RESEARCH ARTICLE
Journal of Biometry Studies (2025) 5(1): 7-20
DOI: 10.61326/jofbs.v5i1.02
www.biometrystudies.com

Journal of Biometry Studies

PRENSİP
www.prensip.gen.tr

A bibliometric analysis of scientific publications on the freshwater crayfish *Pontastacus leptodactylus* in Türkiye: Trends and developments based on the Web of Science database

Hamdi AYDIN[1,*]

[1]Kocaeli University, Faculty of Arts and Sciences, Department of Biology, Kocaeli/ TÜRKİYE

[*]Corresponding author: aydin@kocaeli.edu.tr

Received: 07/04/2025, Accepted: 11/06/2025

Abstract

In this study, a bibliometric analysis is presented that examined 228 publications concerning *Pontastacus leptodactylus* (*Astacus leptodactylus*) in Türkiye, published between 1989 and 2024 and indexed in the Web of Science (WoS) database. The findings reveal that the number of publications increased from the 2000s onward, peaking between 2010 and 2022, but declining in 2023–2024. Research articles (216=94.7%) constitute the main body of academic output, while other document types, such as review articles (7) and conference papers (2), remain limited. Among the most prolific authors, Harlıoğlu, Muzaffer Mustafa (43 publications) leads, followed by Harlıoğlu, Ayşe Gül (17) and Mazlum, Yavuz (16), with research primarily concentrated in the categories of Fisheries (72), Marine and Freshwater Biology (51), and Environmental Sciences (36). Fırat University (73) emerged as the leading institution, with notable contributions from Gazi University (23) and Munzur University (22). The most cited studies include Harlıoğlu and Harlıoğlu (2004) with 77 citations and Kokko et al. (2021) with 62 citations. Keyword analysis highlights the centrality of terms such as *Astacus leptodactylus* (70), crayfish (69), and growth (19), encompassing topics like reproduction, oxidative stress, and artificial neural networks. The findings indicate that research in Türkiye into *P. leptodactylus* is predominantly focused on biological, ecological, and environmental aspects; however, greater efforts are needed to enhance international visibility and strengthen interdisciplinary collaboration. Future studies on issues such as disease, the effects of invasive species, stock protection, climate change and habitat loss will be critical for the sustainable management and scientific contributions of the species.

Keywords: Narrow-clawed crayfish, Scientific productivity, Citations, VoSviewer

Please cite this article as follows:

Aydin, H. (2025). A bibliometric analysis of scientific publications on the freshwater crayfish *Pontastacus leptodactylus* in Türkiye: Trends and developments based on the Web of Science database. *Journal of Biometry Studies*, *5*(1), 7-20. https://doi.org/10.61326/jofbs.v5i1.02

1. Introduction

Freshwater crayfish (Decapoda: Astacidae) are considered among the most ecologically and economically significant invertebrates inhabiting freshwater ecosystems. Furthermore, they represent a strategic resource for the fisheries and aquaculture sectors, making substantial contributions to food security and local economies. *Pontastacus leptodactylus* (*Astacus leptodactylus*), commonly found in Türkiye's freshwater ecosystems, is also known by various names, including the Turkish crayfish, Danube crayfish, or Galician crayfish (Harlıoğlu, 1996, 2004; Farhadi & Harlıoğlu, 2018).

Crayfish within the Astacidae family are classified into four genera: *Pacifastacus*, which is endemic to North America, and *Astacus*, *Pontastacus*, and *Austropotamobius*, which are native to Europe (Boštjancic et al., 2021). P. leptodactylus, a species of European origin, has a broad natural range extending from Europe to eastern Russia and parts of the Middle East (Kouba et al., 2014; Harlıoğlu, 2004; Berezina et al., 2021). Due to its economic importance, the species has also been introduced into various Western European countries for aquaculture purposes (Harlıoğlu, 2008; Harlıoğlu & Farhadi, 2017).

Türkiye was one of the leading countries supplying *P. leptodactylus* to European markets between 1970 and 1986 (Harlıoğlu & Holdich, 2001; Harlıoğlu & Harlıoğlu, 2004; Aydın et al., 2012). However, since 1985, overfishing and the crayfish plague caused by *Aphanomyces astaci* have led to significant declines in natural stocks. Crayfish harvesting, which amounted to 7,936 tons in 1984, steadily decreased in subsequent years, dropping to 304 tons by 1992 (Harlıoğlu & Harlıoğlu, 2006; Aydın et al., 2012). From 1995 onward, a partial recovery in stocks was observed, with harvest levels reaching 2,317 tons in 2004. However, this increase was not sustained, and harvesting declined again in the following years. According to the latest data, 662 tons of crayfish were harvested in 2022, and 736 tons in 2023 (Anonymous, 2023, 2024; Mazlum et al., 2025). Although the crayfish plague has had significant impacts on stocks, both historically and in recent times, it is reported that the current population has largely remained stable (Souty-Grosset et al., 2006; Gherardi & Souty-Grosset, 2017; Kokko et al., 2012, 2018).

P. leptodactylus is a species that, in addition to being harvested from natural waters, can also be cultured, and its production ranks fifth globally in crayfish production (Özturan et al., 2022; Nuc et al., 2023). In recent years, there has been an increase in studies aimed at enhancing the reproductive efficiency of this species, its aquaculture, and the reinforcement of local crayfish populations affected by diseases, including the crayfish plague (Harlıoğlu et al., 2012, 2013a, 2013b, 2014, 2017, 2018; Farhadi et al. 2018; Farhadi & Harlıoğlu, 2019).

Fisheries science has been experiencing rapid development worldwide in recent years, shaped by a combination of environmental, economic, technological, and societal factors. Primarily, global population growth and the increasing demand for food have rendered fishery products an increasingly important source of protein, thereby heightening interest in fisheries science (Pauly et al., 2022). In addition to the global increase in publications in the fields of fisheries and aquaculture, research using bibliometric analysis of these publications has also begun to emerge (Natale et al., 2012; Jaric et al., 2012; Radael et al., 2014; Aksnes and Browman, 2015; Syed et al., 2019; See et al., 2021; Bujas et al., 2023; Sheikh et al., 2024; Qin et al., 2024; Sarameh & Falahatkar, 2024). The number of publications concerning the bibliometric analysis of crayfish-related studies remains extremely limited. Fetzner (2009) published an article within the scope of the Freshwater Crayfish Symposium Books, addressing the impact factor (IF) and various bibliometric indicators of publications on crayfish. Mihaela et al. (2022) examined more than 700 articles about crayfish published in 189 different journals over the past thirty years, evaluating keywords, main research topics, institutional and author collaboration networks, as well as co-citation and co-occurrence analyses. Azra et al. (2023) investigated the trends and development of crayfish research through scientific measurement analyses, focusing on published literature, authors, affiliations, international collaboration networks, and co-citation datasets. In a more recent study, Ion et al. (2024) developed a web platform presenting real-time global mapping of freshwater crayfish and their pathogens. However, despite extensive literature reviews, a specific bibliometric analysis targeting the species *P. leptodactylus* has not yet been documented in the literature

Publishing scientific articles in journals indexed by the Web of Science (WoS) is important in terms of academic credibility, increased citation counts, and international recognition. These journals ensure the maintenance of scientific quality through rigorous peer-review processes and enable research to reach a broad academic audience. Furthermore, they offer advantages for academic promotion, scientific incentives, and international collaboration.

The aim of this study was to conduct a bibliometric analysis of articles about *P. leptodactylus* published in WoS from 1989 to 2024 with a Turkish affiliation. By examining all WoS-indexed documents affiliated with Türkiye, the study sought to identify influential authors, journals, institutions, key trends, and collaboration networks, thereby providing insights into the national scientific, economic, and environmental significance of this species. Furthermore, through the analyses conducted, the study aimed to identify gaps in the existing literature, encourage future research collaborations, and contribute to a deeper understanding of the conservation and aquaculture potential of *P. leptodactylus* in light of historical and ongoing challenges, such as overfishing and diseases.

2. Material and Methods

In this study, bibliographic data were retrieved from the Web of Science (WoS) Core Collection, including the Science Citation Index Expanded (SCIE), Conference Proceedings Citation Index – Science (CPCI-S), and Emerging Sources Citation Index (ESCI). The search was conducted on March 15, 2025, covering the publication period between 1989 and 2025. An advance search was adopted and used the following keywords for searching and retrieving data "*Pontastacus leptodactylus*" or "*Astacus leptodactylus*". The query path was: "*Astacus leptodactylus*" (All Fields) or "*Pontastacus leptodactylus*" (All Fields).

The results were refined by selecting "Türkiye" in the country rankings, and there were no restrictions on the language of the articles. The bibliographic data related to *P. leptodactylus* or *A. leptodactylus* included publication trends, publication types, top WoS categories, most productive authors, top journals, top affiliations, most cited publications, highly collaborative authors, highly cited articles and most used keywords. A total of 228 bibliographic records were retrieved and bibliographic

records were analyzed and mapped using the VoSviewer version 1.6.20 (https://www.vosviewer.com/). Additionally, Microsoft Excel 2016 was employed for the preparation of graphical representations.

