

Adaptation/management plan for Neretva River Delta

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1. Foreword

This document has been produced in the framework of the INTERREG Italy – Croatia CHANGE WE CARE Project. CHANGE WE CARE fosters concerted and coordinated climate adaptation actions at transboundary level, tested in specific and representative pilot sites, exploring climate risks faced by coastal and transitional areas contributing to a better understanding of the impact of climate variability and change on water regimes, salt intrusion, tourism, biodiversity and agro-ecosystems affecting the cooperation area. The main goal of the Project is to deliver integrated, ecosystem-based and shared planning options for different problems related to climate change (CC), together with adaptation measures for vulnerable areas, to decision makers and coastal communities. Additional information and updates on the CHANGE WE CARE can be found at <https://www.italy-croatia.eu/web/changewecare>.

2. Aims and content of the document

This document is the final Adaptation plan of the Neretva Delta and corresponds to the Deliverable 5.2.3. indicated in the Application Form. It represents the synthesis of Adaptation/management Plans for the Pilot Sites, where the shared knowledge base on the present and expected dynamics of coastal systems in the cooperation area and Pilot sites, built in WP3 and WP4, is conveyed.

The definition of such Plans is foreseen to be pursued by means of participatory processes (see Deliverable 5.2.1) determined in order to get all information available, shared decision and consensus by the stakeholders to make the Plan effectively implementable in a collaborative way by all subjects and decision makers involved.

Starting from a “preliminary document” concerning the knowledge framework, threats and opportunities, prepared by each Partner responsible for the Pilot Area to feed the start of the Participatory Process, the Adaptation Plans will be developed taking into account outcomes of WP3, WP4 and of the Participatory process itself, including shared vision, objectives, measures/ actions/ interventions, possible resources/financing, roles and commitments for its implementation beyond the end of CWC project.

3. CHANGE WE CARE project and the objectives of WP5

CHANGE WE CARE fosters concerted and coordinated climate adaptation actions both at Pilot Sites and transboundary level. The project explores climate risks faced by coastal and transition areas contributing to a better understanding of the impact of climate variability and change on water regimes, salt intrusion, tourism, biodiversity and agro-ecosystems affecting the cooperation area.

WP5 main objective is the preparation of climate change Adaptation Plans in Pilot Site, containing the assessment of present state and of foreseen scenarios, the jurisdictional references, the indication of measures and intervention priorities, conforming to the local environmental and socio-economical needs, monitoring strategies on key parameters and on the efficacy of the Plan.

The Planning options presented are the result of participated processes involving local authorities and stakeholders. The Adaptation Plans include actions and interventions, where appropriate, indicating the timeline and the financial strategy for the implementation of the envisaged activities and Monitoring Plans (taking stock also of WP4 indications) for observing and ensuring the durability of the project outcomes and of the implementation of the Plan.

4. Description of the Pilot Area, Knowledge Framework and Scenarios

4.1 Characteristics of the pilot area

Geographical characteristics

Neretva Delta is one of the most valuable wetlands on the eastern Adriatic coast and one of the rare remaining wetlands in the European Mediterranean. It is the only real delta and also the largest river mouth in the Republic of Croatia. It consists of remnants of rare Mediterranean wetlands with preserved coastal lagoons and large areas of wetland habitats, and especially stands out for reed vegetation because they are inhabited by numerous endangered species, especially birds. The delta is surrounded by hilly karst rich in groundwater that supply numerous springs, streams and lakes.

There are several reasons why the Neretva River formed delta at its mouth. The delta area itself consists of three triangular extensions which did not form the river with their erosion action, but were tectonically predisposed - they were formed due to tectonic movements. At the end of the ice age, 10 000 years ago, the sea level rose, so those extensions, which were part of the central course of the Neretva River before the transgression, were near the mouth. Through its course, Neretva brought large quantities of suspended material, and by depositing this material to the mouth of the river a river delta was created. Neretva springs near mountain Zelengora in Bosnia and Herzegovina, at an altitude of 1095 m above sea level. The course of the river has a total length of 218 km, of which only around 20 km are in Croatia. Neretva forms a delta with a total surface area of about 20 000 ha, of which the area of about 12 000 ha is a part of the Croatian territory.

Neretva Delta is very densely populated and there live about 35 600 people and the population mostly uses land for agricultural purposes. Therefore, the main visual identity of the area is a meliorated agricultural landscape with many irrigation channels.

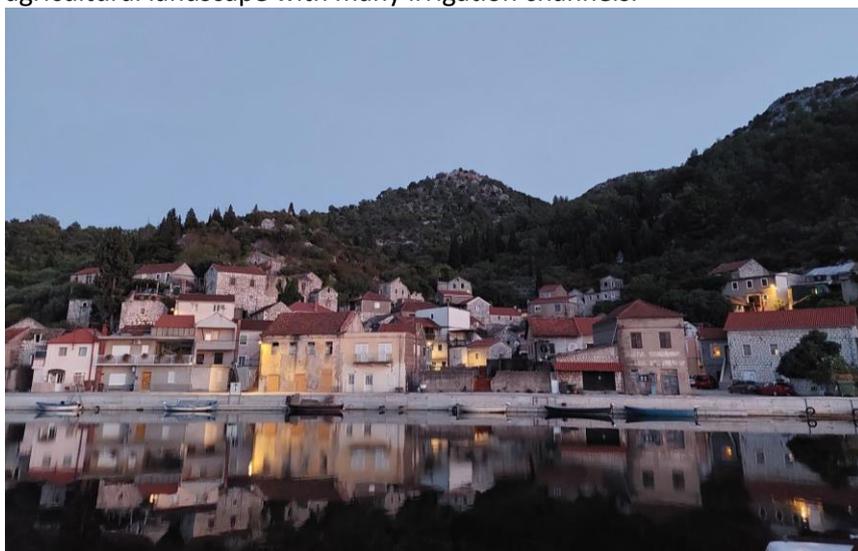


Fig. 1. City of Opuzen located in the Neretva river valley

The most important functions of wetland habitats are flood control, groundwater restoration, shoreline hardening and protection from weather hazards in the coastal area, the retention of nutrients and sediments, climate change mitigation and water purification. In addition, wetland habitats represents the habitats of biological and genetic diversity and habitats of numerous economically usable plant and animal species, provide opportunities for development of tourism and recreation and have cultural value.

The climate of the Neretva Delta area is mediterranean with mild and rainy winters and warm and dry summers. The Dinaric karts borders the delta from all sides except from the west, where it is opened towards the sea, which affects the characteristics of the climate. According to the Köppen climate classification, climate type Csa is present in this area. According to DHMZ data, in the period from the 1971 to 2000 the average annual air temperature in Opuzen was 15.6°C and in Ploče was 15.5°C. The highest mean temperature in the same period was recorded in July - 24,9°C (Opuzen) and 25°C (Ploče), while the coldest was recorded in January – 6,9°C. December, January and February are the coldest months in the area of Delta Neretva. The occurrence of cold days ($t_{min} < 0^{\circ}C$) in this area is very rare because of its positive maritimic influence. The highest temperature occurs in July and August and can reach over 40°C. The soil temperature does not drop below 5°C. The maximum air humidity is in September, December and January – 72%, and the lowest is in July and August – 54%. 2404 sunny hours per year have been recorded in this area. The mean annual precipitation during the period 1971-2000 was 1095 mm (Ploče) and 1276 mm (Opuzen). The delta is characterized by shorter periods of several days with a large amount of precipitation. In this area, east and western winds dominate. 40% of wind are east and southeastern winds that prevail during the winter and autumn. The frequency of western and eastern winds during the summer is almost the same (about 30%). The strongest are the northern winds (N, NE) that blow from November to April at an average speed of 2.8-3.3 m/s. The rise of warm air masses above the mainland is expressed during the first part of the day, and in the second part of the day the air blows from the sea to these areas. During the night, the direction of currents is reversed.

The Neretva Channel is directly influenced by the Neretva River and during heavy rains its influence can be felt all the way to the island of Vis. Near the city of Ploče, the currents of the sea are in the north direction, while in other part of the channel is in the west direction. The Neretva River estuary is an area of permanently low salinity and changes in temperature are also significant. The Adriatic is classified as a low-productive sea, while the mouth of the Neretva falls into the areas of highest productivity as it is under strong influence of land, fresh water and forest (on average 150gC/m²/year). It is protected from strong currents of the sea, which favour to sedimentation of organic and inorganic material, of which a large part comes from mainland and causes reduction of uneven seabed areas. Mouth bottom sediments are silty sand and fine sand, and the surrounding sea is up to 20 m deep. Sea quality in 2016 for all stations was characterized as excellent and satisfactory, while in 2017 it was assessed as good and satisfactory.

Biodiversity and protected areas

From the point of view of biological and landscape diversity, the Neretva delta is one of the most valuable areas in Croatia since it is part of the Natura 2000 protected areas network with the aim of preserving habitats and target species. Protected areas and areas of Natura 2000 network are managed by the Public Institution for Management of Protected Natural Areas of Dubrovnik-Neretva County. The wider area of Neretva Delta is a part of the ecological network of the Republic of Croatia and as Special protection areas (SPA) HR1000031 Delta Neretva and as Special areas of conservation (SAC) HR5000031 Delta Neretva.

As a key area for birds migrating along the Adriatic flyway, the Neretva provides shelter for more than 10,000 winter birds, including several different types of ducks (*Anatidae*) and coots (*Fulica atra*), hundreds of small pygmy cormorants (*Microcarbo pygmaeus*), and various species of herons (*Ardeidae*). In addition, wetland species such as bearded reedling (*Panurus biarmicus*), Eurasian bittern (*Botaurus stellaris*), western marsh harrier (*Circus aeruginosus*) and Baillon's crane (*Porzana pusilla*) nest there (Šarić and Budinski, 2018).



Fig. 2. Abundance of ornithofauna in the Neretva estuary

There are six special reserves in the Delta Neretva area in the Republic of Croatia of protected natural values:

- five ornithological: Orepak, Modro oko and jezero Desne, Pod Gredom, Kuti and Prud,
- one ichthyological and ornithological: Neretva mouth,

one significant landscape:

- Predolac-Šibenica,

and one protected mineral:

- The stone balls near Otrić-Seoca.

4.2 Status and trends of hydrological, geomorphological and biological process

The status and trends of hydrological, geomorphological and biological processes will be presented based on the results of 'Research on physico-chemical factors as a potential drivers of climate change in the ecological network River Neretva Delta (HR5000031)' and 'Report on water and sediment fluxes within the Neretva River Delta ecological network (HR5000031)'.

4.2.1 Hydrological, thermohaline physical and meteo-marine climate setting

The quantity of water discharge is related to the drainage basin lithology and pattern of precipitation over the drainage basin. The lithology of the river drainage basin has a significant role in the hydrological characteristics of the Neretva River Delta. Unlike in the case of other Croatian coastal rivers, the upper reaches of the Neretva River flow through mountain areas in Bosnia and Hercegovina of mixed lithology: metamorphic, magmatic, and clastic sedimentary rocks. However, lower reaches flow through the karstic bedrock, composed mostly of carbonate rocks and less present clastic flysch (Raić et al., 1976; Mojićević and Laušević, 1973a, 1973b; Raić et al., 1980; Sofilj and Živanović, 1980; Mojićević and Tomić, 1982; Juračić, 1998). Therefore, the Neretva River is considered as an allogenic karst river, supplying more water compared to other autogenic karstic rivers along the eastern Adriatic coast. Hydrologic characteristics of the Neretva River Delta are rather complex due to the mixing of the freshwater, seawater and water supplied from karstic springs of highly variable water discharge. According to Orlić et al. (2006) and Trockner et al. (2009) the annual average water discharge of the Neretva River is 332 and 380 m³/s, respectively. Seasonal variation of Neretva River discharge is considered low, due to the relatively low snowmelt contribution and considerable karstic flow (approx. 26% of the runoff; Glamuzina et al., 2002). On other places, part of the water is lost in the underground when the river reaches carbonate terrain (Štambuk-Giljanović, 1999). The flow regime in the upper part of the drainage basin is nivo-pluvial. Water level fluctuations may reach 14 m in the Mostar area. In the deltaic plain these fluctuations are much lower due to the flood control measures and continued karstic input (Glamuzina et al., 2002). Obstructions of water flow in the upper part of the drainage basin resulted in lowered water discharge and in a modified hydrological regime downstream of artificial reservoirs. Water column of the main course, Neretva River, has been stratified, with the seawater intrusion extending upstream all the way to the town of Metković. Other watercourses are mainly freshwater courses (Jurina et al., 2013). One of the consequences of reduced water discharge is saltwater intrusion in many places over the deltaic plain, thereby degrading the quality of both, freshwater and soils in the area used for intensive agriculture.

