3.7.1. Climate Change Adaptation Plan in Brijuni MPA

MPA ENGAGE

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1. Introduction

Climate change is dramatically affecting the Mediterranean Sea, which is warming at a rate 20% faster than the world's average. Marine Protected Areas (MPAs), despite the nature-based solution they offer to support efforts towards climate change adaptation and mitigation, they experience too, the climate change effects. In fact, several Mediterranean MPAs are already facing major biodiversity and functional alterations due to climate change, whereas others will likely face them in the next few decades. There is, therefore, an urgency to mitigate these risks and to consider adaptation options in partnership with local communities, decision-makers, civil society organizations, research bodies, and other socio-economic actors at local, national and regional level.

This document was prepared within the framework of the MPA Engage project. MPA Engage is an Interreg Med funded project that aims to support Mediterranean MPAs to adapt to and mitigate the ongoing climate change effects in the Mediterranean Sea. Participatory approaches lie at the heart of the MPA Engage project; through a participatory approach, MPA Engage monitored in a harmonized way the climate change impacts, elaborated vulnerability assessments and developed climate change adaptation action plans in 7 Marine Protected Areas located in 6 Mediterranean countries, namely Albania, Croatia, France, Greece, Italy, Malta, Spain.

This report summarizes the results of a climate change impact in Brijuni National Park and the results of the vulnerability assessment and the participatory approach with the overall goal to determine those actions needed to address the climate change impacts, mitigate, and adapt in Brijuni National Park.

Figure 1. Brijuni National Park

2. Brijuni National Park

The Brijuni National Park consists of 14 islands, islets and cliffs situated along the western coast of Istria, not far from the city of Pula. Today's boundaries of the National Park have been aligned with Amendments to the National Park Act and the Memorial Site of Brioni (NN 45/99), made in 1999. The park area now includes the islands, along with the surrounding shelf and sea area, such that the total area is 33.95 km2. The park was named after the two largest islands within the archipelago, Veliki and Mali Brijun.

County	Istria
Municipality	Pula
Total area of the National Park	3.395,0 ha
Sea area	2.651,7 ha
Land area	743,30 ha
Total coastline length	46,82 km
Length of the NP sea boundary	22,93 km
Greatest sea depth	50 m

Source: Spatial Plan of Brijuni National Park

Figure 2. Information about Brijuni National Park

The area of the Brijuni Islands, thanks to the geomorphological-hydrological, climatic and overall landscape features, along with the existing flora, fauna and cultural heritage, was declared a National Park and Memorial Site on November the 1st 1983, by the National Park Act and the Brijuni Memorial Site (NN 46/83 and later amendments 57/89, 05/90 and 47/91). Brijuni was opened to the public in April 1984. On April 23rd 1999, Members of the Croatian Parliament passed amendments to the Act on the National Park and Memorial Site of Brioni (NN 45/99), which changed the name of this law to the Act on the Declaration of the Brijuni National Park, correcting through this process the coordinates defining the boundary of the Brijuni National Park.

The Brijuni National Park is managed by a public institution based on Brijuni - Pula. The founder of the Public Institution Brijuni National Park is the Croatian Government. The activity of the Public Institution includes the protection, preservation, maintenance, promotion and use of the national park, in order to protect and preserve the natural environment, and to oversee the smooth running of natural processes, the sustainable use of natural resources, and monitoring of the implementation and the conditions of nature protection measures in the area in which it operates. The public institution also carries out other activities that serve the basic needs of nature protection, namely: catering, museum activities, care of the cultural heritage in the area of the Brijuni National Park, the breeding of native domestic animals, the cultivation of vegetables, flowers, ornamental plants and planting material, retail and publishing.

The Public Institution is managed by a Governing Board of five members appointed by the Minister of Environmental Protection and Energy. The Governing Board adopts the Statute of the Public Institution with the consent of the Ministry of Environmental Protection and Energy. The board also adopts the Management Plan and the annual program of protection, maintenance, preservation, promotion and use of the protected area, with the prior opinion of the Croatian Agency for Environment and Nature and the consent of the Ministry of Economy ana Governance and follows its implementation.

The internal organization is made up of internal organizational units, ensuring harmonious, professional and systematic functioning of the Institution and management of Brijuni National Park. The institution has a total of 9 organizational units: the Office of the General Manager, the Department of Expert Protection, Maintenance, Preservation and usage of the National Park, the Department for Supervision and Protection, the Department of Hotel Management, the Department for Excursion Tourism, the Department for Promotion and Sales, the Department for Finance, Accounting and Procurement, the Department for Maintenance and Transport, and the Department for Human Resources, Legal and General Affairs. All departments combined have a total of 265 employees.

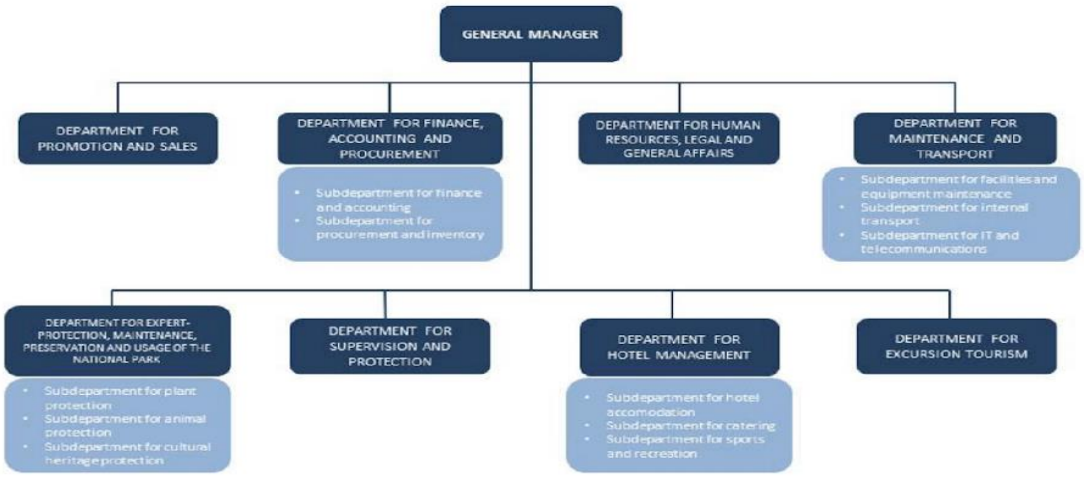

FIGURE 3. SCHEME OF THE INTERNAL ORGANIZATION OF THE PUBLIC INSTITUTION BRIJUNI NP, MANAGEMENT PLAN 2016

The Brijuni National Park is one of eight national parks in the Republic of Croatia. This category of protection was determined because the area is defined as one of the most biologically valuable sea areas of our country. Apart from biological features, Brijuni also has a unique cultural-historical and geological-paleontological value.

Brijuni Islands are full of history and the National Park is characterized by numerous and rich archaeological sites from different time periods. A good geographical and strategic position, along with a pleasant climate, natural resources and fertile soil, favoured the Islands' population since prehistoric times.

