Historical trends and current status of the European eel, *Anguilla anguilla* (Linnaeus, 1758) fishery in the Neretva estuary (eastern Adriatic, Croatia)

Povijesni trendovi i recentni status ribarstva europske jegulje, Anguilla anguilla (Linnaeus, 1758) u estuariju Neretve (istočni Jadran, Hrvatska)

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Abstract

The European eel, *Anguilla anguilla* was the most important fishery resource in European estuaries for centuries. In more recent times, most local populations throughout the species' range have collapsed for various reasons. This article deals with the historical records and current status in the Neretva estuary (Croatia), the most important eel fishing area on the eastern Adriatic coast. The historical records were analysed by reviewing various available databases, including scientific articles and professional literature. Additional descriptions were obtained using local ecological knowledge and interviews with various stakeholders. The comparative analysis shows that the historical silver eel catch (1930-1940) under pristine habitat conditions should be estimated at 100 tons, officially recognized and additionally estimated. The decline in silver eel catches began between 1960 and 1970 and was related to the massive reclamation of important eel lagoons and wetlands for agriculture and port areas, when officially recognized silver eel catches at state stations averaged 45 tons per year. Recent scientific articles and reports as well as a survey of professional and recreational fishermen show that the annual catch in the period 2020-2022 is only 2 tons. The main reasons for this recent dramatic decline in eel fisheries and biological status in the Neretva estuary after 2015 are: a significant increase in recreational fishing, the establishment of invasive predatory fish and crab species, and the strong development of local tourism demand. The results of this study indicate that the local eel population is likely to be threatened with extinction in the near future unless various measures are developed and applied to protect it, including the restriction of fishing and better market control, habitat restoration and the control of invasive and competing species.

KEY WORDS

European eel
professional and recreational fisheries
stock decline
Neretva estuary

Sažetak

Europska jegulja, Anguilla anguilla, stoljećima je bila najvažniji ribolovni resurs u europskim estuarijima. U novije vrijeme većina lokalnih populacija jegulje smanjena je iz raznih razloga. Ovaj članak bavi se povijesnim izvorima i trenutnim stanjem u delti Neretve (Hrvatska), povijesno najvažnijem ribolovnom području za jegulju na hrvatskoj obali Jadrana. Povijesni izvori analiziraju se pregledom različitih dostupnih baza podataka, uključujući znanstvene članke i stručnu literaturu. Dodatni podaci dobiveni su korištenjem metodologijom lokalnog ekološkog znanja i intervjua s različitim dionicima sektora tijekom 2023. Usporedna analiza pokazuje da povijesni ulov srebrne jegulje (30-ih godina 20. stoljeća) u uvjetima netaknutog staništa treba procijeniti na 100 tona, službeno priznatih ulova i dodatno procijenjenih ulova za vlastite potrebe ribara. Pad ulova srebrne jegulje započeo je 1960-ih i bio je povezan s velikim melioracijama važnih laguna za razvoj poljoprivrede i izgradnju lučkih područja, kada je službeni ulov srebrne jegulje u prosjeku iznosio 45 tona godišnje. Najnoviji znanstveni članci i izvješća, kao i anketa profesionalnih i rekreativnih ribolovaca pokazuju da je recentni godišnji ulov samo 2 tone. Glavni razlozi za ovaj dramatičan pad ulova i biološkog statusa jegulje u delti Neretve jesu: značajno smanjenje pogodnih staništa, naseljavanje i rast brojnosti invazivnih predatorskih vrsta riba i rakova te snažan razvoj lokalne turističke potražnje za jeguljom. Rezultati ove studije pokazuju da će se lokalna populacija jegulja nastaviti smanjivati ako se ne primijene razne mjere za njezinu zaštitu, poput ograničavanja ribolova i kontrole tržišta, obnovu staništa za jegulju i iskorjenjivanje invazivnih i konkurentskih vrsta.

KLJUČNE RIJEČI

europska jegulja
komercijalni i rekreacijski ribolov
smanjenje populacije
ušće Neretve

1. INTRODUCTION / *Uvod*

The European eel, *Anguilla anguilla*, was the most important fish in European estuaries for centuries. For various reasons, stocks on European coasts have recently reached their historic low point [1]. The results of recent projections show that (i) habitat loss plays an important role in the decline of the European eel; (ii) the viability of the overall stock is at risk if appropriate conservation measures are not taken; (iii) restoration of spawning escapement requires a significant reduction in fishing mortality; and (iv) recovery of recruitment may not be possible unless reproductive performance is improved [2]. The European Council has adopted a regulation (EC 1100/2007) that requires Member States to establish national eel management plans to restore the eel stock and sets a specific target that "the biomass of silver eel should be at least 40% of the estimated escapement that would have occurred before anthropogenic impacts" [3]. The targeting and effectiveness of such measures can be improved by understanding the ecological processes underlying population dynamics and the abiotic and biotic factors that influence them, particularly at the local level [4].

The European eel is of great ecological and cultural importance in the Mediterranean, as it is closely linked to artisanal fishing and the traditional management of lagoons on the Mediterranean coast; the decline of the eel also threatens the survival of these traditional activities and the associated cultural heritage. As the decline is linked to environmental problems that affect the habitats in which the eel spends part of its life cycle, intervening with measures to protect the eel also means contributing to the restoration and recovery of these habitats [5]. One of the objectives of the management plans in Mediterranean countries is to assess the European eel population in the Mediterranean and to support the long-term management of the species to contribute to its recovery. Several studies have also focused on local stocks in the Mediterranean and contributed to knowledge on the biology of the eel in its continental stages (e.g. growth, differentiation, reproductive biology, population structure, ecology) as well as work on recruitment, spawner quality and assessment of local stocks [5]. Expanding the knowledge base on the European eel in the Mediterranean is an important ongoing task, especially in areas with insufficient data such as the eastern Adriatic coast. The situation in the traditionally important habitat for the eel in the eastern Adriatic, the Neretva estuary, is characterized by a similarly sharp decline in the results of traditional fisheries, and the total catch was recently estimated at only two tons in 2021 [6].

This article describes the historical trends and current status of the European eel fishery in the Neretva estuary (Croatia) based on available published data and a survey of local fishermen, and explains the main reasons for the decline of the eel fishery and the poor status of the local eel population.

