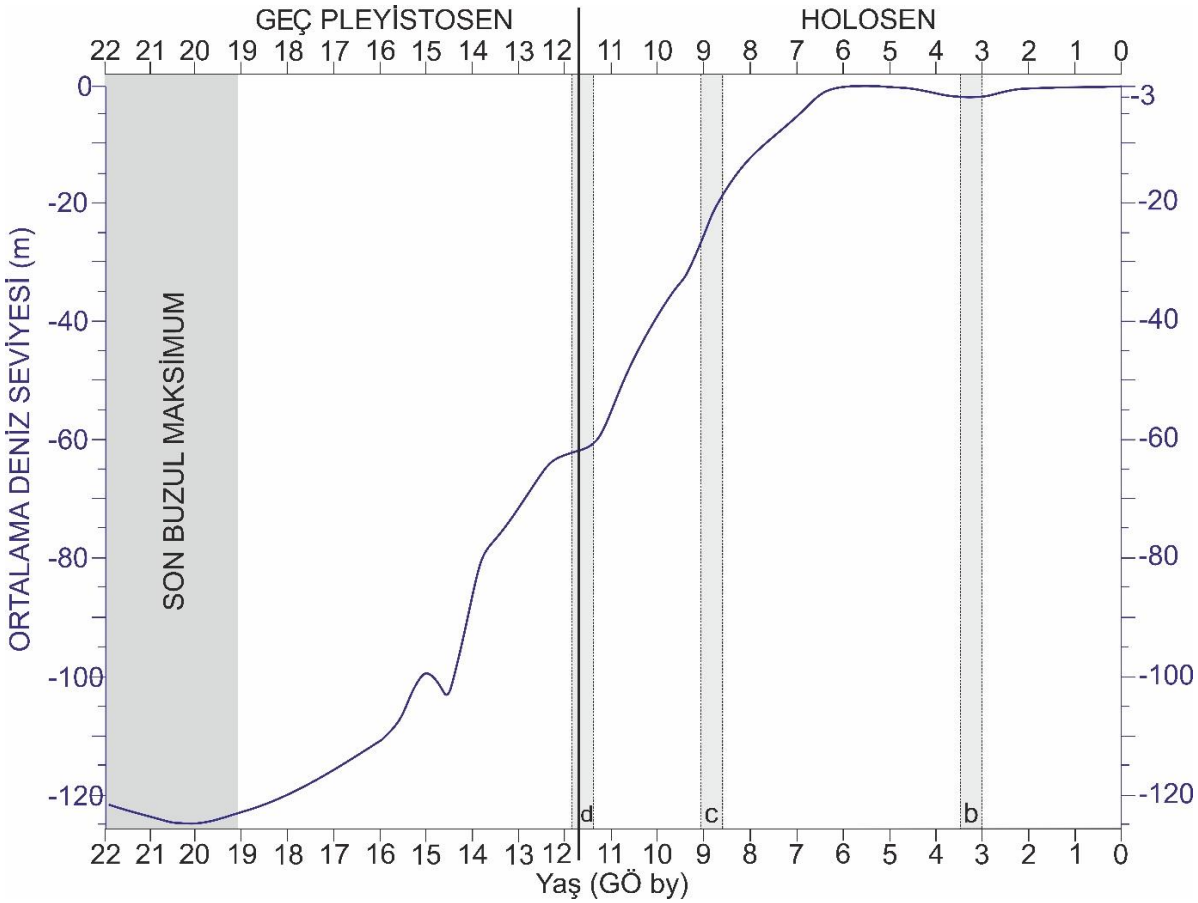

Figure 2. Graph of global-regional sea level change over the last 22 millennia. (This figure has been prepared using data and graphics from Kayan, 1997; Lambeck et al., 2014; Benjamin et al., 2017. The vertical gray areas with lowercase letters represent the times used for the coastline, and the line between 11-12 thousand years is ~11,700 years old from today. shows the corresponding Pleistocene-Holocene transition)

Şekil 2. *Son 22 binyıldaki küresel-bölgesel deniz seviyesi değişim grafiği. (Bu şekil Kayan, 1997; Lambeck vd., 2014; Benjamin vd., 2017'deki veri ve grafiklerden yararlanılarak hazırlanmıştır. Küçük harflerin bulunduğu dik gri alanlar kıyı çizgisi için kullanılan zamanları, 11-12 bin yıl arasındaki çizgi ise günümüzden ~11.700 yıl öncesine karşılık gelen Pleyistosen-Holosen geçişini göstermektedir)*

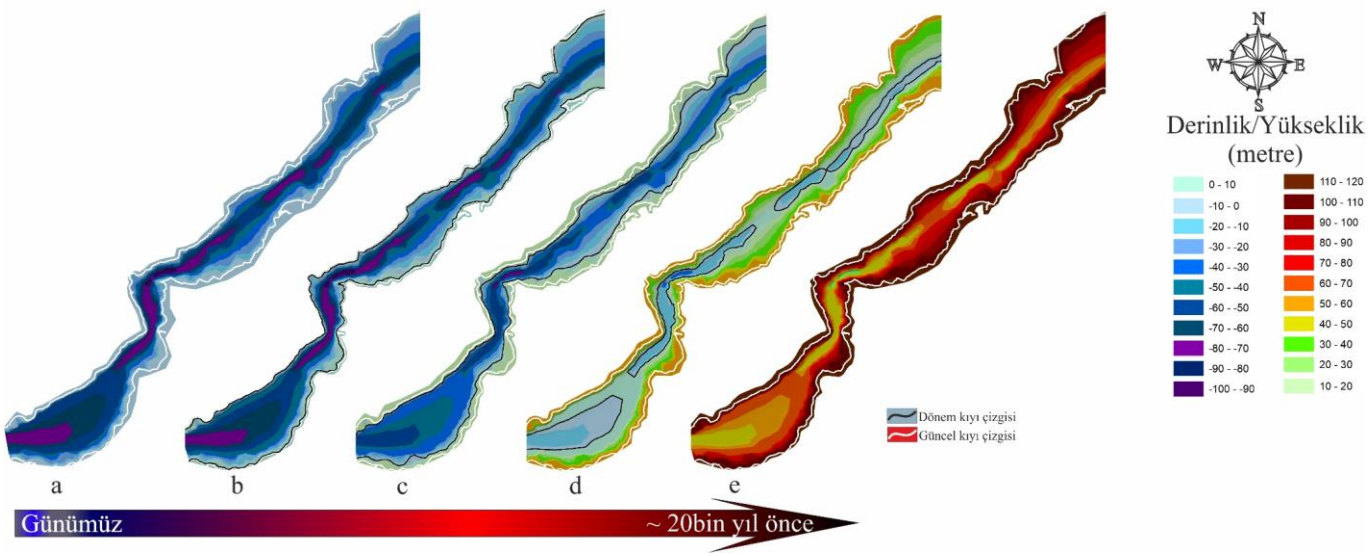

Figure 3. Coastline changes in the Çanakkale Strait from the last glacial maximum to the present according to the bathymetry values (MTA, 2005; SHODB, 1997) and KBDS (Şekil 2) change graphs, and the height-depth maps of different times were prepared by the TIN method using the bathymetry values. a) Current bathymetry map, b) The situation 3300 years ago from today, c) The situation about 9 thousand years ago from today, d) The situation during the Late Pleistocene-Holocene transition (about 11,700 years ago), e) The situation at the Last Glacial Maximum (about 20,000 years ago (Information on sea level changes is taken from Kayan (1997), Lambeck et al. (2014), Benjamin et al. (2017)).

Şekil 3. *Çanakkale Boğazı kıyı çizgisinin batimetri değerlerine (MTA, 2005; SHODB, 1997) ve KBDS (Şekil 2) değişim grafiklerine göre son buzul maksimum'dan günümüze yer değişimi ve batimetri değerleri kullanılarak TIN yöntemi ile hazırlanmış olan farklı zamanlara ait yükseklik-derinlik haritaları.* ***a.*** *Güncel batimetri haritası,* ***b.*** *Günümüzden 3300 yıl önceki durum,* ***c.*** *Günümüzden yaklaşık 9 bin yıl önceki durum,* ***d.*** *Geç Pleyistosen-Holosen geçişi esnasındaki durum, (yaklaşık 11.700 yıl önce),* ***e.*** *Son Buzul Maksimum dönemindeki (günümüzden yaklaşık 20 bin yıl önceki) durum (Deniz seviye değişimlerine ait bilgiler Kayan (1997), Lambeck, vd. (2014), Benjamin vd. (2017)'den alınmıştır).*

Son Buzul Maksimum'un sona ermesinden günümüze buzulların erimesinin sonucu olarak KDS'de yaklaşık 120 metrelik bir deniz seviyesi yükselimi olduğu bilinmektedir (Fairbanks, 1989; Edwards, 2006; Benjamin vd., 2017), (Şekil 2). Bu çalışmada da Son Buzul Maksimumu'ndaki deniz seviyesi Şekil 3e'nin hazırlanmasında kullanılmıştır. Çanakkale Boğazı'nın günümüzde en derin noktasının Nara Burnu kuzeyinde –113 m olduğu (Gökaşan vd., 2007) geri kalan alanlarda da derinliğin ortalama –55 metre olduğu düşünüldüğünde o dönemde denizel kökenli suların boğazda gözlenmediği hazırlanan haritada da (Şekil 3e) anlaşılmaktadır. Elde edilen bu harita Ege Denizi'nin o dönemdeki kara-deniz ilişkisini gösteren çalışmalarla da uyumluluk göstermektedir (Kayan vd., 1980; Galanidou vd., 2020). Çanakkale Boğazı'nın Karadeniz–Akdeniz bağlantısını sağlayan su yolu olmadığını gösteren Şekil 3e'ye uygun olarak Marmara Denizi'nin de göl olarak varlığını sürdürdüğünü gösterir veriler de Marmara Denizi kıyı ve taban alanlarında gözlenmektedir (Kırcı-Elmas, 2006; Çağatay, 2015).

TARTIŞMA

Yer şekillerinin gelişimi, dinamik yapıdaki yer yuvarının iç ve dış merkezli kuvvetler kaynaklı bazı olayların belirli bir süre içerisinde çalışması, yer bilimleri açısından belirli süreçlerin sonucunda şekillenmektedir. Bu süreçlerin etkenlerinden biri çalışmanın da konusu olan iklimdir ve çalışmada sadece bu etken dikkate alınmıştır. Yalnız bu süreçlerin önemli etkenlerinden bir diğeri yer yuvarının iç kuvvetlerini temsil eden tektonizmadır ki tektonizmanın etkisi örneğin deprem aktivitelerinin sonucunda anlık olarak yükselimler şeklinde gözlenebilirken, bazen de izostasi gibi çok uzun süreçlerin sonucu olarak bölgesel yükselim değişimleri şeklinde kendini gösterebilmektedir. Çanakkale Boğazı hem iklim değişikliğinin etkisi olan küresel deniz seviyesi değişimlerinin delillerini hem de tektonizmanın etkisi olan yükselimleri gösteren kıyılara sahiptir. Çanakkale Boğazı'nın oluşumunu inceleyen çalışmalarda genellikle en önemli faktörün tektonizma olduğunu jeolojik, jeofizik ve jeomorfolojik unsurlara dayanarak açıklanmaktadır (Erol & Nuttall, 1972, Kayan vd., 1980; Yaltırak vd., 2000; Hiscott & Aksu, 2002; Gökaşan vd. 2010; Avcıoğlu vd., 2013; Komut & Kapan, 2020). Çanakkale Boğazı ve çevresinde etkili olan

tektonizmayı açıklayan bu çalışmalarda ise bölgesel yükselim miktarlarının bulunmasında genellikle küresel deniz seviyesi grafikleri dikkate alınarak yorumlar yapılmaktadır (Yaltırak vd., 2000; Avcıoğlu vd., 2009; Komut & Kapan, 2020).

Bu çalışmada ise paleoiklim değişimlerine de örnek verebilmek için Çanakkale Boğazı kıyı çizgisinin son 22 bin yıllık zaman dilimindeki farklılıklarının küresel/bölgesel deniz seviyesi değişimleri olduğu kabul edilmiş ve tektonik hareketlilikler gibi iç ve bazı dış yer süreçleri ihmal edilmiştir. KBDS değişimleri çift haneli yükseklik değerleri şeklinde olduğundan hazırlanan modellerin gösterimi daha anlaşılır olmaktadır. Yalnız Holosen'de günümüzden yaklaşık 2500-4000 yıl önceki zaman aralığında –3 metre seviyelerine tekrardan düşen deniz seviyesi derinliği ele alındığında kıyı çizgisi değişimini göstermek daha da zorlaşmakta ve bu bölgelerde daha ayrıntılı batimetrik verilere ihtiyaç duyulmaktadır.

SONUÇ

Sonuç olarak bu çalışmada hazırlanan küresel-bölgesel deniz seviyesi değişim grafiğine dayanarak, Çanakkale Boğazı'nın Holosen başlangıcından bir süre önce deniz sularının istilasına uğradığı, 2 farklı özellikteki deniz (Karadeniz-Akdeniz) için bir su bağlantı yolu olduğu kıyı çizgisinin genellikle kıyılara doğru ilerlediği ve Holosen öncesinde (sadece KBDS dikkate alındığında) özellikle Son Buzul Maksimumu'nda deniz su yolunun/bağlantısının olmadığı ve Marmara Denizi'nin kapalı bir havza (göl) olduğu gözlenmektedir.

TEŞEKKÜR

Yazarlar, makalenin titiz biçimde hakem incelemesini gerçekleştirerek yapıcı eleştirileriyle makalenin geliştirilmesine katkı sağlayan hakemlere teşekkür ederler. Bu çalışma MB'nin yüksek lisans çalışmasında elde ettiği verilerin bir bölümünü kapsamaktadır ve çalışmanın özeti International Global Climate Change Congress (Çanakkale, Türkiye, 03-05 Haziran 2021)'de sunulmuştur.

Etik Standartlar İle Uyum

Yazarların Katkısı

Yazarlar bu makaleye eşit katkıda bulunmuştur.

Çıkar Çatışması

Yazarlar herhangi bir çıkar çatışması olmadığını deklare etmektedir.

Etik Onay

Yazarlar bu tür bir çalışma için resmi etik kurul onayının gerekli olmadığını bildirmektedir.

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Characterization of Genetic Diversity Among *Cucumis* Accessions Based on Morphological and Phytochemical Characters

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ABSTRACT

The genus *Cucumis* L. of the Cucurbitaceae family is widely cultivated all over the world. Despite wide distribution and consumption, there is little information for the assessment of genetic diversity among Iranian *Cucumis* species. In this study, genetic diversity among 21 accessions of Iranian *Cucumis* species (*C. sativus* and *C. melo*) was assessed using 20 morphological characters of fruit and leaf and 4 phytochemical characters. High phytochemical and morphological diversity at intra- and interspecific levels were revealed among *Cucumis* species, which reflects the industrial potential of Iranian accessions for breeding and commercial usage. The grouping pattern of genetic diversity was constructed using the UPGMA dendrogram. The results of the grouping pattern revealed high efficiency of morphological and phytochemical characteristics for uncovering the genetic diversity of *Cucumis* accessions. Moreover, using morphological characters, cucumbers were separated according to their ecological zones. Considerable amounts of phytochemical properties were revealed among Iranian *Cucumis* accessions, which were comparable to those reported in other studies. Furthermore, unlike Total phenol content and total flavonoid content, melons showed more total sugar and DPPH radical scavenging activity than cucumbers. These results could be important for *Cucumis* gene bank management, agriculture, and breeding programs.

INTRODUCTION

Assessment of genetic diversity among and within species is considered essential for agricultural programs including breeding (Humphreys, 2003; Jump et al., 2008). The program is also supported by international and local organizations that emphasize the conservation and use of agricultural biodiversity as a priority (Szamosi, 2005). However, information on the extent and pattern of genetic diversity is necessary for adequate use of plant genetic resources (Kresovich & McFerson, 1992; Sheikhi et al., 2019; Pandey et al., 2021). Moreover, studies clearly showed the need to save and manage the local germplasm and wild

relatives of agricultural crops (Solankey et al., 2015; Naghavi et al., 2019; Aryakia, 2020), since these materials may contain valuable genes for future breeding programs (Elbekkay et al., 2008; Chikh-Rouhou et al., 2021a).

In terms of plant breeding programs, the Cucurbitaceae family, among horticultural/vegetable crops, has a high position due to its commercially valuable species. This large plant family, also known as cucurbits, has about 130 genera and 800 species, with pumpkins (*Cucurbita* genus), watermelon (*Citrullus* genus), melon, and cucumber (*Cucumis* genus) being the most commercially important (Rolnik & Olas, 2020). However, the genus *Cucumis* L., with 32 species, is the most important genera of the Cucurbitaceae family. Some of the most well-known species in this genus are used as vegetables, medicinal plants, or ornamental plants (such as *C. dipsaceus* and *C. myriocarpus*) (Chen & Zhou, 2011). Melon (*Cucumis melo* L.) and cucumber (*Cucumis sativus* L.) are two commercial vegetable crops in the genus *Cucumis* that are extensively cultivated and consumed all over the world (Chen & Zhou, 2011). Nonetheless, there is an increasing global demand for qualitative and quantitative improvements in *Cucumis* crops, and several studies emphasize the importance of expanding the genetic basis of this genus, particularly cucumber and melon. (Chen et al., 1997; Stepansky et al., 1999a; Mangmang et al., 2016; Karakurt et al., 2020). Unfortunately, cucumber has a very narrow gene pool (Karakurt et al., 2020). It has been apparent that the genetic base of commercial cucumber germplasm is not extremely heterogeneous (Pierce & Wehner, 1990; Liu et al., 2015) which limits the development of cucumber breeding programs. On the other hand, since melon varies in leaf and fruit characters, it is considered to be the most morphologically diverse species in the genus *Cucumis* (Kirkbride, 1993; Pandey et al., 2021). In addition, knowing the relationships and characterization of the natural composition of the *Cucumis* accessions are important to improve melon (*C. melo*) and cucumber (*C. sativus*) with valuable characters during breeding programs (Deakin et al., 1971; Yu et al., 2015).

Studies on *Cucumis* species are in progress worldwide (Ismail et al., 2010; Raghami et al., 2014; Chikh-Rouhou et al., 2021a). In Tunisia, one of the rich centers of *Cucumis* genetic diversity, melon landraces have been reported as highly tolerant to many biotic stresses such as powdery mildew, fusarium wilt, aphids, and viruses. Moreover, a considerable phenotypical and molecular diversity among *Cucumis* accessions for many characters including those related to agronomical performance has been reported (Chikh-Rouhou et al., 2021a; Chikh-Rouhou et al., 2021b). Iran is also one of the richest genetic diversity resources of *Cucumis* species (Raghami et al., 2014). It is reported that the country with a total *Cucumis* production of 1,600,000 tons ranks fourth in the world (FAO, 2012). It seems that the characterization of genetic diversity could reveal their industrial potential. However, there is little information for diversity assessment of Iranian *Cucumis* species (Raghami et al., 2014). In this regard, genetic markers including morphological, biochemical, and molecular markers have been used to assay genetic diversity and germplasm characterization, monitor changes in population structure, and manage variation through concerted conservation strategies (Ghafoori et al., 2013; Chikh-Rouhou et al., 2021b).

Evaluation of genetic diversity based on morphological characters is very important to reveal valuable horticultural traits in *Cucumis* (Chikh-Rouhou et al., 2021b). It is also applied for evaluating taxonomic arrangement (Kashyap et al., 2021), for ecological studies such as the interaction between plants and pollinators (Bernhardt et al., 2008), and also the other evolutionary consequences (reviewed in Schemske, 1980). For example, assessment of the shape and size of the leaf could be an important factor influencing the success of plants as its roles in the absorption of light energy and gas exchanges (Tsukaya, 2005). However, there is no report for assessment of intra- and interspecific morphodiversity among Iranian *Cucumis* species. Besides, assessment of phytochemical diversity among them could be important in terms of nutritional, pharmacological, and breeding programs (Ismail et al., 2010; Aryakia et al., 2018; Manchali et al., 2021). In this study, we assessed genetic diversity among 21 accessions of Iranian *Cucumis* species using 20 morphological characters represented by UPOV (2019), along with 4 phytochemical characters of total phenolic content (TPC), total flavonoid content (TFC),

total sugar (TS), and DPPH (2,2-diphenyl-1-picryl-hydrazyl-hydrate) free radical.

MATERIAL AND METHODS

Plant Material and Experimental Design

This study was conducted at the Iranian Biological Resource Center (IBRC), Karaj, Iran. Seeds of 21 *Cucumis* accessions (12 accessions belonging to *C. sativus* and 9 accessions belonging to *C. melo*) from 9 Iranian provinces (major cultivation areas of *Cucumis*) were collected by the experts from open-pollinated accessions at the full ripening stage. The seeds were then cleaned, sorted, and stored in the seedbank before being directly examined in this study. The description of each accession is given in Table 1. The greenhouse experiment was arranged in Randomized Complete Block Design (RCBD) with three blocks (replications). Each block contained 21 *Cucumis* accessions, each accession with six plants.

Morphological Characteristics

Twenty qualitative characteristics related to fruit and leaf (Table 2) were assessed according to the list of descriptors given by the UPOV (2019). The frequency (%) of each qualitative morphological trait was calculated and is presented in Table 3.

Phytochemical Characteristics

Extraction

Plant materials including the air-dried fruit of each *Cucumis* accession were ground to a fine powder in liquid nitrogen and then extracted with 80% ethanol solvent in the ratio of 10 % w/v, filtered by Whatman filter paper no. 40, and the solvent was removed under vacuum using a rotary evaporator at 40°C.

Determination of Total Phenolic Content

The amount of total phenolic content was determined according to Spanos & Wrolstad (1990) who used folin-ciocalteu reagent and gallic acid as standard. A volume of 30 µl of the sample was transferred into a test tube and 500 µl of folin-ciocalteu reagent was added and mixed. The mixture was allowed to stand at a temperature of 25°C for 3 min. A volume of 500 µl of saturated sodium carbonate solution (Na_2CO_3) was added to the mixture and mixed gently. After keeping the mixture at 25°C for 60 min, absorbance was read at 725 nm using a UV–vis spectrophotometer. The TPC was expressed as milligram gallic acid equivalents (GAE) per gram dry weight (mg GAE/g DW).

Determination of Total Flavonoid Content

Total flavonoid content was calculated using the aluminum chloride colorimetric method described by Hosu et al. (2014). Treating sample, 2.5% $AlCl_3$ solution, 10% sodium acetate solution and distilled water were mixed at a ratio of 100:80:80:800 µl, respectively. After incubation at room temperature for 15 min, the absorbance of the reaction mixture was measured at 430 nm. The results were expressed as milligrams of quercetin equivalents (QE) per gram of dry weight (mg RE/g DW).

Determination of DPPH Radical-Scavenging Activity

The ability of the extracts to scavenge DPPH radicals (inhibitory concentration at 50% activity (mg/ml)) was assessed according to the method described by Brand-Williams et al. (1995) using the 1, 1-diphenyl-2-picrylhydrazyl (DPPH) radical-scavenging capacity with some modifications. Fifty µl of the sample was mixed with 350 µl of DPPH (1 mM in methanol) and then methanol 100% was added to the final volume of 2 ml. Following incubation of the test in the dark at room temperature for 15 min, the absorbance of the reaction mixture was read at 517 nm using a UV–vis spectrophotometer. Methanol and ascorbic acid were used as controls and the inhibition ratio was calculated from the following equation (1):

$$Inhibition(\%) = \frac{Absorbance\ of\ control - Absorbance\ of\ the\ test\ sample}{Absorbance\ of\ control} \times 100 \quad (1)$$

Table 1. Accession description of the studied *Cucumis* species

Herbarium No.	Species	Ecological Zones	Address (Province-City)
IBRC P1012223	*Cucumis sativus* L.	Irano-Turanian Zone	Khorasan-Sabzevar
IBRC P1012231	*Cucumis* cf. *sativus* L.	Hyrcanian Zone	Rasht-Shajaghi
IBRC P1012625	*Cucumis sativus* L.	Irano-Turanian Zone	Hamedan-Hamedan
IBRC P1012258	*Cucumis* cf. *sativus* L.	Hyrcanian Zone	Rasht-Langerood
IBRC P1012832	*Cucumis sativus* L.	Zagros Zone	Lorestan-Brojerd
IBRC P1012280	*Cucumis* cf. *sativus* L.	Hyrcanian Zone	Rasht-Lahijan
IBRC P1012296	*Cucumis* cf. *sativus* L.	Hyrcanian Zone	Rasht-Dastak
IBRC P1012407	*Cucumis sativus* L.	Irano-Turanian Zone	Azarbayejan-Basmenj
IBRC P1012316	*Cucumis* cf. *sativus* L.	Hyrcanian Zone	Rasht-Astaneh
IBRC P1012299	*Cucumis* cf. *sativus* L.	Hyrcanian Zone	Rasht-Kiashahr
IBRC P1012710	*Cucumis sativus* L.	Zagros Zone	Ilam-Ilam
IBRC P1012250	*Cucumis* cf. *sativus* L.	Hyrcanian Zone	Rasht-Astaneh
IBRC P1012563	*Cucumis melo* var. *flexuosus* (L.) Naudin	Irano-Turanian Zone	Qom-Gazran
IBRC P1012652	*Cucumis melo* var. *flexuosus* (L.) Naudin	Zagros Zone	Kermanshah-Kermanshah
IBRC P1012564	*Cucumis melo* var. *flexuosus* (L.) Naudin	Irano-Turanian Zone	Qom-Gazran
IBRC P1012651	*Cucumis melo* var. *flexuosus* (L.) Naudin	Zagros Zone	Kermanshah-Kermanshah
IBRC P1012632	*Cucumis melo* var. *flexuosus* (L.) Naudin	Irano-Turanian Zone	Hamedan-Hamedan
IBRC P1012686	*Cucumis melo* var. *flexuosus* (L.) Naudin	Zagros Zone	Kermanshah-Sahneh
IBRC P1012468	*Cucumis melo* var. *flexuosus* (L.) Naudin	Irano-Turanian Zone	Qom-Qom
IBRC P1012793	*Cucumis melo* var. *flexuosus* (L.) Naudin	Zagros Zone	Lorestan–Dorood
IBRC P1012383	*Cucumis melo* var. *flexuosus* (L.) Naudin	Irano-Turanian Zone	Qazvin-Takestan

Table 2. List of qualitative morphological descriptors

Characteristics states (score)					Characters
		Drooping (3)	Horizontal (2)	Erect (1)	Leaf blade: attitude
Very large (9)	Large (7)	Medium (5)	Small (3)	Very small (1)	Leaf blade: ratio length of terminal lobe/length of blade
Very strong (9)	Strong (7)	Medium (5)	Weak (3)	Absent or very weak (1)	Leaf blade: blistering
		Strong (3)	Moderate (2)	Absent or weak (1)	Leaf blade: undulation of margin
Very strong (9)	Strong (7)	Medium (5)	Weak (3)	Very weak (1)	Leaf blade: dentation of margin
	Rounded (4)	Obtuse (3)	Right-angled (2)	Acute (1)	Leaf blade: shape of apex of terminal lobe
		Dark (7)	Medium (5)	Light (3)	Leaf intensity of green color
Predominantly three or four (5)	Predominantly two or three (4)	Predominantly two (3(	Predominantly one or two)2(	Predominantly one)1(	Plant: number of female flowers per node
	Other (99)	Obtuse (3)	Acute (2)	Necked (1)	Fruit predominant shape at stem end (table use)
	Other (99)	Green (3)	Yellow (2)	White (1)	Predominant fruit skin color (table use)
Very long (9)	Long (7)	Medium (5)	Short (3)	Very short (1)	Fruit: length
		Large (7)	Medium (5)	Small (3)	Fruit: diameter
Very large (9)	Large (7)	Medium (5)	Small (3)	Very small (1)	Fruit: ratio length/diameter
		Angular (3)	Round to angular (2)	Round (1)	Fruit: shape in transverse section
	Truncate (4)	Rounded (3)	Obtuse (2)	Acute (1)	Fruit: shape of calyx end
			Present (9)	Absent or weak (1)	Fruit: dots
		Evenly distributed (3)	Predominantly in bands (2)	In bands only (1)	Fruit: distribution of dots
		Strong (3)	Medium (2)	Absent or weak (1)	Fruit: ribs
			Present (9)	Absent (1)	Fruit: sutures
Very dense (9)	Dense (7)	Medium (5)	Sparse (3)	Absent or Very sparse (1)	Fruit: density of vestiture

Table 3. Frequency (%) of 20 leaf and fruit qualitative characteristics in Cucumis species

Characters	Melon	Cucumber
Leaf blade: attitude	Horizontal (36.4), Drooping (18.2)	Erect (45.4)
Leaf blade: ratio length of terminal lobe/length of blade	Large (36.4), Medium (4.5), Very large (13.6),	Very large (13.6), Large (31.8)
Leaf blade: blistering	Weak (31.8),Medium (18.2), Absent or very weak (4.5)	Absent or very weak (4.5), Medium (41)
Leaf blade: undulation of margin	Moderate (36.4), Absent or weak (18.2)	Strong (41), Moderate (4.5)
Leaf blade: dentation of margin	Weak (13.6), Medium (22.7), Strong (18.2)	Very strong (45.4)
Leaf blade: shape of apex of terminal lobe	Acute (18.2), Right-angled (18.2), Obtuse (18.2)	Rounded (41), Obtuse (4.5)
Leaf intensity of green color	Medium (22.7), Light (18.2), Dark (13.6)	Medium (9.1), Light (36.4)
Plant: number of female flowers per node	Predominantly one (36.4), Predominantly one or two (9.1), Predominantly three or four (4.5), Predominantly two (4.5)	Predominantly one (36.4), Predominantly one or two (9.1)
Fruit predominant shape at stem end (table use)	Necked (13.6), Obtuse (31.8), Acute (9.1)	Necked (9.1), Obtuse (36.4)
Predominant fruit skin color (table use)	Yellow (31.8), Green (22.7)	Green (18.2), White (27.3)
Fruit: length	Long (22.7), Very long (9.1), Short (9.1), Medium (13.6)	Very long (22.7), Very short (4.5), Medium (4.5), Long (13.6)
Fruit: diameter	Medium (45.4), Large (4.5), Small (4.5)	Large (22.7), Small (4.5), Large (4.5)
Fruit: ratio length/diameter	Very large (27.3), Medium (22.7), Large (4.5)	Very large (31.8), Small (4.5), Medium (4.5), Large (4.5)
Fruit: shape in transverse section	Angular (22.7), Round to angular (13.6), Round (18.2)	Round (31.8), Angular (9.1), Round to angular (4.5)
Fruit: shape of calyx end	Obtuse (50), Rounded (4.5)	Rounded (27.3), Obtuse (9.1), Truncate (9.1)
Fruit: dots	Present (54.5)	Absent or weak (45.5)
Fruit: distribution of dots	Evenly distributed (45.5), Predominantly in bands (9.1)	In bands only (27.3), Evenly distributed (18.2)
Fruit: ribs	Medium (31.8), Absent or weak (22.7)	Absent or weak (9.1), Medium (27.3), Strong (9.1)
Fruit: sutures	Present (45.5), Absent (9.1)	Present (41), Absent (4.5)
Fruit: density of vestiture	Absent or Very sparse (54.5)	Dense (4.5), Sparse (13.6), Absent or Very sparse (22.7), Very dense (4.5)

Determination of Total Sugar

Total sugars were determined according to the phenol-sulfuric acid method with minor modifications (DuBois et al., 1956). A total of 0.17 g dry weight was mixed with 10 ml of distilled water and the extract was filtered. 0.25 ml of the solution was mixed with 0.25 ml of 5% phenol. Subsequently, 1 ml of 98% sulfuric acid was added rapidly to the mixture. Following incubation of the test in the dark at room temperature for 15 min, test tubes were placed in a water bath at 30°C for 20 min for color development. The absorbance was measured at 490 nm wavelength using UV–visible spectrophotometer. A blank solution was prepared in the same way as above. Glucose solution was used for the construction of the standard curve. The content of TS was expressed as mg/gr dry weight (DW).

Data analysis

The frequency (%) of morphological variables and mean ± standard deviation of phytochemical characters were calculated using Microsoft Excel software. Dendrograms were constructed using the Unweighted Pair Group Method with Arithmetic mean (UPGMA) algorithm by SPSS 16.0. In addition, relationships among traits were determined using the Pearson correlation analysis.

RESULTS AND DISCUSSION

Leaf Characteristics

The results of the morphological descriptions and frequency (%) are given in Table 3. A high level of variation for the following leaf characteristics was found at intra- and interspecific levels: attitude, blistering, undulation and dentation of margin, the shape of the apex, and ratio length of terminal lobe/blade and leaf intensity of the green color (Table 3 and Figure 1). However, the following characteristics were only observed in melon: attitude (Erect), undulation, dentation (strong and very strong), and shape of the apex (rounded) (Table 3).

Table 4. DPPH radical scavenging activity, TPC, TFC and TS of the fruit of Cucumis species

Herbarium No.	Species	Total Phenol (mg GAE/ gr DW)	Total Flavonoid (mg QE/gr DW)	DPPH (IC50 (mg/ml)	Total sugar (mg/gr DW)
IBRC P1012231	Cucumber	3.42± 0.06	1.03± 0.04	10.37± 0.21	35.73± 1.55
IBRC P1012250	Cucumber	4.35± 0.18**	1.64± 0.05**	5.66± 0.12	32.95± 0.72
IBRC P1012258	Cucumber	2.20± 0.13	0.78± 0.02	11.01± 0.22	55.88± 3.29
IBRC P1012280	Cucumber	2.88± 0.02	0.72± 0.02	14.62± 0.20	37.75± 1.16
IBRC P1012296	Cucumber	3.00± 0.08	1.04± 0.02	10.09± 0.11	26.67± 1.39
IBRC P1012299	Cucumber	3.91± 0.17	1.58± 0.04	5.04± 0.12	45.51± 2.10
IBRC P1012316	Cucumber	2.29± 0.03	0.75± 0.03	13.92± 0.14	51.11± 1.07
IBRC P1012407	Cucumber	1.11± 0.01*	0.51± 0.02*	35.23± 1.78*	43.09± 1.32
IBRC P1012223	Cucumber	2.60± 0.07	0.69± 0.02	19.49± 0.24	20.67± 1.06*
IBRC P1012710	Cucumber	2.01± 0.04	0.60± 0.01	20.95± 0.49	34.74± 1.55
IBRC P1012832	Cucumber	2.14± 0.05	0.70± 0.01	15.14± 0.55	38.83± 0.92
IBRC P1012625	Cucumber	1.82± 0.03	0.64± 0.05	25.40± 0.96	38.10± 2.13
IBRC P1012383	Melon	1.60± 0.05	0.63± 0.01	7.94± 0.54	43.75± 3.47
IBRC P1012468	Melon	2.22± 0.04	1.04± 0.03	7.68± 0.01	51.36± 3.15
IBRC P1012563	Melon	1.53± 0.04	0.56± 0.01	7.63± 0.03	32.20± 1.45
IBRC P1012564	Melon	1.24± 0.03	0.53± 0.00	10.09± 0.16	43.39± 0.43
IBRC P1012632	Melon	1.26± 0.07	0.53± 0.02	10.1± 0.18	42.66± 1.86
IBRC P1012651	Melon	2.12± 0.06	1.05± 0.04	6.70± 0.43	54.92± 2.81
IBRC P1012652	Melon	2.26± 0.07	0.69± 0.01	10.8± 0.14	55.90± 0.85**
IBRC P1012686	Melon	1.76± 0.04	0.77± 0.05	7.48± 0.07	53.41± 1.30
IBRC P1012793	Melon	2.26± 0.10	1.42± 0.03	3.08± 0.07**	53.28± 2.38
Mean	Cucumber	**2.64± 0.92**	**0.89± 0.37**	15.58± 8.62	38.42± 9.74
	Melon	1.81± 0.42	0.80± 0.31	**7.94± 2.32**	**47.87± 7.87**

Note: *and ** represent minimum and maximum phytochemical properties, respectively.

Leaf attitude predominantly was erect (45.4), but horizontal (36.4) and drooping (18.2) of leaf attitude also were observed. Furthermore, the shape of the apex predominantly was rounded (41) and this was scarcely obtuse (4.5). Leaf blistering was classified as weak, medium, absent, or very weak. Other characters including leaf blade undulation and leaf blade dentation also were recorded. Leaf blade undulation mainly was strong (41), with leaf blade dentation of very strong (45.4) among melons.

The assessment of genetic diversity is required for the efficient organization, conservation, and improvement of *Cucumis* germplasm (Chikh-Rouhou et al., 2021b). Among different plant parts, leaf diversity plays an important role in plant breeding programs and many other subjects including plant taxonomy, ecology, and evolution (Schemske, 1980; Bernhardt et al., 2008; Kashyap et al., 2021; Chikh-Rouhou et al., 2021b). Previous studies reported morphological traits of leaf for distinguishing *Cucumis* germplasm (Stepansky et al., 1999a; Parvathaneni et al., 2011; Chikh-Rouhou et al., 2021b). Their results revealed drastic genetic diversity among cucumbers and melons, which was consistent with our findings. This is the first report of leaf morphometric assessment of Iranian *Cucumis* accessions based on these characters. The results showed that leaf blade characters could be considered species-specific characters for breeding programs to develop and characteristics of new varieties (UPOV, 2019).

Leaf intensity of green color was mainly observed as light, but others such as medium and dark (especially in cucumber) were also observed. Variation in leaf color is a common feature between and within *Cucumis* species (UPOV, 2019; Parvathaneni et al., 2011). Diversity in leaf color was reported in other plants (De Souza et al., 2012; Aryakia et al., 2016) which may be important for evolutionary and ecological studies such as plant-insect interactions (Maskato et al., 2014).

Fruit Characteristics

There are many types of *Cucumis* fruit, different in dimensions, shape, and color (UPOV, 2019; Chikh-Rouhou et al., 2021b; Chikh-Rouhou et al., 2021c). Fruit characters are important quality factors for many plants (Grandillo et al., 1996). These characteristics are

Table 5. Correlation among morphological traits

	Leaf blade: shape of apex of terminal lobe	Leaf blade: attitude	Leaf intensity of green color	Leaf blade: ratio length of	Leaf blade: blistering	Leaf blade: undulation of margin	Leaf blade: dentation of margin	ant: number of female flowers	Fruit predominant	Predominant fruit skin color	Fruit: shape of calyx end	Fruit: dots	Fruit: distribution of	Fruit: ribs	Fruit: sutures	Fruit: length	Fruit: diameter	Fruit: ratio length/diamete	Fruit: shape in transverse
Leaf blade: attitude	-0.841**																		
Leaf intensity of green color	-0.420	0.419																	
Leaf blade: ratio length of terminal lobe/length of blade	-0.179	0.043	0.006																
Leaf blade: blistering	0.688**	-0.443*	-0.111	-0.127															
Leaf blade: undulation of margin	0.906**	-0.796**	-0.341	-0.136	0.635**														
Leaf blade: dentation of margin	0.535*	-0.727**	-0.421	0.336	0.458*	0.516*													
Number of female flowers per node	-0.536*	0.369	-0.061	0.443*	-0.463*	-0.610**	0.107												
Fruit predominant shape at stem end	0.255	-0.092	-0.371	-0.029	0.206	0.054	0.267	0.084											
Predominant fruit skin color	-0.421	0.359	0.251	0.359	-0.31	-0.0584**	-0.144	0.513*	-0.024										
Fruit: shape of calyx end	0.516*	-0.554**	-0.434*	0.335	0.289	0.518*	0.656**	0.147	0	-0.042									
Fruit: dots	-0.830**	0.886**	0.498*	-0.129	-0.500*	-0.836**	-0.862**	0.247	-0.158	0.377	-0.69**								
Fruit: distribution of dots	-0.448*	0.494*	0.307	-0.082	-0.361	-0.619**	-0.449*	0.349	-0.039	0.374	-0.392	0.584**							
Fruit: ribs	0.421	-0.341	-0.111	-0.127	0.237	0.532*	0.122	-0.0382	0.115	-0.03	0.174	-0.347	-0.361						
Fruit: sutures	0.069	0.032	-0.227	0.175	-0.151	0.303	-0.016	-0.23	-0.259	-0.421	0.101	-0.097	-0.287	0.07					
Fruit: length	0.374	-0.223	-0.036	-0.244	0.279	0.606**	-0.044	-0.529*	0.04	-0.57**	-0.062	-0.231	-0.58**	0.484*	0.530*				
Fruit: diameter	0.187	0	-0.297	-0.413	0.178	0	-0.096	0	0.127	0.131	0.162	0	0	-0.178	-0.311	-0.191			
Fruit: ratio length/diameter	0.387	-0.282	-0.124	-0.365	0.239	0.550**	-0.155	-0.64**	-0.069	-0.59*	-0.104	-0.158	-0.56	0.392	0.489*	0.856**	-0.107		
Fruit: shape in transverse section	-0.25	0.199	0.026	-0.406	-0.421	-0.216	-0.286	-0.119	0.111	0.034	-0.234	0.328	-0.032	0.008	0.068	0.105	0.241	0.201	
Fruit: density of vestiture	0.439*	-0.427*	-0.056	0.488*	0.388	0.463*	0.416	-0.026	-0.134	-0.074	0.469*	-0.482*	-0.182	0.02	0.175	0.151	-0.103	-0.012	-0.357

Note: ** and *, Significant at the probability of 0.01 and 0.05, respectively.

used to classify current cultivars and plant species into different groups (Aryakia et al., 2016; UPOV, 2019).

Among fruit morphological characters studied herein, only fruit creasing showed the monomorphic feature (data do not show). However, a high level of diversity in fruit traits was observed at intra-and interspecific levels (Table 3 and Figure 1). Fruit characteristics include white color of skin, very long size, truncate calycate, smooth texture, and strong ribs just observed in melons, while yellow skin and dense of vestiture (absent or very sparse) in cucumbers were observed.

The predominant fruit skin color was green. However other colors such as yellow and white were also observed. The fruit's green color is favorite for Iranian consumers. Variation in skin color is a common feature between and within *Cucumis* species (Parvathaneni et al., 2011; UPOV, 2019; Chikh-Rouhou et al., 2021c), which is also observed in other plants (Aryakia et al., 2016). Fruit predominant shape at stem end was classified as necked, obtuse, and acute. This character was mainly observed as obtuse. The other fruit shape criteria were the transverse section and the shape of the calyx end. Obtuse, rounded, and truncate were recorded in the calyx. Furthermore, fruit length, diameter, and ratio length/diameter were recorded to determine the fruit dimensions. These characters were classified as long, short, very long, medium, and very short. The predominant Fruit diameter was medium. In addition, fruit dots, ribs, sutures, and vestiture density were revealed in the studied species.

Although previous works have reported many classifications and evaluations of different *Cucumis* accessions based on commercial traits of fruit (Stepansky et al., 1999b; Parvathaneni et al., 2011; Raghami et al., 2014), there is little information on the morphological assessment of Iranian *Cucumis* species. Our findings show that 12 morphological characters of fruit can be accurately used to distinguish and represent potential new sources of *Cucumis* accessions.

In addition, the number of female flowers per node was variable among them. Moreover, this trait was predominantly one, but three to four female flower per node was only observed in cucumbers. It could be considered a valuable industrial potential for breeding programs because some cucumber varieties have been bred to have multiple flowers per node (Hikosaka & Sugiyama, 2004). This morphovariable trait is also applied for evaluating taxonomic arrangement in other plants (Espírito-Santo et al., 2012).

Phytochemical Characteristics

Our results revealed wide variation in DPPH, TPC, TFC, and TS among accessions of *Cucumis* species (Table 4). DPPH, TPC, TFC and TS varied from 3.08±0.07 to 35.23±1.78 mg/ml, 1.11±0.01 to 4.35±0.18 mg GAE/g DW, 0.51±0.02 to 1.64±0.05 mg RE/g DW and 20.67±1.06 to 55.90±0.85 mg/g DW, respectively. Favorable to the extreme amount of phytochemical properties were revealed among *Cucumis* accessions, which were comparable to those observed in other melons or cucumbers (Stepansky et al., 1999b; Ismail et al., 2010). Moreover, assessment of the diversity of DPPH, TPC, TFC, and TS could reveal a good source of phytochemical characteristics among plant germplasm (Chen et al., 2013; Aryakia, 2020; Chikh-Rouhou et al., 2021c; Shahrivari et al., 2022).

Phenolic compounds which proved to be associated with health benefits, exhibit a wide range of physiological properties, such as antioxidant, anti-allergenic, anti-artherogenic, anti-inflammatory, anti-microbial, anti-thrombotic, cardioprotective, and vasodilatory effects (Balasundram et al., 2006). Therefore, evaluation of phenolic content and antioxidant activity in plant extracts are very important issues from pharmaceutical and medical aspects. TPC was several times more than that of TFC in each *Cucumis* accession. Moreover, cucumbers showed more TPC and TFC than melons, but melons showed more TS and DPPH radical scavenging activity than cucumbers (Table 4). Previous reports showed that interspecific crossing among cucumber and melon could result in new crops (Deakin et al., 1971; Chen et al., 1997; Yu et al., 2015). So, these results could be considered for agricultural breeding programs. This research is the first report that studies DPPH, TPC, TFC, and TS of the Iranian native *Cucumis* accessions. Overall, complementary studies along with molecular and phytochemical research could help to promote *Cucumis* genetic database.

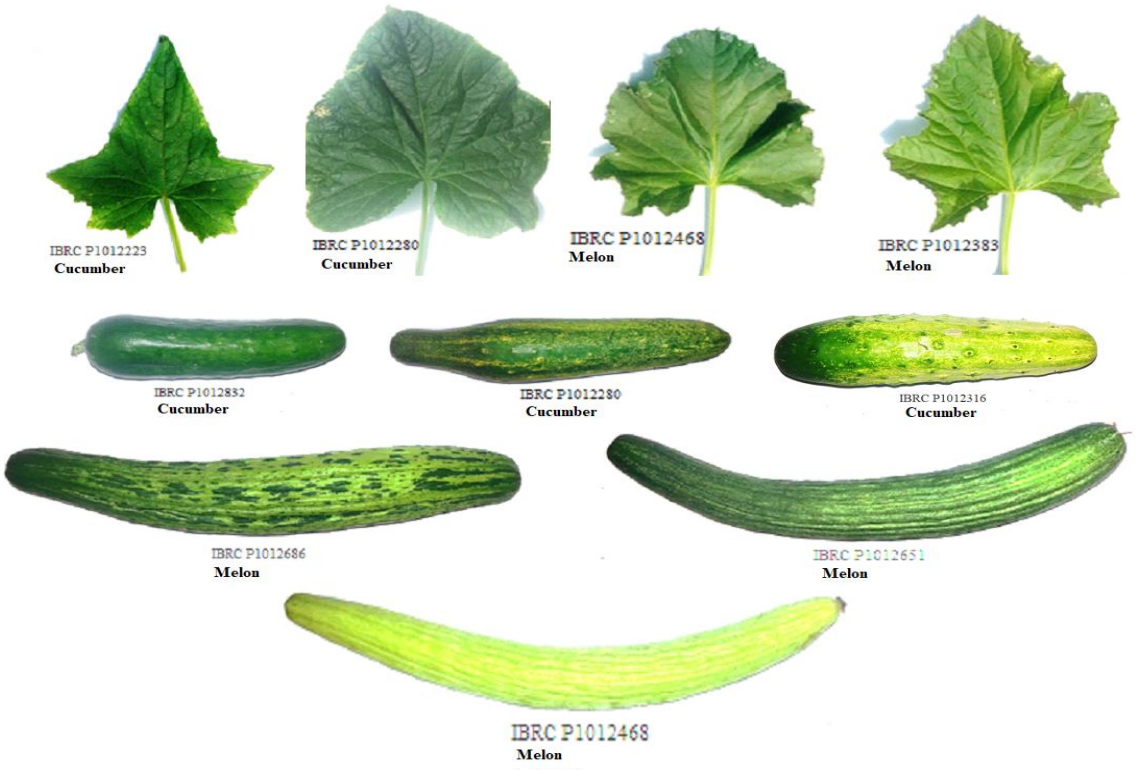

Figure 1. Morphodiversity of leaf and fruit among *Cucumis* accessions

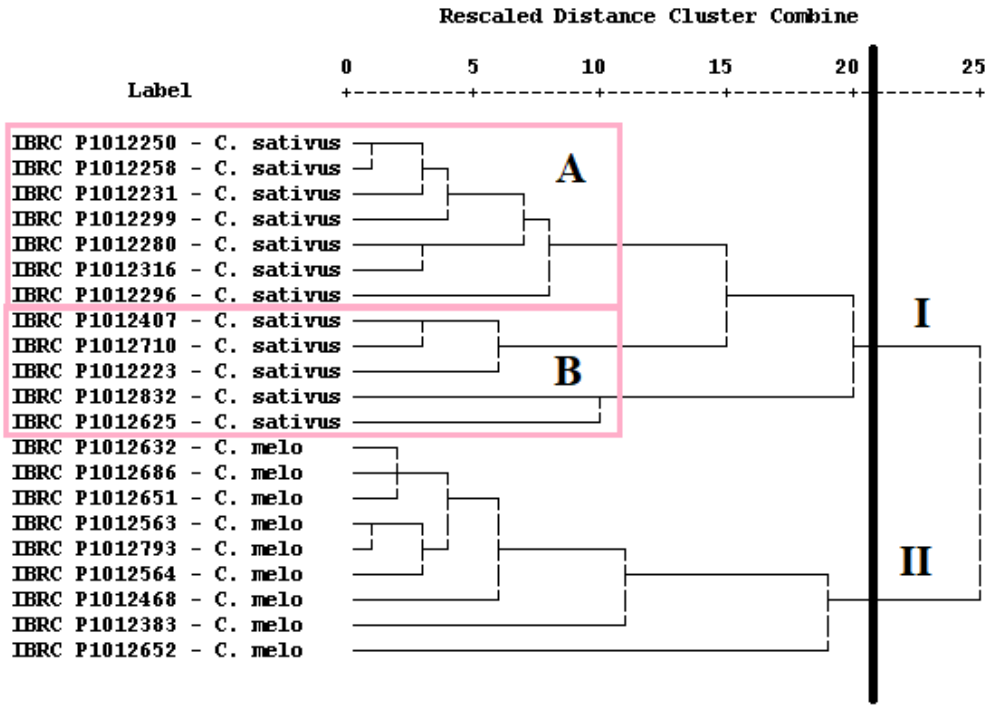

Figure 2. Relationships among 21 accessions of *Cucumis* species using 20 qualitative characters of leaf and fruit

Cluster Analysis

Analysis of the cluster divided all accessions into the two major groups, cucumber and melon (**I** and **II**) (Figure 2) which were clearly defined by twenty qualitative morphological characteristics. The first group (**I**) included cucumber accessions with two district subgroups of **A** and **B** originating from the Hyrcanian zone and other different ecological zones, respectively. It might be since accessions originated from different locations of the Hyrcanian zone have been ecologically influenced by the same climate conditions. The second group (**II**) included melon accessions. This cluster revealed a high accuracy level of intra-and interspecific morphodiversity among *Cucumis* accessions studied herein. However, similar reports in the *Cucumis* genus (Parvathaneni et al., 2011; Stepansky et al., 1999a) and other plant species (Arrieta-Espinoza et al., 2005; Aryakia et al., 2016) could confirm the classification based on morphological traits.