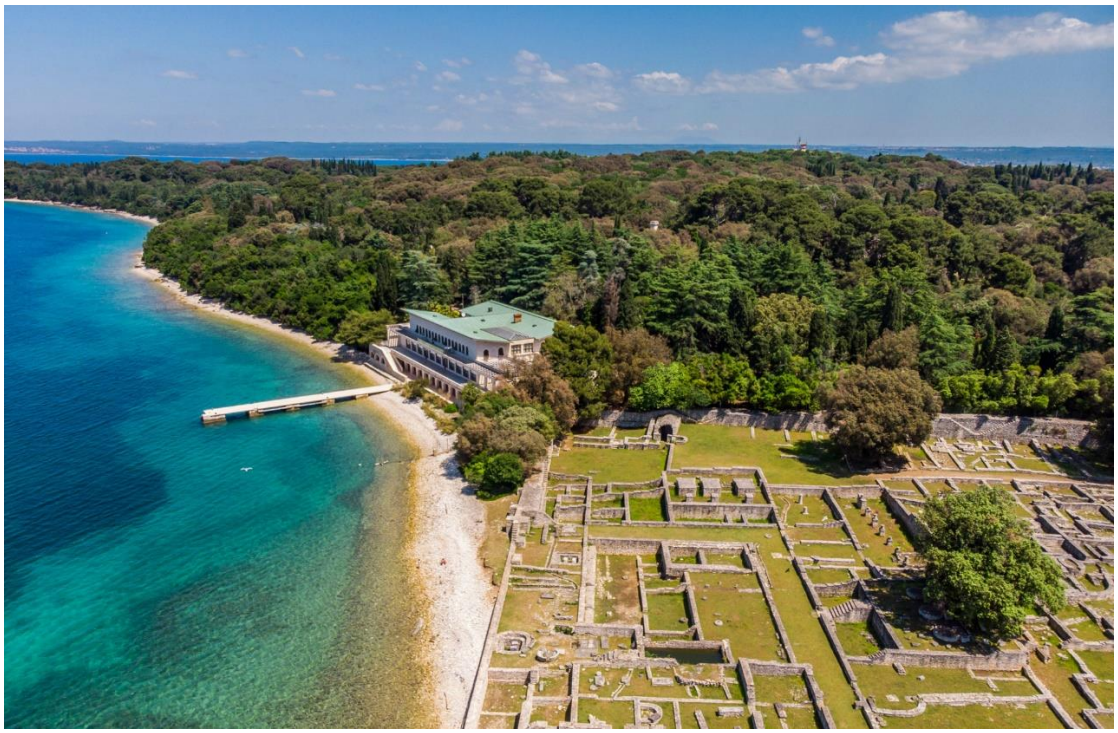

Figure 4. Arheological site of Castrum in Brijuni National Park

Beside the sea also the land has a very high natural and paleontological value. The landscape of Veliki Brijun is unique on the Croatian coast of the Adriatic, as it represents a mix of natural and anthropogenic elements. The Islands are predominantly marked by the Mediterranean evergreen macchia, holm oak forest and grass vegetation. Brijuni are also an extremely important seasonal settlement for northern bird populations, with Soline (Saline) on Veliki Brijun as the most interesting site for wetland birds.

The Brijuni Islands were formed from geological processes occurring over millions of years, and the natural resources existing are the result of centuries of conservation in this area. The landscape on the Islands has been formed by human activity from the distant to recent past (the remains of quarries, modification of meadows and forests through land cultivation, building of villas etc.). Today, when these unique areas are rarely found on land and sea, it is crucial that they are managed in a thoughtful and sustainable way so that their value is not lost, diminished or neglected with future generations in mind, but are instead protected, preserved and enhanced appropriately.

With the aim to mitigate human impacts in the protected area, the Park has been zoned in few areas. The zones range from a “strict” protection zone where virtually no human impact is allowed to a “use” zone where the natural space inside the zone can be significantly altered. It is important to note that these designations do not imply the value of the area, but reflect

the need for managing the protected area for the purpose of preserving the overall biological, geological and landscape diversity.

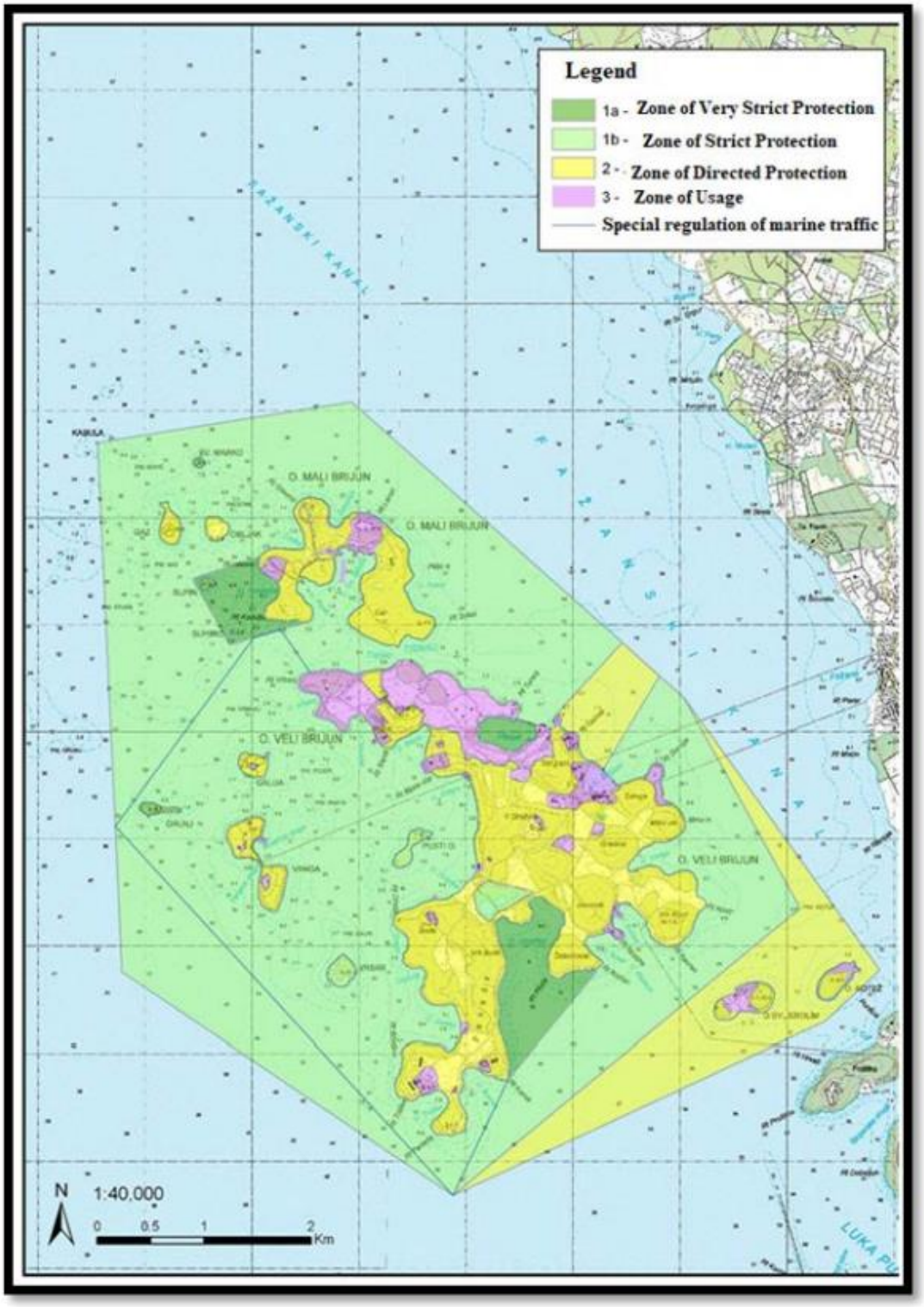

Figure 5. Map of the National Park with the different zones of usage

3. Goals and objectives of the climate change adaptation plan

The overarching goal of the Climate Change Adaptation Plan is to determine those actions needed to address the climate change impacts in the Brijuni National Park and facilitate its efforts in achieving its conservations goals.

The key objectives of the plan are:

i. Reduce the vulnerability of key habitats and species in the Brijuni National Park to the impacts of climate change, according to the Vulnerability Assessment.

ii. Improve the adaptive capacity of the marine ecosystems in the Brijuni National Park to the CC impacts, by means of preserving its natural values and reducing the social vulnerability.

iii. Reduce environmental pressures, such as pollution, water consumption and use of energy, on biodiversity and marine ecosystems in the Brijuni National Park.

iv. Ensure that CC adaptation measures are integrated in the general Management plan for the Brijuni National Park and implemented as part of its regular management practice.

4. The key steps followed for the elaboration of the plan

The elaboration of the Climate Change Adaptation Plan followed a four-phase process as presented below. Within each phase a set of specific actions were undertaken.

- **Phase 1 – Establishment:** The overall aim of the establishment phase was to make known the intention for drafting the plan and identify the convening body responsible for the overall coordination of the planning. All parties that should be involved were identified and a core group/team with the mandate to prepare and implement the plan was established. Effort was directed to identify the stakeholders and design the stakeholders' engagement and participatory process, in line with the MPA Engage quintuple helix approach.

- **Phase 2 – Analysis and Scenarios:** The aim of the analysis phase was to establish the foundation on which the preparation of the plan and its implementation will be based. Any available information on the climate change issue impacts and vulnerabilities were collected, including information on pre-existing relevant plans. In parallel, within this stage the engagement of stakeholders was initiated.

- **Phase 3 – Setting the Vision:** The aim of this stage was to achieve the engagement and consensus building with the stakeholders and the wider community on the action plan based on the findings from the phases 1 and 2. Within this stage stakeholders were engaged in the identification of the key problems and issues for the plan to deal

with and set the course for the eventual 'shape' of the plan and its implementation by reviewing the proposed scenario (from Phase 2).

