MPA-ADAPT PROJECT

JOINT GOVERNANCE PLAN

APRIL 2019

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CSIC Consejo Superior de Investigaciones Científicas
ISPRA Istituto Superiore per la Protezione e la Ricerca Ambientale
IUCN
Parc national de Port-Cros
CORSE CORSICA Office de l'Environnement de la Corse
portofino
BRIJUNI

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Developing adaptation plans to face climate change impacts in Mediterranean Marine Protected Areas.

APRIL 2019

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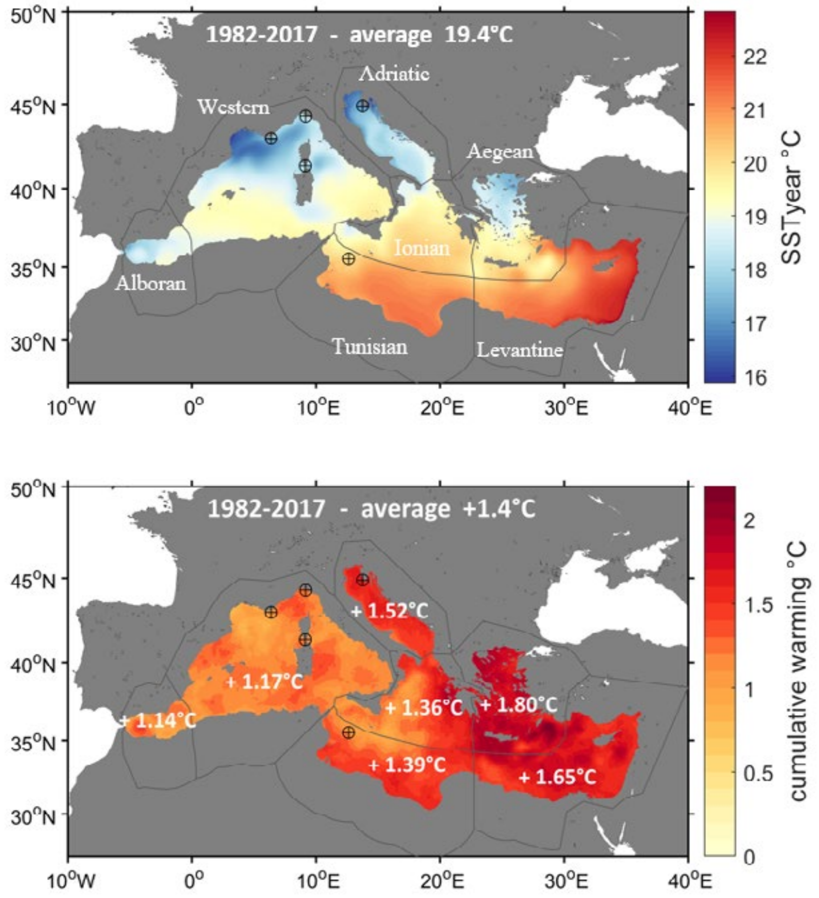
Introduction

The Mediterranean Sea is considered a hot spot for marine biodiversity (Coll et al. 2010). Covering less than 1% of world's oceans is home of about 10% of marine species with a high percentage of species that are only found in this area. The Mediterranean marine ecosystems are key supporting the development of coastal and national wide socio-economic activities such as food provision, tourism industry and coastal protection. For instance, the Mediterranean area is one of the first tourist destinations in the world with more than 343 million annual visitors which are expected to increase at least 20% during the next five years. However, the Mediterranean faces multiple pressures such overfishing, pollution, arrival of non-indigenous species and climate change that are challenging the conservation of the rich biodiversity and the services that support.

MPA-Adapt partners participating in workshop organized by the Biodiversity Community (Panace Project) in Montenegro (2018) sharing the experiences and lessons learnt from the project activities. © Brijuni National Park

The Mediterranean Sea is a temperate warm sea with mean annual sea surface temperature of 19.4 ± 1.3 °C (**FIGURE 1**). It exhibits important North to South and West to East environmental gradients, spanning over more than 6°C difference in yearly mean temperature (range 16 – 22.8°C). The Mediterranean coastal and shelf area can be subdivided into 7 ecoregions from Alboran to the West, to Levantine to the East (Spalding et al. 2007). The Mediterranean region is considered a hot-spot for climate change (Cramer et al. 2018). In fact, the entire Mediterranean Sea is extremely responsive to regional climate change. Over the 1982-2017 period, the Mediterranean sea surface temperature has warmed by 1.4°C on average over the basin. Highest warming occurred in the Adriatic, Aegean and Levantine ecoregions (1.5-1.8°C average, locally >2°C) and lowest in the Alboran and Western ecoregions (1.1-1.2°C average, loally > 1.5°C) (**FIGURE 1**). These warming trends are associated to amplification of conditions now perceived as extreme, exacerbating the potential heat stress with multiple effects on marine ecosystems.

FIGURE 1



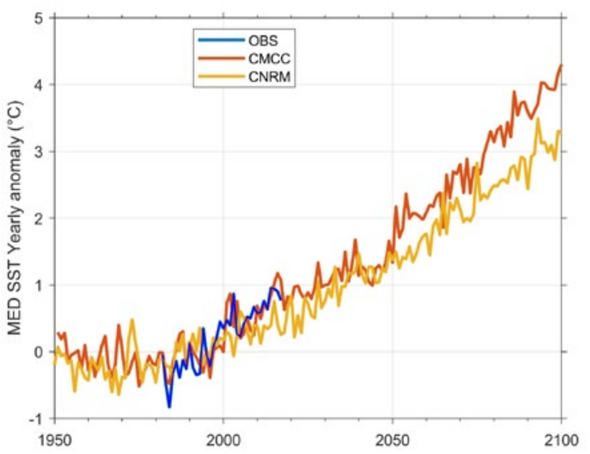
Spatial maps of satellite derived sea surface temperature and warming trends for the 7 Mediterranean ecoregions. A) Yearly average sea surface temperature over the 1982-2017 period. B) Cumulative warming (in °C) over the period 1982-2017. The location of the 5 pilot Marine Protected areas participating in MPA-Adapt are indicated by circles. Figure generated using E.U. Copernicus Marine Service Information.

Future evolution of Mediterranean Sea surface temperature has been evaluated using a dedicated ensemble of fully-coupled Regional Climate System Models from the Med-CORDEX initiative and a multi-scenario approach (Darmaraki et al. 2019). Considering the multi-model mean, average SST increase of 3°C is expected by the end of the century while temperature extremes 4°C warmer are projected (2071-2100 period compared to 1950-2005 period) (**FIGURE 2**). By 2100 and under RCP8.5 scenario, long-lasting Marine Heatwave events are expected to occur every year, to be about 4 times more intense and increase in duration, being up to 3 months longer than under present conditions. Although Marine Heatwaves might reach deeper layers and be amplified at some depth (Schaeffer et al. 2017, Bensoussan et al. 2019 a,b), these trends for SST are considered reliable signs of possible harmful conditions for coastal ecosystems.

The current climate change trajectory is considered one of the major concerns for the conservation of marine biodiversity (Hughes et al. 2017).

In the Mediterranean the observed warming is already affecting marine ecosystems. The two main impacts underway are: i) the shift in species distribution (native and non –indigenous) and ii) the occurrence of unprecedented mass mortalities events (MMEs).

FIGURE 2



Observed (blue line) and modelled (orange and red lines) Mediterranean yearly average SST. Figures generated using E.U. Copernicus Marine Service Information and MedCORDEX/CNRM-CMCC simulations(Historical run and RCP8.5).