3. Results

3.1. Number of articles published by year

Figure 1 presents the annual distribution of academic articles published by authors from Türkiye on *P. leptodactylus* and indexed in the WoS database. The first study about *P. leptodactylus* with a Turkish affiliation was titled "Identification of the Pathogenic Fungus Causing Destruction to Turkish Crayfish Stocks (*Astacus leptodactylus*)", and was conducted by Rahe and Soylu (1989). No further studies were recorded from 1989 to 2000; however, an increase in the number of publications was observed starting in the 2000s. A significant rise in publications occurred after 2010, with the highest levels reached in 2018, 2020, and 2022, when the number of articles peaked at 18 per year.

3.2. Publication types

The majority of identified studies consisted of research articles (216). In addition, there were review articles (7) and proceedings papers (2). A smaller number of publications included a meeting abstract (1), editorial material (1), and a correction (1). These data indicate that the studies were largely based on original research (Figure 2).

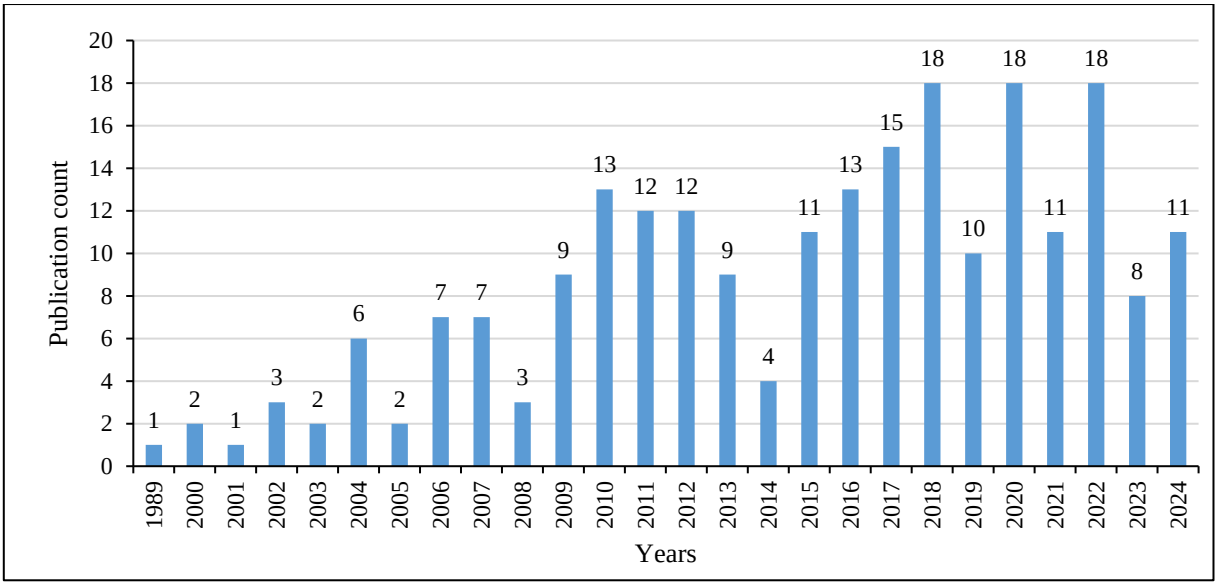

Figure 1. The number of publications on *P. leptodactylus* in WoS between 1989 and 2024 from Türkiye

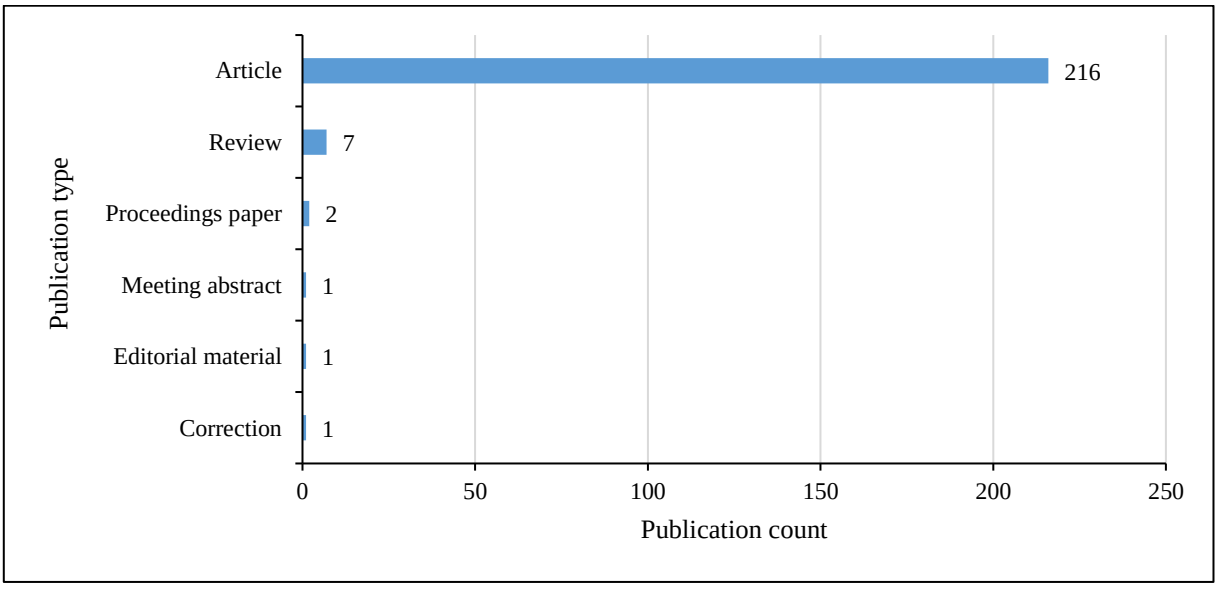

Figure. 2. Distribution of publication types and their counts about *P. leptodactylus* in Türkiye

3.3. Most productive authors

The top 15 most productive authors of publications about *P. leptodactylus* are shown in Figure 3. The researcher with more than twice as many publications as other Turkish authors was Harlıoğlu, Muzaffer Mustafa. He was followed by Harlıoğlu, Ayşe Gül and Mazlum, Yavuz. Other authors with more than 10 publications included Aksu, Önder, Günal, Aysel Çağlan, and Berber, Selçuk. Other researchers have contributed to the literature with publication counts ranging between six and nine articles. Furthermore, a large number of researchers with lower publication counts have also made contributions to the field. These data indicate that the studies are concentrated around certain researchers while also demonstrating broad academic participation.

3.4. Web of Science categories

Research into *P. leptodactylus* conducted in Türkiye is categorized under various scientific fields in WoS. The highest number of publications is concentrated in the categories of Fisheries, Marine and Freshwater Biology, and Environmental Sciences. These are followed by Veterinary Sciences, Zoology, and Biochemistry and Molecular Biology. Although fewer in number, studies have also been conducted in areas such as Toxicology, Food Science, Agriculture, Ecology, and Reproductive Biology. This distribution suggests that research into *P. leptodactylus* is primarily focused on aquatic products, environmental sciences, and biology, while also showing an interdisciplinary spread (Figure 4).

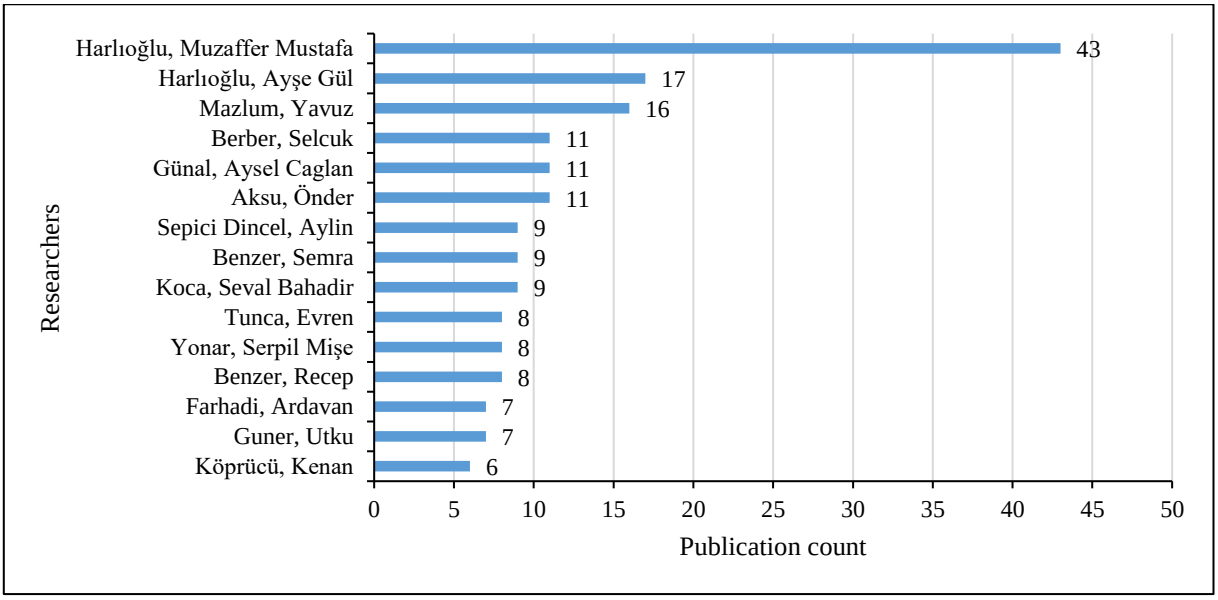

Figure 3. The top 15 most productive authors involved in *P. leptodactylus* publications in Türkiye