Most of the scientific research and collection of professional data from state agencies and societies, which can be found in the literature up to 2000, mainly refers to data related to the reduction of wetland habitats and data related to the Neretva flows from the installation of hydrological stations in Metković. Most salinity data are linked either to biological research of mainly fish or to water salinity measurements used to irrigate agricultural land. Therefore, it is difficult to make a direct assessment of their historical condition from these historical data, but at least by comparing historical and current Neretva flows and sporadically recorded catches of marine fish, it is possible to indirectly describe the state of Neretva waters before the construction of the dam in Jablanica. Thus, data can be found that the summer flows of the Neretva before the construction of dams were at a minimum of some 35 m³/s (Prskalo and Bevanda, 2019), and winter flows were at a maximum of 6000 m³/s, which was related to large traditional floods of the entire Neretva delta. Average winter flows were 400-600 m³/s. Based on the analysis of these historical flows and the impact of today's flows on the salinization of the Neretva, it can be concluded that during the historically low summer water levels, the waters of the Neretva (at least as far as Opuzen) were significantly saline. This is supported by recorded catches of sharks and benthic fish in the shallows of the Neretva near town of Opuzen. As the Neretva flows required for the complete discharge of the sea from the mainstream and tributaries according to today's models are higher than 500 m³/s, it can be concluded that in historical conditions the waters of the Neretva delta had a completely freshwater character until today's bridge in Rogotin, while low salinity in lagoons on both sides of the Neretva, in the period from October to May. Low waters that

would consequently lead to the salinization of the Neretva to Opuzen were recorded only during the three summer months, from July to September.

Today's situation of the hydrology of the Neretva Delta and its biological component is significantly more complex and most unpredictable in the short term, because the main influence on hydrology is hydropower systems in the main Neretva, and on the left and right banks. The operation of these hydropower plants mainly depends on the electricity market, which in addition to the existence of three independent power companies, leads to significant and still unappreciated damage to the Neretva ecosystems and wetlands of the Neretva delta. The exception is Hutovo Blato wetlands for which WWF Adria, Mostar developed detailed action plan, but still without the implementation of this plan. Measures to mitigate the damage caused by dams to the living world of the Neretva River itself are few, and the most important measure is to establish a minimum flow behind the last dam in Mostar at 55m³/s, which with additional waters of the Buna, Bregava, Trebizat and other smaller rivers and springs brings at least 70m³/s, during the dry summer months, which is twice as much as in historical values. Winter flows are generally reduced to average flows of 500-1500 m³/s, with occasionally higher flows due to higher rainfall and the limited capacity of reservoirs. According to the data collected in this project, it can be concluded that the main flow of the Neretva to the mouth, lakes Desne and rivers Crna Rika and Norin, is a completely freshwater ecosystem in the period from December to March. After March, a wedge of seawater appears, which from June completely enters the Neretva to Metković and Crna Rika and Lake Desne. On the left side, due to the built embankments, dams, and pumping of freshwater from the Neretva into the system, slightly increased salinity occurs only in the limited waters of the Mala Neretva along the dams at the mouth. The Baćina lakes, the Lake Modro oko, and most of the Norin micro-basin on the right side of the Neretva are still protected from the influence of seawater. From the results of this project, but also from the previous research, it is clear that the River Neretva has a freshwater profile from late November to early May, when it is suitable for the life of freshwater flora and fauna. The freshwater ecological conditions of the main course of the Neretva and the area of Lake Desne change abruptly in June, when the entire profile of the Neretva, except for a narrow layer of fresh surface water, is salinized, and consequently, the entire fauna, especially fish species, is changed to marine type. This annual change in ecological conditions has major consequences for the entire flora and fauna, and instability and variability, especially of salinity, also leads to significant mortalities of both freshwater and marine species.

According to Tab. 1. minimum and maximum temperatures measured at eight selected locations in the area of the Delta Neretva ecological network are presented. The measurement was carried out as a part of the Research on physico-chemical factors as a potential drivers of climate change in the ecological network River Neretva Delta, and the location of the investigated stations is shown in the Fig. 3. According to the table, it is clear that the highest and lowest temperature differences were recorded in the lagoon Parila and the lake Kutu. Lagoon Parila and the lake Kutu are shallow water surfaces which explains why the highest and lowest temperatures have been recorded at these locations. The smallest differences between the maximum and minimum temperatures were recorded at the locations of the Norin River and estuary/dam on the Mala Neretva. With regard to the physico-chemical characteristics of the water, the Norin river is in good ecological condition for most of the year due to the good and constant richness of the main source in Prud. With the cessation of fresh water inflow from the left bank of the Neretva river, the mouth/dam station on the small river Neretva gets a typical maritime character, and temperatures depend mostly on the winds.

Tab. 1. Minimum and maximum temperature measured on the chosen locations in the area of ecological network of River Neretva Delta (July 2020-June 2021)

Number of the station	Location of the station	Minimum temperature (°C)	Maximum temperature (°C)
1.	1 km in front of lagoon Parila	13	26,6
2.	Middle of the line between the island of Osinj and the mouth on Neretva		
3.	Lagoon Parila	4	>30
4.	Mouth/the dam on Mala Neretva	15	25
5.	River Crna	8,1	25,6
6.	River Norin	9,9	18,4
7.	River Neretva near Opuzen	No data	No data
8.	Lake Kutli	6,8	30,4

Source: Research on physico-chemical factors as a potential drivers of climate change in the ecological network River Neretva Delta (HR5000031), 2021

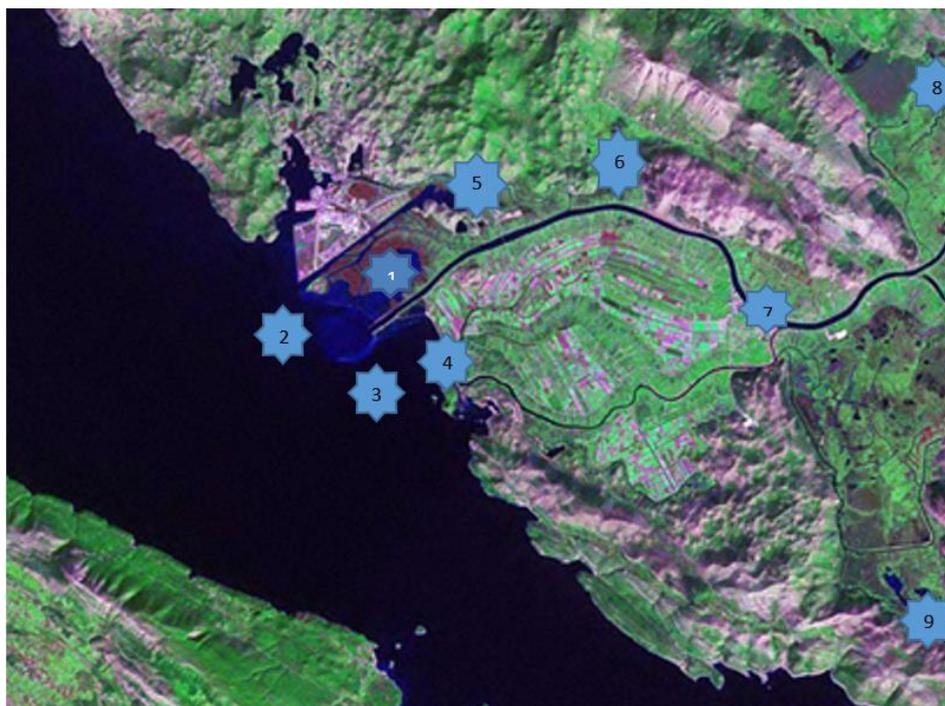


Fig. 3. Locations of sampling stations of physico-chemical factors in the ecological network of Neretva Delta

Source: Research on physico-chemical factors as a potential drivers of climate change in the ecological network River Neretva Delta (HR5000031), 2021

4.2.2 Geological and geomorphological setting and recent history

In its upper and middle course, Neretva flows through the canyons, gorges and valleys of the External Dinarides, which is why the river valley in this area is narrow and canyon-like and has torrential erosive characteristics. Neretva in its mountainous part flows through the lithological heterogeneous area (Juračić, 1998), whose terrains are built of various sedimentary, metamorphic and magmatic rocks. In addition to Mesozoic carbonate succession (shallow-sea fossiliferous, algal and foraminiferous limestones and early diagenetic dolomites) we also find Triassic clastic rocks, Triassic volcanic rocks and volcanic-sedimentary series, and Cretaceous flysch (lapors, sandstones, conglomerates) with fossil (mostly rudist) limestones. Due to the great energy potential of the Neretva River, several hydropower plants were built in its upper and middle course: Jablanica, Grabovica, Salakovac and Mostar, in order to take advantage of its hydropower. The lower, lowland course of the Neretva River begins behind Počitelj, where it enters a vast valley with wetland areas, begins to meander and create an irregular delta that continues into the Adriatic Sea. The area of the lower Neretva course is placed mainly through the carbonate base. NE from Počitelj there is a syncline whose trough is built of Eocene flysch and Alveolina-Numulite limestones, and limbs made of Liburnian layers. From Cern on NW, through Počitelj and onwards on SE there is syncline, which contains clastic deposits of Eocene in the trough, and on the limbs of Eocene limestone. From Ljubuški (NW) to Počitelj and Svitava (SE), stretches the thrust fault of Upper Cretaceous limestones to Eocene clastites and limestones. South of this fault there is a syncline whose trough is built of Eocene limestones and clastics. Further south towards Metković, across Čapljina, there are deposits of Upper Cretaceous and Eocene limestones, and Eocene flysch, which contain an abundance of rudists in their lower (older) parts, and in the upper (younger) parts of thinly layered and plate limestone along with rare finds of rudists. NW from Metković, between Bijača and Svitava, there is a syncline built from Eocene clastic sediments, and Alveolina-Numulite limestones and Liburnian layers in the trough of syncline. The northwestern part of the syncline to Metković, is overturned and disturbed by numerous transverse faults of the approximate direction of N-S. From Nova Sela through Metković to Kolojan, the overturned synclines built of Eocene limestones can be traced, on which Upper Cretaceous sediments are drawn from the NE side. SW from Metković, above Kravac, from Desna to Norinska Kula, through Neretva to Bijeli Vir, there is an overturned syncline built of Eocene sediments, on whose limbs Upper Cretaceous sediments are drawn from the NE side. In the area of Donja Gora stretches anticline built of rudist limestones. Structurally, this area is characterized by numerous overturned folds whose limbs fall on NE (Raić et al., 1977).

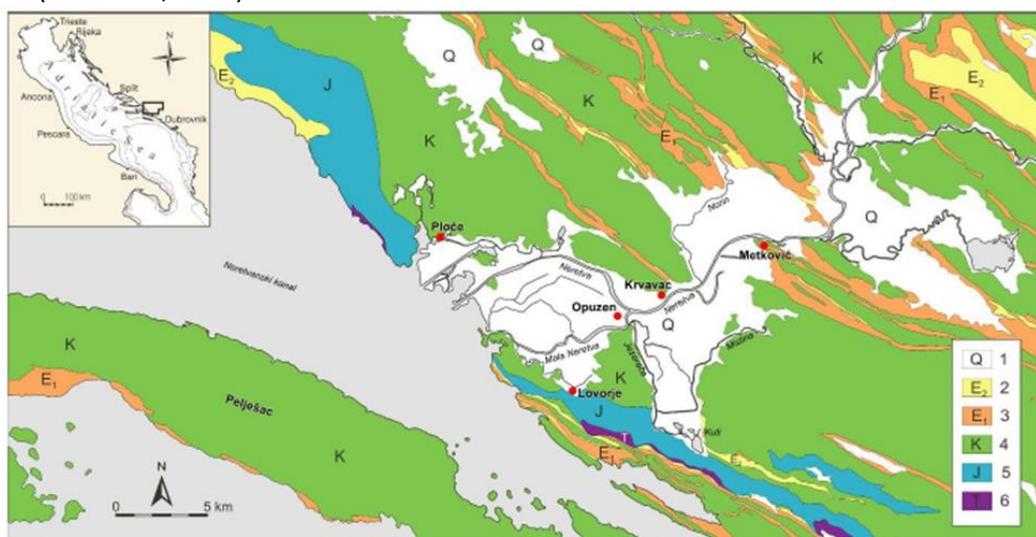


Fig. 4. Geological map of the delta plain of the Neretva River

Source: Jurin et al., 2015, according to EGMY 1: 100 000, sheets Metković (Raić et al., 1976), Ploče (Marinčić et al., 1978), Ston (Raić et al., 1982) and Imotski (Raić et al., 1977)

(Legend: 1- Quaternary alluvial deposits, 2 – Eocene flysch, 3 – Eocene limestones, 4 – Cretaceous limestones and dolomites, 5 – Jurassic limestones and dolomites, 6 – Triasian limestones)

The valley of the lower Neretva flow is tectonically predisposed (Juračić, 1998). Almost all of the described folds have NE limbs destroyed by the reverse faults of Dinaric provision – NW-SE, along which there is a switching and overturning of complete or individual parts of the limbs of syncline and anticline, which caused alternating repetition of stratigraphic layers developed in this part of the terrain (Raić et al. 1977). In addition to reverse faults, faults almost perpendicular to direction of stretching of the Dinaric Alps – NW-SE, which are difficult to track at larger lengths due to their reduced intensity, but they are also very common. These faults were formed by neotectonic movements during the last orogenesis, which formed a rock frame with four extensions whose edges were characterized by a sharp change in inclination and rock type (Juračić, 1998). Within this rock frame the recent Neretva Delta is placed and defined as a flattened area along the lower river course located in Quaternary loose, unconsolidated sediments (gravel, sands, clay) (Juračić, 1998). These sediments are deposited in different wetland, lake, river and marine environments. The rocks in the base of the delta are mainly limestones, which make characteristic protrusions in the form of so-called ‘hums’ that erupt from the Quaternary delta sediments.

