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Assessing the status and management of European eel, *Anguilla anguilla* (Linnaeus 1758) fisheries in Türkiye: Trends, challenges, and conservation strategies (2019-2023)

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A B S T R A C T

The European eel, *Anguilla anguilla* (Linnaeus 1758) is a species of critical ecological importance, facing significant population declines due to anthropogenic pressures such as habitat degradation, migration barriers, pollution, overfishing, and climate change. This study investigates the status of European eel fisheries in Türkiye from 2019 to 2023, focusing on the implications of local management practices and environmental changes on eel populations. Utilizing official catch data from the Turkish Statistical Institute, the study analyses trends across three Eel Management Areas (EMAs) in Türkiye. The results reveal a significant decline in eel catches in EMA-1, suggesting urgent conservation needs, while EMA-2 and EMA-3 exhibit relative stability, potentially reflecting effective local management practices and habitat suitability. The results underscore the necessity for region-specific management strategies that consider ecological, environmental, and socio-economic factors. This research contributes to the development of informed management strategies aimed at ensuring the sustainability of European eel fisheries in Türkiye, aligning with international conservation efforts.

INTRODUCTION

The European eel, *Anguilla anguilla* (Linnaeus 1758) is a critically important species in both freshwater and marine ecosystems, recognized for its complex life cycle and ecological significance. This species is in IUCN as a Critically Endangered fish species on the Red List (Pike et al., 2020). Historically, the European eel was abundant across Europe and North Africa; however, it has experienced a dramatic population decline over the past few decades. This decline is largely attributed to various anthropogenic pressures, including habitat degradation, migration barriers, pollution, overfishing, and the impacts of climate change (Bilotta et al., 2011; Denis et al., 2024; ICES, 2024). One notable aspect of the European eel's life history is its long migration from freshwater habitats to spawning grounds in the Sargasso Sea, which poses significant challenges for its survival (van Ginneken et al., 2005; Righton et al., 2016). This migratory behaviour, combined with environmental stressors, has rendered the species particularly vulnerable. Factors such as the construction of dams, alteration of river flows, and loss of wetlands significantly impact the availability of suitable habitats for eels (Cresci, 2020; Podda et al., 2022; Chen et al., 2023).

Türkiye's unique geographical position offers diverse ecological conditions suitable for eel habitats; however, the current status of European eel fisheries in the country has not been extensively studied, highlighting a crucial gap in

knowledge regarding the sustainability of this species. Recent conservation efforts, including fishing quotas and habitat protections, aim to address the decline in eel populations, but their effectiveness remains to be fully evaluated (Violi et al., 2015; Rohtla et al., 2020; Gurkan et al., 2024). Moreover, the International Council for the Exploration of the Sea (ICES) has emphasized the need for urgent management actions to mitigate the decline of the European eel, recommending further research into recruitment dynamics and habitat conditions (ICES, 2023). Given the increasing pressures on freshwater ecosystems and fish populations, it is critical to conduct comprehensive assessments of eel fisheries in Türkiye.

The Eel Management Area (EMA) is an area-based concept for the conservation and sustainable utilization of eels within defined geographical zones. An EMA sets out to achieve two objectives: the shrinking of the eel population base and the sustainable development of its ecosystems. EMAs are generally delimited by the natural features of a river basin. This makes it possible to administer more effectively, eel fisheries in as much as it looks at the relationship of ecosystems in which these species are found. By examining eel fishery in an area, advocated EMAs would assist in sustainable fish harvesting by providing pre-emptive recommendations. Which include the establishment of the annual limits for catches, suspension of fishing activities within specific timeframes, and ways of minimizing incidental catch (Dekker, 2016; Drouineau et al., 2018). This study aims to explore the status of European eel catches in Türkiye from 2019 to 2023, focusing on the implications of local management practices and environmental changes on the species' populations. Understanding these dynamics will contribute to the development of informed management strategies that support the sustainability of European eel fisheries in Türkiye. In this context, changes in fishing data in eel management plan areas in Türkiye were examined.

MATERIALS AND METHODS

This study examines the catches of European eel from various regions of Türkiye between 2019 and 2023. The research is based on official fishing data obtained from the Turkish Statistical Institute (TÜİK). The coverage of the study includes the eel catch data reported from provinces of Adana, Antalya, Aydın, Balıkesir, Denizli, Edirne, Hatay, Isparta, Kahramanmaraş, Manisa, Mersin, Muğla, Osmaniye, Çanakkale, and İzmir. The dataset includes annual catch amounts (tons) for each province.