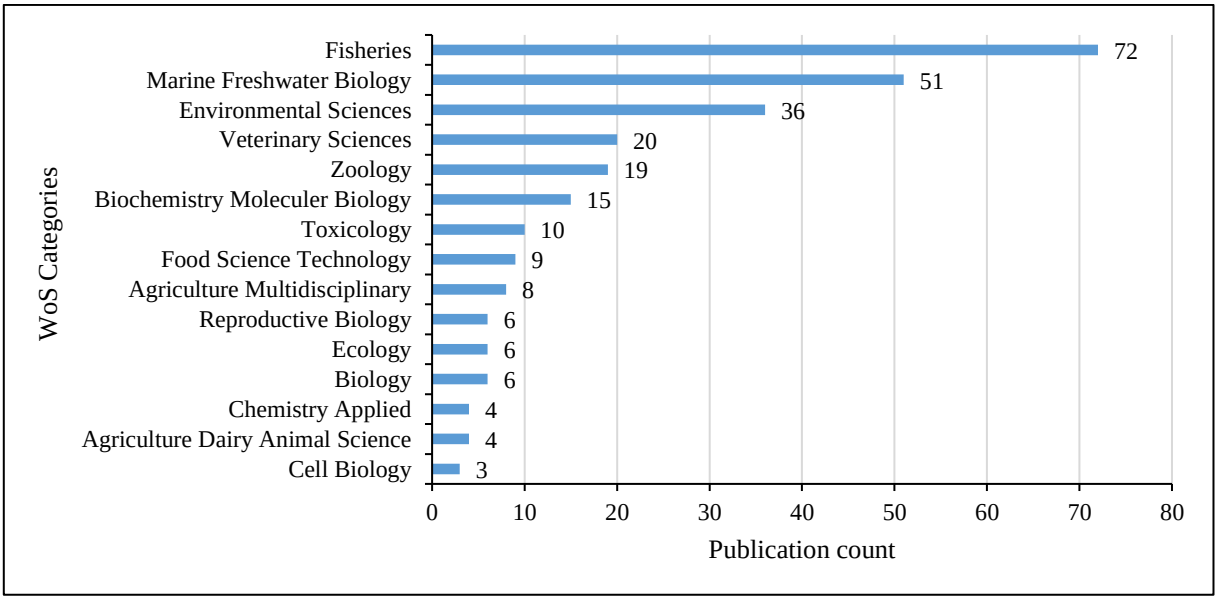

Figure 4. Number of publications on *P. leptodactylus* according to top 15 of WoS categories

3.5. Affiliations

In Türkiye, the institution with the highest contribution to research into *P. leptodactylus* is Fırat University, followed by Gazi University and Munzur University. Istanbul University, Süleyman Demirel University, and Ankara University are also among the major contributors. In addition, the Ministry of Agriculture and Forestry and its affiliated institutes, various research centers, and international universities, including Harvard University, the Technical University of Denmark and the University of Eastern Finland, have also contributed to the studies. Overall, the top 15 universities and public research institutions in Türkiye that have made the most contributions to the research are shown in Figure 5.

3.6. Publication titles

In Türkiye, among the journals with the highest number of publications about *P. leptodactylus*, the Fresenius Environmental Bulletin stands out, followed by Crustaceana, Aquaculture International, and Aquaculture Research. The Turkish Journal of Fisheries and Aquatic Sciences and Su Ürünleri Dergisi host studies originating from Türkiye. In addition, many national and international journals focusing on environmental sciences, veterinary medicine, ecotoxicology, and aquaculture have also published research. This finding highlights the multidisciplinary nature of research into *P. leptodactylus* (Figure 6).

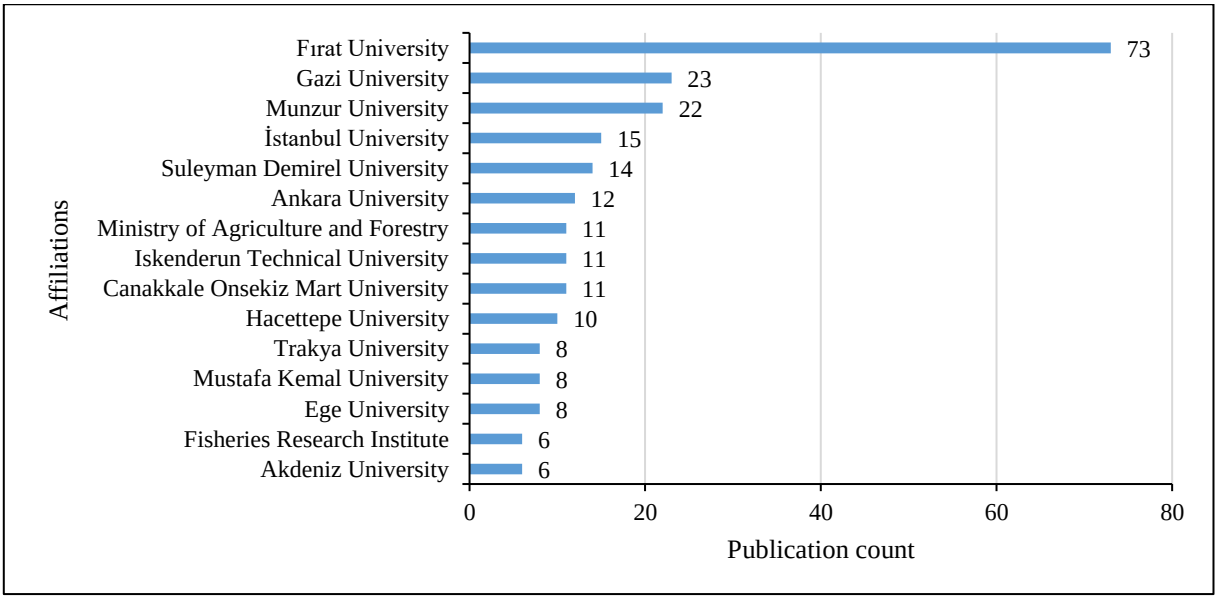

Figure 5. The top 15 affiliations with the most publications involved in *P. leptodactylus* in Türkiye

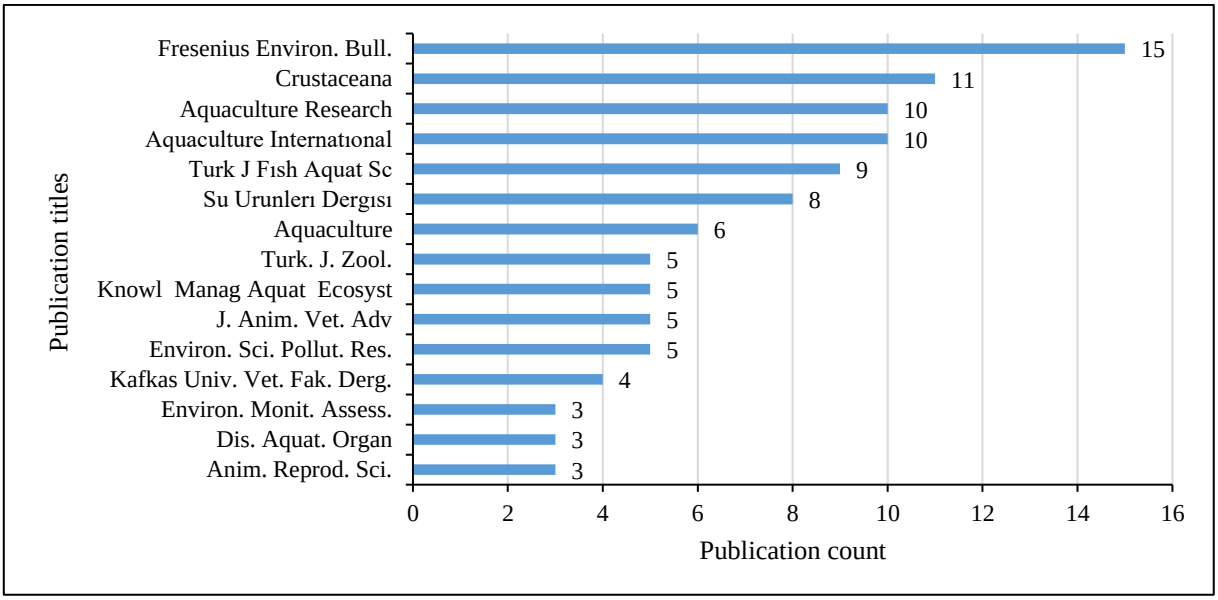

Figure 6. The top 15 journals and publication numbers in which studies on *P. leptodactylus* are most published

3.7. Most cited publications

According to WoS data, of the 228 articles published on *P. leptodactylus* between 1989 and 2024, 14 articles were not cited at all, while 193 articles were cited between 1 and 77 times. The most cited publication was Harlıoğlu (2004a) with 77 citations, Kokko (2012) was second with 62 citations, and Svoboda (2012) was third with 58 citations. The most cited articles are shown in Table 1.