The morphology of the Neretva Delta is characterized by four larger extensions in generally direction of Dinaric Stretching (NW – SE) (Juračić, 1998). The most significant is the last, final extension, which covers the area of Ploče-Krvavac-Lovorje and forms the area of today's active delta, with a total area of about 170 km², of which 120 km² is located on the territory of the Republic of Croatia.

In the not-so-distant past, just over 100 years ago, the Neretva River Delta was much larger, and for several reasons: due to the fact that the Adriatic Sea is a low-energy environment, we know that in the past sedimentation in the river mouth was dominated by the influence of the river, and Neretva itself created a branched delta with elongated lobes. Furthermore, increased human activity, mainly in the form of the exploitation of the river and the surrounding area, led to a decrease in the water discharge, and therefore the donation of sediment in the delta (Vranješ et al., 2007). In this way, of the former 12 distributary channels that delivered sedimentary material to the Neretva Channel, today there are only two channels left - Velika and Mala Neretva, which dominate the Neretva Delta Plain. In the delta plain of the Neretva River, in addition to distribution channels, we also find smaller, local tributaries (Norin, Jezerača and Mislina), two freshwater lakes: Lake Deransko (Herzegovina) and Lake Kutina (Croatia), and a number of freshwater and brackish springs.

4.2.3 Characterization of water and sediment fluxes from the mainland

The main source of sediment material in the Adriatic Sea are rivers, and major directions of the terrigenous sediment supply are from the north-western Italian coast, and from its south-eastern part of the Albanian coast. Prior to dam construction, Albanian rivers contributed about 60% of the total sediment (approx. 85 Mt/y), while Italian rivers loaded approx. 56 Mt/y (Milliman et al., 2016, and references therein) (Fig. 5.). Considering its carbonate lithology, only the Neretva river of all Croatian rivers yields a considerable amount of sediment– approx. 14 Mt/y (prior to dam construction).

The main difference between the depositional area of sediment brought by Italian and Albanian rivers is the morphology of the Adriatic basin: sediment from Albania is deposited on its narrow shelf, backed by South Adriatic Pit, where much of the sediment has been deposited by turbidity flows (Milliman et al., 2016 and reference therein). On the contrary, the north-western shelf is wide and shallow and covered by thick Plio-Quaternary deposits in form of series of clinofolds (Trincardi et al., 1994; Correggiari et al., 2005; Ridente and Trincardi, 2005; Cattaneo et al., 2007). Under the present-day conditions of typical cyclonic circulation in the northern Adriatic, much of the discharged sediment remained in the narrow coastal belt along the Italian coast, after being distributed southward by the longshore drift driven by western Adriatic Current (Ravaioli et al., 2003; Steckler et al., 2007). Hence, the central section of the northern Adriatic shelf is sediment deprived and covered by relict sediment (Ravaioli et al., 2003; Steckler et al., 2007; Pikelj, 2010) (Fig. 6.).

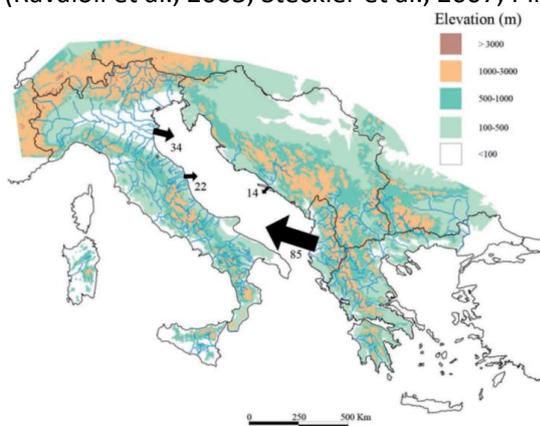


Fig. 5. Mean annual sediment flux to the Adriatic Sea from 29 Italian, 1 Croatian and 5 Albanian rivers prior to dam construction in million tons per year

Source: Milliman et al., 2016

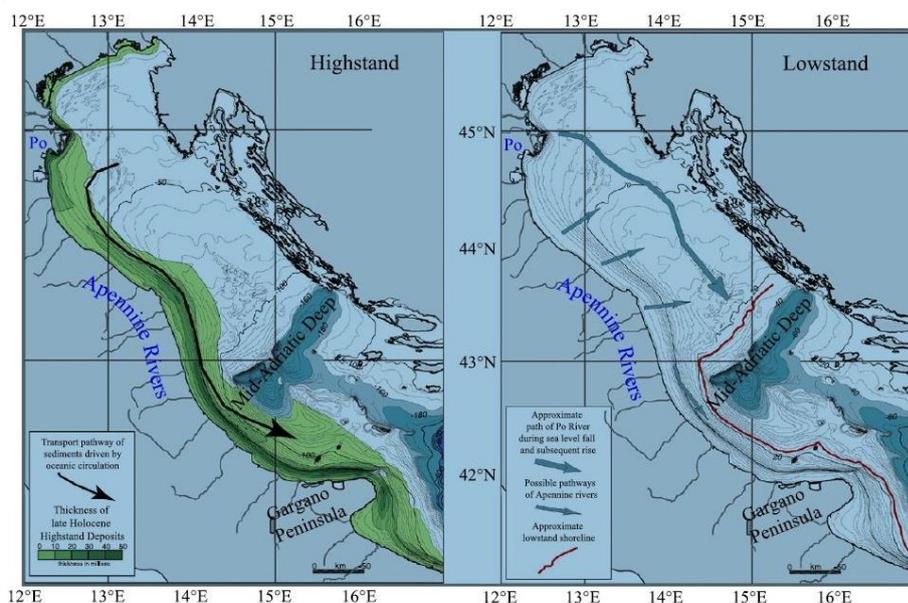


Fig. 6. The difference in sediment pathways in the Adriatic Sea today during the high stand conditions (left) and during the low stand conditions (right)

Source: Steckler et al., 2007

Due to its karstic nature, the eastern Adriatic coast and its hinterland are characterized by small or limited discharge of mostly karstic rivers, as previously mentioned. Due to their generally lower sediment load compared to non-karstic rivers, and the predominant direction of the eastern Adriatic Current, the eastern Adriatic shelf is sediment starved depositional environment under significant influence of biogenous carbonate production (Pikelj, 2010; Pikelj et al., 2016). Mixed terrigenous-carbonate or terrigenous sediment dominates in highly closed and protected bays, as well as in places where the terrigenous sediment input is higher, such as off the Neretva River delta (Jurina et al., 2013; Pikelj et al., 2016; Fiket et al., 2017) or in places of local weathering of non-carbonate coastal rocks (Pikelj and Juračić, 2013; Pikelj et al., 2018; Pikelj and Furčić, 2020) (Fig. 7.). The eastern part of the Adriatic Sea is a highly folded and faulted karstic relief, partially submerged after the post-Holocene sea-level rise. Due to its developed morphology submergence of the eastern Adriatic Sea seabed led to numerous and diverse depositional environments.

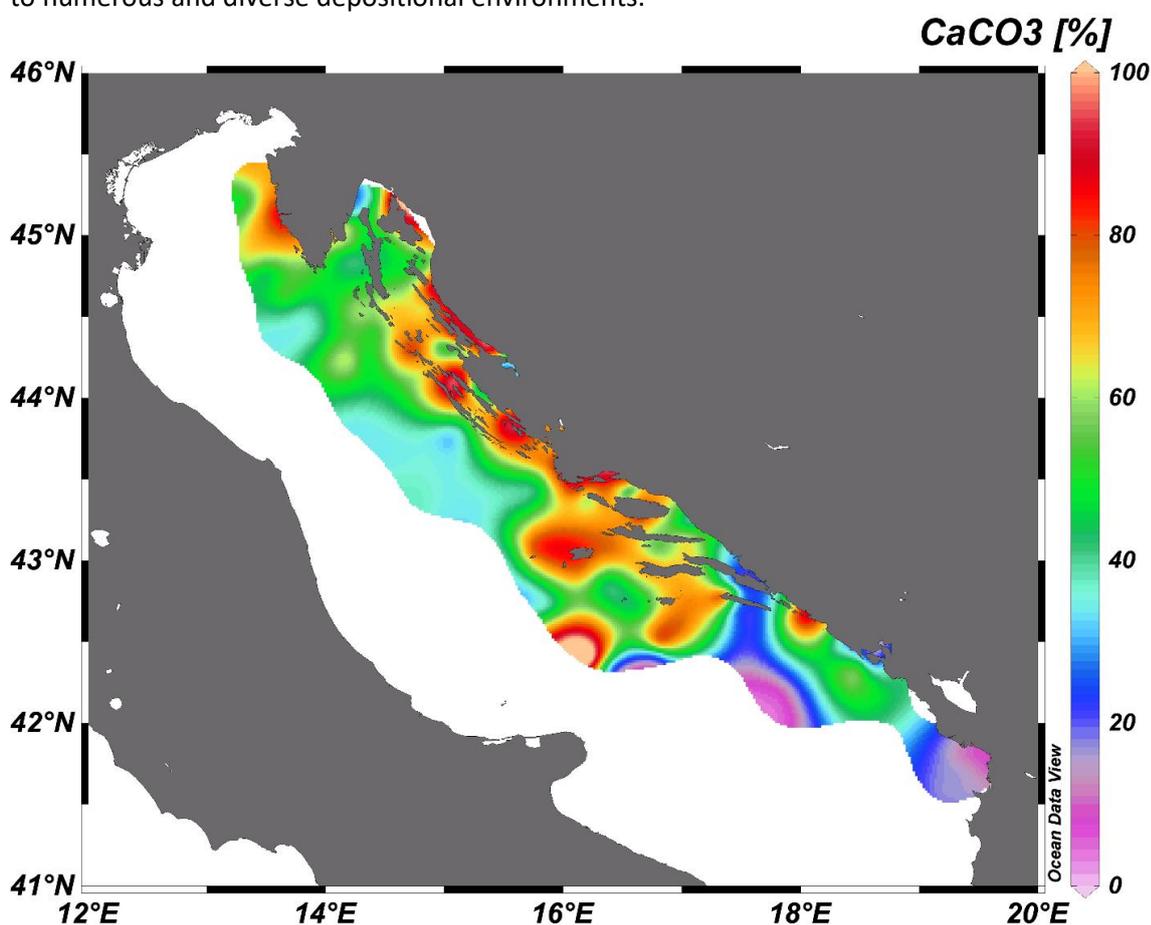


Fig. 7. Carbonate content in the surface sediment of the eastern Adriatic shelf

Source: Pikelj, 2010

4.2.4 Habitats and biodiversity mapping and aquatic ecological quality elements: status and trend

Neretva Delta is one of the most valuable wetlands on the eastern Adriatic coast and one of the rare remaining wetlands in the European Mediterranean. The most important functions of wetland habitats are flood control, groundwater restoration, shoreline hardening and protection from weather hazards in the coastal area, the retention of nutrients and sediments, climate change mitigation and water purification. In addition, wetland habitats represents the habitats of biological and genetic diversity and habitats of numerous economically usable plant and animal species, provide opportunities for development of tourism and recreation and have cultural value.

Although wetland habitats have been significantly reduced in recent decades, and wetland delta has largely been turned into a rich agricultural area, large areas of natural wetland habitats have still been preserved. Here are the most representative areas of wetlands with halophyte vegetation (*Salicornia* species) and the largest areas of reeds in Croatia, which makes this area important as a migration resting place, place for overwintering of numerous bird species and as a nesting place for some European species.

Neretva Delta is internationally recognized and was included on the Ramsar List on January 18, 1993. The Neretva Delta is one of the remaining four Ramsar sites in Croatia. The Ramsar Convention obliges each party to ensure the general preservation of wetlands on its own territory, as well as special obligations related to wetlands of international importance registered in the Ramsar List. This area of the Neretva River delta has a surface area of 12.742 ha and represents the remains of rare relict Mediterranean wetlands with preserved coastal lagoons. The protection of representative wetland habitats in the Ramsar area of the Neretva delta, in the category of special ornithological reserves, creates conditions for effective management with the aim of preservation and protecting ornithofauna and wetland habitats to which it is associated and thus the Republic of Croatia actively contributes to the preservation of these habitats on the world level and fulfils a part of its obligations under the Ramsar Convention.

Biodiversity is currently largely threatened by degradation and loss of habitat, unsustainable exploitation of natural resources and pollution. The most important climate impacts in this sector are: changes in average air temperatures; reduction of quantities and changes in spatial distribution of precipitation; occurrence of climate extremes and heating, acidification and sea level rise. The most vulnerable ecosystems are freshwater ecosystem, underground ecosystem, mountain ecosystem and semi-natural grassland ecosystem.

Although there is no complete list of flora (ferns and spermatophytes) in the Neretva delta, according to available literature, field research conducted between 1995-2005 and in April 2011, approximately 820 plant species were found in the Neretva delta which represents about 15% of Croatian flora. According to the floristic research conducted from 1950 to the present days The Flora Croatica Database has established 81 plant varieties protected by the Nature Protection Act (OG 80/13, 15/18) and the Ordinance on Strictly Protected Species (OG 144/13, 73/16). Of these, 72 species are endangered at the national level and are listed in the Croatian Red Book of vascular flora (Nikolić and Topić, 2005).