Eel Management Area (EMA) Classification

Eel Management Area (EMA) is a geographical area created for the protection and sustainable management of a series of river basins (Özdilek and Özdilek, 2020). EMA regions facilitate the evaluation of province-based eel fisheries and give reliable suggestions for sustainable fishing.

Table 1 presents the distribution of eel catch data recorded in each province by EMA regions. The classification of provinces was evaluated by (Özdilek and Özdilek, 2020). According to this classification, the annual catch amounts and their importance for European eel conservation will be evaluated for the relevant regions. This regional classification is crucial for developing sustainable management strategies.

Table 1. EMA classification of Türkiye's European eel catching provinces

EMA Region	Provinces
EMA-1	Balıkesir, Çanakkale, Edirne, Manisa, İzmir
EMA-2	Aydın, Muğla, Antalya, Denizli, Isparta
EMA-3	Adana, Hatay, Mersin, Osmaniye, Kahramanmaraş

To assess the trends in European eel (*Anguilla anguilla*) catches across the different Eel Management Areas (EMAs) in Türkiye, we conducted a Mann-Kendall trend test on the annual catch data from 2019 to 2023.

RESULTS

The total European eel catch in Türkiye from 2019 to 2023 across all three Eel Management Areas (EMAs) amounted to 1549 tons. The distribution of catches by EMA is as follows: EMA-1 accounted for 184 tons (11.88%), EMA-2 contributed 821 tons (53%), and EMA-3 represented 544 tons (35.12%).

The European eel catch in EMA-1 exhibited a clear declining trend over the five-year period (Figure 1, Table 2). Starting with 46 tons in 2019, the catch declined progressively each year, reaching a low of 14 tons by 2023. This decline suggests either a decrease in eel population or changes in fishing effort and efficiency, a pattern that necessitates further investigation to establish underlying causes. The results obtained from the Mann-Kendall trend test showed a statistically significant declining trend of eel catch in EMA-1 region ($S= -10$, $P=0.0373$).

In contrast, EMA-2 demonstrated relative stability in catch amounts (Figure 2, Table 2). Beginning with 175 tons in 2019, there was a fluctuation in catch amounts over the years, with a dip to 157 tons in 2021 and 2022 followed by an increase to 166 tons in 2023. This variability showed a statistically insignificant trend over the study period ($S= -3$, $P=0.788$). The relatively stable catch figures suggest that local management practices, potentially including habitat protection efforts, might be maintaining stable eel populations in this region.

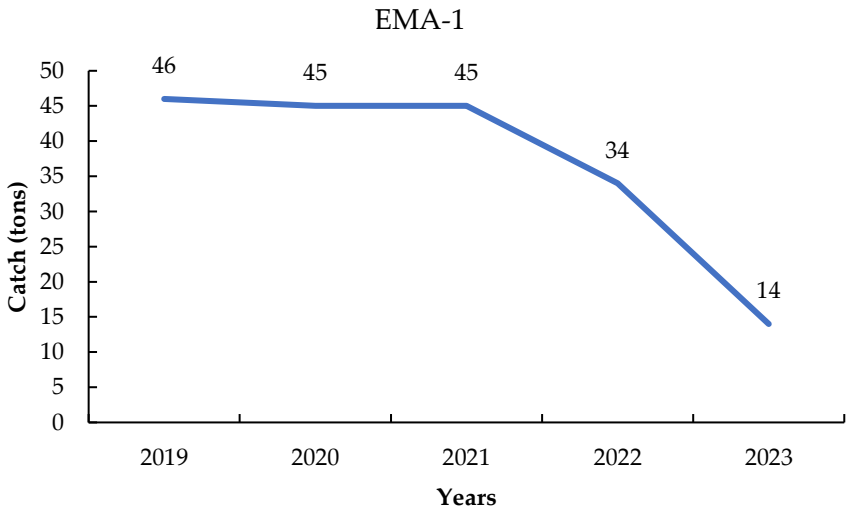

Figure 1. Annual catch amount of European eel in EMA-1 region of Türkiye (2019-2023)