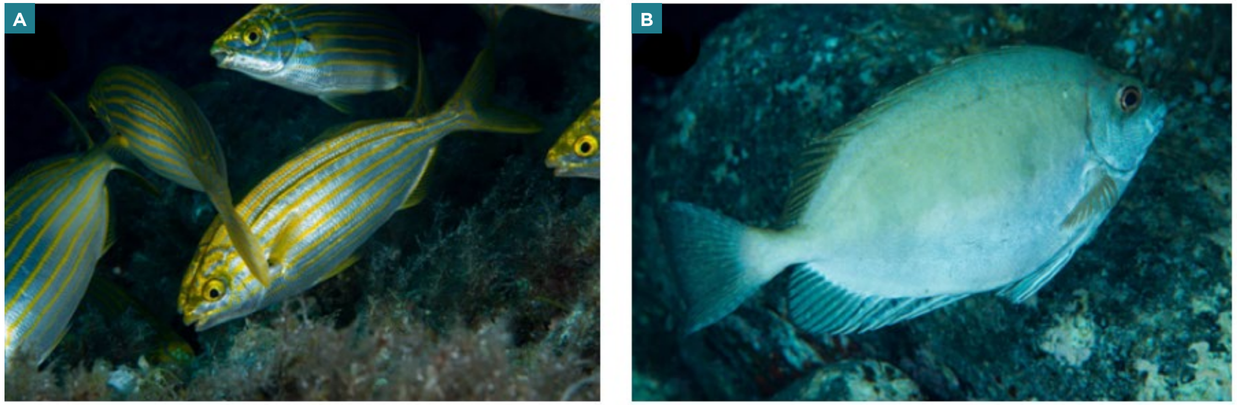
A diver setting up a temperature data logger at 30 m depth at the Réserve Naturelle de Scandola (Corsica, France). © Alexis Rosenfield

SHIFTS IN SPECIES DISTRIBUTION

Under warming, the abundance and distribution of Mediterranean species is rapidly changing. Current warming trends ultimately favors the spread of warm-water affinity species while, due the geographic position and shape of the Mediterranean, cold-water affinity species are reducing their abundance and distribution areas. These changes, affecting many different taxa and through the different sub-regions of the basin (e.g. Bianchi 2007), also involve invasive species of tropical origin, which take advantage from novel climatic conditions to successfully spread over novel areas (Hiddink et al. 2012).

As examples of how fauna is responding to warming, the northward spreads are extremely clear for warm-affinity native species such as the bluefish, *Pomatotus saltarix*, whose Mediterranean distribution was historically restricted to the southern and eastern sectors of the basin (Tortonese, 1986). Yet, in the last decades, this species started to be observed northward (e.g. Dulčić et al. 2005). This process has been also noted in Atlantic waters (Contreras-Balderas et al. 2002), and it has been linked to the increase in water temperatures (Sabates et al. 2012). While native Cold-water affinity species such as the sprat, *Sprattus sprattus* (Margonski et al. 2010) have contracted their geographical distribution. The sprat typically occupies the coldest sectors of the Mediterranean, such as the northern Adriatic and the Gulf of Lyon but populations drastically declined since the 1990s (Lloret et al. 2001, Grbec et al. 2002, Hidalgo et al. 2019). Finally, non-indigenous warm-adapted species of tropical origin are widely considered to have increased their success probabilities in the Mediterranean Sea due to water warming (e.g. Raitsos et al. 2010). This is the case of the rabbitfishes *Siganus luridus* and *S. rivulatus*, which are rapidly expanding their distribution and increase in abundance (Azzurro et al. 2017) at the expenses of their native counterpart *Sarpa salpa* (Marras et al. 2015) (**FIGURE 3**).

FIGURE 3



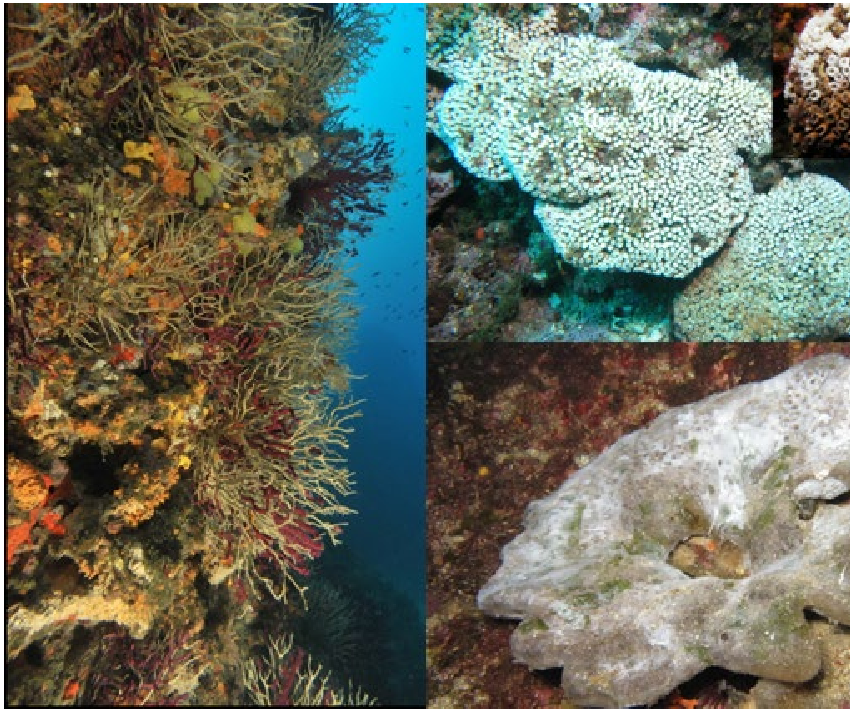
Fish species responding to climate change in the Mediterranean **A** the herbivorous native species *Sarpa Sarpa salpa* and **B** the invasive rabbit fish *Siganus luridus*. © Giovanni Ombrello

MASS MORTALITY EVENTS

In 1999, the first unprecedented large scale mass mortality events impacting populations of more than 30 species from different phyllums over thousands of kilometers of coastaline from French and Italian coasts was observed (Cerrano et al. 2000, Perez et al. 2000, Garrabou et al. 2009). During the last two decades at least two other major mortality events were observed in 2003 and 2018 (Garrabou et al. 2009, Garrabou et al. 2019), while almost every other year mortality events were reported, however, usually concerning either few species or smaller geographic areas or both (Rivetti et al. 2014, Marba et al. 2015, Garrabou et al. 2019). These events, in general, were associated to the observation of severe and recurrent marine heat waves in the last decades in the Mediterranean area (Bensoussan et al. 2019a).

Overall more than 90 species from 7 major taxonomic groups (*Cnidaria, Porifera, Bryozoans, Bivalvia, Ascidacea, Rhodophyta, Annelida, Clorophyta, Echinodermata*) were affected during mass mortality events (**FIGURES 4** and **5**). The NW Mediterranean region with more than half of observations of mortality followed by the Adriatic Sea were the most concerned by these events. It is noteworthy that most information concerned the coast of EU countries while there is almost a complete lack of reports from the southern Mediterranean coasts from Morocco to Turkey (**FIGURE 4**). Thus it is likely that the observed geographic pattern on the incidence of mass mortality resulted more from biased reporting than the absence of these phenomena in the South and East Mediterranean regions.

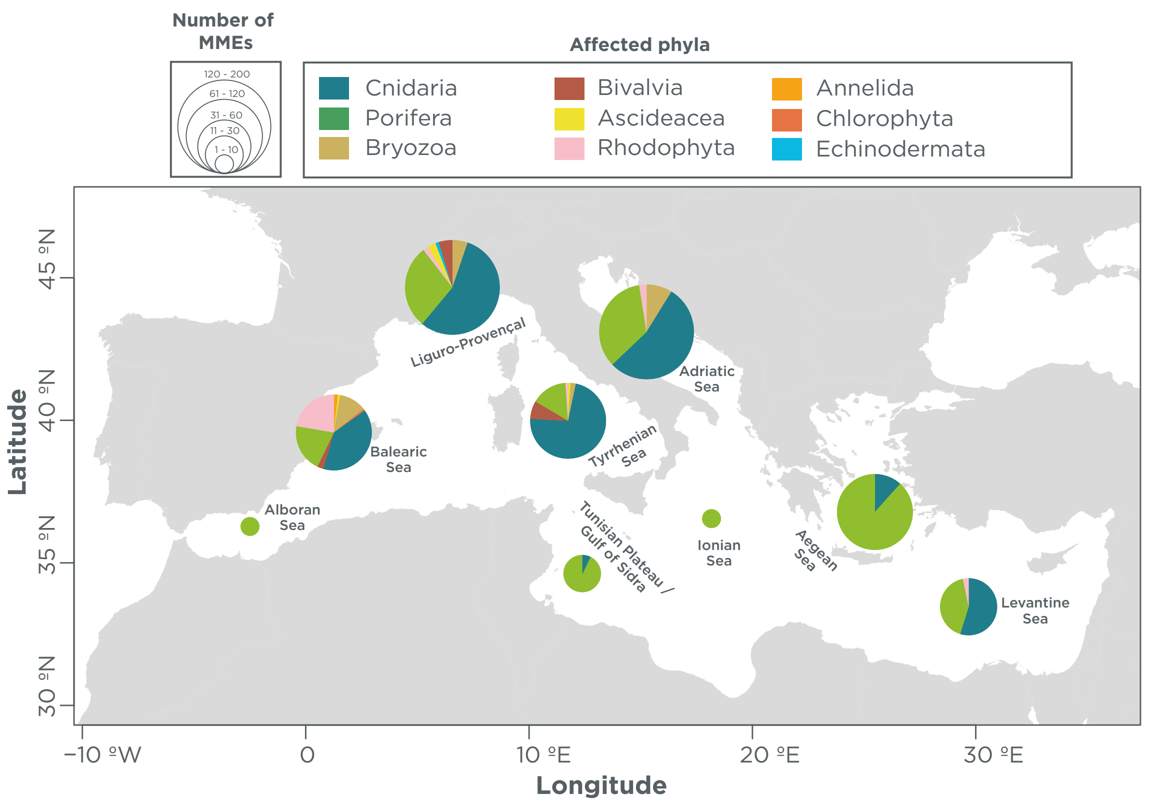
FIGURE 4



Macrobenthic key species affected during mass mortality events in the Mediterranean sea. From left the red gorgonian *Paramuricea clavata*, right up the scleractinian coral *Cladocora caespitosa* and right down the horny spong *Spongia lamella*. © Olivier Bianchmani, Diego K. Kersting and Joaquim Garrabou

Besides these major impacts, shifts in species distribution and mass mortality events, other effects associated to warming are being reported in the Mediterranean such species proliferations and changes in species reproduction timing and migration patterns are also affecting different species in different Mediterranean areas (Otero et al. 2013).