In the mouth area of the Neretva River and its tributaries, it is not easy to demarcate seawater and freshwater fish because, due to the mixing of fresh and seawater, this area is mostly brackish water habitat. Neretva and its tributaries are a very important ichthyological area. Until recently, the total number of fish species coming to the lower course of the Neretva River was barely known. Along the course of the Neretva, certain species are differently distributed. Some are present along the entire length of the course, while others are located only in the lower course of the river. The lower course of the Neretva is populated by 22 fish species. More recent research of the lower course of the Neretva river and its tributaries, at the border of sweet and brackish water biotope, found 49 fish species. 12 allochthonous species have been introduced into the Neretva Basin area, four of which have been introduced from the Danube basin – grayling, common carp, sander and ruffe. Most other allochthonous species were introduced at the beginning or mid-20th century by fish restocking of the upper and central course of the Neretva river, where they migrated to the lower course of the river. Other introduced species were rainbow trout, prussian carp, cyprinid fish, stone moroko, brown bullhead, mosquitofish, largemouth bass and pumpkinseed. Due to number of endemic species and diversity of the Neretva mouth, it is one of the most interesting areas in Croatia. Eight species of fish – *Alburnus neretvae*, *Lampetra soljani*, *Squalius microlepis*, *Cobitis narentana*, *Chondrostoma nasus*, *Rutilus basak*, *Knipowitschia croatica*, *Knipowitschia radovici* live in Neretva River catchment. They represent a rare endemic ichthyofauna and a biologically remarkable natural heritage. There also live 18 endemic species in the Adriatic basin, three of which are endemic species of Croatia.

The Neretva Delta contains a large number of fish species occasionally coming to this area from the sea. Delta, lagoons and brackish waters are biologically extremely important habitats because they form areas of intensive growth of fish juveniles, which then spend the rest of their life cycle in the sea or fresh water (PI DNC, 2018). 69 different species in the form of juveniles were recorded in the mouth of the Neretva river, Mala Neretva river and Parila lake indicating the importance of this area as a hatchery site. Among other, flathead grey mullet (*Mugil cephalus*), vulnerable species according to IUCN category of threatened species whose number has been significantly reduced in recent decades, mainly due to loss of favourable habitats. Furthermore, this area is important for the migration of anadromous and catadromous fish. Lagoon Parila is one of the rare remaining brackish habitats on the eastern Adriatic coast of European eel (*Anguilla Anguilla*) which is today one of the most endangered fish species in Europe (PI DNC, 2018). Along the channel lake Vlaška-sea almost all mentioned fish species migrate. The most extensive are the migrations of adult eels towards the sea in the autumn, or younger eels in the opposite direction in the spring and early summer. Before the winter soles, gilt-head breams and mullets move upstream for spawning and come to shallow sea. Also, many species of fish and cephalopods migrate to the shallow waters in the autumn and spring in search of food. Daily migrations are also significant, so that fish of Sparidae family come from deeper sea at night (gilt-head breams, sand steenbras, annular sea breams, white seabreams, common two-banded Fsea breams etc.) and surmullets (DZZP, 2007).

In the area of the Neretva delta, more than 300 bird species have been recorded in literature so far. Neretva delta is primarily important as a resting place for migrations to Africa and for overwintering of bird populations coming from northeast and central Europe. About one thirds of recorded species are wintering birds, which are joined by sedentary birds in winter. Shallow parts and shoals of the mouth of the Neretva River is important for the migration of shorebirds, terns and seagulls, while wetland area (reeds and water surfaces) are important for the migration and overwintering of ducks, reed birds and coots. Among the nesting birds, particularly important are communities of reed birds whose abundance here is most expressed compared to other coastal areas of Croatia. Spacious reeds such as those in the area of Special ornithological reserves *Modro oko and Desne lake* and *Kuti* are the last Mediterranean nesting sites of great bitterns (*Botaurus stellaris*), little bitterns (*Ixobrychus minutus*), western marsh harrier (*Circus aeruginosus*) and ferruginous ducks (*Aythya nyroca*) in

Croatia. The population of great bittern in the Neretva delta is one of the largest in the Mediterranean. Kentish plover (*Charadrius alexandrinus*) nests on sandy shores at the mouth of the Neretva river. Neretva reeds are the only nesting site in the coastal part of Croatia for bearded reedling (*Panurus biarmicus*), and these reeds are also important as nesting site of water rails (*Rallus aquaticus*), porzanas (*Porzana sp.*), reed warblers (*Acrocephalus sp.*) and other species.

Research of other fauna groups in these areas has not been systematically conducted. In the area of the mouth of the Neretva river and the proposed special reserve, there live a large number of molluscs which are represented by numerous species. Among the shellfish, the most abundant are the ones of the families *Cardiidae* and *Veneridae*. Analysis of shellfish settlements shows that on the outer side of the lagoon there is rich habitat of *Chamalea gallina*, while on the edges of inner part of the lagoon is only one species registered – common cockle (*Cerastoderma edule*). In this area, cephalopods are also present. Squid, cuttlefish, octopuses and muskrats prefer especially deeper areas. Benthic malacostraca are not present to any significant extent, except for the group of decapods (*Decapoda*) of which the most common are *Crangon crangon* and various species of the *Peneidae* family (DZZP, 2017).

The mammalian fauna of the Neretva Delta includes 53 species most of which are strictly protected. The widespread species are: Kuhl's pipistrelle, Mediterranean horseshoe bat, house mouse, black rat, shrew, wood mouse, fox and badgers. Among the bats in this area, there are as many as 25 species, and some of them are extremely rare. All bats are protected in Croatia and at European level, and as many as 11 recorded species are target species of Natura 2000 site HR5000031 Delta Neretve. Here lives also Eurasian otter (*Lutra lutra*) which is rare in our coastal area. Marine turtles and marine mammals (dolphins) can also be seen in the area of river mouth (DZZP, 2007). There are also recorded 4 species of endangered and/or strictly protected species of crustaceans that live in freshwater and brackish water. 17 species of reptiles and 7 types of amphibians are recorded in the upper course of Neretva river. It is interesting to note that the endangered species Balkan pond turtle (*Mauremys rivulata*), which is according to Annex II of The Habitats Directive present only in several sites of southern Croatia, once was present in the area of Baćina lakes. In the area of Baćina lakes in the past lived a large population of European pond turtle (*Emys orbicularis*) which together with other water fauna has been significantly depleted in recent years. Frogs represent delicacy in this area and locals traditionally collect them for diet.

In this study, the results of the research on ichthyofauna of the ecological network Neretva Delta (HR5000031), in the period from July 2020 to June 2021, are presented. The research covered all three typical ecosystems in the ecological network, including the marine area, transitional habitats, and freshwater areas. The main goal of the research was to map fourteen target fish species that are key species of protection in the mentioned ecological network and to propose new levels of endangerment, main threats and necessary measures to improve the status of target species. The results pointed that a significant number of target species are less important for the ecological network due to their biological-ecological characteristics, with the main reason that several species (marble trout, softmouth trout, sea lamprey and Imotski minnow) do not have a complete life cycle in the ecological network and these can be considered random and sporadic species. The other ten target species are significant for this area, all of which are endangered with two recent occurrences; salinization of the ecological network during the summer period and the recent increase in the number of invasive predators, especially a largemouth bass. An exception to these species is the twait shad, whose main threat in the ecological network is the construction of dams on the pathways to spawning grounds (Baćinska lakes and remnant the old Neretva watercourse). Compared to the situation twenty years ago, it can be generally concluded that the number of total ichthyofauna has significantly decreased, and the main reason is excessive legal and especially illegal fishing with a number of

prohibited tools. Three main measures to improve the status of target species are proposed: stopping the salinization of the main Neretva by building a mobile dam near city of Opuzen, more effective control of illegal fishing and reducing the number of invasive species. The state of the ichthyofauna in the marine zone of the ecological network indicates the good status of this ecosystem, while invasive species such as bluefish in the pelagic part and blue crab in the benthic part of the ecosystem are emerging. In the transitional habitats, which are characterized by waters with lower salinity, the worst state of the ecosystem was determined in the Lagoon Parila as the most important transitional habitat of the ecological network and special ornithological-ichthyologic reserve. These waters are markedly dominated by invasive blue crab, and the identified damages include the complete disappearance of benthic shellfish such as striped venus clam, lagoon cockle, and Mediterranean mussel, declining native green crab, and some fish species that were previously numerous such as leaping grey mullet. During the work on the project, migrations of blue crab to the main Neretva riverbed all the way to Metković and to River Mala Neretva to Opuzen were determined, and significant damage can be expected in these areas as well. It is proposed to take actions to significantly reduce the number of blue crab in the area of the ecological network with official eradication and commercial fishing. In freshwater habitats, a decrease in the number of native ichthyofauna has generally been found, and a large increase in foreign invasive species, which are competitors for food resources with native species or are direct predators. Of particular concern is the increased numbers of largemouth bass in the area of Lake Kutina and River Mala Neretva, and it is necessary to immediately undertake projects to reduce the number by eradication and sport fishing.

The overall state of ichthyofauna in the ecological network Neretva Delta indicated dramatic recent phenomena of declining native species, with a significant increase of number and abundance of invasive alien species, and for the preservation and protection of target species of flora and fauna, a number of measures are proposed.

One of important characteristics of each water resource system is the ability of its satisfactorily operation under a wide range of natural hydrologic conditions and demands. Understanding of the system functioning and knowledge about its current ecological state provides a rational basis for predicting system behaviour under new conditions such as extreme weather episodes (e.g. droughts), increasing anthropogenic demands and climate changes. In order to describe this behaviour during additional demands, Hashimoto (1982) proposed a comprehensive analysis of the system performance. System performance can be described from three aspects: how often the system fails (reliability), what is the recovery rate of the system from unsatisfactory state (resilience) and how severe the damage caused by a system failure may be (vulnerability). Thus, the analysis based on these three criteria: reliability, resilience, and vulnerability (RRV analysis). This analysis focuses on system failure, defined as any output value reaching the predefined failure threshold. Measurement of these three criteria should be used in water resources management and operating policies.

Due to the anthropogenic causes and climate changes, functioning of water resource systems are becoming increasingly complex with increasing number of possible risks. In order to manage these risks determination of system baseline conditions is needed, however, baseline performance analysis for most of water systems is not done. Furthermore, the RRV concept requires determination of failure thresholds as well as the criterion for satisfactory state. In case of the Neretva River Delta baseline condition does not exist. Overall, collected data compiled within this activity gave an insight into overall picture of sediment and water fluxes within the Neretva River Delta, however, quantification of both fluxes is still highly missing. One of main difficulties in case of the Neretva River in whole is a general lack of data and the continuity of data collection required for baseline condition determination (sediment flux, hydrological and meteorological data etc.). Compiled and here presented data have shown that the Neretva River Delta is a rather complex area, with sediment and water supply from

drainage basin of mixed lithology. Its water discharge is considerably influenced by its karstic relief. Due to this complexity and the involvement of karstic groundwater discharge within, estimation and calculation of natural water discharge within the Neretva River Delta may vary (probably by several magnitude of order as in case of other Croatian coastal rivers). Despite the general data gaps, reconstruction of the water flux data is recommended in the future, especially for adaptation measures to be delivered within this project. As far as the sediment flux within the Neretva River Delta is concerned, data were not collected so far and only a rough estimation is given in this report.

In order to establish baseline conditions, satisfactory state and failure threshold for RRV analysis, monitoring of sediment flux needs to be established in the future as well. As described throughout the report, independent research results have shown that the topmost sediment cover within the Neretva River Delta and along the Neretva Channel where the sediment from the river plume is deposited contains generally fine-grained particles, compared to coarse-grained material deposited below (and before dam construction). This sediment fining clearly indicates considerable reduction of sediment input. As a consequence, erosion of the deltaic deposits has been detected. Due to the unknown quantities of natural sediment deposition rates within the deltaic plain, a careful reconstruction and estimation of sediment flux need to be established for period without measurements, in order to perform RRV analysis.

Together with dam construction in its upper part, intensive agriculture in deltaic part is the main recognized anthropogenic cause of water and sediment flux reduction, resulting in changes of sedimentological characteristics of deposited sediment material. As a consequence, delta erosion and seawater intrusion frequently occur. These processes are recognized as the main risks posed within the Neretva River Delta for both, protected areas and agricultural land. It is expected that climate change with recognized warming trend will further cause a decrease in water and sediment discharge. This reduction may further induce changes in physical and chemical conditions within the Delta and they may be a trigger of harmful substances remobilization, causing thus their release within the deltaic system. This domino effect may threaten the human population as well, largely depend on food production within the Delta. Thus, from the current point of view, quantities of both water and sediment supplied by the Neretva River need to be increased to reduce posed threats and/or annul their negative effects.

4.3 Evolution dynamics in the Pilot area under Climate Change

Evolution of key hydrological and physical quantities and fluxes

Using the AdriSC model for the Delta Neretva area, the mean annual sea surface temperature increased from the beginning of the measured period (1987) when it was 18.5-19.0 °C until the end of the measured period (2017) when it reached 19.0-20 °C (Fig. 8.). Positive trends are expressed in all seasons. Sea surface salinity has a strong annual variability ranging from 38.2 to 38.7 with the lowest values in the summer months (Fig. 9.). Sea level (Fig. 10.) continuously increased during the observed period, but it had a significant inter-annual variability.