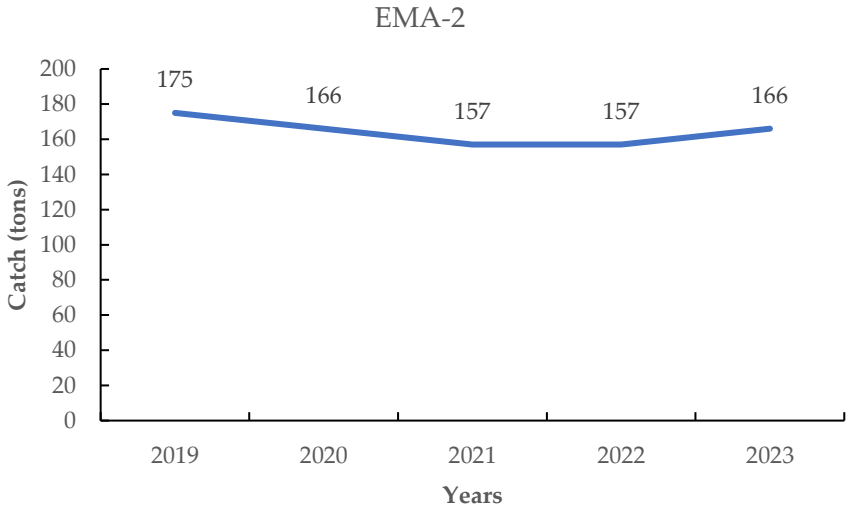

Figure 2. Annual catch amount of European eel in EMA-2 region of Türkiye (2019-2023)

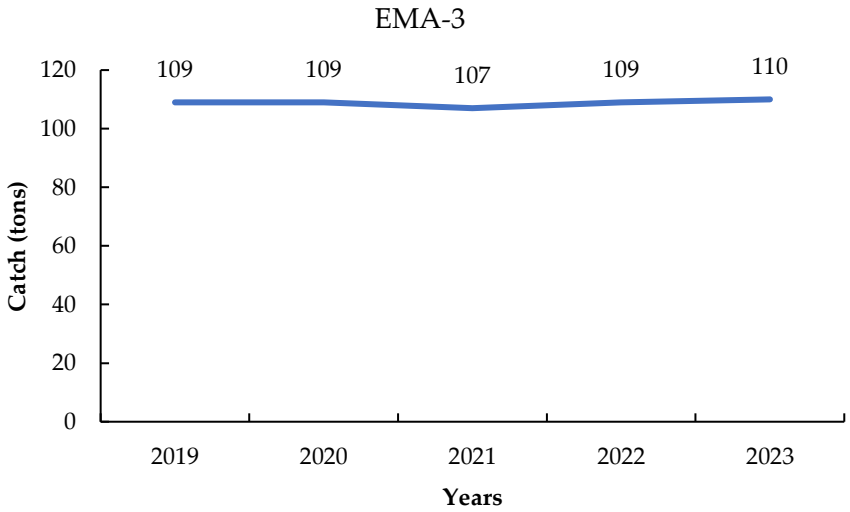

Figure 3. Annual catch amount of European eel in EMA-3 region of Türkiye (2019-2023)

Table 2. Annual European eel catch amount by EMA region and province in Türkiye (2019-2023)

Year	EMA Region	Provinces	Catch Amount (tons)
2019	EMA-1	Balıkesir, Balıkesir, Çanakkale, Edirne, Manisa, İzmir	46
	EMA-2	Aydın, Muğla, Antalya, Denizli, Isparta	175
	EMA-3	Adana, Hatay, Mersin, Osmaniye, Kahramanmaraş	109
2020	EMA-1	Balıkesir, Çanakkale, Edirne, Manisa, İzmir	45
	EMA-2	Aydın, Muğla, Antalya, Denizli, Isparta	166
	EMA-3	Adana, Hatay, Mersin, Osmaniye, Kahramanmaraş	109
2021	EMA-1	Balıkesir, Çanakkale, Edirne, Manisa, İzmir	45
	EMA-2	Aydın, Muğla, Antalya, Denizli, Isparta	157
	EMA-3	Adana, Hatay, Mersin, Osmaniye, Kahramanmaraş	107
2022	EMA-1	Balıkesir, Çanakkale, Edirne, Manisa, İzmir	34
	EMA-2	Aydın, Muğla, Antalya, Denizli, Isparta	157
	EMA-3	Adana, Hatay, Mersin, Osmaniye, Kahramanmaraş	109
2023	EMA-1	Balıkesir, Çanakkale, Edirne, Manisa, İzmir	14
	EMA-2	Aydın, Muğla, Antalya, Denizli, Isparta	166
	EMA-3	Adana, Hatay, Mersin, Osmaniye, Kahramanmaraş	110