In addition, analysis of clusters based on four phytochemical characters (including TPC, TFC, TS, and DPPH) could also cluster most of the *Cucumis* accessions according to their genetic pattern (cucumber and melon) (Figure 3). These results suggest that clustered relative accessions have similar bioactive compounds responsible for their phytochemical characters. Chikh-Rouhou et al. (2021c) used phytochemical characters including TFC and TPC for the classification of different *Cucumis* species. Their results showed that the cluster analysis could segregate *Cucumis* species into four different groups. Moreover, TFC and TPC were affected by the botanical group and genotype within the same group. Maietti et al. (2012) found similar results, demonstrating that two distinct clusters were clearly identified in melons belonging to the same cultivar, confirming a significant effect on the chemical composition of the fruit.

This valuable diversity observed among *Cucumis* accessions revealed a good industrial potential for commercial exploration of them. In addition, Iran is one of the most cultivated areas of Cucurbitaceae species comprising drastic variable accessions. Therefore, determination of the distribution and the level of genetic diversity using morphological and phytochemical characters could provide basic data for designing conservation and breeding programs for *Cucumis* species (Xiao et al., 2004; Hao et al., 2006).

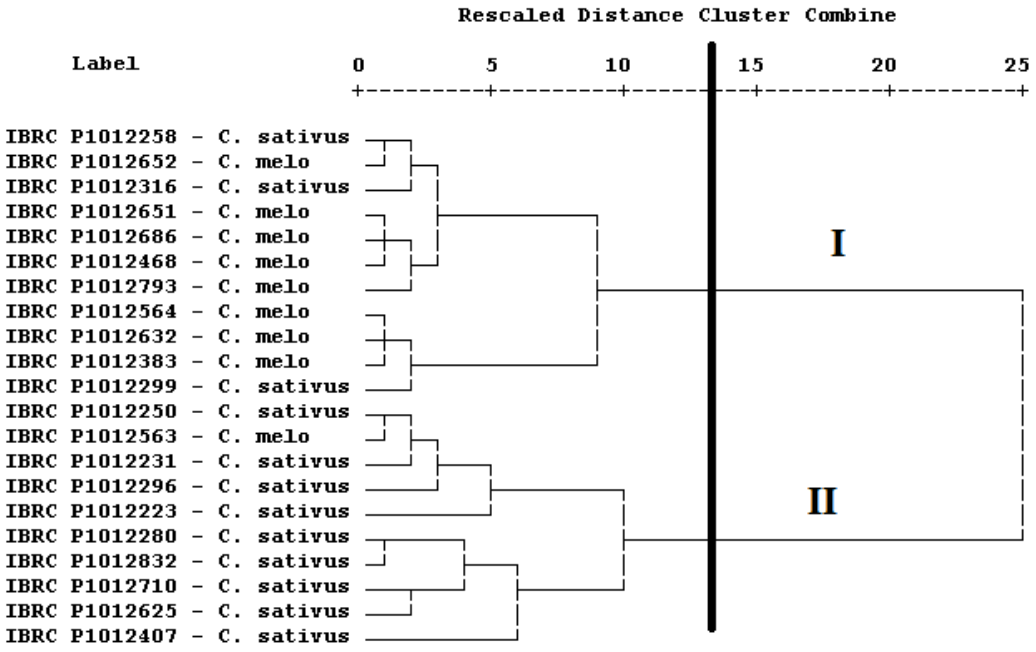

Figure 3. Relationships among 21 accessions of *Cucumis* species using 4 phytochemical characters

Correlation Among Characters

Pearson's correlation analysis could find significant relationships among characters (Tables 5 and 6). A significant correlation among all leaf characters was observed except for leaf color and terminal lobe/blade. No similar results were observed among fruit characters. However, some significant correlations were revealed, such as fruit length/diameter and fruit length with ribs and sutures. In addition, the correlation between fruit and leaf characters was also observed. Correlation among morphological characters was reported by previous studies (De Souza et al., 2012; Aryakia et al., 2016). These correlations could be due to the evolutionary mechanism (Davis, 2001). For example, correlation among fruit and leaf characters might be the consequence of some allometric relationship affecting all plant parts (Herrera, 2002). The correlation between different organs can be useful for breeders to predict expected morphological traits, so the breeding process can be shortened. For farmers, they can observe the shape and size of other organs to predict relative traits of fruit and to harvest commodity fruit (Cui et al., 2020).

Table 6. Correlation among phytochemical traits

	TPC	TFC	DPPH
TFC	0.787**		
DPPH	-0.358	- 0.553**	
TS	-0.258	0.079	-0.292

Note: ** Significant at the probability of 0.01.

Correlation between phenolic content and antioxidant activity was revealed in this study (Table 6) according to previous reports (Aryakia et al., 2015). However, no correlation was found between TS and phenolic content or antioxidant activity. It has been demonstrated that hydroxyl functional groups of phenolic compounds, are responsible for antioxidant activity and flavonoids also stabilize the reactive oxygen species (Nijveldt et al., 2001). These compounds interrupt the propagation of the free radical autoxidation chain by contributing a hydrogen atom from a phenolic hydroxyl group, followed by the formation of a relatively stable free radical that does not initiate or propagate further oxidation processes (Bahramikia et al., 2009). These correlations might be useful as a powerful tool for the selection and breeding of economically valuable traits with low heritability.

CONCLUSION

This study increased our knowledge about the intra- and interspecific diversity of Iranian *Cucumis* germplasm. Both morphological and phytochemical properties can be used effectively in the identification and classification of *Cucumis* accessions. These results might also be considered in the characterization and distinguishing of other *Cucumis* species. Further morphological and phytochemical studies, especially the extraction of different parts using different solvents, as well as the evaluation of other phytochemical properties, might be necessary for a better understanding of the *Cucumis* breeding program.

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Compliance with Ethical Standards

Authors' Contributions

Both authors have contributed equally to this paper.

Conflict of Interest

The authors declare that there is no conflict of interest.

Ethical Approval

For this type of study, formal consent is not required.

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ACTA NATURA ET SCIENTIA

Farklı Biçim Zamanlarının Yulaf ve Tritikale Otunun Verim ve Kalitesine Etkileri

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ÖZET

Bu araştırma, farklı zamanlarda hasat edilen yulaf ve tritikale otlarının verim ve kalitesini araştırmak amacıyla Çanakkale Onsekiz Mart Üniversitesi Ziraat Fakültesi Dardanos Yerleşkesi deneme alanında 2018-2019 ve 2019-2020 yetiştirme dönemlerinde yürütülmüştür. Araştırmada bitkiler üç gelişme döneminde (başak/salkım oluşumu, çiçeklenme ve süt olum) biçilmiştir. Deneme tesadüf blokları deneme desenine göre 6 tekerrürlü olarak kurulmuştur. Araştırmada yeşil ve kuru ot verimleri ile otun ham protein (HP), ham kül (HK) ve sindirilebilir kuru madde (SKM) oranları incelenmiştir. Biçim zamanı ilerledikçe yeşil ve kuru ot verimleri önemli miktarda artmıştır. İki yılın ortalamasında başak/salkım dönemindeki biçimde kuru ot verimi 494,5 kg/da'dan süt olumda 2049,8 kg/da'a yükselmiştir. Buna karşılık HP, HK ve SKM oranları azalmıştır. Genellikle yulaf ve tritikaleye ait değerler birbirine yakın bulunmuştur. Sonuç olarak, ot kalitesinde bir miktar düşüş olmasına karşın, ot verimi yükseldiği için hem yulaf hem de tritikalenin süt olum döneminde biçilmesinin uygun olacağı kanısına varılmıştır. Yüksek kalitede ot üretimi hedefleniyorsa, biçim çiçeklenme döneminde yapılmalıdır.

Effects of Different Harvesting Times on Yield and Quality of Oat and Triticale

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ABSTRACT

This research was carried out to investigate the yield and quality of the hay of oat and triticale harvested at different timings in the growing seasons of 2018-2019 and 2019-2020 at the Research and Application Field of Çanakkale Onsekiz Mart University, Faculty of Agriculture situated in Dardanos Çanakkale. Plants were harvested in three different growth stages (earing/heading formation, flowering and milk dough stages) in this study. The experiment has been established by using a randomized complete block design with 6 replications. Crude protein (CP), crude ash (CA) and digestible dry matter (DDM) along with the fresh and dry yield of hay were determined in this study. The fresh and dry yield of hay increased when the harvesting time was delayed. In the results of two years harvesting stage of earing/heading, the average hay yield increased from 494.5 kg/da to 2049.8 kg/da at milk dough stage. On the other hand, the ratios of CP, CA and DDM were decreased. In general, the values of oat and triticale were found to be close to each other. Consequently, it has been concluded that it would be appropriate to harvest both oat and triticale during their milk dough stage, although, there is a slight decrease in hay quality since the hay yield is very high. Harvesting should be done during the flowering stage, if the high quality hay production is expected.

GİRİŞ

Türkiye'de halen 23.446 bin ha işlenen tarım alanı ve 14.617 bin ha çayır ve mera alanı bulunmaktadır (TÜİK, 2021). Çayır ve meralar kaba yem üreten doğal yem alanlarıdır. Bu alanların küçülmesi ve verimlerinin azalması nitelikli kaba yem üretiminin azalmasına neden olmaktadır. Bu sebeple Türkiye'de çiftlik hayvanlarının nitelikli kaba yem ihtiyaçlarının yaklaşık %40-65 kadarı karşılanabilmektedir (Gökkuş & Hanoğlu, 2022). Ülkemizde çayır ve meraların aşırı otlatılması, hayvanların meraya erken sokulması, meraların bakımlarına önem verilmemesi kaba yeme olan ihtiyacı arttırmaktadır (Yolcu & Tan, 2008). Yem bitkileri tarımı, kaba yem üretmenin çayır ve meralara göre daha sürekli ve güvenli bir yoludur (Akman vd., 2007). Kaliteli kaba yemler kendiliğinden oluşan doğal ve yapay meralar ile yem bitkilerinden elde edilen yemlerdir. Serin iklim tahılları üretimleri ve besleme değerleri ile önemi giderek artan kaba yem kaynakları içerisindedir. Örneğin merada otlayan bir hayvan için tüketilen kaba yemin %7 ve üzerinde HP içermesi önerildiği (Meen, 2001) halde, tahıl meralarında HP oranı %20 ve üzerindedir (Torell vd., 1999; Holman vd., 2011). Özellikle tahıllar dünyada en çok ekimi yapılan bitki grubudur. İnsan gıdası olarak yetiştirilmesinin yanında, otları da kaba yem olarak kullanılmaktadır. Kaba yem olarak yetiştirilmesindeki temel sebepler, uyum yeteneklerinin çok yüksek olması, çok ekstrem şartlarda bile yetişebilmeleri (tritikale ve çavdar), tuzlu topraklarda yetişme özelliği (arpa), çimlendikten sonra gelişimlerinin hızlı olması ve karbonhidrat, karoten, bazı vitamin ve minerallerce zengin olmalarıdır (Tan & Serin, 1997).

Dünyada 9,77 milyon ha alanda 25,18 milyon ton yulaf üretimi yapılmaktadır (FAO, 2020). Türkiye'de ise 137 bin ha alanda 276 bin ton yulaf üretilmektedir (TÜİK, 2021). Yulaf bol yapraklı olduğu için tercih edilmekte ve kaba yem üretiminde ilk sırayı almaktadır. Buğdaygiller arasında baklagiller ile karışık ekime en uygun bitki yulaftır. Kaba yemlerde besleme değeri açısından en önemli unsur olan HP oranı hayvanların rasyonlarında en az %6 düzeyinde olmalıdır (Şenel, 1986). Yapılan birçok çalışmada geçci ve bol yaprak oluşturan yulaf çeşitlerinin en yüksek HP oranına sahip oldukları belirlenmiştir (Mayland vd., 1976; Bishnoi vd., 1978; Tan, 1995). Tahıllar arasında yüksek protein ve yağ içeren yulaf, hayvancılıkta gerekli yemin kaynağını oluşturmaktadır. Yulaf tanesi sığır, koyun ve atların beslemesinde kullanılır. Yulafın bir diğer avantajı, her dönemde yeni sürgünlerinin varlığıdır. Bol yapraklı olmasından dolayı yem bitkisi olarak tercih edilmektedir (Tan & Serin, 1997).

Tahılların kaba yem olarak kullanılması için gelişme evreleri ot verimi ve kalitesi bakımından önemlidir. Bitkilerin gelişmesi ilerledikçe genelde ot verimi artarken, ot

kalitesinde özellikle HP oranında azalma olmaktadır. Kuru ot verimi artacağı düşüncesi ile biçimi geç yapmak tercih edilebilir. Ancak olgunlaşma evresine yaklaştıkça HP oranı ve sindirilebilme oranındaki düşüş hızlanır. Geç biçim yapmak artan kuru ot verimindeki artış ile telafi edilebilir. Bu sebeple ot üretimi amacıyla yetiştirilen tahılların süt olum evresine kadar değerlendirilmesi önerilmektedir. (Bishnoi vd., 1978; Hasar & Tükel, 1993; Tan, 1995).

Bu çalışmanın amacı Türkiye'de daha çok ot üretimi amacıyla yetiştirilen yulaf ve tritikalede en yüksek verim ve kaliteli otun üretildiği zamanı belirlemektir. Bunun için Çanakkale şartlarında iki yıl süreyle yulaf ve tritikale başak veya salkım oluşturma zamanında, çiçeklenme döneminde ve süt olum evresinde biçilmiş ve biçilen otların verim ve kalite özellikleri belirlenmiştir.

MATERYAL VE YÖNTEM

Deneme 2018-2019 ve 2019-2020 kışlık yetiştirme dönemlerinde Çanakkale Onsekiz Mart Üniversitesi Ziraat Fakültesi'nin Dardanos Yerleşkesi'ndeki deneme alanında yürütülmüştür. Denemenin yürütüldüğü dönemde ortalama sıcaklık 16,6°C ve ortalama toplam yağış 659,9 mm olmuştur (Anonim, 2020). Deneme alanı toprakları killi-tınlı bünyeye sahip olup, orta kireçli, azot ve fosfor bakımından yetersiz, potasyum yönünden yeterli ve organik maddece fakirdir. Bitki materyali olarak yulafın Kahraman çeşidi ile tritikalenin Tatlıcak-97 çeşidi kullanılmıştır. Araştırma tesadüf blokları deneme desenine göre 6 tekerrürlü olarak kurulmuştur. Denemede parsel genişliği 1,2 m, parsel uzunluğu 5 m, toplam parsel alanı 6 m^2 ve bloklar arası 1 m, parseller arası 50 cm mesafe bırakılmıştır. Araştırmada biçim zamanı (başak/salkım oluşturma, çiçeklenme ve süt olum) ve bitki türü (yulaf ve tritikale) faktör olarak ele alınmıştır. Uygun şekilde hazırlanan deneme alanına yulaf ve tritikale tohumları ilk yıl 7 Kasım 2018, ikinci yıl ise 14 Kasım 2019 da ekilmiştir. Sonbaharda ekim öncesi taban gübresi olarak DAP (diamonyum fosfat) (%46 P, %18 N) ile dekara toplam 8 kg P ve 3,15 kg N verilmiştir. Erken ilkbaharda ise üre (%46 N) formunda dekara 5,2 kg N uygulanarak toplam verilen azot miktarı 8,35 kg'a çıkarılmıştır. Yabancı otlar elle yok edilmiş ve sulama yapılmamıştır. Araştırmada otun HP ve HK analizleri AOAC (1990)'e göre sindirilebilir kuru ve organik madde (SKM) oranı ise Canbolat (2012)'tan yararlanarak hesaplanmıştır. Denemeden elde edilen verilerin istatistik analizinde JMP 11 istatistik paket programı kullanılmıştır.

BULGULAR VE TARTIŞMA

Yeşil Ot ve Kuru Ot Verimi

Yeşil ot verimi ile ilgili yapılan varyans analizi sonuçlarına göre, 2019 yılının hasat dönemleri arasındaki farklılık ile bitki, hasat dönemi ve bunlar arasındaki etkileşim önemli bulunmuştur. 2020 yılı yeşil ot verimi sadece hasat dönemlerine göre önemli farklılık gösterirken, iki yıllık ortalamada bitki ve hasat dönemindeki farklılıkların önemli olduğu görülmüştür. Kuru ot verimi ile ilgili yapılan varyans analiz sonuçlarına göre, araştırma yılları ve ortalamasında sadece hasat dönemleri arasındaki farklılık istatistik olarak önemli bulunmuştur.

Denemenin iki yılı ve ortalamalarında yeşil ve kuru ot verimleri gelişme dönemleri ilerledikçe düzenli olarak artmıştır. Yıllar ve bitki türlerinin ortalamasında yeşil ot verimi başak/salkım oluşturmadan süt oluma kadar 2538,9 kg/da'dan 4211,8 kg/da'ya yükselmiştir. Kuru ot verimindeki artış ise 494,5 kg/da'dan 2049,8 kg/da şeklinde gerçekleşmiştir. Yulaf ve tritikalenin verimleri arasındaki farklılık yeşil ot veriminde önemli, kuru ot veriminde önemsiz bulunmuştur. Ancak yulaf daha yüksek ot üretmiştir (Tablo 1).

Büyüme ilerledikçe yaprak sayısı artmakta, sap uzamakta ve başak ve salkımlar ortaya çıkmaktadır. Bunlar da doğal olarak bitkinin kütlesini, yani verimi artırmaktadır. Bu sebeple başak/salkım oluşumundan süt olumuna kadarki süreçte verim sürekli ve düzenli olarak artmıştır. Bu durum birçok araştırmada ortaya konmuştur (Işık vd., 2014; Bulut, 2021). Bu artış türlere göre değişmektedir. Yulaf genellikle uygun yetiştirme şartlarında en fazla kaba yem üreten tahıldır (Tan & Serin, 1997). Bu durum bu araştırmada da görülmüş ve her iki deneme yılında da yulaf tritikaleden daha yüksek yaş ve kuru ot verime sahip olmuştur.

Ham Protein ve Ham Kül Oranı

Araştırmanın ilk yıl ve ortalamada yulaf ve tritikale otunun HP içeriklerindeki değişim bitki ve hasat dönemlerine göre istatistiki olarak önemlilik arz etmiştir. İkinci yılda ise sadece hasat dönemlerine bağlı olarak HP içerikleri önemli değişim göstermiştir. Araştırma yılları ve ortalamasında farklı dönemlerde hasat edilen yulaf ve tritikale otlarının HK içerikleri arasındaki farklılık yalnızca hasat dönemlerinde önemli bulunmuştur (Tablo 2).

Yulaf ve tritikalenin ortalama HP oranları ilerleyen hasat dönemleri ile sürekli azalmıştır. İlk yıl başak/salkım oluşturma döneminde %15,34 olan HP oranı, süt olumda %9,90'a, ikinci yılda da %13,07'den %8,43'e düşmüştür. Doğal olarak iki yıllık ortalamalarda da değişim benzer şekilde gerçekleşmiştir. Her iki deneme yılı ve ortalamasında tritikale daha yüksek HP düzeyine sahip olmuştur. Ancak aralarındaki farklılık ilk yıl ile yıllar ortalamasında önemli bulunmuştur (Tablo 2).

Yulaf ve tritikale otlarının ortalama HK oranlarının biçim zamanlarına göre değişimi, HP oranındaki değişime benzer

Table 1. Mean fresh and dry hay yields of oat and triticale harvested at different growth stages (kg/da)

***Tablo 1**. Farklı gelişme dönemlerinde hasat edilen yulaf ve tritikale otunun ortalama yeşil ve kuru ot verimleri (kg/da)*

Yeşil Ot Verimi	Başak/Salkım Oluşturma	Çiçeklenme	Süt Olum	Ortalama
2019				
Yulaf	2711,1^{a}	3252,7^{b}	4116,6^{a}	3360,2^{A}
Tritikale	2241,6^{d}	3272,2^{b}	4125,0^{a}	3213,0^{B}
Ortalama	2476,4^{C}	3262,5^{B}	4120,8^{A}	3286,6
2020				
Yulaf	2544,4^{e}	3411,1^{c}	4438,9^{a}	3464,8^{A}
Tritikale	2658,3^{e}	3105,5^{d}	4166,6^{b}	3310,2^{B}
Ortalama	2601,4^{C}	3258,3^{B}	4302,8^{A}	3387,5
İki yıllık ortalama				
Yulaf	2627,7	3331,9	4277,7	3412,5^{A}
Tritikale	2450,0	3188,9	4145,8	3261,6B
Ortalama	2538,9^{C}	3260,4^{B}	4211,8^{A}	3337,1
Kuru ot verimi				
2019				
Yulaf	583,7	943,6	1660,2	1062,5
Tritikale	370,3	687,8	1723,2	927,1
Ortalama	477,0^{C}	815,7^{B}	1691,7^{A}	994,8
2020				
Yulaf	490,2	905,6	2412,0	1269,3
Tritikale	533,9	857,2	2403,6	1264,9
Ortalama	512,1^{C}	881,4^{B}	2407,8^{A}	1267,1
İki yıllık ortalama				
Yulaf	537,0	924,6	2036,1	1165,9
Tritikale	452,1	772,5	2063,4	1096,0
Ortalama	494,5^{C}	848,5^{B}	2049,8^{A}	1131,0

***Not:** Üst simge ile gösterilen küçük harfler etkileşimlerin; büyük harfler ise ortalamaların önemliliğini göstermektedir.*

olmuş, fakat ilk iki biçim zamanı otların kül oranları arasında önemli fark görülmemiştir. Nitekim iki yılın ortalamasında başak/salkım oluşumu ve çiçeklenmede ortalama HK oranları %8,53 ve 8,27 olurken, süt olumda biçilen otların HK oranları %6,33 seviyesinde kalmıştır. Yulaf ve tritikalenin HK oranları birbirine yakın olup, iki yılın ortalamasında %7,89 ve %7,53 olarak belirlenmiştir (Tablo 2).

Nitelikli kaba yemlerde aranan en önemli özellik hayvanlar için yeterli HP oranına sahip olmasıdır. Ancak yeterli ham proteine sahip serin iklim tahıllarının gelişme dönemleri de önemlidir. Çünkü tahılların gelişimi hızlı olduğundan HP oranı da hızla düşmektedir (Bishnoi vd., 1978; Hasar & Tükel, 1993; Tan, 1995). Genelde vejetatif dönemden generatif döneme doğru HP oranında %30-35'ten %8-10'a kadar düşüş gözlenmektedir (Kilcher & Troelsen, 1973; Smith, 1976). Zira hücredeki çözünen maddeler (örneğin proteinler) aktif olarak büyüyen bitki dokusunda en yüksektir ve bitkiler olgunlaştıkça ve durgunluğa girdikçe azalmaktadır (Lyons vd., 1999). Protein oranındaki azalmada yaprak oranındaki azalma da etkili olmaktadır (Başbağ vd., 2000). Bulut (2021)'un çalışmasında olduğu gibi bu araştırmada da HP oranı başaklanma döneminden süt olum zamanına doğru azalmıştır.

Table 2. Mean crude protein and crude ash contents of oat and triticale grass harvested at different growth stages (%)

Tablo 2. *Farklı gelişme dönemlerinde hasat edilen yulaf ve tritikale otunun ortalama ham protein ve ham kül içerikleri (%)*

Ham Protein	**Başak/Salkım Oluşturma**	**Çiçeklenme**	**Süt Olum**	**Ortalama**
2019				
Yulaf	13,71	12,11	9,18	11,67^{B}
Tritikale	16,97	14,20	10,63	13,93^{A}
Ortalama	15,34^{A}	13,16^{B}	9,90^{C}	12,80
2020				
Yulaf	12,53	10,87	8,15	10,52
Tritikale	13,62	11,28	8,71	11,20
Ortalama	13,07^{A}	11,08^{B}	8,43^{C}	10,86
İki yıllık ortalama				
Yulaf	13,12	11,49	8,67	11,09^{B}
Tritikale	15,29	12,74	9,67	12,57^{A}
Ortalama	14,21^{A}	12,16^{B}	9,17^{C}	11,83
Ham Kül				
2019				
Yulaf	9,65	8,64	6,46	8,25
Tritikale	8,88	8,81	5,07	7,59
Ortalama	9,27^{A}	8,72^{A}	5,77^{B}	7,92
2020				
Yulaf	7,74	7,46	7,41	7,53
Tritikale	7,83	8,19	6,39	7,47
Ortalama	7,79^{A}	7,82^{A}	6,90^{B}	7,50
İki yıllık ortalama				
Yulaf	8,69	8,05	6,93	7,89
Tritikale	8,36	8,50	5,73	7,53
Ortalama	8,53^{A}	8,27^{A}	6,33^{B}	7,71

Not: *Üst simge ile gösterilen küçük harfler etkileşimlerin; büyük harfler ise ortalamaların önemliliğini göstermektedir.*

Table 3. Mean DDM contents of oat and triticale grass harvested at different growth stages (%)

Tablo 3. *Farklı gelişme dönemlerinde hasat edilen yulaf ve tritikale otunun ortalama SKM içerikleri (%)*

SKM ve SOM İçerikleri	**Başaklanma**	**Çiçeklenme**	**Süt Olum**	**Ortalama**
2019				
Yulaf	69,54	56,84	54,29	60,22
Tritikale	63,87	58,77	57,82	60,15
Ortalama	66,70^{A}	57,80^{B}	56,05^{B}	60,19
2020				
Yulaf	58,83	56,90	53,76	56,49^{B}
Tritikale	63,56	59,63	59,49	60,89^{A}
Ortalama	61,19^{A}	58,26^{B}	56,62^{B}	58,69
İki yıllık ortalama				
Yulaf	64,18	56,87	54,02	58,36^{B}
Tritikale	63,71	59,20	58,65	60,52^{A}
Ortalama	63,95^{A}	58,03^{B}	56,34^{B}	59,44

Not: *Üst simge ile gösterilen küçük harfler etkileşimlerin; büyük harfler ise ortalamaların önemliliğini göstermektedir.*

Kaba yemlerin kalitelerinin belirlenmesinde ayırt edici özelliklerden birisi HK, yani toplam mineral oranıdır. Bitkilerde büyüme ve gelişme öncelikle kök faaliyeti ile başlar. Kökler mineral alımına başladıklarında toprak üstü aksamı yeterince gelişmemiştir. Bu sebeple büyümenin başlangıç dönemlerinde genellikle bitkilerin mineral kapsamı yüksektir. Zamanla üretilen organik kütlenin artışı ile oransal olarak mineral içeriğinde azalma olmaktadır. Bu durum yapılan birçok çalışmada ortaya konmuştur (Aksoy & Nursoy, 2010; Keleş, 2014; Can & Ayan, 2017). Bu araştırmada da benzer sonuçlar elde edilmiştir. Özellikle yapısal karbonhidratların arttığı süt olum döneminde otun HK oranı önemli düzeyde düşmüştür. Göçmen & Özaslan Parlak (2017) tarafından da belirtildiği gibi, bitki yapılarının benzerliği sebebiyle yulaf ve tritikale otlarının HK içerikleri de birbirine yakın olmuştur.

Sindirilebilir Kuru Madde Oranı

Araştırmanın yıllar ve ortalamasında yulaf ve tritikale otunun SKM oranları hasat dönemlerine göre istatistiki olarak önemli ölçüde değişmiştir. Yulaf ve tritikale arasındaki SKM oranlarındaki farklılıklar ise ikinci yıl ve yıllar ortalamasında önemli çıkmıştır (Tablo 3).

Yulaf ve tritikale otlarının SKM oranları büyüme ilerledikçe azalmıştır. İlk yıl ortalama SKM oranları başak/salkım oluşumundan süt olumuna kadar %66,70'den %56,05'e, ikinci yılda %61,19'dan %56,62'ye ve yıllar ortalamasında %63,95'ten %56,34'e düşmüştür. Biçimlerin ortalaması olarak yulaf ve tritikale otunun SKM oranları ilk yıl birbirine yakın olurken (%60,22 ve 60,15), ikinci yıl tritikale daha yüksek SKM oranına sahip olmuştur (%56,49 ve 60,89) (Tablo 3).

Sindirilebilirlik otun HP, NDF ve ADF oranları ile ilişkilidir. Bitkilerde büyüme ilerledikçe HP oranı azalıp, NDF ve ADF oranları artarken sindirilebilirlik azalmaktadır (Kilcher, 1981; Aksoy & Nursoy, 2010; Keleş, 2014). Yulaf ve tritikale otlarının SKM oranları genelde benzer değerlere sahiptir. Ancak bu araştırmanın ikinci yılında tritikale otunun SKM oranının yüksek olması, iki yıllık ortalamada da aralarında farklılığın doğmasına sebep olmuştur.

SONUÇ

Türkiye'de çiftlik hayvanlarının nitelikli kaba yem ihtiyacının yeterince karşılandığı söylenemez. Yapılan hesaplamalara göre nitelikli yem ihtiyacının ancak %40-65'i karşılanabilmektedir (Gökkuş & Hanoğlu Oral, 2022). Yulaf ve tritikale nitelikli kaba yem üretiminde yaygın olarak kullanılmaktadır. Yulaf ekim alanlarının %74,1'i ve tritikale ekim alanlarının da %81,2'si kaba yem üretimine tahsis edilmiştir (Gökkuş & Hanoğlu Oral, 2022). Bu nedenle bu çalışmada Çanakkale'de yulaf ve tritikalenin kaba yem üretim potansiyeli ve bunun için en uygun biçim zamanı araştırılmıştır. Bitkiler başak/salkım oluşumu, çiçeklenme ve süt olum dönemlerinde biçilmiştir. Biçim dönemi ilerledikçe ot verimi artarken, otun kalite özellikleri (HP, HK ve SKM oranı) azalmıştır. İncelenen özellikler bakımından genellikle yulaf ve tritikaleye ait değerler birbirine yakın bulunmuştur. Sadece yulafın yeşil ot verimi, tritikalenin ise HP ve SKM oranları daha yüksek çıkmıştır. Sonuç olarak, ot kalitesinde bir miktar düşüş olmakla birlikte, ot verimi oldukça yüksek olduğu için hem yulaf hem de tritikalenin süt olum döneminde biçilmesinin uygun olacağı kanısına varılmıştır. Verimli hayvanlar için yüksek kaliteli ot üretimi talep edildiğinde ise biçimin çiçeklenme döneminde yapılması uygun olacaktır.

TEŞEKKÜR

Bu çalışma birinci yazarın yüksek lisans tezinden üretilmiştir.

Etik Standartlar İle Uyum

Yazarların Katkısı

Bu çalışma birinci yazarın yüksek lisans tezinden üretilmiştir. Yazarlar bu makaleye eşit katkıda bulunmuştur.

Çıkar Çatışması

Yazarlar herhangi bir çıkar çatışması olmadığını deklare etmektedir.

Etik Onay

Yazarlar bu tür bir çalışma için resmi etik kurul onayının gerekli olmadığını bildirmektedir.

KAYNAKLAR

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An Overview of Destructive Fishing in the Philippines

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ABSTRACT

The Philippines, being positioned in the center of the coral triangle, is among the major-fish producing countries globally. However, in many parts of the country, illegal fishing is rampant, particularly destructive fishing practices (DFPs). Fisheries involving DFPs cause direct ecological damage to the corals. These fishing activities threaten both natural habitats and aquatic resources. In this review paper, we reviewed available scientific literature reporting the DFPs in the Philippines from 1979 to 2022. Results revealed that most DFPs, such as dynamite fishing, cyanide fishing, and muro-ami fishing, were prevalent and remained a lingering problem in the Philippines from the 1930s up to this date. The weak enforcement of the existing laws and regulations fuels these activities, compromising the productive coral reef areas in the Philippines. Thus, it is urgently necessary to cease these DFPs as well as protect the integrity of vital and fragile ecosystems. It is therefore recommended that strict implementation of the laws and regulations at local and national levels is likely to stop or if not least, reduce the pressing issues of destructive fishing techniques.

INTRODUCTION

As an archipelagic country in Southeast Asia, the Philippines has 7,641 islands with 2,200,000 km^2 of total territorial water, including an exclusive economic zone (EEZ) and a 27,000 km^2 coral reef area (BFAR, 2019; Tahiluddin & Terzi, 2021). The Philippine archipelago lies at the center of the Coral Triangle, the area that is home to the most marine species in the world (Veron, 1995; Allen & Werner, 2002; Carpenter & Springer, 2005; Muallil et al., 2014; Tahiluddin & Terzi, 2021; Mohamad et al., 2022). There are 3,645 fish species in the Philippines, and 3,213 species are marine (Froese & Pauly, 2022). The Philippines is known as one of the major fish producers in world fisheries. In 2020, the Philippines ranked 13th globally, contributing nearly 1.76 million metric tons in terms of marine capture production (FAO, 2022). Philippine capture fisheries are divided into commercial and municipal sectors. The municipal capture fisheries sector contributed 1.10 million metric tons to the total production in 2020, whereas the commercial capture fisheries sector contributed 0.98 million metric tons (PSA, 2021).

Fishing is one of the oldest forms of subsistence, relying on the abundance of aquatic resources for survival. Millions of people still rely on marine fisheries for livelihood and food even up to this date. However, due to the high demand, many fishers used illegal methods in order to catch fish faster and more profitably. Various forms of illegal fishing contribute to the depletion of fish stocks (Alvarico et al., 2021). Globally, nearly 80 percent of fish stocks have been depleted or overexploited. Ocean scientists claim that overfishing threatens not only aquatic ecosystems but also food webs and the aquatic food supply (Purcell et al., 2013; Arias & Pressey, 2016; Pala et al., 2018). The Philippines remains one of the most threatened countries with regard to marine ecosystems due to illegal fishing (Quiazon et al., 2013). Over the last years, fishing rates of the Philippine municipal fisheries have been decreasing (PSA, 2021); this may be attributed to the use of illegal fishing practices. Illegal and destructive fishing is one of the challenges facing marine fisheries (Tahiluddin & Terzi, 2021).

An illegal fishing practice that damages either the fished habitat or the primary habitats providing sustenance to the fished habitat is a destructive fishing practice (Pet-Soede & Erdmann, 1998a). The term destructive fishing refers to fishing gears or methods that cause ecosystem components to be destroyed or cease to function normally. In addition, a limited number of fishing gears or catches are inherently destructive methods, usually explosives and synthetic toxins (Willer et al., 2022). Due to increasing population growth and economic pressures, coral reef areas in the Philippines have been prone to destructive fishing since 1985, triggered by the coastal villagers (McManus et al., 1997). Destructive fishing has been one of the main causes of fishery decline in small-scale fisheries in the country for the last decades (Muallil et al., 2014).

The practice of destructive fishing is associated with poverty, as this is the faster way of capturing fish (Lauraya et al., 2010). A study by Alvarico et al. (2021) explored Filipino fishers' stories about why they used illegal fishing and the socio-economic and cultural factors that influenced the use of destructive fishing practices in coastal areas of northern Mindanao, Philippines, particularly Misamis Oriental. According to their findings, illegal fishing assisted the fishers in doing more and providing for their families with their essential needs since it doubled their catch, earned them more, and paid for medication for their sick family members. Since they used to fish together, they acquired their illegal fishing technique from their families, friends, and peers, which, according to them, was much more convenient and profitable than conventional fishing methods. The enforcement of laws is essential to restoring damaged marine habitats by curbing destructive and illegal fishing practices (Dalabajan, 2005). However, there are still persisting practices of destructive fishing in the Philippines, despite existing laws and regulations prohibiting them. In this paper, we reviewed and compiled the dispersed peer-reviewed scientific articles and books detailing destructive fishing practices, which were only confined to dynamite, cyanide, and muro-ami fishing practices in the Philippines from 1979 to 2022.

DYNAMITE (BLAST) FISHING

Dynamite fishing, also called bomb fishing or blast fishing, is one of the destructive fishing practices that uses explosives to stun or kill schools of fish (Katikiro & Mahenge, 2016). In the Philippines, the first dynamite is commonly prepared in a powder form consisting of 75% potassium chlorate, 15% charcoal, and 10% sulfur or cornstarch (Naughton, 1985). The commonly used blast fishing in the country is the use of dynamite or ammonium nitrate (Rubec, 1988). Anecdotal evidence shows that in the Philippines, an alternative to dynamite such as the use of locally available resources, like fertilizers (ammonium nitrate or sodium nitrate), prepared and mixed with kerosene or gasoline, and the explosive mixture is poured into an empty glass bottle. A makeshift fuse is created, stuck in the bottle, and sealed with rubber part of a flip-flop sandal around the fuse. As part of its operation, the explosive bottle is tied to a steel rod or similar heavy material to sink quickly. In the local fishing ground, explosive bottle with sinker is thrown at schools of fish or in coral reef areas. A few minutes after the explosion, the fishers dive and start collecting dead and stunned fish with the aid of a scoop net and compressor. The groupers (*Cephalopholus* spp., *Plectropomus* spp., and *Epinephelus* spp.), rabbitfish

(*Siganus* spp.), snappers (*Lutjanus* spp.), as well as reef associates such as fuseliers (*Pterocaesio* spp. and *Caesio* spp.) are the primary targets of dynamite fishers because of the increase in exports and the expansion of hotels and restaurants in the region (Pet-Soede & Erdmann, 1998b).

Apart from injuring and killing fish, dynamite fishing also destroys coral reefs, decimates reef habitats, breaks natural barriers that protect the coastline against storm surges and erosion, and threatens the reputation of the Philippines as an internationally renowned marine tourism destination (Chevallier, 2017). Marine organisms and coral habitats are damaged by dynamite fishing, which is a destructive and wasteful method (Alcala & Gomez, 1979; Yap & Gomez, 1985; Alcala, 2000; Raymundo et al., 2007). It is fairly straightforward to determine what the influences of dynamite fishing practices would be on the structure of reefs and productivity (Riegl & Luke, 1999; Alcala, 2000; Fox et al., 2003), and an increasing body of research is indicating that the removal of coral habitats likely to cause a decline in fish species (Lewis, 1997; Halford et al., 2004).

Dynamite fishing is a common issue worldwide, such as in Southeast Asia (Yap & Gomez, 1985; Pet-Soede & Erdmann, 1998a; Erdmann et al., 2000; Chou, 2000; Raymundo et al., 2007; Pacini et al., 2016; Hampton-Smith et al., 2021), Africa (Bigot et al., 2000; Wells, 2009; Pacini et al., 2016), and Oceania (Sulu et al., 2002; Brewer, 2013). In the Philippines, a number of different islands have practiced dynamite fishing since the 1930s, including the islands of Babuyan, Mactan, Bohol, Palawan, eastern Mindanao, Ozamis, Basilan, Misamis Occidental, Zamboanga Peninsula, and part of the Sulu Archipelago such as Turtle Island (Thomas, 1985; Magdaong et al., 2014), as fishers seek to improve production in the easier fashion (Pastoral & Ramiscal, 1997). Thus, dynamite fishing continues today, but it occurs at a local level, indicating that it still exists (Magdaong et al., 2014), and anecdotal evidence supports this study that even up to this date, dynamite fishing still continues to persist.

The use of dynamite fishing has also likely impaired innocent marine mammals. Veloria et al. (2021) stressed that marine mammals' ability to communicate, locate food, and navigate underwater was severely impacted by underwater noise including dynamite fishing. Dynamite and related impulsive sound exposure are associated with the hearing loss of marine life (Pacini et al., 2016). An experimental study assessed the effects of blast fishing on marine mammals, especially cetaceans, in San Fernando, La Union; the results indicated that marine mammals with more than 100 m from the explosion would suffer debilitating injuries (disorientation, acoustic trauma) even from a single pulse of the blast (Veloria et al., 2021). Over the past few years, a number of marine mammals have been stranded in the Philippines due to underwater explosions caused by blast fishing (Pacini et al., 2016). In addition, fishers accidentally wounded a British volunteer in 1991 with blast fishing while surveying coral reefs in the Samar Sea (Saeger, 1993).

CYANIDE FISHING

Cyanide fishing is widely used in the marine live reef fish food trade and marine aquarium fish trade, using sodium cyanide, a toxic chemical utilized to stupefy hard-to-catch species (Magdaong et al., 2014). Cyanide fishing in the Philippines has been practiced since 1962 in Central Visayas and Batangas, targeting tropical marine fish, especially agile and inaccessible reef fishes, and contributes an important role to the devastation of coral reefs and food and the dwindling of aquarium fish (Rubec, 1986; Cudia & Romero, 2022). Since the beginning of its use, over a million kg of toxic sodium cyanide have been spurted onto the Philippines' coral reefs to stupefy and collect ornamental aquarium fish species fated for the aquariums and pet shops in Western countries like North America and Europe (Barber & Pratt, 1997). Along with other illegal fishing practices, cyanide fishing is still a common problem in municipal waters (Baticados, 2004). In the late 2000s, it was estimated that over 260 000 cyanide fishers and fishing trips were recorded in the Calamianes Group of Islands alone (Dalabajan, 2005).

The preparation and operation of cyanide are clearly described by Rubec & Soundararajan (1990). Firstly, the cyanide tablets, about the size of hockey pucks, are broken down and placed into bottles of plastic detergent. The dissolved hydrocyanic acid (HCN) is used by the collectors to stupefy aquarium

fishes and kill food fish; as the collector swims toward the target area, the fish hide in the coral. The collectors ensure all the exits are sealed off by spurting clouds of milky hydrocyanic acid solution on the coral head. During the dive, the concentration of hydrocyanic acid in the bottle is successively diluted. Nearly 50% of the exposed fish die of acute doses (5-50 mg L^{-1}) of being unable to control the concentration from the bottle. At the same time, the other remaining fish become bewildered and run away. Some stunned fish are retrieved from the bottom, while others are driven into gill nets. Roughly 10% of the exposed fish are being selected by the fish collectors choosing only the colorful species of interest to aquarists. Most fish can get recovered once placed in clean seawater (Rubec & Soundararajan, 1990).

A number of colorful species, including the clownfish *Amphiprion ocellaris* and large-sized wrasses and groupers, are targeted by illegal cyanide fishing in the Indo-Pacific region, including the Philippines (Madeira et al., 2020). However, the use of sodium cyanide is deleterious to non-target aquatic organisms, like corals and other invertebrates (White & Wells, 1982; Rubec, 1988; Barber & Pratt, 1997), especially larvae forms (Werorilangi et al., 2019), including phytoplankton such as marine diatom (Pablo et al., 1997), as a consequence of uncontrollable exposure doses of cyanide by the fish collectors during dive operation (Rubec & Soundararajan, 1990). Coral reefs of the Philippines have been threatened by cyanide fishers for the past years. White & Wells (1982) estimated that in every 100 fish collectors that use cyanide, about 11 million coral heads are being squirted by cyanide. The authors also mentioned coral heads exposed to cyanide are typically dead but intact, unlike dynamited corals which are fragmented. In addition, cyanide is highly dangerous to humans once inhaled, absorbed across the skin, or ingested (White & Wells, 1982; Graham & Traylor, 2022).

MURO-AMI FISHING

Muro-ami is destructive fishing that originated in Japan around the 1930s, where Okinawan migrant fishers came to the central Philippines to fish (Anonymous, 1985; Olofson, 2014). It consists of a big stationary bag net (37 m long × 10 m deep), held open with the aid of a current (Dalzell & Ganaden, 1987; Gomez et al., 1994). There are two detachable wings with a size of 100 m × 10 m, which serve as a guide for the fish towards the net (Anonymous, 1985). It is usually set over the coral reefs with a depth ranging from 13-30 m, with flagpole buoys serving as markers (Anonymous, 1985). Scarelines, made of ropes with plastic strips which are tied at intervals and 3-5 kg of stone weights on edge, are held by the swimmers aiming to drive fish into the nets and to jig them up and down on the corals as they proceed (Anonymous, 1985; Magdaong et al., 2014). Commercial muro-ami uses 200-300 swimmers, which are typically young boys, to frighten the fish (Anonymous, 1985; Dalzell & Ganaden, 1987). The majority of fish caught by muro-ami fishing in the Philippines are shoaling herbivores and planktivores of the Acanthuridae (surgeon fishes, *bagis* and *labahita*) and Caesionidae (fusiliers or *dalagang-bukid*) families (Anonymous, 1985).

A modified form of muro-ami, which is *kayakas*, used bamboo instead of rocks to scare the fish driving into the net (White & Wells, 1982; Magdaong et al., 2014). Banging the bottom by the swimmers with rocks or bamboo, the habitats are being disturbed, and pronounced effects are the corals which are pounded and broken as a result of this mode of operations (White & Wells, 1982). The reduction of coral reef cover has been attributed to these operations inducing overfishing as a result of slow recovery and replenishment of disturbed fish stocks (Magdaong et al., 2014). With the frequent use of muro-ami, it is no longer providing a livelihood for coastal villagers but rather further creating poverty among rural Filipinos (Olofson & Tiukinhoy, 1992). Moreover, due to its extensive damage to coral reef habitats brought about by muro-ami, which can cause depletion of the fish stock population, increasing protests from different sectors raised awareness of this destructive gear (Miclat et al., 1991). Additionally, socio-economic issues like child labor, inequitable profit-sharing system practiced among fishing cooperation, and lack of health and shipboard sanitary conditions (Miclat et al., 1991). These have prompted demands to ban this fishing method in the country, and in 1986, commercial muro-ami was banned (Dalzell & Ganaden, 1987; Miclat et al., 1991). Considering an alternative

Table 1. Philippines' regulations and penalties for dynamite fishing, cyanide fishing, and muro-ami fishing

Regulation Categories	Specific Regulations	Penalties
Republic Act 10654, section 92 (Prohibition on the use of fishing through toxic or poisonous substances and explosives)	Actual use of toxic or poisonous substances, explosive including those not caught illegally if they co-exist with those caught illegally	• Taking the gears and catch and inflicting an administrative fine equivalent to five times the catch's value • A fine of 3,000,000 pesos is imposed for large-scale commercial fishing • A fine of 1,500,000 pesos is imposed for medium-scale commercial fishing • A fine of 300,000 pesos is imposed for small-scale commercial fishing • A fine of 30,000 pesos is imposed for municipal fishing • 5 to 10 years in prison
	Explicit criminal cases are filed when explosives, toxic or poisonous substances are actually used and result in physical harm or death	• Taking the gears and catch and inflicting an administrative fine equivalent to twice the catch's value • A fine of 1,000,000 pesos is imposed for large-scale commercial fishing • A fine of 500,000 pesos is imposed for medium-scale commercial fishing • A fine of 300,000 pesos is imposed for small-scale commercial fishing • A fine of 10,000 pesos is imposed for municipal fishing • 6 months to 2 years in prison
Republic Act 10654, section 97 (Prohibition on Muro-ami drive fishing)	Actual use of muro-ami fishing	• Taking the gears and catch and inflicting an administrative fine equivalent to five times the catch's value • A fine of 2,000,000 pesos • In the case of failure to pay the fine, fishworkers who serve as pounders will be penalized with 20,000 pesos or community service • A fine equivalent to twice the administrative fine and imprisonment of 2 - 10 years
Act No. 2255	An act prohibiting the manufacture, possession, and sale of dynamite and other explosives without a special permit, providing a penalty, therefore, and for other purposes.	• Fine not to exceed 2,000 pesos but not to be less than 600 pesos, and by imprisonment for not less than 3 months nor more than 3 years, in the discretion of the court.
Presential Decree No. 534 August 8, 1974	Imposing stiffer penalties for illegal fishing	• If explosives are used, 10-12 years in prison • In the case of a physical injury caused by the explosion, the punishment may range from 12-20 years in prison, and if human life is lost, then the penalty is life in prison or death • If toxic or poisonous substances are used, 8-10 years in prison • In the case of a physical injury caused by such substances, the punishment may range from 10-12 years in prison, and if human life is lost, then the penalty is up to 20 years or life in prison or death
Republic Act 6969	The Act provides penalties for violations of the sale, purchase, and possession of toxic and hazardous substances, including sodium cyanide.	• The penalty ranges between 6 years and 1 day to 12 years in prison, and a fine of at least 250,000 pesos
FAO 163	Governing Philippine waters by prohibiting the operation of *kayakas* and muro-ami	• The Court may impose a fine of 500 pesos to 5,000 pesos, or imprisonment of 6 months to 4 years, or both

non-destructive method, the Bureau of Fisheries and Aquatic Resources of the Philippines proposed a "Pa-aling," a new modified gear as a substitute to muro-ami. The new technique involves the use of bubbles, powered by surface-supplied air via plastic hoses, to frighten and drive towards a set-net (Miclat et al., 1991).

REGULATION OF DESTRUCTIVE FISHING

Law enforcement is an efficient way of controlling the widespread use of destructive fishing in the Philippines as a promising solution to regenerate deteriorated marine habitats (Dalabajan, 2005). The Philippines has various existing laws and regulations against destructive fishing and penalties for committing these unlawful practices (Table 1). However, over the last decades, weak law enforcement is still one of the main reasons for the prevalence use of destructive fishing (Barber & Pratt, 1998). Areas that are far from law enforcement are among the most users of destructive fishing, such as dynamite fishing (Dalzell & Ganaden, 1987). Scientists and researchers are even developing or improving some way of detecting fish caught by destructive fishing. For instance, the use of potentiometry for cyanide detection has recently been improved by Cudia & Romero (2022); this method can be used to monitor any cyanide-caught fish for better regulation.

Aside from national laws and regulations, municipal ordinances throughout the country also exist. However, in most municipalities, these ordinances are not being implemented or are weakly enforced (Lauraya et al., 2010). For example, in Barangay Atulayan, Sangay municipality, Camarines Sur province, due to the indolent grind of the wheels of justice, the barangay captain lost hope in implementing the law. There were many instances when the barangay captain had apprehended many violators caught with dynamite possessions, reported and turned them over to the Philippine National Police (PNP) officers. However, after the investigation, the PNP argued that the confiscated dynamites were sodium nitrate or fertilizers. The lack of further investigation by the higher authority ignited the barangay captain's loss of faith in implementing the ordinance (Lauraya et al., 2010).

CONCLUSION

It is evident that destructive fishing practices, such as dynamite fishing, cyanide fishing, and muro-ami fishing, are still prevalent methods of capturing marine resources in the Philippines. These practices threaten marine habitats, particularly the coral reefs - crucial habitats of most reef fishes, and jeopardize the sustainability of local fishing livelihood. Despite existing law enforcement governing these illegal, destructive fishing practices, the lack of effective regulation still fuels the lingering of these practices. It is therefore recommended that strict implementation of the laws and regulations at the local and national levels is likely to stop or if not least, reduce the pressing issues of destructive fishing techniques. Sustainable fishing practices, such as spear fishing and line fishing, are still the friendly way to capture fishing sustainably while maintaining a sound and healthy environment.