FIGURE 5



Number of mass mortality events reported in the literature by geographic area and species phylum.

Overall climate change is already dramatically affecting the abundance and distribution of species as well in the functioning of ecosystems (Givan et al. 2018, Sala et al. 2011). It is difficult to foresee with precision to what extent the current climatic trends will affect marine ecosystems and key species in the Mediterranean Sea in the next decades. However, recent studies indicate that an increased extinction risk for endemic fauna, loss of habitat complexity and changes ecosystem configurations (Lasram et al. 2009, 2010, Sala et al. 2011, Azzurro et al. 2019, Montero-Serra et al. 2019). In any case, management and conservation strategies of Mediterranean should therefore be wise enough to anticipate vulnerability to these new threats and to provide local communities with the adaptive capacity to cope with the related pressures (Fulton et al. 2015).

Marine Protected Areas (MPAs) are considered a primary tool for conservation biology for adapting and mitigating threats associated to climate change. In general, removing the impacts of local stressors in effectively managed MPAs demonstrated their effectiveness in the recovery of fish and coral populations (e.g. Linares et al. 2010, Edgar et al. 2014, Gill et al. 2017). Yet the effectiveness of MPAs to counteract global effects of climate change has been questioned (Coté & Darling 2010, Bruno et al. 2018), there are evidences that MPAs may play a central role in enhancing the resilience of marine habitats to climate change (Micheli et al. 2012, Simard et al. 2016).

THE PROBLEM LACK OF ADAPTATION PLANS TO CLIMATE CHANGE

As mentioned at present and even more over the upcoming decades, climate change will represent a rapidly increasing challenge for the ecosystems conservation and the livelihoods in the Mediterranean area. Direct evidence of climate change is already being observed in the Mediterranean coast including the Marine Protected Areas (MPAs) network. There is a consensus at global (Convention on Biological Diversity), European Union (Directive on Birds and Habitats) and Mediterranean (UNEP/MAP, MAPII, MSSD; Barcelona Convention) levels to strengthen the MPAs as key tools to prevent further biodiversity loss and maintain ecosystem.

Although the EU policy, Marine Spatial Planning (MSP) and Marine Strategy Framework Directive (MSFD), provides the framework to address climate change effects, their current implementation is essentially missing. Likewise, recent Interreg MEDprojects beyond MPA-Adapt (e.g., EcoSUTAIN, AMAre) highlighted that most MPAs lack of specific adaptation plans to Climate Change.

Capacity building session on Local Ecological Knwoledge (LEK) protocols in Isole Pelagie MPA (Lampedusa, Italy). Ernesto Azzurro trained MPA-Adapt partners with the collaboration of local fishermen on how conducting the interviews. © Joaquim Garrabou

MPA-ADAPT GOALS

The MPA-Adapt project was developed to tackle those challenges through a multi-level approach. Five MPAs from three Mediterranean countries were chosen to act as pilot sites for the development of climate change adaptation action plans and their integration into existing management frameworks.

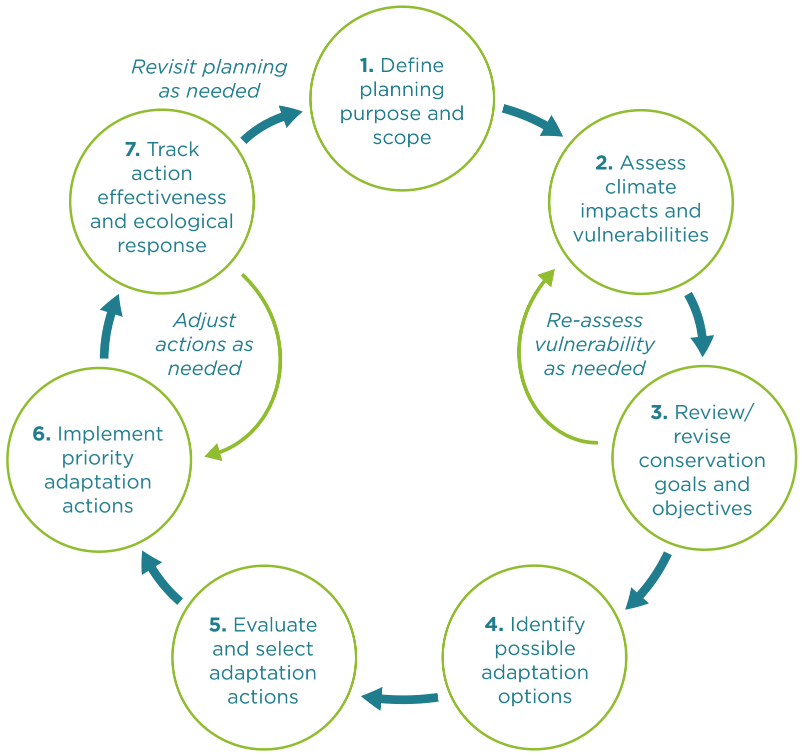
In order to achieve this, they have been monitoring the effects of the climate change with a set of fine-tuned protocols; undergoing Biodiversity and Socio-economic vulnerability assessments to CC and improving the capacity and common knowledge by setting a program of training and data sharing throughout the duration of the project. Based on their experiences and other available data, the project has delivered guidelines for climate change adaptation in MPAs of the Mediterranean, which should lead other MPAs through the same process and facilitate the development of basin-wide application of adaptive management standards for dealing with climate change related issues.

The main goal of MPA-Adapt was to enhance the role of MPAs as nature-based solutions for the implementation of EcAp to the adaptation and mitigation to ongoing climate change effects. To develop and efficient and cost-effective strategy for the full implementation, it is crucial to identify and prioritize key territorial challenges.

Framework to develop MPA climate change adaptation action plans

In MPA-Adapt, we adopted the process proposed by Stein et al (2014) on the international best practices for the development of adaption actions (**FIGURE 6**). In this process MPA managers go through seven steps to take a detailed consideration of the issues related to climate change, irrespective of the state and extent of their management plan. Through this approach MPA managers starts 1) defining the purpose and scope of the adaptation action plan, 2) assess current and future climate impacts and vulnerabilities of MPA's habitats and species based on the available information; 3) review the conservation goals based on the potential vulnerability to climate change ; 4) explore and identify possible adaptation options for the MPAs in order to reduce the key climate-related vulnerabilities through local management actions, 5) evaluation and selection of adaptation actions bearing in mind which are the most effective in the ecological and socio-economic setting of each MPA; 6) implementation of adaptation actions selected; and 7) finally evaluate the effectiveness of adaptation actions through an array of monitoring tools able to inform MPA managers for effective adaptive management.