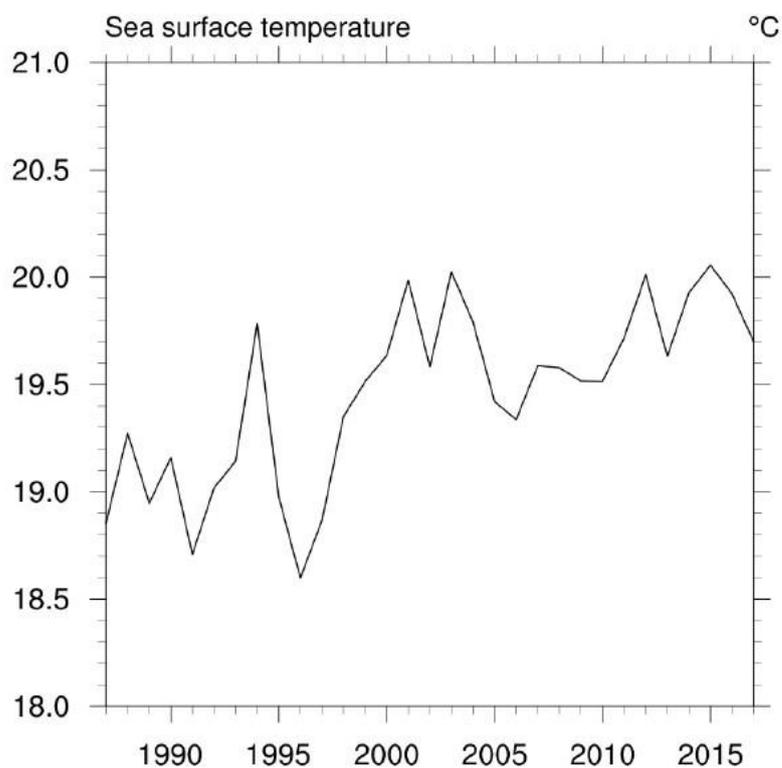


Fig. 8. Annual sea level temperatures in the Neretva River area simulated by the AdriSC model (1987-2017)

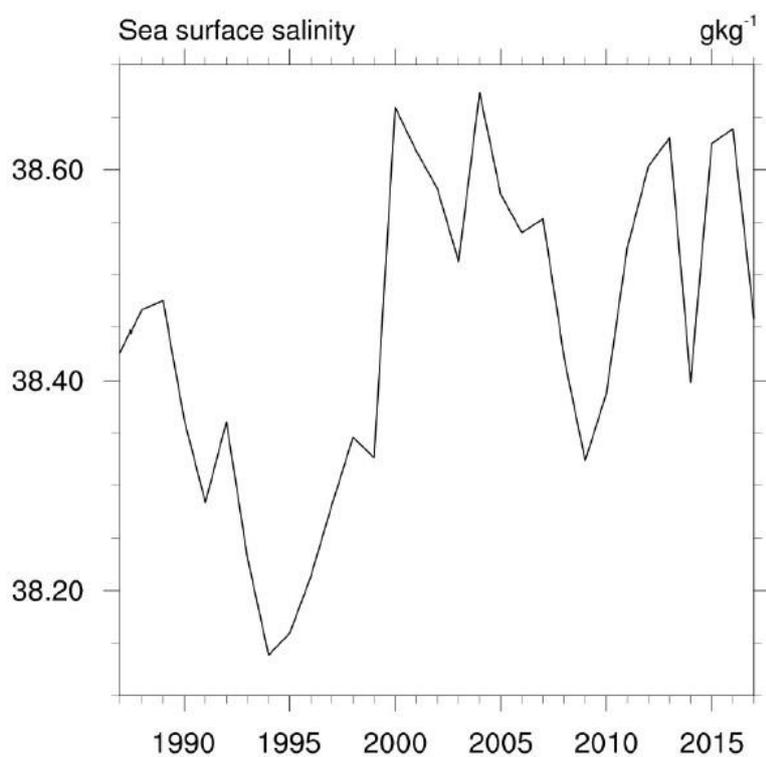


Fig. 9. Annual salinity rate of the sea surface in the Neretva River simulated by the AdriSC model (1987-2017)

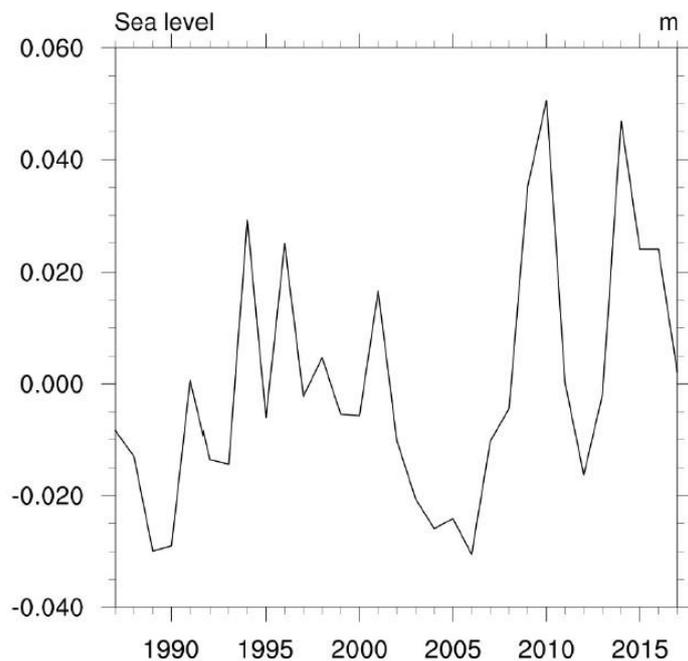


Fig. 10. Annual sea levels in the Neretva River area simulated by the AdriSC model (1987-2017)

Morphological evolution at the multidecadal scale

Due to the nivo-pluvial regime with an impermeable upper drainage basin, together with high relief ration, climatic variation, and scarce vegetation, Neretva River is considered to have a high sediment flux. Additional sediment load is due to the flysch bedrock in its lower drainage basin. As an allogenic karstic river, Neretva discharges a large quantity of particulate sediment into the Adriatic compared to other Croatian rivers. However, sediment input is nowadays substantially reduced due to the sediment trapping in reservoirs behind large dams. In totally, 9 dams most of the particulate material in the part of the drainage basin upstream of Mostar. The most complex dam is one on the Trebišnjica River which has a negative impact on the deltaic plain and the Neretva River - it significantly reduces water and sediment discharge, increasing thus riverbed. Besides built dams, the anthropogenic cause of reduced water and sediment input is intensive agriculture. Delta erosion and frequent intrusion of seawater occur as a consequence. The climate change is expected to further reduce the flow of water and sediment. Reducing the input of water and sediments could lead to further changes in physical and chemical conditions within the delta. Also, these changes could cause threats to human population dependent on food production.

Evolution of coastal and transitional aquatic ecosystems at the multidecadal scale

The prediction of the future of individual species and habitats in the Neretva delta can be based on an analysis of local trends over the past ten years and an analysis of changes in the southern areas of Adriatic and Aegean Seas. Local trends in the 21st century show that some invasive thermophilic species are rapidly spreading along the Adriatic coast, and some have already established a sex population such as blue crab (Fig. 11.). In addition, some Adriatic species that prefer warmer temperature conditions, such as sea bass, have significantly increased their number in the Neretva

delta waters. Some other species that used to be numerous in the Neretva delta, such as flathead grey mullet are now very rare, although they were the main species in the Neretva fishery. Examples from similar areas of Greece, such as the Mesolonghi and Amvrakikos lagoons, pointed to significant changes in the composition and quantity of species with certain species starting to dominate (gilt-head bream, blue crab, etc.) and some species of red mullet, flatfish and other species losing their significance.



Fig. 11. Blue crab

4.4 *Monitoring and information gap-filling strategies*

Public Institution for Management of Protected Natural Areas of Dubrovnik-Neretva County in cooperation with external experts, conducts annual monitoring activities for ornithofauna. Over the years, several different surveys have been carried out by public institution concerning the ornithofauna and ichthyofauna of the Natura 2000 ecological network sites. Hrvatske vode (Croatian waters) are in charge of collecting data related to physico-chemical parameters of water.

There were no new “in situ” measurements of geomorphological data within the framework of the Change We Care project. However, data on the sediment yield and carrying capacity of the Neretva River are important for future predictions of sediment accumulation trends. Also, no research is available on the current sediment dynamics around the mouth of the Neretva River. In addition, it is considered important to conduct research on the dynamics of ‘Škanj’ sediments. Finally, sedimentary research and precise geodetic monitoring along the river estuary are necessary for the analysis of evolutionary trends. Also, there are no ‘in situ’ measurements of sediment, water or nutrient input. A large quantity of data, especially those related to the quality, composition and future movements of the port sediment in Ploče.

Coastal and aquatic transitional habitats in the Neretva delta (the wider area of the small Neretva River, the mouth of the Neretva River, the lagoon Parila, Vlaško lake, the Neretva River until the city of Opuzen) are poorly explored and should be mapped on the basis of salinity criteria for brackish water from 1 to 25 ppt. In addition to biodiversity research, it is important to define the ecological status of these transitional habitats by classifying the Water Framework Directive.

5. Elements of the participatory process for the Neretva Delta Pilot Area

The overall objective of the participatory process was to achieve communication with local stakeholders. Establishing communication with local stakeholders can contribute to raising awareness of climate change challenges and synergy among stakeholders in the realization of climate change adaptation measures. Also, an important objective of this activity is to supplement the knowledge that is missing. Establishing communication with the local community through workshops can significantly contribute to the complementarity of existing knowledge. The workshops focused on the impact of climate change on the Delta Neretva ecological network (HR50000031). The workshops discussed the impact of climate change on the economy and the environment. By defining potential challenges in the future related to climate change, possible objectives, measures and adaptation activities of the area were discussed.

5.1 Stakeholders involved

In Tab. 2. all stakeholders involved in the participatory process are listed. In the participatory process 19 stakeholders were involved, and the Tab. 2. shows sector or focus area of each stakeholders. The largest number of stakeholders is from the public sector, while the number of stakeholders from the private and civil sector is smaller. Representatives of the public sector who were involved in the participatory process are mostly representatives of institutions competent for a particular segment of spatial development or spatial resource management. Representatives of the public sector represent an important role in the process because they have the capacity to implement climate change adaptation measures. In addition, the workshops gathered representatives of the tourism and education sector, which proves the importance of this topic for the future of the Neretva delta. The participatory process brought together several representatives of the civil sector who are engaged in promoting the development of cultural heritage, environment protection and regional development. Private sectors representatives were mostly representatives of family farms.

Tab. 2. List of stakeholders involved into participative process

Sector	Stakeholder	Area of interest
Public	Public Institution for Management of Protected Natural Areas of Dubrovnik-Neretva County	Protection, conservation and promotion of the protected parts of nature
	Institute for Spatial Planning of Dubrovnik-Neretva County	Spatial planning
	Administrative Department for Environmental Protection, Property Law and Utility Affairs of Dubrovnik-Neretva County	Environment protection
	Administrative Department for Economy and Maritime Affairs	Economy
	City of Opuzen	City administration
	Plora d.o.o.	Regional development
	Elementary school Stjepana Radića Metković	Education institution
	Public Open University Ploče	Education institution
	Radio station Ploče	Media
	Hrvatske vode	Water resources management
	Tourist board of the City of Metković	Tourism
	Tourist board of the City of Ploče	Tourism
Civil	Association 'Baštinik'	Promoting the protection of natural and cultural heritage of the Neretva river
	Association BIOM	Environment protection
	Local action group Neretva	Regional development
	Association Bioteka	Education and environment protection
Private	Family Farm Joško Curić Babić	Agriculture
	Family Farm Tiha Blažević	Organic agriculture
	Urbanex d.o.o.	Consulting company

5.2 Design and implementation of the participatory process

Workshop was chosen as a basic participatory technique to involve as many stakeholders as possible in the development of the adaptation plan. The design phase included the choice of an ideal participatory approach method, the definition of workshop programmes, as well as the identification of potential stakeholders. During the design phase, the way in which the workshop parts of the participatory approach are implemented has been designed in detail. The implementation phase followed the design phase, with three participatory workshops, each of which has a specific objective.

The first workshop 'Effects of climate change on the Neretva delta' took place at the Metković City Library on 30 March 2021. The first workshop brought together 12 stakeholders from civil, public and private sectors. The first workshop entitled 'Effects of climate change on the Neretva delta' presents the results of previous research and experiences of the effects of climate change on agriculture, fisheries and ecosystems in the area of the Delta Neretva ecological network (HR5000031) and

presents current and planned measures for the prevention of impacts and reduction of damage. The presentation was followed by a discussion divided into four topics: water resources, agriculture, fisheries and aquaculture and biodiversity. When the discussion ended, there was a brief discussion in which stakeholders proposed key words to define vision of space in adapting to climate change.



Fig. 12. The first participative workshop (Metković, March 2021)

The second workshop 'Adaptation measures to different climatic scenarios for the delta Neretva' Was held at the City Library in Opuzen on 30 August 2021. The second workshop presents the measures for adapting to different climatic scenarios for the area of the Delta Neretva ecological network (HR5000031) as well as the results of the research carried out (,..) in order to collect additional data on distribution and status of populations of target species. After the presentation, climate change adaptation measures were presented. The following part of the programme required that stakeholder be actively involved in defining objective, measures and activities for 4 key areas: water, resources, agriculture, fisheries and aquaculture and biodiversity.