3.8. Citation network of publications

The bibliographic citation network of publications of research into *P. leptodactylus* (1989-2024) in Türkiye is shown in Figure 7. This figure, created using WoSviewer, based on data retrieved from WoS on March 15, 2025, presents a network analysis of bibliographic citation across the 228 publications. Publications that received at least one citation were included in the visualization. Citation network analysis has revealed the relationships between key studies in the field and the most influential publications. The map shows that Harlıoğlu (2004a) occupies a central position, with studies such as Harlıoğlu (2008a), Kokko (2012), and Harlıoğlu (2017c) also receiving high citation counts. The colour scale indicates that early studies serve as fundamental citation sources, and new research is built upon these works. Particularly, the strong connections between Harlıoğlu (2004a), Harlıoğlu (2008a), and Kokko (2012) highlight that these studies are reference points within a specific research trajectory.

3.9. Analysis of the most used keywords

In the 228 documents identified, 525 different keywords were found, with the most frequently used keywords listed in Table 2. When examining the frequency and total link strength of the keywords used in the publications, *Astacus leptodactylus* (70) and *crayfish* (69) were the most frequently used terms, with their total link strengths reaching the highest values of 289 and 290, respectively (Figure 8). These results indicate that these keywords played a central role in the research, with most studies being centered around these concepts. Among the other keywords, *growth* and *survival* (19), *freshwater crayfish*, *oxidative stress*, and *reproduction* (10) are prominent. These terms suggest studies of biological processes and environmental factors. Furthermore, the use of the word *Türkiye* 19 times emphasizes a specific focus on the ecological context of the species in Türkiye. Keywords such as *Pontastacus leptodactylus*, *artificial neural networks*, and *decapoda* have been used less frequently, yet these are important components of specific research fields. These data demonstrate that research into *P. leptodactylus* tends to focus on both biological and environmental factors in Türkiye, with these areas being extensively studied through the use of keywords.

Table 1. Ranking of the most cited top 20 publications on *P. leptodactylus* in WoS in Türkiye

Rank	First Author*	Documents	Citations ▼	Link
1	Harlıoğlu (2004a)	Harlıoğlu and Harlıoğlu (2004)	77	50
2	Kokko (2012)	Kokko et al. (2021)	62	11
3	Svoboda (2012)	Svoboda et al. (2012)	58	9
4	Harlıoğlu (2008a)	Harlıoğlu (2008)	49	30
5	Harlıoğlu (2017c)	Harlıoğlu and Farhadi (2017)	38	27
6	Barım (2010)	Barım and Karatepe (2010)	37	8
7	Duman (2016)	Duman and Kaya, (2016)	37	1
8	Harlıoğlu (2004b)	Harlıoğlu and Harlıoğlu (2004)	36	31
9	Yıldız (2004a)	Yıldız and Banli (2004)	36	7
10	Rahe (1989)	Rahe and Soylu (1989)	36	23
11	Harlıoğlu (2006a)	Harlıoğlu and Harlıoğlu (2006)	36	16
12	Mazlum (2011b)	Mazlum et al. (2011)	34	6
13	Parrillo (2017)	Parrillo et al. (2017)	34	0
14	Akhan (2014)	Akhan et al. (2014)	32	10
15	Varol (2018a)	Varol and Sünbül (2018)	32	6
16	Harlıoğlu (2018)	Harlıoğlu et al. (2018)	32	12
17	Güner (2007)	Güner (2007)	29	12
18	Benli (2007)	Benli et al. (2007)	29	3
19	Harlıoğlu (2004c)	Harlıoğlu et al. (2004)	28	20
20	Kurun (2010)	Kurun et al. (2010)	27	10

*The top 20 most cited articles in the table were automatically obtained from the VoSviewer application, and only the first author's name has been retrieved. The correct sources are displayed in the "Documents" column.

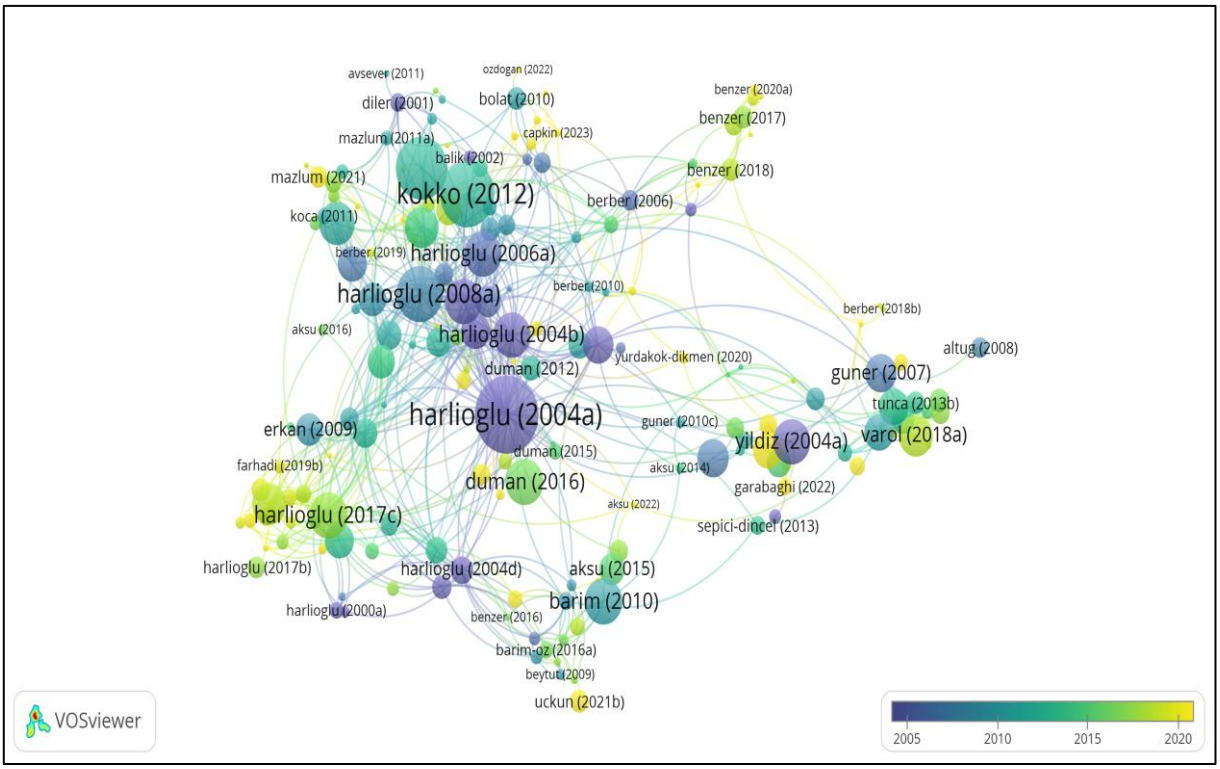

Figure 7. Publications featuring *P. leptodactylus* with at least 1 or more citations between 1989–2024 in Türkiye