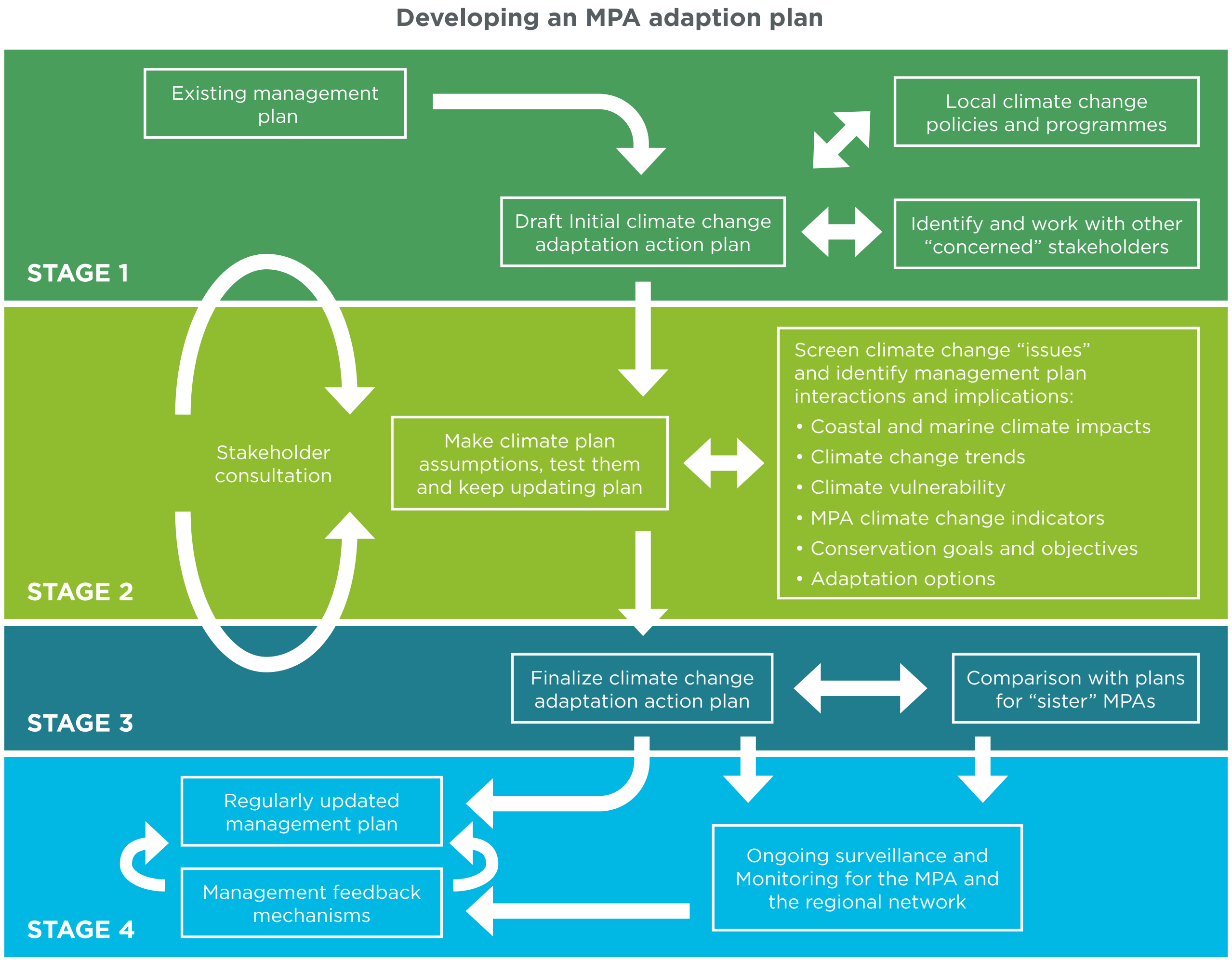
FIGURE 6



General framewok for adaptation planning and implementation from Stein et al (2014) on the international best practices for the development of adaption actions.

For MPA-Adapt, we readapted the general scheme proposed by Stein et al (2014) from seven to a four-stage process (**FIGURE 7**). The final goal is to propose and develop the climate change action plan, which can then be used to inform and revise the MPA management plan through an ongoing iterative process involving a structured program of surveillance and monitoring. In MPA-Adapt we emphasized the participatory approach with the support of the Quintuple Helix: MPa managers, scientists, local socio-economic stakeholders, public authorities and citizens (see below).

FIGURE 7



Process towards a MPA climate change adaptation action plans adopted in MPA-Adapt project (IUCN MPA Adapted from Workshop, 2018).

STAGE 1

The purpose of this first stage is to reflect on the existing management plan, what is readily known about climate change issues with the MPA, as well as a broader perspective on local climate change policies and programs in order to develop an initial idea of what the action plan should look like and include. A key aspect of this stage should be to identify key stakeholders to work with who have a relationship to some aspects of climate change impacts that affect the MPA and adjacent areas.

STAGE 2

This is an analytical stage informed by consultation where the first screening of climate change issues is explored and tested to refine what changes are needed to the structuring, content and application of the original management plan. This may involve iterating the adaptation plan with stakeholders to progressively build in details as understanding of climate change issues is developed by the MPA.

STAGE 3

This stage brings together the information from STAGES 1 and 2 into a final climate change adaptation action plan for the MPA, which has been also informed by discussions on climate change impacts and adaptation actions with adjacent ‘sister’ MPAs in the regional network or MPAs in the broader region with the same ecosystems and issues. Such an approach may lead to economy of effort in tackling climate change issues common across the network in the subsequent adaptation actions that are identified.

STAGE 4

This stage is about refining the management plan in light of the climate change adaptation action plan. This stage will tend to be a much longer process and is likely to fall outside the end date of MPA-ADAPT.

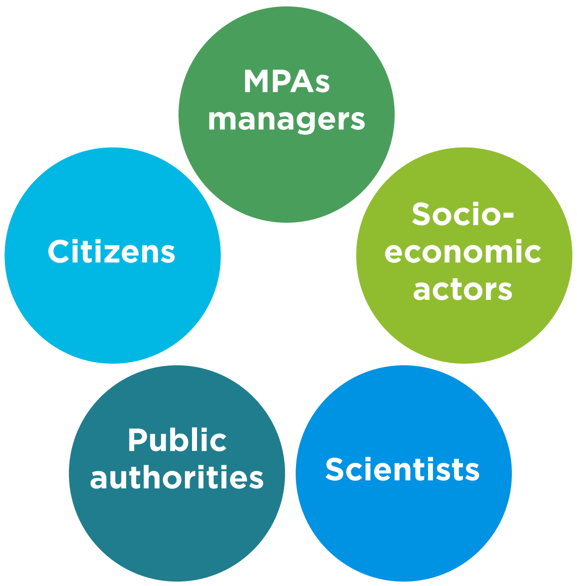
More particularly the focus of the MPA-Adapt MPAs work was on STAGES 1-3, as the process to take the finalized action plan and incorporate the key points into a revision of the management plan will stretch beyond the timescale of the project.

A series of stakeholder’s consultation through participatory events were conducted in the MPAs participating in the project.
© Gianpaolo Rampini

Actors: the quintuple helix of MPAs

Within MPA-Adapt we promoted the engagement of the Quintuple helix [Managers, socio-economic actors, local and regional authorities, scientists and citizens] using different participatory approaches (**FIGURE 8**). The final goal was to develop MPA climate change adaptation action plans.

FIGURE 8



The quintuple helix engaged to develop the Adaptation Action plans in each MPA.

Actors and role:

1. **MPA managers**

   MPA managers are in charge adapting their management to Climate Change through a co-participative approach supported by monitoring and vulnerability assessments.

2. **Socio-economic actors**

   Local socio-economic stakeholders are essential in the participatory approach to design adaptation plan in view to support the sustainability of their activities affected by the climate change.

3. **Scientists**

   Scientists, capitalizing on proved experiences, bring the best available scientific information to the set of tools to be tested both at local and regional level.

4. **Citizens**

   Citizens through dissemination and communication activities and marine citizen science initiatives can contribute to the monitoring and fosters the awareness rising.

5. **Public authorities**

   Public authorities that lead the capitalization and mainstreaming objectives to implement the climate change adaptation measures at different levels.

Overall the five marine protected areas engaged about 160 entities and organizations implying hundreds to thousands of participants at different levels (**TABLE 1**). For detail in the entities and organizations see the **ANNEX 1**. As expected the Local socio economic stakeholders and Public authorities displayed the largest number of entities engaged. The main groups participating for local socio-economic stakeholder were Local Fishermen entities, diving centers, Tourism Offices, nautical representatives and different NGOs. Regarding Public authorities, municipalities were highly represented with about 30% of entities, followed by organizations managing at regional level; in some cases even ministerial representatives were present. Regarding Citizens, the MPAs have been quite active engaging public ranging from tourists to school classes. Special mention to Portofino and Isole Pelagie which developed specific programs on citizen science in collaboration with local diving centers and international organizations PADI and DAN with a very interesting and promising output. The MPAs could take advantage of scientific expertise by collaborating with about 20 research institutions mainly universities and national research organizations. These interactions allowed to inform on the proposed adaptation actions on the science based evidences available.

Finally, few managers from other MPAs were involved, however representatives of nature conservation departments and authorities participated ensuring in most cases at least transmitting the information.

TABLE 1

Number of entities/organizations engaged in the participatory to develop the Adaptation Action plans in each MPA.