Fig. 13. The second participative workshop (Opuzen, August 2021)

The third workshop ‘Action Plan for adaptation to expected climate change in the Neretva delta’ was held on 20 September 2021 at the Public Open University in the city of Ploče. The third workshop brought together 13 participants. On the third workshop Action Plan for adaptation to climate change was presented, as well as the Fishery and economic study of the area of the Delta Neretva ecological network and the results of the research of socio-economic status of main stakeholders in the fisheries sector in the area of the delta Neretva ecological network. After the presentation of the Action Plan, participants were invited to comment on each objective, measure and activity. Participants with their knowledge of are and key problems, significantly contributed to the amendment of the existing action plan.



Fig. 14. The third participatory workshop (Ploče, September 2021)

5.3 Outcomes of the participatory process

The conclusions of three workshops that were recognized as important and implemented in the drafting of this document are presented below.

Main conclusion of the first workshop:

- The available quantities of water coming to the Neretva delta represent the greatest problem;
- Construction of a dam and closing of natural paths on the Trebišnjica River to which water was coming, influenced by the loss of fresh water inflow;
- An increase in sea level identified as an important problem;
- The need to address the problem of adaptation to climate change at international level;
- The need for systematic resolution of conflicts between farmers and environmental bodies is highlighted;
- Highlighted problem of poaching;
- Reduced sediment content in the Neretva bed is also recognized as a problem;
- The importance of education of local population in the adaptation to climate change;
- The importance of fostering organic agriculture has been emphasized;
- The problem of inadequate waste management has been identified;
- Photo safari recognized as potentially dangerous form of tourism;
- When defining the vision of space, participants repeated words: completeness, coexistence, development, local community, harmony, unity.

Main conclusions of the second workshop:

- The representatives of the 'Croatian waters' think that the problem is that activities such as deepening are prohibited by environmental protection;
- Conventional agriculture has been recognized as the main polluter of the area;
- The importance of organised linking of stakeholders in agriculture is emphasized;
- The importance of encouraging the practice of organic agriculture has been emphasized;
- Objectives and measures for adaptation to climate change were proposed:
 1. Development of organic agriculture
 - Fostering organic agriculture
 - Building a defence system against extreme conditions
 - Systematic adaptation of agriculture to climate change
 2. Conservation of biodiversity
 - The abuse of invasive species
 - Fostering the use of renewable energy sources.

Main conclusions of the third workshop:

- Recognized completeness of the proposed Action Plan;
- The importance of the Action Plan being a publicly available document and presented to key stakeholders in the area;
- In the context of sustainable water ecosystem management, the importance of preventing illegal activities is emphasized;

- The importance of local educational institutions in awareness of importance of preserving local resources has been recognized;
- The orientation of eel hunting into hunting for tourism purposes has been recognized as a measure that can contribute to the reduction of the excessive eel fishing;
- Intensive agriculture is recognized as a polluter in space.

6. *Adaptation Plan for the Neretva Delta Pilot Area*

6.1 *Jurisdictional framework*

The importance of the Neretva Delta area in the context of nature protection has been recognized at the national, European and global level. According to the Nature Protection Act of the Republic of Croatia, protected areas of national importance and protected areas of local importance are distinguished. In the category of protected areas of national importance in the Neretva Delta, there are six special reserves: five ornithological (Orepak, Modro oko and Lake Desna, Pod Gredom, Kuti and Prud) and one ichthyological-ornithological reserve (Neretva mouth). In the category of protected areas of local importance in the Neretva Delta, one significant landscape stands out - Predolac-Šibenica. In the area of Neretva there is also a protected mineral Stone Ball (Kamene kugle) in the Municipality of Pojezerje.

The Neretva Delta area is also recognized as part of the ecological network Natura 2000, ie the ecological network of the European Union, which consists of natural habitat types and habitats of wild species of interest to the European Union. Within the ecological network Natura 2000, the Neretva Delta has been identified as an area of conservation important for birds (HR1000031) and as an area important for the conservation of habitat types and species (HR5000031). The Public Institution for Management of Protected Areas of Nature of the Dubrovnik-Neretva County manages 34 protected nature sites of the Dubrovnik-Neretva County, including protected sites in the Dubrovnik-Neretva County.

In addition, the Neretva Delta area has been recognized as an internationally important wetland habitat, so in 1993 the area was included in the Ramsar List. The Neretva Delta is one of four wetlands accepted into the Ramsar List in 1993. The aim of this convention is to preserve the wetlands which are crucial for the survival of many plant and animal species from which man benefits in many ways.

6.2 *Identification of the vision for the Pilot Area*

Climate change poses a growing threat in the 21st century due to its impact on all aspects of the environment and the economy. The area of the Neretva Delta ecological network belongs to the Mediterranean region, which is recognized as a climatic 'hot spot' and has already reached an average increase of 1.5°C with particularly pronounced effects of climate change. For this reason, the development of this document, which will define the strategy for adaptation to climate change, is extremely important for the future of the Neretva Delta.

Defining the vision of the Neretva Delta area in adaptation to climate change was performed by involving the local population. One of the tasks during the first participatory process workshop held in Metković was to define the vision of the area in adapting to climate change. Each stakeholder was asked to select three keywords that describe the best the vision of the area coexisting with climate change. At the end of the workshop, it was clear how certain words - comprehensive, coexistence, development, local community, harmony, lasting harmony, togetherness, future and balance were continuously repeated. According to the results of the first workshop, the vision of the ecological network of the Neretva Delta in adapting to climate change is:

'Symbiosis of river and people'

Symbiosis in the narrow sense (or mutualism) means the interactivity of two organisms from which both organisms benefit. The vision emphasizes the importance of realizing the harmonious

coexistence of two 'organisms' - the Neretva River and the people who live near it. The vision of adaptation to climate change is elaborated through a hierarchy of goals and measures. Measures and activities are explained in detail in Chapter 6.3.

In line with the vision, the following five goals have been defined:

1. **Preserved and adaptable ecosystem**
2. **Sustainable management of aquatic ecosystems**
3. **Improving the functionality of important ecosystems**
4. **Sustainable and resistant economy**
5. **Aware and proactive population**

The vision, goals and measures for adaptation to climate change are harmonized with the following documents at the national level:

- a) **The Climate Change Adaptation Strategy in the Republic of Croatia for the period to 2040 with a view to 2070.** whose implementation should make vulnerable systems more resilient than they are today and more useful in the overall adaptation of society to climate change, and the damage from natural disasters should be less, which will contribute to the long-term sustainable development of the Republic of Croatia. The aim of the adaptation strategy is to raise awareness of the importance of the impact of climate change on society, point out the threats and the need to integrate the concept of climate change adaptation into existing and new policies, strategic and planning documents, programs and other activities.
- b) **Integrated National Energy and Climate Plan for the Republic of Croatia for the period from 2021 to 2030** which aims to reduce greenhouse gas emissions, energy from renewable sources, energy efficiency and electricity interconnection.
- c) **National Recovery and Resilience Plan 2021-2026** with the aim of transforming the economy, which will enable the formulation of innovative policies through modernization and digital and green transition of the economy, which will have a positive impact on the long-term and more sustainable development of Croatia.
- d) **The Development Strategy of the Republic of Croatia until 2030** according to which one of the four key goals is Green and Digital Transition. With this goal, Croatia would strive to become a European leader in transforming climate and environmental challenges into opportunities, ensuring a fair and inclusive transition to climate neutrality.

At the level of the European Union, the most important document is the European Strategy for Adaptation to Climate Change, by which the European Union sets its long-term vision to become a climate-resilient society fully adapted to the effects of climate change by 2050. The strategy aims to strengthen the European Union's adaptation capacity and reduce vulnerability to the effects of climate change, in line with the Paris Agreement and the proposal for a European climate law.

6.3 Action Plan for the Pilot Area Neretva Delta

Implementation of Objective 1. Preserved and adaptable ecosystem is possible through the implementation of four measures: 'Improvement of water resources management', 'Environmentally friendly drainage and waste management', 'Adaptation to extreme weather events' and 'Biodiversity conservation and control of invasive species'. Construction of a temporary movable dam near Opuzen as part of the measure 'Improving water resources management' will enable sustainable management of water resources. Activities within the measure 'Environmentally friendly drainage and waste management' aim to solve two major environmental problems for the Neretva area. 'Building a monitoring and warning system against extreme weather events' and 'Building a Flood Defense Center' seek to achieve adaptation to extreme weather events. 'Biodiversity conservation and control of invasive species' is planned by the measures 'Introduction of systematic research on the state of biodiversity', 'Control and removal of invasive plant species' and 'Better labeling of all important ecological areas'.

Realization of Objective 2. 'Sustainable management of aquatic ecosystems' is possible by implementing the following measures: 'Protection and improvement of eel status', 'Protection and improvement of target and endemic fish species in the ecological network of the Neretva Delta', 'Control of invasive fish species', 'Organization freshwater sport fishing' and 'Development of fishing tourism'. 'Detailed research on the status of the eel population in the Neretva delta and monitoring', 'Development of the Eel Management Plan in the Neretva delta' and 'Improvement of the eel population in the Neretva delta with targeted restocking' were identified as activities that can improve eel status. In order to protect the status of target and endemic fish species, it is necessary to prohibit fishing, protect hatcheries and provide spawning routes. Reducing the number of invasive fish species is planned to be achieved through selective and sport fishing. In order to organize freshwater sport fishing, it is important to develop a Sport Fishing Management Plan and establish sustainable fish populations for sport fishing and protection of target species. The last measure under Objective 2 is 'Fishing tourism', the development of which requires the promotion of traditional fishing tools for tourism purposes.

The implementation of Objective 3 'Improving the functionality of important ecosystems' is organized through four measures: 'Improving the functionality of the Parila lagoon', 'Improving the functionality of the Kuti Lake area', 'Improving the functionality of Baćina Lakes' and 'Improving the function of Lake Desna'. 'Improving the functionality of the Parila lagoon' can be achieved by deepening the lagoon in the northern part and the Široka-Parila pass, providing greater inflows of fresh water and the restoration and upgrade of the stone embankment 'diga' of the lagoon towards the sea. For the implementation of the measure 'Improvement of the functionality of the Kuti Lake area', it is important to ensure the inflow of fresh water from the Neretva in the summer. By modifying the concrete dam at the exit of the lake towards the sea to enable the migration of the cap to spawning, 'Improvement of the functionality of Baćina lakes' can be achieved. The 'improvement of the functionality of Lake Desna' is planned to be achieved by the construction of a temporary movable dam during the summer period.

Objective 4 'Sustainable and resilient economy' is planned to be achieved through 3 measures: 'Development of sustainable tourism', 'Development of ecological agriculture' and 'Sustainable fisheries and fish stock management'. 'Development of sustainable tourism' is possible by drafting a Management Plan for tourist boats on the canals and backwaters of the Neretva, by introducing ships that use alternative energy sources and drafting a Plan for the development of year-round tourism. In order to enable the 'Development of organic farming', it is necessary to educate the local population

about the importance of switching to organic farming, encourage stakeholders to engage in organic farming, encourage the establishment of organic farmers' cooperatives, brand organic products and build a center for processing organic products. For the realization of sustainable fisheries and sustainable management of fish stocks, it is necessary to develop fisheries management plans and certain species and tools in the ecological network, limit the number of stakeholders in all types of fishing, limit catches or completely ban eel or beet fishing; to direct hunting in demonstrations for tourist needs, to introduce a program for reducing the populations of invasive species or catches in sport-recreational fishing, and to control and punish catches outside the legal regulations.

Objective 5. 'Aware and proactive population' can be achieved through education on climate change and the participation of local people in the adoption of strategic documents important for the sustainability of space and adaptation to climate change. Climate change education includes launching education on the consequences of climate change and ways to adapt, opening a center for climate change monitoring and educating citizens on climate change, creating and distributing educational materials and launching an educational web platform or mobile application thematically focused on environmental protection. Involvement of the local community in climate change adaptation can be achieved by organizing workshops to discuss the challenges of climate change, involving local people in the adoption of strategic documents important for spatial sustainability and climate change adaptation and implementation of volunteer programs thematically related to climate change.