2. MATERIALS AND METHODS / *Materijali i metode*

The compilation of historical data on the eel fishery in the Neretva estuary in the central eastern Adriatic, Croatia (43°01'55.3 "N 17°27'05.2 "E), was carried out by analysing available scientific articles, various professional articles, grey literature, local newspapers and reports, which were cited at the appropriate places in the article. In parallel, the available statistical data from the various governments and institutions (Yugoslavia, Croatia, FAO) that have been active on the eastern Adriatic coast over the last 100 years were examined, together with the data published in the articles based on official reports [7, 8, 9, 10]. In the search for the possible causes of the decline of the eel stock in Croatia, various aspects of this process were considered, e.g. changes in water characteristics and water surface, land reclamation, changes in salinity and temperature, demography, fishing pressure, development of fishing gear in terms of type and number, marketing, processing, consumption and development of tourism.

Additional data was collected in 2023 using the Local Ecological Knowledge (LEK) method through interviews with various local stakeholders, including fishermen, restaurant owners and government officials. In order to facilitate a more open and fruitful discussion about eel fisheries, the interviews did not follow a strictly structured questionnaire, but consisted of a series of specific questions asked during the interviews. Due to the nature of the questions, the data was qualitative rather than quantitative in nature [11]. Seven out of 14 licensed professional fishermen and 24 out of 60 recreational fishermen known to author were interviewed.

The participants were asked the following questions

- When did you start eel fishing?
- What types of fishing gear did you use in the different periods?
- How do you estimate the size, range and population development of eel in the different parts of the Neretva estuary?

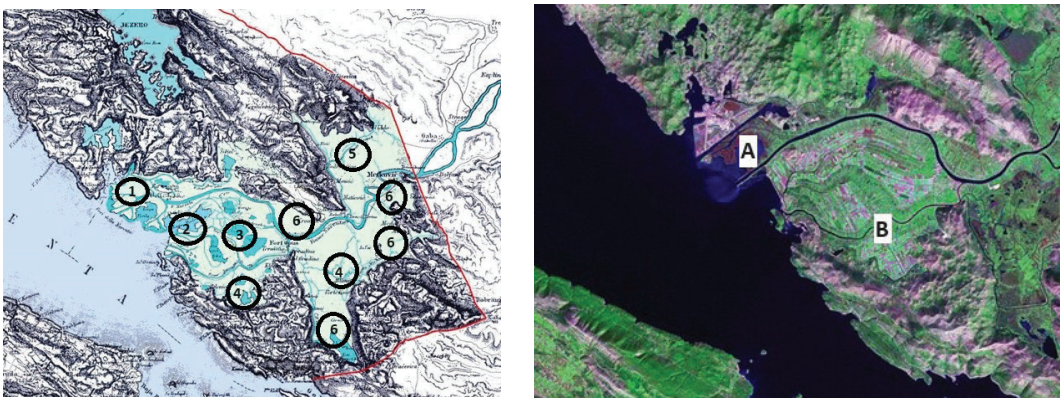

Figure 1 Morphology of the Neretva estuary (Republic of Croatia) from the 18th and 20th centuries, before (left) and after (right) the series of human interventions. (Numbers in the left image as described in Table 1; right image A: Parila lagoon and B: Mala Neretva river as the left arm of the main stream of the Neretva)

Slika 1. Morfologija ušća rijeke Neretve (Republika Hrvatska) iz 18. i 20. stoljeća, prije (lijevo) i poslije (desno) niza ljudskih intervencija. (brojevi na lijevoj slici, kao što je opisano u Tablici 1; desna slika A: laguna Parila i B: rijeka Mala Neretva kao lijevi rukavac glavnog toka Neretve)

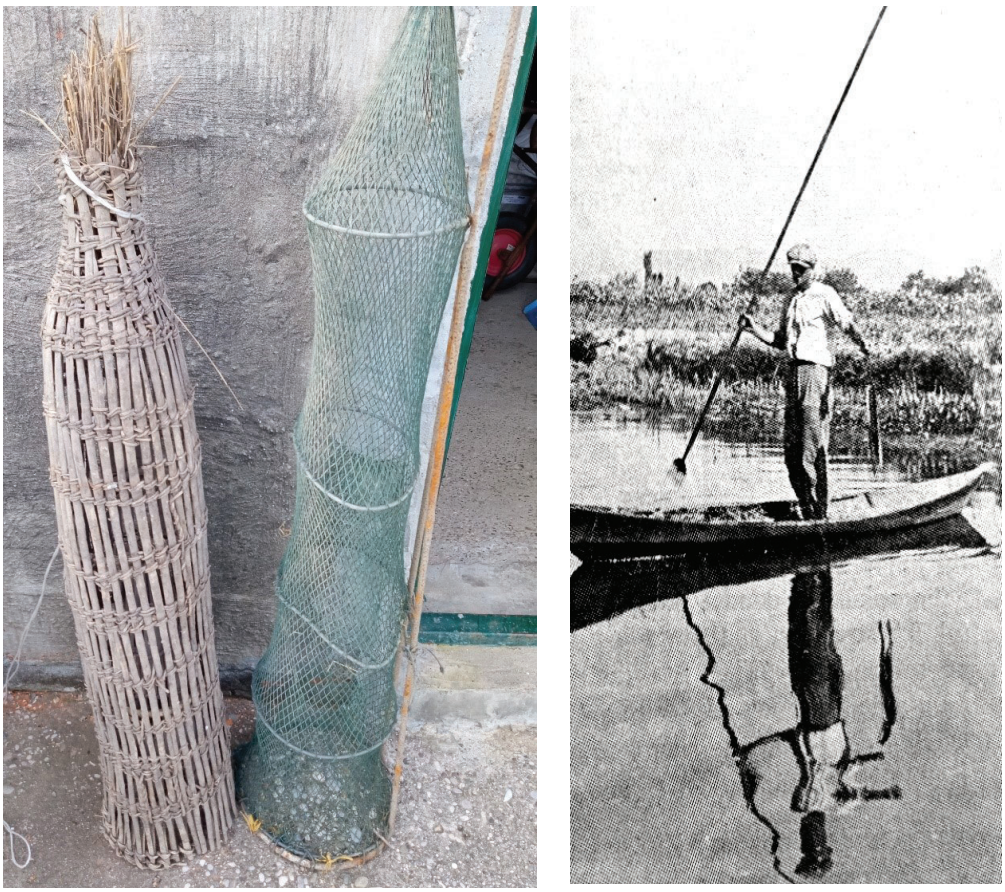

Figure 2 A) Traditional eel trap (left) made of willow branches and modernized eel trap (right) made of nets on metal frames, which have recently been used in large numbers in the Neretva estuary (photo B. Glamuzina) and B) traditional fishermen with local spear gear for catching eels (photo Dr. V. Križanec)