- **Phase 4 – Designing the Future:** The aim of this stage was the actual drafting and finalization of the local climate change adaptation plan, which will contribute in shaping the future of the MPA. Within this stage stakeholders were engaged in the finalization and final adoption of the local plan.

5. The key steps in Brijuni National Park

In Brijuni National Park all the 4 phases were respected and put in place. Brijuni National Park sets up a team tasked to elaborate the climate change mitigation and adaptation plan. The team consist of the general manager Marno Milotić, the MPA managers Sandro Dujmović, Alena Sprčić and Martina Hervat, the project manager Andrea Blašković, the project assistant Lena Kukoleča and the external experts Vesna Vukadin and Krešimir Kovačec, Park bureau d.o.o., Zagreb.

The first step was defining the initial territorial scope and related governance and policy context. Through a participatory process, in line with the "Guidelines for applying a Quintuple Helix Participatory Approach" a stakeholders mapping was defined. In the very beginning of the participatory process, we set the vision and with the external expert a participatory process plan was defined.

During the second phase a report of the monitoring of key species and habitats affected by the CC were elaborated, as well as the vulnerability assessment. Recognizing the strong role of citizens in collecting scientific data, a well-structured Citizen Science activity was also included in the activities of Brijuni MPA, which was the first step in that direction for Brijuni MPA. In this phase, a crucial activity was also to collect all the information on pre-existing relevant plans. In Brijuni National Park the most relevant document revised were the Spatial plan, the Management plan currently in place, all the document produced within the framework of MPA Adapt project (CC Adaptation plan, Rapid Vulnerability assessment and Evaluation of monitoring activity) but also the documents elaborated within the MPA Engage project as the Monitoring protocol, Vulnerability assessment and the Participatory Approach report.

The third phase was characterized by the direct engagement of stakeholders. In order to ensure a variety of viewpoints, all local and relevant stakeholders and interdisciplinary team of people were involved in the process.

First stakeholder meeting was held at the MMC Multimedia Centre in Fažana on November 25, 2021. The meeting was attended by the heads of all departments, sub-departments, and the General manager. The main topic of the workshop was the presentation of the proposed climate change adaptation measures and their revision with

regards to incorporation into the existing general Management plan for the Brijuni NP. The attendance and level of participation of invited participants wa and this is considered as success, considering otherwise weak communication between different departments of the Public Institution. Improvement and adaptation of existing water and energy infrastructure in the Park, as well as reducing the amount of waste (and generally improving current practices of waste management) were among the main topics of the discussion, since they created major interest from the participants. These topics are among the biggest challenges for the Brijuni NP Public Institution with regards to the implementation of adaptation measures, due to their potentially high impact on reducing the existing environmental pressures on biodiversity and marine ecosystems.

The first stakeholder meeting was organized on December 17, 2021, through the digital platform Zoom, with the aim of jointly finding the best solutions for mitigation of impacts of climate change and conserving the natural values of the area. The workshop was attended by 12 stakeholders from different fields of expertise operating in the National Park. Representatives of the Armed Forces of the Republic of Croatia, a representative of the Administrative Department for Sustainable Development of the Istrian County, a representative of the State Real Estate, a representative of the Fažana Tourist Board, a diver from The Old Diver Club and local fishermen participated. After a short introduction, the proposed adaptation measures for Brijuni NP were presented to stakeholders, and a discussion followed, about the possibilities for cooperation on their implementation, between the stakeholders and the Park. Stakeholders showed high interest for cooperation and involvement in the implementation of proposed adaptation measures, especially with regards to data collection and monitoring of biodiversity, as well as improvement or adaptation of infrastructure in the park (such as water, energy and waste management) with the aim of reducing the existing environmental pressures on biodiversity and marine ecosystems.

After the first meetings with the stakeholders was set a direction observing the priorities and the consistency of the objectives of the plan.

And a list of indicators to measure the success of the planning process were defined. In Brijuni National Park the number of stakeholders participating in the engagement activities, the numbers of stakeholder workshops/meetings and attendance levels of various stakeholder groups and the number of press releases were taken into account. After the next meetings planned for late February or March 2022., a number of comments submitted/received throughout the participation process will be evaluated. The qualitative indicators take into account in Brijuni National Park were related to the common vision, action plan, timelines and concerns affecting the stakeholders.

Since the participatory process is not completed yet in Brijuni National Park, all the following phases were based on the inputs agreed upon by all stakeholders during the first meetings and are considered by us, as MPA managers, relevant to be included in the joint plan.

During the fourth phase the local climate change mitigation and adaptation action plan was drafted and in the first month of next year (January, February 2022) it will be validated by the stakeholders. The decision of extending the participatory process and the implementation of the CC mitigation and adaptation plan was decided in cooperation with the leading partner and the task leader since in Brijuni National Park a revision of the Management Plan (2015.-2025.) was necessary. Taking the opportunity of revision, all voted measures will be included in the current management plan. An additional phase will be than added to the four already in place. The next step that will be planned for next year (phase 5) will be focusing on planning a core group that will ensure the implementation of the action plan, coordinate all the supporting actions related to awareness-raising, partnerships, financing and investment and monitor and review the implementation of the plan.

Through the whole process and because of the specificity of Brijuni National Park, harnessing stakeholder consensus throughout the five-phase planning process was crucial. To build consensus towards reaching agreement is very important, no decision is made against the will of an individual or a minority which lead to find at the end of the process win-win solutions that address everyone's needs and ensure a collaborative management of the MPA with the aim to protect natural resources with the mitigation and adaptation to the climate change.

All the stakeholders were engaged from the very beginning of the project, through range of communication activities (lectures, presentations, exhibition, citizen science, programs, etc). Keeping them informed and part of the process from the very beginning ensure their collaboration and interest. A separate section on the webpage of Brijuni National Park has been created to present the project and inform the stakeholders. Overall, it was crucial to detect the most important actions for engaging the stakeholders: education and raising awareness activities. A long-time collaboration and a long-time relationship with the stakeholders are crucial for their trust which is then related to the amount and the quality of information gathered from them.

Externalizing the process in Brijuni National Park, with the external expert from Park bureau, we set up a clear decision-making process where all stakeholders have a common understanding of how it works. It is not easy to have such a big network of employees and head of department and subdivision with extremely different jobs, backgrounds and responsibilities since the National Park is a self-founding MPA a disbalance between economy and nature protection could be a threat. Externalizing the process, it has brought employees into balance and placed emphasis on nature conservation which is

crucial in management. All stakeholders shared doubts, disagreements and goals, everybody involved was openminded and cooperative, they all worked together towards the common identified goals. Externalizing the process in Brijuni National Park also helped to create a respectful and trusting atmosphere for everyone to express their ideas and opinions. However, it was challenging to find a balance between ambition and realism, Brijuni National Park is a very big system with already a lot of work and a lot of activities in place. Climate change is an extensive topic and it was crucial to first find the activities that already contribute to mitigate or adapt to climate change and then to define the one needs to be added. The unfortunate Covid 19 situation did not allow all the meetings to be face to face which also contribute to the results and affected the stakeholder's engagement.

6. Key facts and figures on climate change in the Brijuni MPA

5.1 INTRODUCTION

The archipelago of Brijuni National Park in the North Adriatic is one of the hotspots of marine biodiversity in the region. However, apart from being an area of decreased human activities, it is in more or less extent under various influence of non-climate and climate stressors.
Brijuni according to Köppen's classification of climate have the so-called. "Camellia climate", a moderately warm rainy climate without a dry period and with a hot summer (Cfa). As there are no meteorological and climatological stations on the island, the climate of the Brijuni area is based on the data of the nearest meteorological stations in Pula, Fažana and Rovinj. Given that there are a number of small islands heavily affected by the sea and lush vegetation, even with the interpolation of reliable data from these three meteorological stations, it is difficult to obtain reliable data related to the specific microclimate of the islands.

Summers are pleasant with an average air temperature of about 22.7°C, and mild winters have an average of about 5.5°C. This kind of mild, Mediterranean climate with plenty of sun, heat and humidity in the air, provides for lush vegetation growth and a comfortable environment on the islands. The most common winds are Bura and Jugo, both of which affect sea level changes. When the south wind blows, the water mass accumulates in the north due to the characteristic geographical position of the Adriatic. This leads to tidal waves along the northern Adriatic coast and particularly the Brijuni Islands, especially the bays which are open to the southeast such as Javorika Bay on Veliki Brijun. These bays are also greatly influenced by the accumulation of large waste which accumulates in the coastal area, but also on the seabed. Waste which reaches the Brijuni shores sometimes travels several hundred kilometres and arrives from as far south as Albania and Montenegro. The average sea temperature in winter is around 9°C, and in summer around 24°C with more frequent

periods where it reaches 28°C. The salinity of sea water along the western coast of Istria is about 38 ‰, but during the spring and summer there was a decrease (34 to 37‰) due to the supply of fresh water by the river Po, which flows into the northern Adriatic.