Objective 1. Preserved and adaptable ecosystem

Measure	Activity	Risk or vulnerability affected	Implementation status and implementation timeframe	Stakeholders involved	Responsible body for implementation	Implementation indicator	Cost estimation and method of financing
Improvement of water resources management	Construction of a temporary movable barrier near Opuzen	Salinization and disappearance of freshwater ecosystems	Implementation has begun, 2021.-2030.	Croatian Waters, City of Opuzen	Croatian Waters	A temporary movable barrier built	120.000.000,00 HRK; EU funds
Environmentally friendly drainage and waste management	Construction of wastewater drainage systems from households	Intake of organic matter that eutrophies closed or closed freshwater ecosystems during the summer	Implementation has begun, 2017.-2022.	Dubrovnik-Neretva County, local self-government units	Dubrovnik-Neretva County	Built households drainage system	500.000.000,00 HRK; EU funds, Republic of Croatia, Dubrovnik-Neretva County
	Development of a circular waste management plan	The problem of inadequate waste management	Implementation has not started, 2022.-2025.	Dubrovnik-Neretva County, local self-government units	Dubrovnik-Neretva County	Circular waste management plan developed	100.000,00 HRK; Dubrovnik-Neretva County, Self-government unities
Adaptation to extreme weather events	Construction of a system for monitoring and warning of extreme weather events	Lack of a system for monitoring and warning of extreme weather events	Implementation has not started, 2022.-2026.	Croatian Waters, Dubrovnik-Neretva County,	Croatian Waters	Built system for monitoring and warning of extreme weather events	3.000.000,00 HRK; EU funds

	Construction of the Flood Defense Center	Low level of organizational flood defense system	Implementation has started, 2018.-2021.	Croatian Waters, Dubrovnik-Neretva County, DUNEA, City of Opuzen	Croatian Waters, City of Opuzen	Flood Defense Center built	18.000.000,00 HRK; EU funds, Republic of Croatia
Biodiversity conservation and control of invasive species	Introduction of systematic research on the state of biodiversity	Insufficient research	Implementation in progress, 2021.-2030.	University of Dubrovnik, University of Zagreb, Public Institution for Management of Protected Natural Areas of the Dubrovnik-Neretva County; BIOM, Sun, BIOTA, IZOR, HYL A	University of Dubrovnik, Public Institution for Management of Protected Natural Areas of the Dubrovnik-Neretva County	Number of conducted biodiversity surveys	500.000,00 HRK; EU funds, Dubrovnik-Neretva County
	Control and removal of invasive plant species (eg variegated crocus)	Occurrence of invasive plant species	Implementation has begun, 2017.-2030.	University of Dubrovnik, University of Zagreb, Public Institution for Management of Protected Natural Areas of the Dubrovnik-Neretva County,	Ministry of Economy and Sustainable Development, Public Institution for Management of Protected Natural Areas of the Dubrovnik-Neretva County, Croatian Waters, Neretvanski sliv	Carried out actions of control and removal of invasive plant species	4.000.000,00 HRK; EU funds, Ministry of Economy and Sustainable Development, Croatian Waters, Dubrovnik-Neretva County, Public Institution for Management of Protected Natural Areas of the

				Croatian Botanical Society			Dubrovnik-Neretva County
	Better marking of all important ecological areas	Poorly marked important ecological areas	Implementation has not started, 2025.-2030.	Public Institution for Management of Protected Natural Areas of the Dubrovnik-Neretva County, local self-government units	Public Institution for Management of Protected Natural Areas of the Dubrovnik-Neretva County, local self-government units	All ecologically important areas are marked	200.000,00 HRK; EU funds, Dubrovnik-Neretva County, Public Institution for Management of Protected Natural Areas of the Dubrovnik-Neretva County

Objective 2. Sustainable management of aquatic ecosystems

Measure	Activity	Risk or vulnerability affected	Implementation status and implementation timeframe	Stakeholders involved	Responsible body for implementation	Implementation indicator	Cost estimation and method of financing
Protection and improvement of eel status	Detailed research of the population status in the Neretva delta and eel monitoring	Threat of complete extinction of the species in the Neretva delta	Implementation has begun in 2021.-2030.	Scientific institutions, Ministry of Agriculture, Dubrovnik-Neretva County, City of Ploče	Dubrovnik-Neretva County, Ministry of Agriculture	Study on the status of eels in the Neretva delta	220.000,00 HRK; EU funds, Ministry of Agriculture
	Development of the Eel Management Plan in the Neretva Delta	Poor biological status of the eel population in the Neretva delta	Implementation has not started, 2022.-2025.	Scientific institutions, Ministry of Agriculture, Public Institution for Management of Protected Natural Areas of the Dubrovnik-Neretva County	Ministry of Agriculture Dubrovnik-Neretva County	Eel Management Plan in the Neretva Delta / National Management Plan	75.000,00 HRK; Republic of Croatia, Dubrovnik-Neretva County
	Improvement of eel population in the Neretva delta with targeted restocking	Poor biological status of the eel population in the Neretva delta	Implementation has not started, 2023.-2025.	Scientific institutions, Ministry of Agriculture, Dubrovnik-Neretva County, Public Institution for Management of Protected Natural Areas of the Dubrovnik-Neretva County	Ministry of Agriculture, Dubrovnik-Neretva County	Commencement of glass eel / juvenile restocking in the Neretva delta	345.000.000,00 HRK; EU funds, Ministry of Agriculture, Dubrovnik-Neretva County
Protection and improvement	Improving the status and effective protection of fish	Decreased abundance of most endemic	Implementation has begun, 2020.-2025.	Scientific Institutions, Ministry of Economy and	Scientific Institutions, Ministry of Economy and Sustainable	Protected hatcheries, especially source	50.000,00 HRK; Ministry of Economy and

of the status of target and endemic fish species in the ecological network of the Neretva Delta	biodiversity in the Neretva delta: ban on fishing, protection of hatcheries, provision of spawning routes	species in the Neretva delta		Sustainable Development, Ministry of Agriculture, Public Institution for Management of Protected Natural Areas of the Dubrovnik-Neretva County	Development, Ministry of Agriculture, Public Institution for Management of Protected Natural Areas of the Dubrovnik-Neretva County	zones, cleared spawning routes, enabled migrations to hatcheries	Sustainable Development, Public Institution for Management of Protected Natural Areas of the Dubrovnik-Neretva County
Control of invasive fish species	Reducing the number of harmful invasive fish species through increased fishing by selective and sport fishing	Harmful effects on indigenous ecosystems and species	Implementation has not started, 2025.-2030.	Ministry of Agriculture, Ministry of Economy and Sustainable Development, Public Institution for Management of Protected Natural Areas of the Dubrovnik-Neretva County	Ministry of Agriculture, Public Institution for Management of Protected Natural Areas of the Dubrovnik-Neretva County	Significantly reduced the number of harmful invasive fish species	362.000,00 HRK; Republic of Croatia, Public Institution for Management of Protected Natural Areas of the Dubrovnik-Neretva County
Organization of freshwater sport fishing	Development of a Sport Fishing Management Plan and selection of rights holders	Large illegal fishing in all waters of the Neretva delta	Implementation has not started, 2025.-2030.	Scientific institutions, Ministry of Agriculture, Dubrovnik-Neretva County, Public Institution for Management of Protected Natural Areas of the Dubrovnik-Neretva County	Dubrovnik-Neretva County	Sport fishing management plan, Selected user of sport fishing rights	70.000,00 HRK; Republic of Croatia, Dubrovnik-Neretva County

	Establishing sustainable fish populations for sport fishing and protection of target species	Poor status of target species, large number of invasive fish species	Implementation has not started, 2025.-2030.	Scientific institutions, Ministry of Agriculture, Dubrovnik-Neretva County, Public Institution for Management of Protected Natural Areas of the Dubrovnik-Neretva County	Ministry of Agriculture, Public Institution for Management of Protected Natural Areas of the Dubrovnik-Neretva County	Good status of fish populations in freshwater ecosystems of the Neretva delta	500.000,00 HRK; EU funds, Republic of Croatia, Dubrovnik-Neretva County
Development of fishing tourism	Promotion of traditional fishing tools for tourism purposes	Large-scale illegal fishing using traditional tools	Implementation has not started, 2022.-2025.	Ministry of Agriculture, Tourist Board, PLORA, Ecological Diving Club Periska, Traditional Neretva fishermen	Tourist communities	More traditional fishermen in the tourism sector and providing an alternative income compared to traditional fishing	30.000,00 HRK; EU funds, Republic of Croatia

Objective 3. Improving the functionality of important ecosystems

Measure	Activity	Risk or vulnerability affected	Implementation status and implementation timeframe	Stakeholders involved	Responsible body for implementation	Implementation indicator	Cost estimation and method of financing
Improving the functionality of the Parila lagoon	Deepening of the lagoon in the northern part and the Široka-Parila pass, and ensuring greater inflows of fresh water	Lagoon shallowing and summer warming above the biological characteristics of indigenous species	Implementation has not started, 2022.-2023.	Croatian waters, Dubrovnik-Neretva County	Croatian Waters, Dubrovnik-Neretva County	Increased lagoon depth and increased freshwater inflows	40.000.000,00 HRK; Croatian Waters, Dubrovnik-Neretva County
	Renovation and extension of the stone embankment "diga" of the lagoon towards the sea	Devastation of the stone embankment and pollution from port terminals for bulk and liquid cargo	Implementation has not started, 2022.-2023.	Croatian waters, Dubrovnik-Neretva County, City of Ploče	Croatian Waters, Dubrovnik-Neretva County, City of Ploče	Renovated and built stone embankments	100.000,00 HRK; Dubrovnik-Neretva County, City of Ploče
Improving the functionality of the Kuti Lake area	Ensuring the inflow of fresh water from the Neretva in the summer	Reduced flows, summer warming, shallowing of the lake	Implementation has not started, 2022.-2023.	Croatian waters, Dubrovnik-Neretva County	Croatian Waters, Dubrovnik-Neretva County	Secured summer tributaries to the river Mislina	20.000.000,00 HRK; Croatian Waters, Dubrovnik-Neretva County
Improving the functionality of Bačina lakes	Modification of the concrete dam at the exit of the lake towards the sea, to enable the migration of the cap to spawning	Larger migrations of the cap are prevented	Implementation has not started, 2027.-2030.	Croatian Waters, Dubrovnik-Neretva County, Public Institution for Management of Protected Natural	Croatian Waters, Dubrovnik-Neretva County	Bundle-type system built for undisturbed spawning migrations and increased number of juveniles in lakes	

				Areas of the Dubrovnik-Neretva County, City of Ploče			
Improving the functionality of Lake Desna	Construction of a temporary movable barrier during the summer period	Salting during the summer period	Implementation has not started, 2027.-2030.	Croatian Waters, Public Institution for Management of Protected Natural Areas of the Dubrovnik-Neretva County, City of Ploče	Croatian Waters, Dubrovnik-Neretva County	A movable dam was built at the confluence of the Desanka and Crna rivers	

Objective 4. Sustainable and resilient economy

Measure	Activity	Affected risk or vulnerability	Implementation status and timeframe	Included stakeholder	Body responsible for implementation	Implementation indicator	Cost estimation and funding methods
Sustainable tourism development	Drafting of Tourist Boat Traffic Management Plan through Neretva canals and inlets	Negative impact of tourist boat traffic on water resources quality	Implementation has not begun, 2022.-2030.	Public Institution for Management of Protected Natural Areas of the Dubrovnik-Neretva County, Tourist board of Dubrovnik-Neretva County, other tourist boards, local stakeholders involved in tourist boat traffic, Dubrovnik-Neretva County itself, local self-government units	Tourist board of Dubrovnik-Neretva County and the County itself	Completed Tourist Boat Traffic Management Plan through Neretva canals and inlets	70.000,00 HRK; Dubrovnik-Neretva County, Local self-government units
	Introduction of marine vehicles using alternative energy sources	So-far use of energy forms with adverse effects on the environment	Implementation has not begun, 2022.-2025.	Dubrovnik-Neretva County, local self-government units, local development agencies, stakeholders from private sector	Dubrovnik-Neretva County, local self-government units	Introduction of marine vehicles using alternative energy sources	500.000,00 HRK; EU funds, Republic of Croatia, Dubrovnik-Neretva County
	Drafting of The Year-round Tourism Development Plan	Lack of strategic management of tourism development	Implementation has not begun, 2022.-2024.	Tourist board of Dubrovnik-Neretva County, other tourist boards, LAG Neretva, local self-government units inside the ecological network,	Tourist board of Dubrovnik-Neretva County, Dubrovnik-Neretva County itself	Completion of The Year-round Tourism Development Plan	300.000,00 HRK; Dubrovnik-Neretva County, Local self-government units

				local self-government units, Dubrovnik-Neretva County itself			
Organic farming development	Education of the local population regarding the importance of turning towards organic farming	Lack of awareness regarding the importance of turning towards organic farming, adverse effects of intense agriculture on the environment	Implementation has not begun, 2022.-2025.	Ministry of Agriculture, Dubrovnik-Neretva County, Public Institution for Management of Protected Natural Areas of the Dubrovnik-Neretva County, local self-government units	Ministry of Agriculture, Dubrovnik-Neretva County	Completed education of the local population regarding the importance of turning towards organic farming	50.000,00 HRK; Ministry of Agriculture
	Incentives to stakeholders in organic farming	Lack of incentives for engaging in organic farming	Implementation has not begun, 2023.-2026.	Dubrovnik-Neretva County, local self-government units inside the ecological network, Public Institution for Management of Protected Natural Areas of the Dubrovnik-Neretva County, LAG Neretva, Ministry of Agriculture, Agency for Payments in Agriculture, Fisheries	Dubrovnik-Neretva County, local self-government units	Issued incentives to stakeholders in organic farming	1.000.000,00 HRK; EU funds, Dubrovnik-Neretva County

				and Rural Development			
	Organic farmers` co-op establishment initiative	Independence of small business stakeholders engaged in organic farming, lack of organized purchase	Implementation has not begun, 2023.-2026.	Dubrovnik-Neretva County, local self-government units inside the ecological network, LAG Neretva	Dubrovnik-Neretva County, local self-government units	Established organic farmers` co-op	100.000,00 HRK; EU fund, Dubrovnik-Neretva County
	Organic product branding	Absence of organic product branding	Implementation has not begun, 2022.-2026.	Dubrovnik-Neretva County, local self-government units, Public Institution for Management of Protected Natural Areas of the Dubrovnik-Neretva County, LAG Neretva, NGO	Dubrovnik-Neretva County, local self-government units	Single organic product branded	100.000,00 HRK; Dubrovnik-Neretva County, local self-government units
	Building an organic product processing center	Absence of an organic product processing center	Implementation has not begun, 2024.-2028.	Dubrovnik-Neretva County, local self-government units	Dubrovnik-Neretva County, local self-government units	Built organic product processing center	60.000.000,00 HRK; EU funds, Dubrovnik-Neretva County
Sustainable fisheries and fish stock management	Development of a Plan regarding fisheries, individual species and tools management within the ecological network	Endangered fisheries (especially fishermen engaged in traditional fisheries)	Implementation has not begun, 2022.-2025.	Dubrovnik-Neretva County, local self-government units inside the ecological network, Dubrovnik-Neretva County public	Public Institution for Management of Protected Natural Areas of the Dubrovnik-Neretva County, Dubrovnik-Neretva County, local self-	Drafted Plan regarding fisheries, individual species and tools management for all ichtyological reserves	80.000,00 HRK; EU funds, Ministry of Agriculture, Public Institution for Management of Protected Natural Areas of the

