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RESEARCH ARTICLE ARAŞTIRMA MAKALESİ

Infection of the swim bladder parasite *Anguillicoloides crassus* in the European eel (*Anguilla anguilla*) caught from the Gediz Delta (Aegean Sea)

Gediz Deltası (Ege Denizi)'ndan avlanan Avrupa yılanbalığında (*Anguilla anguilla*) yüzme kesesi paraziti *Anguillicoloides crassus* enfeksiyonu

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Abstract: The wild European eels (776 fish, mean total length of 547±91 mm, mean weight 340±198 g) were obtained monthly between October 2015-September 2016 in Gediz Delta (Izmir Bay, Aegean Sea). A total of 263 nematode parasites (*Anguillicoloides crassus*) were isolated from the swim bladders of 52 parasitized fish. Parasitological indices were found relatively low. The prevalence was 6.7% and the mean intensity was 5.05. The abundance of *A. crassus* was also calculated as 0.33 in all sampled eels.

Keywords: *Anguilla anguilla,* swimbladder parasites, *Anguillicoloides crassus*, Aegean Sea

Öz: Gediz Deltası'ndan (İzmir Körfezi, Ege Denizi) Ekim 2015-Eylül 2016 tarihleri arasında Avrupa yılan balıkları (776 balık, ortalama boy 547±91 mm, ortalama ağırlık 340±198 g) aylık olarak temin edilmiştir. Parazitli 52 balığın yüzme keselerinden toplam 263 nematod (*Anguillicoloides crassus*) izole edilmiştir. Parazitolojik indeksler nispeten düşük bulunmuştur. Görülme sıklığı; %6,7 ve ortalama yoğunluk 5,05 olarak belirlenmiştir. *A. crassus* bolluğu da örneklenen tüm yılan balıklarında 0,33 olarak hesaplanmıştır.

Anahtar kelimeler: *Anguilla anguilla*, yüzme kesesi paraziti, *Anguillicoloides crassus*, Ege Denizi

INTRODUCTION

The European eel, *Anguilla anguilla* Linnaeus, 1758, is a catadromous species found in all European waters distributes from the Atlantic coast of Europe to northern Africa, the Black Sea and the Mediterranean (Bilecenoğlu et al., 2014). Over the past decades, the abundance of the eel population has decreased dramatically. Since 2008 it has been included in IUCN Red List of threatened species as critically endangered (Durif et al., 2011). The population of European eels is in decline due to several factors including parasitism (Moriarty and Dekker, 1997). For example, *Anguillicoloides crassus* Kuwahara, Niimi & Itagak, 1974 defined as a swim bladder parasite, was introduced accidentally into European waters with live *Anguilla japonica* from Asia in the early 1980s imported for consumption and aquaculture (Hafir-Mansouri et al., 2018). Palstra et al., (2007) suggested that this swim bladder parasite poses a serious threat to reproductive success as it causes damage to the swim bladder hence infected European eels cannot reach their spawning grounds during their breeding migration and they consider it therefore likely that *A. crassus* played a role in the current collapse of the European eel population.

Many studies have been carried out to determine the density of the swim bladder parasite *A. crassus*, which has entered the European eel population in the last two decades, according to abiotic factors in different regions of the Mediterranean (Aly et al., 2007; Quadroni et al., 2013; Koyuncu et al., 2017; Kantzoura et al., 2021) or in different ecosystems (Sauvaget et al., 2003; Loukili and Belghyti, 2007; Mayo-Hernandez et al., 2015; Bakaria et al., 2018; Giari et al., 2021), or to determine its life cycle (De Charleroy et al., 1990; Kirk, 2003; Rolbiecki, 2008) in the Mediterranean region. This study aims to determine the infection rates in the study area based on the prevalence data of *A. crassus* and to compare these values with different regions and habitats of the Mediterranean.

MATERIALS AND METHODS

The Gediz Delta (30°38' N; 55°26' E) is located northeast of the İzmir Bay (Aegean Sea) and protected by Ramsar convention covers an area of 20.400 km^2. It is composed of four lagoons and the Gediz River. Eel specimens were obtained from the commercial fishers who are using fyke nets (12 mm mesh size) in the Gediz Delta: between October 2015 and September 2016 (Figure 1). Besides that, some of the physicochemical parameters such as oxygen, pH, salinity and temperature of the delta water were measured every month with portable WTW multi 3420 set G (Figure 2).