The sea covers almost 80% of the territorial area of the Brijuni National Park. Based on the National Classification of Marine Habitats in Croatia, there are five types of coasts: muddy, sandy, gravelly, rocky seacoast and anthropogenic seacoast habitats. Due to the indentation and complexity of the coast of the Brijuni Island, all five types of coasts are represented in Park. The smallest marine habitat which plays a very important role in ecosystems are the Posidonia oceanica meadows and the coralligenous habitats which are outside the protected areas extremely endangered as they are threatened daily by anchoring and trawling, intensive diving visits, pollution and the appearance of invasive species.

On the Brijuni Islands, the largest meadow of Posidonia is located at Pojer between the northwestern part of Veliki Brijun and the island of Galija, which is one of the northern areas of its distribution in the Adriatic. A much smaller fragmented meadow is located in Javorika Bay in the south of Veliki Brijun. Research and monitoring of the Posidonia meadows condition on the Brijuni Islands began in 2011, and in 2018 the focus is on climate change, primarily changes in sea temperature and the possible impact on existing meadows within the park. Although there is no local influence within the park, there are signs of deterioration of meadows, especially Pojer. The only local impact is the spread of the invasive *alga Caulerpa cylindracea* which is slowly spreading and suppressing Posidonia. This appears to be a consequence of the impact on the environment on a larger geographical scale, since an increase in sea temperature has been recorded which causes a weakening of the resistance of seagrass meadows.

The preservation and richness of the flora and fauna of the Brijuni under-sea world are one of the main reasons for the protection of this area, many strictly protected species are found in Brijuni underwater habitats, such as the noble pen shell (*Pinna nobilis*), the marine sponge (*Axinella cannabina*) the orange puffball sponge (*Tethya aurantium*), the date shell (*Lithophaga lithophaga*) and many others. Brijuni National Park began in 2008 with the research of fish stock with the methodology of fish visual census, and the results confirmed the status of Brijuni as one of the few marine parks in which the benefits of protection are positively reflected in the fish stock. Although Brijuni continuously records higher numbers of fish compared to the surrounding unprotected area, over the years there has been a concerning decline in the number of species, abundance and weight of fish regardless of the level of protection. An important phenomenon of a protected marine areas and their impact on the conservation of fish stocks is experienced locally due to the “spillover effect”. Fish reproduce, spawn and grow unhindered within the protection limits, protected from external influences which enhances their survival. Part of the reason for the decrease in the number and weight of fish within the borders of Brijuni can be attributed to the overflow, but despite the huge efforts of protection, poaching also plays a role. On the Brijuni Islands, all forms of

fishing are prohibited, except in a small area around the island of Sv. Jerolim and Kozada where recreational fishing is allowed with strictly prescribed restrictions. The spillover effect is one of the reasons why marine protected areas also benefit surrounding areas outside protection zone, and local fisheries. Taking into account all the knowledge and the current state of the Brijuni marine life, the role and importance of protection in the preservation of original and untouched areas is becoming increasingly clear.

5.2 CLIMATE CHANGE ISSUE IMPACTS

Recent changes in climate have caused increased impacts such as storms, droughts, rainfall, and sea level rise. This will continue and worsen throughout the 21st century and even no take protections may not offer much long-term cover from dramatic disruption, including significant shifts in species and habitats. This calls for urgent preparation, adaptation and building of the resilience. MPA managers are already dealing with practical realities of climate change, which tend to stress already-slim management capacities and budgets.

The Adriatic Sea is the northernmost area of the Mediterranean Sea and is considered a separate entity as it is quite closed and has specific hydrographic features - complex winds and currents, lower and variable salinity, relatively shallow basin depths and tidal oscillations. The Northern Adriatic, as one of the areas rich in nutrients and one of the most explored parts of the Adriatic, is an excellent area for studying current and predicting future impacts of climate change on the marine environment. The impact of climate change will be particularly pronounced in areas where species will not adapt very well and they will migrate to more favourable habitats, as is the case in the Mediterranean and especially in the northern Adriatic. In this sense, the coldest parts of the Mediterranean, such as the Adriatic Sea and especially the North Adriatic, will initially serve as a kind of refuge for such species, but with time and continued warming, many species could find themselves in a hopeless situation. Brijuni National Park is the area with the highest level of protection in the North Adriatic. Situated in the coldest part of the Mediterranean Sea makes this an ideal area to study the impact of climate change on biodiversity and to act in terms of adaptation and action plans to face the impacts of climate change.

Results indicate accelerated warming over recent decades when compared to the long-term (century) trends. For the past 30 years (1986-2015) it shows an increase of about 0.4 °C per decade (Sakalli, 2017). Regarding Brijuni NP (Figure 15) updated analysis over the full observational period (from 1982 to end of 2017), a cumulative warming of +1.58 °C for SST is detected (i.e. +0.044°C/year, Satellite derived SST data product obtained from Copernicus Marine Environmental Monitoring Service (CMEMS)). Soon the results of two additional locations (Grunj and Sv. Marko will be available.

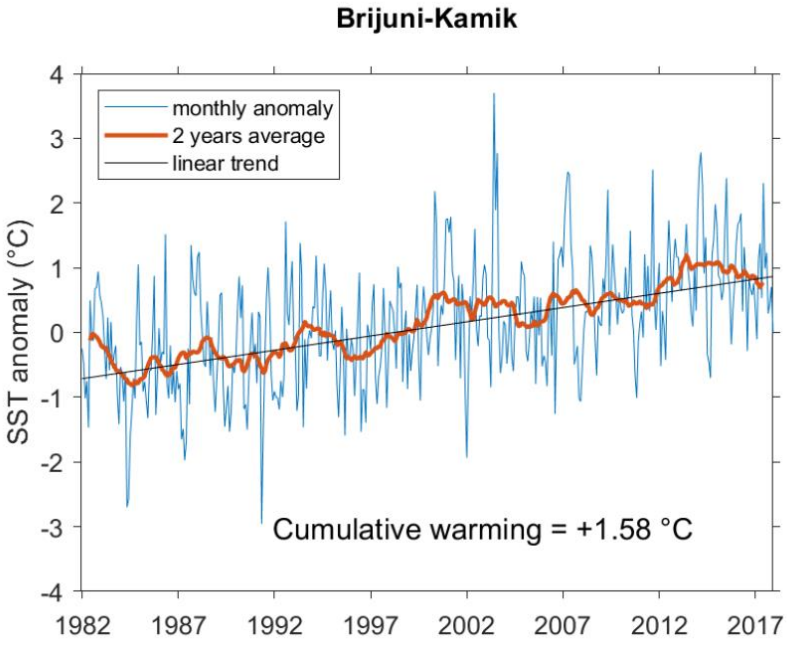

Figure 6. *Historical satellite derived SST data for NP Brijuni in period 1982-2017 (data source CMEMS, processed by the Spanish National Research Council (CSIC)).*

Another point to consider is the air temperature change. The projected change in maximum air temperature by 2040 for the Croatian coastal area are similar to those for mean (daily) temperature and are expected to increase in all seasons. In winter and summer, the highest projected air temperature increase would be from 1.1. to 1.3 °C and 0.7 °C in spring time (MZOE, 2018).

The northern Adriatic is a shallow sea basin (up to 120 m, average 35 m) affected by tectonic subsidence and very vulnerable to sea level rise. In the last 2000 years the sea level rise in Brijuni for about 1.60-1.80 m ± 0.60 m (Figure 17), the changes included a vertical tectonic signal at the rate of ~0.75 mm/a, which produced a significant downward displacement of the coastline (Antonioli et al., 2009).