				administration, Ministry of Agriculture	government units inside the ecological network, Ministry of Agriculture		Dubrovnik-Neretva County
	Restrict number of stakeholders in all fishing types	Excessive fishing	Implementation has begun, 2021.-2027.	Dubrovnik-Neretva County, local self- government units inside the ecological network, Public Institution for the Management of Protected Areas of Nature of the Dubrovnik-Neretva County, Ministry of Agriculture	Dubrovnik-Neretva County, local self- government units inside the ecological network Ministry of Agriculture	Implemented restricted number of stakeholders in all fishing types	0,00 HRK; Ministry of Agriculture, Public Institution for the Management of Protected Areas of Nature of the Dubrovnik-Neretva County
	Limit or completely ban catches of eel and mullet	Eel and mullet are nearly extinct and biologically endangered	Implementation has not begun, 2022.-2025.	Dubrovnik-Neretva County, local self- government units inside the ecological network, Public Institution for the Management of Protected Areas of Nature of the Dubrovnik-Neretva County, Ministry of Agriculture	Dubrovnik-Neretva County, local self- government units inside the ecological network Ministry of Agriculture	Limited or completely banned catch of eel and mullet	0,00 HRK; Ministry of Agriculture, Public Institution for the Management of Protected Areas of Nature of the Dubrovnik-Neretva County
	Redirecting catch of eel and mullet towards demonstrational catch for tourism purposes	Excessive eel catch	Implementation has not begun, 2023.-2026.	Dubrovnik-Neretva County, local self- government units inside the ecological network Ministry of Agriculture, Tourism	Dubrovnik-Neretva County, local self- government units inside the ecological network, Ministry of Agriculture, Tourism Board of	Implemented demonstrational catch of eel and mullet	50.000,00 HRK; Ministry of Agriculture; Dubrovnik-Neretva County

				Board of Dubrovnik-Neretva County	Dubrovnik-Neretva County		
	Introducing programs that either reduce the population of invasive species or excessive fishing in sport-recreational fishing	Major increase in the number of invasive species which threaten other species` (especially endemic) survival	Implementation has not begun, 2022.-2025.	Fishing rights-holder, local self-government units, sport fishing associations, Ministry of Agriculture	Local self-government units, fishing rights-holder, Ministry of Agriculture	Introduced programs that either reduce the population of invasive species or excessive fishing in sport-recreational fishing	20.000,00 HRK; Ministry of Agriculture, Dubrovnik-Neretva County
	Supervision and penalties of fish hunting outside legal regulations	Poor illegal hunting control	Implementation has not begun, 2022.-2028.	Ministry of the Interior, inspection of fishery activities, Public Institution for Management of Protected Natural Areas of the Dubrovnik-Neretva County	Ministry of the Interior, inspection of fishery activities, Public Institution for Management of Protected Natural Areas of the Dubrovnik-Neretva County	Introduced supervision and penalties of fish hunting outside legal regulations	50.000,00 HRK; Ministry of Agriculture, Public Institution for the Management of Protected Areas of Nature of the Dubrovnik-Neretva County

Objective 5. **Aware and proactive population**

Measure	Activity	Affected risk or vulnerability	Implementation status and timeframe	Included stakeholders	Body responsible for implementation	Implementation indicator	Cost estimation and funding methods
Education on climate change	Initiating education on the consequences of climate change and adaptation ways	Lack of local population education on climate change and ways to adapt	Implementation has begun, years 2019-2023	Public Institution for the Management of Protected Areas of Nature of the Dubrovnik-Neretva County, local population, educational institutions of the Dubrovnik-Neretva County, local associations	Educational institutions of the Dubrovnik-Neretva County	Completed education on the consequences of climate change and adaptation ways	40.000,00 HRK; Public Institution for the Management of Protected Areas of Nature of the Dubrovnik-Neretva County
	Opening a center for climate change monitoring and citizen education on climate change	Lack of monitoring of the effect on climate change and education of the local population on climate change and ways to adapt	Implementation has not begun, years 2022-2026	Local self-government units in the Neretva delta area, Educational institutions of the Dubrovnik-Neretva County, scientific institutions, associations	Local self-government units in the Neretva delta area	Opened center for climate change monitoring and citizen education on climate change	5.000.000,00 HRK; Dubrovnik-Neretva County, Self-government units
	Drafting and distributing educational material with the aim of spreading knowledge	Lack of local population education on climate change and ways to adapt	Implementation has begun, years 2019-2023	Public Institution for Management of Protected Natural Areas of the Dubrovnik-Neretva County, local population	Public Institution for Management of Protected Natural Areas of the Dubrovnik-Neretva County	Printed publicity materials with the aim of spreading knowledge about necessary adaptation to climate change	50.000,00 HRK; Public Institution for the Management of Protected Areas of Nature of the

	about necessary adaptation to climate change						Dubrovnik-Neretva County
	Starting an educational website or smartphone app focused on environmental protection and climate change in the Neretva Delta	Lack of awareness on the importance of environment preservation and adaptation to climate change	Implementation has not begun, years 2025-2030	Local self-government units, Dubrovnik-Neretva County, Public Institution for Management of Protected Natural Areas of the Dubrovnik-Neretva County	Public Institution for Management of Protected Natural Areas of the Dubrovnik-Neretva County	Created website or smartphone app	100.000,00 HRK; Public Institution for the Management of Protected Areas of Nature of the Dubrovnik-Neretva County
Local population and wider community participation in adaptation to climate change	Organizing workshops to discuss important challenges of climate change	Lack of local population education on climate change and ways to adapt	Implementation has begun, years 2019-2025	Public Institution for Management of Protected Natural Areas of the Dubrovnik-Neretva County, local population, Dubrovnik-Neretva County	Public Institution for Management of Protected Natural Areas of the Dubrovnik-Neretva County	Organized workshops to discuss important challenges of climate change	20.000,00 HRK; Dubrovnik-Neretva County, Public Institution for the Management of Protected Areas of Nature of the Dubrovnik-Neretva County, local government units

	Involvement of local population in drafting strategic documents important for sustainability of space and adaptation to climate change	Poor involvement of local population in drafting strategic documents important for sustainability of space and adaptation to climate change	Implementation has begun, years 2019-2025	Public Institution for Management of Protected Natural Areas of the Dubrovnik-Neretva County, local population, local self-government units inside the ecological network, Dubrovnik-Neretva County	Local self-government units inside the ecological network, Dubrovnik-Neretva County	Organized participative workshop while drafting strategic documents	
	Implementation of volunteering programmes focused on issues related to climate change	Lack of human capacity	Implementation has not begun, years 2022-2025	Public Institution for Management of Protected Natural Areas of the Dubrovnik-Neretva County, local population, volunteers	Public Institution for Management of Protected Natural Areas of the Dubrovnik-Neretva County, local population	Implemented volunteering programme; number of participants within the programme	50.000,00 HRK; Public Institution for the Management of Protected Areas of Nature of the Dubrovnik-Neretva County

6.4 Monitoring Plan

The Monitoring Plan is shown below in order to enable systematic monitoring of the successfulness of measures and activities implementation of the Action Plan of adaptation to climate change. 28 parameters in total were defined for 17 measures listed in the Action Plan. **Table 3** shows a list of parameters and target values which must be met by 2031.

Table 3. Monitoring Plan

No.	Measure name	Parameter	Measure (unit)	Initial value (2021.)	Target value (2031.)	Monitoring frequency	Source
1.	Improvement of water resources management	Built temporary movable barrier	1	0	1	At the end of the period	Project implementation report
2.	Environmentally friendly drainage and waste management	Built drainage system	1	0	1	At the end of the period	Project implementation report
		Drafted Circular Waste Management Strategy	1	0	1	At the end of the period	Circular Waste Management Strategy
3.	Adaptation to extreme weather conditions	Built system for monitoring and warning regarding extreme weather conditions	1	0	1	At the end of the period	Project implementation report
		Built Flood Defense Center	1	0	1	At the end of the period	Project implementation report
4.	Biodiversity preservation and invasive species` control	Biodiversity research conducted	Number	0	2	At the end of the period	Conducted research results
5.	Protection and improvement of eel status	Eel status research conducted	1	0	1	At the end of the period	Conducted research results
		Drafted Eel Management Plan in the Neretva Delta	1	0	1	At the end of the period	Eel Management Plan in the Neretva Delta
6.	Protection and improvement of target and endemic fish status in the ecological network of the Neretva Delta	Banned endemic species hunt	1	0	1	At the end of the period	Banned endemic species hunt

7.	Invasive species control and freshwater sport fishing organization	Drafted Sport Fishing Management Plan	1	0	1	At the end of the period	Sport Fishing Management Plan
8.	Fishing tourism development	Drafted Fishing Tourism Development Strategy	1	0	1	At the end of the period	Fishing Tourism Development Strategy
9.	Improvement of Parila lagoon functionality	Restoration of „diga“ lagoon stone embankment towards the sea	1	0	1	At the end of the period	Project implementation report
10.	Improvement of lake Kuti functionality	Actions of removing aquatic vegetations taken	1	0	1	Yearly	Project implementation report
11.	Improvement of Baćina lakes functionality	Concrete dam modification enabling twait shad migration	1	0	1	At the end of the period	Project implementation report
12.	Improvement of Desne lake functionality	Temporary mobile dam built	1	0	1	At the end of the period	Project implementation report
13.	Sustainable tourism development	Drafted Tourist Boat Traffic Management Plan through Neretva canals and inlets	1	0	1	At the end of the period	Tourist Boat Traffic Management Plan through Neretva canals and inlets
		Introduction of marine vehicles using alternative energy sources	Number	0	2	At the end of the period	Project implementation report
		Drafted Year-round Tourism Development Plan	1	0	1	At the end of the period	Year-round Tourism Development Plan
14.	Organic farming development	Education on the importance of organic farming	1	0	1	Yearly	Conducted education report
		Incentives in organic farming	1	0	1	At the end of the period	Report on introduced incentives
		Organic product processing center built	1	0	1	At the end of the period	Project implementation report
15.	Sustainable fishing and fish fund management	Drafting of The Plan regarding fisheries, individual species and tools	1	0	1	At the end of the period	Drafted Plan regarding fisheries, individual species and tools management within the ecological network

		management within the ecological network					
		Introduced hunting supervision outside legal regulations	1	0	1	At the end of the period	Initiative implementation report
16.	Education on climate change	Education on the consequences of climate change and adaptation ways	1	0	1	Yearly	Conducted education report
		Opening a center for climate change monitoring and citizen education on climate change	1	0	1	At the end of the period	Project implementation report
		Printed educational material with the aim of spreading knowledge about necessary adaptation to climate change	1	0	1	At the end of the period	Educational material with the aim of spreading knowledge about necessary adaptation to climate change
		Starting educational website or smartphone app focused on environmental protection and climate change	1	0	1	At the end of the period	Educational website or smartphone app focused on environmental protection and climate change
17.	Local population participation in adaptation to climate change	Organizing workshops to discuss important challenges of climate change	1	0	1	Yearly	Workshops to discuss important challenges of climate change
		Volunteering programmes focused on issues related to climate change	1	0	1	Yearly	Programme implementation report

7. Closing remarks and indications for the implementation of the Plan for the Pilot Area

This document defines vision, objectives, measures and activities by which the pilot area of the Neretva Delta can adapt to climate change in the next 10 years. For successful implementation of the Plan for this pilot area, it is important to establish communication between a large number of civil, private and public sector stakeholders. Only quality cooperation and synergy of these stakeholders (listed in the Action Plan) can this area successfully adapt to climate change.

For implementation of this document, the following is important:

- Formal acceptance/approval of the Plan,
- Strategic Environmental Assessment implementation with the aim of estimating significant impacts on the environment, which can arise from implementing this Plan,
- Implementation of the Environmental Impact Assessment procedure with the aim of estimating the acceptability of some of the activities defined by the Plan with regard to the environment and determining the necessary environmental protection measures,
- In the implementation phase of the Adaptation Plan for Climate Change Adaptation, the umbrella institution responsible for implementation is the Public Institution for Management of Protected Natural Areas of the Dubrovnik-Neretva County,

It is important to explicitly point out that the Public Institution for the Management of Protected Natural Areas of Dubrovnik-Neretva County is not responsible for the success of the implementation of this plan, as the complexity of the climate change problem requires a number of sectors and institutions at local, regional and national level to act together. The Adaptation Plan adopts a series of measures not only under the responsibility of the Public Institution, but also under the responsibility of a number of other organisations and institutions. This document should serve as a basis for the adaptation of the area to climate change and as a basis for the adoption of key strategic documents at local or county level.

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