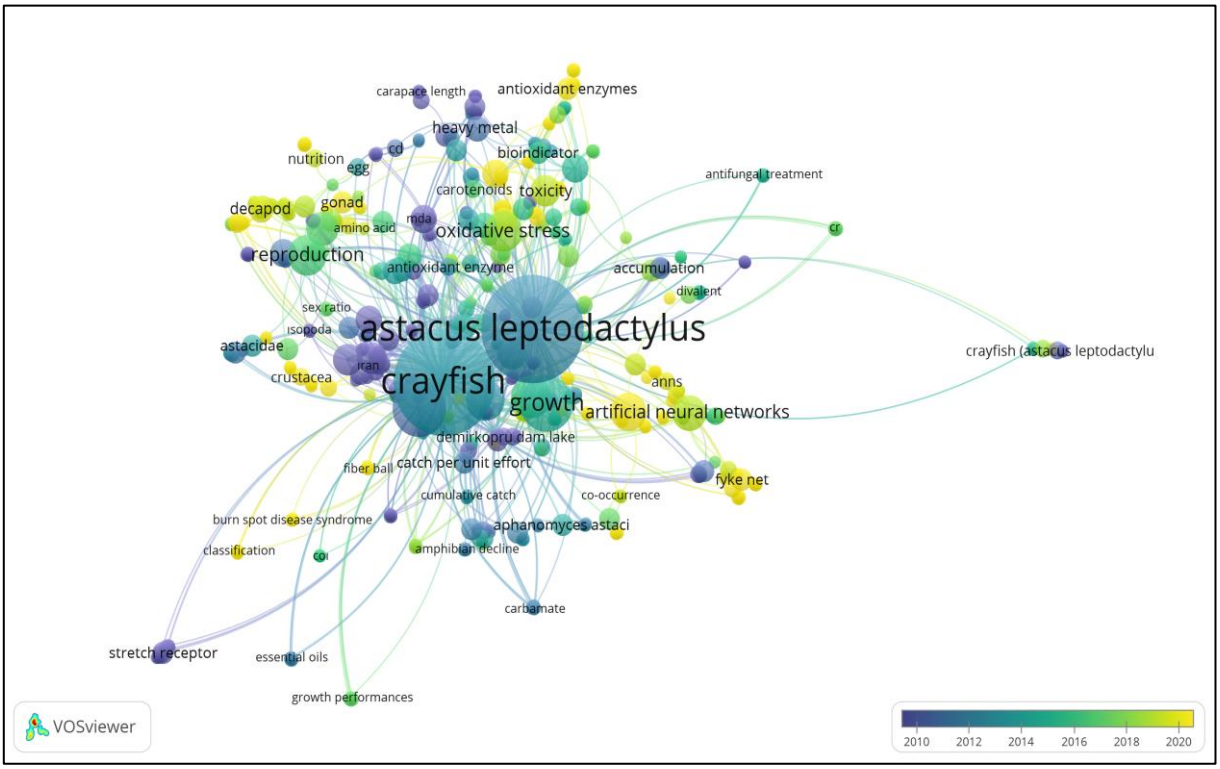

Figure 8. Analysis of keywords in published documents on *P. leptodactylus*

Table 2. Most frequently used keywords and link strength in published documents on *P. leptodactylus*

Rank	Keywords	Occurrences ▼	Total Link Strength
1	*Astacus leptodactylus*	70	289
2	Crayfish	69	290
3	Growth	19	77
4	Türkiye	19	91
5	Survival	11	48
6	Freshwater crayfish	10	43
7	Oxidative stress	10	41
8	Reproduction	10	47
9	*Pontastacus leptodactylus*	9	34
10	Artificial neural networks	8	28
11	Decapoda	7	29
12	Distribution	6	30
13	Harvest	6	32
14	Juvenile	6	28
15	Toxicity	6	26

4. Discussion

Research on freshwater crayfish has garnered significant global attention due to their ecological roles and economic value. Among these species, *Pontastacus leptodactylus* is widely recognized as one of the most economically important, particularly in European and Eurasian contexts. This study presents a bibliometric analysis of WoS-indexed publications on *P. leptodactylus* affiliated with Türkiye between 1989 and 2024.

The distribution of these publications affiliated with Türkiye over the years provides valuable insights into national research trends and the evolution of scientific interest in this species (Figure 1). Studies about *P. leptodactylus* began with only one publication in 1989 but showed a significant increase from the early 2000s onward. Notably, between 2010 and 2022, there was a remarkable rise in the number of publications, with annual publication counts generally exceeding 10, peaking at 18 in 2018. However, despite the importance of the species, the decline in the number of publications in 2023 and 2024 may be attributed to factors such as the impact of the COVID-19 pandemic or the redirection of resources and research interest toward other fields. According to WoS data, a significant decrease in the number of publications on *P. leptodactylus* has been observed in European countries in the last two years compared to previous periods. This trend mirrors the recent decline in the number of publications observed in Türkiye

Although numerous national studies on *P. leptodactylus* have been published in recent years (Cilbiz et al., 2020; Özkök et al., 2021; Baltacı et al., 2023; Kan et al., 2024; Aydın & Serdar, 2024; Gençay et al., 2024), inclusion in the WoS database increases international visibility and contributes to academic impact through peer review, citation indexing, and funding eligibility. Promoting WoS-indexed publication of Türkiye-originated research on this species is crucial for global recognition of its ecological and economic importance.

An analysis of the document types identified in the present study revealed that academic output was predominantly focused on research articles, highlighting the primary objective of contributing original research to the scientific literature. Other document types included review articles, and a few conference papers, corrections, editorial comment, and a meeting abstract. The low number of conference papers suggests a need to enhance the international visibility of Türkiye-affiliated researchers at academic events. While academic production in Türkiye is largely built on a strong research foundation, increasing the number of review articles and conference papers would contribute to both the synthesis of scientific knowledge and the enhancement of international visibility.

An analysis of the identified documents showed a total of 201 researchers contributing to this field from Türkiye. A few of these researchers contributed a significant proportion of all the articles. These were Muzaffer Mustafa Harlıoğlu, Ayşe Gül Harlıoğlu, and Yavuz Mazlum. M.M. Harlıoğlu and A.G. Harlıoğlu, as the leading authors, have primarily conducted research on the freshwater crayfish *Astacus leptodactylus*, focusing on topics such as reproductive biology, nutrition, aquaculture, population status, the impacts of invasive species, and harvesting practices (Harlıoğlu, 1996; Harlıoğlu & Harlıoğlu, A.G. 2004; Harlıoğlu, 2004; Harlıoğlu et al. 2004; Harlıoğlu & Harlıoğlu, 2006; Harlıoğlu, 2008; Harlıoğlu et al. 2012; Harlıoğlu et al. 2013a; Harlıoğlu et al. 2013b; Harlıoğlu et al. 2014; Harlıoğlu et al. 2017; Harlıoğlu & Farhadi 2017; Harlıoğlu et al. 2018). Ranked third, Yavuz Mazlum has primarily conducted aquaculture-oriented research on *Pontastacus leptodactylus*, focusing on growth performance, nutritional strategies, environmental influences, body composition, and capture characteristics (Mazlum, 2007; Bolat et al. 2010; Tufan et al. 2012; Berber & Mazlum, 2016; Öksüz & Mazlum, 2016; Şirin & Mazlum, 2016; Mazlum et al. 2017; Mazlum et al. 2021). Other authors contributed around 5% of the output including Aksu Ö, Günal A.Ç, and Berber S. (Figure 3). Furthermore, the WoS database indicates that 80 authors have contributed a single publication, 60 authors have two publications, 15 authors have three, 20 authors have four, and 7 authors have five publications each. These findings suggest that research into *P. leptodactylus* is concentrated around specific individuals, with M.M and A.G Harlıoğlu particularly standing out in this field. Variations in publication counts may be attributed to researchers' areas of expertise or collaborative efforts within the scientific community.

The WoS categorization of studies into *P. leptodactylus* was primarily focused on aquatic ecosystems, environmental factors, and the economic value of the species. Notably, the high number of publications in the

fields of *Fisheries* and *Marine & Freshwater Biology* underscores the ecological and economic significance of P. leptodactylus in freshwater habitats. The prominence of the *Environmental Sciences* category is probably a reflection of the growing research interest in the effects of water quality and habitat changes on the species. Studies under the categories *Veterinary Sciences*, *Zoology*, and *Biochemistry & Molecular Biology* focus on the physiology, genetic structure, and diseases of *P. leptodactylus*, further highlighting the species' biological and ecological importance. Furthermore, research in the fields of *Toxicology* and *Food Science & Technology* focused on human consumption, safety, and nutritional value (Figure 4). While studies in other disciplines were more limited, subjects explored included reproductive biology, ecological role, and relationship of P. *leptodactylus* with agricultural activities. Overall, studies into *P. leptodactylus* from Türkiye primarily concentrated on environmental factors and economic value. In the future, increasing research into topics such as the effect of climate change, habitat loss, and sustainable harvesting will be important for the conservation and management of this species.

In the present study, Fırat University made the highest contribution followed by Gazi University and Munzur University. Other significant contributors included Istanbul University, Süleyman Demirel University, and Ankara University. Moreover, Çanakkale Onsekiz Mart University, İskenderun Technical University, and the Turkish Ministry of Agriculture and Forestry contributed >10 studies to this field. Ege University, Mustafa Kemal University, and Trakya University made moderate contributions, while Hacettepe University contributed ten studies. Akdeniz University and the Fisheries Research Institute also contributed some studies (Figure 5). This distribution showed that research on *P. leptodactylus* is concentrated in specific universities, but this is probably associated with the small number of active authors in this field being affiliated with specific institutions. The interest of various academic and public institutions in Türkiye in this subject provides a significant academic framework for the conservation of freshwater ecosystems and biodiversity. In the future, fostering research through greater institutional involvement and interdisciplinary collaborations will contribute to a more comprehensive understanding of the species' ecological, genetic, and biological dynamics.

The 228 studies included in this analysis were published in 96 different journals indexed in the WoS database. The journal with the highest number of published articles was *Fresenius Environmental Bulletin*. Journals such as *Crustaceana*, *Aquaculture International*, and *Aquaculture Research* also stand out in this field with these four journals publishing almost a quarter of the 228 studies. Local academic journals such as the *Turkish Journal of Fisheries and Aquatic Sciences* and *Su Ürünleri Dergisi* were also notable (Figure 6). This distribution supports the notion that the studies were primarily concentrated in the fields of environmental sciences, aquaculture, and zoology. The publication of these studies in international journals demonstrates that research on *P. leptodactylus* in Türkiye had appreciable visibility within the global academic community. In the future, an increase in interdisciplinary studies and publications in high-impact journals will contribute to scientific advances in this field.