Slika 2. A) Tradicionalna kogol-trata za jegulje (lijevo) od vrbovih grana i modernizirana kogol-trata za jegulje (desno) od mreža na metalnim okvirima, koje se u novije vrijeme masovno koriste u ušću Neretve (foto B. Glamuzina) te B) tradicionalni ribolovac s lokalnom podvodnom opremom za lov jegulja (foto dr. V. Križanec)

- Are there anecdotal reports of interesting catches or observations, e.g. in terms of size, abundance or frequency of eels?
- Do you have any data or information on the status of eels in your habitat?
- What actions and measures do you propose to protect and improve the eel population in the Neretva estuary?

Of the fishermen, two who are either professional or recreational and who keep logbooks and records of their catches were selected for in-depth interviews. The commercial eel fisherman recorded the catch of silver eels in the Mala Neretva River area (marked as B in Figure 1), while the recreational fisherman recorded the catch of yellow and silver eels in the Parila Lagoon area (marked as A in Figure 1) using traditional and modernized eel fishing gear (Fig. 2). Both fishermen have written records of their eel catches in the period 2000-2022 and of problems in this fishery in the last 20 years. The other responses were used for the qualitative description of the traditional eel fishery in different time periods.

The historical original shape of the Neretva estuary and the water surface suitable as eel habitat were determined from an 18th century cadastral map (https://maps.arcanum.com/en/) and the current shape and surface of the water body from satellite maps (google.com; March 2024), while various habitats and surface changes were documented from scientific sources [12], [13].

3. RESULTS / *Rezultati*

3.1. Natural eel habitats loss / *Gubitak prirodnih staništa jegulja*

The total area of pristine lagoons and wetlands that were meliorated for agriculture and infrastructure development in the second half of the 20th century is shown in Table 1. The total area of drained estuarine lagoons and wetlands amounted to 11,490 hectares and consisted mainly of typical Mediterranean lagoon ecosystems, followed by Mediterranean freshwater wetlands with low salinity, shallow lakes, small tributaries and canals. The most important and productive untouched eel habitats were converted into agricultural areas (lower left side of the Neretva estuary below the town of Opuzen) and port, railroad and industrial areas (lower right side of the Neretva estuary, today the urban area of Ploče). These two former lagoon areas originally had an area of 2600 hectares and 1661 hectares respectively, making a total of 4261 hectares of reclaimed natural lagoons. The remaining drainage measures were carried out in the upper part of the estuary, where the Mediterranean fresh and brackish water bodies predominate. The total meliorated area of these specific habitats amounted to 6955 ha (Figure 1). The total area and specific area of meliorated estuarine habitats were determined based on the estimated potential of silver eel production based on the production reported in similar Mediterranean estuaries. The estimated total loss of silver eel biomass due to reclamation and disappearance of the original habitats is 157.4 tons compared to the silver eel biomass in the original habitats before anthropogenic activities in the Neretva estuary (Table 1).

Table 1 Total area of lagoons and wetlands meliorated in the 20th century: meliorated habitat types, potential silver eel biomass per lost habitat and estimated silver eel biomass loss.

Tablica 1. Ukupna površina laguna i močvara melioriranih u 20. stoljeću: meliorirani tipovi staništa, potencijalna biomasa srebrne jegulje po izgubljenom staništu i procijenjeni gubitak biomase srebrne jegulje

Meliorated areas: habitat types	Total reclaimed area (hectare)*	Potential silver eel biomass (kg/ha)**	Estimated total loss of silver eel biomass	Reference
Lower estuary (brackish 15-30 psu)				
1. Mediterranean lagoons (town of Ploče area)	1,661	20	33,200	[14]
2. Mediterranean lagoons (area bellow town of Opuzen)	2,600	20	52,000	[15]
Middle estuary (brackish 10-20 psu)				
3. Mediterranean lagoons- middle estuary area	274	15	4,100	[15]
Upper estuary (0.3-5 psu)				
4. Freshwater lakes	2,410	10	24,100	[16]
5. Freshwater rivers and channels	1,900	10	19,000	[17]
Other areas				
6. Other smaller wetland areas (not divided to specific habitat type)	2,500	15	25,000	[15]
Total	11,490		157,400	

*The surface area analysis is based on data published by [12] and [13], and locations of specific meliorated areas are indicated in Fig 1.
**The estimation of potential silver eel biomass per hectare of different Neretva estuary habitat types were used from scientific articles mentioned in the reference column.

3.2. Historical captures / *Povijesni pregled ulova*

Figure 3 provides an overview of the historical eel captures based on the available official statistical records from the various periods. For the eel fishery in the Neretva estuary, five different periods of the last 100 years are presented, taking into account the eel catch, the fishing gear used, the organized marketing and the changes in the ecosystems. The period from 1930 to 1940 was characterized by the organized purchase of silver eel at the state station in the town of Opuzen and its processing by drying or salting for sale in other markets. According to the available data, about 68.5 tons were bought annually in the Neretva Delta during this period. In addition to the officially registered catches, recreational fishing with spears and longlines was also practiced during these years, but mostly for personal use, as resale was not possible. This period can be considered the pristine natural state of the eel population in the Neretva estuary, and the estimated catch of 100 tons of silver eel per year from commercial and traditional artisanal fishing can be considered relatively reliable given the natural areas and their potential for eel growth.