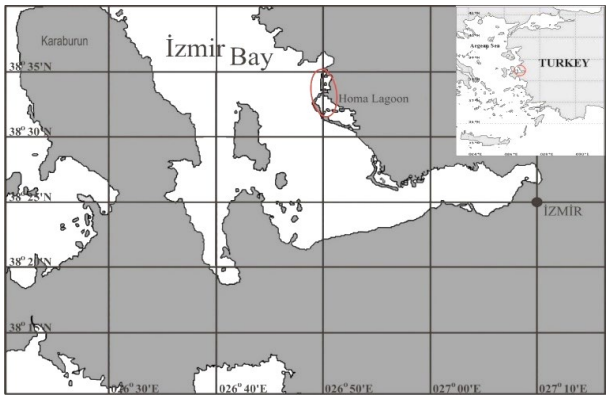

Figure 1. Sampling area

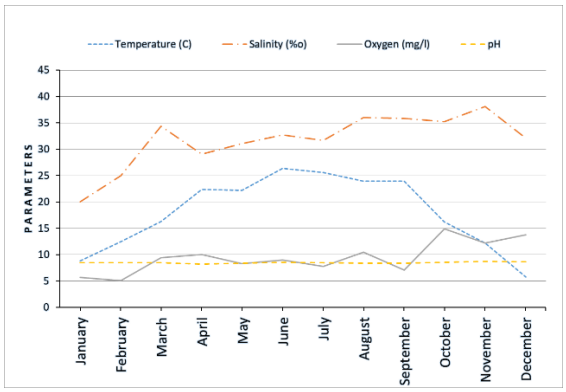

Figure 2. Monthly changes in some physicochemical parameters in the study area

A total of 776 wild European eels with a mean length of 547 ± 91 mm and mean weight of 340±198 g. which were obtained monthly between October 2015 to September 2016 from a local fisherman who has fished with fyke net in the Gediz delta of Izmir Bay. Collected samples were kept frozen until analysis. The swim bladder of each fish was removed and examined macroscopically. The presence of pre-adult and adult *A. crassus* was collected from the lumen of the eels by forceps. To identify the parasite, determined as *A. crassus*, we used the descriptions given by Moravec and Taraschewski (1988). Classical epidemiological parameters—i.e.

Abundance: abundance is the number of individuals of a particular parasite in/on a single host regardless of whether or not the host is infected [A: parasite abundance (A=Pn/N)].

Mean intensity: Mean intensity is the average intensity of a particular species of parasite among the infected members of a particular host species. In other words, it is the total number of parasites of a particular species found in a sample divided by the number of hosts infected with that parasite [Mi: mean intensity Mi=Pn/Ni)].

Prevalence: Prevalence is the number of hosts infected with 1 or more individuals of a particular parasite species divided by the number of hosts examined for that parasite species. It is commonly expressed as a percentage [P: Prevalence P=(Ni/N) x100)] (N: Number of samples; Ni: Number of infected eels; Pn: Total number of parasites) were used as defined by Bush et al., (1997).

RESULTS

Anguillicoloides crassus nematode parasites were found in the swim bladder of 52 out of 776 individuals examined in the region. The total body length (LT) ranged from 303 to 852 mm, and their average length was calculated as 547±91 mm.

The total number of *A. crassus* in the examined parasitized individuals was 263, and a maximum of 25 (adults and pre-adults) recorded in a single eel were found in the swim bladder of a sampled fish. One of the parasitological indices the prevalence of *A. crassus* among all samples was, 7%, and the abundance was 0.33 nematodes per all sampled eel (Table 1). The minimum and maximum lengths of the parasitized individuals were 336 mm and 678 mm, respectively (Figure 3).

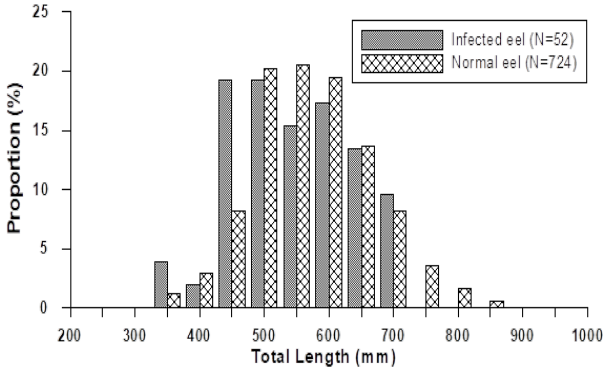

Figure 3. Length distribution of *Anguillicoloides crassus* Infected individuals within the sampled individuals

When the distribution of the parasites encountered according to the seasons is examined, it has been determined that the abundance is observed at the highest level in the summer season, and it decreases gradually in the autumn and winter seasons (Table 1).