Compliance with Ethical Standards

Authors' Contributions

Both authors have contributed equally to this paper.

Conflict of Interest

The authors declare that there is no conflict of interest.

Ethical Approval

For this type of study, formal consent is not required.

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Some Population Parameters of *Cyprinus carpio* (L., 1758) From Yeşilırmak (Samsun, Türkiye)

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ABSTRACT

Current study was carried out between March 2019 and February 2020 to determine the biological characteristics of *Cyprinus carpio*, which is brought to fish markets of Alaca (Çorum) from Hasan Uğurlu Dam Reservoir (Samsun). Total, fork, standard lengths, and weights of 406 individuals were measured and recorded. Sex ratio was calculated as 1:2.1 (♀:♂). Ages were determined by using lateral scales and thus age groups were formed. According to the data collected, equation of length-weight relationship was $W = 0.0163 \times TL^{2.935}$ and an isometric growth pattern was observed for combined individuals. VI age group has the most individuals (n=148). Fulton's condition factor (K) and phi-prime growth index (Φ') were calculated as 1.3 and 2.42, respectively. This study makes a contribution to common carp stock related studies for further common carp fishery management.

INTRODUCTION

The Cyprinidae family is the largest of all freshwater fish families and comprises of about 367 genera and about 3006 species (Nelson, 2016). As a member of this family, *Cyprinus carpio* (Linnaeus, 1758) has a wide distribution area consisting of freshwater ecosystems, especially rivers and lakes (Zencir Tanır, 2020). Due to being one of the most dispersed freshwater fish, *C. carpio* is an ecologically harmful and invasive species (Kulhanek et al., 2011; Vilizzi, 2018; Das et al., 2019) and is listed among the 100 most harmful alien species of the world (Lowe et al., 2000). Being durable, adapting to changing climatic conditions (Crespi & New, 2009), tolerance to temperature fluctuations (Syed et al., 2020) and being able to tolerate changes oxygen levels in water (Rashid et al., 2018). In addition, its rapid growth, rapid reach to sexual maturity, and high fecundity lead to a high invasion potential (Winker et al., 2011; Troca & Vieira, 2012; Vilizzi & Copp, 2017). Common carps have omnivorous (Khan et al., 2020) and opportunistic feeding behaviour (Feher et al., 2021).

In the inland waters of Türkiye, especially gillnets are used for carp fishing and carp fishing has been taken under control with the "Communiqué on the

Regulation of Commercial Fisheries Fishing" (Anonymous, 2020). While the catch amount of carp was ≈10.000 tons in 2011, it decreased to ≈3.000 tons by 2020 (TUIK, 2021). Stock estimation studies related to carp have been made in different water bodies throughout Türkiye (Vilizzi et al., 2014a), and the making of fishery regulations depends entirely on obtaining biological data.

To have information about the biological characteristics of populations, species-specific length-weight relationships and condition factors, are essential for fish biology and population dynamics studies in terms of; i) weight estimation using the length or length classes of the samples; ii) evaluation of available biomass if the length frequency is known; iii) calculation of relative condition value and relative weight; iv) calculate weight at a given age by converting growth in length to growth in weight in stock assessment models; v) comparison of life history parameters and sizes of populations from different locations (Anderson & Gutreuter, 1983; Froese, 2006).

On the other hand, sampling is done by various methods and one of them is market sampling. The market sampling provides an access to some population related parameters such as length-weight relations, age and growth parameters etc. The market sampling is relatively important and has been used for many fishery related studies (Daan, 1974; Bromley, 2003; van Keeken et al., 2004; Spaet & Berumen, 2015; Eltholth et al., 2018). According to our observations market sampling, if the source is well-known, the accurate estimations could be done properly.

Considering the important roles played by *C. carpio* in Turkish inland waters, the determination of the biological characteristics of common carp samples offered for sale in fish markets can be a guide in evaluating their compliance with fisheries regulations. Because, while offering both local fish fauna and carp stocks for human use, it is important to protect the species and use of fish stocks within the framework of the concept of sustainability (Vilizzi et al., 2014a).

This study aims to determine some biological characteristics of *C. carpio*, which was taken from Yeşilırmak (Çarşamba, Samsun) and sold in Alaca (Çorum) fish market. When evaluated in terms of pressures on fisheries and the climate crisis, the data obtained will provide scientific advice in fisheries management, species management, conservation, aquaculture and population comparison. It is also expected to contribute a comprehensive view to develop an effective local fisheries management.

MATERIAL AND METHODS

Study Area

Sampling was carried out between March 2019 and February 2020 to determine the biological characteristics of *C. carpio*, which is brought to fish markets of Alaca, Çorum. The common carp individuals were caught from Hasan Uğurlu Dam Reservoir is located on Yeşilırmak River (Samsun) (Figure 1). Reservoir area is ~ 13,1 km² (Enerji Atlası, 2022). The reservoir is rented to fishermen by state for fishery. Common carps are caught by trammel nets with mesh sizes vary between 70 and 120 mm from the reservoir. Location of the fish samples was corrected by fishermen and fish market owner.

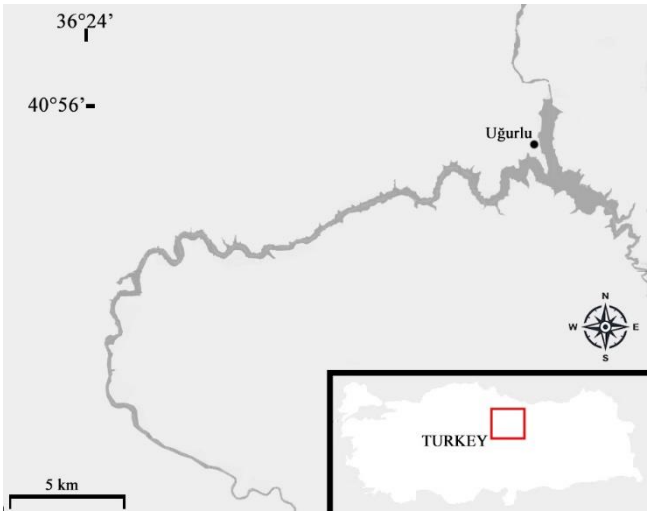

Figure 1. Hasan Uğurlu Reservoir: Origin of the *Cyprinus carpio* samples

Sampling

Within the scope of the study, common carp individuals were obtained monthly from a fish market in Alaca. Fish samples were randomly selected, were iced and were brought to the laboratory where measurements would be made.

Laboratory Examinations

Total length (TL), fork length (FL) and standard length (SL) of the samples were measured (±0.1 mm). Total weights were determined with precision balance (±0.01g).

Length-Weight and Length-Length Relationships

The length-weight relationship was calculated by Equation (Eq.) (1) (Ricker, 1973);

$$W = a \times TL^b \quad (1)$$

In the formula where *TL* is total length and *W* is total weight of fish. Logarithmic transformation was applied to both weight and length parameters to make linear regression analysis. Thus, *a* and *b* values of the length-weight relationship were estimated by Eq. (2);

$$\log(W) = \log(a) + b\log(TL) \quad (2)$$

a and *b*, the coefficient of determination r^2 were also estimated (0.95 CI). Length-weight relationships were determined separately for female, male and all individuals. A "*b*" value of 3 means isometry, < 3 means negative allometry, and > 3 means positive allometry. Whether the "*b*" values obtained were suitable for isometry (*b* = 3) was evaluated with the "*t* test".

Total, fork and standard lengths were used in determinations of length-length relationships. Transformation of all lengths with each other were presented. The length-length relationship with total length among other body lengths with a simple linear regression model by Eq. (3);

$$Y = a + bX \quad (3)$$

where *Y* is various body lengths, *X* is total length, *a* is proportionality constant and *b* is regression coefficient (Alam et al., 2012).

Fulton's Condition Factor

Fulton's condition factor (K) was calculated in Eq. (4) (Froese, 2006);

$$K = \left(\frac{W}{TL^3}\right) \times 100 \quad (4)$$

In the formula where *K* is condition value, *W* is total weight and *TL* is total length of fish.

Growth

Von Bertalanffy's (1957) equation was used to calculate the growth in length (Eq. (5));

$$L_t = L_\infty[(1 - exp^{-k(t-t_0)})] \quad (5)$$

In the formula, L_t is the predicted fish length at age *t*, L_∞ is the asymptotic length, *k* is growth coefficient and t_0 is age of fish at zero length.

Growth performance index (phi-prime)

The phi-prime was calculated to compare the growth parameters in the current study with those of other studies (Munro & Pauly, 1983) (Eq. (6)).

$$\Phi' = \log k + 2\,\mathrm{Log}L_\infty \quad (6)$$

In the formula, Φ' is growth performance index, *k* is growth coefficient ($year^{-1}$) and L_∞ is asymptotic length.

Age Determination

For age determinations, scales between the dorsal spines and the linea lateral were used (Chugunova, 1963). The scales of each fish were taken into separate zip lock bags and tagged. The scales were washed before being taken into zip lock bags, and the mucus and epidermis layer on them were cleaned with the help of a brush. In order to avoid difficulties in the reading process and to avoid mistakes, the scales were kept in 5% NaOH for 2 hours before they were read and washed in 96% alcohol for a while to remove any residues that may be on them (Bolat & Yağcı, 2018). The scales were then examined under a light microscope. Ages were read by three independent readers.

Mean lengths (LaA) of previous ages were evaluated by using the Fraser–Lee back-calculation method (Francis, 1990) (Eq. (7));

$$L_t = c + (TL_c - c)(S_t/R) \quad (7)$$

where L_t is the total length when annulus t was formed, TL_c is total length at capture, S_t is the distance from scale focus to the annulus t, *R* is the scale radius, and *c* is the intercept on the length axis from the linear

relationship of total length versus scale radius (the Fraser-Lee correction factor) (Heidarsson et al., 2006; Top et al., 2018).

Sex Determination

All individuals were dissected to determine the genders than male and female individuals were determined by macroscopic examination.

Data Analysis

All data were evaluated in MS Excel (Microsoft Corporation, 2018) and Statistica (StatSoft, 2012) software. The chi-square (χ^2) test was used to determine the differences in sex ratios. The differences between the total length and weight values of female and male individuals were determined by two-sample independent *t*-test. The Kruskal-Wallis test was used to determine the change in K value according to gender and months. All tests were performed at p = 0.05.

RESULTS

Length-Weight and Length-Length Relations

Totally, 406 individuals were examined in the current study. Among these individuals, 130 were female and 272 were male. The sex of 4 individuals could not be determined. The sex ratio was found as 1:2.1, female to male, and a statistically significant difference was observed in sex ratio ($p < 0.05$).

The total length frequency distribution indicated a dominance of fish between 29.0 and 30.0 cm TL (Figure 2). Total lengths and weights were ranged between 24.9-46.5 cm and 226.7-1369.5 g, respectively. Mean total length and total weight were estimated as 32.88 ± 3.77 cm and 479.46 ± 177.56 g, respectively. The mean total length of females (33.59 ± 3.63 cm TL) was significantly larger than the males (32.57 ± 3.80 cm TL) ($p < 0.05$). The mean weight of females (514.52 ± 181.77 g) also was significantly greater than those of the males (464.8 ± 173.56 g) ($p = 0.008$). The highest (40.8 cm) and lowest (29.9 cm) mean lengths were recorded in October and August, respectively, and the highest mean weight (845.9 g) was observed during October, while the lowest value (337.9 g) was observed in August. The length-weight relationships showed isometric growth for female, male and all (Table 1).

The relationships between TL, FL and SL of the *Cyprinus carpio* including 406 specimens along with the estimated parameters of the length-length relationship and the coefficient of determination R^2 are presented in Table 2.

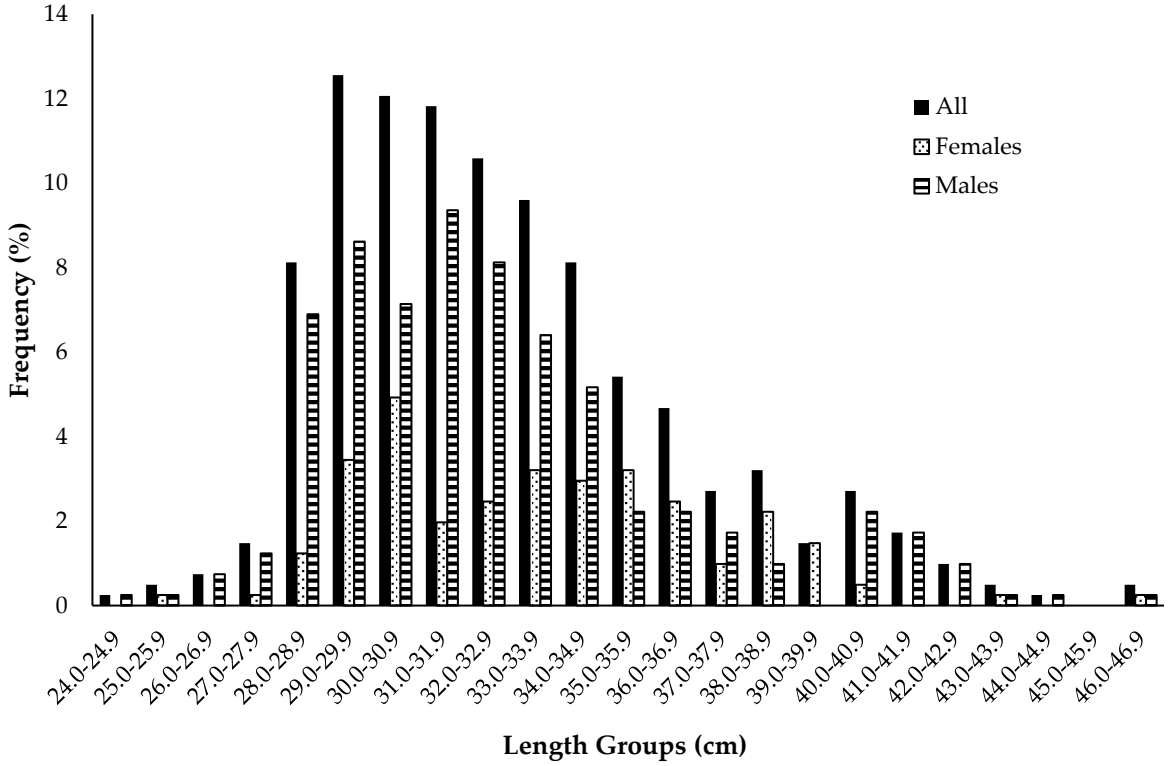

Figure 2. Length frequency of *Cyprinus carpio* acquired from Hasan Uğurlu Reservoir

Table 1. Length-weight relations of common carp (S.E. of b; standard error of b, CI of b; confidence interval of b)

Sex	N	TL_{min}-TL_{max}	W_{min}-W_{max}	a	*b*	S.E. of *b*	CI of *b*	R^2	Growth
All	402	24.9-46.5	226.7-1369.5	0.0163	2.935	0.06	2.862-3.008	0.939	I
Female	130	25.0-46.4	232.5-1103.8	0.0114	2.972	0.11	2.832-3.112	0.932	I
Male	272	24.9-46.5	226.7-1369.5	0.0184	2.898	0.07	2.812-2.984	0.942	I

Table 2. Morphometric relationships between total length (TL), fork length (FL) and standard length (SL) for *Cyprinus carpio* from Hasan Uğurlu Reservoir (N=406)

Equation	a	*b*	95% CI of a	95% CI of b	S.E. of b	R^2
$FL = a + b \times TL$	-1.3937	0.9268	-1.698 to -1.090	0.918 - 0.936	0.005	0.9899
$FL = a + b \times SL$	1.193	1.096	0.858 to 1.528	1.083 - 1.109	0.007	0.9855
$SL = a + b \times TL$	-2.033	0.8357	-2.410 to -1.656	0.824 - 0.847	0.006	0.981
$SL = a + b \times FL$	0.7025	0.8992	-1.016 to -0.389	0.888 - 0.910	0.005	0.9855
$TL = a + b \times FL$	3.0111	1.068	2.600 to 3.422	1.057 - 1.079	0.005	0.9899
$TL = a + b \times SL$	1.821	1.1739	1.511 to 2.131	1.158 - 1.190	0.008	0.981

Growth

Growth coefficient (k), t_0 and L_∞ of all sexes was found as 0.09 $year^{-1}$, -3.02 years and 57.77 cm, respectively (Table 3).

Table 3. Growth parameters of combined, female and male individuals

Sex	k	t_0	L_∞	Φ′
All	0.09	-3.02	57.77	2.48
Female	0.11	-2.63	52.09	2.47
Male	0.05	-4.61	72.31	2.42

Fulton's condition factor

The overall Fulton condition factor (*K*) values for samples ranged from 0.91–1.67 (mean = 1.3). Also, for females and males the K values ranged from 1.06–1.67 and 0.91–1.58, respectively. The Fulton's condition factor varied significantly during the study months ($p < 0.05$), with the peak mean condition value being observed during January (1.36) as shown in Figure 3.

However, there was no significant difference ($p > 0.05$) in the mean condition factor between males (1.30) and females (1.31). The highest (1.36) mean condition for all samples was recorded in size class 29–29.9 and the least (1.20) in size class 31–31.9.

Age

Ages based on actual readings were varied between 3 and 13 years. According to mean lengths of the females and males, it was not detected significant differences. Therefore, the first two ages of mean lengths can be used for both sexes (Table 4).

DISCUSSION

The parameter *a* is the scaling coefficient of the weight of a fish corresponding to its measured length (Kuriakose, 2017). According to previous studies, *a* values varies between 0.00003 and 0.05477. In this study, the *a* parameter was estimated as to be 0.0163. Our estimated *a* value relatively takes place between maximum and minimum values (Table 5).

b value gives information about fish shape and growth type. According to length-weight relationships, considering estimated *b* values, it can be stated that an isometric growth pattern is evident for the specimens. *b* values determined by other authors

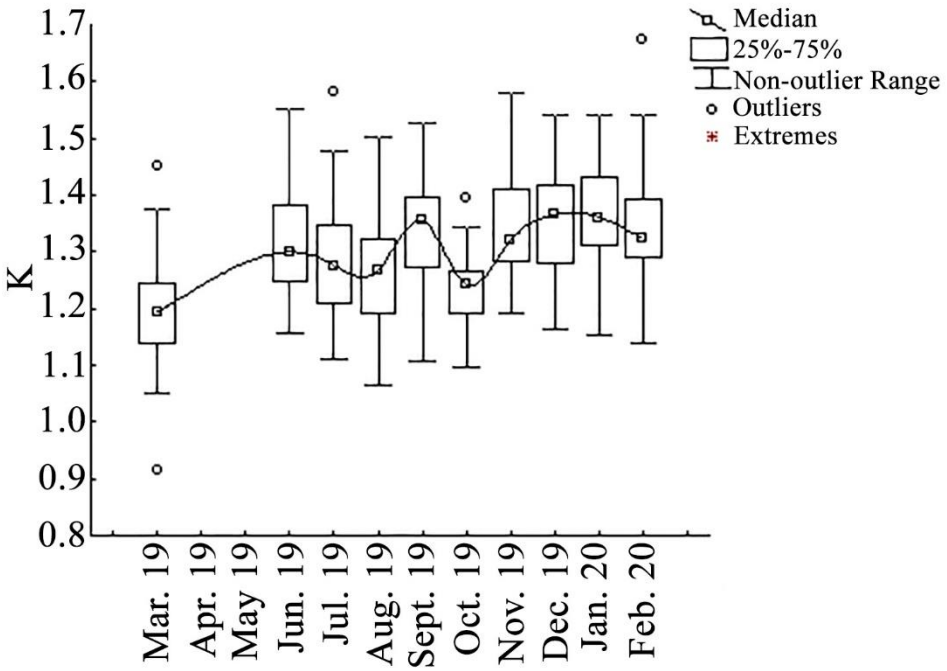

Figure 3. The change of overall mean Fulton's condition factor values by months

Table 4. Age at length of *Cyprinus carpio* samples from fish market, Alaca, Çorum

Sex	Age												
	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	13
All	17.1	21.2	25.0±0.1	26.1±0.2	29.0±0.8	31.4±1.1	34.0±0.8	35.8±1.1	38.3±0.8	41.1±0.5	41.6±0.1	42.6±0.9	44.3
Female			25.0	26.0	29.2±0.8	31.3±1.2	34.4±0.9	36.0±1.1	38.6±0.7	39.6±0.1	41.6	42.1±1.5	
Male			24.9	26.1±0.2	29.0±0.8	31.5±1.1	33.8±0.7	35.5±0.9	37.8±0.7	40.6±0.4	41.6±0.1	42.5±0.7	44.3

Table 5. Comparison of *a*, *b*, R^2, t_0, L_∞, k, K, Φ′ and growth type values regarding previous studies and current one

Researcher/s	Location	*a*	*b*	R^2	t_0	L_∞	k	K	Φ′	Growth type
Balık et al. (2006)	Karamık Lake	0.0245	2.952	0.99	-0.245	130	0.075	2.022	7.15	
Karataş et al. (2007)	Almus Dam Lake	0.005	3.319	0.94	-1.922	46.39	0.153	1.34	5.8	+A
Demirkalp (2007a)	Çernek Lake	0.0547	2.665	0.95				1.767		-A
Demirkalp (2007b)	Liman Lake	0.0283	2.871	0.96				1.876		-A
Elp et al. (2008)	Koçköprü Dam Lake	0.04	2.847	0.95	-0.80	84.07	0126	2.471	2.949	
Mert et al. (2008)	Apa Dam Lake	0.000054	2.83	0.93				1.96		
Yilmaz et al. (2010a)	Altınkaya Dam Lake	0.0260	2.825	0.99						-A
Yilmaz et al. (2010a)	Bafra Fish Lakes	0.0298	2.802	0.97						-A
Yilmaz et al. (2010a)	Derbent Dam Lake	0.0210	2.894	0.97						I
Yilmaz et al. (2010a)	Karaboğaz Lake	0.0197	2.895	0.98						I
Yilmaz et al. (2012)	Bafra Fish Lakes	0.0349	2.822	0.98	-0.802	60.96	0.274	1.869	3.00	-A
Macun (2014)	Karaboğaz Lake	0.00003	2.88	0.96				1.78		-A
Saylar & Benzer (2014)	Mogan Lake	0.00006	2.87	0.93	-1.74	49.6	0.24	1.984		
Birecikligil et al. (2016)	Nevşehir - Kızılırmak	0.001	3.138	0.93				1.52		+A
Buhan et al. (2016)	Almus Dam Lake	0.0138	3.018	0.99						I
Present study	Hasan Uğurlu Reservoir	0.0163	2.935	0.94	-4.61	72.31	0.09	1.3	2.42	I

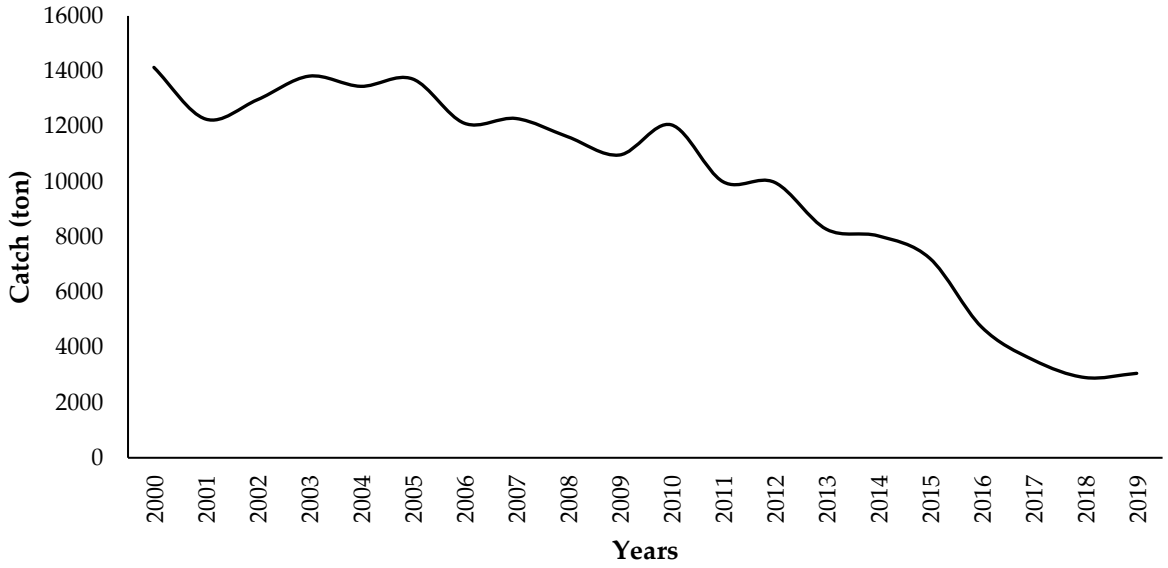

Figure 4. Common carp catch of Türkiye by years (TUIK, 2021)

(Balık et al., 2006; Mert et al., 2008; Yilmaz et al., 2010a, 2012), are also in accordance with the findings of the current study. *b* values of the studies range between 2.83 to 3.31. As found in the most of the previous studies that *C. carpio* shows isometric and negative allometric growth. However, two studies, Birecikligil et al. (2016) and present study, show positive allometric growth (Table 5). These variations may be associated with some biotic and abiotic effects such as latitude, altitude, temperature, food abundance, population density.

As it is known, the exponential regression is used to determine the length-weight relationships. In this estimation, R^2 shows the model accuracy and more close R^2 to 1 means more accurate the model becomes. All R^2 values of the previous studies are very close to 1. Our R^2 value was estimated as 0.94 and this value is acceptable for exponential model accuracy (Table 5).

Vilizzi et al. (2014b) calculated the average growth coefficient (k) of the *C. carpio* species found in Anatolia as 0.135 $year^{-1}$. The k values in the present study were found as 0.09 $years^{-1}$, 0.11 $years^{-1}$ and 0.05 $years^{-1}$ for females, males and all individuals, respectively. The calculated values are close to the averages of the studies conducted in Anatolia. The t_0 values in the current study were found higher than the values calculated for Anatolia. This difference may be attributed to the calculation methods applied for t_0 (Table 5).

The relatively low growth coefficient for the *C. carpio* species is an indicator that this species reached larger sizes later on. Also it can be seen in Table 6, captured common carp reach high ages. Denney et al. (2002) reported that large, slow-growing stocks and species had significantly low rates of stock participation. They also revealed that maturation at older ages has a significant relationship with low stock participation. On the other hand, the studies on the first reproductive age of *C. carpio* species are examined, it was observed that the common carp reproduce between the ages of 2 and 5 (Vilizzi et al., 2014b). In this context, many factors such as water temperature, latitude differences, nutrition of the study regions may have affected the growth and first reproductive age (Wotton, 2012). Considering that the carp individuals used in the present study have slow growth. According to the literature (Vilizzi et al., 2014b), 5-year-old individuals reached their first reproduction length (29.0 cm). Captured individuals were below the first reproduction length represent 11.8% in total. This ratio was thought be low and the length prohibition in the fishery communique serves for common carp stock sustainability.

Fulton's condition values were found between 1.34 and 2.47 in studies on common carp in Türkiye (Table 5). Also the present result of study, 1.3, is quite close to values of the previous studies.

C. carpio is an important species for Turkish inland fishery. Although there are regions where they are naturally found, this species is released to some regions by the state for restocking. However, due to the small size of the released individuals, morphological similarities with some other invasive species (such as *Carassius gibelio*), inappropriate stocking strategies, and limited breeding areas, it can be stated that the release does not reach its goal completely (Gaygusuz et al., 2015). This situation may be supported by annual common carp catch in Türkiye (TUIK, 2021).

Considering the common carp catch by years, a significant decrease can be observed (Figure 4). This decrease could be attributed to harvesting in gonadal development times of common carp. According to Turkish fishery communique, common carp has various seasonal closures throughout the Türkiye. However, factors such as nutritional conditions and altitude variations originating from regional differences, can affects its reproduction and stock recruitment relationships. Therefore, seasonal closures should be reconsidered, and climate change and regional differences should be taken into account to determine seasonal closures.

On the other hand, in the meaning ecological perspective, considering the recommendations made by Flajshans & Hulata (2007), the importance of keeping common carp populations under control becomes apparent. As common carp is an important angling species in many countries, precautions should be taken to prevent its release into new water bodies and stocking for recreational aims should be restricted to closed bodies of water.

CONCLUSION

In conclusion, common carp is commercially important for local fishermen in many freshwater bodies in Türkiye. Therefore, proper management strategies should be applied for sustaining common carp stocks in the direction of biological data.

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Compliance with Ethical Standards

Authors' Contributions

ÖY: Manuscript preparation, edit

HC: Manuscript preparation, draft, visualisation

Conflict of Interest

The authors declare that there is no conflict of interest.

Ethical Approval

For this type of study, formal consent is not required.

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Siyam Kavgacı Balığı Beta'nın (*Betta splendens* Regan, 1910) Larval Gelişimi

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Süs balıkları
Larva
Yetiştiricilik

ÖZET

Bu çalışmada, süs balıklarının en önemli türlerinden bir tür olan Siyam kavgacı balığı betanın (*Betta splendens*) larval gelişim aşaması incelenmiştir. Larval gelişim safhası, yumurtadan çıkıştan jüvenil periyodun başlangıcına kadar kaydedilmiştir. Döllenen yumurtalar 28±0,5°C su sıcaklığında kuluçka edilmiştir. Embriyonik gelişim, döllenmeden sonra 28-32 saatte tamamlanmış ve yumurta açılımı olduğu gözlemlenmiştir. Yumurtadan çıktıktan sonraki 1. gün ağız ve anüs kapalıdır. Ağız ve anüs 2. günde açılmıştır. Yumurtadan çıktıktan sonraki 3. gün dış beslenme başlamıştır. Hava kesesi 2-3. günlerde şişmektedir. Besin kesesi 4. günde tamamen tükenmekte ve larva serbest yüzme hareketleri yapabilmektedir. *Betta splendens*'in larval gelişim aşaması dört periyoda ayrılmıştır: Besin keseli larva (1-4. gün), notokord ucunun kıvrımından önceki periyot (preflexion larva periyodu) (4-8. gün), notokord ucunun kıvrıldığı periyot (flexion larva periyodu) (11-12. gün) ve notokord ucu kıvrıldıktan sonraki periyot (post-flexion larva periyodu) (13-30. gün). Yumurtadan çıktıktan sonraki 30. günlerde larval metamorfoz tamamlanmış ve jüvenil aşamaya geçilmiştir.

Larval Development of Siamese Fighting Fish (*Betta splendens* Regan, 1910)

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ABSTRACT

In this study, the larval development stages of one of the most important ornamental fish Siamese fighting fish betta (*Betta splendens* Regan, 1910) were examined. The larval development stage was documented from hatching until the beginning of the juvenile period. The fertilized eggs were incubated at a water temperature of 28±0.5°C. The embryonic developmental stage was completed and hatching was observed at 28-32 hours post fertilization (hpf). The mouth and anus were closed 1 day after hatching (DAH). The mouth and anus were opened at 2 DAH. Exogenous feeding started on 3 DAH. The swim bladder was inflated at 2–3 DAH. The yolk sac was completely consumed at 4 DAH and the larvae began to swim freely. The larval development of *Betta splendens* was divided into four different periods: Yolk-sac larva (1–4 DAH), preflexion larva (4–8 DAH), flexion larva (11-12 DAH) and post-flexion larva (13–30 DAH). The larval metamorphosis was completed, and the larvae transformed into juveniles at 30 DAH.

GİRİŞ

Larval dönem, embriyonun yumurtadan çıktığı günden itibaren başlayan, morfolojik ve fizyolojik metamorfozun tamamlandığı, vücut formunun ergin birey görüntüsü aldığı jüvenil (genç) aşamaya kadar olan yaşam evresini kapsamaktadır (Jůza vd., 2010; Garrido vd., 2015; Zhang vd., 2017). Balık yaşamının bu erken evresinde görülen ölüm oranlarının daha ileriki genç aşamalara göre çok daha yüksek olduğu yaygın olarak bilinen bir bulgudur. Balıkların larva, jüvenil (genç) ve ergin aşamalarının tamamını kapsayan tüm yaşam evreleri boyunca görülen ölüm oranlarının büyük kısmı (~%90) larval aşamada gerçekleşmektedir (Forsythe vd., 2013; Kaemingk vd., 2014; Garrido vd., 2015; Bogner vd., 2016; Vindenes vd., 2016). Larval aşamadaki yüksek ölüm oranları, uzun ömürlü türlere kıyasla daha kısa ömürlü olan türler üzerinde çok daha büyük bir etkiye sahiptir (Ohlberger & Langangen, 2015). Bu nedenle balık yetiştiriciliği uygulamalarında larval aşamalarda vuku bulan gelişim olaylarının çok daha iyi anlaşılması gerekmektedir. Özellikle de ekonomik türlerin larval gelişim sürecinin iyi bilinmesi, türün üretiminin sürdürülebilirliği açısından çok önemlidir.

Siyam kavgacı balığı olarak bilinen *Betta splendens*, Asya kökenli (Mekong Havzası) ekonomik değeri yüksek bir tatlı su akvaryum balığıdır. Amerika Birleşik Devletleri başta olmak üzere Avrupa ve diğer pek çok dünya ülkesinde en önemli süs balığı türlerinden biri olarak kabul edilmektedir (Chapman vd., 1997). Popülaritesi ve yüksek kârlılık oranından dolayı akvaryum balığı pazar ve endüstrisinde önemli bir türdür (Chapman vd., 1997). Bununla birlikte, balık üretiminde özellikle bir darboğaz olarak kabul edilen larva yetiştirme aşamasında ortaya konulan bilgiler yeterli değildir (Portella & Dabrowski, 2008). Bu alandaki veri havuzuna katkıda bulunmak amacıyla beta balığının larval aşamasıyla ilgili bir çalışma yapma ihtiyacı duyulmuştur. Bu çalışmada, laboratuvar ortamında üretilen beta balığı larvalarının morfolojik gelişim süreci incelenmiştir.

MATERYAL VE YÖNTEM

Embriyoların yumurtadan çıktıkları gün başlayıp jüvenil aşamaya kadar olan aşamayı kapsayan larval gelişim sürecini gözlemleyebilmek için balıklar laboratuvar ortamında üretime alınmıştır. Bunun için 1 yaşını aşmış 3 çift beta (*B. splendens*) kullanılmıştır. Çiftleştirmeden önce dişi anaçlar 9 litrelik (30 cm boy × 20 cm en × 15 cm su yüksekliği) dikdörtgen cam bir akvaryumda tutulurken, erkek anaçların her biri birbirlerini göremeyecek şekilde 1'er litrelik cam kavanozlara stoklanmıştır. Anaçlar bu tanklarda *Artemia* sp., pul yem ve pelet yem karışımından oluşan besleme programıyla üremeye hazırlanmıştır. Anaç yemlenmesi günde iki öğün yapılmıştır. Su kalite parametrelerinden su sıcaklığı 28±0,5°C, pH 7,0–7,5 ve iletkenlik 400–600 µS aralığında değişmiştir. Su sıcaklığını sabit tutmak için laboratuvarda anaçların tutulduğu çalışma alanının havası klimayla ısıtılmıştır. Erkek anaçların köpük yapma oranları arttığında bir dişi ile bir erkek üreme tankına birlikte alınmıştır. Yapılan tüm denemelerde dişi ve erkeğin bir arada tutulduğu üreme akvaryumlarında çoğunlukla ilk gün ya da en geç ikinci gün yumurtlama davranışının olduğu gözlenmiştir. Beta balıkları köpük yuva yapan türler olduğundan, üreme esnasında erkek birey hem suyun üstüne köpük yuva yapmış hem de dişiye kur yapmaya devam

etmiştir. Yuva yapımı bittikten sonra erkek birey, dişiyi yuvanın altına getirip, dişinin vücudunu sarmış ve dişinin karın kısmı yukarıya yani köpük yuvaya gelecek şekilde dişiyi sıkmıştır. Bu davranış 2-4 saat aralığında ara ara tekrarlanarak yumurtlama işlemi tamamlanmıştır. Yumurtlama tamamlandıktan sonra dişi üreme akvaryumundan alınmış, erkek yumurtalara bakması için tankta bırakılmıştır. Erkek bireyler tank zeminine düşen döllenmiş yumurtaları köpük yuvaya taşıyarak parental bakıma başlayıp, larvalar serbest yüzünceye kadar bu davranışlarını sürdürmektedirler. Döllendikten sonra 28-32 saat aralığında yumurtalar açılmış ve larval dönemin ilk günü başlamıştır. Yumurtaların açıldığı gün larval aşamanın ilk günü kabul edilerek jüvenil aşamaya kadar periyodik canlı örnekleri alınmıştır.

Günlük olarak örneklenen larvalar sabit oda sıcaklığında petri kabının içerisinde (27–28°C sabit su sıcaklığında) tutularak mikroskop altında (Olympus BX51 model araştırma mikroskobu (Tokyo, Japonya) ve Olympus SZX7 model zoom stereomikroskop (Tokyo, Japonya)) morfolojik açıdan incelenmiş ve mikroskoba bağlı bir kamerayla periyodik olarak fotoğrafları çekilmiştir (Q Imaging, Micropublisher 3.3 RTV, Kanada). Bu şekilde genel morfolojik değişimler günlük olarak kaydedilmiştir.

BULGULAR

Beta balıklarının yaşam döngüsünün başlangıcı olan embriyonik gelişim evresi, su sıcaklığına bağlı olarak 28-32 saat sürmektedir. Larvaların yumurtadan çıktıkları ilk günde ise larval gelişim evresi başlamaktadır. Bundan dolayı yumurtadan çıktıkları ilk gün larvaların 1. yaş günü olarak tanımlanmaktadır. Bu çalışmada da larvaların yumurtadan çıktıkları gün, larvanın 1. günü kabul edilmiştir. Buna göre diğer günler sıralanmıştır. Yumurtadan çıktıkları ilk günden, fizyolojik ve morfolojik gelişimlerini tamamlayarak ergin birey formunu aldıkları ilk güne kadar olan larval gelişim aşaması içerisinde geçirdikleri değişimler morfolojik olarak gözlenmiştir.

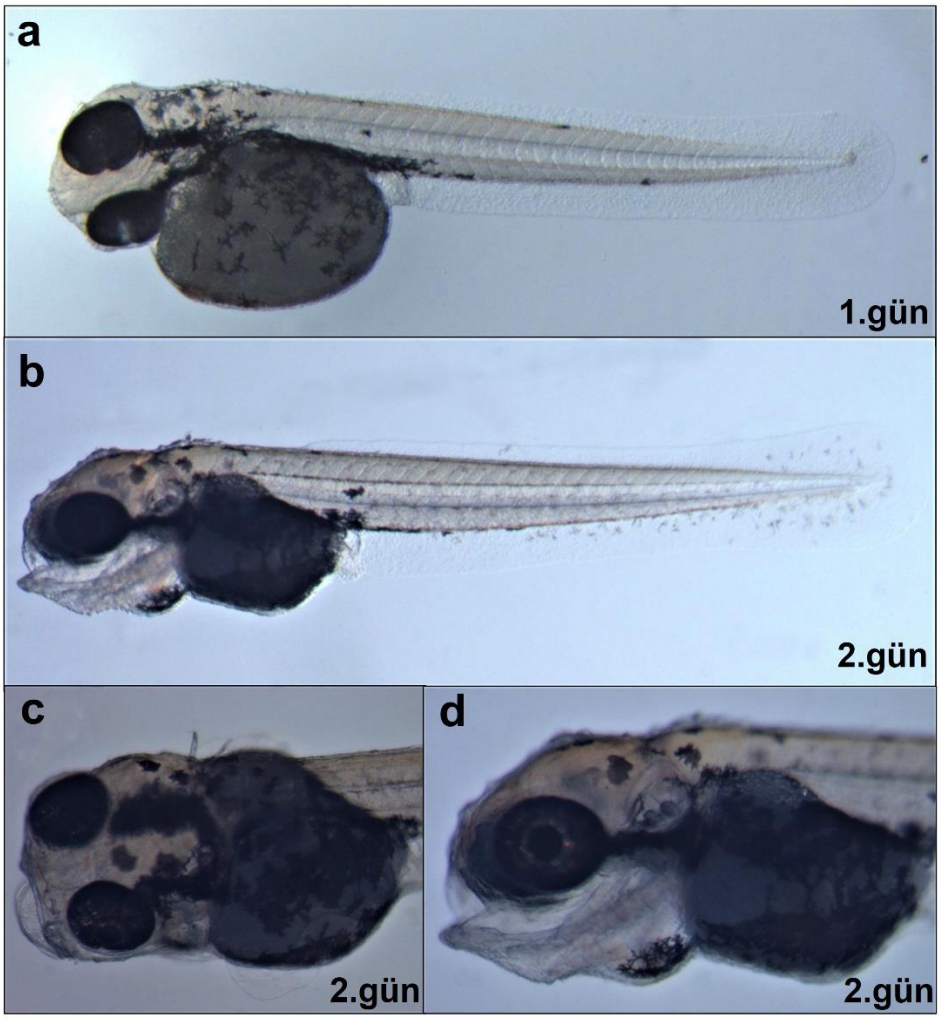

Figure 1. Photographs of *Betta splendens* larvae in the first 2 days after hatching (DAH). a: day 1 DAH, b, c and d: 2 DAH.

Şekil 1. *Betta splendens larvasının yumurtadan çıktıktan sonraki ilk 2 gün fotoğrafları. a: 1. gün, b, c ve d: 2. gün.*

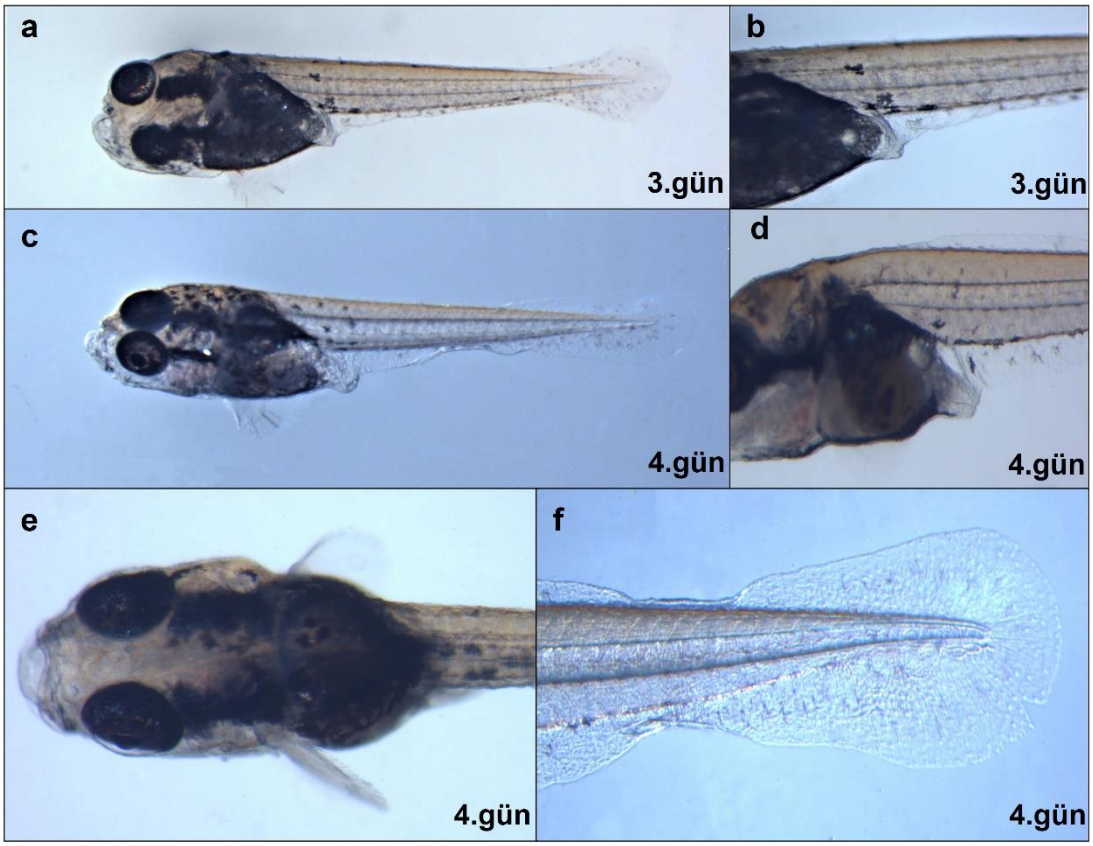

Figure 2. Photographs of *Betta splendens* larva 3 and 4 days after hatching. a: Whole body view of the larva on the 3rd day, b: Anus and ventral area on the 3rd day, c: General view of the larva on the 4th day, d: Anus and ventral area on the 4th day, e: Top view of the head, f: Tail.

Şekil 2. *Betta splendens larvasının yumurtadan çıktıktan sonraki 3. ve 4. gün fotoğrafları. a: 3. gün larvanın bütün vücut görüntüsü, b: 3. gün anüs ve karın bölgesi, c: 4. gün larvanın genel görüntüsü, d: 4. gün anüs ve karın bölgesi, e: 4. gün kafa bölgesinin üstten görüntüsü, f: 4. gün kuyruk kısmı.*

Şekil 1'de *B. splendens* larvasının yumurtadan çıktıktan sonraki 1. ve 2. günlerine ait fotoğraflar gösterilmiştir. Bu şekilde de görüldüğü gibi, 1. gün larvanın ağzı kapalı, premordial yüzgeç formu net, anüs kapalı, oldukça büyük bir besin kesesi mevcuttur (Şekil 1a). Vücudun nerdeyse tamamı renksiz, renk pigmentleri henüz oluşmamış durumdadır. Kafa orta iç kısmında otolitler görülebilmektedir. İlk günde de larva kısa süreli kuyruk hareketleri yaparak hareket edebilmektedir. Ancak serbest yüzme söz konusu değildir. İlk günlerde larvalar suyun hava ile temas eden üst kısmında yer alan köpük yuvada tutunmaktadır. Yuvadan tank zeminine düşen larvalar babaları tarafından tekrar köpük yuvaya taşınmaktadır. Bu davranış modeli 3-5. günlere kadar devam etmekte, daha sonra baba tanktan alınarak larvalar yalnız bırakılmaktadır. 2. günde larvanın ağzının açıldığı görülmektedir (Şekil 1a, 1b, 1c). Pektoral yüzgeç oluşumunun 2. günlerde başladığı anlaşılmaktadır (Şekil 1c). 2. günde de kafa kısmında pigment yapıları benek şeklinde ve dağınık konumda yer almaktadır. Şeffaf görüntü hala devam etmektedir. Besin kesesi 1. güne oranla oldukça küçülmüş durumdadır (Şekil 1b).

Larvanın 3. gününde besin kesesi nerdeyse bitmek üzeredir. Anüs açık, yüzme hareketleri biraz daha aktifleşmiştir (Şekil 2a). Larvanın vücut rengi kafa kısmındaki bir bölüm dışında hala şeffaf görünümdedir (Şekil 2). Kuyruk ucu (notokord) hala eğilmemiş düz formdadır (Şekil 2f). Hava kesesinin 2-3. günlerde şişmiş olduğu fark edilmiştir. Bu günlerden sonra larva kısa süreli serbest yüzme hareketleri yapabilmektedir. Besin kesesinin 4. günde tamamen tükendiği söylenebilir (Şekil 2d).

Larvanın ilk 5, 6 ve 7. günlerdeki genel morfolojik görünümüne bakıldığında (Şekil 3a, 3d, 3g); renk ve dış vücut yapısı açısından birbirlerinden çok farklı olduklarını söylemek oldukça zordur. Bu günlerde notokord hala kıvrılmamıştır (Şekil 3c, 3f, 3h). Ancak 8. günde notokord ucu yukarı doğru kıvrılmaya başlamıştır (Şekil 3j). Bugünden itibaren notokord ucu düz larva (preflexion larva) periyodu tamamlanmış, notokord ucunun kıvrıldığı süreci kapsayan larva periyodu (flexion larva) başlamaktadır. Notokord ucunun kıvrılmaya başladığı 8. günde kuyruk yüzgecinin yumuşak ışınlarının gelişimi de daha net görülebilmektedir (Şekil 3i). Vücudun baş kısmının dışında geriye kalan

bölümünde şeffaf renk yapısı devam etmektedir. Karın kısmının renginden larvanın *Artemia* sp. yemiş olduğu anlaşılmaktadır. Hatta canlı *Artemia* sp.'nın yanı sıra açılmamış *Artemia* sp. yumurtalarını da yediği görülebilmektedir. Larvalar bu dönemde açılmamış *Artemia* sp. yumurtalarını da yemektedirler, ancak bu yumurtalar sindirilemeden dışarı atılmaktadır (Şekil 3g, 3i, 4a). Şekil 3i'de sindirim sisteminde larva tarafından yenmiş *Artemia* sp. yumurtaları rahatlıkla görülebilmekte iken, Şekil 4a'da sindirilmeden anüsten dışarı atılmış *Artemia* sp. yumurtaları görülmektedir. Larvanın 9, 10, 11, 12 ve 15. günlerdeki morfolojik görüntüsü Şekil 4'te verilmiştir. Bu şekildeki larvaların hepsine birden bakıldığında 10. günden itibaren başta kuyruk yüzgeci olmak üzere diğer yüzgeçlerin de (dorsal yüzgeç, anal yüzgeç) gelişmeye başladığı dikkat çekmektedir (Şekil 4). 15. günlerde ise yüzgeçlerin daha bariz şekiller aldığı görülebilmektedir (Şekil 4e). 11-12. günlerde notokord ucunun tamamen kıvrıldığı gözlenmektedir (Şekil 5a, 5b, 5c). Bu günlerden sonra flexion larva periyodu sona ermektedir.

Larval gelişim periyodunda, balıkların bu yaşam evresine dair morfolojik açıdan fikir veren en önemli organlardan biri de yüzgeçlerdir. Bu dönemde yüzgeçlerin gelişimine bakılarak larval gelişim hakkında isabetli bulgular ortaya konulabilmektedir. Bundan dolayı larvaların yüzgeçleri dikkatli bir şekilde gözlenmektedir. Beta larvalarının 10. günle 19. günler arasındaki gelişim sürecinde yüzgeç gelişimlerine bakıldığında (Şekil 5); kuyruktaki notokord kıvrımının 10-11. günlerde tamamlandığı ve 11-12. günlerden sonra kuyruk yüzgecinin daha farklı ve biraz daha gelişmiş bir form kazandığı rahatlıkla gözlenebilmektedir (Şekil 5a, 5b, 5c). Dorsal ve anal yüzgeçlerin de 17. ve 19. günlerde daha gelişmiş bir form kazandığı görülmektedir (Şekil 5d, 5e).