Actors	Marine Protected Areas					TOTAL
	Port-Cros	Portofino	Bonifacio	Isole Pelagie	Brjuni	
MPA managers	3	1	0	0	4	8
Scientists	5	7	3	1	8	24
Local Socio-economic	17	15	9	2	10	53
Public Authorities	12	3	28	1	8	52
Citizen Science	5	14	2	2	0	23
TOTAL	42	40	42	6	30	160

Methodologies and main outcomes

MONITORING

Tracking Climate-related transformations in the marine environment is crucial to support Integrate Coastal Zone Management (ICZM) and to inform maritime spatial planning (MSP). Nevertheless, the complexity of ecological transformation along with inadequate human and financial resources typically hampers our observation capabilities. To overcome these major drawbacks, the MPA-Adapt project has implemented, tested and made available a series of standardized technical tools that provide a practical guidance to monitor climate related responses in the coastal biota. The guiding principles and architecture of these tools respond to the requirements of the Ecosystem Approach undertaken under the auspices of UNEP/MAP Barcelona Convention, with the ultimate objective of achieving the Good Environmental Status (GES) of the Mediterranean Sea and coasts. Technically, these tools are inspired to the concept of Essential Climate Variables and focus on a restricted set of simple measurements to capture greater dimensions of environmental change. Indicators have been chosen on the basis of their scientific relevance, feasibility and cost effectiveness. The engagement of local stakeholders is another key feature in some of these methodologies. Adopting these protocols, allow participants to join to a common and consolidated strategy to track climate change effects. This will improve, complement or extend the ongoing monitoring initiatives in the different Mediterranean countries.

The implementation of monitoring activities was one of the main outcomes of the MPA-Adapt. The different protocols adopted by the MPAs provide information on indicators for 4 out 5 categories defined to track climate change in the Mediterranean MPAs by Otero et al. 2013 (**TABLE 2**).

TABLE 2

Categories of indicators to develop monitoring plans for climate change in MPAs extracted from Otero et al. 2013.

Following the evaluation of a long list of indicators by regional scientists using the criteria described above, five categories of indicators were selected as being of priority interest:
1. Physical and biochemical condition
2. Changes in reproduction and breeding dates of key species
3. Episodic events
4. Shifts in species distribution patterns
5. Migration changes

During the pilots MPAs applied the standardized monitoring protocols (See **ANNEX 2**) concerning the monitoring of temperature conditions, episodic mass mortality events and shifts in species distribution of fish indicator species. Besides, these protocols the MPAs, based in their needs and opportunity, applied other protocols informing on different aspects of climate change effects such as beach dynamics, mass mortality of the bivalve *Pinna nobilis*, the colonization by invasive macroalgae species (**TABLE 3** and **ANNEX 3**). Beyond the capacity building of MPA managers on climate change monitoring, the results obtained during the project are relevant contributing to our understanding on how warming is affecting at local as well as at regional level. For instance, MPAs reported mass mortality event impacts on macrobenthic species in 2018 which affected many areas in the Western Mediterranean and the involvement of recreational divers (through citizen science initiatives) provided good basis for tracking shifts in fish species distribution related to warming.

The protocols and approach applied within the framework of the MPA-Adapt, in coordination with other Mediterranean initiatives, demonstrated its great potential to develop solid monitoring networks on the large scale (Azzurro et al. 2019, Bensoussan et al. 2019b, Garrabou et al. 2019). The resulting picture helps to better understand the regional dimension of climate change impacts such as species redistributions (Albouy et al. 2013) and mass mortality events (Garrabou et al. 2019). Overall the adopted approach would provide the needed information to adaptive management.

TABLE 3

Summary of monitoring activities on climate change indicators in the MPA-Adapt Marine Protected Areas.* Categories of indicators following Otero et al. 2013.

MONITORING ACTIVITIES FOR CLIMATE CHANGE IN THE PILOT MPAs							
Protocol	**Category of indicator ***	**Indicator**	**Port-Cros**	**Portofino**	**Bonifacio**	**Isole Pelagie**	**Brijuni**
MONITORING ACTIVITIES FOR CLIMATE CHANGE IN THE PILOT MPAs							
Temperature	1. Physical and biochemical	Seawater temperature indicators	Two sites 8 depths, five sites one depth	Two sites 7 to 8 depths each	One site 9 depths, three sites four depths	One site 8 depths	One site six depths
Mortality	2. Episodic events	Mortality events, percent affected, conservation index	Gorgonians 10 sites	Gorgonians 3 sites	Gorgonians 3 sites	-	Sponges, corals 7 sites
LEK_1	3. Shift in species distribution	Long-term evolutions in fish captures	-	2 interviews, 13 fish sp.	13 interviews, 10 fish sp.	-	20 interviews, 27 fish sp.
LEK_2	3. Shift in species distribution	Warm/cold affinity fish indicator species	-	-	13 interviews	-	20 interviews
Visual census	3. Shift in species distribution	Warm/cold affinity fish indicator species	-	4 sites	-	-	4 sites
OTHER PROTOCOLS							
Weather	1. Physical and biochemical	Weather records	1 site	-	-	-	-
Soil moisture	1. Physical and biochemical	T, rain, moisture	2 sites	-	-	-	-
Coastal erosion	1. Physical and biochemical	Coastline and cliffs dynamics	14 sites	-	-	-	-
Pinna nobilis	2. Episodic events	Mortality events, percent affected	-	3 sites	11 sites	-	-
Posidonia oceanica	2. Episodic events	Health status, flowering events	-	-	5 sites	-	2 sites
Caulerpa cylindracea	3. Shift in species distribution	Settlement/ Distribution/Density	-	-	-	-	6 sites
Marine caves	Mapping and inventory	Benthic species	-	-	5 sites	-	1 cave

* Following Otero, M., Garrabou, J., Vargas, M. 2013. Mediterranean Marine Protected Areas and climate change: A guide to regional monitoring and adaptation opportunities. Malaga, Spain: IUCN. 52 pages.

VULNERABILITY ASSESSEMENTS

The development of the ecological and socio-economic vulnerability assessments has been tackled by a coordinated action among the five MPAs by fostering participatory approaches with specific groups of stakeholders. Despite the social and ecological heterogeneity of the MPAs involved, the assessment strategy primarily focused on a pre-identification of key habitats and an initial overview on the key issues and vulnerabilities affecting individual MPAs with their likelihood of occurrence (exposure) and possible consequences (sensitivity). Consequently, detailed vulnerability assessments were carried out on example habitats that were identified the risk was calculated by comparing information on the likelihood and the consequence (**TABLE 4**). Furthermore, the adaption capacity was estimated based on several ecological factors (**TABLE 5**). The main groups of stakeholders consulted over the process were researchers, small-scale fishers, recreational divers (e.g., scuba diving or freediving) and local communities.

Consultation with local fishermen in Portofino MPA (St. Margheritte de Ligure, Italy). © Portofino MPA

TABLE 4

General scheme in the assessing the consequences of climate change stressors.

CONSEQUENCES					
Likelihood	**Negligible**	**Minor**	**Moderate**	**Major**	**Catastrophic**
Rare	Low	Low	Low	Low	Low
Unlikely	Low	Low	Moderate	Moderate	Moderate
Possible	Low	Moderate	Moderate	High	High
Likely	Low	Moderate	High	High	Extreme
Almost certain	Low	Moderate	High	Extreme	Extreme