Table 1. Seasonal variation of *Anguillicoloides crassus* in Gediz delta (N: Number of specimens; Ni: Number of infected eels; Pn: Total number of parasites; P: prevalence [P=(Ni/N) x100)]; A: Parasite abundance (A=Pn/N)], Mi: mean intensity (Mi=Pn/Ni))

SEASONS	N	Ni	Pn	P	Mi	A
Spring	191	14	65	7.3	4.64	0.34
Summer	176	19	133	10.7	7	0.97
Autumn	209	10	32	4.78	3.2	0.15
Winter	200	9	33	4.5	3.66	0.17
Total	776	52	263	6.7	5.05	0.33

DISCUSSION

According to Moravec and Taraschewski (1988), *Anguillicoloides crassus*, which started to be found in Europe in the early 1980s, was first reported in Turkey by Genç et al., (2005) in the Ceyhan river. In the following years, different studies have been found in the river systems of the northeastern coasts of the Mediterranean (Genç et al., 2008; Koyuncu et al., 2017; İnnal et al., 2019). However, a limited number of studies have been reported on the Turkish coasts of the Aegean Sea, including Köyceğiz-Dalyan (Çolak et al., 2012), İzmir Bay Çamaltı (Gürkan et al., 2022) and Vistonis Lake (Macnamara et al., 2014; Kantzoura et al., 2021) on the Greek coasts. Among these studies, only the study in İzmir Bay Çamaltı region was carried out in a salty environment, and it was determined as the study with the lowest prevalence (2.24%), (Table 2). The prevalence value in this study conducted in the Gediz Delta was calculated as 6.7%. It has been observed that this value is quite low when compared to other parts of the Mediterranean such as 78% in the Seyhan river (Genç et al., 2005), 75.2% in Egypt (Aly et al., 2007), 61.7% in the eutrophic lakes of Greece (Macnamara et al., 2014) and 39.7% in Macedonia (Cakić et al., 2002).

Prevalence values vary considerably according to the salinity values of the environments where the samples are taken. Many researchers have reported that *A. crassus* is less common in saltwater environments than in fresh waters (Louklidi and Belghyti, 2007; Aly et al., 2007; Mayo-Hernandez et al., 2015; Bakaria et al., 2018; Hafir-Mansouri et al., 2018; Wariaghli and Yahyaoui, 2018; Oudjane, 2021), (Table 2).

Table 2. Occurrence of *Anguillicoloides crassus* according to different regions in the Mediterranean (N: Number; iN: Infected eel number; P: Prevalence; ‰S: Salinity; pN: Parasite number in a host; Mi: Mean intensity; Npt: Number of total parasites)