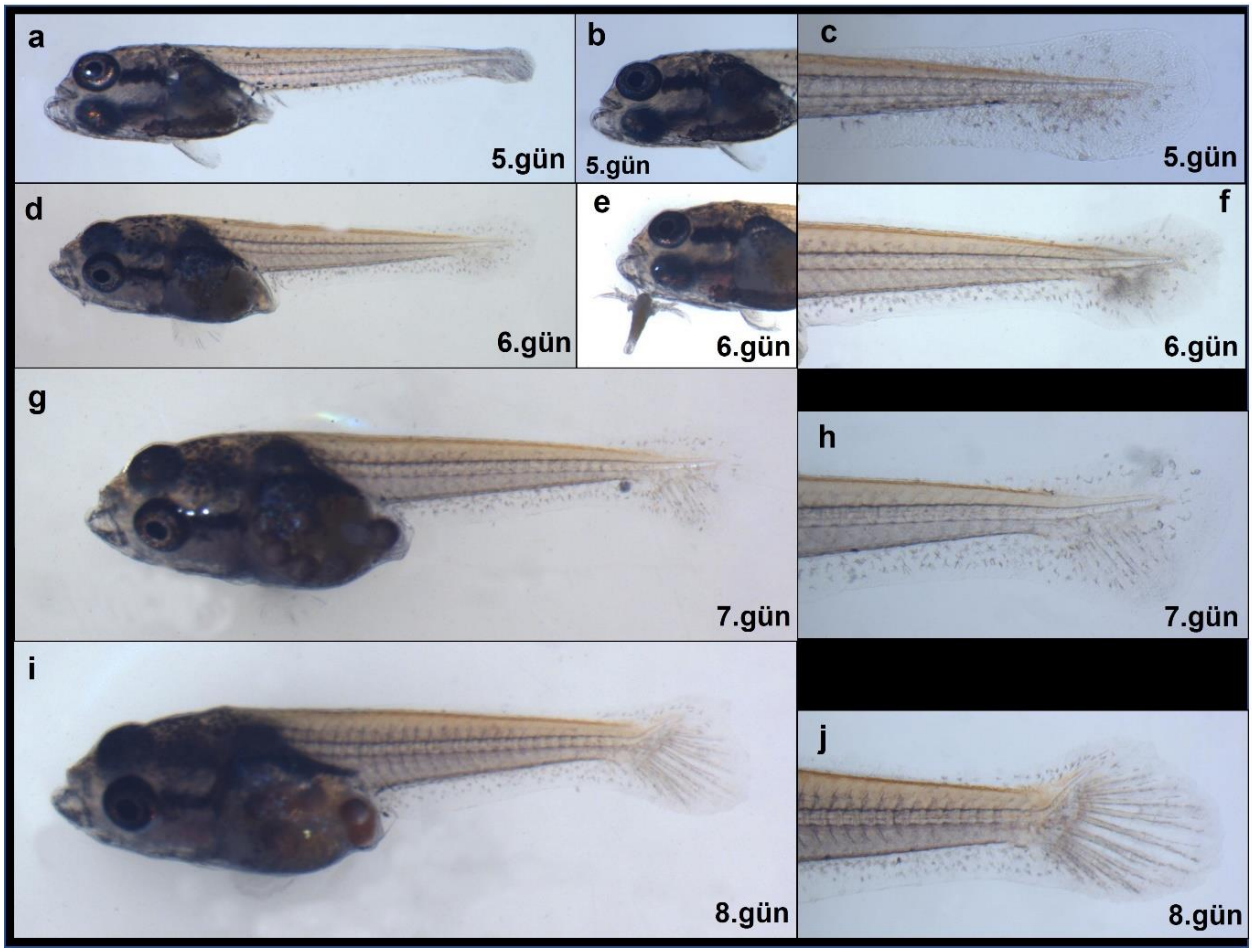

Figure 3. Photographs of *Betta splendens* larva 5, 6, 7 and 8 days after hatching. a: Body image of the larva on the 5th day, b: Head region, c: Tail region on the 5th day, d: Larva on the 6th day, e: Head of the larva on the 6th day and *Artemia* sp. f: Tail region on the 6th day, g: Larva on the 7th day, h: Tail region, i: Larva on the 8th day, j: Tail region on the 8th day.

Şekil 3. *Betta splendens* larvasının yumurtadan çıktıktan sonraki 5, 6, 7 ve 8. gün fotoğrafları. a: 5. gün larvanın vücut görüntüsü, b: Kafa bölgesi, c: 5. gün kuyruk bölgesi, d: 6. gün larva, e: 6. günde larva kafa kısmı ve o günlerde canlı yem olarak kullanılan *Artemia* sp. f: 6. gün kuyruk bölgesi, g: 7. gün larva, h: 7. gün kuyruk bölgesi, i: 8. gün larva, j: 8. gün kuyruk bölgesi.

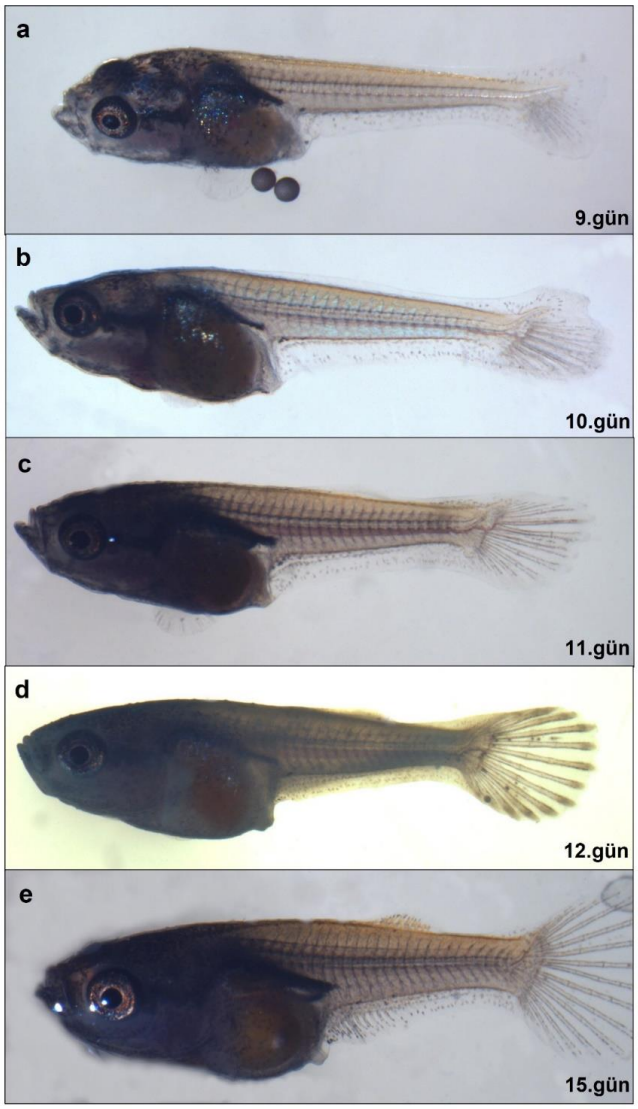

Figure 4. General body photos of *Betta splendens* larvae at 9, 10, 11, 12 and 15 days after hatching.

Şekil 4. *Betta splendens larvasının yumurtadan çıktıktan sonraki 9, 10, 11, 12 ve 15. günlerde genel vücut görüntüleri*

Yumurtadan şeffaf bir vücut rengi formunda çıkan beta larvalarının bu şeffaf yapısı 15. günlere kadar devam etmektedir. Ancak 1. günden itibaren kafa bölgesinde yoğun olmak üzere renk pigmentlerinin her geçen gün biraz daha arttığı görülmektedir. 15. günlerden sonra vücudun tamamında şeffaf görüntü kaybolmaya başlamaktadır (Şekil 5, 6). Beta larvalarında vücudun genel itibariyle tamamen renklendiği zamanın 15-25. günler arasına denk geldiği söylenebilir (Şekil 5, 6, 7). Şekil 6'da 17 ve 22 günlük beta larvaları görülmektedir. Bu dönemlerde yüzgeçler biraz daha gelişmiş ve vücut rengi iyice şeffaf görüntüsünü kaybetmiş durumdadır. Kuyruk, dorsal ve anal yüzgeçler önceki günlere göre daha da uzamıştır (Şekil 6).

Larval gelişimin 24. günlerinde larvalar morfolojik açıdan ebeveynlerinin vücut şeklini almaya başlamıştır (Şekil 7a).

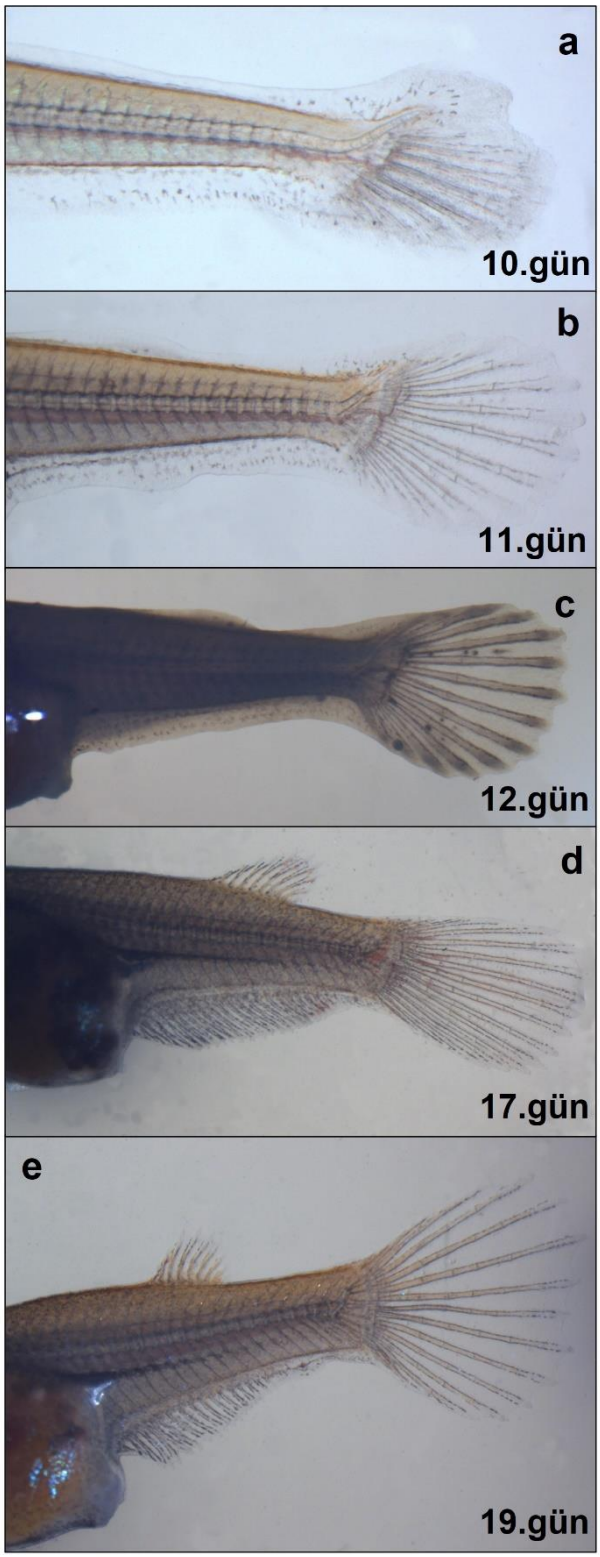

Figure 5. Photographs of the tail region of *Betta splendens* larvae at 10, 11, 12, 17 and 19 days after hatching.

Şekil 5. *Betta splendens larvasının yumurtadan çıktıktan sonraki 10, 11, 12, 17 ve 19. günlerde kuyruk bölgesinin fotoğrafları*

Vücudun genelinde gelişmiş pulların olduğu anlaşılmaktadır (Şekil 7a). 30. günlerde ise larva tamamen ergin birey vücut formunu almıştır (Şekil 7b, 7c).

Vücudun ergin birey formunu kazandığı bu günlerde, beta balıklarında larva dönem sona ermiş, jüvenil aşamaya geçilmiştir. Bu günlerden sonra larvaların vücut renkleri de ebeveynlerininkine benzemektedir (Şekil 7b, 7c). Bu çalışmada incelenen beta larvalarının 30. günlerde 2 cm total boya ulaştıkları gözlenmiştir (Şekil 7c). Beta balıklarında erkek bireylerin yüzgeç formları bu günlerden sonra daha da uzamaya devam etmektedir. Dişi bireylerin yüzgeçleri ise Şekil 7b'deki haliyle kalmaktadır. Betalarda ergin dönemde dişi erkek ayrımı yüzgeçlerden yapılmaktadır. Erkeklerin yüzgeçleri dişilerden çok daha uzun olmaktadır. Yüzgeçlerinin şekli de varyeteden varyeteye değişim göstermektedir.

TARTIŞMA

Kendall vd. (1984) balıklarda tanımlanan larval gelişim safhalarını dört periyoda ayırmıştır;

I. periyot (Besin keseli larva): Yumurtadan çıkıştan besin kesesinin tüketilmesine kadar olan periyot.

II. periyot (Düz omur çizgili (Preflexion) larva): Besin kesesinin tüketilmesinden, omurga (notokord) ucunun kıvrılmaya başlamasına kadar olan aşama.

III. periyot (Omur çizgisi kıvrılmakta olan (Flexion) larva): Notokord ucunun tamamen kıvrılmış duruma geldiği süreye kadar geçen zaman periyodu.

IV. periyot (Omur çizgisi kıvrılmış (Postflexion) larva): Notokord ucunun tamamen kıvrılmasından sonra başlayıp, larval gelişimin sona erip, jüvenil (ergin birey formunda olan yavru) aşamaya kadar geçen zaman periyodu.

Bu tanımlamaya göre *B. splendens* türünün mevcut çalışmadaki larval gelişim aşaması için aşağıdaki tanımlamalar yapılabilir.

I. periyot (Besin keseli larva): Yumurtadan çıktıktan sonraki 1. gün ile besin kesesinin tüketildiği 4. günleri kapsamaktadır.

II. periyot (Preflexion larva): Beta balıklarında besin kesesinin tükendiği 4. gün ile notokord ucunun kıvrıldığı 8. gün arasındaki aşamayı kapsamaktadır.

III. periyot (Flexion larva): Bu periyot notokord ucunun tamamen kıvrılmış duruma geldiği süreye kadar geçen zaman periyodunu tanımlamaktadır. Beta larvalarında ilk defa 8. günde kıvrılmaya başlayan notokord ucu 11-12. günlerde tamamen kıvrılmış formu almaktadır. Dolayısıyla bu dönem yani 8. günle 11-12. günler arası kıvrılma devam ettiğinden bu aşama betalarda flexion larva olarak tanımlanabilir.

IV. periyot (Postflexion larva): Notokord ucunun tamamen kıvrıldıktan sonra başlayıp, larval gelişimin sona erip, jüvenil (ergin birey formunda olan yavru) aşamaya kadar geçen zaman periyodunu tanımladığından, betalarda bu aşamanın 11-12. günlerle 30. günler arasında olduğu tespit edilmiştir.

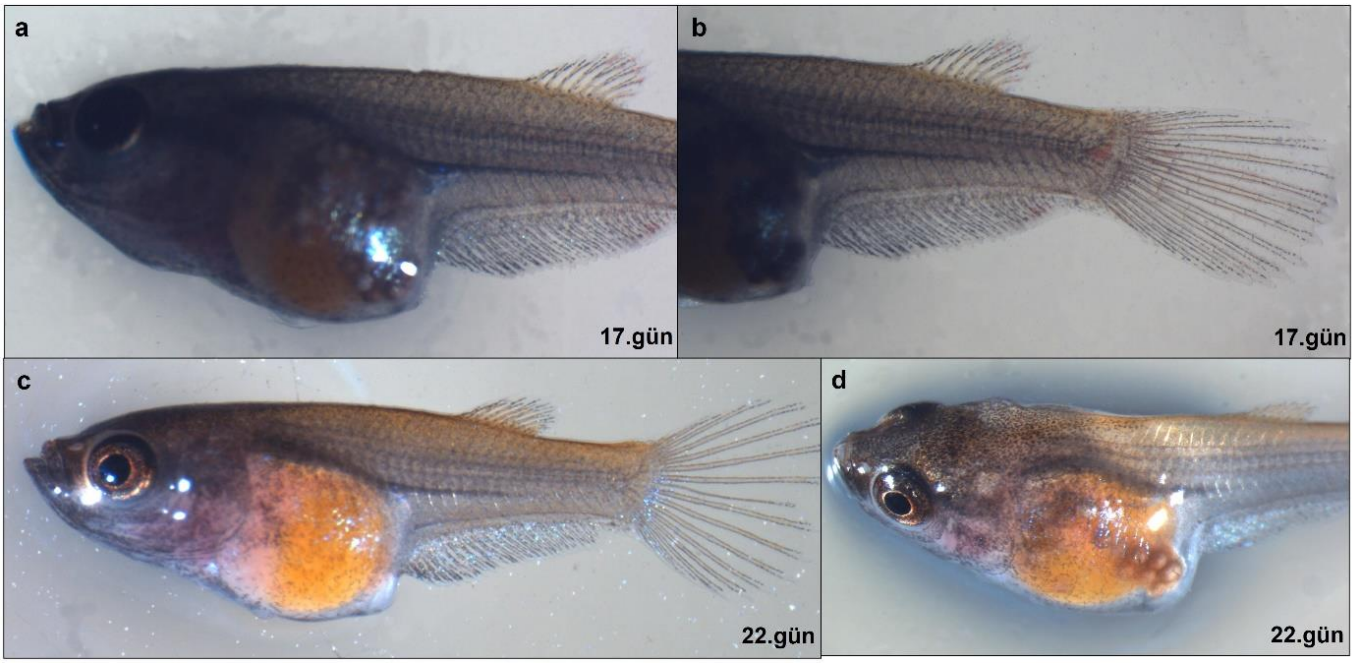

Figure 6. Photographs of *Betta splendens* larvae 17 and 22 days after hatching

Şekil 6. *Betta splendens larvasının yumurtadan çıktıktan sonraki 17. ve 22. gün fotoğrafları*

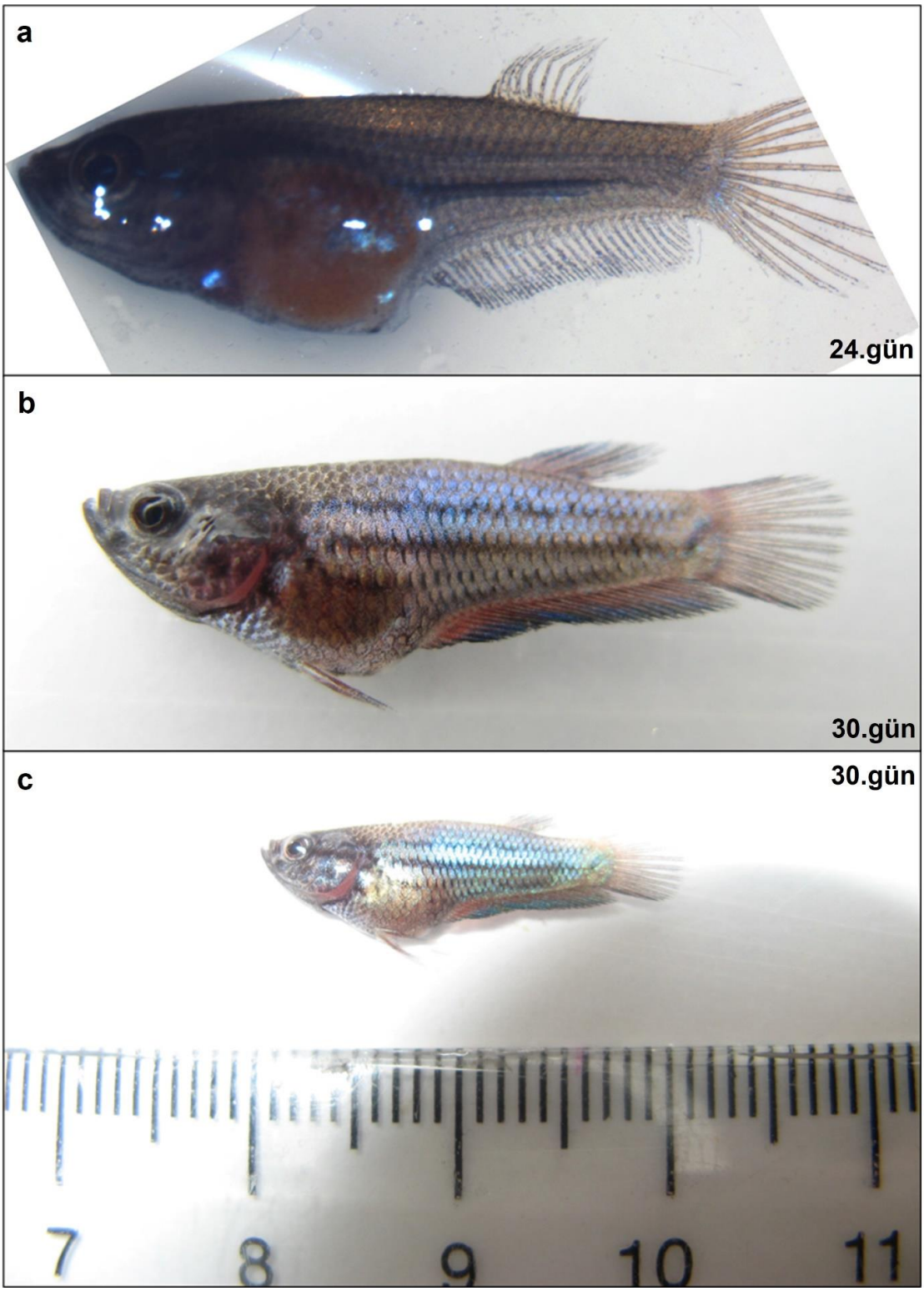

Figure 7. Photographs of *Betta splendens* larva 24 and 30 days after hatching

Şekil 7. *Betta splendens larvasının yumurtadan çıktıktan sonraki 24. ve 30. gün fotoğrafları*

Bu çalışmada beta anaçları ortalama 28°C (28±0,5°C) su sıcaklığında bakılmış ve üretilmiştir. Üretimden sonra da yine yumurtalar ve larvalar bu su sıcaklığında (28±0,5°C) yetiştirilmiştir. *B. splendens*'in erken dönem gelişimiyle ilgili yapılan bir çalışmada 24, 27 ve 30°C su sıcaklıkları kullanılmıştır (Forsatkar & Nematollahi, 2013). Ancak yumurtlama için 28°C tercih edilmiştir. Su sıcaklığının 28,4±0,2°C seviyelerinde tutulduğu başka bir çalışmada *B. splendens* embriyolarının döllenmeden sonra 29 saatte açıldığı bildirilmiştir (Valentin vd., 2015). Yapılan denemelerde betaların 24-30°C sıcaklık aralıklarında yumurtlayabildiği görülmüştür. Fakat 28°C'nin diğer sıcaklık değerlerinden daha verimli olduğu kanaatine varılmıştır. Bundan dolayı da bu çalışmada yumurta alımı ve

larva yetiştirme için 28±0,5°C su sıcaklığı tercih edilmiştir. Çalışma kapsamında yapılan gözlemlerin sonucuna göre; 28±0,5°C su sıcaklığında yumurta alımı ve larva yetiştirme süreçlerinde hiçbir sorun yaşanmaması nedeniyle, bu su sıcaklığının *B. splendens* üretimi için optimum su sıcaklığı aralığı olma olasılığı yüksektir.

Betaların yumurtadan çıkma süreleri de su sıcaklığı ile doğrudan ilişkilidir. Bu çalışmada yumurtlar 28±0,5°C su sıcaklığında 28-32 saatte açılmıştır. Ancak bu sürenin daha da uzun olabileceği bilinmektedir (Groth, 1970). Su sıcaklığı artıp azaldıkça yumurtadan çıkış süreleri de değişmektedir. Betaların embriyonik ve larval gelişimiyle ilgili yapılan çalışmalardan birinde (Groth, 1970), yumurta açılımının döllenmeden sonraki 44. saatlerde olduğu rapor edilmiştir. Bu sürenin kısa ya da uzun olması fizyolojik açıdan sorun teşkil etmeyebilir. Ancak yeni çalışmalarda bu konu detaylı bir şekilde araştırılabilir. Yani farklı su sıcaklıklarında gelişen embriyo ve larvaların fizyolojik açıdan incelenmesi yeni bulgulara ulaşılmasına vesile olabilir. Farklı su sıcaklıklarında yetiştirilen larvaların farklı büyüme parametrelerine sahip olduğu konu ile ilgili herkes tarafından bilinen bir gerçektir. Ancak bu farklılıkların larvadan anaç oluncaya kadar fizyolojik olarak incelenmesiyle yeni bulguların olup olmadığı araştırılabilir.

Bu çalışmada 28±0,5°C su sıcaklığında larvaların ağzının 2. günde açıldığı tespit edilmiştir. Bu çalışmayla nerdeyse aynı su sıcaklık derecesinin (28±0,2°C) kullanıldığı başka bir çalışmada (Valentin vd., 2015), *B. splendens* larvalarının ağızlarının yumurtadan çıktıktan sonraki 11-43. saat aralığında açıldığı rapor edilmiştir. Ancak başka bir çalışmada betaların ağız açılımının yumurtadan çıktıktan sonraki 18 saat sonra olduğu bildirilmiştir (Silva vd., 2016). Bu çalışmada larva yaşını tanımlarken saat yerine gün kavramı kullanıldığından iki çalışmada da ağız açılımının 2. günlerde olduğu anlaşılmaktadır. Valentin vd. (2015) yaptığı çalışmada betaların besin kesesini 73. saatte tamamen tükettiği bildirilmiştir. Yani yumurtadan çıkışı takip eden 3. günün sonunda besin kesesi tükenmiştir. Bir diğer araştırmada yapılan histolojik analizlere göre, beta larvalarının besin kesesi rezervlerini 74. saate yani 4. gün başlangıcına kadar koruduğu rapor edilmiştir (Silva vd., 2016). Bu çalışmada da besin kesesinin 4. günde tamamen tüketildiği görülmüştür. Bu sonuçlara göre her üç çalışmanın bulguları da birbirleriyle örtüşmektedir. Buradan yola çıkarak genel bir literatür bilgisi olarak; 28±0,5°C su sıcaklığı aralığında betaların besin kesesini 4. günde tamamen tükettiği bulgusu bir kez daha kanıtlanmıştır. Larva yetiştiriciliğinde ağzın açılımı ve besin kesesinin tüketilme süreçleri çok önemli bir olay olarak kabul edilmektedir. Çünkü larvanın beslenme rejimi doğrudan bu iki fizyolojik gelişim olayı üzerine kurgulanmaktadır. Larvanın ağzının ne zaman açılacağı ve besin kesesinin ne zaman tükeneceğine göre yemleme programları hazırlanmaktadır. Larva yetiştiriciliğinde besin kesesi tamamen tükendikten sonra veya tükenmesine yakın zamanlarda toplu larva ölümlerinin en yoğun görüldüğü periyotlar olduğu bilinen bir gerçektir. O bakımdan larval gelişimde ağız açılımı ve besin kesesinin tüketilme süreçleri çok önemlidir. Silva vd. (2016) yaptıkları çalışmada yumurtadan çıktıktan sonraki 74. saatte beta larvalarının sindirim sistemi tamamen açık ve işlevsel olduğunu rapor etmiştir. Aynı çalışmada, *B. splendens* larvalarının 74. saatten itibaren verilen yemi tüketebilecek duruma geldikleri ve bu saatten itibaren larvalara canlı yem verilmesi gerektiği sonucuna varılmıştır. Bu çalışmada da benzer bulgulara rastlanmıştır.

Morfolojik gelişimin dış gözlemlerle yapıldığı bu çalışmada beta larvalarının hava kesesinin ağız açılımını takip eden 2-3 günlerde gerçekleştiği gözlenebilmiştir. Diğer yandan beta larvalarının gelişiminin histolojik bulgularla incelendiği bir çalışmada hava kesesinin 36. saatlerde şiştiği bildirilmiştir (Silva vd., 2016). Buna göre bu çalışmada elde edilen bulguların, Silva vd. (2016) tarafından yapılan çalışmanın bulguları ile örtüştüğünü söylemek mümkündür.

Kuyruk notokordunun kıvrılmasının bittiği 11-12. günlerde, kuyruk (kaudal) yüzgeci tam formunu almıştır. Betalarla yapılan benzer bir çalışmada da kaudal yüzgecin 11. günde tam formunu aldığı bildirilmiştir (Valentin vd., 2015). Aynı çalışmada 18. günlerde dorsal, anal ve kuyruk yüzgeçlerinin iyice şekillendiği rapor edilirken, bu çalışmada da benzer şekilde bu bulgular 17-19. günlerde gözlenmiştir. Valentin vd. (2015) larvaların ebeveynleri ile karakteristik olarak benzer görünüm kazanmalarının 32. günlerde olduğunu bildirmiştir. Bu çalışmada da bu durumun 30. günlerde gerçekleştiği tespit edilmiştir. Benzer gelişim safhaları bazı tetra balıklarında da gözlenmiştir. Yapılan çalışmalarda bazı tetra türlerinin de larval gelişim sürecinin yumurtadan çıktıktan sonraki 28-32. günlerde tamamlandığı ve bugünlerden sonra jüvenil aşamaya geçildiği rapor edilmiştir. Larval aşama serpae tetra (*Hyphessobrycon eques*) türünde 28-30 günde tamamlanırken (Çelik & Cirik, 2020), siyah tetrada (*Gymnocorymbus ternetzi*) 30-32 günde tamamlanmıştır (Çelik vd., 2012).

SONUÇ

Bu çalışmada ortaya konulan bulgular, türleri farklı da olsa pek çok balık türünün larval gelişim aşamasında benzer şekilde olduğu gözlenen somut verilerdir. Buradan yola çıkılarak benzer türlerin larval gelişim süreçlerinin incelenmesinde bu çalışmanın bulgularından istifade etmek mümkündür.

Etik Standartlar İle Uyum

Yazarların Katkısı

İÇ: Makalenin tasarlanması, Taslağın hazırlanması, Laboratuvar çalışmaları, Düzeltme.

PÇ: Makalenin tasarlanması, Taslağın hazırlanması, Laboratuvar çalışmaları, Düzeltme.

SA: Makalenin tasarlanması, Taslak kontrolü, Okuma, Düzeltme.

Tüm yazarlar makalenin son halini okumuş ve onaylamıştır.

Çıkar Çatışması

Yazarlar herhangi bir çıkar çatışması olmadığını deklare etmektedir.

Etik Onay

Yazarlar bu tür bir çalışma için resmi etik kurul onayının gerekli olmadığını bildirmektedir.

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Modeling the Inflation of Türkiye Considering the Impact of Maritime Transport Costs

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ABSTRACT

We modeled Turkish inflation using causality analysis by considering the impact of maritime transport costs. We also supported the results with impulse and response, and variance decomposition analyses. The results show that the exchange rate, commodity price, dry bulk freight rate and container freight rate have significant effects on inflation, and their shocks cannot be eliminated from the system for a long time. The most important factor affecting inflation is its historical value and the effect of exchange rates is also quite high. The container freight rate has a greater impact on inflation than the dry bulk freight rate. The forecast made using the vector autoregressive (VAR) model showed that inflation will continue to increase, but the rate of increase will slow down. It is important to implement appropriate policies to break the effect of expectations on inflation due to the new economic policies. Additionally, it is important to develop stabilizing tools to protect freight rates from the permanent effects of unexpected shocks.

INTRODUCTION

The concept of globalization is a concept based on minimizing costs and increasing total welfare by specializing countries in different raw materials, products, or services (Kütting, 2004). However, in this system, it is assumed that the supply chain functions perfectly (Hult et al., 2014). Based on this assumption, the dependence of countries on each other is high. However, events such as the current COVID-19 pandemic (Arunmozhi et al., 2021) and the Ukraine-Russia war (FAO, 2022) have shown that globalization does not actually eliminate borders completely, and that the struggle between countries can generate major problems in supply chains. Disruptions in the supply chain have also extended product and service lead times and increased transportation and capital costs (Zemmrich & Hofmann, 2022). These increased transportation costs generated inflationary pressures in countries (Carriere-Swallow et al., 2022). However,

the economic policies implemented by the Federal Reserve (FED), considering the current global economic situation, necessitated an increase in interest rates (Bloomberg, 2022a). Developing countries, which are highly dependent on foreign exchange and investment, were the most affected by this policy. Increasing interest rates caused hot money to come out of developing countries and depreciation of national currencies against the dollar (Akhtaruzzaman, 2019). For countries that are depend on raw materials and energy and often have budget deficits, domestic prices have increased and an inflationary situation has emerged.

Expectations are critical in inflation modeling and expectations are generally based on backward-looking and forward-looking theories. In one of the backward-looking models, expectations are based on extrapolations of past behavior. Future expectations are formed based on past inflation rates and the reaction of inflation to past policies. It therefore consists of a moving average of past rates and has a slow response to prices. In another backward-looking model, going one step further, the margin of error between the past situation and the realized inflation is also considered in the next expectations. This can be defined as adaptive expectations. In forward-looking modeling, rational expectations come to the fore. The players rationally calculate the future inflation by analyzing the current situation, considering every new information and the results of the policies implemented in past (Lipsey & Chrystal, 2020). Although it is assumed that people make rational decisions most of the time, their irrational aspects are also high and the influence of people's expectations on the shaping of inflation is huge.

While modeling inflation, factors such as money supply (e.g. Van, 2020; Matthews & Ong, 2022; Samal et al., 2022), demand (e.g. Osorio & Unsal, 2013; Charef & Ayachi, 2018), interest rates (e.g. Dogan et al., 2020; Egilsson, 2020), raw material prices (e.g. Chen & Yang, 2021), energy prices (e.g. Bachmeier & Cha, 2011; Aloui et al., 2018), exchange rates (e.g. Guo, 2013; Khan et al., 2019; Şen et al., 2020), public sector prices (e.g. Berument, 2003; Us, 2004), fiscal deficit (e.g. Metin, 1998; Okoye et al., 2019), economic policy uncertainty (e.g. Balcilar et al., 2017; Ghosh et al., 2021), expectations (e.g. Stockhammar & Österholm, 2018; Ciccarelli & García, 2021) and domestic transport costs (e.g. Kpodar & Liu, 2022) are generally taken into consideration to explain the formation of the inflation. However, the problems experienced in the supply chains in the last period have led to an incredibly high level of freight, especially in container transportation. This shows that international transportation costs can also contribute significantly to an inflationary environment in countries. Since the price of transportation constitutes a cost item in both the supply of raw materials and the delivery of final products, it affects the final prices of the products in the market and this situation is reflected in the market as a price increase. The ability to access non-local markets also depends on transport costs (Press, 2006). Under normal conditions, while the share of transportation costs in the final price for manufactured products is between 2-4%, it occurs between 20-40% for raw materials such as iron ore, coal, timber, and phosphate (Jansson & Shneerson, 2012). However, in some extraordinary periods, transportation costs reach very high levels. This situation has been felt in the global sense, especially in recent times. In our study, we dealt with inflation from a Keynesian perspective. Keynes classifies the factors affecting inflation as demand-pull and cost-push. According to demand-pull view, because of increased demand for goods in the market, supply may become insufficient and this may cause prices to rise. According to cost-push view, the increase in costs in the market affects the final prices of the products and the general level of prices may increase. Additionally, Keynes points out that expectations and agreements such as labor wages, are also important in inflation (Comley, 2015). In this study, we have positioned our perspective and analyzes according to the concept of cost-push view.

In this study, we modeled the Turkish economy, whose inflation has increased at an extraordinary rate both to the policies implemented and global developments, in terms of cost-push inflation, considering the transportation costs. Unlike the literature, we included both the costs of raw material supply and the costs of delivery of the final product in the model. We also added the exchange rate and global commodity prices to enrich the model. Both increased

input and transportation costs can cause final prices to rise. Additionally, even if global prices are stable, increases in exchange rates may cause domestic prices to rise.

In our analysis, we preferred the VAR model because we think that the relationship between costs and prices is not instantaneous, but also influenced by the past values of the variables. Using the obtained model, we applied Granger causality, impulse and response, and variance decomposition analyzes. Finally, we made an inflation forecast until December 2023 using the VAR equation. The results show that all the variables in the model have a significant effect on inflation, the most important factor feeding inflation is the exchange rate, and container transportation costs are more effective than dry bulk cargo transportation costs. It also shows that a countless proportion of the change in inflation is affected by its own past values and that inflationary perceptions have permanent effects on future values. The estimation results, on the other hand, show that inflation will continue to rise, but there will be a partial slowdown in the rate of increase.

DATA AND METHODOLOGY

The names, descriptions, units and sources of the data sets we used in the research are presented in Table 1. The dataset covers the period between January 2003 and July 2022 and consists of 235 monthly observations. Inflation, exchange rate and commodity price index variables were obtained monthly from their sources. China Containerized Freight Index (CCFI) and Baltic Dry Index (BDI) variables were formed by taking the monthly averages of daily observations. The effect of all the variables on inflation is expected to be positive. Past inflation affects expectations about future inflation and causes inflation to increase. An increase in the nominal exchange rate increases costs and this causes an increase in final prices of the products. Additionally, international demand for cheaper national goods increases and the supply and demand balance deteriorate in the domestic market, which consequently causes an increase in the price levels. BDI representing the raw material transportation cost and CCFI representing the final product transportation cost, on the other hand, cause an increase in the prices of the final products and make a positive contribution to inflation.

The GSCI is the price index calculated for 5 sectors based on the world's leading production-based commodity future contracts. The index determines a weight for each sector in each year, considering the annual production and trade volumes. Weights for 2022 are 53.47% for energy, 20.48% for agriculture, 7.36% for livestock, 12.71% for industrial metals, and 5.96% for precious metals (SPGLOBAL, 2022). With this inclusive feature, the GSCI variable can represent both energy and raw material in different dimensions at the same time. The effect of this variable on inflation is naturally positive. Increasing energy and raw material costs are expected to have a positive impact on price levels in the country.

The course of the variables with inflation over time can also provide preliminary ideas for possible results. Figure 1 presents the movements of inflation and the other 4 variables in the period under consideration. As can be seen, there is a parallelism between CCFI and inflation in the recent period (a). However, this

Table 1. Definitions of the variables

Variable	Definition	Source	Expected Impact
Inflation	Consumer Price Index (2003=100)	CBRT (2022a)	(+)
Exchange Rate	USD / TL Parity	CBRT (2022b)	(+)
CCFI	China Containerized Freight Index (1998=1000)	Bloomberg (2022b)	(+)
BDI	Baltic Dry Index (1985=1000)	Bloomberg (2022b)	(+)
Commodity	Commodity Price Index - S&P GSCI (the Goldman Sachs Commodity Index)	Bloomberg (2022b)	(+)

Table 2. Descriptive statistics of the variables

Statistics	Inf.	CCFI	BDI	Exc.	Com.	R Inf.	R CCFI	R BDI	R Exc.	R Com.
Mean	262.3	1145.3	2443.2	3.24	4249.5	0.010	0.004	0.0008	0.010	-0.0003
Median	211.6	1040.0	1710.4	1.80	4257.2	0.007	0.003	0.023	0.003	0.009
Maximum	1001.0	3510.8	10843	17.38	10558	0.127	0.268	0.874	0.251	0.179
Minimum	94.7	641.5	306.9	1.17	1349	-0.014	-0.098	-1.012	-0.087	-0.348
Std. Dev.	167.7	553.4	2070.4	3.01	1748	0.014	0.047	0.23	0.04	0.070
Skewness	1.91	3.05	1.91	2.41	0.63	4.13	1.57	-0.427	1.63	-1.12
Kurtosis	7.40	11.8	6.90	9.40	3.24	28.96	9.58	5.40	9.49	6.43
Jarque-Bera	333.2	1129.2	292.6	630.7	16.58	7241.3	519.8	63.6	514.8	163.91
Probability	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Observations	235	235	235	235	235	234	234	234	234	234

Note: Source: Bloomberg (2022b); CBRT (2022a;2022b).

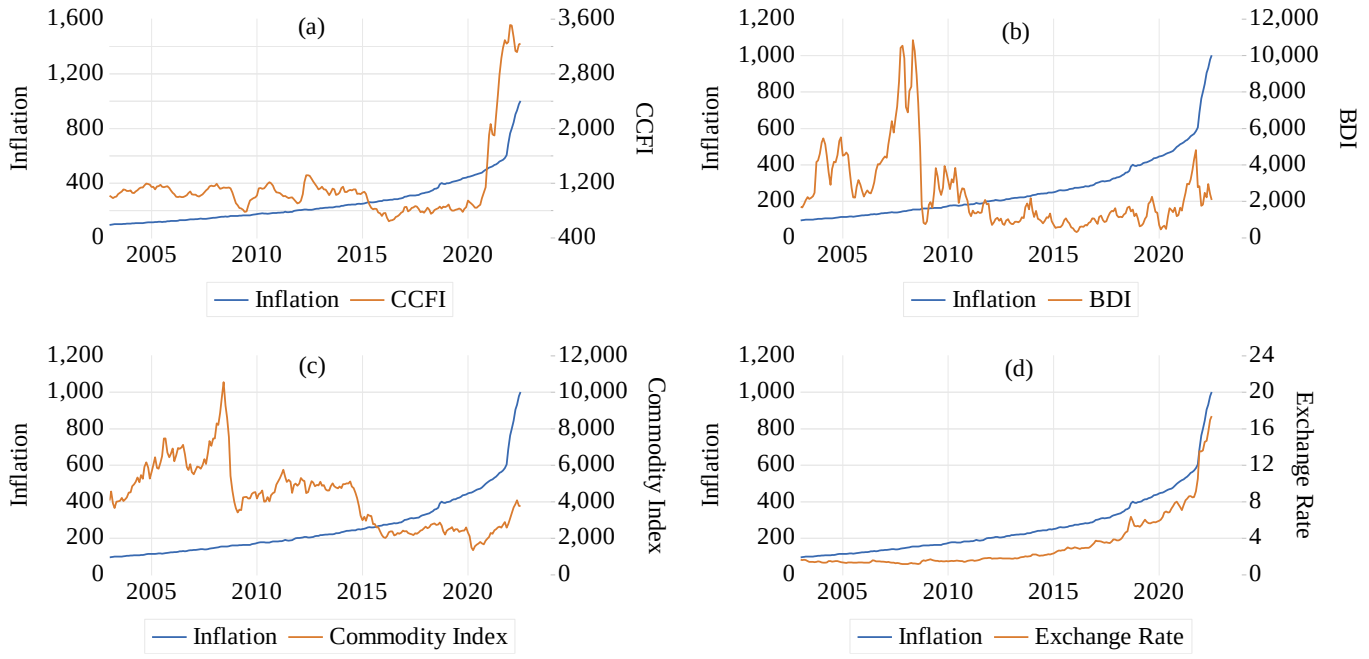

Figure 1. Historical movements of the variables

situation arises not only from the increased freight rates, but also from the increased exchange rates due to the economic policies implemented. Until the start of the COVID-19 period, there was no clear parallelism between the CCFI index and inflation. In this regard, the correlation between them is positive, but it is insignificant (r: 0.06, p: 0.36). Similarly, although a parallelism has been observed recently with the BDI variable, it is difficult to talk about co-movement in general (b). Correlation between them is positive, but it is insignificant (r: 0.06, p: 0.31). The most striking graphic is the one about the nominal exchange rate. The movements of the exchange rate and inflation show a regular parallelism (c). There is a positive and significant correlation between them (r: 0.42, p: 0.00). Finally, although there does not seem to be a clear relationship between the commodity price index and inflation (d), the correlation analysis reveals that there is a low degree of positive and significant correlation between them (r: 0.16, p: 0.01). Additionally, a significant positive correlation is observed between the commodity index and BDI (r: 0.15, p: 0.01). This may be due to the transportation of products such as coal, grain, industrial metals by dry bulk carriers. Increasing demand for commodities may increase commodity prices, while at the same time increasing bulk freight

rates. The decline in commodity demand may also have the opposite effect.

The fact that the graph is misleading is because the correlation analysis was performed between stationary series with first difference taken. While applying the correlation analysis, variables were included in the analysis by considering the unit root test results in Table 3. To make a general assessment, variables that seem meaningless one-on-one can become meaningful by including lagged values and other variables in the model. Market players cannot be expected to react immediately to the shocks. For example, shipping times can sometimes take weeks. Additionally, there are protective instruments against exchange rate volatilities. Since future agreements are made according to current market conditions, there may be a dependency between time intervals. For this reason, the selection of the VAR model is considered a correct approach. In addition, this structure ensures that the forecasts made with the VAR models are more accurate (Brooks, 2014).

Descriptive statistics of the variables used in the analysis for the period under consideration are presented in Table 2. In addition, statistics on log return versions are also presented. The coefficient of variation (standard deviation/mean) can provide explanatory information about the volatility and stability of the variables. This coefficient was calculated as 64% for inflation, 48% for CCFI, 85% for BDI, 93% for the exchange rate and 41% for commodity price. Exchange rate (93%) has the highest volatility. As shown in Figure 1, especially after July 2016, the volatility of the exchange rate has highly increased. Undoubtedly, the military coup attempt in the country was also effective in this situation. This volatility naturally showed a spillover effect toward inflation. Another variable that is most volatile is BDI (85%). Since dry bulk cargo transportation has the characteristics of a perfectly competitive market, the imbalances between supply and demand change very rapidly. This situation causes freight rates to change very quickly. However, the volatility of the container market (48%) is much lower, as it sometimes shows monopoly and sometimes oligopoly characteristics in the short run. However, the recent trade imbalances between countries and the container crisis due to COVID-19 have caused container freight rates to rise dramatically with a historical record. On the other hand, commodity prices seem to follow a decreasing trend considering the monthly log returns (-0.0003). However, in this price index, it is necessary to consider the situation of the U.S. dollar against other currencies. Increasing commodity prices with the increasing dollar exchange rate recently put the trade balances of developing countries in a very difficult situation. Parallel to this, considering the monthly log returns, the variables that increased the most were inflation (0.010) and exchange rate (0.010). Finally, the exploded kurtosis values show that the tail effects of the series are very high. In other words, outliers and changes are high, especially in the inflation.

Table 3. Unit root test results

		Level		First Difference		
		Intercept	**Intercept & Trend**	**Intercept**	**Intercept & Trend**	**Conclusion**
ADF	Inflation	2.702	3.220	-4.710***	-5.318***	I (1)
	CCFI	0.095	-0.076	-8.937***	-9.121***	I (1)
	BDI	-3.023**	-3.650**	-12.129***	-12.109***	I (0)
	Exchange	3.381	-0.260	-10.707***	-11.711***	I (1)
	Commodity	-1.627	-2.389	-12.097***	-12.072***	I (1)
PP	Inflation	3.685	5.905	-7.381***	-8.015***	I (1)
	CCFI	0.051	-0.126	-8.358***	-8.458***	I (1)
	BDI	-2.633*	-3.236*	-11.880***	-11.843***	I (0)
	Exchange	3.799	-0.063	-9.845***	-10.109***	I (1)
	Commodity	-1.585	-2.547	-12.151***	-12.127***	I (1)

Note: (1) CVs: -3.458 for ***1%, -2.873 for **5%, -2.573 for *10% at Intercept; -3.998 for ***1%, -3.429 for **5%, -3.138 for *10% at Intercept & Trend. (2) Bartlett kernel spectral estimation method and Newey-West Bandwidth were selected.

In our research, we preferred to use the causality analysis of the suggestions by Granger (1969) as the method. Assuming that analysis is applied between 2 variables and we call the dependent variable Y and the independent variable X. It can be said that X is the cause of Y if the past values of X contribute to explaining the present and future values of Y in a significant way (Yu et al., 2015). Granger causality testing simply tests this situation. In other words, it tests the correlation between the past values of the first variable and the current and future values of the second one (Chiou-Wei et al., 2008). If there is a mutual interaction between Y and X, it is defined as a feedback relationship. The Granger causality test can also be used to determine the direction of information flow. For example, in order to test the random walk in financial markets, there should be no causality from any other variable to the financial asset (Kirchgässner & Wolters, 2007).

Simple VAR models consisting of 2 variables and estimated with 1 lag can be shown as follows:

$$y_t = \beta_{10} + \beta_{11} y_{t-1} + \propto_{11} x_{t-1} + u_{1t} \quad (1)$$

$$x_t = \beta_{20} + \beta_{21} x_{t-1} + \propto_{21} y_{t-1} + u_{2t} \quad (2)$$

The selected method requires the series to be stationary in the VAR estimations (Brooks, 2014). Various unit root and stationarity tests can be used to determine whether the series are stationary or not. If any of the series contains a unit root, it is made stationary by applying the difference taking operation. The appropriate lagged vector autoregressive (VAR) model should then be determined. In the determination of this model, information criteria are used and the number of lag(s) that minimizes the relevant information criterion is determined as the most appropriate value (Kočenda & Černý, 2015). The roots of the predicted VAR model are then expected to be less than 1. Additionally, various diagnostics related to residues can also be checked. After ensuring the reliability and validity of the model, the relationship between the variables is modeled by applying analysis such as causality, impulse and response, and variance decomposition.

Impulse and response analysis allows us to determine how the dependent variable responds to shocks from other variables. Since the coefficients from the VAR equation are useless in determining the direction of the effect, the impulse and response analysis is very practical for determining the direction of the shock and how long it remains in the system. The variance decomposition method allows to determine how much proportion of the movement in the dependent variable is caused by its own shocks and how much is caused by shocks in other variables. Often the proportion of the dependent variable's own shocks is determined to be greater, but the method is a practical tool for comparing the effect of other variables (Brooks, 2014).

RESULTS AND DISCUSSION

Augmented Dickey-Fuller (1979) and Phillips-Perron (1988) tests were applied to all variables to test their stationarity, which is a requirement of Granger causality analysis. Augmented Dickey-Fuller (ADF) is one of the most common unit root tests. However, if the series has a root of moving average (MA), the Phillips-Perron (PP) test is considered more reliable because it is a nonparametric test that corrects for long-term variance (Cross, 1995). The results of the tests performed are presented in Table 3. Both the ADF and PP tests presented parallel results. The results obtained show that the null of the unit root hypothesis was rejected only in the BDI variable at the level, while in the other variables it was rejected at the first difference. Here, the BDI variable was determined as I (0) and the remaining variables were determined as I (1).

The unit root hypothesis can also provide information about the effect of shocks. For example, inflation data contains a unit root. This shows that inflation carries the shocks it is exposed to, that these shocks have permanent effects and that inflation does not tend to return to the average in the long run. Similarly; exchange rates, commodity prices and container freight also carry permanent shocks which they are exposed. Only dry bulk freights tend to return to the average in the long run. Of course, these results may vary depending on the period covered and the frequency of the data. In addition, breaks in the series can also be effective in the results. However, it can be said that especially inflation and exchange rate are a result of the new economic policies and have permanent effects.

After analyzing the unit root levels of the variables, the VAR model was estimated. As a result of the information criteria and sensitivity controls, it was determined that the most appropriate lag was 2 with the smallest Akaike value (-16.35). To use the VAR model in a proper way, autoregressive (AR) roots must remain within the unit circle. In Figure 2, the positions of the roots within the unit circle are presented. Accordingly, the requirement for roots has been met and the model can be used. However, when the autocorrelation and heteroscedasticity conditions of the residuals were tested, inadequacies were observed in meeting some assumptions. This is probably due to the tail effects in the variables and magnitude of the shocks. At this stage, these shortcomings have been neglected and it is recommended to use nonlinear models for future studies.