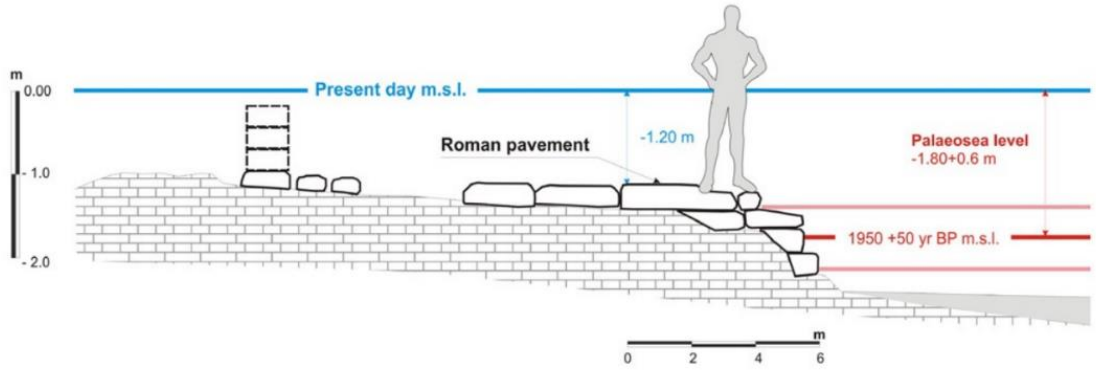

Figure 7.

The north Adriatic is subject to high anthropogenic pressure, surrounded by highly industrial regions that emit CO2 into the atmosphere, resulting in the acidification process of 0.0025 pHT units/year as observed in the NAdDW mass formed in the winters of 1982–1983 and 2007–2008 (Luchetta et al., 2010). Increase CO2 with the changes in ocean chemistry may alter species composition as some species may actually 'prefer' lower pH, or because reductions in numbers of one species will leave more resources available for another. Ocean acidification-related effects may vary from impacts at the cellular level up to individuals, populations, and species, making it difficult to predict the compounding effects of climate change at the ecosystem level (Fabry et al. 2008; Pörtner 2008).

A marine heatwave is a short period of abnormally high temperatures in a sea or ocean. Marine heatwaves are caused by a variety of factors and have been associated with severe biodiversity changes such as sea star wasting disease, toxic algal blooms, and mass mortality of benthic communities. According to the literature for the period 2071–2100, some Mediterranean regions as the Levantine basin, Balearic Islands, Tyrrhenian Sea, Ionian Sea and North Adriatic Sea exhibit the highest MMM SST anomalies in every scenario (Darmanski et al., 2019).

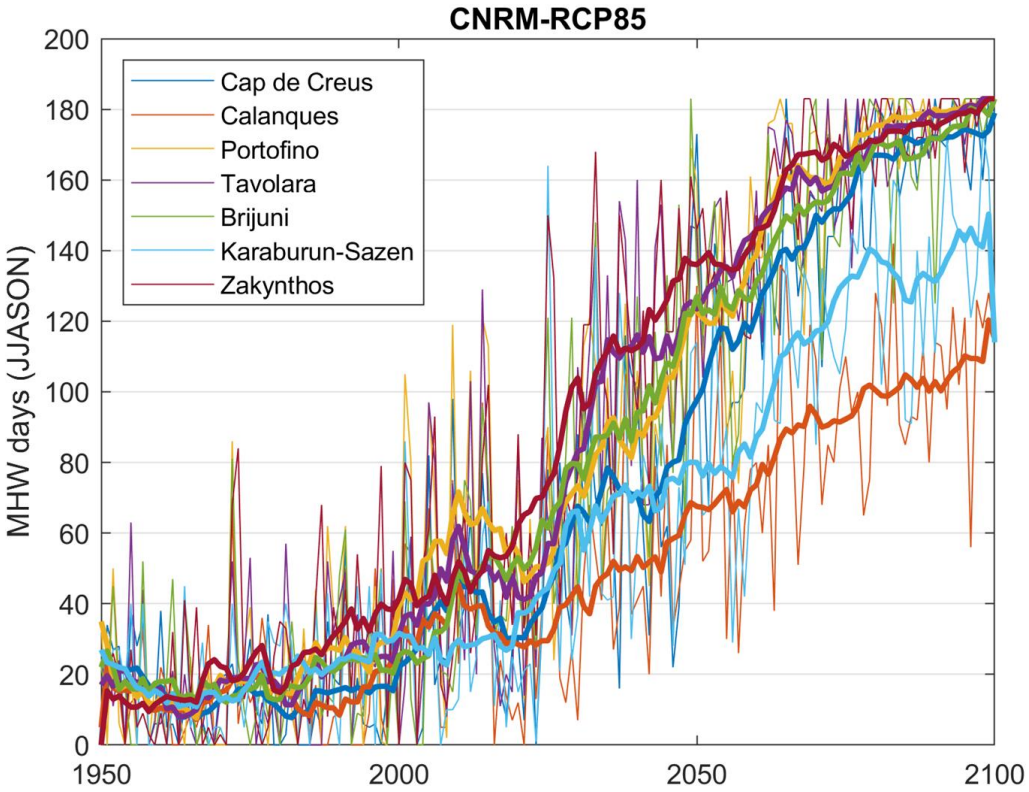

Figure 8. Projected MHW-days over the warm period (JJASON) of each year under climate change scenario 8.5.

Since the increase in ocean temperature is one of the main signs of climate change, the sea temperature on Brijuni has been continuously monitored since 2015 using temperature sensors placed between the surface to a depth of 30m at a location close to Cape Kamik. In 2020. and within the MPA ENGAGE project, two more locations are added for temperature sensors. This recording locations are part of the T-MedNet observation system which monitors temperature trends throughout the Mediterranean.

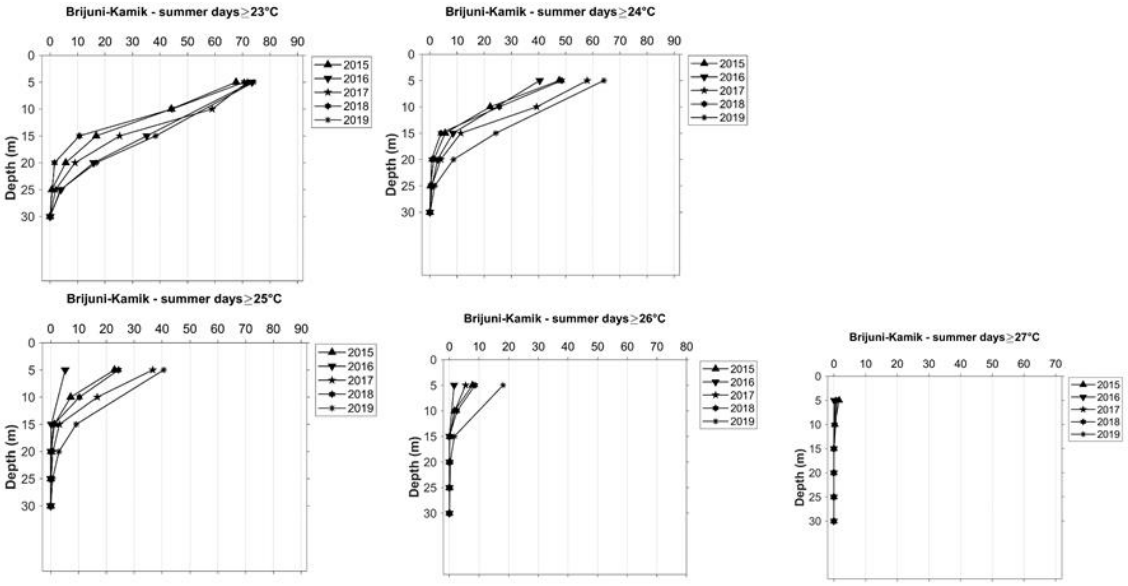

Figure 9. Number of days with temperatures equal to or higher than the above limits (set from 23 to 27 ° C) at the Kamik station on Veli Brijun

Mortalities of coral individuals and sponges have been determined in Brijuni National Park in 2018. and continued during 2020. Sponges are not immune to more frequent and intense climate change, especially with rising sea temperatures that can affect tissue damage. Increased concentrations of organic matter, plankton and other microorganisms in the water can also lead to serious illness and even death. Climate related mass deaths have become increasingly common. Yellow tube sponge (*Aplysina aerophoba*) and *Scalarispongia scalaris* were selected as key species for research of mass mortality in Brijuni. The effect was recorded as the percentage of damaged tissue on these sponges. Tissue damage was recorded for both species at all study sites, with *Scalarispongia scalaris* having a higher percentage of damage. It is assumed that organisms on the east coast of Brijuni will suffer greater damage and the consequences of climate change associated with longer and warmer summers as they are more exposed to pollution coming from the nearby mainland. The main causes of coral mass mortality and bleaching are high temperatures, sea pollution and reduced transparency and penetration of sunlight. In addition, Brijuni corals are threatened by algae blooms and the spread of the invasive alga *Caulerpa cylindracea*. Excessive flowering of the sea creates a thick opaque layer (mucus) that covers the coral and prevents it from feeding. The bacteria that break down this mucus consume oxygen and reduce the water quality where the corals live. Due to the endangerment of Brijuni corals, it is necessary to continuously monitor their condition in order to detect any negative changes in these organisms over time.