The period from 1960 to 1970 was characterized by large-scale melioration of the main eel fishing areas below the town of Opuzen (Modrič lagoon and some salt lakes) and the town and port of Ploče (lagoons), and later also below the town of Metković,

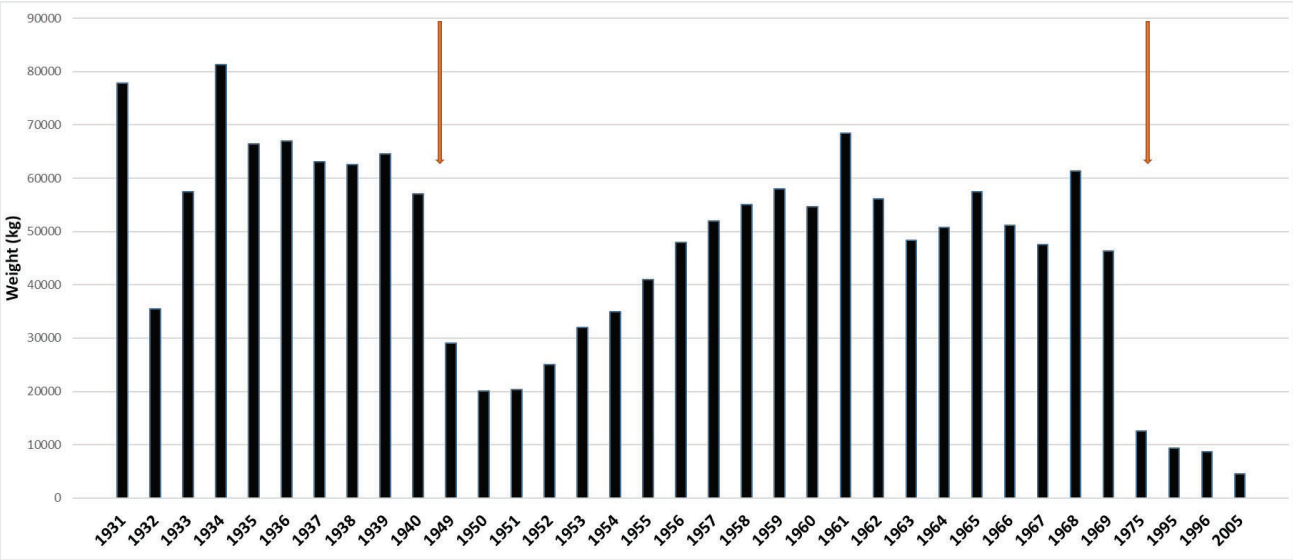

Figure 3 Historical overview of catches of the silver stage of the European eel in the Neretva estuary from 1931 to 2005, based on official statistical records from the various periods of organized commercial eel fisheries. The periods marked with red arrows are the periods of the Second World War and the Croatian Homeland War, for which no official data are available.

Slika 3. Povijesni pregled ulova srebrnog stadija europske jegulje u ušću Neretve od 1931. do 2005. na temelju službenih statističkih podataka iz različitih razdoblja organiziranoga gospodarskog izlova jegulje. Razdoblja označena crvenim strelicama jesu razdoblja Drugog svjetskog rata i Domovinskog rata, za koja nema službenih podataka.

which was followed by a decline in eel catches in the 1970s. During this period, most of the catch was bought by state cooperatives, and a smaller part was used by recreational fishermen for their own consumption, as there was no tourism and no restaurants.

The period from 1970 to 1990 was characterised by a sharp decline in catches in commercial fishing in autumn and winter. However, with the increase in tourist activities and the start of restaurant and hotel operations (summer season), a new market for yellow eel opened up, which led to an increase in recreational fishing with traps, spears and longlines. The period from 1995 to 2013 was characterised by a further decline in catches in commercial fisheries and the rise in the price of eel to up to €20/kg, which increased interest in catching eel with small modernised traps (Figure 2). This was accompanied by an increasing demand for eel, the uncontrolled catch of smaller eels and the decline of entire local populations. The period after 2013 and Croatia's official accession to the EU follows a similar trend with declining catches in commercial fisheries (fall-winter) and even greater fishing effort (larger number of smaller, non-selective traps), with similar effects as in the previous period (Figure 4). The increase in the local market price from 20 €/kg to 40 €/kg, April 2024) has also led to illegal eel fishing in other areas of the Republic of Croatia, so that illegal eel fishing and marketing has a significant negative impact on the eel stock. Due to increased controls by state institutions since 2020, the number of fishing gear used for illegal fishing (especially small eel traps) has decreased significantly.

A historical overview of the officially recorded silver eel catches in the Neretva estuary from 1930 to the present day illustrates the differences between the period before and after melioration. In the period 1930-1940, an estimated 100 tons of silver eel were caught per year in all fisheries and with all fishing gear. Due to the large loss of traditional eel habitat as a result of land reclamation, catches in the official commercial eel fishery began to decline in the 1970s, followed by a decline in the recreational eel fishery. This downward trend has remained constant over the last 30 years and mainly affects the legal silver eel fishery in the fall, as catches and interest in this type of eel fishing are declining. Due to the increased price of eel, catches of yellow eel in recreational fisheries, illegal fisheries and illegal sales are generally higher than in silver eel fisheries, although they remain at a relatively low level (Figure 5).