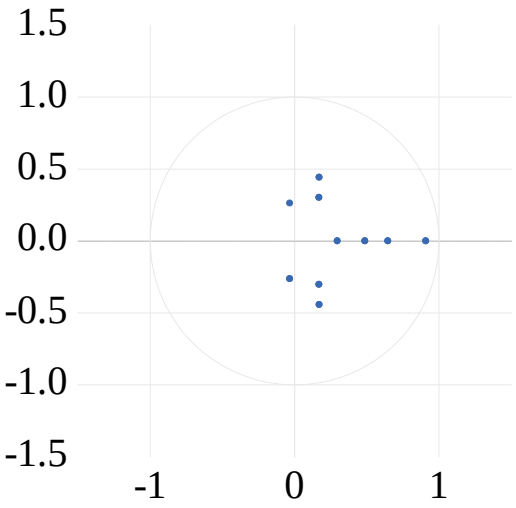

Figure 2. Inverse roots of AR characteristic polynomials

Table 4. Granger causality test results

Dependent	Excluded	Chi-sq	Df.	Prob.
Inflation	dlog CCFI	5.916156	2	0.0519*
	log BDI	1.232898	2	0.5399
	dlog Exchange	45.74104	2	0.0000***
	dlog Commodity	2.800670	2	0.2465
	All	52.86423	8	0.0000***
CCFI	dlog Inflation	4.274682	2	0.1180
	log BDI	2.870919	2	0.2380
	dlog Exchange	0.381899	2	0.8262
	dlog Commodity	4.859630	2	0.0881*
	All	16.88032	8	0.0314**
BDI	dlog Inflation	1.776595	2	0.4114
	dlog CCFI	1.928074	2	0.3814
	dlog Exchange	12.09025	2	0.0024***
	dlog Commodity	12.97618	2	0.0015***
	All	35.17240	8	0.0000***
Exchange	dlog Inflation	7.801047	2	0.0202**
	dlog CCFI	2.052452	2	0.3584
	log BDI	2.500047	2	0.2865
	dlog Commodity	6.517111	2	0.0384**
	All	20.02219	8	0.0103**
Commodity	dlog Inflation	0.433800	2	0.8050
	dlog CCFI	0.911844	2	0.6339
	log BDI	5.617484	2	0.0603*
	dlog Exchange	0.366856	2	0.8324
	All	7.439890	8	0.4900

Note: (1) Null of Granger Non-Causality is Rejected at *10%, **5%, ***1%. (2) Optimal lags according to information criteria when maximum lag is 18: SC=1, AIC=2, HQ=1 (Akaike was selected).

$$inflation_t = \beta_{10} + \beta_{11} inflation_{t-1} + \beta_{12} inflation_{t-2} + \propto_{11} CCFI_{t-1} + \propto_{12} CCFI_{t-2} + \delta_{11} BDI_{t-1} + \delta_{12} BDI_{t-2} + \theta_{11} Exchange_{t-1} + \theta_{12} Exchange_{t-2} + \alpha_{11} Commodity_{t-1} + \alpha_{12} Commodity_{t-2} + u_{1t} \quad (3)$$

The mathematical form of the VAR model estimated for inflation using 2 lags can be represented as shown in equation 3:

This equation is estimated separately for all variables and the results are obtained. It can be determined whether all the variables included in the model are significant for the others. These models, which are estimated according to the academic need, can also be used. The graphic of the inverse AR roots of the model estimated for 2 lags is presented in Figure 2. Findings show that all roots are less than 1 and the model can be used for further analysis.

After it was determined that the AR roots of the model were less than 1 and the optimal lag is 2, Granger causality analysis from VAR models was applied and the results are presented in Table 4. To enrich the results and to examine possible feedback situations, causality results are presented for all variables in the analysis. Nevertheless, obtaining statistically significant results does not mean that they are theoretically meaningful. There may also be relationships formed by chance or by internal correlation problems. Or there may be errors in the obtained data.

Considering the individual results for inflation, it has been determined that there are significant causal relationships from the CCFI and nominal exchange rate variables. There was no significant relationship between commodity price and BDI variable individually. However, when all independent variables are modeled, it can be said that they all carry determinant information for inflation levels in Türkiye. From the impulse and response analysis in Figure 3, the reaction of inflation to unexpected shocks from other variables can be interpreted. Inflation does not react to the 1 standard deviation unexpected positive shock in the CCFI variable in the first period, but gives a negative reaction in the second period. From the third period, the inflation starts to give a positive reaction to the CCFI. Then, this positive effect continues for 10 months and leaves the system. The negative reaction within the 2-month period may be due to a contraction in demand due to increased transportation costs. However, this cost increase may be taken for granted in the following periods and the recovery in demand may contribute positively to inflation. On the other hand, one standard deviation shock in BDI, which shows the cost of raw material transportation, has positive effect on inflation and this effect continues for about one year. However, this effect is not higher than that of the effect from the cost of the container transportation. The variable to which Turkish inflation reacts the most is naturally the nominal exchange rate. Moreover, changes in exchange rates directly affect transportation and commodity costs. Therefore, an unexpected shock in the exchange rate makes the inflation jump in the second period, and this effect disappears from the system after about 9 months. Of course, if the economy is repeatedly exposed to many shocks about the exchange rate due to political environment, it will take a long time for the effect to be removed from system. The reaction of inflation to the shock in the commodity index is naturally positive. The rising commodity price index points to both increased logistics costs as well as raw material costs. The effect of an unexpected one standard deviation shock in prices on inflation lasts approximately for one year.

When the CCFI variable is considered a dependent variable, a significant causality relationship has been determined from commodity price index. Naturally, no effect could be detected from inflation and exchange rate, which are the internal economic factors of Türkiye. The causality determined from commodity price index may be due to remarkable weight of energy prices in the index or the increase in commodity prices used in production due to increased demand, and the reflection of increased demand on maritime transport traffic. As can be seen in the left part of Figure 4, the response of container freight rate to the shock in commodity prices is positive and this effect loses its effect after about 7 months.

In the model where BDI is the dependent variable, significant causality relationships were determined from the USD/TRY nominal exchange rate and the commodity price index. the Turkish exchange rate may

carry information about international interest policies and these policies may affect the demand for bulk cargoes. Therefore, there may be an impression that there is an information flow. The response of the bulk freight rate to the USD/TRY exchange rate was seen as negative in the impulse & response analysis. Considering that the rising exchange rate carries information about the increase in interest rates and that the interest rate is increased against the increasing inflation in the world, it can be said that the consumption in the world is shrinking, and this situation is negatively reflected on the dry bulk transportation demand. On the commodity side, increasing or decreasing demand can be directly reflected in bulk cargo transportation as commodity prices carry information about their demands. Additionally, the oil prices included in the commodity price index can generate an information flow for ships whose most important input is fuel costs. This effect can be seen on the right side of Figure 4. The unexpected shock in the commodity price index generates a positive effect and this effect remains in the system for a very long time.

In the model where the exchange rate is the dependent variable, naturally a significant causality relationship from inflation has been determined. Increasing inflation can cause investors to increase demand by transferring their money to exchange rates to secure their purchasing power. In addition, manufacturing companies may be pushing their purchasing decisions forward or stocking foreign currency rather than buying their raw materials more expensive in the future. The right-hand side of Figure 5 shows that the exchange rate responds immediately to shocks from inflation. In addition, the unexpected shock effect in inflation is felt in the exchange rate for about 10 months. Additionally, it is seen that there is a feedback situation due to the mutual causality relations between the inflation and the exchange rate. There are mutual information flows from both variables and their behavior change according to these information flows.

The significant causality relationship between the exchange rate and commodity prices may be because Türkiye's imports are considerably higher than its exports. As commodity prices increase, trade balancing concerns may also increase, leading to further appreciation of the dollar. Since the international payments are made with the exchange rate and the

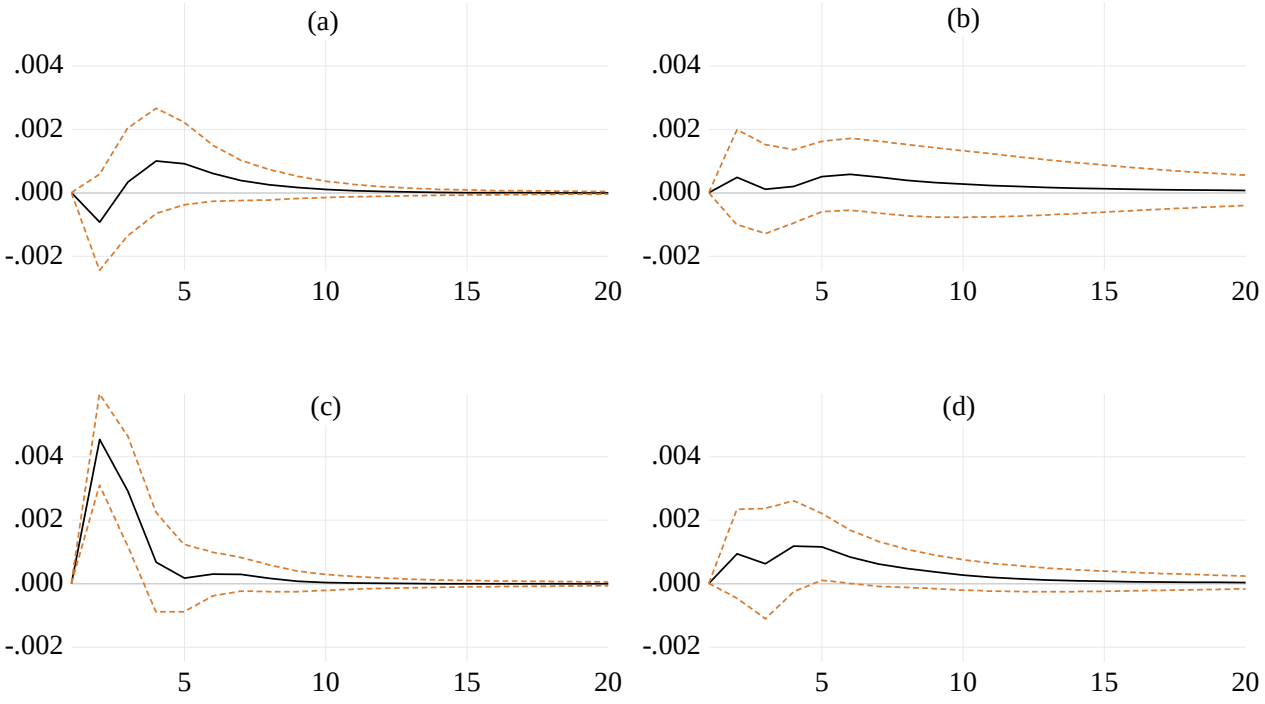

Figure 3. Results of impulse response analysis of inflation. a) Response of inflation to China Containerized Freight Index, b) Response of inflation to Baltic Dry Index, c) Response of inflation to Nominal Exchange Rate, d) Response of inflation to Commodity Price Index. (Response to Cholesky One S.D. (d.f. adjusted) Innovations ± 2 S.E.)

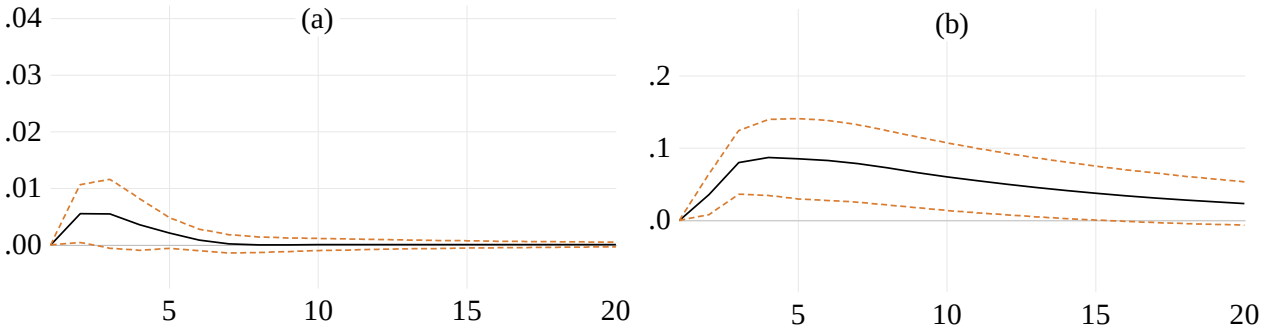

Figure 4. Response of freight indices to commodity price index

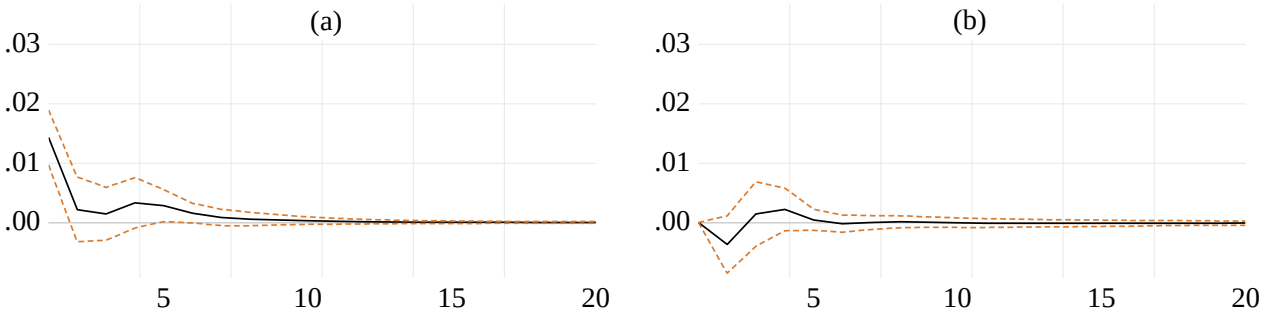

Figure 5. Response of exchange rate

foreign exchange income source of the countries is basically exports, higher imports ensure the pricing of the foreign currency. The right-hand side of Figure 5 shows that the exchange rate response to the unexpected shock in commodity prices was initially negative, but later turned positive and exited the system after about 5 months. Being a composite index makes interpretation difficult. Since precious metals such as gold are also included in this index, increasing gold prices may cause Turkish investors to exit foreign currency and switch to gold. However, the demand for the dollar, which has become cheaper after switching between investment tools, may increase due to the current account deficit and inflation in the country. In addition, volatilities in the exchange rate can change the demand for foreign currency by affecting the payment preferences of Turkish foreign trade stakeholders (Özçelik, 2022).

Finally, in the commodity-priced model, there is only one significant causality relationship from BDI to the commodity price index. This shows that there is a feedback situation between commodity prices and BDI and there is a mutual flow of information. Since the BDI is accepted as the leading indicator of world trade and economy, the slowdown in the dry bulk market may also be reflected as a slowdown in the demand for commodities. Changing expectations may also reflect positively or negatively on commodity prices. As shown in Figure 6, unexpected shock from BDI generates a positive reaction in the commodity price index and this effect continues for about 8 months.

We made some inferences about how much the unexpected shocks from other variables affect inflation. However, it is necessary to examine how much of the changes in inflation are caused by their own shocks and how much are by shocks in other variables. This analysis can be done with the variance decomposition method. Since our main research question is about the inflation, we only included the decomposition of the inflation variable here. The results of our analysis for 12 periods are presented in Table 5. The results show that about 82% of the change in inflation is due to its own shocks, 13% to exchange rate shocks, 2.5% to commodity price shocks, 1.5% to container transportation cost shocks and 0.7% to dry bulk transportation cost shocks. From this table, inferences can be made about the variables that affect inflation the most. It is seen that the most important factor is the changes in the exchange rate because the changes in the exchange rate also affect the costs of purchasing commodities and transportation services, which are supplied in dollars in the international area.

Table 5. Variance decomposition of inflation

Period	S.E.	Inflation	CCFI	BDI	Exchange	Commodity
1	0.010657	100.0000	0.000000	0.000000	0.000000	0.000000
2	0.013334	87.29707	0.478379	0.134257	11.59772	0.492570
3	0.014137	84.19161	0.483514	0.125797	14.56226	0.636819
4	0.014486	83.56437	0.942049	0.138793	14.08543	1.269363
5	0.014713	82.92711	1.300955	0.254646	13.66813	1.849155
6	0.014828	82.50378	1.450976	0.405515	13.49785	2.141881
7	0.014881	82.24310	1.506880	0.511553	13.44000	2.298466
8	0.014906	82.09030	1.529788	0.578818	13.40668	2.394415
9	0.014919	81.99926	1.539254	0.624961	13.38548	2.451036
10	0.014926	81.94407	1.542709	0.657965	13.37337	2.481887
11	0.014930	81.90989	1.543739	0.681453	13.36653	2.498391
12	0.014933	81.88784	1.543920	0.698217	13.36243	2.507599

Note: Cholesky Ordering: Inflation CCFI Exchange BDI

Based on the findings in the variance decomposition analysis that the change in inflation is largely from itself, we also decided to examine the response of inflation to its own shocks. The impulse & response graph of inflation is presented in Figure 7. According to the result, an unexpected shock of 1 standard deviation in inflation causes a large positive reaction in inflation in the following period. It takes almost 12 months for the effect of this shock to be eliminated from the system. This situation reveals a result that is more suitable for the forward-looking based rational expectation theory. Market players hold high inflation expectations by considering historical data, current data in the market, past results of policies implemented and possible results of the policies to be implemented. Since the difference between expected inflation and actual inflation in the previous period is high due to the unexpected shock, inflation expectations for the next period are also higher.

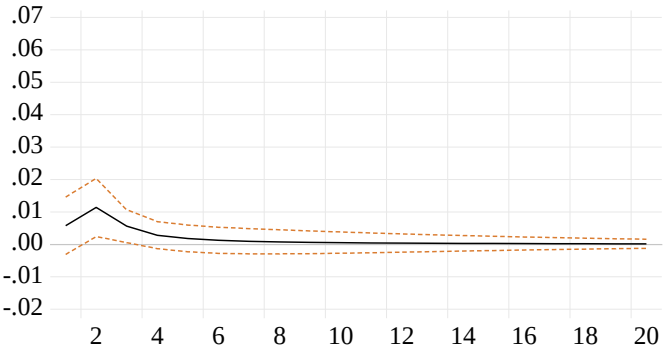

Figure 6. Response of the commodity price index to BDI

As the last step of our analysis, we estimated the Consumer Price Index for August 2022 and December 2023 using the VAR model we obtained. Our estimated result is presented in Figure 8. According to our estimate, inflation will continue to increase in Türkiye, but the rate of increase will decrease over time.

CONCLUSION

Due to the global instability, especially, energy prices have been on the rise in the world recently. In addition, the difficulties experienced in grain supply due to the Russia-Ukraine war caused incredible increases in grain prices, albeit temporarily. Of course, the contribution of these factors to inflation is indisputable and obvious. However, due to the container crisis in the COVID-19 period and the temporary closure of the Suez Canal, the freight rates, which increased to a record level due to the extended routes, have only just begun to be considered from an inflationary perspective. In this study, while modeling inflation with Keynes' push-up cost approach, we differentiated from the literature by including the costs of transporting raw materials and final products in our model. We used VAR models to reveal the effects of costs that we think are not considered in the inflationary environment. After determining the appropriate VAR model, we filtered the information with Granger causality, impulse & response, variance decomposition techniques.

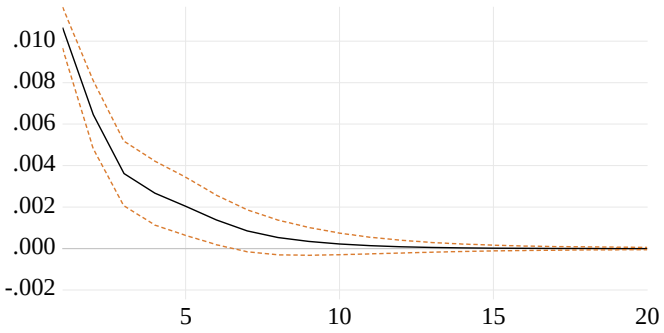

Figure 7. Response of inflation to inflation

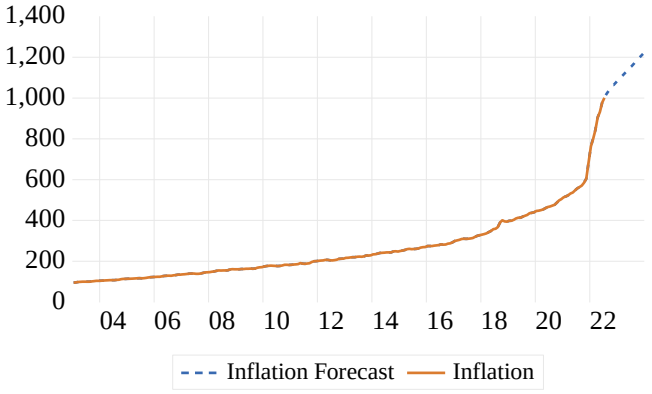

Figure 8. Inflation forecast

We chose Türkiye as the sample. In addition to the global inflationary environment in the world, Türkiye implements new policies as it switches to a new economic model that reduces to importance of hot money flow. These policies accelerated inflation by causing the dollar to appreciate even more in the short term. In this respect, we determined the role of exchange rate, commodity prices and transportation costs in Türkiye's inflation, and to reveal findings about the direction in which political energy should be spent in the near future.

Our results show that first, inflation is heavily affected by its own past shocks. One reason for this situation may be the positive (that will increase) expectations of the citizens and investors of the country about future inflation. The source of these expectations may be the experience of the results of the policies implemented in the past, unkept promises about the economy and the fueling of inflation by negative news in the country (Siebert, 2007). Of course, changes in global energy and commodity prices were also influential in the rate of increase in inflation. However, for example, while the oil price was $57.52 in January 2020, it doubled to $114.59 in June 2022, while the USD/TRY rate increased nearly three times in the same period (from 5.91 to 16.96). These examples were also seen in our causality, impulse & response, and variance decomposition analyses. A significant causal relationship from commodity price index to inflation could not be determined individually. There is a strong causality relationship from the exchange rate. Naturally, the response of inflation to an unexpected shock was highest in the exchange rate. Additionally, unexpected positive shock from the exchange rate generates permanent effects and this effect continues for about 9 months. For this reason, policies that increase the stability of the exchange rate and protection tools should be supported. Trade agreements that reduce the demand for the single exchange rate can also contribute significantly to this stability.

In the context of the effect of transportation on inflation, container transportation and dry bulk cargo transport differ. As a market type, they have a different structure from each other. In the results of the individual causality analysis, container transportation has a significant positive contribution to inflation. Although the first reaction is negative, the following periods turn into a positive dimension, causing inflation to rise. On the other hand, although dry bulk cargo transportation does not perform a significant causality in an individual sense, it has a significant positive contribution to inflation in the collective model. This may be because the Turkish economy is not very strong in terms of heavy industry. Industrial states such as China heavily import raw materials and produce with their developed industries and sell the final products to other countries. However, the Turkish economy's activities are limited to the extent that it will import a very large amount of dry bulk raw materials. There is a production model based mostly on the import of intermediate goods. Intermediate goods import is mostly carried out by container transportation. This may be due to the fact that the Turkish economy is less affected by bulk freight than container freight in terms of inflation. Additionally, in addition, the ratio of transportation costs to the value of the product is higher in raw materials than in manufactured items. Because the added value of manufactured products is higher (Reis & Macario, 2019), and compared to raw materials, manufactured

products are sent to shorter distances (Bairoch, 2006). Accordingly, the higher contribution of the CCFI index to inflation may be mainly due to the rise in exchange rates.

In this respect, it is important to develop the Turkish container transportation network. It is necessary not only to carry out intensive transportation activities by sea, but also to use alternative projects such as OBOR effectively. Additionally, business models that will strengthen national transport security should be developed. For example, with systems such as the pool system, the national fleet can be operated effectively and in a way that supports the national interests. This situation may save our country from the monopoly of international shipowners who exhibit monopoly and oligopoly behavior in the short term. Such players have the power to determine the freights in the market and naturally their primary aim is profit maximization, not the welfare of the countries. For example, the USA has recently enacted regulations regarding international container companies to increase national security.

As a limitation of the study, the used freight indices can be shown. Although BDI and CCFI are leading indicators of their internationally recognized markets, they may not perfectly represent Türkiye's transportation costs. For example, the freights of huge bulk carriers and small bulk carriers can differ greatly, and Turkish ports do not have the physical and economic infrastructure to accommodate huge ships. The same is true for container ships. In this respect, freight indices belonging to more characteristic ships can be used for Türkiye. Unfortunately, we could not reach these values. Suggestions for future studies are to carry out a similar study with a panel data set covering other countries and to support it with different methodologies.

Compliance with Ethical Standards

Authors' Contributions

Author AA designed the study, AA and MRİ wrote the first draft of the manuscript, AA performed and managed statistical analyses, MRİ performed writing - review & final editing. Both authors read and approved the final manuscript.

Conflict of Interest

The authors declare that there is no conflict of interest.

Ethical Approval

For this type of study, formal consent is not required.

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Impact of Stocking Density on the Survival, Growth and Injury of Narrow-Clawed Crayfish (*Pontastacus leptodactylus*) Reared in a Flowing Brackish Water System

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ABSTRACT

The crayfish population dramatically declined in most lakes and dams in Türkiye; hence, crayfish culture is a possible option to increase the supply. This study aimed to determine the effects of stocking density on the growth performance and survival of newly-hatched third instars of narrow-clawed crayfish (*Pontastacus leptodactylus*) in a flowing brackish water system. The third instars were randomly stocked in nine tanks (area: 1.7 m²) for 120 days with three densities of 10, 50, and 100 crayfish/m². The results indicated that the stocking density significantly affected the growth performance, survival rate, proportion of the cheliped injury, biomass, length distribution, and feed conversion ratio (FCR). The mean final weights and total lengths were 2.27, 1.40, and 1.08 g and 4.83, 3.73 and 3.51 cm according to the densities, respectively. The highest stocking density increased the total biomass yield and proportion of the cheliped injury but reduced the survival, growth, molting frequency and regeneration of the appendage. The survival (86.3%) and specific growth rate (1.16 cm/day) in the 10 individuals/m² group were significantly higher than the other groups. The cheliped injury was also found to be the lowest in the 10 individual/m² group ($p<0.05$). Our study results showed that significant differences in FCR value were observed at different stocking densities. In summary, higher stocking density at the end of this study increased the frequency and severity of aggressive interactions of crayfish, limiting molting frequency and growth performance. A density of 10-50 crayfish/m² is recommended for better growth parameters while 100 crayfish/m² is suggested for higher biomass yield.

INTRODUCTION

Pontastacus leptodactylus (named as Turkish crayfish or Turkish narrow-clawed crayfish) is the most commercial Astacid crayfish species in aquaculture with good consumer preference and is widely distributed in Türkiye and Europe (FAO, 2017). It is a highly-priced crayfish and generally harvested from lakes and dams (Gherardi & Souty-Grosset, 2010; Kokko et al., 2018). In the crayfish market, even 25–30 g individuals have good market value (Boštjančić et al., 2021). It is grown in various parts of the world for human consumption and restocking in natural waters (Franke et al., 2013). Crayfish consumption in Türkiye has traditionally very low; thus, this country was a major supplier of *P. leptodactylus* to western Europe from 1970 to 1984 (Baran et al., 1987; Oray, 1990; Holdich, 1993; Harlioglu & Güner, 2006). However, crayfish population was reported to have dropped significantly from 5000 tons to 200 tons per year after in most lakes and dam reservoirs after 1986 (Bolat, 2001). Probable reasons are thought to be the outbreaks of crayfish plague *Aphanomyces astaci* (Svoboda et al., 2012, 2014), climate change and degraded water quality (Kouba et al., 2014). Among the reasons for the decline in the natural stock population of crayfish, factors such as diseases and parasites, predators, cannibalism, unsuitable environmental conditions such as pollution or drought, and directly or indirectly human factors such as overfishing have been the subject of many studies in recent years (Demirol et al., 2017; Kokko et al., 2018). Additional stocking in most lakes and dams in Türkiye increased its production but not to a desired level (Kale & Berber, 2020). It is still under pressure of the crayfish plague in most dams and lakes (Kokko et al., 2018). In 2021, the annual crayfish production was 1011 tons in Türkiye (Turkstat, 2021).

Crayfish are suitable for culture since they are hardy, productive, and adaptable and do not require high-tech cultivation practices (McClain & Romaire, 2004). Unlike the culture of the aquatic species that need hatcheries and formulated feed, crayfish culture is based on self-sustaining populations with a feed-based food system (Eversole & McClain, 2000). For this purpose, studies should be carried out both in controlled laboratory conditions and in natural environments to get more accurate data on survival and growth parameters. Crayfish culture system is categorized by pond type and dominant vegetation but classification according to the main production strategy is perhaps a better alternative. The culture of crayfish is mostly based on semi-extensive and extensive production systems with juveniles stocked in earthen or artificial ponds of various shapes and sizes (Eversole & McClain, 2000).

The production of cultured species is affected by various abiotic and biotic factors that significantly affect crayfish yield and production in earthen ponds (Shoko et al., 2016; Calabrese et al., 2017; Yaun et al., 2018; Mazlum et al., 2019). Many researchers have reported that the stocking density affects crustacean survival, growth, production, molting frequency and chelae injury (Sun et al., 2016; Mazlum et al., 2017; Yu et al., 2020; Zheng et al., 2020). A high stocking density increases the annual production of crayfish (Mazlum et al., 2020), stress level (Nga et al., 2005), competition for resources (McClain, 1995), living place (Mazlum et al., 2017) and cannibalism (Mazlum & Eversole, 2004, 2005; Romano & Zeng, 2017). This case is valid for many crustaceans such as yabby *Cherax destructor* (Verhoef & Austin, 1999), red king crab *Paralithodes camtschaticus* (Daly et al., 2012), red swamp crayfish *Procambarus clarkii* (Mazlum & Eversole, 2004; Yu et al., 2020) and Chinese mitten crab *Eriocheir sinensis* (Yuan et al., 2018). Although higher rearing density is a common way to increase production and maintain economic feasibility, it has a negative impact on growth, survival rate (Rahman & Verdegem, 2010) and cheliped injury or loss (Zheng et al., 2017). For this reason, stocking density in crayfish depends entirely on whether the pond is covered with well-covered plant material or not.

The aggressive behavior of crayfish in aquaculture is affected by density (Golubev et al., 2016). The social factor has a special effect on crustaceans as their growth is associated with their vulnerability to cannibalism as a result of molting (Savolainen et al., 2004). Cannibalism is one of the crucial limiting factors for the productivity and profitability in aquaculture and can significantly change the population dynamics in the wild (Claessen et al., 2004). Both biotic and

abiotic factors affect cannibalism as well as stocking densities, molting status, size heterogeneity, photoperiod, light intensity, and shelter and food availability. These factors depend on the species or species-specific stages (Mazlum & Uzun, 2008; Ariyati et al., 2018). A high stocking density may result in cannibalism of the crayfish especially during the molting process. Similar problems were reported for various crayfish species in the early stages of life resulting in a yield reduction (Duffy et al., 2011; Erol et al., 2017; Mazlum et al., 2017, 2019, 2020).

Crayfish have cannibalistic behavior which limits their productivity and profitability in aquaculture (Franke et al., 2013, 2015; Ghanawi & Saoud, 2012; Saoud et al., 2012) especially in their larval stage (Nakata & Goshima, 2004; Naranjo-Paramo et al., 2004). The juveniles of the crayfish exhibit a strong competition for resources and space (Mazlum & Eversole, 2005). The frequency of cheliped injury or loss significantly increases in higher stocking density condition (Savolainen et al., 2004). For this reason, injuries are becoming more frequent as a result of increased fighting activity of crayfish due to crowding. In natural conditions, the injury rate is associated not only with density but also with the higher proportion of large individuals (Skurdal et al., 1993). Previously-injured individuals are more likely to be re-injured (Kouba et al., 2014). In particular, cheliped injuries are known to affect the health and ability of a crayfish since chelae are important for defense, feeding and mating (Mazlum & Eversole, 2005; Kouba et al., 2016; Romano & Zeng, 2017). A higher stocking density of crayfish causes cheliped loss or injury as a result of the competition for space. Hence, the limited space reduces the survival, body size, growth and molting while it increases the intensity of agonistic interactions in crayfish (Mazlum & Eversole, 2004). Moreover, a higher stocking density tends to cause a lower growth (Jussila et al., 1999), survival (Jussila et al., 1999) and production (Adiyana et al., 2014; Supriyono et al., 2017). Therefore, it is essential to determine the crayfish management strategy to ensure sustainable crayfish production and to increase its economic benefits.

The success of larval production of crayfish depends on conditions, availability of food, shelter, rearing practices and stocking density (He et al., 2021). Among these factors, larval stocking density is known to affect larval performance. In order to solve this problem, comprehensive studies are needed to determine the optimum stocking density to minimize cheliped injury. Thus, the present study was to determine whether stocking density has any effect on the growth performance, survival, molting frequency, cheliped injury, and feed conversion ratio of the third instar of crayfish.

MATERIALS AND METHODS

Study Area

The study was carried out at the Research Center of the Faculty of Marine Sciences and Technology of İskenderun Technical University (formerly Mustafa Kemal University) between 14 June and 14 October 2006 in Dörtyol, Türkiye. The study was conducted in 4 months. The water used in the study was obtained from a well with depth of 160 m. The water temperature was almost constant at 18-19°C with a salinity of 5 parts per thousand (ppt). There are interconnected lakes of different sizes around the well that is used to obtain the groundwater. Besides, while these lakes were previously connected to the Mediterranean Sea, these connections have been closed in the present condition. Lakes still have salinity even if with low concentrations. Wide wooden pieces were placed in each tank close to the water inlet to aerate the groundwater.

Experimental Crayfish and Maintenance

A total of 42 adult female crayfish (*P. leptodactylus*) (TL: 95±0.08 mm) with eggs were obtained with fyke-net (Bolat et al., 2010) from the Egirdir Lake located in Isparta, Türkiye. They were transported to the study site in a styrofoam box without water with cooling units and insulation mesh for the protection of crayfish. Upon arrival, females with eggs were held in fiberglass tanks with 1000 L water and acclimated to hatch in the aquaculture research facility to obtain third-instars young-of-year crayfish (YOY). Hatching occurred 21 days after acclimation and the hatching rate was 97%. PVC pipes were used as refuge and commercial carp diets (35% protein and 12% lipid) were used for feeding the crayfish to develop and shed eggs. Physical and

chemical water quality parameters during the acclimation were as follow: temperature of 23.4±0.75°C, pH of 7.82±0.55, dissolved oxygen of 6.83±1.14 mg/L and photoperiod of 12 h: 12 h. During the acclimation period, no sick or dead crayfish were observed.

Experimental Design

Hatched *P. leptodactylus* (Eschscholtz, 1823) larvae were grown up to the third instar stage (YOY: young-of-the-year). YOY crayfish were kept in a 20 m^3 tank and acclimated for weekdays until the start of the experiment. A commercial trout feed pellet (55% crude protein, 10% lipid) was used in feeding. After the acclimation, YOY was transferred to the experimental units with the planned densities. The start size of the total length of the third instar YOY crayfish (n=50) was measured to the nearest centimeter (cm). The average body weight and total length of YOY was 22.4±0.5 mg and 1.2±0.04 cm, respectively (Figure 1).

Figure 1. Third-instar stage (young-of-the-year, YOY) freshwater crayfish used in the study

Three stocking densities were utilized in the study: (10: group 1, 50: group 2, and 100: group 3) crayfish/m^2 corresponding to 17, 85, and 170 individuals per tank, respectively. The crayfish were randomly placed into 9 tanks (1.7 m^2). The bottom of each tank was equipped with plastic pipes (8×10×10 cm) (n=30) and 6 pieces of 40 cm^2 nettings to provide shelter to reduce cannibalism and antagonist behavior before the YOY crayfish were stocked. Each tank had its own water inlet and outlet. The water depth was about 40 cm while the water flow rate was 7 L/per minute in the tanks having continuous brackish water flow.

The experiment was conducted in a 3×3 completely randomized design with three replications at three stocking densities. Crayfish were fed twice a day (08:00 morning and 5:00 pm evening) with the same feed as used during the YOY acclimation (commercial trout pellet feed, 55% crude protein, 10% lipid). Feeding schedule was planned for each treatment based on the growth and mortality rates as determined with the sampling period. The crayfish were fed using a feeding rate as a proportion of their biomass (5% of their mass per day) (Mazlum et al., 2011; Sirin & Mazlum, 2017). The data were recorded by collecting feces, feed residues, crust and dead on the bottom of the tank once per week. The experiment lasted 120 days.

Water Quality Parameter Measurement

Water temperature (°C) and dissolved oxygen (mg/L) were quantified by using an oxygen meter (YSI 55, Yellow Springs Instruments Co., Ohio, USA) while the water salinity was measured using a salinometer (YSI 85) and pH were determined using a pH meter (YSI Model 50) in each morning. Other water quality parameters such as ammonia, nitrite, nitrate, calcium and magnesium were analyzed monthly.

Sampling Procedure

The first measurement was taken two months after the crayfish were stocked and the other data were obtained monthly not to expose the crayfish to stress and damage. Growth parameter, survival and feed conversion rate (FCR) were periodically examined on the 60th, 90th, and 120th days of the experiment for each treatment group. The number of surviving crayfish was counted in each tank and the total lengths (TL) were measured from the tip of the rostrum to the telson to the nearest 0.1 mm using a measure board. In order to measure the weight of the crayfish (WW), they were put on filter paper to remove excess water and then weighed to the nearest 0.01 g by using an electronic balance. The number of molt crayfish was also determined daily. The sex of crayfish was determined, the number of injured chelipeds (called as missing chelipeds and regenerated chelipeds) for males and females were recorded at the end of the experiment. Dead crayfish were removed and counted on daily basis.

Regression analyses were performed for the relationship between total length (TL in cm) and wet

weight (WW in g), molting frequency (MF) and stocking density (m^2), and total biomass yield and stocking density (m^2) of the crayfish harvested at the end of the experiment is expressed by the following equation (1):

$$WW = aTL^b \quad (1)$$

and log base 10 equation (2):

$$\log WW = \log a + b \log TL \quad (2)$$

where *WW* is the wet weight, *TL* is the total length, and *a* and *b* are constants.

Data Calculation

All crayfish were measured and weighed at the beginning of the feeding trial, on day 60, day 90 and day 120. At the end of the study, survived crayfish, the total number of molt crayfish and the number of cheliped injury crayfish were determined. The measurements were replicated three times in each stocking density group. Crayfish growth performance was estimated through the assessment of weight gain (WG), specific growth rate (SGR), survival rate (SR), feed conversion ratio (FCR), cheliped injury rate (CIR) and mean molting frequency (MMF) by using the formulae given below (equations 3-8):

$$WG = FBW - IBW \quad (3)$$

$$SGR\ (\%/day) = \left[\frac{\ln FTL - \ln ITL}{Rearing\ period(T,\ day)}\right] \times 100 \quad (4)$$

$$SR(\%) = \frac{Final\ number\ of\ crayfish}{Initial\ number\ of\ crayfish} \times 100 \quad (5)$$

$$FCR = \frac{FI}{WG} \quad (6)$$

$$CIR(\%) = \frac{N_{CLIR}}{N_{SC}} \times 100 \quad (7)$$

$$MMF(\%) = \frac{Number\ of\ molt}{Total\ number\ of\ crayfish\ survived} \times 100 \quad (8)$$

where *FBW* is the final body weight (g), *IBW* is the initial body weight (g), *FTL* is the final total length (cm), *ITL* is the initial total length (cm), *FI* is the total amount of feed (g) given to crayfish during the rearing period, N_{CLIR} is the number of crayfish with cheliped loss, injury or regenerate appendage.

The coefficient of variations (CV, %) for the final weight and total length were also calculated for each stocking density using the formula given below (equation 9):

$$CV(\%) = \frac{Standard\ deviation}{Mean} \times 100 \quad (9)$$

Statistical Data Analysis

Data on crayfish growth performance such as final total length (FTL), final wet mass (FWM), weight gain (WG), survival rate (SR), specific growth rate (SGR), feed conversion rates (FCR), molting frequency (MF), cheliped injury (CI), cheliped lost (CL), harvest weight (HW), coefficient of variation (CV) for final wet mass (FWM) and final total length (FTL) were subjected to one-way ANOVA (analysis of variance). Normality and homogeneity were tested by using Kolmogorov Smirnov and Levene tests, respectively. All statistical analyses were carried out by using SPSS (2008) 17.0 software according to Duncan's New Multiple Range Test to identify the 5% level of significance of variance among the different stocking density means. Regression analysis was used to determine the length–weight, molting frequency-stocking density, and total biomass yield-stocking density relationships. All experimental data were expressed as mean ± standard deviation (SD).

RESULTS

Water Quality

The water quality parameters were determined and summarized in Table 1. The water temperature inside the tanks ranged between 21.0 and 24.5°C (mean: 22.7°C) while the dissolved oxygen varied from 5.6 to 6.8 mg/L (mean: 6.2) and the pH value was between 7.0 and 7.8 (mean: 7.4). The nitrite and nitrate concentrations in the flowing water aquaculture system were 0.005 mg/L and 0.17 mg/L, respectively. Groundwater which was used during the rearing period had a salinity of 5 parts per thousand (ppt) in all tanks. No significant differences were found in the measured water quality parameters, which were kept within acceptable limits for the crayfish cultured during the study (Table 1).

Table 1. Water quality parameters of the crayfish in the brackish water flow system during the 120-day trial period

Parameters	Mean ± SD
Water temperature (°C)	22.7±0.06
Dissolved oxygen (mg/L)	6.2±0.09
pH	7.4±0.05
Hardness (mg/L)	47.0±1.6
Calcium (mg/L)	66.5±2.1
Magnesium (mg/L)	63.1±1.2
Salinity (ppt)	5.0±0.44
Ammonia ($NH4^{+)}$	0.05±0.012
Nitrite NO_2 (mg/L)	0.005±0.02
Nitrate NO_3 (mg/L)	0.170±0.003

Note: Data are presented as mean ± standard deviation.

Growth Parameters

It was observed that the stocking density significantly impacted the growth performance of the crayfish (Tables 2 and 3). Total length, body mass, specific growth rate, molting frequency, survival rate and FCR were all negatively influenced by high stocking density; however, the high density increased total biomass and proportion of the cheliped injury for the larval stage (Table 2).

No significant differences in the initial body mass ($p<0.05$) and lengths ($p<0.05$) among crayfish stocked in the three stocking density groups (Table 2). The final mean weights averages were 2.27, 1.40 and 1.08 g while the average final lengths were 4.83, 3.73 and 3.51 cm (Table 2).

A statistical difference was not observed in the groups with a stock density of 50 and 100 crayfish/m². At the end of the trial, the best growth (by weight and length) was observed in the group with the lowest stock density of 10 crayfish/m². Besides, the calculated mass of the male and female crayfish differed significantly at the end of the 120 days (Table 2; Figure 2).

The relationship between total length (TL) and total weight (TW) of the crayfish harvested at the end of the experiment is expressed by the following equation (1) (Figure 3):

$$Total\ weight = (0.8658 \times TL) - 1.9002; (R^2 = 0.9887) \quad (10)$$

Table 2. Various growth and survival parameters of third-instars crayfish reared at three stocking densities in the 120-day experiment

Parameters	Stocking Density (m²)		
	10	***50***	***100***
Initial length (cm)	1.20±0.04	1.20±0.04	1.20±0.04
Initial weight (mg)	22.4±0.50	22.4±0.50	22.4±0.50
Final length (cm)	4.83±0.80^a	3.73±0.75^b	3.51±0.0.75^b
Final weight (g)	2.27±1.41^a	1.40±0.84^b	1.08±0.60^b
Weight gain (WG, g)	2.25±0.91^a	1.38±0.34^b	1.06±0.10^b
Length gain (cm)	3.63±0.76^a	2.53±0.71^b	2.31±0.69^b
Survival rate (SR, %)	86.3±11.31^a	72.2±11.33^a	56.3±13.13^b
Specific growth rate (SGR, %/day)	1.16±0.98^a	0.95±0.80^b	0.89±0.76^b
Feed conversion rate (FCR)	4.52±0.28^a	3.77±0.20^b	1.91±0.30^c
Cheliped injury rate (CIR, %)	6.3±11.26^a	16.3±6.35^b	22.1±8.60^c
Molting frequency (MF, %)	82.2±1.08^a	68.0±1.03^b	47.0±0.98^c
Total biomass yield/harvest (g)	177.2±23.39^a	378.9±17.91^b	431.9±8.54^c

Note: Data are presented as mean ± standard deviation. Means in any row with the different letters are significantly different among the stocking density ($p<0.05$).

Table 3. The total length (TL, cm), cheliped injury (%), and number (N) of male and female crayfish belonging to different stocks at the end of the experiment

Stocking Density	N	Male	N	Female
Total length (TL, cm)				
10	22	4.99±0.64[a]	22	4.45±0.35[a]
50	94	3.77±0.27[a]	90	3.63±0.22[a]
100	138	3.57±0.18[a]	149	3.21±0.12[a]
Cheliped injury (CI, %)				
10	3	13.6±10.46[a]	3	13.6±10.46[a]
50	13	13.8±5.52[a]	29	32.2±12.11[b]
100	30	21.7±14.88[a]	57	38.6±8.87[b]

Note: Data are presented as mean ± standard deviation. Means in rows (male and female) within a stocking density with the same letters are not significantly different ($p<0.05$).

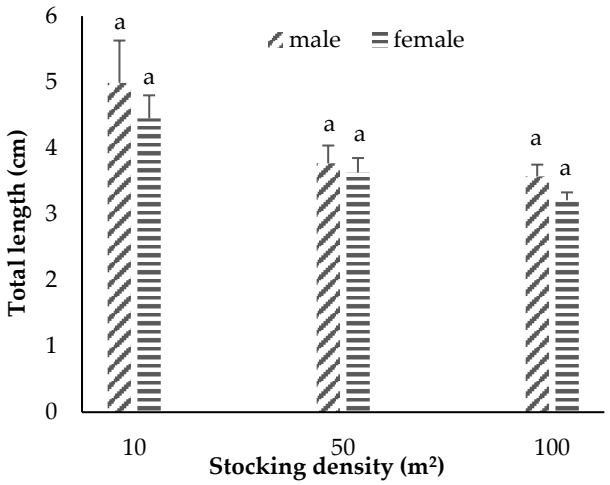

Figure 2. Total lengths according to the stocking density for male and female crayfish

Survival Rate (SR)

Survival rate (SR) of the third instar crayfish after 120 d varied from 56.3% to 86.3% for the stocking densities of 100/m² and 10/m², respectively (Table 2). The survival of crayfish decreased with an increase in the stocking density. The highest SR was found as 86.3% in the group with a stock density of 10 crayfish/m² while the lowest SR was recorded for the density of 100 crayfish/m². There was no significant difference in the SRs between the density groups of 10 and 50 crayfish/m². Besides, the molting frequency (Table 2) and cheliped injury (Figure 4) were significantly different among the stocking density groups ($p<0.05$) with crayfish in the high-density group. Likewise, the highest SR (86.3%) was observed in the group with 10 crayfish/m² followed by the groups with a density of 50 crayfish/m² and 100 crayfish/m² (72.2% and 56.3%) (Table 2).

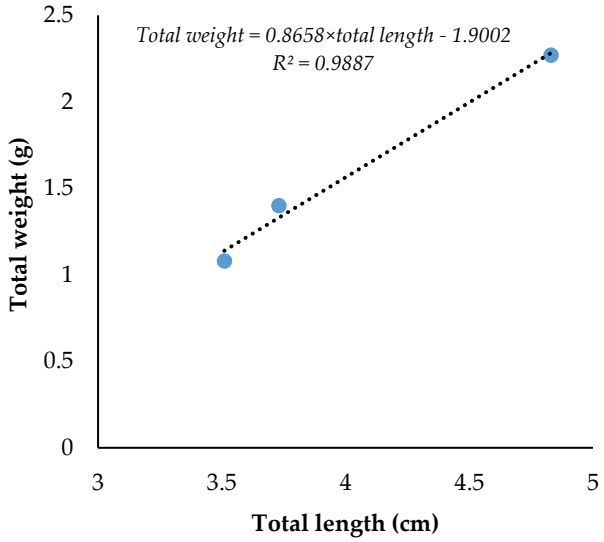

Figure 3. The relationship between the total length (TL) and body weight (TW) of crayfish harvested at the end of the experiment

Specific Growth Rate (SGR)

Stocking density also affected the specific growth rate (SGR), final weight, final length and weight gain (WG) significantly as inversely related to stocking density (Table 2). These values significantly decreased as the stocking density increased. The highest SGR was

calculated in the group of 10 crayfish/m² with a value of 1.16 cm and the lowest SGR was in the group of 100 crayfish/m² with 0.89 cm. At the end of the study, the SGR at 10 crayfish/m² was statistically higher than those of the other two groups ($p<0.05$). WG for the density groups of 50 and 100 crayfish/m² was significantly lower than that of the 10 crayfish/m² group. According to the sampling periods, the highest SGR was obtained from the group of 10 crayfish/m² with a value of 1.5 cm on the 60th day.

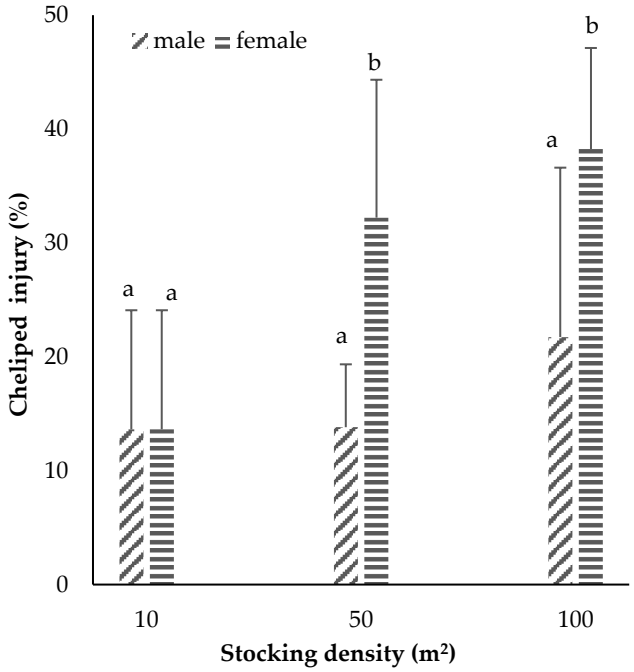

Figure 4. Cheliped injury rate (%) of male and female crayfish third instar for different stocking densities (bars represent the standard deviations of three replicated tanks)

Cheliped Injury Rate (CIR)

Cheliped injury rates (CIR) ranged from 6.3% to 22.1% increasing with stocking density (Table 2). There were significant differences in the CIR values among the three density groups. The CIR was significantly higher at the density of 100 crayfish/m² than those of the other two groups. Besides, the percentage of chelae injury in female crayfish (38.6%) was higher than that of males (21.7%) in the group of the highest stocking density (Table 3). There was no statistical difference in the percent chelae injury rates between the lowest (10 crayfish/m²) and medium (50 crayfish/m²) stocking density for the male crayfish; however, this difference was significant for the female crayfish.