Figure 10. bleeching of coral *Parazoanthus axinellae* in Brijuni National Park

Figure 11. Mortality of colony *Cladocora Caespitosa* in Brijuni National Park

Changes in distribution and abundance of fish species are one of the first and most documented signs of biological effects of climate change in the marine environment (Perry et al., 2005; CIESM, 2008; Otero et al., 2013). Biogeographical shifts related to global warming are most commonly observed as northward spread of thermophilic species (Azzurro, 2008; CIESM, 2008). In the light of recent distributional shifts related to global warming, the northernmost and coldest sectors of the Mediterranean Sea, such as the north Adriatic, become the focal points where monitoring of fish communities should be given special care (Azzurro, 2008; Otero et al., 2013).

The occurrence and abundance of twelve target reef fish species (dusky grouper, *Epinephelus marginatus*, rainbow wrasse, *Coris julis*, ornate wrasse, *Thalassoma pavo*, parrotfish, *Sparisoma cretense*, painted comber, *Serranus scriba*, comber, *Serranus cabrilla*, salema, *Sarpa salpa*, dusky spinefoot, *Siganus luridus,* marbled spinefoot, *Siganus rivulatus*, bluespotted trumpetfish, *Fistularia commersonii*, gilthead seabream, *Sparus aurata*, bluefish, *Pomatomus saltatrix),* chosen on the basis of scientific evidence that they are reliable indicators of climate change, was investigated at four sampling locations in Brijuni National Park. Four of the five target species that were observed (*C. julis*, *S. scriba*, *S. salpa* and *S. aurata*) are all common and frequent in the coastal area of the northern Adriatic, while P. saltatrix is an indigenous species for the Adriatic that was until relatively not long ago sporadic in the northern Adriatic, and recently it is experiencing a population explosion along the entire coast of the eastern Adriatic Sea.

In unfavorable conditions, as during hypoxic events, habitats are more susceptible to diseases and to invasive species that might be better adapted in their physiological and behavioral responses towards this stressor. During the last decade the crucial event experiences in Brijuni National Park were the red tides algal blooms, the *Mneniopsis* bloom, the extensive spared of the green algae *Caulerpa cylindracea* but also the arrival of the barracuda (*Sphyraena sphyraena*) and the blue fish (*Pomatomus saltatrix*).

5.3 VULNERABILITY ASSESSMENT

The goal of the vulnerability assessment (VA) is to identify whether and how expected changes in climate will impact socio economic aspects in Brijuni National Park also by taking in consideration the interaction with the biodiversity and present non-climate stressors. As data are limited, this vulnerability assessment of biodiversity is designed to make the output specifically relevant for Brijuni park management in the next 20 years, but it is also the baseline to give directions for additional surveys that could enhance its accuracy in the next VA revision.

Based on three projections of different climate change scenarios over the periods of 2050 and 2100 a Socio-ecological vulnerability index and an Ecological vulnerability index were obtained. For Brijuni National Park, all the analysis were performed for important species, habitat and users present in the National Park.

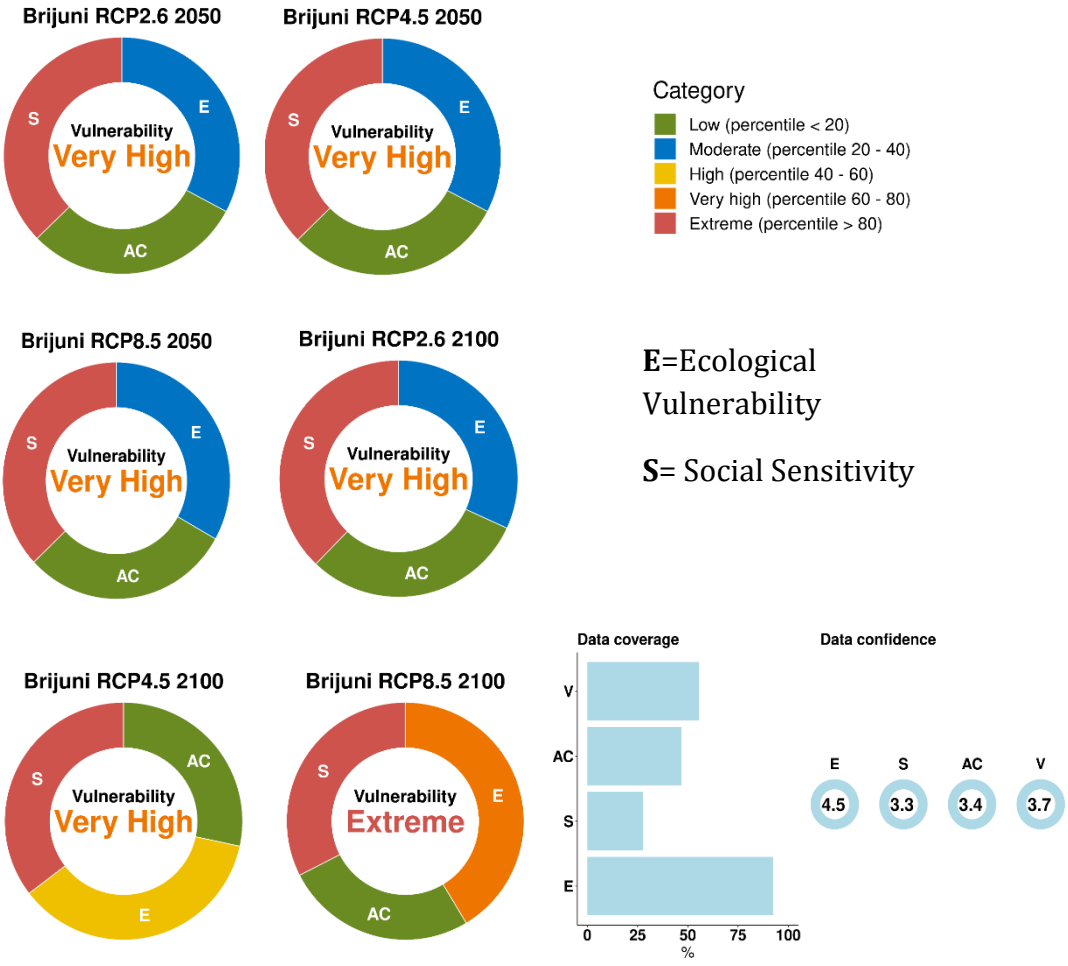

Figure 12. Socio-ecological vulnerability index of the Brijuni MPA.

The results show a very high vulnerability for the best-case scenario (RCP 2.6) both for the projection for 2050 and 2100. The same ecological vulnerability, adaptive capacity and social sensitivity have been estimated. According to the middle scenario (RCP 4.5) both projections, for 2050 and 2100, as well resulted in a very high vulnerability. In this case the ecological vulnerability will increase in the projection for 2100, from moderate to very high. According to the worst-case scenario (RCP 8.5) the biggest change will be experienced. The socio-ecological vulnerability index will change from a very high vulnerability predicted for the period of 2050 to an extreme vulnerability by 2100. This result is mostly influenced by the increase of the ecological vulnerability, from a moderate to very high level. Focusing on

hazards as increased Sea surface temperature (SST) and Marine heat waves (MHW) intensity, the results show in general a high vulnerability score.

All our species, habitat and users are highly affected by the Climate change. All the IPCC scenarios that were taken into account show a strong impact of Climate change on the National Park.

The most affected species are the *Posidonia oceanica*, *Cladocora cespitosa* and a large number of target and commercial fishes. The most affected habitats are the Posidonia meadows and the coralligenous habitats. According to the results related to the users, in Brijuni National Park the nautical sector and the recreational fisherman will be the two sectors affected the most.

The result is quite alarming since the exposure like sea surface temperature (SST) and marine heatwaves (MHW) will increase extremely but it is crucial to take into account that we are considering only two types of exposure, but climate change is much more than that.

For a future vulnerability assessment two more indicators of exposure should be taken into account for Brijuni National Park beside the Sea surface Temperature and the Marine Heatwaves and it needs to be analysed: sea level raise and extreme weather conditions. A wider knowledge, some targeted monitoring and a comprehensive database need to be implemented as well as measures to mitigate the Climate Change impact.