Regions	(N)	(iN)	P (%)	‰S	(pN) Min-max	Mi	(Npt)	Reference
Loukkos Est.	60	-	51.6	-	-	1.9	-	El-Hilali et al., 1996 (Morocco)
Sebou Estuary	60	-	43.3	-	-	1.9	-	
Ohrid Lake	68	27	39.71	-	1-90	10.33	-	Çakiç et al., 2002 (Macedonia)
Ceyhan River	64	50	78.2	-	1-7	3.3	-	Genç et al., 2005 (Türkiye)
Al-Salam Chnl	186	154	82.8	0.2	-	7.48	1152	Aly et al., 2007 (Egypt)
Al-Gohhr, Manzala Lake	204	152	74.5	5.4	-	5.34	812	
Al-Gameel, Port-Said	106	64	60.4	39.8	-	4.20	269	
Bahr el Bakar ShaderAzzam	72	57	79.2	1.2	-	6.88	392	
Total	568	427	75.2	-	-	6.15	2625	
Asi River	18	11	61.1	-	1-18	4.55	50	Genç et al., 2008 (Türkiye)
Salam Channel	65	7	10.7	-	-	1.85	-	Abdelmonem et al., 2009 (Egypt)
Tinga River,	546	-	46.3	19	-	5.6	-	Hizem-Hebbechi et al., 2012 (Tunisia)
Bizerte Lagoon	103	-	15.5	28-38	-	1.6	-	
El Kebir River- Skikda	495	-	9.72	-	-	3.37		Rouag-Laouira et al., 2012 (Algeria)
Köyceğiz-Dalyan	73	29	39.7	15	1-14	3.3	97	Çolak et al., 2012 (Türkiye)
Camargue Lagoon,	277	-	52.7	-	1-37	4.1	-	Lefebvre et al., 2013 (France)
North Aegean Sea Vistonis estuarine system	188	-	61.7	-	1-21	3.41	-	Macnamara et al., 2014 (Greece)
Mar Menor Lagoon,	189	-	3.0	43-46	0-10	1	-	Mayo-Hernandez et al., 2015 (Spain)
Göksu River	45	13	28.8	-	-	4.69	61	Koyuncu et al., 2017 (Türkiye)
Seyhan River	42	8	19.04	-	-	8.12	56	
Ceyhan River	42	8	19.04	-	-	3.12	25	
Asi River	41	18	43.9	-	-	3.44	62	
Sebou Estuary	1138		66.7	13-33	-	2.93	-	Wariaghli and Yahyaoui, 2018 (Morocco)
Loukkos Estuary	100		41.8	22-34	1-5	-	-	
Golf of Bejaia	87		42.5	-	-	6.65	226	Hafir-Mansouri et al., 2018 (Algeria)
Tonga Lake	-	144	40.0	-	-	4.4	628	Bakaria et al., 2018 (Algeria)
El Mellah Lagoon	-	18	5.0	26-35	-	1.4	26	
Manavgat River	22	14	63.6	-		5.7	-	İnnal et al., 2019 (Türkiye)
Göksu River	28	17	60.7	-	1-48	5.9	-	
Seyhan River	20	15	75	-		6.7	-	
Vistonis estr syst.	-	26	-	-	-	2.31	268	Kantzoura et al., 2021 (Greece)
Amvrakikos Gulf	-	10	-	-	-	2.20	-	
Mesolongi Lagoons	-	34	-	-	-	3.88	-	
Peloponnese Lagoons	-	15	-	-	-	3.60	-	
Comacchio Lagoon	339		5.6	35	34	1.68	32	Giari et al., 2021 (Italy)
Gediz Estuary	89	2	2.24	35	1-23	7.5	24	Gürkan et al., 2022 (Türkiye)
Gediz Estuary	776	52	6.7	32	1-25	5.05	263	Present study (Türkiye)

According to these results, we can say that when comparing values such as mean intensity or prevalence, comparing them not according to regions but according to the freshwater or saltwater environments in which the creature is distributed can yield more successful results.

When the *A.crassus* parasite in the European eel and the density of this parasite in the population are examined, many reasons are showing that it is less in salt water than in freshwater.

Some of those; are related to which planktonic crustacea species or small fish they prefer in their first feeding in the regions they come from (Tesch, 1977). Kirk et al., (2000a) reported that the extracellular (pseudocoelomic) fluid of *A. crassus* had a higher mortality rate due to the osmotic pressure difference in saline waters compared to the environment. In addition, this osmotic pressure difference also causes rapid degeneration in parasite larvae and eggs (Kirk et al., 2000b). Palstra et al., (2007) and Sjöberg et al., (2009) reported that *A. crassus* caused damage to the swim bladder of eels, affecting their reproductive migration and not reaching their breeding areas.

In this case, considering that the reproductive ability decreases in areas with high parasites, it can be said that the breeding probability of eels living in the Gediz Delta is quite high compared to other regions and they constitute relatively healthy individuals of the Mediterranean population.

CONCLUSION

According to the data of all these studies, it turns out that eels in saltwater lagoons with low prevalence values are important in ensuring the future of the population in the Mediterranean. In addition, it is a fact that toxic substances carried to these areas by rivers (Aydın et al., 2017) as a result of human activities affect this species, which is already endangered, even more. Therefore, pollution protection and monitoring studies on such deltas are very important for the future of the European eel *Anguilla anguilla*.

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CONFLICT OF INTEREST STATEMENT

The author declares that there is no known financial or personal conflict that may affect the research article.

ETHICS APPROVAL

The author declares that all applicable guidelines for sampling, care, and experimental use of animals in this study have been followed.

DATA AVAILABILITY

The data sets generated during and/or analysed during the current study will be provided by the corresponding author upon the request of the editor or reviewers.

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