Molting Frequency (MF)

The molting frequency (MF) ranged from 47.0% to 82.2% and was significantly affected by stocking density. The stocking density of 10 crayfish/m² had a significantly higher molting frequency (82.2%) than those of the other groups (Table 3). The molting frequency of the crayfish during the study period was displayed in Figure 5.

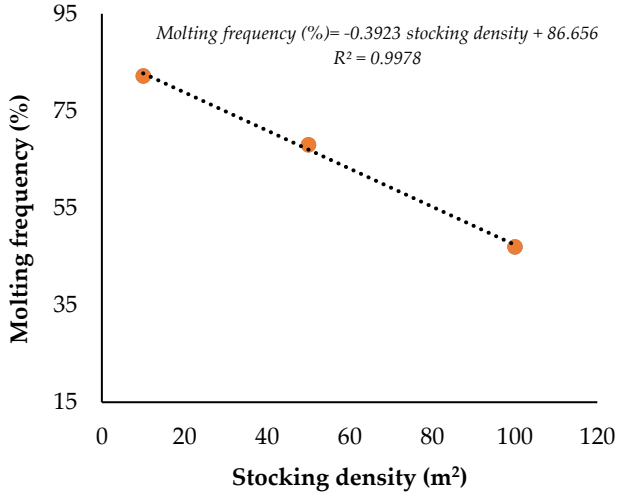

Figure 5. Variation of molting frequency (%) of crayfish according to the three stocking densities over 120-day study period

Feed Conversion Rate (FCR)

Feed conversion rate (FCR) values of the crayfish decreased with the increasing stocking density (Table 2). At the end of the experiment, the best mean FCR value (1.91) was observed in the density group of 10 crayfish/m² and it statistically differed from the other density groups.

Biomass Yield (BY)

It was observed that the total biomass was significantly affected by stocking density (Table 2). The highest crayfish biomass was obtained at 100 crayfish/m² density group (431.9 g), followed by 50 crayfish/m² group (378.9 g) and 10 crayfish/m² group (177.2 g). The differences among the stocking groups were statistically significant ($p<0.05$). Besides, a strong positive relationship was found between the logarithms of the stocking density and the logarithms of the total biomass at the end of the experiment expressed by the following equation (11) (Figure 6):

$$BY\ (g) = (113.3 \times \ln(stocking\ density)) - 79.1; (R^2 = 0.9902) \quad (11)$$

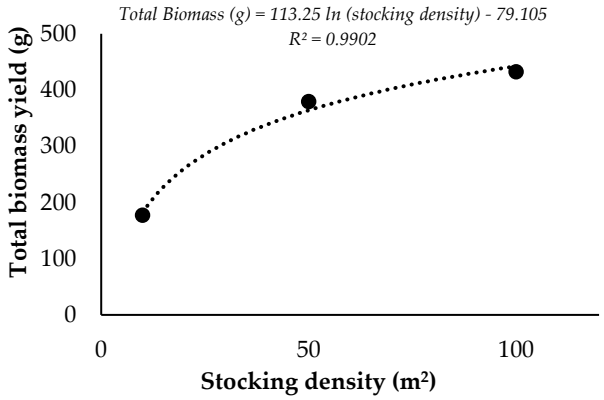

Figure 6. Variation of the total biomass of crayfish according to the three stocking densities over 120-day study period

Body Size (Length Distribution)

Although the male crayfish were larger than the females at the end of the experiment, the difference was not statistically significant ($p>0.05$) (Table 2). The length distribution varied between 2.0 and 6.2 cm. The distribution in the group with low stock density was more homogeneous and wider than in the other two groups (Table 3). However, there was no significant differences between the total lengths of the male and female crayfish at the end of the experiment (Table 3; $p>0.05$). It was observed that the crayfish length distribution was not influenced by the stocking density.

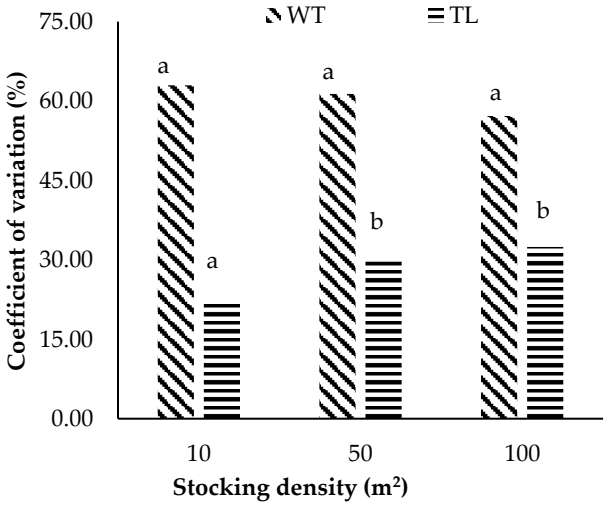

Figure 7. Coefficients of variation (CV) of the total length and body weight of crayfish at three stocking densities over the 120-day study period

The coefficients of variation (CV) values for the body weight did not differ significantly among stocking densities ($p<0.05$) but not among the total length (Figure 7). The mean total length (size) CV values ranged between 22% (for 10 crayfish/m^2) and 33% (for 100 crayfish/m^2) while the mean weight CV values ranged from 57% (for 100 crayfish/m^2) and 63% (for 10 crayfish/m^2) (Figure 7).

DISCUSSION

Successful crayfish culture requires a good survival rate as well as good growth rate (Hammond et al., 2006; Ulikowski et al., 2006; Aksu, et al., 2016). This study was carried out to study the effect of stocking density on the performance of narrow-clawed crayfish production. Stocking density significantly influenced growth performance (both total length and body mass), molting frequency, frequency of cheliped injury, survival and yield of crayfish for the larval stage. Higher stocking density can increase competition among crayfish for space and access to feed and thus reduce the mean size and growth of crayfish (Mazlum & Eversole, 2005; Romano & Zeng, 2017; Mazlum et al., 2020; Yu et al., 2020) as stated in numerous studies on this species (Garcia-Ulloa et al., 2012; Erol et al., 2017; Ponce-Palafox et al., 2018) and on other crayfish species (Geddes & Smallridge, 1993; McClain, 1995; Whisson, 1995; Jones & Ruscoe, 2000). Although the initial lengths and experimental periods of the crayfish are the same, the most important results that make this study different from the other stock studies we have done are; In this study, 5 per thousand salinity was used and the growth results at the end of the study were very different. Mazlum et al. (2020) found the growth at the lowest stock density as 3.2 cm TL in different stock and feed studies, while in this study, they found the growth as 4.83 cm TL at low stock density and 5 per thousand salinity. Ponce-Palafox et al. (2019) stated that *M. americanum* can grow well at low density and they found an inverse relationship between its size and density. The larger animals have advanced growth when reared together with the smaller juveniles at high density (Mazlum & Eversole, 2004, 2005; Mazlum et al., 2007). Hierarchy and cannibalism over smaller animals by the larger ones affect this case (Mazlum & Eversole, 2004;

Mazlum et al., 2007). On the contrary, in the present study, crayfish production (biomass weight) was the highest at the highest stocking density. Depending on the stock density, the final crayfish body mass ranged between 2.27 and 1.08 g while the average length varied from 4.83 to 3.51 cm (Table 2). In a previous study, Qin et al. (2001) reported that marron survival was not improved by size grading. Similar results have also been reported for freshwater prawns (Tidwell et al., 2003, 2004; Peña-Herrejón et al., 2019). Jones & Ruscoe (2000) observed that the stocking size of red claw crayfish had no significant effect on survival. In the present study, the final crayfish biomass weight was significantly higher in the low density group (10 crayfish/m²) as compared to the other two groups ($p<0.05$) (Table 2). An inverse relationship between stocking density and final size has also been observed in studies with cultured *Macrobrachium rosenbergii* (D'Abramo et al., 1995; Tidwell et al., 1998) and *Procambarus clarkii* (Lutz & William, 1989). Moreover, Mazlum (2007) indicated that the length distribution varied among animals in three different density treatment groups.

Survival Rate (SR)

In the present study, the crayfish survival rate (SR) was found to be inversely proportional to the initial stocking density. The SR was found highest (86.3%) at the lowest density (10 crayfish/m²) and lowest (56.3%) at the highest density (100 crayfish/m²) (Table 3). A similar result was reported for *Macrobrachium malcolmsonii* (Mishra, 2017) and some other species (Turan et al., 2012; Xiaolong et al., 2018; Mazlum et al., 2020). Some researchers found mean survivals of less than 50% (D'Abramo et al., 1985; Celada et al., 1993; Sáez-Royuela et al., 1995; Erol et al., 2017). On the other hand, Nystrom (1994) reported high survival rates (75%) for *P. leniusculus* grown at high stocking density similar to the survival results of the current study. Garza de Yta et al. (2012) reported no significant differences in survival (73.3%) of crayfish juveniles fed with mixed meal diets. This result was also confirmed with the findings of Cortes-Jacinto et al. (2004) for *Cherax quadricarinatus* with the SR ranged from 83.0 to 90.0%. Verhoef & Austin (1999) estimated the average survival rate of *Cherax destructor* juveniles at 78%, but found no trend in density even when densities were as high as 150, 300 and 600 individuals/m². Meanwhile, Brown et al. (1995) noted that the survival was significantly lower for *O. virilis* at the two highest densities (27 and 54 individuals/m²). The generally accepted explanation is that high stocking density can increase space and competition for access to forage resources, thereby reducing the average size and growth of crayfish (Mazlum & Eversole, 2005). The stocking density influences the growth, molting and survival of crayfish with an inverse relationship (Ardahan & Jensen, 2016; Mazlum et al., 2017; Sirin & Mazlum, 2017). The relatively high mortality in high stocking density groups is likely to be due to cannibalism as observed in the present study (Table 2). Previous studies have also confirmed that cannibalism during molting could be the main cause of juvenile mortality in prawns (Wu et al., 2001; Romano & Zeng, 2017). The survival rate is also related to nutrition (Cortes-Jacinto et al., 2004). In intensive culture systems, including hatcheries and nurseries, the animals are completely dependent on additional food. Three factors related to feeding should be considered: quality of feed, amount of feed and its availability to the crayfish. D'Abramo et al. (1985) achieved a relatively good 41% survival for newly hatched *P. leniusculus* for 100 days at a density of 200 individuals/m² when appropriate feed was given. In the current study, the growth and survival of crayfish at consistent densities were better than the findings by D'Abramo et al. (1985), Savolainen et al. (2003), and Erol et al. (2017). The better survival combined with the better growth rate results in a higher yield. It is assumed in the current study that most of the deaths were caused by cannibalism or that individuals with cheliped loss were rapidly eaten by the same species. Besides, missing chelae and molting of crayfish were significantly different among the stocking density groups ($p<0.05$) with crayfish in the high-density group having a lower SR than those in the low-density group. Likewise, according to the measurement periods, the highest SR was observed as 92.2% in the group of 10 crayfish/m² at the 60th day followed by 85.0% (50 crayfish/m²) and 73.6% (100 crayfish/m²).

Specific Growth Rate (SGR)

It was found in the present study that the stocking density had a significant effect on the specific growth

rate (SGR), final weight, final length and weight gain (WG) (Table 2). These values decreased significantly as the stocking density increased. The highest SGR was calculated as 1.16 cm (10 crayfish/m²) and the lowest was found as 0.89 cm (10 crayfish/m²). The SGR was correlated with stocking density in which higher stocking density resulted in a significantly poor growth. Similar findings were reported by Erol et al. (2017), Gao et al. (2017), and Mazlum et al. (2020). A negative relationship between stocking density and body weight was also reported for *Litopenaeus vannamei* by Krishna et al. (2015). Significant differences in SGR of *F. merguiensis* were also reported for different stocking densities (Araneda et al., 2008). Similarly, Williams et al. (1996), Araneda et al. (2008), and Sookying et al. (2011) reported that higher stocking density had negative effects on the growth of shrimp (Mazlum et al., 2017). According to the sampling periods, the highest SGR was obtained as 1.5 cm on the 60th day from the group of 10 crayfish/m² followed by the groups of 50 and 100 crayfish/m² in the current study.

Molting Frequency (MF)

In the current study, crayfish stocking density significantly and negatively affected the molting frequency (MF). The group with the lowest density (10 crayfish/m²) had a significantly higher MF (82.2%) than the other groups (68.0% and 47.0%) (Table 2, Figure 7). It is known that faster growing and frequently molting crayfish are more vulnerable to cannibalism and predation and exposing them to attacks by conspecifics that are often predators (Lutz, 1983; Mazlum & Eversole, 2005; González et al., 2010; Sirin & Mazlum, 2017). Fatihah et al. (2020) indicated that the use of coral as a substrate showed improvement in the total number of molts in *C. quadricarinatus*. In the present study, a similar trend was observed in a way that the group in the lowest density (10 crayfish/m²) had higher weight gain (2.25 g) and higher MF (82.2%) (Table 2). At the early stage of life, crayfish have a higher risk of mortality than in the later stages and this may explain the higher SR of advantaged juveniles compared to that of early stages. Increase in the amount of shelters is advised to obtain higher SR for crayfish.

Cheliped Injury Rates (CIR)

Crayfish density influenced the mean number of injuries per individual, the proportion of injured individuals and the mean number of chelae injuries per individual in the present study ($p<0.05$) (Tables 2 and 3, Figure 4**)**. Cheliped injury rate (CIR) increased from 6.3% to 22.1% with the increase in stock density (Table 3). The CIR value in female crayfish (38.6%) was higher than in males (21.7%) especially at high stocking density. The differences in the CIR values of the male and female crayfish were not significant at the lowest density (10 crayfish/m²) while they were significant at medium and high densities (50 and 100 crayfish/m²) (Figure 4).

The frequency and severity of injuries in crayfish culture were positively correlated with the density. Our results indicated that the number and severity of injuries increased when the stocking density increased. These findings are consistent with the findings of previous research on crayfish density and aggression. High stocking densities cause increased competition, frequency and severity of aggressive interactions among crayfish (Savolainen et al., 2004; Mazlum & Eversole, 2004, 2005; Kouba et al., 2011). Chela autotomy is considered as an indicator of agonistic encounters between animals (Fiegel & Miller, 1995; Mazlum et al., 2007) and make the crayfish more vulnerable to conspecifics. In the present study, a positive correlation (from 0.88 to 0.81) between the numbers of animals with lost cheliped and the stocking density for female and male. This result is in agreement with the finding of Fiegel & Miller (1995) who found a lower SR in *Procambarus clarkii* crayfish lacking one or two chelae caused by increased contact with conspecifics coupled with trauma associated with injury. The cheliped state (i.e., size, damage, deficiency) has been widely monitored for its effects on fighting ability and survival as most of the injured individuals were eaten by survivors (Skurdal et al., 1988; Figiel & Miller, 1995; Savolainen et al., 2004). Moreover, stress caused by crowding and cannibalism can also induce mortality (Yuan et al., 2018). Since aggressive behavior typically results in cheliped injury and loss, it makes sense that higher density causes more fighting and injuries than low density (Figiel & Miller, 1995; Savolainen et al., 2004). The effect of

stocking density on CIR was found to be significant in the present study and this was consistent with previous studies. The CIR in female crayfish (38.6%) was found higher than in males (21.7%) especially at highest density. Mazlum et al. (2017) reported that the missing chelae in *P. leptodactylus* increased mortality due to cannibalism or damage inflicted by conspecifics with unbroken chelae. Our results showed that most of the individuals with injured or lost cheliped were eaten by survivors and the same was observed with the molting process.

Feed Conversion Rate (FCR)

Feed conversion ratio **(**FCR) has always been a prime concern for crayfish culture. It was observed in the current study that crayfish FCR values varied between 1.91 and 4.52 with significant differences according to the stocking density groups (Table 2). The best mean FCR value (1.91) was observed at the lowest density stock group (10 crayfish/m^2). Similarly, Jones & Ruscoe (2000) also highlighted that the FCR was affected by stocking levels. Increased FCR at higher densities suggests that the supplemental feed had a poor direct nutritional value for crayfish. Similar results were also reported in European freshwater crayfish (*Austropotamobius pallipes*), red swamp crayfish (*Procambarus clarkii*) (Wheatly & Ayers, 1995) and American lobster (*H. americanus*) (Zhuang & Ahearn, 1996; Cortes-Jacinto et al., 2003). Similar to the results of the presents study, FCR values above 1.0 were reported in crayfish (Wheatly & Ayers, 1995; Turan et al., 2012). No evidence was found to support the hypothesis that supplemental feed was of poor value during the nursery stage as differences in culture conditions and study durations of both studies need to be considered.

Biomass Yield

A number of factors affect commercial crayfish biomass yield including water quality, food abundance, management practices, and harvest protocol (Eversole et al., 2006). Total biomass yield was also significantly affected by the stocking density in the current study (Table 2). The highest crayfish biomass (431.9 g) was obtained with the highest density group (100 crayfish/m^2) while the lowest biomass (177.2 g) ($p<0.05$) (Figure 6). Eversole et al. (1999) reported that the total biomass is directly related to stock density while Pinto & Rouse (1996), and Jones & Ruscoe (2000) stated that the weight and yield of red-clawed crayfish is inversely proportional to the stock density. In studies with cultured *Macrobrachium rosenbergii* (D'Abramo et al., 1989; Tidwell et al., 1999; Yu et al., 2020) and *Procambarus clarkii* (Lutz & Wolters, 1986; Villagran, 1993), an inverse relationship was also found between the stock density and final size. Similar results have also been reported showing an inverse relationship between stock density and final size (Chattopadhyay et al., 2013; Paul et al., 2016; Vivek et al., 2017). Ackefors et al. (1989) showed that biomass gain was similar with *A. astacus* juveniles at the lowest (250 individuals/m^2) and highest (1000 individuals/m^2) densities. The biomass yield obtained in the present study was much lower than levels obtained at similar densities with *A. astacus* reported by Keller (1988).

Body Size (Length Distribution)

In the present study, it was expected that the stocking density could affect the size distribution of crayfish and the highest density (100 crayfish/m^2) would reduce the size variation by disrupting the agonistic behavior. Although the males were larger than the females, the difference was not statistically significant ($p>0.05$) (Tables 2 and 3). At the end of the experiment, the length distribution varied from 2.0 to 6.2 cm. The distribution in the group with low stock density was more homogeneous with wider distribution than the other two groups (Table 3). However, it was determined that there were no significant differences between the total lengths of the male and female crayfish ($p>0.05$). Thus, it was concluded that the length distribution of crayfish was not significantly influenced by the stocking density. Similarly, Berber et al. (2012) also highlighted that the length distribution of crayfish in various population lakes was found similar for male and female.

CONCLUSION

This study was carried out to determine the effects of three stocking densities (10, 50 and 100 crayfish/m^2) on the growth performance, survival, molting frequency, cheliped injury and feed conversion ratio of the third instars of narrow-clawed crayfish

(*P. leptodactylus*) reared in a flowing brackish water system.

At the end of the study, stocking density affected the length distribution, the proportion of the cheliped injury, biomass, survival rate, molting frequency, growth performance, and feed conversion ratio (FCR) of crayfish. The highest stocking density resulted in an increased total biomass and proportion of the cheliped injury but reduced the survival, growth performance, molting frequency and retention of the appendage. The crayfish grew and survived satisfactorily in 0–5 ppt water salinity condition, which implied that this crayfish species can be cultured commercially in this salinity condition. Based on the results of the study, stocking density of 10 or 50 crayfish/m^2 is recommended for the culture of third instars. For intensive farming to be economically efficient, stocking density of 100 crayfish/m^2 or more during the first four months of the growing season may be recommended, but this density should be lower for survival, growth performance, and proportion of cheliped injury rate. As a result, stock density is often considered a key factor influencing production and is therefore one of the most important management strategies in crayfish culture cycle.

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Compliance with Ethical Standards

Authors' Contributions

YM: Manuscript design, Field sampling, Laboratory experiments, Data analysis, Drafting, Writing, Editing.

CU: Manuscript design, Field sampling, Laboratory experiments, Drafting, Writing.

Both authors drafted, contributed and approved the final version of the article.

Conflict of Interest

The authors declare that there is no conflict of interest.

Ethical Approval

Pontastacus leptodactylus is not an endangered or protected species and there was no need for an ethical approval to perform the experiments involving this species in Türkiye.

Data Availability Statement

The data that support the findings of this study are available under reasonable request.

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The Quality and Germination Rate of Seeds Obtained From Garden Cress Grown Under Water Stress

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ABSTRACT

The objective of this study is to determine the sustainability of seeds obtained from plants subjected to water stress. For this reason, seed quality and germination rates were determined in the seeds obtained from the garden cress plant (Lepidium sativum L.) grown under water stress in both laboratory and greenhouse conditions. In the study, apart from the seeds obtained from the 100% irrigated control plants, seeds from the garden cress irrigated with 50% and 25% water were used. The 1000-grain weight of the garden cress seeds, an indicator of seed quality, varied between 1.975-2.227 g in greenhouse conditions and between 2.121-2.248 g in laboratory conditions, where the changes in both conditions were statistically significant. The germination rates of the garden cress seeds grown under different water stress levels were found to be between 97-99% in greenhouse conditions. It was determined that in laboratory conditions all test subjects had a 100% germination rate. As a result, it was concluded that the seeds obtained from the garden cress plant, which was exposed to water stress during their growing period, continued their vitality despite water stress.

INTRODUCTION

Drought, which has been increasing with rising temperature levels as a result of global warming in recent years, is one of the most important factors affecting plant growth. Rising temperature levels and decreasing precipitation create more stress and risk in food security, especially in tropical and subtropical regions (Erken, 2022). In addition, groundwater pollution caused by nitrate leakage as a result of excessive irrigation is an issue that should be considered in terms of sustainable water management practices (Erken & Yıldırım, 2019).

According to Çırak & Esendal (2006), the optimum demands of the plants must be met for an efficient cultivation. The first stage of cultivation in plant production is the germination of seeds. Adverse ecological conditions, technical errors and problems arising from the structure of the seed at this stage,

however, may adversely affect the germination of seeds and seedling emergence (Karakurt et al., 2010).

The garden cress plant (*Lepidium sativum* L.) is one of the annual herbaceous plants grown in the winter season belonging to the Brassicaceae family. This herb has medicinal properties with its antiscorbutic, depurative and stimulating effects. It also is known that the garden cress plant is used against insect bites and as an insect-repellent when sprayed (Kumari & Patel, 2013). Another feature of the garden cress is that it can grow under any climate and soil characteristics (Wadhwa et al., 2012).

Plants, however, can be exposed to adverse conditions starting from the seed, which is the initial stage of development. In this case, both the germination and development of the seed are affected. For this purpose, in order to determine the reproducibility of the garden cress seeds, germination tests were carried out on seeds obtained from plants under water stress. This research was carried out on seeds obtained from the garden cress plants grown in greenhouse and laboratory conditions under water stress.

MATERIAL AND METHODS

This research was carried out in Çanakkale Onsekiz Mart University, Faculty of Agriculture, Department of Agricultural Structures and Irrigation, Plant Stress Monitoring and Thermography Laboratory in 2022. In obtaining the cress seeds, which are the subject of the research, two different water restrictions (50% irrigation, 25% irrigation) were applied besides the control (full irrigation) plants. The experiment was carried out in 8 replications using 10-liter pots. The water restrictions were applied in controlled conditions (at 25°C under 14 hours ~ 54 µE light and 10 hours of dark, and 55-60% relative humidity (Al-Sammarraie et al., 2020). After the flower stalk began to form in the water-stressed garden cress plant, water restriction continued in two different locations. Water restriction was continued until the seeds matured, both in a controlled laboratory condition and in a plastic-covered greenhouse, by dividing the 8 pots used in the research into two, in 4 replications.

After the garden cress seeds matured, the number of branches (pieces), branch length (cm), capsule length (cm) and 1000-grain weight (g) were determined. After some morphological features of the plants were determined, the seeds were collected from the middle of the capsules and preserved for germination tests. In addition, the collected seeds were counted with 100x4 replications. At the end of this counting, 1000-grain weights (g) of the seeds were calculated. In the obtained cress seeds, 50 seeds were taken into germination tests with 3 replications in each subject. All germination tests were performed in petri dishes with a diameter of 10 cm. Filter paper was placed in petri dishes and 50 seeds were placed in such a way that they did not come into contact with each other for each application. Seeds with a radicle length of 2 mm were counted as germinated at the same time every day. At the end of the experiment, the germination percentage and average germination times were measured.

The germination percentage was calculated as (%) according to Bewley & Black (1994).

Germination percentage was calculated using the following equation (1):

$$GP(\%) = \left(\frac{\sum n_i}{N}\right) \times 100 \quad (1)$$

where GP is the germination percentage (%), n_i is the time of germination (day), N is the total number of seeds put in the test.

Average germination time was calculated using the following equation (2):

$$MGT(days) = \frac{\sum(t_i \times n_i)}{\sum n_i} \quad (2)$$

where MGT is the mean germination time (days), t_i is the time elapsed since the beginning of the test (days), n_i is the number of germinated seeds each day $t(i)$.

Germination trials continued until the end of the 4th day. At the end of the experiment, the hypocotyl length (from root collar to cotyledon leaves) and radicle length (from root collar to root tip) were measured with a digital caliper by selecting plants whose seed coats were separated.

Table 1. Some morphological data from the harvested seeds

Treatment	Number of Branches (piece)	Branch Length (cm)	Capsule Size (cm)	1000 Seed Weight (g)
Green House 100% irrigation	9.75 ± 0.50 Ba	52.00 ± 2.94 Aa	22.00 ± 1.63 Ba	1.975 ± 0.12 Bb
Green House 50% irrigation	8.25 ± 0.50 Bb	42.75 ± 2.22 Ab	14.75 ± 0.96 Bb	2.086 ± 0.01 Bb
Green House 25% irrigation	4.50 ± 0.58 Bc	22.00 ± 1.63 Ac	8.75 ± 0.96 Bc	2.227 ± 0.07 Ba
Lab 100% irrigation	11.00 ± 1.16 Aa	49.50 ± 1.92 Aa	24.50 ± 2.52 Aa	2.198 ± 0.02 Ab
Lab 50% irrigation	9.25 ± 0.98 Ab	44.00 ± 2.83 Ab	16.00 ± 1.63 Ab	2.121 ± 0.06 Ab
Lab 25% irrigation	5.00 ± 0.82 Ac	20.00 ± 1.63 Ac	9.50 ± 1.00 Ac	2.248 ± 0.04 Aa
	*p=0.011	*p=0.255	*p=0.030	*p=0.003
	**p= 0.000	**p= 0.000	**p= 0.000	**p= 0.000

Note: *The large letters show the statistical differences ($p<0.05$) between greenhouse and laboratory conditions. **The small letters show the statistical differences ($p<0.05$) between different water treatments.

Table 2. Germination test results

Treatment	Germination Percentage (%)	Average Germination Time (day)	Hypocotyl Length (mm)	Radicle Length (mm)
Green House 100% irrigation	98.5±1.00Ba	3	39.52±1.67B	11.92±0.15ns
Green House 50% irrigation	87.5±6.61Bb	3	33.37±1.64B	11.26±0.47ns
Green House 25% irrigation	97.5±2.52Ba	3	37.61±5.02B	9.82±1.59ns
Lab 100% irrigation	100.0±0.00A	3	41.57±0.54A	12.08±0.15ns
Lab 50% irrigation	99.0±1.16A	3	42.62±4.62A	11.36±0.66ns
Lab 25% irrigation	99.0±1.16A	3	40.24±3.58A	10.91±0.39ns
	*p=0.001	ns	*p=0.009	*p=0.382
	**p=0.200	ns	**p=0.268	**p=0.270

Note: *The large letters show the statistical differences ($p<0.05$) between greenhouse and laboratory conditions. **The small letters show the statistical differences ($p<0.05$) between different water treatments.

Statistical differences of the measured parameters among different irrigation levels of the cultivated Garden Cress plant were estimated using One-Way ANOVA the Tukey Multiple Comparison test, where p-value of <0.05 was considered to be statistically significant. Minitab 19 was used as a software for the statistical analysis.

RESULTS AND DISCUSSION

The number of branches (pieces) and length (cm), capsule length (cm) and 1000-grain weight values obtained at the end of the research are given in Table 1. The highest number of branches in the garden cress grown in greenhouse and laboratory conditions were obtained from 100% control plants grown in the laboratory. When the plants measured for seed yield both in the greenhouse and in the laboratory are evaluated together, it is seen in Table 1 that the number of branches, the length of the branches and the length of the capsules statistically significantly decreased with reduced amount of irrigation water. According to the results of the experiments carried out under greenhouse conditions, the 1000-grain weights were determined as 1.975 in the control treatment, while the highest 1000-grain weight was obtained from the 25% irrigation treatment under heavy stress. Seeds grown under completely controlled conditions were determined at similar weights (2.198; 2.121; 2.248 g) in each trial (Table 1). It has been reported that 1000 grain weight of garden cress plant is between 1.6 – 2.0g (Anonymous, 2022). Compared with the results of the study, it was determined that the 1000-grain weight of the seeds obtained from the water-stressed cress plant was higher.

Germination tests were carried out on the garden cress seeds obtained at the end of the trials carried out in two different locations. The germination rates (%), average germination day and hypocotyl and radicle lengths after germination are given in Table 2. The germination power of cress seeds grown by applying water stress under controlled conditions was determined as 100%. The germination rate of cress seeds grown in greenhouse conditions under water stress varied between 97-99%. These differences were found to be statistically insignificant. Germination rate of garden cress exposed to water stress in both conditions were found to be over 95% and it was determined that water stress had no statistically significant effect on seed viability. Tang et al. (2010), applied different amounts of water stress to the seeds of *Lepidium perfoliatum* L. from the Brassicaceae family. According to the results of the study, it was stated that the germination rate of the seeds decreased significantly when they were exposed to water stress during the germination stage. However, when we look at the results of our study, it is seen that the viability and germination rates of cress seeds grown by applying water stress did not decrease significantly.

After germination started in petri dishes, garden cress seeds reached the maximum germination rate in 3 days (Table 2). Compared to other plants, the germination time of broccoli, which is in the same family as cress, is 10 days (Akyurt et al., 2011), and in another study it was stated that white cabbage (*Brassica oleracea* L. var. capitata cv. Bafra), black sea kale (*Brassica oleracea* L. var. acephala cv.), red cabbage (*Brassica oleracea* L. var. rubra cv. Möhrenkopf), Savoy cabbage (*Brassica oleracea* L. sabauda cv. Chieftain) seed germination times lasted 10 days (Ayhan & Ugur, 2011).

At the end of the germination tests, garden cress shoots separated from the seed coat were measured. When the hypocotyl lengths of garden cress seeds obtained by applying water stress in laboratory conditions were examined (Table 2), results were close to each other. The hypocotyl lengths of the seeds grown in greenhouse conditions after germination varied between 33.37-39.52 mm. Similar results were obtained with radicle lengths varying between 9.82 and 12.08 mm in cress seeds grown both in greenhouse and in vitro. Barış & Ünal (2021), in their study on broccoli, determined the hypocotyl and radicle lengths as approximately 75 and 45 mm, respectively. Post-germination measurements were carried out at the end of 9 days. In our study, the measurements were carried out on the 4th day after sowing, since full germination was completed in 3 days. The difference between the two studies is thought to be due to the measured day.

CONCLUSION

In this study, the viability and germination rates of seeds obtained from garden cress plant (*Lepidium sativum* L.) that were subjected to water stress at two different levels (50%, 25% irrigation) were determined. In previous studies, there are trials in which different levels of water stress are applied in both growing and seed stages. With these studies, it is stated by many researchers that yield and quality decrease with water stress in general. However, there are not many studies

examining the quality of seeds with the aim of maintaining plant production by applying water stress. Therefore, this study presented results on whether the viability of seeds obtained from plants exposed to water stress continued. According to these results, it was determined that the germination rate and strength of garden cress seeds exposed to adverse conditions in terms of water restriction were not affected by these conditions.

Compliance with Ethical Standards

Conflict of Interest

The author declares that there is no conflict of interest.

Ethical Approval

For this type of study, formal consent is not required.

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Relationship Between the Risk of Coronary Heart Disease and Nutritional Status of Adult

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ABSTRACT

Cardiovascular diseases (CVD) have the highest prevalence among non-communicable diseases so prevention from CVD is very important. The aim of this study was to determine the risk of cardiovascular events in adults over the next 10 years with the Framingham Risk Score (FRS) and to evaluate the relationship between this risk and the nutritional patterns of individuals. This study was conducted with a total of 238 individuals (78 males, 160 females) aged between 30-64 years. Energy, micro and macronutrients intake levels of the participants according to FRS and gender were determined by taking a daily food consumption record with a 24-hour retrospective reminder method. Participants' ten-year coronary disease risk was assessed with FRS which was classified as low risk (<10%), moderate risk (10-20%), and high risk (>20%). While 44.9% of the men had moderate/high coronary disease risk, all of women had low risk. Energy, many macronutrients and micronutrients intake levels of men with low risk of coronary heart diseases (CHD) were higher than women. FRS values of all individuals participating in the research were related to energy, carbohydrate (g, %), protein (g), total fat (%), mono-unsaturated fatty acid/MUFA (g), poly-unsaturated fatty acid/PUFA (%), riboflavin, sodium, and zinc. Of these parameters, total fat and PUFA were negatively correlated, while the others were positively correlated. The parameter that most affected the FRS value was carbohydrate (g). These results clearly demonstrate the relationship between nutrition and CVD risk. Therefore, identifying individuals with medium/high FRS and taking nutritional initiatives are important in reducing the CVD prevalence and health costs.

INTRODUCTION

Chronic diseases that are rapidly increasing in prevalence are among the leading causes of mortality and morbidity. It has been reported that 40 million of 56 million deaths that occurred worldwide in 2015 were due to non-communicable diseases (NCDs), and 48% of these deaths occurred in low or middle-income countries. NCDs such as heart disease, stroke, cancer, chronic respiratory diseases, and diabetes are among the leading causes of mortality (WHO, 2021).

Unhealthy dietary habits, which are among the modifiable risk factors of cardiovascular diseases with high prevalence (CDC, 2019), affect many other risk factors that may affect cardiometabolic health such as heart disease and stroke and create significant economic burdens (Micha et al., 2017). Saturated fatty acid (SFA) and carbohydrate contents are high, fiber content is low nutrition; increases intravascular plaque regression, cardiovascular diseases (CVD) morbidity, and mortality. Consumption of high SFA increases LDL-C levels while decreasing HDL-C levels and thus adversely affects heart health (Heart Foundation, 2019). The fiber content of the diet is also an effective risk factor for CVD. It has been reported that dietary fiber plays an effective role in the protection of cardiometabolic health as it decreases high blood glucose and cholesterol levels, and shows anti-inflammatory and antihypertensive properties (Gunashekar et al., 2017). It is possible to reduce the risk of CVD and prevent its development by interventions for nutrition and other cardiovascular risk factors (Buttar et al., 2005). The aim of this study was to determine the risk of cardiovascular events in adults over the next 10 years with the Framingham Risk Score (FRS) and to evaluate the relationship between this risk and the nutritional patterns of individuals.

MATERIAL AND METHODS

Sample Size and Selection

This study was conducted in accordance with the Helsinki Declaration principles with a total of 238 individuals [78 males (32.8%) and 160 females (67.2%)] with a mean age of 48.5±9.80 years who applied to a Family Health Center. Individuals with systemic disorders such as CVD, SVD, complications of diabetes, or severe hepatic, renal or hematological diseases were not included in the study. The sample size of the study was calculated by using one-way variance analysis with 0.05 significance level and 0.80 power. Ethics Committee Approval was obtained in order to conduct the research from Ankara University Clinical Research Ethics Committee.

Data Collection and Evaluation

The food consumption status of the participants was determined by taking a daily food consumption record with a 24-hour dietary recall (24HR). Food and Food Photography Catalog was used for the accurate evaluation of the amount of food consumed (Rakıcıoğlu et al., 2009). Computer-Aided Nutrition Program (BeBis), Nutrition Information System was used to calculate the energy and nutrient intake obtained from the amount of food consumed. The data obtained were evaluated according to Dietary Reference Intakes (DRI). In this evaluation, energy and nutrient intake of individuals were classified as <67.0% "insufficient", 67.0%-133.0% "sufficient", >133.0% "over consumption" according to ±33.0% cut-off point. (National Research Council, 1986).

Evaluation of Risk of Coronary Heart Disease

FRS was used to determine the ten-year coronary disease risk of the participants. 10-year coronary event risks of individuals were calculated with the total score calculated according to values and categories (NIH, 2013). FRS was classified as low risk (<10%), moderate risk (10-20%), and high risk (>20%) (Kannel et al., 1976).

Statistical Evaluation of Data

The data were analyzed with the SPSS statistical package program. Descriptive statistics are shown as mean ± standard deviation (SD) for variables with normal distribution, and median and interquartile range (IQR) values for variables with the non-normal distribution. The relationship between two categorical variables was evaluated by the Chi-Square test. In the study, if normal distribution assumptions are provided independent t-test was used to determine whether there is a statistically significant difference between the

Table 1. Mean, SD, median and IQR values of energy and nutrient intake of individuals according to FRS classification (%)

	<10%					10-20%£	>20%£		
	Male (n:43)	Female (n:160)	Total (n:203)			Male (n:28)	Male (n:7)		
Energy and nutrients	$\bar{x}$±SD Median (IQR)	$\bar{x}$±SD Median (IQR)	$\bar{x}$±SD Median (IQR)	t/z	p	$\bar{x}$±SD Median (IQR)	$\bar{x}$±SD Median (IQR)	χ_e^2/F_e χ_t^2/F_t	p_e p_t
Energy (kcal)	2075.5±719.22	1589.8±471.09	1692.7±567.30	4.194	0.000[b*]	1967.1±569.34	1917.6±399.7	0.338 3.307	0.714[β] 0.038[β*]
Carbohydrate (g)	251.5±104.0	193.6±59.91	205.8±75.07	3.498	0.001[b*]	220.5 (171.4)	210.5 (43.4)	0.047 8.207	0.977[α] 0.017*[α]
Carbohydrate (%)	49.7±10.59	50.4±9.61	50.3±9.81	-0.404	0.686[b]	52.3±9.63	51.2±9.51	0.572 0.579	0.567[β] 0.561[β]
Protein (g)	61.7 (28.7)	48.1 (23.8)	50.9 (24.7)	-3.442	0.001[a*]	59.4 (27.3)	60.7 (45.9)	0.704 5.086	0.703[α] 0.079[α]
Protein (%)	12.0 (4.0)	13.0 (4.0)	13.0 (4.0)	-0.116	0.907[a]	13.0 (5.0)	13.0 (7.0)	0.659 0.648	0.719[α] 0.723[α]
Total fat (g)	80.8 (44.2)	59.7 (35.8)	66.4 (38.6)	-3.674	0.000[a*]	70.9 (42.5)	60.1 (44.5)	1.129 1.894	0.569[α] 0.388[α]
Total fat (%)	36.7±8.62	36.0±9.01	36.2±8.91	0.417	0.677[b]	34.6±9.77	34.0±8.52	0.601 0.564	0.551[β] 0.570[β]
SFA (%)	8.8 (5.3)	10.0 (4.6)	9.8 (4.7)	-0.848	0.396[a]	9.1 (5.0)	8.0 (7.7)	0.056 0.249	0.972[α] 0.883[α]
MUFA (%)	13.0±4.77	12.3±4.13	12.5±4.27	0.938	0.349[b]	11.6±2.82	12.1±2.87	1.037 0.542	0.360[β] 0.583[β]
PUFA (%)	11.9±5.20	11.3±5.47	11.4±5.41	0.699	0.486[b]	8.7 (7.7)	8.6 (8.0)	1.984 1.335	0.371[α] 0.513[α]
Omega-3 (g)	1.3 (1.1)	1.0 (0.8)	1.0 (1.0)	-2.439	0.015[a*]	0.9 (0.6)	0.9 (0.7)	4.117 0.359	0.128[α] 0.836[α]
Omega-6 (g)	23.0 (26.0)	17.0 (13.9)	18.1 (15.4)	-2.822	0.005[a*]	18.1 (22.8)	14.6 (15.7)	1.450 0.401	0.484[α] 0.818[α]
Cholesterol (mg)	209.5 (174.9)	144.0 (193.5)	152.9 (195.8)	-1.810	0.070[a]	123.8 (153.1)	118.0 (320.5)	1.680 0.114	0.432[α] 0.944[α]
Fiber (g)	25.2±12.56	22.5±8.78	23.0±9.73	1.354	0.182[b]	24.2±10.92	25.3±7.52	0.070 0.321	0.932[β] 0.726[β]

Note: £ Since there were no female individuals in this group, the table was not included. χ_e^2, F_e and p_e were used to evaluate men individuals; χ_t^2, F_t and p_t were used to evaluate all individuals in different risk groups. [a] Mann Whitney-U test; [b] Independent-t test [α] Kruskal Wallis test; [β] One Way ANOVA test was used. *p<0.05. SFA: saturated fatty acid, MUFA: mono-unsaturated fatty acid, PUFA: poly-unsaturated fatty acid.

qualitative variables, if not provided Mann-Whitney U test was used. The difference between the quantitative variables with normal distribution was determined by Pearson Correlation, and variables with non-normal distribution were determined by the Spearman Correlation Coefficient. Statistically significant difference situation between the categories of quantitative variables with ≥3 categories was evaluated with One Way ANOVA test if normal distribution assumptions were provided; if not Kruskal Wallis test was used. In all statistical tests, the confidence interval was accepted as 95.0% and it was evaluated at p<0.05 significance level.

RESULTS

Daily Energy and Nutrient Intakes of Individuals

Energy, carbohydrate, protein, total fat, omega-3, and omega-6 fatty acid intake levels of men with low risk of CHD were higher than women (p<0.05). When all the participants were compared according to FRS classification, there was a difference in energy and carbohydrate intake (p<0.05). As a result of the statistical evaluations, it was found that this difference was caused by the difference between low and medium-risk groups (Table 1).

Table 2. Mean, SD, median and IQR values of micronutrient intake according to FRS classification (%)

	<10%					10-20%[£]	>20%[£]		
	Male (n:43)	Female (n:160)	Total (n:203)			Male (n:28)	Male (n:7)		
Micronutrients	$\bar{x}$±SD Median (IQR)	$\bar{x}$±SD Median (IQR)	$\bar{x}$±SD Median (IQR)	t/z	p	$\bar{x}$±SD Median (IQR)	$\bar{x}$±SD Median (IQR)	χ_e^2/F_e χ_t^2/F_t	p_e p_t
Vitamin A (mcg)	683.9 (898.7)	628.7 (511.0)	632.4 (538.5)	-1.044	0.297[a]	585.3 (405.4)	506.8 (800.8)	1.686 1.080	0.430[α] 0.583[α]
Thiamine (mg)	0.7 (0.3)	0.6 (0.3)	0.6 (0.3)	-1.606	0.108[a]	0.7±0.28	0.8±0.23	0.135 3.001	0.874[β] 0.223[α]
Riboflavin (mg)	0.9 (0.8)	0.9 (0.4)	0.9 (0.4)	-2.418	0.016[a]*	1.0 (0.3)	1.0 (0.7)	0.055 4.092	0.055[α] 0.129[α]
Niacin (mg)	18.0 (10.8)	14.4 (7.8)	15.3 (9.0)	-3.401	0.001[a]*	18.0 (8.4)	17.7 (11.6)	0.400 4.034	0.819[α] 0.133[α]
Pyridoxine (mg)	1.1 (0.6)	1.0 (0.5)	1.0 (0.5)	-1.513	0.130[a]	1.1 (0.6)	1.2 (0.6)	1.468 2.277	0.480[α] 0.320[α]
Vitamin C (mg)	76.3 (84.7)	80.3 (85.4)	78.3 (85.5)	-0.626	0.531[a]	72.1 (68.7)	86.3 (82.3)	0.802 0.509	0.670[α] 0.775[α]
Vitamin E (mg)	23.6 (14.9)	16.1 (13.9)	17.9 (15.3)	-3.499	0.000[a]*	17.6 (21.6)	20.3 (8.2)	1.842 0.799	0.398[α] 0.671[α]
Sodium (mg)	4145.2 (2123.0)	3215.8 (1759.8)	3338.6 (1907.4)	-3.573	0.000[a]*	3949.3 (2045.8)	3576.5 (1818.6)	1.605 6.923	0.448[α] 0.031[a]*
Potassium (mg)	1940.8 (1147.9)	1960.4 (1064.6)	1955.0 (1131.9)	-0.420	0.675[a]	1810.6 (887.1)	2280.9 (748.9)	1.003 1.053	0.606[α] 0.591[α]
Calcium (mg)	584.4 (381.5)	530.5 (295.5)	539.9 (310.4)	-1.190	0.234[a]	563.1 (363.1)	561.9 (376.9)	0.064 0.837	0.968[α] 0.658[α]
Phosphorus (mg)	974.4 (627.1)	863.4 (428.6)	880.1 (438.0)	-2.348	0.019[a]*	919.2 (455.4)	1232.9 (402.6)	1.436 3.293	0.488[α] 0.193[α]
Magnesium (mg)	218.8 (147.3)	199.0 (117.4)	203.5 (119.6)	-1.357	0.175[a]	205.4 (116.9)	233.2 (177.5)	1.724 1.288	0.422[α] 0.525[α]
Zinc (mg)	8.8 (5.6)	6.8 (3.8)	7.2 (4.0)	-3.782	0.000[a]*	9.1±3.89	10.1±4.12	0.380 5.205	0.685[β] 0.074[α]

Note: [£] Since there were no female individuals in this group, the table was not included. χ_e^2, F_e and p_e were used to evaluate men individuals; χ_t^2, F_t and p_t were used to evaluate all individuals in different risk groups. [a] Mann Whitney-U test; [b] Independent-t test; [α] Kruskal Wallis test; [β]One Way ANOVA test was used. *p<0.05.

Vitamin E, riboflavin, niacin, sodium, phosphorus, and zinc intake of men with low risk of CHD were higher than female subjects (p<0.05). When all individuals included in the study were evaluated according to CHD risk status, there was a difference in the amount of sodium intake (p<0.05). As a result of statistical evaluations, it was found that this difference was caused by the difference between intake amounts of individuals with low and medium risk (Table 2).

According to the FRS classification and DRI of individuals participating in the research, their levels of meeting their daily energy and nutrients needs are given in Table 3. There was a statistically significant difference between the levels of fiber, thiamine, riboflavin, niacin, vitamin C, vitamin E, sodium, and calcium in men and women at low risk of CHD; omega-3 fatty acid, thiamine, riboflavin, niacin, and vitamin C requirements in all risk groups evaluated in terms of CHD (p<0.05). Since the meeting levels of phosphorus and potassium requirements are high by all individuals and therefore no analysis can be made (Table 3).

According to Table 4, FRS values of men at low risk for CHD are associated with omega-3 fatty acid consumption; FRS values of women are correlated with carbohydrate (%), total fat (%), SFA (%), PUFA (g, %) and omega-6 fatty acid consumption; FRS values of all individuals at low risk are related to energy, carbohydrate (g) and SFA (%) consumption (p<0.05). FRS values of men at medium risk for CHD have a significant correlation with total fat (g) (p<0.05). It was found that FRS values of all individuals participating in the research were related to energy, carbohydrate (g, %), protein (g), total fat (%), MUFA (g), and PUFA (%) (p<0.05) (Table 4).

It was found that FRS values of all individuals at low risk for CHD were associated with riboflavin and sodium; FRS values of individuals at medium risk were associated with niacin, pyridoxine, vitamin C, potassium, and magnesium. FRS values of all individuals participating in the study were found to be related to riboflavin, sodium, and zinc (p<0.05) (Table 5).

Table 3. Levels of individuals meeting their daily energy and nutrient requirements according to FRS classification (%) and DRI

Energy and nutrients	<%10				%10-20[£]	>%20[£]		
	Male (n:43)	Female (n:160)	Total (n:203)	χ^2 p	Male (n:28)	Male (n:7)	χ_e^2 χ_t^2	p_e[b] p_t[b]
	%	%	%		%	%		
Energy (kcal)								
Insufficient	18.6	29.4	27.1	4.952	7.2	-	5.477	0.215
Over consumption	18.6	4.4	7.4	0.084[a]	21.4	-	2.618	0.586
Carbohydrate (%)								
Insufficient	30.2	30.6	30.5	0.073	21.4	42.8	3.584	0.441
Over consumption	4.7	3.8	4.0	0.964[a]	10.7	14.4	6.001	0.157
Protein (%)								
Insufficient	23.3	19.4	20.2	1.909	28.6	14.4	2.132	0.885
Over consumption	2.3	0.6	1.0	0.344[b]	-	-	2.630	0.711
Total fat (%)								
Insufficient	2.3	3.8	3.4	0.207	7.1	-	3.560	0.463
Over consumption	55.8	55.0	55.2	0.902[a]	42.9	28.6	4.530	0.286
SFA (%)								
Insufficient	23.3	18.1	19.2	2.446	25.0	28.6	1.331	0.872
Over consumption	37.2	50.6	47.8	0.294[a]	46.4	42.8	1.259	0.898
MUFA (%)								
Insufficient	48.8	46.9	47.3	0.888	57.2	42.8	3.980	0.415
Over consumption	27.9	23.1	24.1	0.641[a]	10.7	14.4	3.327	0.504
PUFA (%)								
Insufficient	16.3	21.2	20.2	0.633	32.1	28.6	3.962	0.410
Over consumption	62.8	56.9	58.1	0.729[a]	42.9	42.8	3.821	0.402
Omega-3 (g)								
Insufficient	27.9	29.4	29.1	0.210	57.1	71.4	8.370	0.062
Over consumption	23.3	25.6	25.1	0.900[a]	14.3	-	12.128	0.010*
Omega-6 (g)								
Insufficient	16.3	20.0	19.2	0.302	21.4	-	5.872	0.183
Over consumption	58.1	55.6	56.2	0.860[a]	42.9	28.6	7.753	0.076
Fiber (g)								
Insufficient	55.8	25.6	32.0	14.240	46.4	42.8	3.516	0.450
Over consumption	11.6	17.5	16.3	0.001[a]*	3.6	-	5.046	0.252
Vitamin A (mcg)								
Insufficient	44.2	36.3	37.9	1.602	53.6	57.1	3.467	0.489
Over consumption	25.6	23.1	23.7	0.449[a]	10.7	28.6	5.093	0.259
Thiamine (mg)								
Insufficient	100.0	31.9	46.3	30.853	100.0	100.0	-[d]	-[d]
Over consumption	-	7.5	5.9	0.000[b]*	-	-	18.026	0.001*
Riboflavin (mg)								
Insufficient	100.0	31.9	46.3	63.262	100.0	100.0	-[d]	-[d]
Over consumption	-	7.5	5.9	0.000[a]*	-	-	39.195	0.000*
Niacin (mg)								
Insufficient	9.3	-	2.0	92.450	3.6	14.3	2.428	0.640
Over consumption	39.5	100.0	87.2	0.000[b]*	32.1	28.6	49.625	0.000*
Pyridoxine (mcg)								
Insufficient	23.3	38.8	35.5	3.651	42.8	14.3	4.724	0.298
Over consumption	11.6	10.6	10.8	0.161[a]	3.6	-	3.384	0.463

Table 3. (continued)

Energy and nutrients	<%10				%10-20£	>%20£		
	Male (n:43)	Female (n:160)	Total (n:203)	χ^2 p	Male (n:28)	Male (n:7)	χ_e^2 χ_t^2	p_e[b] p_t[b]
	%	%	%		%	%		
Vitamin C (mg)								
Insufficient	11.6	28.1	24.6	18.358	3.6	-	2.069	0.696
Over consumption	76.8	40.0	47.8	0.000[a]*	85.7	100.0	19.564	0.000*
Vitamin E (mg)								
Insufficient	39.5	63.8	58.6	12.413	60.7	42.9	4.817	0.280
				0.002[a]*			5.010	0.251
Over consumption	14.0	3.1	5.4		14.3	-		
Sodium (mg)								
Insufficient	-	-	-	5.404	-	-	3.166	0.298
				0.020[c]*			0.435	0.733
Over consumption	100.0	93.1	94.6		92.9	100.0		
Calcium (mg)								
Insufficient	67.4	87.5	83.2	11.816	67.9	71.4	1.631	0.903
				0.002[b]*			6.447	0.178
Over consumption	4.7	-	1.0		-	-		
Magnesium (mg)								
Insufficient	69.8	56.9	59.6	3.336	85.7	71.4	3.084	0.520
				0.189[a]			7.284	0.088
Over consumption	9.3	7.5	7.9		3.6	-		
Zinc (mg)								
Insufficient	30.2	26.3	27.1	0.300	32.1	14.3	1.733	0.807
				0.861[a]			1.599	0.816
Over consumption	14.0	13.7	13.8		7.2	14.3		

Note: £ Since there were no female individuals in this group, the table was not included. χ_e^2 and p_e were used to evaluate men individuals, χ_t^2 and p_t were used to evaluate all individuals in different risk groups. [a] Pearson chi-square test; [b] Fisher exact chi-square test; Likelihood chi-square test was used. *p<0.05. [d] The evaluation could not be done because there was not enough number of individual.