The most important action that must be taken at the MPA level to prevent the possibly overwhelming loss of biodiversity and ecosystem services due to unmitigated global warming is to increase habitat resilience by reducing or eliminating non-climate stressors where possible, detect and implement measures to mitigate and adapt to CC in the management plan and improve the relationship and the cooperation with the users. Thus, we must also develop adaptation strategies to help ecosystems to cope with the expected changes to their habitats, including some sea-level rise, as we build in the flexibility to deal with unforeseen impacts. Data improvement is much needed as well as continuous monitoring on the effect of CC on the marine habitats and species in the National Park.

5.4 INFORMATION ON PRE-EXISTING RELEVANT PLANS

The park, its real estate and movable property is managed by the Public Institution Brijuni National Park with the exception of certain facilities managed by the State Office for State Property Management and used by the Office of the President of the Republic of Croatia and the Government of the Republic of Croatia. In addition to the Office, another user of the area

in the Brijuni National Park is the Honorary Defence Battalion, which is an ancestral unit of the Armed Forces of the Republic of Croatia (OS RH).

The key documents that regulate the organization, usage, planning, protection and the way of managing the area of the Brijuni National Park are; the Spatial Plan of Areas of Special Character, the Management Plan and internal organisational rules.

The Management Plan is developed by the Public Institution for the management of the protected area, in consultation with stakeholders and expert consultants. The participation of the public in the process of drafting management plans for protected areas is of the utmost importance, as without the support of the public, no further implementation of plans would be possible. The plan is made for a period of ten years, with the possibility of modification and/or amendment (revision) after five years.

The plan is conceived as a public document, available to all stakeholders of the park, the local population, those protecting the natural environment, tourism workers, business people and any other interest groups or individuals. For this reason, the Plan was designed to be written in simple and comprehensible language. It is divided into logical units, from the description of the protected area, to goals and management activities, to as clearly as possible outline what the Public Institution wants to achieve in the next ten years and how it will achieve it.

The Public Institution Brijuni National Park is responsible for managing this area through paying special attention to maintaining a balance between the goals of preserving its natural and cultural value on the one hand, with the desire for and needs of tourism and stakeholders on the other. Managing such a system is therefore a complex task that requires careful consideration on a multidisciplinary level. At the same time all open issues must be taken into account along with the development and implementation of a clear and efficient management strategy. The purpose of this Management Plan is to the display assets, acknowledge the problems and challenges faced taking care of a protected area, defining the goals of the protected area and elaborates on how goals will be achieved. However, the Management Plan is more than just a strategic guideline - it is also a tool to guide and determine the annual work of the Public Institution directed to achieve these goals.

Within the framework of the Interreg MED project MPA Adapt a rapid vulnerability assessment were elaborate. Within this document a Climate Change adaptation plan was developed. The most important action detected that must be taken at MPA level was to prevent the possibly overwhelming loss of biodiversity and ecosystem services due to unmitigated global warming is to increase habitat resilience by reducing or eliminating non-climate stressors where possible.

A short list of actions of measures (strategy) were developed, based on the knowledge of the MPA managers working in Brijuni National Park.

Habitat type	Stressor	Vulnerablity	Strategy	Cost (H, M, L)	Efficacy (H, M, L)
Posidonia meadows	Increased water temperature	High	Effective monitoring of change and timely and appropriate responses	M	L
	Acidification	Moderate	Running educational programs to raise the awareness of our CO_2 footprint	L	L
	Storm severity/frequency	Moderate	Preserve the fitness of the holm oak (Quercus ilex) forest that reduce soil mobility and erosion to to sea	M	L
Rocky habitats and caves	Sea-level rise	Low	Remove/or redesign the coastal infrastructure and roads to allow rocky intertidal community persistance by species inland migration on suitable substrata in response to SLR	H	M
	Increased water temperature	High	Effective monitoring of change and timely and appropriate responses	M	L
	Ocean acidification	Moderate	Running educational programs to raise the awareness of our CO_2 footprint	L	L
Soft bottom	Increased water temperature	High	Effective monitoring of change and timely and appropriate responses	M	L
	Storm severity/frequency	Moderate	Preserve the fitness of the holm oak (Quercus ilex) forest that reduce soil mobility and erosion to to sea	M	L

Figure 13. Proposed adaptation measures for building resilience to climate change of key marine habitats developed within the framework of the project MPA Adapt

It was identified that on the main Veli Brijun island, the water supply system, electric power system, heating and cooling system, wastewater drainage system, traffic system and telecommunications require repair and/or complete replacement. Tit was identified as challenging to meet all these obligations from own generated funding. The solution is EU funds and/or the outsourcing of system maintenance, its functions and obligations to utility companies.

7. Priority actions to address climate change in Brijuni MPA

In this section, the priority actions agreed to be undertaken by the Brijuni MPA are presented in the format of a tables. Each action is featured with a number, a description, the target group, the expected results, the lead and those who should be involved in the implementation, a timeframe and performarnce indicators (used to measure achievement of outputs or outcomes).

Number	#1
Title	Monitor the conservation status of key marine habitats, such as *Posidonia* meadows and the coralligenous communities.
Brief description	Posidonia meadows and the coralligenous communities are the most affected habitats by CC in Brijuni NP and their good conservation status is important for mitigation of the impacts of CC. It is therefore necessary to closely monitor changes in these habitats, to be able to suggest and implement adequate measures on time.
Target group	Researchers, Divers
Expected result	Accurate and updated monitoring data on the state of Posidonia meadows and coralligenous communities in the NPB is available, including in relation to the existing impacts of CC.
Lead	Public Institution Brijuni National Park
Partners	Department of Biology Faculty of Science
Timeframe	< 5 years
Performance indicators	Protocols for research and monitoring of key marine habitats are established. Yearly monitoring reports are available.

Number	#2
Title	Establish targeted research and monitoring of key marine species relevant for monitoring of the impact of climate change.
Brief description	Impacts of climate change can be monitored through the conservation status of key species that serve as indicators of changes in marine ecosystems. Besides *Posidonia oceanica* and

	Cladocora cespitosa that are already identified as among the most affected species by CC, some of the fish or other species, relevant for monitoring of the impacts of CC will be identified.
Target group	Researchers, Divers
Expected result	Accurate and updated monitoring data on the conservation state of key marine species in Brijuni NP is available, including in relation to the existing impacts of CC.
Lead	Public Institution Brijuni National Park
Partners	Department of Biology of the Faculty of Science, NGOs, Divers
Timeframe	< 5 years
Performance indicators	Protocols for research and monitoring of key marine species are established. Yearly monitoring reports are available.

Number	**#3**
Title	Establish targeted research and monitoring of marine invasive species relevant for monitoring of the impact of climate change.
Brief description	In unfavourable conditions, such as during hypoxic events, habitats are more susceptible to diseases and to invasive species that might be better adapted in their physiological and behavioural responses towards this stressor. During the last decade the crucial events experienced in Brijuni NP were the red tides algal blooms, the *Mneniopsis* bloom, the extensive spread of the green algae *Caulerpa cylindracea* but also the arrival of the barracuda (*Sphyraena sphyraena*) and the blue fish (*Pomatomus saltatrix*).
Target group	Researchers, Divers
Expected result	Accurate and updated monitoring data on the presence of marine invasive species in Brijuni NP is available, including in relation to the existing impacts of CC.
Lead	Public Institution Brijuni National Park
Partners	Department of Biology of the Faculty of Science, NGO, Divers
Timeframe	< 5 years

Performance indicators	Protocols for research and monitoring of marine invasive species are established. Yearly monitoring reports are available.

Number	**#4**
Title	Set up weather stations and develop monitoring protocols for extreme weather conditions, especially on specific parameters such as droughts.
Brief description	Increased frequency of extreme weather events (e.g. devastation of the shore by strong winds and high waves) has been observed by local people and users of Brijuni NP in recent years (6-7 years). Systematic monitoring of these changes is required to measure and confirm these observations.
Target group	Researchers
Expected result	Changes in weather related to climate change (especially extreme weather events) are regularly monitored and reported.
Lead	Public Institution Brijuni National Park
Partners	Croatian Meteorological and Hydrological Service
Timeframe	> 5 years
Performance indicators	Protocol for monitoring of extreme weather conditions is established. Number of meteorological stations set up. One report per year

Number	**#5**
Title	Establish and implement monitoring of physico-chemical parameters in the sea relevant for monitoring changes caused by CC.
Brief description	Regular monitoring of physico-chemical parameters is not established in the Brijuni NP and such data is necessary for evaluating the impact of CC.
Target group	Researchers

Expected result	Changes in physico-chemical parameters in the sea related to CC are detected on time.
Lead	Public Institution Brijuni National Park
Partners	Ruđer Bošković Institute
Timeframe	< 5 years
Performance indicators	Number of localities identified for monitoring. Number of data loggers installed on identified localities. Monthly monitoring reports.
Number	#5
Title	Set up weather stations and develop monitoring protocols for extreme weather conditions, especially on specific parameters such as droughts.
Brief description	Increased frequency of extreme weather events (e.g. devastation of the shore by strong winds and high waves) has been observed by local people and users of Brijuni NP in recent years (6-7 years). Systematic monitoring of these changes is required to measure and confirm these observations.
Target group	Researchers
Expected result	Changes in weather related to climate change (especially extreme weather events) are regularly monitored and reported.
Lead	Public Institution Brijuni National Park
Partners	Croatian Meteorological and Hydrological Service
Timeframe	> 5 years
Performance indicators	Protocol for monitoring of extreme weather conditions is established. Number of meteorological stations set up. Two reports per year are available.