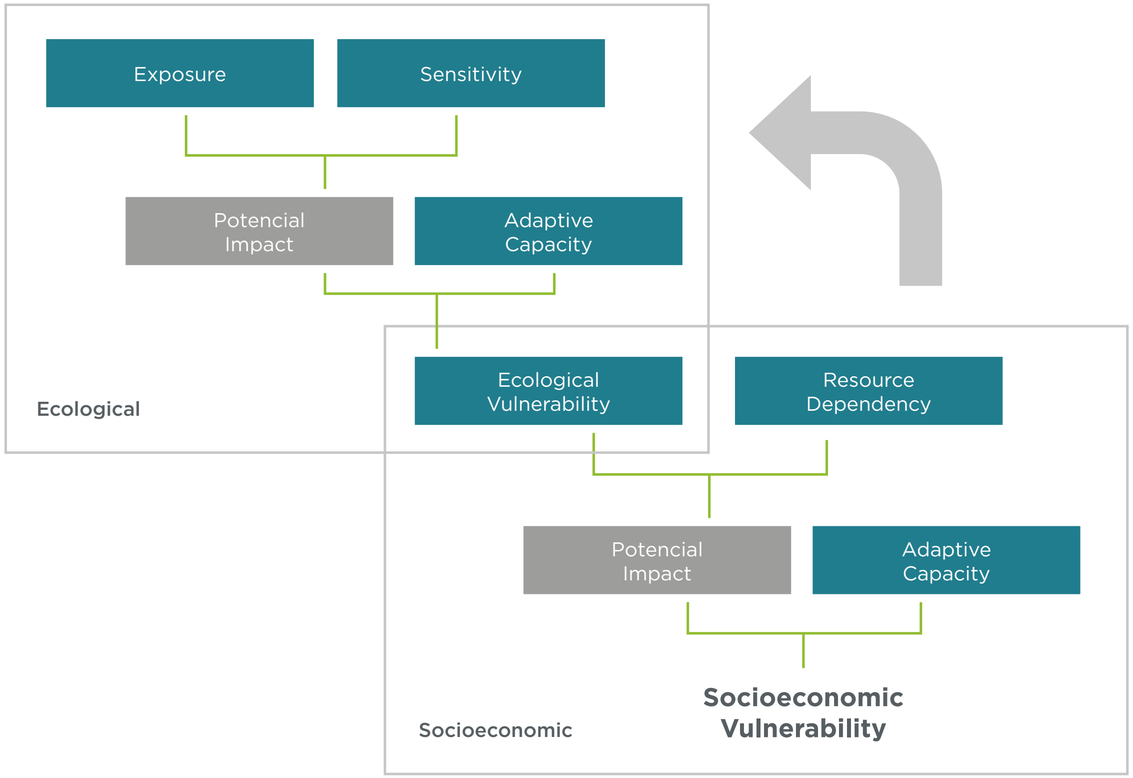
TABLE 5

General scheme in the assessing the adaptative capacity to the risk associated to climate change stressors.

CONSEQUENCES			
Risk	**Low**	**Moderate**	**High**
Low	Low	Low	Low
Moderate	Moderate	Moderate	Low
High	High	Moderate	Moderate
Extreme	High	High	Moderate

The assessments methodology for the socio-economic sector followed the common principles according to the hands-on training also provided to the MPAs managers during the project (**FIGURE 9**). Briefly, the vulnerability of ecological system has been used as a measure of the exposure of the socio-economic system (example: the vulnerability of commercially important fish species is a measure of the exposure to which the fishery will be subjected to); the resource dependence is used as a measure of sensitivity (example: if the fishery depends 100% on vulnerable fish species, they will have a higher sensitivity, i.e. the consequences of climate change will be higher); and the adaptive capacity as it refers to the ability of the socio-economic system to respond to the potential social impact (example: implementing a high frequency monitoring strategy). Such information has been gathered by integrating a deep bibliographic review, previously collected data (e.g., reports) and new acquired data (e.g., interviews).

FIGURE 9



Schematic workflow of the methodological approach used during the ecological and socio-economic vulnerability assessments (adapted from Marshall et al. 2013).

TABLE 6

Initial vulnerability (between parentheses) for the two most vulnerable habitats in each of the five MPAs.

MPA	First most vulnerable habitat	Second most vulnerable habitat
Port Cros	Coralligenous (moderate)	Posidonia meadows (moderate)
Bonifacio	Posidonia meadows (moderate-high)	Coastal lagoons (moderate-high)
Portofino	Coralligenous (high)	Posidonia meadows (high)
Isole Pelagie	Posidonia meadows ()	Shallow biogenic formations ()
Brijuni	Posidonia meadows (moderate-high)	Rocky habitats (moderate)

TABLE 7

Vulnerability (between parentheses) of the socio-economic activities targeted in each of the five MPAs.

MPA	Vulnerability score	Vulnerability score
Port Cros	Small-scale fisheries (moderate)	Diving (moderate)
Bonifacio	European spiny lobster fishery (moderate)	Nautical activity (moderate to high)
Portofino	Small-scale fisheries (moderate)	Diving (moderate)
Isole Pelagie	Small-scale fisheries Ongoing ()	-
Brijuni	Visitors (high)	Diving (moderate)

From an ecological perspective the assessments focused on five key habitats: coralligenous, Posidonia meadows, rocky habitats, infra-mesolitoral, soft bottom habitats, pelagic environment. The main common stressors identified were increasing water temperature, storms, precipitations, algae blooms and coastal erosion. Results indicated that climate change poses an overall medium risk to the ecological and socio-economic aspects related to MPAs (**TABLE 6**). Initial screenings indicates that the coralligenous and the Posidonia meadows emerged as the most endangered habitats with a vulnerability assessment score ranging between moderate and high vulnerable. Such wide range of variability in the assessment score can be explained by site-specific local conditions, as well as information available and should be carefully considered when integrating it for the adaptation plans. For example in Portofino MPA, *Posidonia oceanica* meadows is considered in a high vulnerability risk but at the same time it indicated an overall high recovery capacity with a strong potential for appropriate monitoring activities. By contrast, despite the coralligenous indicated the same vulnerability as *Posidonia oceanica* meadows, it has a slower recovery capacity. Regarding the socio-economic perspective, from the three sectors selected (fisheries, divers and tourism), small-scale fisheries and coastal tourism emerged as the most vulnerable activities with an overall medium vulnerability score (**TABLE 7**). Overall, water temperature increase and extreme storm events are the stressors that pose the main risks to these activities in the MPAs while others such as the increase of air temperatures or mucilaginous algal blooms are also mentioned. In some specific cases such as the MPA of Port Cros, mucilaginous algal blooms have been identified as an extreme risk to tourism as well as for recreational underwater activities.

In summary, MPAs are well concerned about the main ecological and socio-economic vulnerabilities that they need to tackle in the next future in the context of climate change. MPA-ADAPT supported them by focusing on common vulnerabilities, and at the same time, provided an adaptable conceptual framework to face site-specific problems that characterize each MPA.

Matrix Action Plan: Who? What? When?

Weather station setup at Port-Cros National Park as a measures included in Adaptation Plan in this MPA. © Port-Cros National Park

The five MPAs applied the proposed process, methodologies and participatory approaches with the quintuple helix of actors in view to define the adaptation action plan to climate change. From the result of the different activities, experiences and lessons learnt during the pilots studies, the MPAs proposed a series of measures according to six domains of action to be implemented and incorporated in the management plan.

The main domains concerning the measures are:

Technology

Reducing climate risk through technical actions and / or technology.

Research and Monitoring

Notes the need to further explore the climate change effects on natural ecosystems and resource use.

Awareness-raising, training

This refers to the general levels of education and learning awareness of issues such as climate change and its effects, and dissemination of information on climate to initiate changes in practices.

Protection

Recognizes the need to continue the protection actions of natural ecosystems and / or actions to mitigate the effects of climate.

Governance

This concerns the many aspects related to governance, the taking of decision-making and management to ensure sustainable management of natural resources, financial and human resources.

Regulation

Integrating climate change into legislation, institutions and the policies at work: this is about adapting institutions and policies to work by directly integrating climate issues and effects.

Overall more than 30 main measures have been proposed as adaptation for building resilience to climate change for coastal human activities and key marine habitats proposed to be implemented in the 5 MPAs. These adaptation measures are built to reduce the vulnerability by increasing adapting capacity or reducing exposure and the consequences of the effects made by climate change (**TABLE 8**).

These actions do not represent the entirety of what can be implemented to reduce vulnerability in each MPA but rather the ideas generated through a diverse and collaborative effort to identify potential actions that could be taken by the management authorities and the stakeholders to prioritize when addressing climate change.

Given that the amount of knowledge of climate change impacts is still limited at most sites, it is also important to take projected climatic changes into account when preparing updates of current management plans. Thus the identified adaptation actions contain a balanced portfolio of measures in order to support a sustainable and well-structured approach towards adaptation. These actions aim to address activities for the habitats identified as the most vulnerable in the assessment exercises taken by the MPAs, a series of proposed strategies to work to reduce the vulnerability on some key economic sectors (named artisanal fishing, diving and coastal tourism) as well as cross-sectoral management recommendations (**TABLE 8**).

Multiple raise awareness events were conducted in the MPAs during the project. An exhibition on climate change effects in Brijuni National Park (Croatia). © Brijuni National Park

TABLE 8

Proposed adaptation strategies by the 5 MPAs (Port Cros National Park, Réserve Naturelle de Bouches de Bonifacio, Portofino AMP, Isole Pelagie AMP and Brijuni National Park).