Linear regression of parameters with significant correlation in Table 5 is given Table 6. While the FRS values of the participants were statistically significantly explained by the level of energy (4.3%), carbohydrate (g) (6.4%), protein (1.8%), riboflavin (2.2%) and zinc (2.8%) intake, the highest level of explanation among these values belonged to carbohydrates (p<0.05). It was also determined that one gram increase in carbohydrate intake will cause an increase of 0.252 in the FRS value (%) (Table 6).

DISCUSSION

Coronary Heart Disease Risk

The FRS values of men and women participating in the study were 9.7±6.87% and 1.8±2.10%, respectively (p<0.05). While 55.1% of male individuals are low; 35.9% have moderate and 9.0% high CVD risk, all women have low CVD risk. In the study of Meseri et al. (2014) with 10878 individuals, 67.4% of the participants have low, 23.2% are medium and 9.4% are high CVD risk. In the study conducted by Tekkeşin et al. (2011) it has been determined that 57.9% and 46.7% of men and women have low, 32.7% and 48.7% have medium; 9.4% and 4.6% have high CVD risk respectively. According to these results, the rate of individuals with medium risk is at a considerable level. This indicates that improving risk factors is an important requirement for the prevention of CVD.

Daily Energy and Macronutrient Intake

The increasing burden of CVD has increased the need for effective strategies to prevent disease development and health disease. Besides being one of the most important behavioral factors affecting health, nutrition explains approximately one-third of global

Table 4. Correlation between FRS values (%), energy and nutrient uptake of individuals

Energy and nutrients	<10%			10-20%£	>20%£		
	Male (n:43)	Female (n:160)	Total (n:203)	Male (n:28)	Male (n:7)		
	r	r	r	r	r	r_e	r_t
	p	p^{β}	p	p^{β}	p^{β}	p_e^{β}	p_t^{β}
Energy (kcal)	0.246	-0.014	0.214	-0.310	-0.214	0.007	0.223
	0.111$^{\alpha}$	0.856	0.002$^{\alpha}$*	0.108	0.645	0.951	0.001*
Carbohydrate (g)	0.270	0.118	0.259	-0.297	-0.321	0.069	0.270
	0.080$^{\beta}$	0.138	0.000$^{\alpha}$*	0.125	0.482	0.546	0.000*
Carbohydrate (%)	0.048	0.229	0.097	-0.007	-0.179	0.082	0.156
	0.762$^{\alpha}$	0.004*	0.169$^{\alpha}$	0.971	0.702	0.475	0.016*
Protein (g)	0.229	-0.023	0.114	-0.254	0.000	0.011	0.169
	0.139$^{\beta}$	0.775	0.105$^{\beta}$	0.192	1.000	0.923	0.009*
Protein (%)	-0.117	-0.006	-0.032	0.040	0.054	0.008	-0.013
	0.456$^{\beta}$	0.942	0.655$^{\beta}$	0.841	0.908	0.943	0.839
Total fat (g)	0.187	-0.127	0.050	-0.383	0.107	-0.091	0.086
	0.229$^{\beta}$	0.109	0.480$^{\beta}$	0.044*	0.819	0.427	0.188
Total fat (%)	-0.040	-0.239	-0.118	-0.029	0.143	-0.117	-0.162
	0.800$^{\alpha}$	0.002*	0.094$^{\alpha}$	0.883	0.760	0.308	0.013*
SFA (g)	0.265	-0.105	0.034	-0.171	-0.286	0.034	0.083
	0.086$^{\beta}$	0.186	0.630$^{\beta}$	0.385	0.535	0.766	0.201
SFA (%)	0.025	-0.156	-0.138	0.076	-0.179	0.020	-0.119
	0.876$^{\beta}$	0.049*	0.049$^{\beta}$*	0.702	0.702	0.859	0.067
MUFA (g)	0.069	-0.058	0.099	-0.364	-0.179	-0.140	0.139
	0.661$^{\beta}$	0.466	0.160$^{\beta}$	0.057	0.702	0.222	0.032*
MUFA (%)	-0.087	-0.047	-0.040	0.039	0.143	-0.082	-0.051
	0.581$^{\beta}$	0.558	0.566$^{\alpha}$	0.844	0.760	0.474	0.434
PUFA (g)	0.020	-0.177	-0.037	-0.284	0.500	-0.153	-0.014
	0.901$^{\alpha}$	0.025*	0.602$^{\beta}$	0.144	0.253	0.181	0.826
PUFA (%)	-0.194	-0.221	-0.129	-0.191	0.607	-0.206	-0.166
	0.214$^{\alpha}$	0.005*	0.066$^{\alpha}$	0.329	0.148	0.070	0.010*
Omega-3 (g)	0.385	-0.082	0.071	-0.294	-0.342	-0.120	0.032
	0.011$^{\beta}$*	0.302	0.313$^{\beta}$	0.129	0.452	0.297	0.624
Omega-6 (g)	-0.031	-0.180	-0.050	-0.275	0.571	-0.156	-0.023
	0.842$^{\alpha}$	0.023*	0.475$^{\beta}$	0.156	0.180	0.172	0.728
Cholesterol (mg)	0.022	0.014	0.068	-0.257	-0.071	-0.143	0.034
	0.887$^{\beta}$	0.865	0.332$^{\beta}$	0.187	0.879	0.212	0.602
Fiber (g)	0.178	-0.037	0.055	-0.280	-0.071	0.044	0.043
	0.253$^{\beta}$	0.641	0.435$^{\alpha}$	0.149	0.879	0.703	0.505

Note: £ Since there were no female individuals in this group, the table was not included. r_e and p_e were used to evaluate men individuals, r_t and p_t were used to evaluate all individuals in different risk groups. $^{\alpha}$ Pearson correlation; $^{\beta}$ Spearman correlation test was used. *p<0.05.

Table 5. Correlation between FRS values (%) and micronutrient uptake of individuals

Micronutrients	<10%			10-20%£	>20%£		
	Male (n:43)	Female (n:160)	Total (n:203)	Male (n:28)	Male (n:7)		
	r	r	r	r	r	r_e	r_t
	p	p^{β}	p^{β}	p^{β}	p^{β}	$p_e{}^{\beta}$	$p_t{}^{\beta}$
Vitamin A (mcg)	0.076	0.010	0.033	-0.348	-0.571	-0.114	-0.011
	0.627β	0.904	0.642	0.070	0.180	0.322	0.865
Thiamine (mg)	0.160	0.049	0.083	-0.303	-0.393	0.041	0.117
	0.307α	0.542	0.239	0.117	0.383	0.723	0.071
Riboflavin (mg)	0.144	0.082	0.142	-0.229	-0.643	0.028	0.178
	0.356β	0.305	0.043*	0.241	0.119	0.811	0.006*
Niacin (mg)	0.116	-0.053	0.067	-0.414	0.571	-0.056	0.125
	0.460β	0.503	0.346	0.028*	0.180	0.623	0.055
Pyridoxine (mg)	0.067	-0.042	0.002	-0.463	0.000	-0.017	0.037
	0.670β	0.599	0.978	0.013*	1.000	0.882	0.566
Vitamin C (mg)	-0.069	0.065	0.011	-0.391	0.000	-0.002	0.013
	0.658β	0.411	0.881	0.039*	1.000	0.987	0.847
Vitamin E (mg)	-0.040	-0.146	-0.008	-0.270	0.750	-0.175	0.025
	0.798β	0.065	0.908	0.164	0.052	0.125	0.696
Sodium (mg)	0.102	0.089	0.182	-0.294	0.036	-0.061	0.220
	0.514β	0.261	0.009*	0.129	0.939	0.597	0.001*
Potassium (mg)	0.132	0.027	0.034	-0.520	-0.214	0.002	0.037
	0.399β	0.738	0.633	0.005*	0.645	0.988	0.568
Calcium (mg)	0.226	0.012	0.082	-0.211	-0.643	0.027	0.093
	0.146β	0.883	0.245	0.282	0.119	0.812	0.154
Phosphorus (mg)	0.200	-0.048	0.057	-0.364	-0.107	0.014	0.095
	0.199β	0.546	0.422	0.057	0.819	0.903	0.146
Magnesium (mg)	0.156	-0.075	-0.012	-0.444	0.214	-0.054	-0.014
	0.318β	0.346	0.868	0.018*	0.645	0.639	0.834
Zinc (mg)	0.123	-0.034	0.098	-0.228	0.071	-0.028	0.158
	0.430α	0.699	0.164	0.243	0.879	0.809	0.015*

Note: £ Since there were no female individuals in this group, the table was not included. r_e and p_e were used to evaluate men individuals, r_t and p_t were used to evaluate all individuals in different risk groups. α Pearson correlation; β Spearman correlation test was used. *p<0.05.

CVD mortality and is considered as a primary target in the prevention and treatment of CVD. With the first dietary recommendations published by the American Heart Association Nutrition Committee in 1957, a nutrient-based approach began to form (Ravera et al., 2016).

In a study, the amount of total fat and SFA that individuals received with diet were found to be statistically significantly related to systolic blood pressure, which is among the risk factors of CVD; intake of total fat, SFA, MUFA, PUFA, cholesterol were found to be related to diastolic blood pressure (Mazidi et al., 2017). In a study conducted by Xu et al. (2006) it has been observed that the risk of CVD mortality increases with the increase in the consumption of total fat, SFA and MUFA. In a study conducted by Hu et al. (1999) it was found that the risk of CVD increases with increasing the content of the SFA of diet, and this risk decreases with the increase of MUFA and PUFA intake. In the study conducted by Hariri et al. (2017) it was

concluded that the rate of PUFA/SFA was statistically significantly higher in individuals with high risk compared to individuals with low and medium risk according to FRS. In the study carried out by Sohn et al. (2012) it was found that individuals with FRS>20% had lower PUFA intake than those with FRS<10%. There was no significant difference between individuals with high and low FRS levels in MUFA, SFA, and total fat intake. In this study, it was found that a positive correlation between the FRS value and intake of energy and MUFA (g) of all individuals in different risk groups in terms of CHD risk, and a negative correlation between the total fat (%) and PUFA (%) intakes ($p<0.05$) (Table 4).

In a study, the amount of total fat and SFA that individuals received with diet were found to be statistically significantly related to systolic blood pressure, which is among the risk factors of CVD; intake of total fat, SFA, MUFA, PUFA, cholesterol were found to be related to diastolic blood pressure (Mazidi et al., 2017). In a study conducted by Xu et al. (2006), it has been observed that the risk of CVD mortality increases with the increase in the consumption of total fat, SFA and MUFA. In a study conducted by Hu et al. (1999) it was found that the risk of CVD increases with increasing the content of the SFA of diet, and this risk decreases with the increase of MUFA and PUFA intake. In the study conducted by Hariri et al. (2017) it was concluded that the rate of PUFA/SFA was statistically significantly higher in individuals with high risk compared to individuals with low and medium risk according to FRS. In the study carried out by Sohn et al. (2012), it was found that individuals with FRS>20% had lower PUFA intake than those with FRS<10%. There was no significant difference between individuals with high and low FRS levels in MUFA, SFA, and total fat intake. In this study, it was found that a positive correlation between the FRS value and intake of energy and MUFA (g) of all individuals in different risk groups in terms of CHD risk, and a negative correlation between the total fat (%) and PUFA (%) intakes ($p<0.05$) (Table 4).

Various studies have shown that high glycemic index and glycemic load increase the risk of cardiovascular events (Beulens et al., 2007; Sieri et al., 2010; Mursu et al., 2011) as well as increased risk of CVD with increased carbohydrate consumption ($p<0.05$) (Sieri et al., 2010). As a result of the study conducted by Bazzanno et al. (2014) it was found that weight loss, HDL-C level increase, and total fat loss were significantly higher, but the ratio of TC/HDL-C was lower in individuals who followed a low-carbohydrate diet. When all individuals participating in this study are compared according to the risk of CHD, there is a difference in carbohydrate (g) intake ($p<0.05$). At the same time, both the amount of carbohydrate intake (g) and the percentage of the carbohydrate taken in total energy were found to have a positive correlation with the FRS value of all the individuals participating in the study. Also, it was determined that the nutrient that most affected (6.4%) the FRS values of the participants was carbohydrate (g) ($p<0.05$). A study conducted by Dehghan et al. (2017) found that a high intake of carbohydrates in the diet significantly increased total mortality and decreased the intake of fat, SFA, MUFA, and PUFA. It was observed that the total fat, saturated fat, and unsaturated fat content of the diet had no significant effect on CVD mortality and MI risk. In a study by Virtanen et al. (2014) it was determined that the risk of CHD is reduced when the content of SFA and PUFA of diet is replaced with carbohydrate. In a study conducted by Similä et al. (2013) it was observed that when the foods with high GI content in the diet were replaced with low GI foods, the risk of CVD was not decreased, and when replaced with SFA, this risk decreased and increased when replaced with MUFA. As a result of the study, it was stated that the carbohydrate and fat composition of the diet should be evaluated together for the risk of CVD.

In a study in which a diet, high in SFA, sugar, salt content, and low in vegetable and fruit content was accepted as a low dietary quality indicator, it was observed that the risk of CVD, CHD, and stroke increases as the diet quality of individuals decreases ($p<0.05$). This increase has been reported to be more obvious in overweight individuals (Adriouch et al., 2017). In the study conducted by Hariri et al. (2017), it was stated that for each increase in the consumption of fruit portions, a 0.14% reduction in FRS would be achieved. As a result of the study of Setayeshgar et al. (2015) it was found that the rate of FRS>10% was high

Table 6. Linear regression of patients' FRS value (%) and energy, macronutrients, micronutrients

	B	%95 (CI)	β	R^2	p
Energy (kcal)	0.002	0.001-0.003	0.207	0.043	0.001*
Carbohydrate (g)	0.018	0.009-0.027	0.252	0.064	0.000*
Carbohydrate (%)	0.052	-0.022-0.126	0.090	0.008	0.167
Protein (g)	0.024	0.001-0.047	0.134	0.018	0.039*
Total fat (%)	-0.068	-0.149-0.012	-0.108	0.012	0.097
MUFA (g)	0.046	-0.023-0.116	0.085	0.007	0.189
PUFA (%)	-0.098	-0.230-0.033	-0.095	0.009	0.142
Riboflavin (mg)	1.949	0.266-3.631	0.147	0.022	0.023*
Sodium (mg)	0.000	0.000-0.001	0.124	0.015	0.057
Zinc (mg)	0.252	0.061-0.451	0.166	0.028	0.010*

Note: *$p<0.05$

in individuals with abdominal obesity and low vegetable and fruit consumption and high potato consumption. In the study of Bhupathiraju & Tucker (2011), it was stated that inflammation and FRS value decreased with increasing variety compared to the number of vegetables and fruits consumed. In the study of Lairon et al. (2005) it was determined that weight, waist-to-hip ratio, blood pressure, apolipoprotein B, apolipoprotein B/A1, cholesterol, and homocysteine levels, which increase the risk of CVD, decrease as the intake fiber and insoluble fiber intake of individuals increases ($p<0.05$). As a common result of these studies, it has been stated that in societies with high CVD risk, the intake of fiber provided with fruit and vegetable consumption will be an important and effective method in reducing the risk of CVD. In this study, when the energy and nutrient intake levels of individuals were compared, there was a statistically significant correlation in the level of fiber intake between the males and females with FRS<10%, there was no statistically significant correlation between FRS value and fiber consumption.

In this context, the NCEP-ATP III guideline recommends therapeutic lifestyle changes to reduce the risk of CVD. Nutrition rich in unsaturated fatty acids is associated with low TG, high HDL-C levels. Besides, the reduction of SFA and cholesterol intake lowers the level of LDL-C. It is stated that the diet pattern with these features can reduce the disease prevalence with the positive changes in risk factors of FRS that help to estimate the risk of CVD (NIH, 2001).

Daily Micronutrient Intake

Vitamins have positive effects on CVD morbidity and mortality by preventing oxidative stress that causes the development of atherosclerosis (Núñez-Córdoba & Martínez-González, 2011). In the study, a significant difference was observed between thiamine, riboflavin, niacin, and vitamin C intake levels of individuals with different CHD risk (Table 3). At the same time, it has been found that the FRS value has a positive correlation with riboflavin in individuals at low risk of CHD; and has a negative correlation with niacin, pyridoxine, and vitamin C in individuals at moderate risk ($p<0.05$). However, when all individuals in different risk groups are evaluated, there is a positive correlation between FRS value and riboflavin intake ($p<0.05$).

In the study of Sohn et al. (2012), no significant difference was found between the vitamin intakes of individuals with different CHD risks. However, when evaluated according to the Food Quality Index, a significant difference was found between thiamine, niacin, A, B6, and C vitamins. In a study by Horigan et al. (2010), a statistically significant decrease was observed in both SBP and DBP levels of individuals in the group who received 1.6 mg riboflavin daily for 16

weeks compared to the placebo group. As a result of the study, it was stated that riboflavin may be effective in the prevention and treatment of hypertension and may play a role in reducing health expenditures. In the meta-analysis study conducted by Lavigne & Karas (2013), it was found that in addition to diet, niacin supplementation was associated with a decrease in CVD events and major CHD. In the study of Cangemi et al. (2013), vitamin E level was accepted as an independent risk factor for cardiovascular events and it was stated that the risk of CVD increased statistically in individuals with vitamin E level < 4.2 μmol/mmol. In a study by Weber et al. (1996), individuals with increased monocyte adhesion causing atherosclerosis were given daily vitamin C supplements (2 g/day). It was found that this supplement significantly reduced the adhesion level in smokers compared to non-smokers. These results show that adequate intake of all vitamins, especially vitamins with antioxidant properties, and therefore especially increasing the consumption of vegetables and fruits have an important role in reducing the risk of CVD.

Minerals play an important role in the regulation of cardiovascular functions. Mineral level imbalances are a potential risk factor that can lead to the development of CVDs (Mohammadifard et al., 2019). According to the results of this research, the FRS value in individuals with a moderate risk of CVD; has a negative correlation with potassium and magnesium ($p<0.05$). In the study conducted by Lai et al. (2015), the rate of cardiovascular mortality was found statistically significantly higher in individuals with low-normal serum potassium levels compared to individuals with normal potassium levels. In parallel with the results of this study, in a meta-analysis study, it was stated that the risk of stroke and heart failure decreases as a result of increased dietary magnesium intake (Fang et al., 2016). In the study by Kieboom et al. (2016), it was determined that low serum magnesium level increased carotid intima-media thickness, heart rate, CHD, and sudden heart death risks. Sohn et al. (2012), found no significant difference between the mineral intakes of individuals with different CHD risks. In this study, when all individuals in different risk groups are evaluated, among the sodium intake amount; there is a significant difference between the sodium and calcium intake levels of male and female individuals with low CHD risk ($p<0.05$). Besides, when individuals with low CHD risk and all individuals in different risk groups were evaluated, a positive correlation was found between FRS value and sodium ($p<0.05$). Many studies have found that sodium consumption increases the risk of CVD, which supports the results of this study (Aburto et al., 2013; Poggio et al., 2015). Many studies have found that sodium consumption increases the risk of CVD, this data supports the results of this research (Aburto et al., 2013; He et al., 2013; Poggio et al., 2015). Therefore, it is thought that the diet that will ensure the sodium intake to be at the recommended level will be effective in preventing increased CVD prevalence, morbidity and mortality.

CONCLUSION

As a result, CVD is a health problem that can be prevented by a healthy diet and lifestyle change, or that can be improved by medical treatment, nutritional therapy, and lifestyle changes after it occurs. Türkiye as well as in the world, the prevalence of CVD, rates of CVD mortality, and morbidity are increasing day by day. The primary target for preventing the increasing prevalence of CVD is to identify individuals with a high risk of disease and to make individual-specific changes in these individuals regarding risk factors and lifestyle. The measures to be taken will not only increase the quality of life of individuals but also reduce the use of resources. In the study, it was determined that there was a risk of CVD in both genders, more pronounced in male individuals. In this context, limiting salt consumption, reducing consumption of SFA, providing dietitian employment in primary health care centers, providing individuals with adequate and balanced nutrition education starting from an early age, conducting periodic risk screening, raising awareness of individuals about CVD risks, creating healthy living environments, establishing nutritional policies for preventive measures at the country level and ensuring their continuity; among the effective measures that can be taken to prevent CVD and to decrease the prevalence of CVD. Besides, broadcasting that encourages healthy nutrition and exercise and informs about CVD risk

factors via the media will help raise awareness about the disease.

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Compliance with Ethical Standards

Authors' Contributions

SG: Manuscript design, Field study, Statistical analyses, Writing.

AK: Manuscript design, Draft checking.

Both authors read and approved the final manuscript.

Conflict of Interest

The authors declare that there is no conflict of interest.

Ethical Approval

The studies have been approved by the appropriate institutional and/or national research ethics committee and have been performed in accordance with the ethical standards as laid down in the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards.

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Paslı Ciklit Balığının (*Iodotropheus sprengerae* Oliver & Loiselle, 1972) Larval Gelişimi: Morfolojik Gözlemler

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ÖZET

Bu çalışmada paslı ciklit türünün *Iodotropheus sprengerae* larval gelişim safhasının morfolojik olarak tanımlaması yapılmıştır. Paslı ciklit Malavi Gölü'ne özgü ağızda kuluçkalayan ciklit türlerinden biridir. Bu tür süs balıkları endüstrisindeki en popüler ciklit türlerinden biridir. Bu çalışmada *I. sprengerae* türünün yumurtadan çıktıktan sonra jüvenil safhaya geçinceye kadar morfolojik gelişim bulgurları incelenmiştir. Yumurtalar 29±0,5°C su sıcaklığında kuluçkalanmıştır. Embriyonik gelişim döllenmeden sonraki 4. günde tamamlanmıştır. Döllenmeden sonraki 5. günde yumurtlar açılmıştır. Yumurtadan yeni çıkmış larvaların organ gelişimleri farklılaşmamış ve gelişmeye devam etmiştir. Birinci günde ağız ve anüs kapalıdır. Ağız ve anüsün açılımı yumurtadan çıktıktan sonraki 3. günde gerçekleşmektedir. Yumurta sarısının tamamen tüketilmesi 10-11. günlerde olmuştur. Larva 10-12. günlerde tamamen serbest yüzmeye başlamaktadır. Morfolojik bulgulara göre, 13-15. günlerde paslı ciklit *I. sprengerae* larval metamorfozunu tamamlayıp, larval aşamadan jüvenil safhaya geçiş yapmaktadır. Bu sonuçlar ağızda kuluçkalayan ciklit larvalarının morfolojik gelişimlerinin ne kadar erken olduğunu göstermektedir.

Larval Development of Rusty Cichlid Fish (*Iodotropheus sprengerae* Oliver & Loiselle, 1972): Morphological Observations

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ABSTRACT

This study aimed to describe the larval development stage of rusty cichlid, *Iodotropheus sprengerae* morphologically. The rusty cichlid is a mouth-brooding haplochromine cichlid from Lake Malawi. It is one of the most popular cichlids in the ornamental fish industry. We investigated its morphological development of *I. sprengerae* from hatching until the juvenile stage in the present study. The eggs were incubated at a water temperature of 29±0.5°C. Embryonic developmental was completed at 4 days post fertilization (=dpf). The eggs hatched at 5 dpf. In newly hatched larvae, most organs and body parts were not yet differentiated and continued to develop. The mouth and anus were closed at 1 days after hatching (=DAH). The mouth and anus were opened at 3 DAH. The yolk sac was fully absorbed at 10-11 DAH. The larvae begin to swim freely at 10-12 DAH. According to morphological findings, the larval metamorphosis of rusty cichlid *I. sprengerae* was completed, and the larvae transformed into juveniles at 13-15 DAH. These results indicate how early morphological development of larvae of mouth-brooding cichlids.

GİRİŞ

Iodotropheus sprengerae Malavi Gölü'nün Boadzulu ve Chinyankwazi Adaları ve Chinyamwezi Adası bölgelerine ait bir ciklit türüdür. Renginden dolayı paslı ciklit, lavanta mbuna veya lavanta ciklit olarak isimlendirilmektedir (Froese & Pauly, 2013). Yavrular ve dişiler paslı kahverengi, olgun erkekler ise lavanta moru rengine sahiptirler. Paslı ciklitlerin boyları 10.8 cm'ye kadar büyüyebilmekte ve yaşamak için 24-26°C sıcaklık aralığını tercih etmektedirler (Froese & Pauly, 2013). Paslı ciklitler diğer pek çok Malavi ciklit türü gibi ağızda kuluçka yapmaktadır. Ağızda kuluçkalama görevini dişi ebeveyn üstlenmektedir. Bu tür, Malavi Gölü'nün sadece güneydoğu kolundaki adalar ve kayalık alanlar gibi sınırlı bir bölgede yayılım göstermektedir. Uluslararası akvaryum balıkları ticaretinin bu tür üzerindeki etkilerinden dolayı paslı ciklit, IUCN (*The International Union for Conservation of Nature*: Uluslararası Doğayı Koruma Birliği) tarafından sürdürülen IUCN Kırmızı Listesi'nde (*IUCN Red List of Threatened Species*: IUCN Tehdit Altındaki Türlerin Kırmızı Listesi) listelenmiştir (Konings, 1990). Paslı ciklit tamamen barışçıl bir balık olmasa da diğer mbuna ciklit türleri arasında en az agresif olanlardan biri olarak kabul edilmektedir (Scharpf & Lazara, 2013). Omnivor olan paslı ciklitler, Malavi ciklit türlerinin bakımı konusunda daha az deneyime sahip akvaryum severler için ideal bir başlangıç balığıdır. Bakımının kolay olması ve diğer ciklit türlerine göre nispeten daha barışçıl olması, akvaryum severler tarafından daha çok tercih edilmesine neden olmaktadır. Öte yandan küçük ebatlı akvaryumlarda bile üreyebilmeleri dikkat çekmektedir.

Bilimsel araştırmalarda model canlı türleri olarak kullanılan zebra balığı (*Danio rerio* Kimmel vd., 1995), Japon pirinç balığı (Medaka, *Oryzias latipes*) (Iwamatsu, 2004), üç dikenli balık (*Gasterosteus aculeatus*, Swarup, 1958), gökkuşağı alabalığı (*Oncorhynchus mykiss*) (Ballard, 1973) ve Nil tilapyası (*Oreochromis niloticus*) gibi balık türlerinin erken dönem gelişimi ve larval gelişimi hakkında pek çok çalışma yapılmıştır. Ancak tetralar, canlı doğuranlar ve akvaryumda kullanılan özellikle Malavi ciklit türleri gibi küçük türler hakkında yapılmış bilimsel çalışma sayısı oldukça sınırlıdır (Çelik vd., 2012; Walter, 2012; Park vd., 2014; Ferreira-Marinho, 2017; Santos vd., 2017). Yapılan literatür taramalarında paslı ciklit türünün erken dönem gelişimi veya larval gelişi hakkında bilgi sunan bilimsel literatüre

rastlanmamıştır. Bundan dolayı bu türün larval gelişiyle ilgili morfolojik gözlemlere dayalı bir çalışma yapılmıştır. Paslı ciklitin yanı sıra diğer Güney Afrika ciklit türlerinin larval gelişimiyle ilgili mevcut kaynakların da sınırlı olduğu dikkat çekmektedir. Bu çalışmada ortaya konan bulguların Malavi ciklit türleri başta olmak üzere özellikle ağızda kuluçkalayan diğer tüm Güney Afrika ciklit türelerinin larval gelişim süreçlerinin incelenmesi için faydalı olacağı düşünülmektedir. Çünkü bu türlerin üreme davranışları, yumurta kuluçkalama şekilleri, embriyonik gelişim süreçleri ve larval gelişim süreçleri gibi ana gelişim aşamaları fizyolojik ve morfolojik açıdan birbirlerine çok benzer şekillerde gerçekleşmektedir. Dolayısıyla burada sunulan bilgilerin bu türe benzeyen diğer tüm ciklit türlerinin larval gelişim süreçleri hakkında ipuçları verebileceği öngörülmektedir. Ancak yine de bu ve diğer türlerin erken dönem ontogenisi hakkında çok daha detaylı çalışmalar yapılmasına ihtiyaç vardır.

Paslı ciklit, tatlısu akvaryumlarında en çok tercih edilen balık türlerinden biridir. Dolayısıyla akvaryum sektörü içerisinde ekonomik değeri olan bir türdür. Günümüzde akvaryum balıkları ticareti tüm dünyada ülkeler arası ihracat/ithalat ağına sahip ciddi bir sektör konumundadır. Global akvaryum balıkları ihracatı 2000 yılından bu yana istikrarlı bir şekilde artmaktadır. Sektörün ekonomik boyutu daha çok resmi ithalat/ihracat rakamlarına bakılarak tahmin edilmektedir. 2000 yılında 177,7 milyon ABD doları olan küresel ihracat miktarı, 2011'de 364,9 milyon ABD dolarına ulaşmıştır (Dey, 2016). 2014 yılında akvaryum sektörünün değerinin, perakende kısmını da içine alan tüm bitkiler, aksesuarlar, akvaryum, yem ve ilaçların değeriyle birlikte 18-20 milyar ABD dolarından fazla olduğu tahmin edilmektedir (Dey, 2016). Yıllık %10'luk büyüme oranlarına bakılarak sektörün bugünkü değerinin biraz daha fazla olduğu tahmin edilebilir. Dünya genelinde her geçen yıl büyüyerek gelişen akvaryum sektöründe binlerce balık türü kullanılmaktadır. Bu türlerin bir kısmı doğrudan doğadan temin edilirken, büyük bir kısmı ise insan eli altında üretilmektedir. Üretimin her aşaması için ortaya konulacak detaylı bilimsel veriler özellikle profesyonel üreticiler için çok önemlidir. Bu alanda yapılan bilimsel çalışmaların sektörün gelişimine doğrudan fayda sağlama olasılığı yüksektir. Bundan dolayı bu veya benzer çalışmaların süs balıkları yetiştiriciliği alanında faaliyet gösteren ticari işletmelere ve bu alanda çalışma yapan araştırmacılara fayda sağlayabileceği öngörülmektedir.

MATERYAL VE YÖNTEM

Anaç olarak bir yaşını doldurmuş, aktif olarak üreyebilen yetişkin bireyler kullanılmıştır. Anaçlar, su hacimleri yaklaşık 125-130 L olan (80 cm boy × 40 cm en × 45 cm yükseklik; 40 cm su yüksekliği) dikdörtgen cam akvaryumlara 3 erkek (♂) / 15 dişi (♀) olacak şekilde stoklanmıştır. Anaç akvaryumları sadece sünger filtre ile havalandırılmış ve akvaryum içinde hiçbir dekor kullanılmamıştır. Anaç bakımı, yumurtlatma ve larva gelişim süreçlerinde su sıcaklığı 29±0,5°C, pH 7,5-8 civarında sabit tutulmuştur. Su sıcaklığını sabit tutmak için oda ısısı sabit tutulmuştur. Akvaryum içinde ısıtıcı kullanılmamıştır. Üreme sürecince birkaç saat süren yumurtlama işleminden sonra döllenmiş yumurtalar dişi tarafından ağızda kuluçkalamaya alınmaktadır. Bu dönemde ağzında yumurta olan bireylerin ağızlarının alt (ventral) kısmı şişkin görünmektedir. Bu şekilde dişinin ağzında yumurta olup olmadığı kolaylıkla anlaşılabilmektedir. Larval gelişimin gözlenebilmesi için ağzında yumurta olduğu tespit edilen anaçlar not edilip yumurtlamadan bir gün sonra ağzındaki yumurtalar kusturulmuştur. Kusturulan yumurtalar yapay kuluçka ünitesine alınmıştır. Döllenmeden yaklaşık 5 gün sonra yumurtalar açılmıştır. Yumurtadan çıktıkları ilk gün larvanın 1. gün yaşı olarak kabul edilmiştir. Buna göre yumurtadan çıktıkları ilk günden, morfolojik olarak larval gelişimi tamamladıkları ve jüvenil aşamaya geçtikleri güne kadar periyodik olarak her gün örneklerin fotoğrafları çekilmiştir. Günlük olarak örneklenen larvalar sabit oda sıcaklığında ve 29±0,5°C sabit su sıcaklığında kuluçkalama ünitesinde tutularak mikroskop altında (Olympus BX51 model araştırma mikroskobu, Tokyo/Japonya) morfolojik açıdan incelenmiş ve mikroskoba bağlı bir kamerayla (Q Imaging, Micropublisher 3.3 RTV, Kanada) görüntülenmiştir. Fotoğraflama işleminden sonra canlı örnekler yeniden kuluçka ünitesine yerleştirilmiştir. Bu aşamada herhangi bir kimyasal madde kullanılmamıştır.

BULGULAR

Paslı ciklit larvaları yumurtadan çıktıkları ilk gün yani 1. gün neredeyse yumurta boyutu kadar büyük bir besin kesesine sahiptirler (Şekil 1). Besin kesesinin ağırlığından dolayı bu aşamada larvalar tankın zeminindedir (Şekil 1). Ancak arada bir kuyruk hareketleri yapabilmektedirler. Bu günlerde de ağız ve anüs kapalıdır. Vücudun büyük bir kısmı premordial yüzgeç şeklindedir. Besin kesesi yumurta renginde, koyu kahverengi/turuncu/sarı renklerinin kombinasyonu gibi bir görünüme sahiptir. Baş ve diğer vücut kısımları henüz renklenmemiş şeffaf görünümdedir. Kafa kısmı öylesine şeffaftır ki, mikroskopla bakıldığında beynin ön ve arka bölümleri ile kulak vezikülleri rahatlıkla görülebilmektedir. Pektoral yüzgeç uçlarının 1. günde mevcut ve aktif olduğu görülmüştür (Şekil 1a). İlk günlerde anterior kardinal damarlar, posterior kardinal damarlar, anterior vitellin damarları dışarıdan görülebilmektedir (Şekil 1a, 1b). Dorsal aorta, kalp ve vücut boyunca dolaşım sistemi içindeki kan hareketleri gözlenebilmektedir. Yumurtadan çıktıktan sonraki ilk iki gün (Şekil 1a, 1b) oldukça şeffaf olan vücuttaki pigmentasyon seviyesi 3. günde özellikle de kafa bölgesinde yoğunlaşmaya başlamıştır (Şekil 1c). Baş bölgesindeki renklenme vücudun geri kalan bölgelerine kıyasla daha yoğundur. İlk günde oldukça büyük olan besin kesesi özellikle 3. ve 4. günlerde biraz daha küçülmüştür (Şekil 1c, 1d). Ağız ve anüs açılımı 3. günde gerçekleşmektedir, ancak larva ihtiyacı olan enerjiyi hala büyük olan besin kesesinden karşılamaktadır. Bu günlerde larvaya canlı yem verilip verilmemesi hayati derecede önemli değildir (Şekil 1c, 1d). Larva dışarıdan besin almasa da yaşamını sürdürebilmektedir. Ağız açılımıyla birlikte hava kesesi de şişmektedir. 3. günde dorsal ve anal yüzgeç bölümlerinin az da olsa gelişmeye başladıkları görülse de temel olarak hala premordial yüzgeç görünümündedir. Ancak kuyruk yüzgeci gelişim ve farklılaşması daha ileri seviyededir. 4. günden itibaren dorsal ve anal yüzgeç farklılaşması biraz daha dikkat çekmektedir. Vücuttaki pigmentasyon dağılımı 4. günde daha yoğunlaşmış, vücudun şeffaf görünümü giderek kaybolmaya başlamıştır. Bugünlerden itibaren larvalar kısa süreli yüzme hareketleri yapabilmektedir.

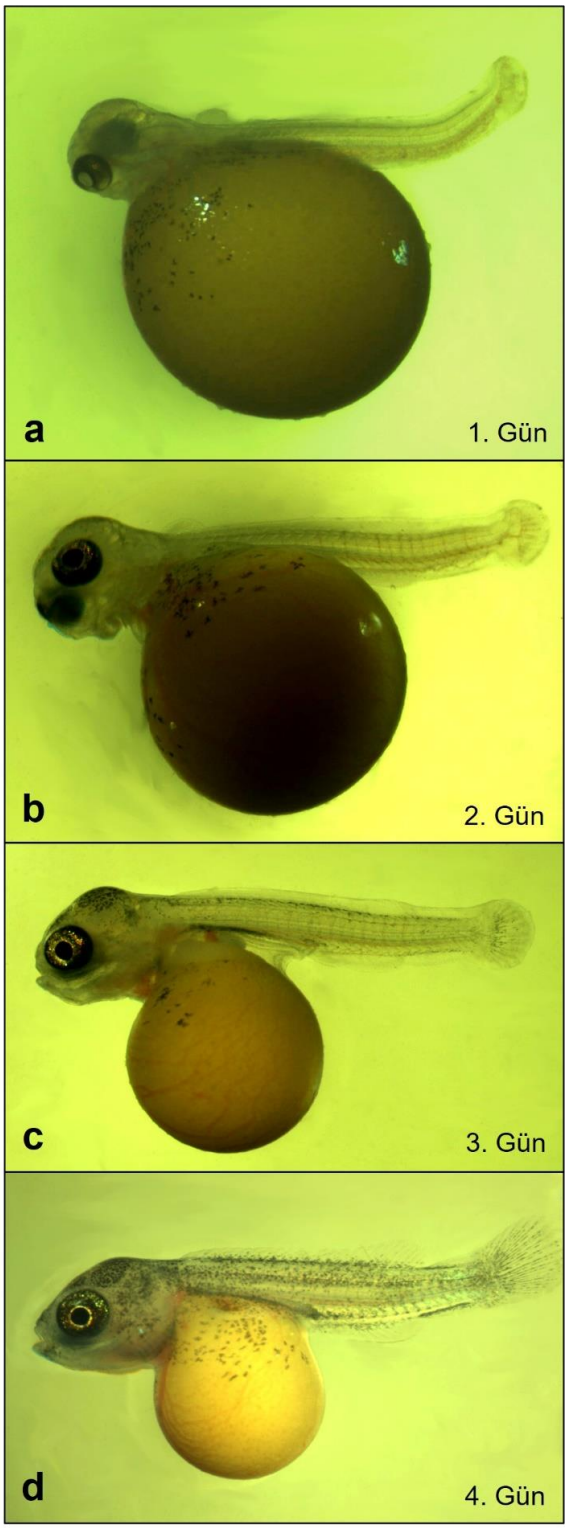

Figure 1. Photographs of rusty cichlid larvae in the first 4 days after hatching (DAH). (Photos were taken under Olympus BX51 model research microscope and Q Imaging, Micropublisher 3.3 RTV microscope camera at 0.8x and 1x magnification)

Şekil 1. *Paslı ciklit larvasının yumurtadan çıktıktan sonraki ilk 4 günlük fotoğrafları (Fotoğraflar, Olympus BX51 model araştırma mikroskobu ve Q Imaging, Micropublisher 3.3 RTV mikroskop kamerası altında 0.8x ve 1x büyütmede çekilmiştir)*

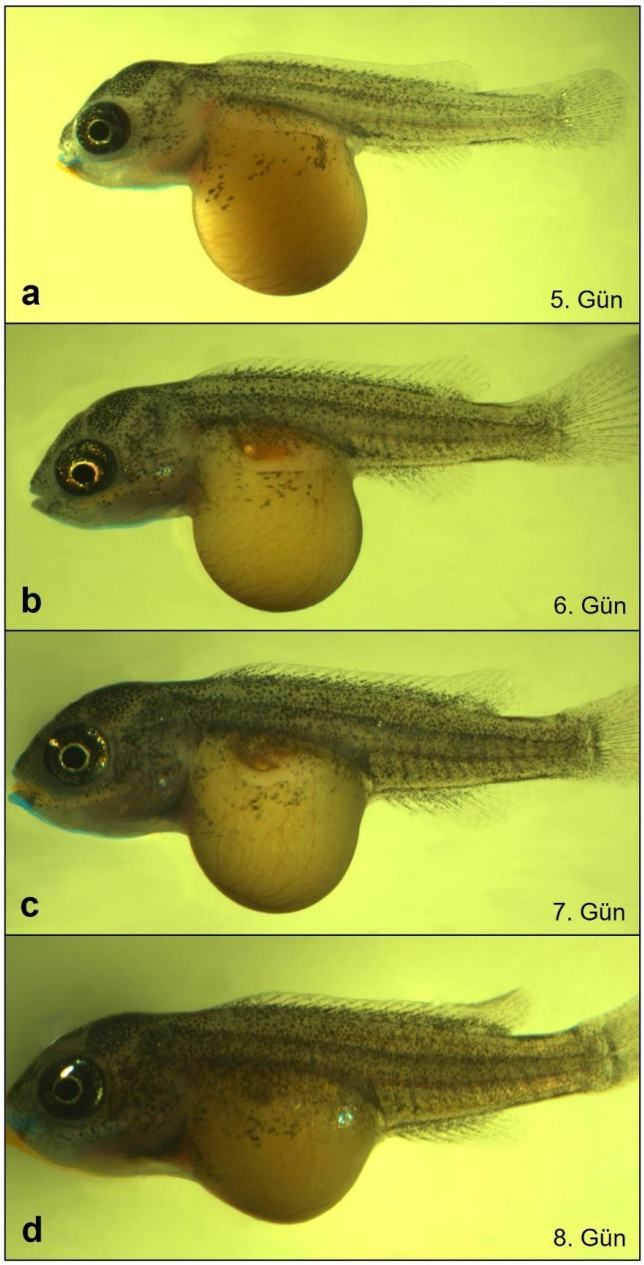

Figure 2. Photographs of rusty cichlid larvae between 5-8 DAH. (Photos were taken under Olympus BX51 model research microscope and Q Imaging, Micropublisher 3.3 RTV microscope camera at 0.8x and 1x magnification)

Şekil 2. *Paslı ciklit larvasının yumurtadan çıktıktan sonraki 5-8. günler arasındaki fotoğrafları (Fotoğraflar, Olympus BX51 model araştırma mikroskobu ve Q Imaging, Micropublisher 3.3 RTV mikroskop kamerası altında 0.8x ve 1x büyütmede çekilmiştir).*

Dorsal ve anal yüzgeç ışınlarının farklılaşması 5. günden itibaren gözlenebilmektedir (Şekil 2a). 6 ve 7. günlerde dorsal ve anal yüzgeçler biraz daha bariz görünüm kazanırken kuyruk yüzgeci çok daha iyi gelişmiş durumdadır (Şekil 2b, 2c). Serbest yüzme hareketleri 6-7. günlerde önceki günlere nazaran daha uzun süreli olmaktadır. Ancak 8-9. günlerden itibaren larva tamamen serbest yüzebilecek kabiliyet kazanmış durumdadır (Şekil 2c, 2d). Bu günlerde dorsal ve anal yüzgeç gelişimleri de yüzmelerinde etkili olmaktadır. Besin kesesi 8. güne doğru iyice küçülmüş durumdadır. Bu günlerde bile larva dışarıdan yem almadan yaşamaya devam edebilmektedir (Şekil 2). Ancak 8. günden itibaren larvalara canlı yem olarak *Artemia* sp. verilmeye başlanması, gelişimleri açısından faydalı olacaktır. Vücuttaki melanofor pigmentleri her geçen gün artarak çoğalmaktadır.

Dorsal ve anal yüzgeç dikenleri 10-11. günlerde önceki günlere göre çok daha iyi gelişmiş ve farklılaşmış durumdadır (Şekil 3a, 3b). Besin kesesi de bu günlerde tamamen tükenmiş, larva dışardan beslenmeye devam etmektedir. Bu çalışmada bu günlerde larvalar *Artemia* sp. ile beslenmiştir. Ancak paslı ciklit larvalarının bugünlerde de toz yem/mikro partikül yem ile beslenebildikleri bilinmektedir. Paslı ciklit larva fizyolojisi 10. günlerden itibaren mikro partikül yemleri de sindirebilecek şekilde gelişmiştir. Ama yine de bu dönemde bu yaştaki larvaların *Artemia* sp. ile beslenmesi tavsiye edilir. Vücut renklenmesi 12-13. günlerde daha yoğun görünümdedir (Şekil 3c, 3d). Hatta larvalara mikroskop ışığı altında değil de akvaryum ortamında çıplak gözle bakıldığında Şekil 3c ve 3d'de besin kesesi gibi görünen karın bölgesinin daha koyu renkli olduğu görülebilmektedir. Karın bölgesinin üst kısmında ergin bireylerin rengine benzer kahverengi renk tonu dikkat çekmektedir. 13-15. günlerde larva morfolojik olarak gelişimini tamamlamış ve vücut formu tamamen bir yetişkin birey görünümünü almıştır. Bundan dolayı da paslı ciklit larvaları için, yumurtadan çıktıktan sonraki 13-15. günlerden itibaren larval gelişim periyodunun sona erdiği ve jüvenil aşamanın başladığı söylenebilir.

Ağızda kuluçkalayan bir Malavi ciklit türü olan paslı ciklitin larval gelişim periyodu 13-15 gün gibi kısa sürede tamamlanmaktadır. Doğada bu günlerde dahi annelerinin ağzında parental bakımına ihtiyaç duyan bu balıkların yapay yetiştirme ortamlarında anaçların parental bakımına ihtiyaçları yoktur. Çünkü bu kontrollü ortamlarda hayatlarını tehlikeye sokabilecek herhangi bir tehdit yoktur. Diğer yandan yaşamaları ve gelişmeleri için ihtiyaç duydukları besin gereksinimleri fazlasıyla tank ortamına girilmektedir.

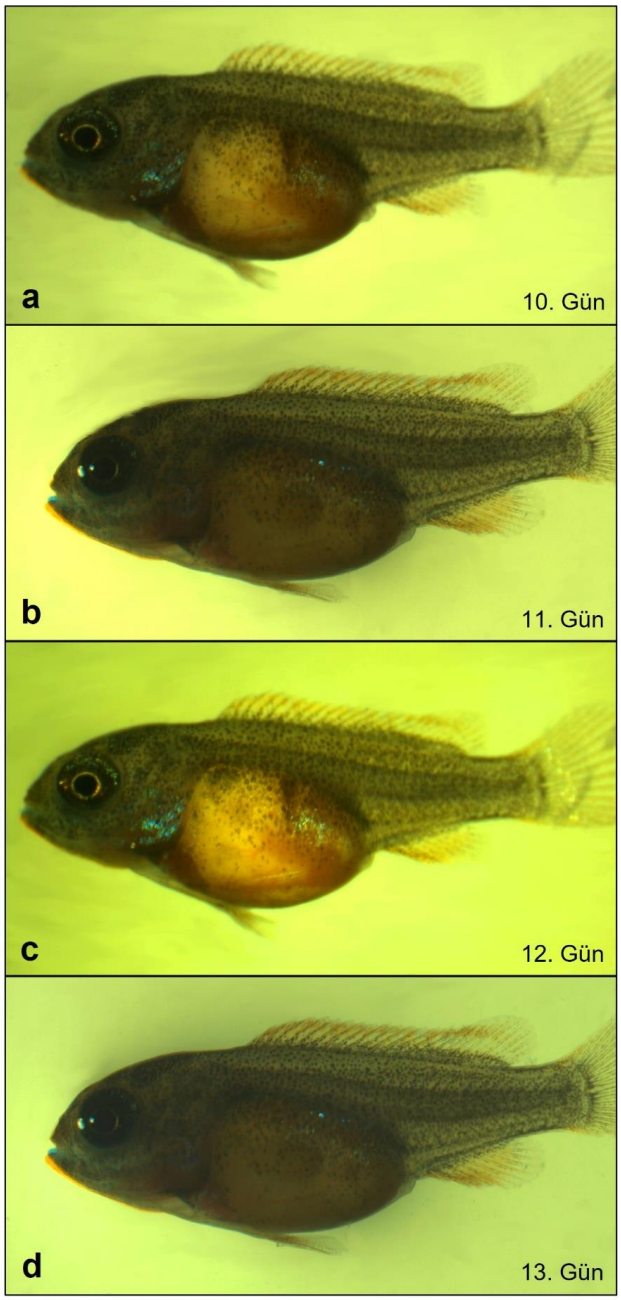

Figure 3. Photographs of rusty cichlid larvae between 10-13 DAH. (Photos were taken under Olympus BX51 model research microscope and Q Imaging, Micropublisher 3.3 RTV microscope camera at 0.8x and 1x magnification)

Şekil 3. *Paslı ciklit larvasının yumurtadan çıktıktan sonraki 10-13. günler arasındaki fotoğrafları (Fotoğraflar, Olympus BX51 model araştırma mikroskobu ve Q Imaging, Micropublisher 3.3 RTV mikroskop kamerası altında 0.8x ve 1x büyütmede çekilmiştir).*

TARTIŞMA

Ciklitler (Cichlidae) tür sayısı bakımından (2500-3000 tür) kemikli balıklar (teleost) içindeki en zengin ailelerden birisidir (Sturmbauer & Meyer, 1992; Meyer, 1993; Farias vd., 2000; Snoeks, 2000; Turner vd., 2001). Ciklit türlerinin büyük çoğunluğu akvaryumlarda süs balığı olarak değerlendirilmektedir. Bundan 15-20 yıl öncesine kadar akvaryumlarda tercih edilen en popüler türler Japon balıkları, lepistes türleri, koi balıkları gibi popülerliğini günümüzde de sürdüren balık türleriydi. Ancak son 15-20 yıldan bu yana ciklit türlerinin popülerliği artmıştır. Özellikle ağızda kuluçkalayan Malavi Gölü ciklitleri öylesine yaygınlaştı ki, bu türlerin satış miktarları popüler olan diğer pek çok akvaryum balığı türünü geride bırakmıştır. Ciklit türlerinin çok tercih edilme nedenlerinin en başında yumurtalarını ve yavrularını ağızda kuluçkalama özellikleri gelmektedir. Bu özelliklerinden dolayı akvaryum severler balık bakmanın yanı sıra bir de onları üretebilmenin zevkine varabilmektedir. Bunun dışında Malavi Gölü ciklitlerinin birbirleri ile uyum içerisinde yaşayabilmelerinden dolayı çok çeşitli renklerdeki ciklit türlerinin tek bir akvaryumda bakılabilmesi de mümkündür. Günümüzde onlarca farklı renkte ciklit balığını kolayca bulmak mümkündür (Meyer, 1993; Kornfield & Smith, 2000). Paslı ciklit de bu popüler ciklit türlerinden biridir. Paslı ciklitler kahverengi, lavanta rengi ve bu iki renk tonlarının birbirleriyle karışımından oluşan, pas rengini anımsatan parlak ve ilgi çekici renklere sahiptirler. Akvaryumdaki diğer balıklarla uyum içerisinde yaşayabilen, barışçıl davranış sergileyen ve bakımları kolay olan balıklardır. Bu ve buna benzer pek çok olumlu yönlerinden dolayı akvaryumlarda çok tercih edilen Malavi ciklit türlerinden biri olmuştur. Tercih edilme seviyesi arttıkça da sektör içindeki ekonomik katma değeri yükselmiştir. İşte bu nedenlerden dolayı bu çalışmada paslı ciklit balığı tercih edilmiştir.