The most cited study was authored by Harlıoğlu and Harlıoğlu in 2004, with 77 citations and a link strength of 50. Other prominent studies included Kokko et al. (2021) and Svoboda et al. (2012). In addition, Harlıoğlu (2008) and Harlıoğlu and Farhadi (2017) also provide noteworthy contributions (Table 1). These data indicate that studies by Harlıoğlu are among the most influential in the field and have a broad academic impact. While the majority of the research focuses on biology, ecology, and aquaculture, the fact that studies from various years continue to receive citations highlights the scientific importance and ongoing relevance of the topic. In the future, an increase in such high-impact studies will contribute to the development of more comprehensive and interdisciplinary approaches in *P. leptodactylus* research.

The citation network of publications was examined, and the results are presented in Figure 7. This citation network map shows the relationships between key studies in the field and the most influential publications. The study by Harlıoğlu (2004a) occupied a central position and had strong connections with other publications in the field. Similarly, Harlıoğlu (2008a), Kokko (2012), and Harlıoğlu (2017c) also figured prominently, were cited relatively frequently and were thus interconnected with many other studies. The color scale used on the map illustrates the distribution of publications over the years. Notably, studies conducted between 2005 and 2010 are predominantly represented in blue and purple tones, while more recent publications are depicted in green and yellow tones (Figure 7). This indicates that early studies in the field are regarded as foundational citation sources, with newer research building upon them. Strong connections between certain publications were observed. In particular, the robust links between the works of Harlıoğlu (2004a), Harlıoğlu (2008a), and Kokko et al. (2012) suggest that these publications serve as key references within a specific research trajectory. On the other hand, more recent studies (e.g., Benzer, 2020; Uçkun, 2022) exhibit fewer connections, implying that these publications offer new contributions to the field and may strengthen their position within the network over time as they accumulate more citations.

The most frequently used keywords suggested research focusing on the biological, ecological, and environmental characteristics of the species. Keywords such as *Astacus leptodactylus* and *crayfish* indicate that the core focus of these studies is on the species *P. leptodactylus*, while

research concentrating on biological processes such as growth, survival, and reproduction points to a significant trend toward understanding the species' life cycle and its sensitivity to environmental factors. Furthermore, *ecotoxicological* topics like *oxidative stress* and *toxicity* emerge as key areas of study, exploring the impacts of environmental pollutants on the species. Keywords such as *freshwater crayfish* and *Pontastacus leptodactylus* provide insights into the species' biogeography, while the use of modern modelling techniques using *artificial neural networks* demonstrated an innovative approach to understanding ecological parameters such as growth, survival, and reproduction (Table 2, Figure 8). Moreover, topics such as *distribution* and *harvest* are considered in studies examining the population dynamics of the species and its relationship with environmental conditions. These findings reveal that research on *P. leptodactylus* in Türkiye adopts a multidisciplinary approach, encompassing not only biological characteristics but also ecotoxicology, environmental factors, and advanced modelling techniques, thereby offering significant contributions to future studies.

5. Conclusion

This study reveals that research on *Pontastacus leptodactylus* in Türkiye, as indexed in the Web of Science (WoS) database, has made noteworthy contributions to the global scientific literature, particularly within the domains of biology, ecology, aquaculture, and ecotoxicology. The bibliometric analyses demonstrate a notable increase in publications over the years, reaching its peak in 2018. Prominent scholars such as Harlıoğlu M.M. have played a pivotal role in the development of the field, as evidenced by their frequently cited publications and central positions within citation networks. The concentration of studies in disciplines such as fisheries, marine freshwater biology, and environmental sciences underscores the species' ecological and economic importance, while the use of innovative approaches like artificial neural networks highlights the adoption of multidisciplinary methods. Despite these advancements, the recent absence of publications in 2023 and 2024, alongside the relatively low number of review articles and conference proceedings, highlights a need for greater efforts toward international visibility and comprehensive knowledge synthesis. Moving forward, increasing interdisciplinary collaborations, targeting high-impact journals, and addressing emerging challenges, such as climate change and sustainable harvesting, will be key to advancing the conservation and management of *P. leptodactylus* and enhancing its scientific and economic significance on a global scale.

Conflict of interest

The author declares that they have no known competing financial or non-financial, professional, or personal conflicts that could have appeared to influence the work reported in this manuscript.

Ethical Approval

The author declares that formal consent is not required for this type of study.

References

Akhan, S., Bektaş, Y., Berber, S., & Kalaycı, S. (2014). Population structure and genetic analysis of narrow-clawed crayfish (*Astacus leptodactylus*) populations in Türkiye. *Genetica*, *142*, 381-395. https://doi.org/10.1007/s10709-014-9782-5

Aksnes, D. W., & Browman, H. I. (2015). An overview of global research effort in fisheries science. *ICES Journal of Marine Science*, *73*(4), 1004-1011. http://doi.org/10.1093/icesjms/fsv248

Anonymous (2023-2024). Fisheries Statistics of Prime Ministry State Planning Organization. Republic of Türkiye, Ankara.

Aydın, H., Harlıoğlu, M. M., & Bök, T. D. (2012). Harvest, export and economic status of freshwater crayfish (*Astacus leptodactylus* Esch. 1823) in Turkey. *African Journal of Agricultural Research*, *7*(16), 2463-2468, https://doi.org/10.5897/AJAR12.768

Aydın, A. N., & Serdar, O. (2024). Determination of terbium's oxidative stress and antioxidant responses in *Pontastacus leptodactylus*. *Acta Aquatica Turcica*, *20*(1), 23-32. https://doi.org/10.22392/actaquatr.1294250

Azra, M. N., Wong, L. L., Aouissi, H. A., Zekker, I., Amin, M. A, Adnan, W. N. W., Abdullah, M. F., Latif, Z. A., Noor, M. I. M., Lananan, F., & Pardi, F. (2023). Crayfish research: A global scientometric analysis using CiteSpace. *Animals*, *13*, 1240. http://doi.org/10.3390/ani13071240

Baltacı, M. A, Aydın, H., Seyhun, N., & Deniz, T. (2023). Morphometric characteristics of freshwater crayfish (*Pontastacus leptodactylus* Eschscholtz, 1823) caught in Sapanca Lake, Türkiye. *LimnoFish-Journal of Limnology and Freshwater Fisheries Research*, *9*(2), 63-75. http://doi.org/10.17216/LimnoFish.1149864

Barim, O., & Karatepe, M. (2010). The effects of pollution on the vitamins A, E, C, beta-carotene contents and oxidative stress of the freshwater crayfish, *Astacus leptodactylus*. *Ecotoxicology and Environmental Safety*, *73*(2), 138-142. https://doi.org/10.1016/j.ecoenv.2009.08.002

Benli, A. Ç. K., Sarıkaya, R., Sepici-Dincel, A., Selvi, M., Şahin, D., & Erkoç, F. (2007). Investigation of acute toxicity of (2, 4-dichlorophenoxy) acetic acid (2, 4-D)

herbicide on crayfish (Astacus leptodactylus Esch. 1823). *Pesticide Biochemistry and Physiology*, *88*(3), 296-299 https://doi.org/10.1016/j. pestbp.2007.01.004

Benzer, S. (2020). Artificial neural networks approach to growth properties *Atherina boyeri* Risso 1810 in Yamula Dam Lake Türkiye. *Fresenius Environmental Bulletin*, *29*(2), 1145-1152.

Berber, S., & Mazlum Y, (2009). Reproductive efficiency of the narrow-clawed crayfish, *Astacus leptodactylus*, in several populations in Turkey. *Crustaceana*, *82*(5), 531-542, https://doi.org/10.1163/156854009X407713

Berezina, N. A, Terentiev, P. M., Sharov, A. N., & Maximov, A. A. (2021). New records and disappearance from old sites of narrow-clawed crayfish *Pontastacus leptodactylus* in northwestern Russia. *Bioinvasions Records*, *10*(4), 894-903. http://doi.org/10.3391/bir.2021.10.4.14

Bolat, Y., Demirci, A., & Mazlum, Y. (2010). Size selectivity of traps (Fyke-Nets) of different mesh size on the narrow-clawed crayfish, *Astacus leptodactylus* (Eschscholtz, 1823) in Eğirdir Lake, Turkey. *Crustaceana*, *83*(11), 1349-1361. http://doi.org/10.1163/001121610X536969

Boštjančić, L. L., Bonassin, L., Anušić, L., Lovrenčić, L., Besendorfer, V., Maguire, I., Grandjean, F., Austin, C. M., Greve, C., Hamadou, A. B., & Mlinarec, J. (2021). The *Pontastacus leptodactylus* (Astacidae) repeatome provides insight into genome evolution and reveals remarkable diversity of satellite DNA. *Frontiers in Genetics*, *11*, 611745. http://doi.org/10.3389/fgene.2020.611745

Bujas, T., Vladimir, N., Koričan, M., Vukić, M., Ćatipović, I., & Fan, A. (2023). Extended bibliometric review of technical challenges in mariculture production and research hotspot analysis. *Applied Sciences*, *13*(11), 6699. http://doi.org/10.3390/app1311669