The catch data from EMA-3 remained relatively consistent, with only minor fluctuations noted throughout the five years (Figure 3, Table 2). Starting with 109 tons in 2019, the catches slightly decreased to 107 tons in 2021, returning to 110 tons in 2023. The Mann-Kendall test showed an insignificant trend (S=1, P=0.85), indicating a stable capture that mirrors EMA-2's dynamics. This stability may reflect either robust local populations or consistent fishing practices.

The analysis of European eel catches in Türkiye from 2019 to 2023 revealed significant trends and regional variations across different Eel Management Areas (EMAs). Catch data were used to assess the population status of the European eel, complementing ongoing efforts to develop effective fishery management strategies.

DISCUSSION

The current investigation into the status of European eel, *A. anguilla* fisheries in Türkiye from 2019 to 2023 highlights critical trends that underscore the complexity of managing eel populations amidst varying regional pressures. The drastic reduction experienced in EMA-1 (Marmara and North Aegean Region) corresponds with some existing works which highlight the similar constraints facing the European eel populations where aquatic habitats are destroyed, migrations are disrupted and pollution abounds (Dekker, 2003; ICES, 2023; Órfão et al., 2024). These stressors have been widely acknowledged as primary factors contributing to the decline of eel populations across their range. Such stressors have been recognized widely as dominant reasons for the depletion of eel in all geographies. This emphasizes that there should be no further delay in taking all possible conservation measures, especially habitat restoration and stricter exploitation measures.

On the other hand, while the trends of eel landings in EMA-2 (Western Mediterranean Region) and EMA-3 (Eastern Mediterranean Region) were similar to other regions of the country, this could indicate inefficient regional variation monitoring exercises or adaptation to the environmental conditions and effects of 'the management measures in place. It has been reported that the Black Sea basin and the coast of the Mediterranean Sea are quite possibly enthusing more eel population due to the peculiar ecological condition or effective conservation strategies in place (Gurkan et al., 2024). Our results are consistent with the outcome obtained from previous studies emphasizing the need for localized strategies in the management of eels (Özdilek and Özdilek, 2020). For instance, current studies indicate that eels should be studied and potentially exploited as regional stock units with specific environments and economies. Such regional specificity is important in devising measures aimed at the management of eels that take into account the prevailing local conditions.

In the same vein, it has been reported that growth of European eels inhabiting some Turkish rivers varies with respect to environmental conditions (Yalcin Ozdilek et al.,

2006), showing their dependence more on local rather than migratory study and management approaches. This has been echoed in the many research programs working towards the international society for eel management that has decried ineffective generic approaches to eel management that do not reach the geographical local in which the eels are (ICES, 2023).

These results underscore the importance of region-specific management strategies, considering the varying trends observed in different EMAs. The notable decline in EMA-1 highlights an urgent need for targeted conservation efforts, including stricter fishing quotas or habitat restoration projects. Conversely, the stable conditions in EMA-2 and EMA-3 suggest that current strategies may be sufficient but also require ongoing monitoring to ensure effectiveness amidst potential environmental changes.

CONCLUSION

In conclusion, this study underscores the imperative of embracing a regionally nuanced management approach that considers ecological, environmental, and socio-economic factors to preserve European eel populations. Future policies should prioritize evidence-based adaptive management strategies, including continuous monitoring and data evaluation, to safeguard this critical species. Given the mounting pressures on freshwater ecosystems globally, a collaborative, informed approach to fisheries management will be crucial in sustaining eel populations and ensuring the long-term viability of Türkiye's eel fisheries.

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COMPLIANCE WITH ETHICAL STANDARDS

Authors' Contributions

AA: Data curation, Investigation, Visualization, Writing – original draft

HA: Conceptualization, Investigation, Methodology, Visualization, Writing – original draft, Writing – review & editing

All authors read and approved the final version of the article.

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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Not applicable.

Data Availability

The data supporting the findings of this study are available from the corresponding author upon request.

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