Vulnerability area	Domain	Strategy	Action measure	MPA implementing	When (present, < 5 years, > 5 years)
Diving	Awareness	Increase adaptive capacity	Sensitize divers about the effects of climate change on marine ecosystems	Port-Cros Bonifacio Portofino Brijuni Isole Pelagie	Present Present Present < 5 years Present
	Research and monitoring	Increase adaptive capacity	Engage divers in participatory monitoring to amplify and support the MPA capabilities to detect and quantify the ongoing ecological changes (e.g. invasive species, mass mortalities, population declines)	Port-Cros Bonifacio Portofino Brijuni Isole Pelagie	< 5 years < 5 years Present < 5 years Present
	Regulation	Reduce consequence (sensitivity)	Close/change diving paths in damaged sites with coralligenous or limit the presence of divers in affected sites	Portofino	< 5 years
Coastal tourism	Research and monitoring	Adaptive capacity	Evaluate the impact of tourist frequentation and disturbance (e.g. trampling) on sensitive species	Bonifacio Portofino Isole Pelagie	< 5 years < 5 years Present
	Protection	Reduce consequence (sensitivity)	Prevent fire risks by reinforcing surveillance, updating the fire programme and evacuation measures	Port-Cros Bonifacio Brijuni	Present < 5 years < 5 years
	Technology	Increase adaptive capacity	Optimize water consumption and improve availability	Bonifacio	< 5 years
	Awareness	Increase adaptive capacity	Develop communication activities to visitors on the current knowledge on climate change and its impacts, also providing information on good practices and illustrating the actions undertaken by the MPA	Bonifacio Portofino Brijuni Isole Pelagie	Present Present > 5 years Present
	Awareness	Increase adaptive capacity and likelihood (exposure)	Develop educational activities to raise ocean literacy among fishers and promote good practices	Port-Cros Bonifacio Brijuni	Present < 5 years Present

Vulnerability area	Domain	Strategy	Action measure	MPA implementing	When (present, < 5 years, > 5 years)
Artisanal and recreational fisheries	Research and Monitoring; Governance	Increase adaptive capacity	Access the knowledge of local fishermen (professionals and recreational) to detect signals of ecological change and engage them in a regular monitoring plan	Bonifacio Portofino Brijuni	Present Present Present
	Awareness	Increase adaptive capacity and reduce likelihood	Increase educational activities in order to make environmental consciousness in the population also promoting good practices	Bonifacio Portofino	Present Present
	Regulation	Reduce likelihood (exposure) and consequence (sensitivity)	Limit or ban the use of disposable plastic by fishers	Bonifacio Portofino	< 5 years > 5 years
	Regulation	Reduce likelihood (exposure) and consequence (sensitivity)	Apply restrictions on artisanal and recreational fishing in order to avoid or decrease damages on coralligenous habitat and loss of nets	Bonifacio Portofino	< 5 years < 5 years
	Research and Monitoring	Increase adaptive capacity	Evaluate the abundance and distribution of cold and warm water species to guide future adaptation measures	Bonifacio Portofino Isole Pelagie	Present Present < 5 years
	Research and Monitoring	Increase adaptive capacity	Develop specific research actions orientated to understand and fill the information gaps for key species targeted by artisanal fisher's sector	Bonifacio Portofino	< 5 years Present
	Economy	Increase adaptive capacity	Promote the consumption and commercialization of warm-water species of either native or exotic origin (e.g. *Pomatomus saltatrix, Callinectes sapidus*)	Bonifacio Portofino	Present < 5 years
	Governance	Increase adaptive capacity	Reinforce the partnership with fisheries associations for implementing adaptive management measures, with a special focus on the use of natural resources	Bonifacio Portofino Isole Pelagie	Present Present < 5 years
Posidonia habitat	Regulation	Reduce consequence (sensitivity)	Reinforce the implementation of existing regulations on anchoring and/or forbid anchoring activities on Posidonia meadows to reduce seagrass fragmentation	Portofino	Present
	Protection	Increase adaptive capacity	Implement restoration activities on protected/rare species	Bonifacio Portofino	< 5 years Present
	Research and monitoring	Increase adaptive capacity	Monitor the status of *Posidonia oceanica* meadows, depth limit and flowering events	Port-Cros Bonifacio Portofino Brijuni	Present > 5 years Present < 5 years
	Protection	Reduce livehood (exposure)	Preserve coastal forest to contain erosion	Port-Cros Brijuni	< 5 years > 5 years

Vulnerability area	Domain	Strategy	Action measure	MPA implementing	When (present, < 5 years, > 5 years)
Coralligenous habitat and communities	Technology	Increase adaptive capacity	Implement restoration activities of protected/rare species	Bonifacio Portofino	Present Present
	Research and monitoring	Increase adaptive capacity	Monitor the status of coralligenous communities and impacts	Port-Cros Bonifacio Portofino Brijuni	Present Present Present < 5 years
Rocky, soft and other infralittoral habitats	Protection	Increase adaptive capacity	Implement restoration activities of protected/rare species	Portofino	Present
	Research and monitoring	Increase adaptive capacity	Establish a monitoring programme for *Lithophyllum byssoides* to sea level rise	Bonifacio	Present
	Technology	Reduce likelihood (exposure)	Identify the locations that are critical for coastal habitat expansion and that have roads or infrastructure that reduce habitat connectivity and redesign them	Bonifacio	< 5 years > 5 years
Cross sectoral actions	Governance	Increase adaptive capacity	Upgrade the existing health management plan of the park with other organisations	Port-Cros Bonifacio Portofino Brijuni Isole Pelagie	< 5 years Present < 5 years < 5 years < 5 years
	Technology	Increase adaptive capacity	Develop pilot actions for reducing energy consumption and increase use of renewable energy	Bonifacio Brijuni	< 5 years < 5 years
	Awareness	Increase adaptive capacity	Continue developing the climate education activities	Bonifacio Portofino Brijuni	Present Present Present
	Research and Monitoring	Increase adaptive capacity	Deploy salinity and pH sensors on the MPA territory; set up weather stations and developing terrestrial monitoring protocols, especially on specific parameters such as drought.	Port-Cros Bonifacio Brijuni	Present < 5 years > 5 years
	Research and Monitoring	Increase adaptive capacity	Establish a baseline and continuous monitoring of beaches and cliffs to prepare future adaptation measures	Bonifacio	Present

The implementation of an effective Action plan is a major challenge for the MPA management bodies due the need for the acquisition of new competences, supporting new activities with scarcity of personnel and funding resources. However, the Plan for the implementation of the proposed adaptation measures should be for some actions feasible thanks to the capacity building and experience provided by the MPA-Adapt project. It is important to underline that the measures will concern the quintuple helix with almost 160 groups of actors across the 5 MPAs (**TABLE 1**). Besides most of the proposed measures are intended be implemented within the next 5 years (**TABLE 8**).

We contend that this climate change oriented package of measures will effectively guide the MPAs towards sound governance plans to support adaptation to climate change of the MPAs while contributing to put the Mediterranean MPAs network in the frontline to adapt to climate change.

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Annex 1:
Quintuple helix actors

ACTOR	PORT-CROS MPA
MPA managers	Conservatoire du littoral Communautés de communes du Golfe de Saint-Tropez Agence française de la biodiversité
Scientists	Conseil scientifique du Parc national de Port-Cros GIS POSIDONIE INRA Air Climat BRGM
Local Socio-economic Stakeholders	Conseil économique social et culturel du Parc national de Port-Cros Fédération Varoise des activités nautiques CRPMEM PACA Les amis de Porquerolles Association de sauvegarde des forêts varoises Agribiovar Association des amis du Parc national de Port-Cros Camping Pin de Galles Office du Tourimse du Pradet Office du Tourisme de la Croix-Valmer Office du tourisme de Ramatuelle Les amoureux de Porquerolles Guides partenaires du Parc national Pôle Mer Méditerranée Société nautique de l'île de Porquerolles Structures de plongée IUCN-Med
Public Authorities	Conseil d'administration du Parc national de Port-Cros Communauté de communes du Golfe de Saint-Tropez Métropole Toulon Provence Méditerranée Mairie de Hyères Mairie de La Garde Mairie du Pradet Mairie de Ramatuelle Mairie de La Croix-Valmer Mairie de Bormes-les-Mimosas Région SUD DREAL-PACA
Citizen Science	Les Petits Débrouillards France Nature Environnement Naturoscope Pêcheurs professionnels Science Tour Port-Cros 2017-2018 : 2 500 personnes