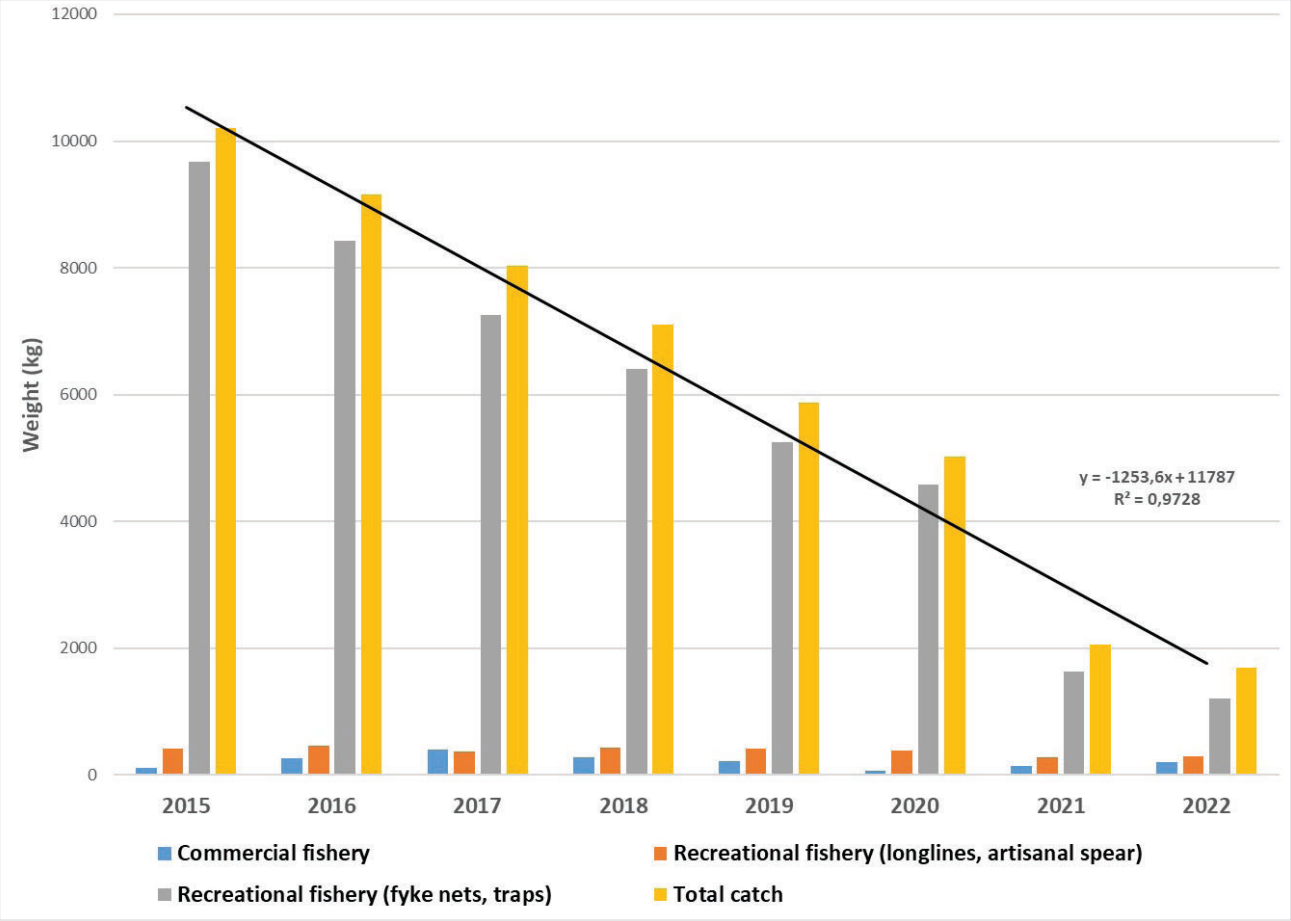

Figure 4 Catches of European eel (official silver eel catches from Ministry of Agriculture, Forestry and Fisheries of Croatia and LEK data from recreational fisheries) in the Neretva estuary, Croatia, after EU accession (2013) and the adoption of the Common Fisheries Policy Regulation.

Slika 4. Ulovi europske jegulje (službeni ulovi srebrne jegulje iz Ministarstva poljoprivrede, šumarstva i ribarstva RH i podaci Lokalnog ekološkog znanja rekreacijskog ribolova) u ušću Neretve, Hrvatska, nakon ulaska u EU (2013.) i usvajanja Uredbe o zajedničkoj ribarstvenoj politici.

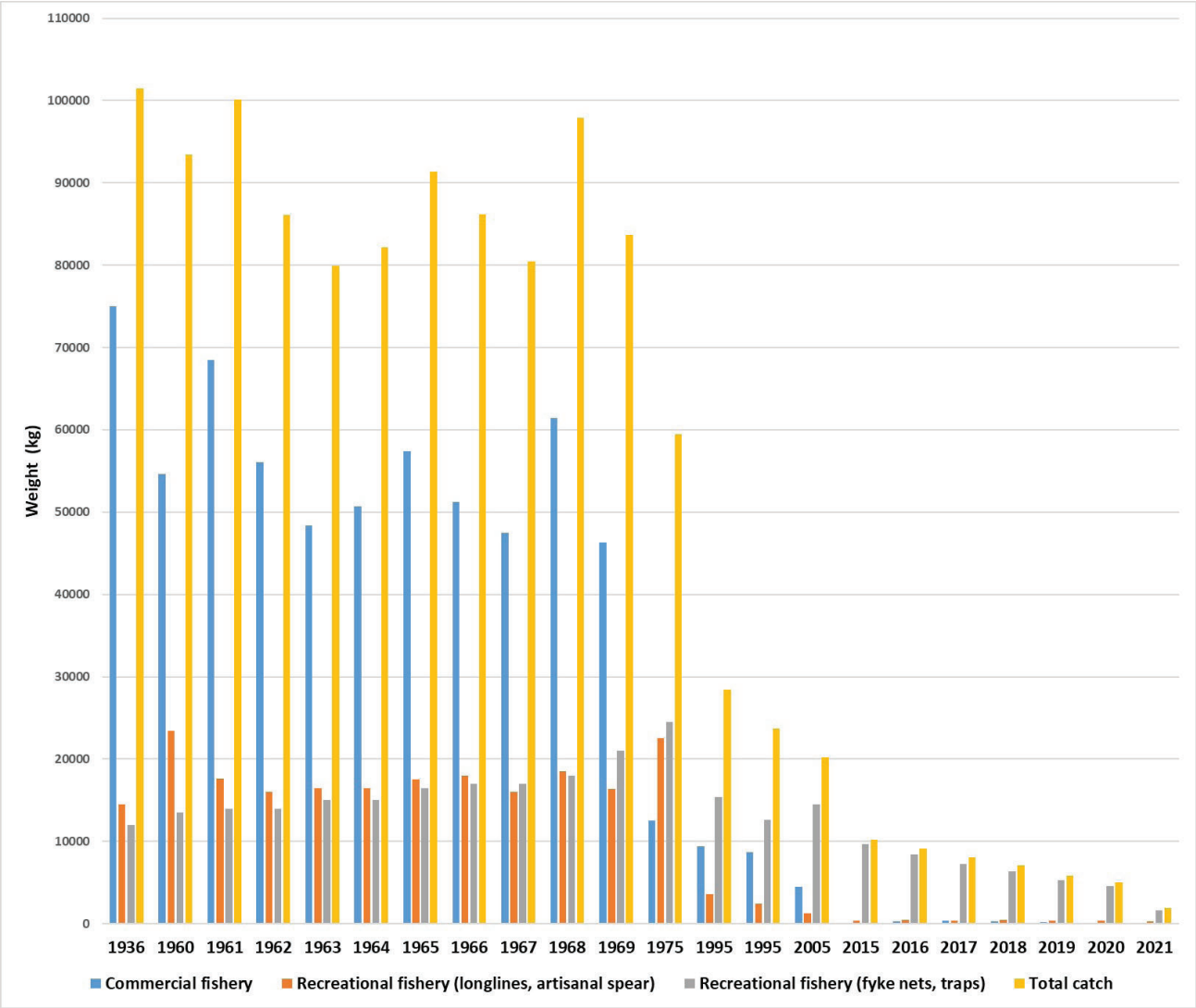

Figure 5 Historical overview of European eel catches in the Neretva estuary from 1936 to 2021, based on the integration of various data sets from official sources, private data and data obtained using the LEK method by various stakeholders. (the individual years in the graph were selected on the basis of the best available data).