Number	#6
Title	Develop communication tools and materials about climate change and opportunities for adaptation to climate change, for the general public and visitors of the Brijuni NP to raise their awareness on the topic.
Brief description	Raising awareness and thereby understanding the effects of climate change on biodiversity and marine ecosystems will facilitate both behavioural change and social support for the implementation of measures needed to mitigate the impacts of the CC.
Target group	Visitors of Brijuni NP, Public, Media
Expected result	Increasing number of individuals who support and/or implement CC adaptation measures in the Brijuni NP.
Lead	Public Institution Brijuni National Park
Partners	Media, NGO, Local schools
Timeframe	Present
Performance indicators	Number of communication tools and materials developed. Number of participants / content range.

Number	#7
Title	Develop and implement programs for involvement of citizens in monitoring biodiversity and ecosystems (citizen science) and collect their knowledge and observations on changes in the marine environment, including in relation to the impacts of CC.
Brief description	Engaged individuals can significantly contribute to monitoring the status of endangered habitats and species, raising awareness of the importance of such monitoring and related research, and finally they contribute to capacity building of public institutions such as Brijuni NP.
Target group	Divers, Fishermen, Visitors, Public
Expected result	Increased number of individuals involved in citizen science-based monitoring in Brijuni NP

	Increased amount and frequency of data received from the citizen science programmes
Lead	Public Institution Brijuni National Park
Partners	Divers club, NGO, Schools
Timeframe	< 5 years
Performance indicators	Number of reports from divers / fishers / others per year Number of participants in citizen science programs per year.

Number	**#8**
Title	Develop and implement Brijuni NP certificates for concessionaires (e.g., "friends of Brijuni") that operate in accordance with the objectives of preserving the value of the Brijuni NP and measures to adapt to climate change.
Brief description	Among the concessionaires there are those who invest in their development in a way that is sustainable and less harmful to the environment. The intention of developing Brijuni NP certificate for such concessionaires is to promote them and raise the value of their services and products.
Target group	Concessionaires
Expected result	Increased number of concessionaires who implement adaptation measures and operate in line with the goals and objectives of Brijuni NP.
Lead	Public Institution Brijuni National Park
Partners	Divers, fishers, tourist boats and others
Timeframe	< 5 years
Performance indicators	Number of certificates issued. Certificate user records.

Number	**#9**
Title	Collaborate with fishers on development and implementation of sustainable fishing activities and the promotion of added value of sustainable fisheries products.

Brief description	Fishers are on the frontline of the battle against negative impacts of climate change, fighting to maintain their catches, their income, and livelihoods. Collaboration and integration of sustainable fishing activities is a way to find sustainable solutions for the conservation of marine ecosystems and preservation of their way of life.
Target group	Fishers
Expected result	Increased number of fishers who develop and implement sustainable fishing activities.
Lead	Public Institution Brijuni National Park
Partners	Fishermen's associations
Timeframe	< 5 years
Performance indicators	Number of fishers who are actively involved in the implementation of CC adaptation measures.

Number	**#10**
Title	Collaborate with divers on development and implementation of sustainable tourist activities of the Brijuni NP and the promotion of added value of such activities.
Brief description	Conserved and diverse marine habitats and species of the Brijuni NP are essential for fulfilled diving experience. Divers, through their organisations, are therefore interested in the development and diversification of sustainable diving activities in the Brijuni NP.
Target group	Divers
Expected result	Sustainable use of marine habitats and species for tourist activities.
Lead	Public Institution Brijuni National Park
Partners	Diving clubs
Timeframe	< 5 years

Performance indicators	Number of diving clubs cooperating with Brijuni NP. Diving sites and paths are in line with conservation of endangered habitats and species.

Number	**#11**
Title	Collaborate with other users of Brijuni NP (Ministry of Defence, State Real Estate, concessionaires) on the development and implementation of CC adaptation measures.
Brief description	In order to efficiently implement CC adaptation measures all users of Brijuni NP have to be informed and involved.
Target group	Users of Brijuni NP
Expected result	Alliance is formed between the users of Brijuni NP, supporting the implementation of CC adaptation measures, for the benefit of all.
Lead	Public Institution Brijuni National Park
Partners	Ministry of Defence, State Real Estate, concessionaires
Timeframe	< 5 years
Performance indicators	Number of jointly implemented activities and CC adaptation measures.

Number	**#12**
Title	Advocate establishment of a buffer zone around Brijuni NP with special regulations for commercial fishing.
Brief description	Commercial fishing is not allowed in the Brijuni NP. However, better control of fishing activities in the surrounding area is necessary in order to implement this rule and reduce impact of commercial fishing to the fish populations in the NP.
Target group	Commercial fishers
Expected result	Improved control of commercial fishing activities. Reduced impact of commercial fishing activities on fish populations in Brijuni NP.
Lead	Public Institution Brijuni National Park

Partners	Ministry of Economy and Sustainable Development, Ministry of Agriculture
Timeframe	> 5 year
Performance indicators	Established buffer zone. Negative impacts of commercial fishing activities on fish populations in Brijuni NP are reduced.

Number	**#13**
Title	Optimize consumption of water in Brijuni NP and modernize the water supply and wastewater management infrastructure.
Brief description	Brijuni NP lacks efficient wastewater drainage system and water consumption can be reduced in hotels and other facilities.
Target group	Users and visitors of Brijuni NP
Expected result	Consumption of water and negative impacts of wastewater to marine ecosystems in Brijuni NP are reduced.
Lead	Public Institution Brijuni National Park
Partners	Water supply and drainage company, Ministry of Defence, State Real Estate, concessionaires
Timeframe	> 5 years
Performance indicators	Efficient wastewater drainage system in Brijuni NP is constructed. Water consumption is reduced. Brijuni Hotels are managed in accordance with the highest ecological standards. Environmentally friendly cleaning products are used in Brijuni NP Filter system for washing machines to reduce plastic

Number	**#14**
Title	Establish efficient waste management in Brijuni NP, including the reduction of waste.

Brief description	Necessary improvements of waste management system in Brijuni NP are recognized with regards to selection of waste on the site and reduction of the total amount of waste collected within the NP.
Target group	Users and visitors of Brijuni NP
Expected result	Waste management in Brijuni NP is efficient and in in accordance with the highest ecological standards.
Lead	Public Institution Brijuni National Park
Partners	Waste management company, Ministry of Defence, State Real Estate, concessionaires
Timeframe	> 5 years
Performance indicators	Number of "Green corners" for recycling established on the main island. Number of communication activities to encourage visitors to "leave no trace" principle. Recyclable packaging is used in Brijuni NP. Adopt a beach

Number	**#15**
Title	Implement projects to reduce energy consumption and increase the use of renewable energy sources.
Brief description	Energy infrastructure in Brijuni NP is old, in bad condition and requires renovation. Possibilities for implementing renewable energy sources, such as solar panels, are limited with regards to conservation requirements for cultural heritage in Brijuni NP.
Target group	Users of Brijuni NP
Expected result	Increased energy efficiency in Brijuni NP.
Lead	Public Institution Brijuni National Park
Partners	Ministry of Defence, State Real Estate, concessionaires, culture conservator experts
Timeframe	> 5 years

Performance indicators	Modernized energy infrastructure in Brijuni NP, in accordance with the requirements for conservation of cultural heritage and biodiversity.

8. References

Hervat, M., Blašković, A. (2019): Local vulnerability assessment of marine habitats to climate change. Public Institution Brijuni National Park – Interreg MPA-ADAPT project.

Management Plan 2016. – 2025., Brijuni National Park, 2016.