Genel olarak ağızda kuluçkalayan ciklit türlerinin larvaları precocial larva olarak tanımlanırken substrata yumurtlayanların larvaları altricial olarak tanımlanmaktadır (Noakes, 1991). Ağızda kuluçkalayan türlerin yumurtaları daha büyük ve parental bakıma ihtiyaç duyarken, substrata yumurtlayanların yumurtaları daha küçüktür ve diğerlerinden daha az parental bakıma ihtiyaç duyarlar (Noakes, 1991). Bu bilgilere göre paslı ciklit larvaları da precocial larvadır. Yumurtalar ve larvalar ağızda kuluçkalanır. Yumurta ve larvaların parental

bakıma ihtiyaçları vardır. Ancak bu çalışmada döllenmiş yumurtalar anaçların ağzından alınmış ve yapay kuluçkalama sistemlerine konulmuştur. Profesyonel üretimlerde çoğunlukla bu yöntem tercih edilmektedir. Çünkü dişi birey, yumurtlamadan sonra ağzında kuluçkalamaya başladığında yumurta ve larvalara 20-30 gün gibi uzunca bir süre bu şekilde bakmaktadır (parental bakım). Bu süre boyunca dişi nerdeyse bütün enerjisini yumurta ve larva bakımına harcamaktadır. Bu sürede çok az beslenir, daima kendisini ve yavrularını koruma içgüdüsüyle hareket etmektedir. Larvalar büyüyüp anaçtan ayrılıncaya kadar dişi yeni bir üreme periyoduna girmemektedir. Bir sonraki üreme periyoduna girebilmesi için enerji ve güç toplaması da gerekmektedir. İşte bu durumda dişinin yıllık bazdaki üretim performansı daha da düşük olmaktadır. Profesyonel üreticiler, bir dişiden birim zamanda en fazla verimi almayı hedeflemektedir. Dişilerin parental bakım yapmaları yıllık yavru elde etme verimini düşüreceği için bu yöntem pek tercih edilmemektedir. Bu çalışmada da yapay kuluçkalama uygulamalarında larvaları erken dönem gelişimleri incelenmiştir.

Balıkların erken dönem gelişim ve büyüme paternleri akuakültürde kuluçkahane üretiminin optimizasyonu ve değerlendirilmesi için çok önemlidir (Koumoundouros vd., 1999; van Maaren & Daniels, 2000). Ayrıca, fenotipik gelişim mekanizmasının anlaşılması benzer konularda yapılan diğer çalışmalar için de önemlidir (Salzburger & Meyer, 2004; Henning & Meyer, 2014; Kratochwil & Meyer, 2015; Kratochwil vd., 2015). Yüzlerce balık türünün erken larval dönemlerini incelemiş pek çok çalışma mevcutken, Cichlidae ailesine ait türler hakkında yapılmış bu tür çalışmalar oldukça az sayıdadır (Britz, 1997; Stiassny & Meyer, 1999; Lopes vd., 2015). Bu açıdan bakıldığında bu çalışmanın literatüre küçük de olsa olumlu yönde bir katkı sağlayacağı düşünülmektedir. Bu çalışmada ağızda kuluçkalayan paslı ciklitin larval gelişimiyle ilgili morfolojik gözlemler sunulmuştur. Burada ortaya konan verilerin diğer ağızda kuluçkalayan ciklit türlerinin erken dönem gelişim evrelerinin anlaşılabilmesi için de önemli olacağı varsayılmıştır.

Ağızda kuluçkalayan Malavi ciklitlerinden en çok bilinen ve tercih edilen türlerinden biri Türkiye'de sarı prenses ismiyle bilinen *Labidochromis caeruleus* türüdür. Diğer Malavi ciklitleri gibi sarı prenses ciklitin de paslı ciklite çok benzer yanları vardır. Üreme davranışları, kuluçkalama şekilleri, embriyonik gelişim süreçleri, larval gelişim süreçleri, beslenme ve davranış modelleri gibi pek çok yönden benzerlik göstermektedirler. Sarı prensesin (*L. caeruleus*) erken dönem gelişim evresinin incelendiği bir çalışmada (Saemi-Komsari vd., 2018). Ağız ve anüs açılımının yumurtadan çıktıktan sonraki 5. günde gerçekleştiği rapor edilmiştir. Bu durum paslı ciklitte 3. günlerde meydana gelmiştir. Aynı çalışmada 9. günlerde besin kesesinin yarısının tüketildiği, serbest yüzmeye ise 11. günde tamamen geçildiği bildirilmiştir (Saemi-Komsari vd., 2018). Paslı ciklit için ise bu iki olayın birkaç gün önce gerçekleştiği söylenebilir. Sarı prenses türünün larval gelişim evresini tamamlayıp jüvenil evreye geçmesi yumurtadan çıktıktan sonraki 15-16. günlerde olduğu rapor edilirken (Saemi-Komsari vd., 2018), paslı ciklitte de aşağı yukarı aynı günlerde (13-15. günler) larval gelişim periyodundan jüvenil aşamaya geçiş sağlanmıştır. Bu iki türün erken dönemde larval gelişimleri esnasında gerçekleşen fizyolojik ve morfolojik bulguların birbirlerine çok benzer oldukları bu iki çalışmanın verilerine bakılarak anlaşılabilir. Larval metamorfoz esnasında gerçekleşen olayların zamanlaması birebir örtüşmese de olayların genel oluş pozisyon ve şekilleri açısından oldukça benzerlik göstermektedir. Benzer durumun Malavi Gölü ciklit türlerinin pek çoğu belki de hepsi için aynı olma ihtimali çok yüksektir. Onun için bu türler hakkında daha detaylı çalışmalar yapılması Malavi Gölü'ne endemik ciklit türlerinin anlaşılmasına önemli katkılar sağlayacaktır. Bununla beraber bu çalışmada sunulan verilerinden yola çıkılarak diğer tüm Malavi Gölü ciklitlerinin yetiştiricilik uygulamaları için yönlendirici seviyede fikir edinilmiş olacaktır.

Renk, pigmentasyon dağılımı ve şekil yapıları larva ve jüvenillerin taksonomik tanımlanmasında kullanılan önemli parametrelerdir (Nascimento & Araújo-Lima, 1993; Meijide & Guerrero, 2000; Godinho vd., 2003; Oliveira vd., 2012). *Astronotus ocellatus* (Nakatani vd., 2001; Paes vd., 2011), *Oreochromis niloticus* (Nakatani vd., 2001; Fujimura & Okada, 2007), *Cichlasoma nigroasciatum* (Martinez & Murillo, 1987), *Hypsophrys nicaraguensis* (Molina, 2011) gibi ciklit türlerinin larval dönemde vücuttaki pigmentasyonun

öncelikle kafanın üst bölgesinden başlayıp vücudun üst bölgesine doğru yoğunlaştığı bilinmektedir. Bu çalışmada incelenen paslı ciklit, *Iodotropheus sprengerae,* larvalarında da pigmentayon dağılımının benzer şekilde geliştiği gözlenmiştir. Pigmentasyon yoğunluğu önce kafa bölgesinde artmış, sonra vücudun üst bölgelerine dağılmış, kuyruk bölgesini kapsamış, en sonra da karın bölgesi renklenmiştir.

Yapışma bezleri türlerin tanımlanmasında önemli karakteristik özelliklerden biridir. Genellikle kafanın üst bölgesinde bulunan yapışma bezleri yumurtadan yeni çıkmış larvanın sabit bir bölgeye tutunmasını sağlamaktadır. Bu bezler larvanın yumurtadan çıktıktan sonraki ilk günlerde aktif olup, gün geçtikçe yavaşça kaybolmaktadır. Özellikle substrata yumurtlayan ciklit türlerinin çoğunda yapışma bezleri gözlenebilmektedir. Örneğin; *C. dimerus* (Meijide & Guerrero, 2000), *A. ocellatus* (Nakatani vd., 2001; Paes vd., 2011), *Symphysodon* spp. (Çelik, 2010), *H. nicaraguensis* (Molina, 2011), *Pterophyllum scalare* (Çelik vd., 2014) ve *Satanoperca pappaterra* (Lopes vd., 2015) gibi ciklit türlerinin larval dönemlerinde kafalarının ön/üst kısımlarında yapışma bezleri mevcuttur. Bu yapışma bezleri bazı türlerde üç çift bazılarında iki çift olmaktadır. Jones (1972), substrata yumurtlayan türlerin kafalarının üstünde yapışma bezlerinin olduğunu ancak ağızda kuluçkalayan türlerde bu bezlerin ilkel formda kaldığını rapor etmiştir. Bu çalışmada incelenen ağızda kuluçkalayan paslı ciklit larvalarında yapışma bezlerine rastlanmamıştır.

Balık yetiştiriciliğinde tercih edilen su sıcaklığı rejimi, larval gelişim sürecini doğrudan etkileyen bir faktördür. Su sıcaklığına göre besin kesesinin tüketilme zamanı kısalıp uzayabilir, buna göre dışarıdan yem alma zamanı değişebilir, ağız açılımı ve serbest yüzme gibi larva yetiştiriciliği için hayati derecede önemli olan gelişim olaylarının zamanlaması değişebilir (Vlahos vd., 2015). Paslı ciklitin larval gelişiminin incelendiği bu çalışmada 29±0,5°C tercih edilmiştir. Bu sıcaklık değerinin altlarında larval gelişim biraz daha yavaş olabilir. Besin kesesinin tüketilme süresi, serbest yüzmeye geçiş zamanı ve larval aşamadan jüvenil aşamaya geçiş zamanları da değişebilir. Bu değişim doğrudan su sıcaklığı ile ilgili olacaktır. Yeni çalışmalarla farklı sıcaklıklarda larval gelişim süreçlerinin karşılaştırılması da mümkündür. Ancak bu çalışmada ortaya konulan veriler 29±0,5°C su sıcaklığında elde edilmiştir.

SONUÇ

Bu çalışmada ağızda kuluçkalayan Malavi Gölü ciklit türlerinden olan paslı ciklitin, *Iodotropheus sprengerae,* erken dönem larval gelişim aşaması morfolojik açıdan incelenmiştir. Yapılan gözlemler sonucu elde edilen morfolojik verilerin ağızda kuluçkalayan diğer ciklit türlerinin erken dönem larval gelişimlerinin incelenmesinde faydalı olacağı düşünülmektedir. Ancak bundan sonraki çalışmalarda paslı ciklit ve diğer türlerin larval dönemlerinin çok daha detaylı çalışmalarla incelenmesi bu alanda çalışan bilim insanları ve bu bilgileri sahadaki uygulamalarda kullanan profesyonel üreticiler için çok daha faydalı olacaktır.

Etik Standartlar İle Uyum

Yazarların Katkısı

İÇ: Makalenin tasarlanması, Laboratuvar çalışmaları, İstatistiksel analizler, Taslağın hazırlanması, Düzeltme.

PÇ: Makalenin tasarlanması, Laboratuvar çalışmaları, Taslağın hazırlanması, Düzeltme

SA: Laboratuvar çalışmaları

Çıkar Çatışması

Yazarlar herhangi bir çıkar çatışması olmadığını deklare etmektedir.

Etik Onay

Yazarlar bu tür retrospektif çalışmalar için resmi etik kurul onayının gerekli olmadığını bildirmektedir. Ayrıca, yazarlar hayvanların bakımı ve kullanımı için geçerli tüm uluslararası, ulusal ve/veya kurumsal yönergelere uyulduğunu bildirmektedir.

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Characterization of Fisheries Violations From the Türkiye's Mediterranean Coasts Within the Scope of Fisheries Law No. 1380

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ABSTRACT

In this study, fisheries violations within the scope of the Turkish Fisheries Law No. 1380 were characterized for the Mediterranean Coasts of Türkiye. For this purpose, by taking into account the frequency and amount of the fines, the patterns of violations in terms of fishing gear, region, season, region-season and fishing gear-season by regions interactions were determined. Data were derived from the Turkish Coast Guard Command' fisheries surveillance activities during 2014 for areas between coordinates of (36°00′00″ N-29°00′00″ E) and (36°00′00″ N-35°45′00″ E). A total of 491 violations against the Fisheries Law No. 1380 were considered. It was determined that the most violations were made by angling (23.22%) and the least by drift nets (0.4%). According to penalties amounts for the 2014, a total of $298,817 administrative fines were imposed. Trawl violations accounted for the highest total administrative fines (48.38%), while the lowest total administrative fines (0.17%) were for violations with drift nets. While the most violations were detected in Antalya region, the highest administrative fine was applied in Adana-Mersin region. According to seasons, there was a decrease in fisheries violations due to closed season measurement for fishing during summer. In terms of administrative fines, the season-region interaction was experienced the most in Adana-Mersin region during winter, and the least in Hatay-Adana region during summer. In season-region interaction, the most violations were observed in Antalya region in spring, while the least in summer in Hatay-Adana region. In interaction related to fishing gear-season by regions, it was determined that the highest number of violations and administrative fines occurred in winter during angling in Adana-Mersin region and in autumn during purse seine fishing in Hatay-Adana region. As a result, in short term, these findings could assist decision-making mechanisms for the effectiveness and efficiency of MCS (Monitoring, Control and Surveillance) system, which is an important part of fisheries management regime. In long term, these findings could also be used in a regional Decision Support System for fishery management with integrating with other elements of fisheries management regime.

INTRODUCTION

Fishing activities around the globe increase the welfare of humanity, meet the basic food needs of hundreds of millions of people, provide job opportunities, create recreation opportunities and provide foreign exchange resources. Considering today's increasing world population and the negative effects of global climate change, if MCS does not work effectively, besides the disappearance of the benefits it provides to society, it will cause more damage to the ecosystem with illegal fishing. (Flewweling, 2001; Boubekri et al., 2021). Extending usage of implementation of responsible fishing principles in all countries of the world will help for a sustainable fishing industry with all its components. In the context of responsible fishing principles, the MCS (monitoring, control and surveillance) is a term developed by the FAO MCS Conference of Experts in 1981 which is now widely accepted as a key principle in sustainable fisheries management and identified as the best hope in preventing, deterring and eliminating IUU (illegal, unregistered and unregulated) fishing (FAO, 2018).

All fishing activities, whether managed or not, take place within a general framework of social institutions. This institutional framework is called the fisheries management regime. Essentially, the fisheries management regime is a set of social guidelines and procedures that control fishing activities. All fisheries management regimes should logically include the following three key components; (i) Fisheries management system, (ii) the monitoring, control and surveillance system; and (iii) Fisheries jurisdiction (Fisheries Legislation). The fisheries management system (FMS) contains all the rules that the fishing activity must comply with. It specifies the regulatory framework for fishing activity such as fishing gear and area restrictions, fishing licenses, harvest quotas, etc. The primary task of the monitoring, control and surveillance (MCS) system is to monitor the activities of the fishing industry and ensure that the fisheries management system complies with its rules. Its secondary but still crucial task is to collect data on fisheries that can be used to improve fisheries management and judicial systems, as well as the monitoring, control and surveillance system itself. The fisheries justice system processes allegations of violations of fisheries management rules and imposes sanctions on those deemed to have violated the rules. The fisheries jurisdiction thus complements the monitoring, control and surveillance activities in the implementation of fisheries management rules. To take full advantage of fisheries management, all three components of the fisheries management regime must be properly designed, fully functional and well-coordinated. These three components of fisheries management regimes are like links in the same chain. If any of these fails, there will be little benefit, no matter how well-designed and implemented the other components are (Arnason, 2009).

MCS systems have the greatest long-term potential in reducing illegal fisheries, with implementation objectives such as spatial, temporal, managerial and practical solutions (Miller et al., 2013). Flewweling (1994) defines the MCS as follows: Monitoring covers measurement and analysis of all fishing activity such as catch, species composition, fishing effort, by-catch, discards, area of operations, and related issues. This information is used as base data for fisheries managers to arrive at management decisions. In case of unavailable, inaccurate or incomplete of this information, will lead the managers to be handicapped in developing and implementing management measures. Specification of the terms and conditions under which resources can be harvested is termed as control activity. These specifications are normally contained in national fisheries legislation and other arrangements that might be nationally, sub-regionally, or regionally agreed. The legislation provides the basis for which fisheries management arrangements, via MCS, are implemented. To get maximum efficiency from control activity, the framework legislation should clearly state the management measures being implemented and define the requirements and prohibitions that will be enforced. Surveillance involves the regulation and supervision of fishing activity to ensure that national legislation and terms, conditions of access, and management measures are observed. Surveillance is critical for ensuring that resources are not subject to over-exploited, poaching is minimized and management arrangements are implemented (FAO, 2002).

Ünal et al. (2016) stated that to prevent illegal fishing activities on the Mediterranean coast of Antalya and to strengthen weak MCS components, fishermen must periodically submit catch data (catch composition, target catch, bycatch, fishing duration, etc.) to the Ministry of Agriculture and Forestry, associations related to "marine and coastal protected areas" and to the Coast Guard Command (Within the scope of MCS activities in Türkiye, the most active official institution in terms of especially surveillance in Türkiye). Workshops, seminars and symposiums should be organized with riparian countries to prevent illegal fishing. The gains to be obtained as a result of these meetings; Ensuring coordination between audit institutions is an indication that MCS components will have a dynamic structure (Tanrıverdi, 2021a).

It is well recognized that to reduce fishing violation, the control system should be strengthened and sanctions for violations should be increased (Falautano et al., 2017). However, performing the MCS component is a costly process in terms of both human resources and equipment. Optimizing this process in terms of resource use is required a good characterization of the MCS based on past audit activities. Studies on this subject in Türkiye, especially in the Mediterranean region, are limited in terms of both materials and methods (Ünal et al., 2016; Tolon, 2017; Karabacak, 2019; Tanrıverdi, 2021b).

In the present study, it has been tried to reveal the characterization of all violations made under the Fisheries Law No. 1380 along the Mediterranean coast of Türkiye, taking into account the frequency and penalty amounts according to the interaction of fishing gear, region, season, region-season and fishing gear-season by regions. With this study aimed to create a basis for the decision-making authorities (relevant ministries, institutions and organizations) for the regulation and management of fisheries on a scientific base.

MATERIAL AND METHODS

Data were derived from the Turkish Coast Guard Command surveillance activities during the year 2014. A total of 491 violations against the Fisheries Law No. 1380 were considered. The violations examined were located between coordinates of (36°00′00″ N - 29°00′00″ E: Firnaz Bay-Kas, Antalya) and (36°00′00″ N - 35°45′00″ E: Yayladagi, Hatay). That geographic range has a coastline of 1577 km on the Mediterranean Sea (Öztürk & Başeren, 2008). In order to better evaluate the change along the coastline, the Mediterranean Sea coast of Türkiye was divided into three regions and called as following; from Kas to Gazipasa is "Antalya region", from Anamur to the west of Karatas Cape is "Adana-Mersin region" and, from the east of Karatas Cape to Denizgören is "Adana-Hatay region" (Figure 1).

The analysis was aimed, by taking into account the frequency and amount of the fines, to extract the patterns of the violations for the fishing gear, region, season, region-season and region-fishing gear-season by region interactions. Although the fines were in Turkish Lira, they have been converted to US dollars at the 2014 exchange rate in order to compare with other studies. Microsoft Excel and Past 4.0.9 software were used for the calculations, statistical analyses (Chi-square goodness of fit test and Chi-square test of independence), and summarization (as tables and graphs). Chi-square tests were performed with 5 % significant level (McHugh, 2013; Connelly, 2019). In case of rejecting the null hypothesis of chi-square test,

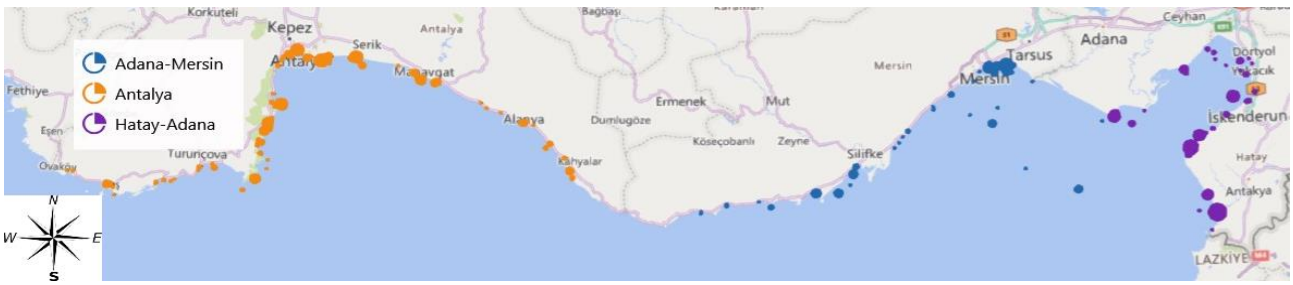

Figure 1. Study area. Circle points show logged penalties with their frequencies (The larger circle, the more penalty records)

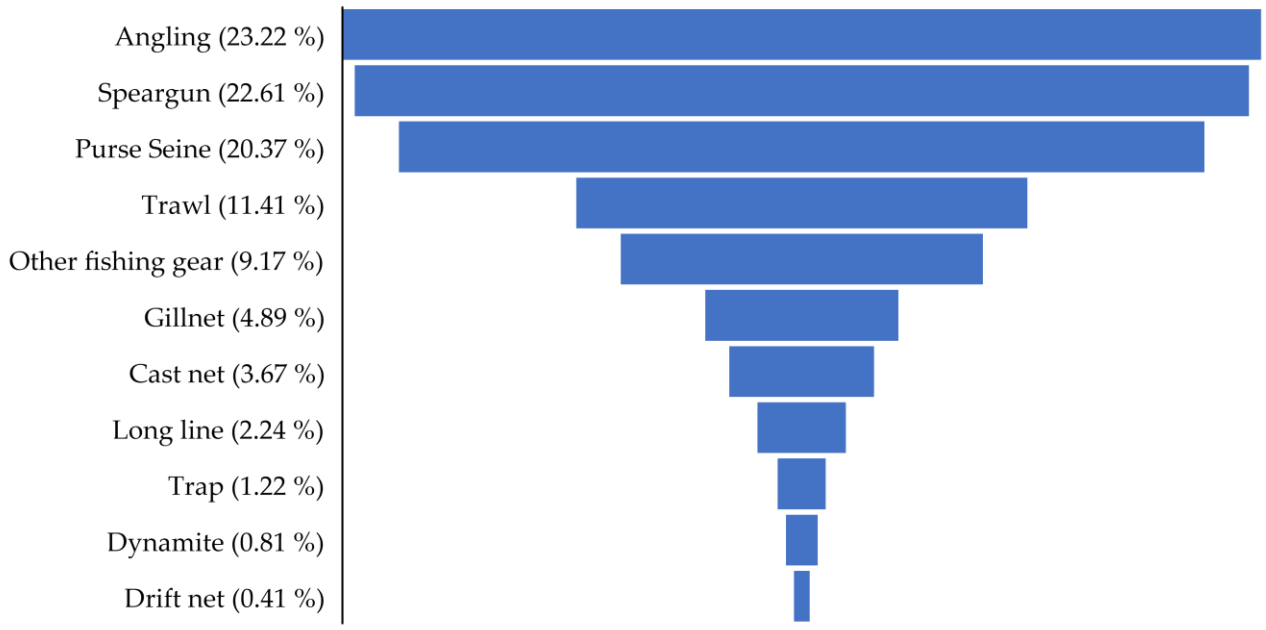

Figure 2. Distribution of fisheries violations in the Mediterranean by fishing gear

contingency coefficient (C) is used to measure the degree of relationship (dependency degree) between two categorical variables. (Munro, 2005). If C is near zero (or equal to zero) the variables are independent of each other; there is no association between them. The larger the table chi-squared coefficient is calculated from, the closer to 1.0 (or 100%) a perfect association will approach (Khan & Farooqi, 2022).

RESULTS

Taking into account the penalty frequency and penalty amounts, the characterizations were made according to the gear, region, season, region-season interaction and, gear-season by regions interaction.

Characterization of Fishing Gear

The most violations were fishing with angling (n=114, 23.22%), followed by speargun (n=111, 22.61%), purse seine (n=100, 20.37%), trawl (n=56, 11.41%), other fishing gear (n=45, 9.17%), gillnet (n=24, 4.89%), cast net (n=18, 3.67%), longline (n=11, 2.24%), trap (n=6, 1.22%), dynamite (n= 4, 0.81%) and drift net (n=2, 0.4%) (Figure 2).

Characterization of Season

According to Figure 3, it is seen that 146 (29.74%) violations were committed in winter months, 143 (29.12%) violations in autumn, 124 (25.25%) violations in spring and 78 (15.89%) violations in summer. It was determined that the difference in terms of the number of penalties according to the seasons was statistically significant ($p<0.05$).

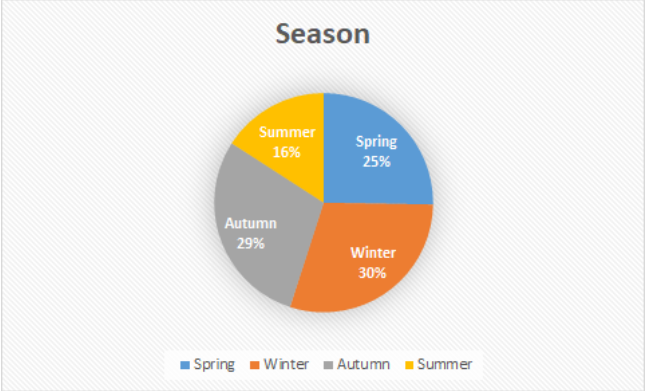

Figure 3. Distribution of seasons fisheries violations in the Mediterranean

Characterization of Region

There were 119 (24.23%) violations in the Adana-Mersin region, 231 (47.05%) in the Antalya region and 141 (28.72%) in the Hatay-Adana region. The total distribution of the fines according to the regions is given in Figure 4. It was determined that the difference in terms of the number of penalties according to the regions was statistically significant ($p<0.05$).

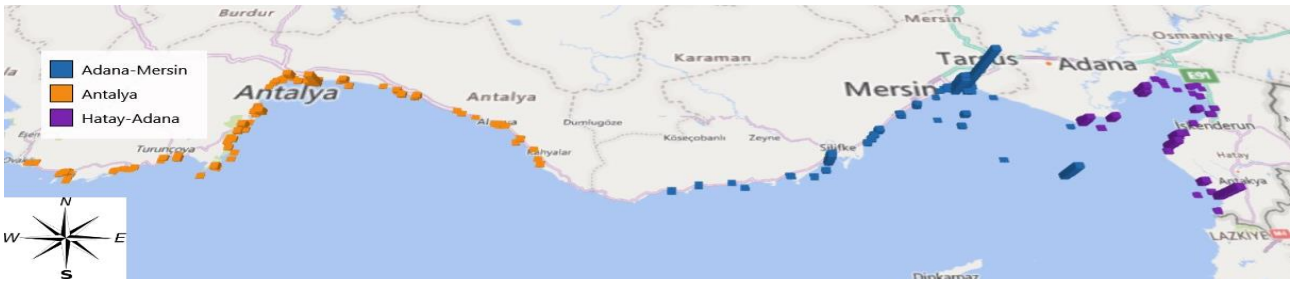

Figure 4. Distribution of penalties totals by region

When the data is examined, it was seen that the highest total penalty amount according to the regions, as a result of illegal fishing activities carried out in the MCS activities, was experienced in the Adana-Mersin region with 49.31%. This is followed by Hatay-Adana region (27.19%) and Antalya region (23.49%).

Characterization of Region-Season Interaction

Considering all regions, the total amount of penalties for violations on a seasonal basis was the highest with $131,445 (43.99%) in winter, and the least with $19,975 (6.68%) in summer. When the distribution of the total fines for violations, both regionally and seasonally was analyzed, the highest amount was from Adana-Mersin region in winter with $89,077 (29.81%), and the least was from Hatay-Adana region in the summer season with $3,030 (1.01%).

The highest number of violation cases occurred in the Antalya region with 231 cases (47.05%). This was followed by Hatay-Adana region with 141 cases (28.72%) and, Adana-Mersin regions with 119 cases (24.23%). Region-season interaction in terms of violation numbers was significant with 22.33% dependency (Contingency coefficient=0.2233, p=0.0002). Considering the frequency distribution of violations on a seasonal basis, it was seen that 143 violation cases (29.12%) were reported in autumn and 146 (29.74%) of them were reported in winter. In terms of region-season interaction for violation cases, the highest was occurred with 64 cases (13.03%) from Antalya region in the spring season, and the least with 9 cases (1.83%) from Hatay-Adana region in the summer (Table 1).

Characterization of Gear-Seasonal Interaction by Regions

Adana-Mersin region

In the Adana-Mersin region, 119 fisheries violations, located at northern latitudes between 36.08°-36.80° and eastern longitudes between 32.99°-35.30°, were investigated. In the region, gear-region-seasonal interaction for fines amount produced (in total) the following outcomes; "other fishing gear" in spring was $5,066 (43.67%), trawling in winter was 79 $707 (89.48%), in autumn was $32,222 (74.88%), and "other fishing gear" in summer was $1,267 (34.76%) (Table 2).

Table 1. Violations by regions and seasons

Season	Region					
	Adana-Mersin		Antalya		Hatay-Adana	
	n	%	n	%	n	%
Spring	23	4.68	64	13.03	37	7.54
Winter	46	9.37	54	11.00	46	9.37
Autumn	33	6.72	61	12.42	49	9.98
Summer	17	3.46	52	10.59	9	1.83
Total	**119**	**24.24**	**231**	**47.05**	**141**	**28.72**

Table 2. Penalties ($) for fisheries violations in Adana-Mersin region according to seasons and fishing gear

Fishing Gear	**Season**							
	Spring		**Winter**		**Autumn**		**Summer**	
	Total	**%**	**Total**	**%**	**Total**	**%**	**Total**	**%**
Angling	1,506	12.98	629	0.71	1,677	3.90	1,211	33.23
Purse seine	1,264	10.90	3,811	4.28	5,506	12.80		
Trap							124	3.41
Drift net	124	1.07						
Cast net			794	0.89	421	0.98		
Other	5,066	43.67	1,905	2.14	2,538	5.90	1,267	34.76
Speargun	124	1.07	421	0.47	248	0.58	794	21.79
Trawl	3,392	29.24	79,707	89.48	32,222	74.88		
Gillnet			967	1.09	421	0.98		
Longline	124	1.07	843	0.95			248	6.82
Total	**11,600**	**100.00**	**89,077**	**100.00**	**43,034**	**100.00**	**3,644**	**100.00**

Table 3. Penalties of fisheries violations in Adana-Mersin region according to seasons and fishing gear

Fishing Gear	**Season**							
	Spring		**Winter**		**Autumn**		**Summer**	
	n	**%**	**n**	**%**	**n**	**%**	**n**	**%**
Angling	8	34.78	3	6.52	8	24.24	7	41.18
Purse seine	3	13.04	3	6.52	4	12.12		
Trap							1	5.88
Drift net	1	4.35						
Cast net			4	8.70	1	3.03		
Other	8	34.78	3	6.52	3	9.09	3	17.65
Speargun	1	4.35	1	2.17	2	6.06	4	23.53
Trawl	1	4.35	27	58.70	14	42.42		
Gillnet			3	6.52	1	3.03		
Longline	1	4.35	2	4.35			2	11.76
Total	**23**	**100.00**	**46**	**100.00**	**33**	**100.00**	**17**	**100.00**

Table 4. Penalties amounts ($) for fisheries violations in Hatay-Adana region according to seasons and fishing gear.

Fishing Gear	**Season**							
	Spring		**Winter**		**Autumn**		**Summer**	
	Total	**%**	**Total**	**%**	**Total**	**%**	**Total**	**%**
Angling	838	4.73	2,013	7.30	838	2.69		
Purse seine	10,546	59.47	13,514	49.00	14,339	45.92	843	27.82
Cast net	421	2.38	843	3.06	124	0.40		
Other	2,011	11.34	1,057	3.83	1,393	4.46		
Speargun	967	5.45	2,107	7.64	1,810	5.80	497	16.40
Trawl			6,784	24.59	10,175	32.59		
Gillnet	1,686	9.51	1,264	4.58			843	27.82
Dynamite					2,542	8.14	847	27.97
Longline	1,264	7.13						
Total	**17,734**	**100.00**	**27,582**	**100.00**	**31,222**	**100.00**	**3,030**	**100.00**

The frequency of violations in the Adana-Mersin region according to fishing gear and seasons are as given in Table 3. The fishing gears with the highest number of violations in the region by the seasons were "angling" and "other fishing gear" with 8 cases (34.78%) in spring (for each of the two gear groups), trawling with 27 cases (58.70%) in winter, trawl with 14 (42.42%) cases in autumn and, angling with 7 (41.18%) cases in summer. In terms of violation numbers, region-season interaction was significant with 61.86% dependency (Contingency coefficient=0.6186, $p<0.05$) in the region. The number of the penalties in the region was identified mostly in winter (46 cases) in terms of season, in terms of fishing gear, 42 of them were trawls.

Hatay-Adana region

In the Hatay-Adana region, 141 fisheries violations, located between 35.95°-36.86° northern latitudes and 35.37°-36.21° east longitudes, were observed. The data of the penalty amounts and frequencies for the season and fishing gear were as given in Table 4 and Table 5, respectively.

In terms of the sum of the fines for violations in the Hatay-Adana region, purse seine fishing produced the highest amounts in all seasons as $10,546 (59.47%) in spring, $13,514 (49%) in winter, $14,339 (45.92%) in autumn, and $843 (27.82%) in summer. It was observed that the penalties for dynamite (27.97%) and gill net (27.82%) fishing gained importance in the region during the summer months. While the total amount of fines in the region in terms of season was maximum in autumn with $31,222 (39.24%), in terms of gear, fishing with purse seine produced the most with $39,242 (49.32%) (Table 4).

In Hatay-Adana region, among 141 violations, the most occurred violations according to the season and fishing gear were purse seine in spring, in winter and, in autumn with 17 cases (45.95%), 23 cases (50.00%), and 26 cases (57.78%), speargun in summer with 4 cases (44.44%), respectively (Table 5). In terms of violation numbers, region-season interaction was significant with 57.85% dependency (Contingency coefficient=0.5785, $p<0.05$) in the region

Antalya region

In the Antalya region, 231 fisheries violations, located between 36.14°-36.88° northern latitudes and 29.37°-32.27° east longitudes, were investigated. The data of the penalty amounts and frequencies for the season and fishing gear were given in Table 6 and Table 7, respectively.

In Antalya region, the highest fine amounts were from trawling with $10,175 (36.24%) in spring, from angling with $3,478 (23.52%) in winter, from speargun with $6,450 (45.93%) in autumn and $5,558 (41.79%) in summer. While the highest total amount of fines in the region was $28,077 (40%) in the spring in terms of season, the highest amount was from speargun with 20 $194 (27.76%) in terms of fishing gear (Table 6).

Table 5. Penalties of fisheries violations in Hatay-Adana region according to seasons and fishing gear

Fishing Gear	**Season**							
	Spring		**Winter**		**Autumn**		**Summer**	
	n	**%**	**n**	**%**	**n**	**%**	**n**	**%**
Angling	4	10.81	9	19.57	4	8.89		
Purse seine	17	45.95	23	50.00	26	57.78	2	22.22
Cast net	1	2.70	2	4.35	1	2.22		
Other	5	13.51	2	4.35	3	6.67		
Speargun	3	8.11	5	10.87	5	11.11	4	44.44
Trawl			3	6.52	3	6.67		
Gillnet	4	10.81	2	4.35			2	22.22
Dynamite					3	6.67	1	11.11
Longline	3	8.11						
Total	**37**	**100.00**	**46**	**100.00**	**49**	**100.00**	**9**	**100.00**

Table 6. Penalties ($) for fisheries violations in Antalya region according to seasons and fishing gear.

Fishing Gear	**Season**							
	Spring		**Winter**		**Autumn**		**Summer**	
	Total	**%**	**Total**	**%**	**Total**	**%**	**Total**	**%**
Angling	3 772	13.43	3 478	23.52	6 083	43.31	2 222	16.71
Cast net	1 264	4.50	1 340	9.06				
Drift net	421	1.50						
Gillnet	1 686	6.00	1 340	9.06	124	0.88	124	0.93
Longline	843	3.00	124	0.84				
Other	2 103	7.49	2 232	15.09	419	2.98	1 057	7.95
Purse seine	2 950	10.51	2 950	19.95			3 372	25.35
Speargun	4 862	17.32	3 323	22.47	6 450	45.93	5 558	41.79
Trap					546	3.89	967	7.27
Trawl	10 175	36.24			421	3.00		
Total	**28 077**	**100.00**	**14 786**	**100.00**	**14 043**	**100.00**	**13 301**	**100.00**

Table 7. Penalties of fisheries violations in Antalya region according to seasons and fishing gear

Fishing Gear	**Season**							
	Spring		**Winter**		**Autumn**		**Summer**	
	n	**%**	**n**	**%**	**n**	**%**	**n**	**%**
Angling	17	26.56	17	31.48	27	44.26	10	19.23
Cast **net**	3	4.69	6	11.11				
Drift net	1	1.56						
Gillnet	4	6.25	6	11.11	1	1.64	1	1.92
Longline	2	3.13	1	1.85				
Other	7	10.94	7	12.96	2	3.28	2	3.85
Purse seine	7	10.94	7	12.96			8	15.38
Speargun	20	31.25	10	18.52	28	45.9	28	53.85
Trap					2	3.28	3	5.77
Trawl	3	4.69		1	1.64			
Total	64	100.00	54	100,00	61	100.00	52	100.00

From a total of 231 violations in the Antalya region; In terms of season, speargun was the most prominent in spring with 20 cases (31.25%), in autumn with 28 cases (45.9%) and in summer with 28 cases (53.85%). Violations due to angling using with 17 cases (31.48%) in winter were the most. While the violation frequencies the region were mostly in the spring (64 cases) in terms of season, the most cases were from the speargun (86 cases) in terms of fishing gear. In terms of violation numbers, region-season interaction was significant with 50.05% dependency (Contingency coefficient=0.5005, $p<0.05$) in the region.

DISCUSSION

Totally, 491 violations from the Turkish Mediterranean coast in 2014 were detected by the Coast Guard Command. Yağcılar (2009) examined the violations of the fisheries law along the site of Turkish Mediterranean coast. The number of violations researcher examined between 2004 and 2008 was 586 in total. It is noteworthy that the number of violations examined in our study that only covering one year of period was 491.

The size and equipment of the patrol ships used in inspection activities, the size of the working area and the number of inspection personnel have also important in MCS (Fujii et. al., 2021). There are seven Coast Guard Command stations in the Antalya region, three in the Adana-Mersin region and 4 in the Hatay-Adana region. When the regions are compared, in terms of the frequency of violations; Antalya>Hatay-Adana>Adana-Mersin pattern was observed. In this sense, it could be said that the number of stations belonging to the coast guard command is compatible with the frequency of violations. Because logically, as the number of stations increases, the chances of detecting violations are expected to increase. In addition, when the coordinates of the fisheries violations were examined, it was an average of 21.87 nautical miles to the nearest Coast Guard Command stations. In our study, as a result of the examination of fishing violations in the Antalya region, it was observed that there was a decrease in violation cases as you move away from the central station of the Coast Guard. Öztürk (2009) emphasized that the control in international waters in the Mediterranean remained weak and stated that biodiversity should be protected except for marine or coastal protected areas.

It was determined that the frequency of violation pattern according to the fishing gears made throughout the entire study area was angling>spearman>purse seine>trawl, and seasonally, the pattern was winter>autumn>spring>summer. Considering that the fishery structure in the region is small-scale fisheries and angling is used more widely in this type of recreational fishing, it was seen that the findings of the study were compatible. Moreover, it was seen that the seasonal pattern showed an expected structure, considering that there is more fishing gear in the sea and inspection activities are carried out more frequently during the open season.

In terms of administrative fines, the order of fine amount according to the regions (from the most to the least) were "Adana-Mersin", "Hatay-Adana" and "Antalya" regions. In studied area, 48.38% of the administrative fines due to violations against the law were accounted for trawls, 19.78% for purse seine, and 8.12% for angling. When the penalty amount patterns of the regions and fishing gears were considered together, this situation could be seen as a function of the intense use of the relevant fishing gears in the regions. It was seen that the pattern of administrative fine amount according to the seasons (winter>autumn>spring>summer) was also compatible with the fishing season. The reason for the decrease in administrative fines in summer season is the ban on trawl and purse seine.

In terms of administrative fines amount in Antalya region, the pattern of fishing gear was; speargun>angling>trawl>purse seine, and the pattern of seasons was; spring>winter>autumn>summer. In terms of violation frequency, the pattern of fishing gear was; speargun>angling>purse seine, and the pattern of season was; spring>autumn>winter>summer. Considering these patterns, speargun and angling stand out as fishing gear in the first two rows, and spring and winter as the seasons. Despite the high number of violations in the Antalya region, it is noteworthy that it ranks third in terms of administrative fines. While fisheries violations with angling and speargun are observed in all four seasons in the region, it is striking that fisheries violations with trawlers occur frequently in the spring. The high total administrative fine in the spring is probably due to trawler fishing gear.

In Adana-Mersin region, in terms of administrative fines amount, the pattern of fishing gear was; trawl> purse seine, and the pattern of seasons was; winter>autumn>spring>summer. In terms of violation frequency, the pattern of fishing gear was; trawl>angling, and the pattern of season was; winter>autumn>spring>summer. Although it ranks third in the Adana-Mersin region in terms of the number of violations, it ranks first in terms of administrative fines, especially due to trawl. Considering these patterns, trawl and purse seine stand out as fishing gear in the first two rows, and winter and autumn as the seasons. It was observed that fisheries violations made with angling in the region decrease in winter months and increase in other seasons compared to winter months.

In Hatay-Adana region, in terms of administrative fines amount, the pattern of fishing gear was; purse seine>trawl, and the pattern of season was; autumn>winter>spring>summer in Hatay-Adana

region. In terms of violation frequency, the pattern of fishing gear was; purse seine>angling=speargun, and the pattern of season was; autumn>winter>spring>summer. According to the patterns mentioned, purse seine as a fishing gear in the region, winter and spring as the seasons come to the fore. In addition, violations of fishery products with purse seine and speargun were observed in the region in all four seasons. In addition, it was observed that violations with purse seine fishery was mostly experienced in autumn with the start of the fishing season, and then decreased towards spring. Fisheries violations made by trawling in the region are similar to the times of purse seine violations in the region and there are no trawl violations in the spring. Dynamite is not a fishing gear. This forbidden method, which takes place in the Hatay-Adana region, is difficult to detect by law enforcement since it is carried out from the coast. Additional measures are needed in the region regarding dynamite, which is easily made with substances such as dry ice and agricultural fertilizers. Arslantaş (2017) determined that 52% of the fishing activities in the Hatay-Adana region are illegal. He also pointed out that when the sample carrying out illegal fishing activities with angling was examined, illegal fishing activities increased as the income level decreased.

Yağcılar (2009) stated that trawl violations increase significantly with the opening of the fishing season in autumn, and decreases occur in the spring. A similar situation was seen in the current study, which was similar to Adana-Mersin and Hatay-Adana regions, but was not compatible with Antalya region. Karabacak (2019) studied trawler and purse-seine violations between years 2014-2018 in Turkish seas. Researcher found that the most trawling violations were experienced in Mersin. This result was similar to current study. Also, researcher calculated the administrative fine per violation was two times higher for trawl violations than purse purse-seine violations. However, in this study, administrative fine per violation ratio was calculated as 3.53. Öztürk (2015) stated that illegal fishing activities in the Mediterranean are mostly made with trawl, purse seine, and towed fishing gear.

CONCLUSION

The activities that were detected and penalized during the surveillance activities carried out by the Coast Guard Command on the coastline of the Mediterranean coast of Türkiye in 2014 were considered. Considering the population density on the Mediterranean coastline, as well as industrialization and global warming, fishing pressure has increased in fishing areas. This fishing pressure has caused an increase in IUU activities day by day. In these circumstances, the importance of ecosystem-based sustainable fisheries management has increased in the 21st century. Therefore, the findings obtained as a result of the research could assist decision-making mechanisms for the effectiveness and efficiency of the MCS system, which is an important part of the fisheries management regime in the short term. In the long term, these outputs may also be used in a regional fishery management Decision Support System, integrating with other elements of the fisheries management regime (VMS, BAGIS, AIS, SUBIS). However, most importantly, the government should develop and finance policies that will increase the efficiency of this system, which requires investment and is therefore expensive, like MCS.

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Compliance with Ethical Standards

Authors' Contributions

HBK: Drafting, Performed and managed statistical analyses.

MFC: Manuscript design, Performed and managed statistical analyses.

Both authors read and approved the final manuscript.

Conflict of Interest

The authors declare that there is no conflict of interest.

Ethical Approval

For this type of study, formal consent is not required.

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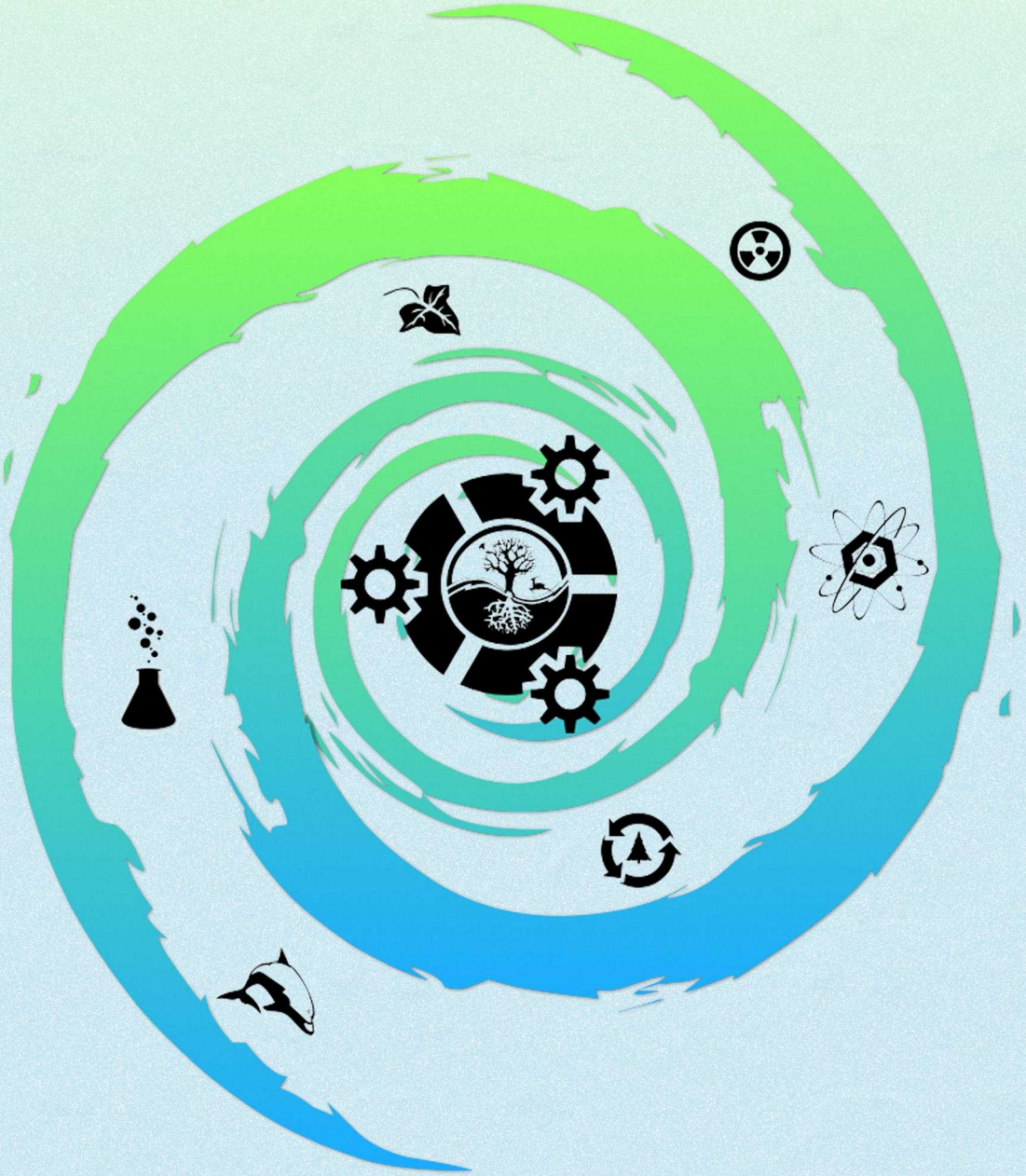

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