Slika 5. Povijesni pregled ulova europske jegulje u ušću Neretve od 1936. do 2021., temeljen na integraciji različitih skupova podataka iz službenih izvora, privatnih podataka i podataka različitih dionika dobivenih LEK metodom (Lokalno ekološko znanje) (odabrane su pojedinačne godine u grafikonu na temelju najboljih dostupnih podataka).

3.3. Eel catches by professional and recreational fishermen in the period 2000-2023 in the Neretva estuary / *Ulov jegulje profesionalnih i rekreativnih ribolovaca u razdoblju od 2000. do 2023. u ušću Neretve*

Figure 6 shows the results of the commercial silver eel fishery in the Mala Neretva River drainage in the period 2000-2022. The average catch per season in this period was 443.6±132.9 kg, including the seasons with gear problems and lower catches (2004, 2010, 2019). Excluding these years, the average catch per season was 490.5 kg of silver eels. The results from this area show that silver eel catches have declined in recent years, and the fishermen interviewed pointed to problems with the increase of the population of invasive largemouth bass (*Micropterus salmoides*) and wels catfish (*Silurus glanis*) in recent years as potential eel predators.

Figure 7 shows the annual catches of European eel in the Parila lagoon by a recreational fisherman in the period 2000-2022, primarily using traditional fyke nets as fishing gear. The total catch of this fisherman during this period amounted to 2219 kg of eel, of which 1085 kg were yellow eel and 1134 kg were silver eel. The average annual total catch of eel was 96.47± 18.6 kg, of which 47.17±11.3 kg were yellow eel and 49.3±9.8 kg were silver eel per year. The annual catches were almost stable during this period, with the exception of the last three years, in which a decline was recorded. The fishermen attributed this decline to the significant increase in the population of Atlantic blue crab (*Callinectes sapidus*) in the Parila lagoon.

The eel catches per unit effort with the traditional fyke net in the Parila lagoon by a recreational fisherman in the period 2000-2022 is shown in Figure 8. The average annual catch with a traditional fyke net was 2.1±0.36 kg of eel, with a high of 2.57 kg in 2005 and a low of 1.24 kg in 2022. It shows two periods of decline associated with the establishment of the Atlantic blue crab population (2010-2013) and its significant increase in the period 2018-2022 (Figure 8).

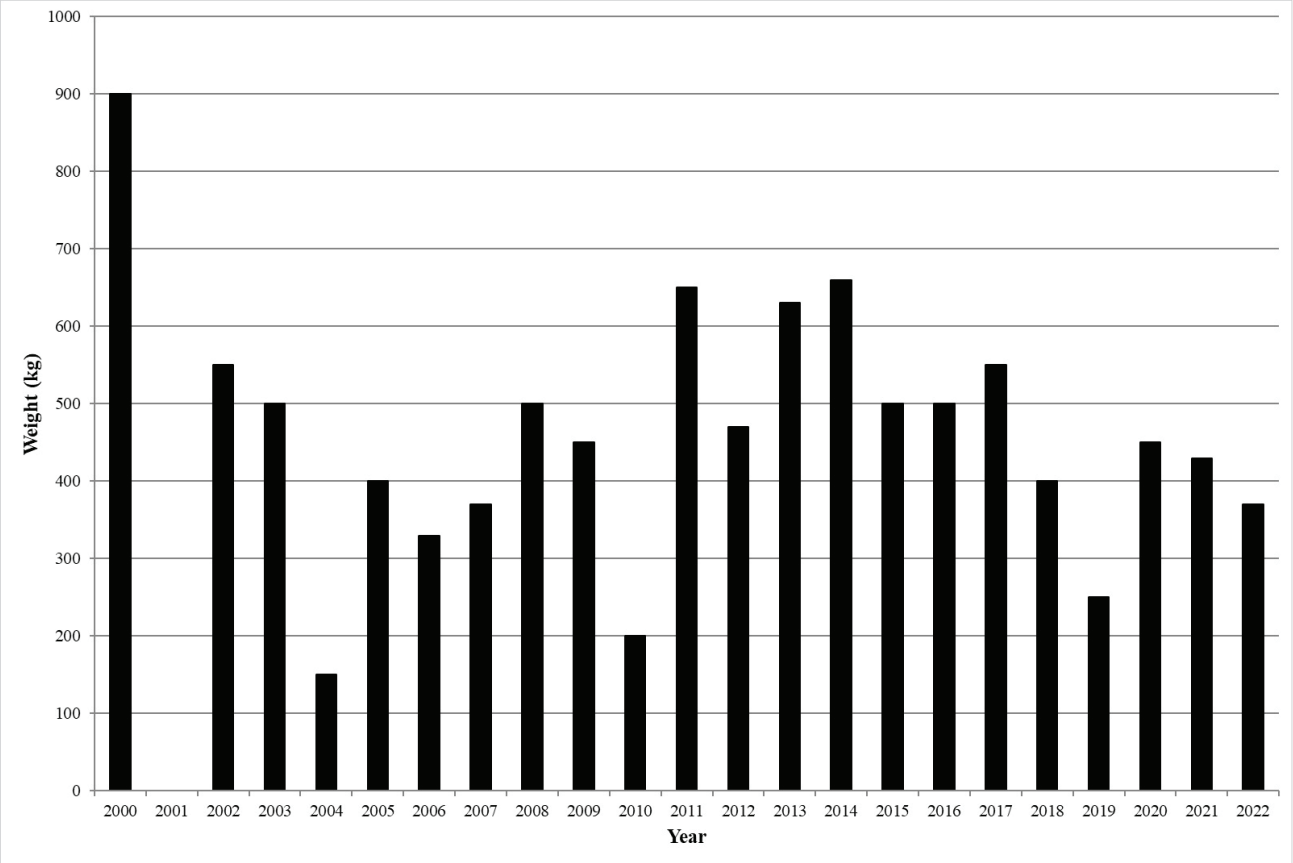

Figure 6 Annual catches of European eel by legal professional fishermen during the September-March fishing season in the Mala Neretva river drainage in the period 2000-2022.