Cilbiz, M,, Aydın, C., & Uzunmehmetoğlu, O. Y. (2020). Evaluation of Turkey's crayfish (*Pontastacus leptodactylus* (Eschscholtz, 1823) production in national and global scale. *LimnoFish-Journal of Limnology and Freshwater Fisheries Research*, *6*(1), 59-74. http://doi.org/10.17216/LimnoFish.561180

Duman, F., & Kaya, M. (2016). Crayfish chitosan for microencapsulation of coriander (*Coriandrum sativum* L.) essential oil. *International Journal of Biological Macromolecules*, *92*, 125-133. https://doi.org/10.1016/j.ijbiomac.2016.06.068

Farhadi, A., Harlıoğlu, M. M., Gür, S., & Acısu, T. C. (2018). Optimization of the incubation time and temperature for spermatozoa extraction in freshwater crayfish *Pontastacus leptodactylus* (Eschscholtz, 1823). *Animal Reproduction Science*, *193*, 153-157. http://doi.org/10.1016/j.anireprosci.2018.04.063

Farhadi, A., & Harlıoğlu, M. M. (2019). Photoperiod affects gamete production, and protein and lipid metabolism in male narrow-clawed crayfish *Pontastacus leptodactylus* (Eschscholtz, 1823). *Animal Reproduction Science*, *211*, 106204. http://doi.org/10.1016/j.anireprosci.2019.106204

Fetzner, J. W. (2009). The journal impact factor: rating the scientific importance of freshwater crayfish. *Crayfish News*, *31*(4), 1-7.

Gençay, İ., Sorguç, B. U., & Saygı, Y. (2024). An investigation on the population parameters of freshwater crayfish *Pontastacus leptodactylus* Eschscholtz, 1823) in Lake Yeniçağa (Bolu). *Fisheries and Aquatic Life*, *32*, 166-174, https://doi.org/10.2478/aopf-2024-0015

Gherardi, F., & Souty-Grosset, C. (2017). *Pontastacus leptodactylus*. The IUCN Red List of Threatened Species: e.T153745A120103207. http://doi.org/10.2305/IUCN.UK.2017-3.RLTS.T153745A120103207.en

Güner, U. (2007). Freshwater crayfish *Astacus leptodactylus* (Eschscholtz, 1823) accumulates and depurates copper. *Environmental Monitoring and Assessment*, *133*, 365-369. https://doi.org/10.1007/s10661-006-9590-1

Harlıoğlu, M. M. (1996). Comparative biology of the signal crayfish, *Pacifastacus leniusculus* (Dana), and the narrow-clawed crayfish, *Astacus leptodactylus* Eschscholtz. [PhD Thesis, University of Nottingham].

Harlıoğlu, M. M., & Harlıoğlu, A. G. (2004). The harvest of freshwater crayfish, *Astacus leptodactylus* (Eschscholtz, 1823) in Türkiye. *Reviews in Fish Biology and Fisheries*, *14*, 415-419. https://doi.org/10.1007/s11160-005-0812-3

Harlıoğlu, M. M. (2004). The present situation of freshwater crayfish, *Astacus leptodactylus* (Eschscholtz, 1823) in Türkiye. *Aquaculture*, *230*, 181-187. https://doi.org/10.1016/S0044-8486(03)00429-0

Harlıoğlu, M. M., Barim, Ö., Türkgülü, İ., & Harlıoğlu, A. G., (2004). Potential fecundity of an introduced population, Keban Dam Lake, Elaziğ, Türkiye, of freshwater crayfish, *Astacus leptodactylus leptodactylus* (Esch., 1852). *Aquaculture*, *230*, 189-195. https://doi.org/10.1016/S0044-8486(03)00430-7

Harlıoğlu, M. M., & Harlıoğlu, A. G. (2006) Threat of non-native crayfish introductions into Türkiye: Global lessons. *Reviews in Fish Biology and Fisheries*, *16*, 171-181. https://doi.org/10.1007/s11160-006-9010-1

Harlıoğlu, M. M. (2008). The harvest of the freshwater crayfish *Astacus leptodactylus* Eschscholtz in Türkiye:

Harvest history, impact of crayfish plague, and present distribution of harvested populations. *Aquaculture International*, *16*, 351-360. https://doi.org/10.1007/s10499-007-9145-7

Harlıoğlu, M M., Köprücü, K., Harlıoğlu, A. G., Yılmaz, Ö., Aydın, S., Mişe Yonar, S., Çakmak Duran, T., & Özcan, S. (2012). The effects of dietary n-3 series fatty acid on the fatty acid composition, cholesterol and fat-soluble vitamins of pleopodal eggs and stage 1 juveniles in a freshwater crayfish, *Astacus leptodactylus* (Eschscholtz). *Aquaculture*, *356*, 310-316. http://doi.org/10.1016/j.aquaculture.2012.05.001

Harlıoğlu, M. M., Çakmak, M. N., Köprücü, K., Aksu, Ö., Harlıoğlu, A. G., Mişe Yonar, S., Çakmak Duran, T., Özcan, S., & Gündoğdu, H. (2013a). The effect of dietary n-3 series fatty acids on the number of pleopodal egg and stage 1 juvenile in freshwater crayfish, *Astacus leptodactylus* Eschscholtz. *Aquaculture Research*, *44*(6), 860-868. http://doi.org/10.1111/j.1365-2109.2012.03090.x

Harlıoğlu, M. M., Köprücü, K., Harlıoğlu, A. G, Mişe Yonar, S., Çakmak Duran, T., Çakmak, M. N., …& Gündoğdu, H. (2013b). Effect of dietary n-3 series fatty acids on sperm production in the freshwater crayfish, *Astacus leptodactylus* (Eschscholtz) (Astacidae). *Aquaculture International*, *21*, 273-282. http://doi.org/10.1007/s10499-012-9549-x

Harlıoğlu, M. M., Harlıoğlu, A. G., Mişe Yonar, S., & Çakmak Duran, T. (2014). Effects of dietary l-tryptophan on the agonistic behavior, growth, and survival of freshwater crayfish *Astacus leptodactylus* Eschscholtz. *Aquaculture International*, *22*, 733-748. http://doi.org/10.1007/s10499-013-9702-1

Harlıoğlu, M. M., Yonar, M.E., Harlıoğlu, A. G., Yonar, S. M., & Farhadi A. (2017). Effects of different methods and times of 17β-estradiol treatment on the feminization success in the narrow-clawed crayfish *Astacus leptodactylus* (Eschscholtz, 1823). *Invertebrate Reproduction and Development*, *61*(4), 245-252. http://doi.org/10.1080/07924259.2017.1340353

Harlıoğlu, M. M., & Farhadi, A. (2017), Factors affecting the reproductive efficiency in crayfish: Implications for aquaculture. *Aquaculture Research*, *48*, 1983-1997. https://doi.org/10.1111/are.13263

Harlıoğlu, M. M., Farhadi, A., & Gür, S. (2018). Determination of sperm quality in decapod crustaceans, *Aquaculture*, *490*, 185-193. https://doi.org/10.1016/j.aquaculture.2018.02.031

Ion, M. C., Bloomer, C. C., Bărăscu, T. I., Francisco, J. O., Nathaniel, F. S., Bronwyn, W. W., …& Pârvulescu, L. (2024). World of Crayfish™: a web platform towards real-time global mapping of freshwater crayfish and their pathogens. *PeerJ*, *12*, e18229. http://doi.org/10.7717/peerj.18229

Jarić, I., Cvijanović, G., Jarić, J. K, & Lenhardt, M. (2012). Trends in fisheries science from 2000 to 2009: A bibliometric study. *Reviews in Fisheries Science*, *20*(2), 70-79.

Kan, Ş., Yıldırım, P., Özmen, Ö., Bahadır Koca, S., & Kubilay, A. (2024). Aeromonas septicemia infection and histopathologic findings in cultured narrow clawed crayfish (*Pontastacus leptodactylus*, Eschscholtz, 1823). *Acta Aquatica Turcica*, *20*(2), 89-96. https://doi.org/10.22392/actaquatr.1298890

Kurun, A., Balkıs, N., Erkan, M., Balkıs, H., Aksu, A., & Ersan, M. S. (2010). Total metal levels in crayfish *Astacus leptodactylus* (Eschscholtz, 1823), and surface sediments in Lake Terkos, Türkiye. *Environmental Monitoring and Assessment*, *169*, 385-395. https://doi.org/10.1007/s10661-009-1181-5

Kokko, H., Koistinen, L., Harlıoğlu, M, M., Makkonen, J., Aydin, H., & Jussila, J. (2012). Recovering Turkish narrow-clawed crayfish (*Astacus leptodactylus*) populations carry *Aphanomyces astaci*. *Knowledge and Management of Aquatic Ecosystem*, *404*, 12. https://doi.org/10.1051/kmae/2012006

Kokko, H., Harlıoğlu, M. M., Aydin, H., Makkonen, J., Gökmen, G., Aksu, Ö., & Jussila, J. (2018). Observations of crayfish plague infections in commercially important narrow-clawed crayfish populations in Türkiye. *Knowledge and Management of Aquatic Ecosystem*, *419*, 10. http://doi.org/10.1051/kmae/2018001

Kouba, A., Petrusek, A., & Kozák, P. (2014). Continental-wide distribution of crayfish species in Europe: update and maps. *Knowledge and Management of Aquatic Ecosystem*, *413*, 5. http://doi.org/10.1051/kmae/2014007

Mazlum, Y. (2007). Stocking density affects the growth, survival, and cheliped injuries of third instars of narrow-clawed crayfish, *Astacus leptodactylus* Eschscholtz, 1823 juveniles. *Crustaceana*, *80*(7), 803-815.