Slika 6. Godišnji ulov jegulje legalnih profesionalnih ribara tijekom ribolovne sezone rujan – ožujak u slivu Male Neretve u razdoblju od 2000. do 2022.

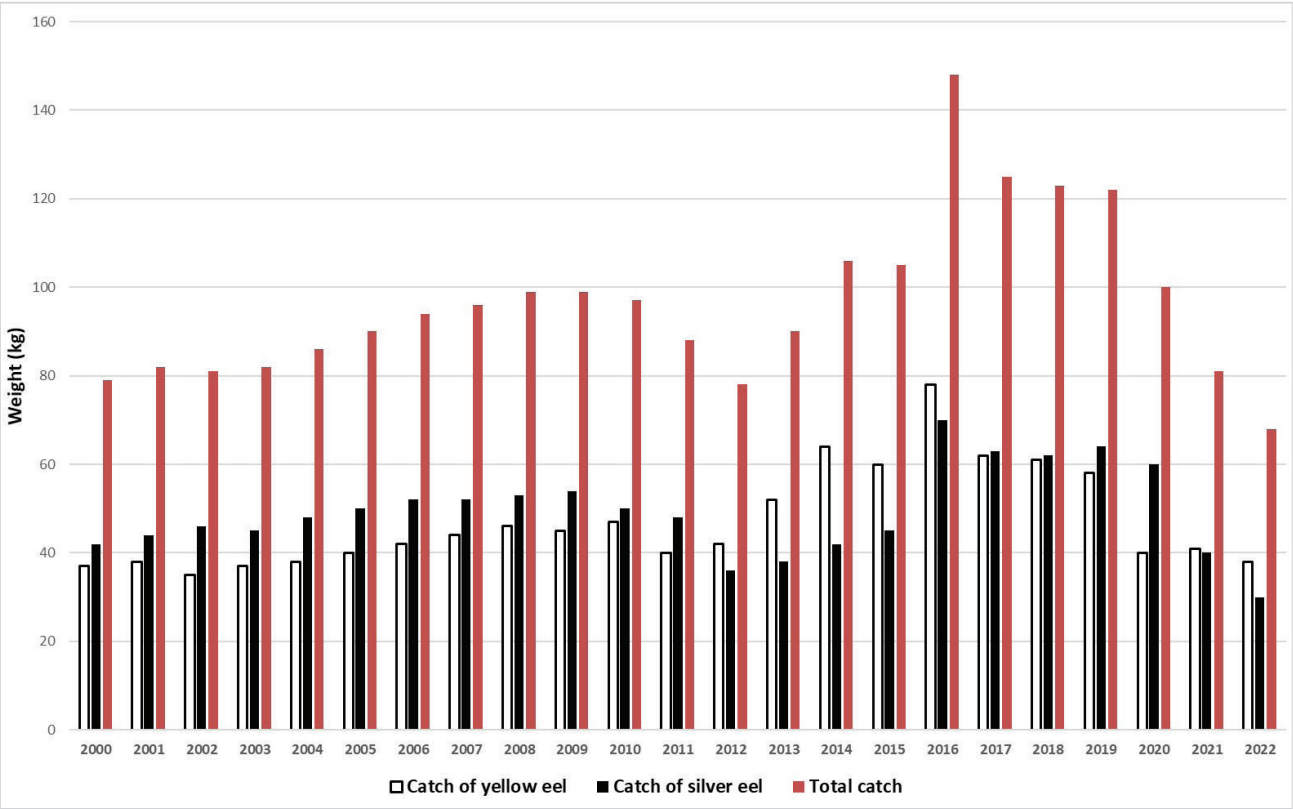

Figure 7 Annual catches of European eel in the Parila lagoon (Neretva estuary) by a recreational fisherman in the period 2000–2022.

Slika 7. Godišnji ulov europske jegulje u laguni Parila (ušće Neretve) rekreacijskog ribolovca u razdoblju od 2000. do 2022.

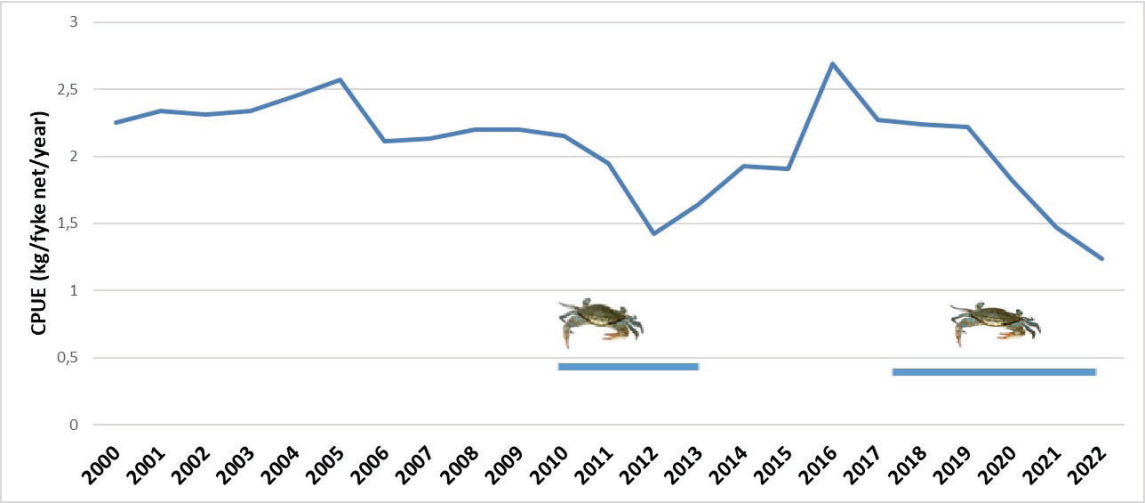

Figure 8 Catch per unit effort (traditional fyke net) of European eel in the Parila lagoon (Neretva estuary) by a recreational fisherman in the period 2000-2022. (Atlantic blue crab and the blue lines indicate that it is particularly abundant in the lagoon at certain times).