Mazlum, Y., Yılmaz, E., Genç, M. A., & Güner, O. (2011). A preliminary study on the use of mannan oligosaccharides (MOS) in freshwater crayfish, *Astacus leptodactylus* Eschscholtz, 1823 juvenile diets. *Aquaculture International*, *19*, 111-119. http://doi.org/10.1007/s10499-010-9345-4

Mazlum, Y., Güner G. O., & Sirin, S. (2017). Effect of different substrates on survival and growth of juveniles of the freshwater narrow-clawed crayfish *Astacus leptodactylus* Eschscholtz, 1823 (Decapoda, Astacidae). *Crustaceana*, *90*(11-12), 1289-1302. https://doi.org/10.1163/15685403-00003724

Mazlum, Y., Turan, F., & Yıldırım, Y. B. (2021). Evaluation of mealworms (*Tenebrio molitor*) meal as an alternative protein source for narrow-clawed crayfish (*Pontastacus leptodactylus*) juveniles. *Aquaculture Research*, *52*, 4145-4153. https://doi.org/10.1111/are.15253

Mazlum, Y., Demirci, A., Şimşek, E., & Demirci, S. (2025). An assessment on harvest, exports, and marketing income relationships of freshwater crayfish in Turkey. *Momona Ethiopian Journal of Science*, *17*(1), 99-120. http://doi.org/10.4314/mejs.v17i1.7

Mihaela, C. I., Antonio, V. L., Dumitru, M., & Lucian, P. (2022). Mapping the scientific research on crayfish behaviour: A bibliometric analysis [Oral presentation]. 23rd Symposium of the International Association of Astacology, Hluboká nad Vltavou, Czech Republic.

Natale, F., Fiore, G., & Hofherr, J. (2012). Mapping the research on aquaculture. A bibliometric analysis of aquaculture literature. *Scientometrics*, *90*(3), 983-999. http://doi.org/10.1007/s11192-011-0562-z

Nuc, Z., Brusotti, G., Catenacci, L., Grenha, A., Pontes, J. F., Pinto da Silva, J., …& Caramella, C. M. (2023). *Pontastacus leptodactylus* (Eschscholtz, 1823) and *Faxonius limosus* (Rafinesque, 1817) as new, alternative sources of chitin and chitosan. *Water*, *15*(17), 3024. https://doi.org/10.3390/w15173024

Öksüz, A., & Mazlum, Y. (2016). Determination of proximate composition and fatty acid profiles of *Astacus leptodactylus* Eschscholtz, 1823 in Turkish freshwater resources. *Crustaceana*, *89*(10), 1135-1147. https://doi.org/10.1163/15685403-00003574

Özkök, R., Aktaş, M., Erol, K. G., Didinen, B. I., Ceylan, M., Çetinkaya, S., Uzunmehmetoğlu, O. Y., Çınar, Ş., Çavdar, N., & Pazar, M. (2021). Effect of melatonin on development, survival rate and immune response in the juveniles of freshwater crayfish (*Pontastacus leptodactylus* Eschscholtz, 1823). *LimnoFish-Journal of Limnology and Freshwater Fisheries Research*, *7*(2), 108-114. http://doi.org/10.17216/LimnoFish.761841

Özturan, S., Gülgün, F., & Ünal Şengör, G. F. (2022). Effects of cooking methods on the quality and safety of crayfish (*Astacus leptodactylus* Eschscholtz, 1823) during chilled storage. *Journal of Food Processing Preservation*, *46*(10), e16887. http://doi.org/10.1111/jfpp.16887

Pauly, D., Christensen, V., Guénette, S., Pitcher, T. J., Rashid, S. U., Walters, C. J., Watson, R., & Zeller, D. (2022). Towards sustainability in world fisheries. *Nature*, *418*, 689-695. http://doi.org/10.1038/nature01017

Parrillo, L., Coccia, E., Volpe, M. G., Siano, F., Pagliarulo, C., Scioscia, E., Varricchio, E., Safari, O., Eroldogan, T., & Paolucci, M. (2017). Olive mill wastewater-enriched diet positively affects growth, oxidative and immune status and intestinal microbiota in the crayfish, *Astacus leptodactylus*. *Aquaculture*, *473*, 161-168. https://doi.org/10.1016/j.aquaculture.2017.02.013

Qin, Q. Y., Liu, J.Y., Chen, Y. H., Wang, X. R., & Chu, T. J. (2024). Knowledge mapping of the development trend of smart fisheries in China: A bibliometric analysis. *Fishes*, *9*, 258. http://doi.org/10.3390/fishes9070258

Radael, M. C., Shimoda, E., Duarte, S. C., Andrade, D. R, Guimaraes, H. A., & Vidal, J. R. M. V. (2014). Fish reproduction: Bibliometric analyses of worldwide and Brezilian publication in Scopus Database. *Acta Biomedica Brasiliensia*, *5*, 1-15.

Rahe, R., & Soylu, E. (1989). Identification of the pathogenic fungus causing destruction to Turkish crayfishstocks (*Astacus leptodactylus*). *Journal of Invertebrate Pathology*, *54*(1), 10-15. https://doi.org/10.1016/0022-2011(89)90132-8

Sarameh, P. S., & Falahatkar, B. (2024). Tracking scientific gaps in the conservation of endangered sturgeon: A bibliometric approach and content analyses. *Aquaculture Research*, *2024*(1), 4496931. http://doi.org/10.1155/2024/4496931

See, K. F., Ibrahim, R. A, & Goh, K. H. (2021). Aquaculture efficiency and productivity: A comprehensive review and bibliometric analysis. *Aquaculture*, *544*, 736881. http://doi.org/10.1016/j.aquaculture.2021.736881

Sheikh, H. I., Alhamadin, N. I. I., Liew, H.J., Fadhlina, A., Wahid, M. E. A, Musa, N., & Jalal, K. C. A. (2024). Virulence factors of the zoonotic pathogen *Vibrio alginolyticus*: A review and bibliometric analysis. *Applied Biochemistry and Microbiology*, *60*, 514-531. http://doi.org/10.1134/S0003683823602822

Şirin, S., & Mazlum, Y. (2016). Effect of dietary supplementation of calcium chloride on growth, survival, moulting frequency and body composition of narrow-clawed crayfish, *Astacus leptodactylus* (Eschscholtz). *Aquaculture Nutrition*, *23*, 805-813. https://doi.org/10.1111/anu.12447

Souty-Grosset, C., Holdich, D. M., Noël, P. Y., Reynolds, J. D., & Haffner, P. (2006). *Atlas of crayfish in Europe*. French National Museum Natural History.

Svoboda, J,. Kozubíková, E., Kozák, P., Kouba, A., Koca, B.S., Diler, Ö., Diler, İ., Policar, T., & Petrusek, A. (2012). PCR detection of the crayfish plague pathogen in narrow-clawed crayfish inhabiting Lake Eğirdir in Türkiye. *Diseases of Aquatic Organisms*, *98*, 255-259. https://doi.org/10.3354/dao02445

Syed, S., Aodha, L., Scougal, C., & Spruit, M. (2019). Mapping the global network of fisheries science

collaboration. *Fish and Fisheries*, *20*(5), 830-856. http://doi.org/10.1111/faf.12379

Turan, F., Mazlum, Y., Yıldırım, Y.B., & Gezer, A. (2012). Use of dietary *Pelargonium sidoides* extract to improve growth and body composition of narrow-clawed crayfish *Astacus leptodactylus* Eschscholtz, 1823 juveniles. *Turkish Journal of Fisheries and Aquatic Sciences*, *12*(2), 233-238. http://doi.org/10.4194/1303-2712-v12_2_06

Uçkun, M. (2022). Assessing the toxic effects of bisphenol A in consumed crayfish *Astacus leptodactylus* using multi biochemical markers. *Environmental Science and Pollution Research*, *29*, 25194-25208. https://doi.org/10.1007/s11356-021-17701-1

Varol, M., & Sünbül, M. R. (2018). Biomonitoring of trace metals in the Keban Dam Reservoir (Türkiye) using mussels (*Unio elongatulus eucirrus*) and crayfish (*Astacus leptodactylus*). *Biological Trace Element Research*, *185*(1), 216-224. https://doi.org/10.1007/s12011-017-1238-1

Yıldız, H. Y., & Benli, A. C. (2004). Nitrite toxicity to cray fish, *Astacus leptodactylus*: The effects of sublethal nitrite exposure on hemolymph nitrite, total hemocyte counts, and hemolymph glucose. *Ecotoxicology and Environmental Safety*, *59*(3), 370-375. https://doi.org/10.1016/j. ecoenv.2003.07.007