Slika 8. Ulov po jedinici napora (tradicionalnom fyke mrežom) europske jegulje u laguni Parila (ušće Neretve) rekreativnog ribolovca u razdoblju od 2000. do 2022. (Atlantski plavi rak i plave linije pokazuju da u određenim razdobljima laguna obiluje rakom).

4. DISCUSSION / *Rasprava*

This study presents historical data on the eel fishery in the Neretva estuary (eastern Adriatic coast) and the results of recent studies and surveys describing the state of the local eel population and its fishery. According to the available data from official statistics [7], average of 68,85 tons of silver eels were purchased annually in the period from 1930 to 1940, i.e. before the major human interventions in this area. This period can be considered the natural, untouched state of the eel population in the Neretva estuary. The period from 1960 to 1970 was characterized by large-scale land reclamation in the main eel fishing areas, which led to a decline in catches. Annual catches during this period ranged from 68.5 tons in 1961 to 46.3 tons in 1969, which represents a sharp decline [8,9,10]. A similar trend of declining catches in commercial (fall-winter) fisheries was observed in the subsequent period from 1970 to 2015 and to date [6].

The decline of the local eel population and eel fishery is comparable to the situation in most European estuaries [5, 18], including the estuaries and lagoons of the Mediterranean and the western Adriatic [1]. Most comparable are the long-term records (1781–2013) of eel production in the Comacchio lagoon (Italy), where similar land reclamation, among other reasons, has led to a remarkable decline in catches over the last 40 years [14]. This decline is generally attributed to various natural and anthropogenic factors [14, 15], the most important being the increase in commercial and artisanal fishing and habitat loss [18]. The decline in eel catches in the Neretva estuary over the last sixty years has had an exponential trend due to a number of anthropogenic activities. The most important of these are large-scale land reclamation in the Neretva Delta, which has led to a drastic reduction in suitable habitats. The total area of drained pristine estuarine wetlands and lagoons amounted to 11,490 hectares and consisted mainly of typical Mediterranean lagoon ecosystems, followed by Mediterranean freshwater wetlands with low salinity, shallow lakes, small tributaries and canals [13]. The most important and productive pristine eel habitats have been converted into agricultural areas (lower left side of the Neretva estuary below the town of Opuzen) and port, railroad and industrial areas (lower right side of the Neretva estuary, today the urban area of Ploče). These two former lagoon areas originally had an area of 2600 hectares and 1661 hectares, i.e. a total of 4261 hectares of reclaimed natural lagoons [13].

The historical and current data on the eel stock in the Neretva estuary should be compared with similar lagoon systems in the western Adriatic (Italian coast), where the data are more accurate and reliable due to a long-term organized and controlled fishery. The historical estimate for the Comacchio lagoons in Italy, where only silver eels were fished, was a maximum catch of 20.5 kg/ha of silver eels [14, 15]. Furthermore, the total biomass of eels per ha was estimated at 75.85 kg, while the production of silver eels averaged 19.32 kg/ha per year [18]. Considering these data against the background of historical eel catches in the pristine habitats of the Neretva estuary, it can be concluded that the total production of silver eels in the pristine habitats of the Neretva estuary was about 180 tons, which corresponds to the estimates of catches of 100 tons in this article based on the officially recorded and estimated recreational catches.

The estimated production of silver eels in the Bages-Sigean lagoon (France, Mediterranean coast) was 30 kg/ha [19], which is higher than the reported average of 15-20 kg/ha in lagoons and 0.003-6.9 kg/ha in freshwater systems [20]. Mean annual silver eel production in colder Norwegian rivers was significantly lower than in Mediterranean lagoon ecosystems, with a mean annual production of 3.51 kg/ha and a mean yield of 2.27 kg/ha [16]. However, such colder river ecosystems do not exist in the Neretva estuary, but in the upper Neretva catchment, including the colder main streams, tributaries, reservoirs and lakes in Bosnia and Herzegovina [21].

The main reasons for eel decline in the Neretva estuary are: significant habitat loss due to land reclamation for agriculture and port construction, construction of dams and other water

management infrastructure. The most obvious reason for the decline of the native eel is clearly habitat loss, which accounts for about 80 %. For the Japanese eel (*Anguilla japonica*), habitat reduction due to human activities in 16 rivers in East Asia, including Japan, Korea, Taiwan and China, was also the main reason for the decline: 76.8 % of the actual habitat area was lost between the 1970s and 2010s. Widespread habitat loss, together with regional climate phenomena such as ENSO and overfishing, may also play an important role in the decline of the Japanese eel in East Asia [22].

Among other factors, the introduction and high incidence of the swim bladder parasite [6, 23] and pollution from agriculture, upstream industries and mining [24, 25] have already been mentioned. More recently, the threat to local eel populations has been exacerbated by the massive increase of invasive species such as the largemouth bass in freshwater areas [26, 27] and the Atlantic blue crab in brackish water ecosystems [28, 29], which either feed on eels or compete with them for food. In addition, global warming scenarios in the eastern Adriatic indicate a higher risk of invasion by alien organisms compared to current climate conditions [30], and several species (largemouth bass, Atlantic blue crab, wels catfish) pose a high risk threat to ecosystem services and native populations, including the European eel.

5. CONCLUSIONS / *Zaključci*

With regard to future eel management in the Neretva estuary, it is clear that an important measure for restoring eel populations in Europe, namely ensuring the migration of at least 40% of silver eel biomass to the sea based on the potential of the pristine historical environment, is most likely not realistic due to massive habitat loss. It can therefore be concluded that this measure should only be applied to current eel habitats and new estimates of escapement from these habitats. Future work should focus on a better understanding of the habitats currently present and their ecological status and their accurate identification using GIS [31], as well as a better understanding of the impact of invasive species on the local eel population from recruitment to spawning migration. For the future eel management plan for the Neretva River basin, which should have a transnational aspect (Bosnia and Herzegovina as a partner), several important measures should be proposed, such as research on current eel recruitment and migration of glass eel to promote the restoration of abundance in different habitats, a cooperative approach to local eel management, the implementation of better fisheries and local market control, and the improvement of available eel habitats.

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