ACTOR	BONIFACIO MPA
MPA managers	
Scientists	Institute of Higher Education and Research: Universtà di Corsica The OEC also works with the CNRS, IFREMER within the framework of knowledge and awareness programs related to the CC
Local Socio-economic Stakeholders	The representant of the fishermen of Bunifaziu The President of the Comité Régional des Pêches Maritimes et Elevages Marins de Corse The representatives of the boatmen Representatives of scuba diving organizations Recreational fishermen's representatives Representatives of beach establishments The Union of Professionals of Outdoor Activities The Federation of the Nautical Industries The recreative boaters' Association
Public Authorities	Local public authorities: the municipalities of Porto Vecchio, Bonifacio, Pianottoli, Figari and Monaccia were informed of the programme at the meeting of the Advisory Committee of the Bouches de Bonifacio Nature Reserve. Regional public authority: the Corsican local authority is aware of the MPA- ADAPT activities. Local elected representatives representing local authorities or their groups: The President of the Executive Council of Corsica The President of the Corsican Environment Office The President of the Corsican Tourism Agency The President of the Corsican Agency for Sustainable Development, Urban Planning and Energy The President of the Corsican Economic Development Agency The Mayor of BUNIFAZIU The Mayor of PORTI-VECHJU The Mayor of MONACCIA D'AUDDE The Mayor of FIGARI The Mayor of PIANOTTOLI-CALDARELLO The President of the Community of Communes of South Corsica Representatives of the civil and military administrations and public institutions of the State concerned: The Prefect of Corsica The Maritime Prefect The Regional Director of the Environment, Planning and Housing of Corsica The Departmental Director of the Territories and the Sea of South Corsica The Departmental Director of Social Cohesion and Population Protection The Commander of the Navy in Corsica The Director of the Departmental Office of Veterans Affairs The Director of the French Biodiversity Agency The Interregional Delegate of the National Hunting and Wildlife Office The Regional Delegate of the Rhone-Mediterranean and Corsica Water Agency The Interregional Director for the Mediterranean Sea The Delegate of the Conservatoire de l'Espace Littoral et des Rivages Lacustres
Citizen Science	General public Recreational fishermen. During the meeting of the RNBB Advisory Committee and during consultation meetings, representatives of associations in southern Corsica for recreational fishing were made aware of MPA-ADAPT.

ACTOR	PORTOFINO MPA
MPA managers	MPA managers from Capo Mortola (Regional Marine Protected Area)
Scientists	University of Genoa
Local Socio-economic Stakeholders	Local fishermen cooperatives (Cooperativa Pescatori Camogli, Cooperativa La Calata, Cooperativa Portofino) NGO (Ziguele, Outdoorportofino, Posidonia green Festival) Diving Center (Diving Evolution)
Public Authorities	Santa Margherita Municipality Ventimiglia Municipality Coast Guard
Citizen Science	Sport fishermen associations (“La porticciolo”, “Lady Martina”) Local fishermen cooperatives (Cooperativa pescatori Camogli, Cooperativa La Calata, Cooperativa Portofino) Diving Center (Diving Evolution, Portofinodivers,Diving Group Portofino, Diving Nervi, Subassai ASD, Pianeta Blu ASD) Diving Association (PADI, DAN)

ACTOR	BRIJUNI MPA
MPA managers	Kornati National Park Mljet National Park Nature Park Telašćica Strunjan Landscape Park, Slovenia
Scientists	Faculty of Science of the University of Zagreb Center for Marine Research (CMR) of the Ruđer Bošković Institute in Zagreb D.I.I.V. Ltd., for marine, freshwater and subterranean ecology Institute of Oceanography and Fisheries, Split Juraj Dobrila University of Pula NGO Sunce, Split Eventor, Vrsar Fourlink
Local Socio-economic Stakeholders	Tourism Office Pula NGO Zelena Istra, Pula Istrian Development Agency (IDA) Ltd, Pula NGO WWF Adria NGO Biom, Zagreb Diving centre Pula Hippocampus diving center Diving club Loligo Geosfera d.o.o.
Public Authorities	Istrian Region City of Pula Public Institution Natura Histrica Ministry of Environment and Energy Ministry of Agriculture Public Institution Kamenjak City of Poreč Public Institution Priroda
Citizen Science	High school Pula

Annex 2:
Monitoring protocols

Garrabou J., Bensoussan N. & Azzurro E., 2018.
Monitoring Climate-related responses in Mediterranean Marine Protected Areas and beyond: FIVE STANDARD PROTOCOLS
36 pp. Edited by: Institute of Marine Sciences, Spainsh Research Council ICM-CSIC,
DOI: http://dx.doi.org/10.20350/digitalCSIC/8612

Annex 3:
Monitoring activities

MONITORING PLAN FOR CLIMATE CHANGE THE MPA PORT-CROS				
Protocol	**Category of indicator**	**Indicator**	**Next 5 years**	**Next 10 years**
MPA-ADAPT PROTOCOLS				
Temperature	1. Physical & biochemical conditions	Seawater temperature	Yes	-
Mortality	2. Episodic events	Mortality Eunicella singularis	Yes	-
LEK_1	-	-	-	-
LEK_2	-	-	-	-
Visual census	-	-	-	-
OTHER PROTOCOLS				
Monitoring of beaches and cliffs	1. Physical & biochemical conditions	Coastal erosion	Yes	-
Weather station	1. Physical & biochemical conditions	Meteorological data / soil moisture	Yes	-

MONITORING PLAN FOR CLIMATE CHANGE THE MPA BONIFACIO				
Protocol	**Category of indicator**	**Indicator**	**Next 5 years**	**Next 10 years**
MPA-ADAPT PROTOCOLS				
Temperature	3. Physical & biochemical conditions	Seawater temperature	Yes	-
Mortality	4. Episodic events	Percentage affected, conservation index	Yes	-
LEK_1	5. Shift in species distribution	Historical trends fish	Yes	-
LEK_2	3. Shift in species distribution	Periodic monitoring fish	Yes	
Visual census	-	-	-	-
OTHER PROTOCOLS				
Pinna nobilis	2. Episodic events	Mortality benthic species	Yes	-

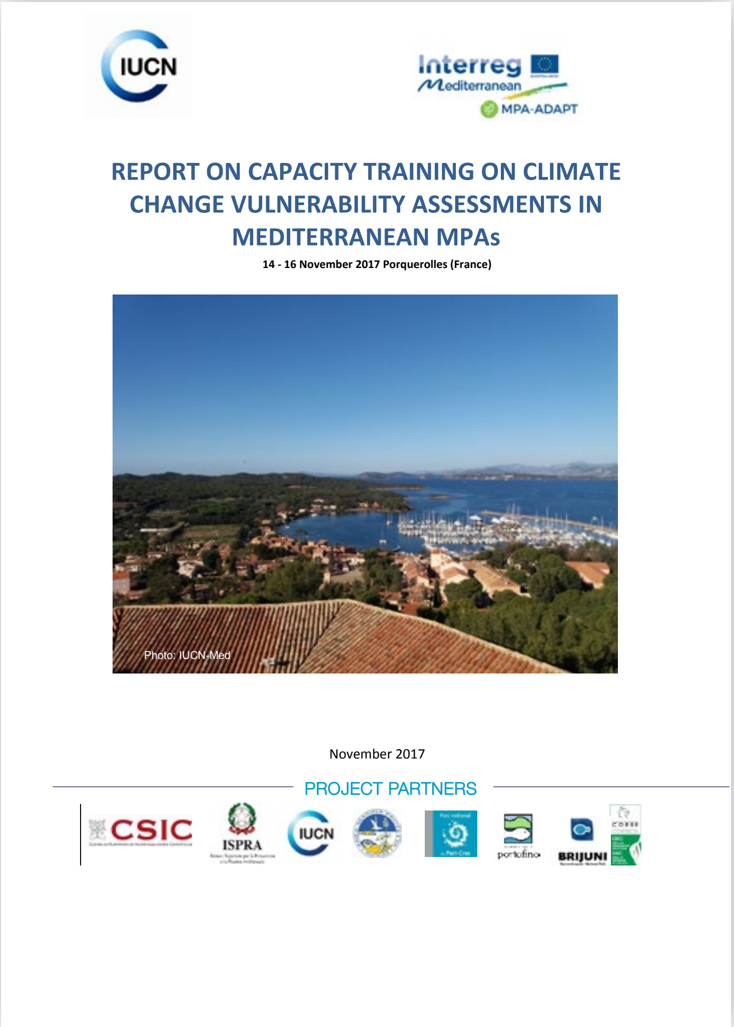
MONITORING PLAN FOR CLIMATE CHANGE THE MPA PORTOFINO				
Protocol	**Category of indicator**	**Indicator**	**Next 5 years**	**Next 10 years**
MPA-ADAPT PROTOCOLS				
Temperature	6. Physical & biochemical conditions	-	Yes	-
Mortality	7. Episodic events	Percentage affected, conservation index	Yes	-
LEK_1	8. Shift in species distribution	Historical trends fish	Yes	
LEK_2	4. Shift in species distribution	Periodic monitoring fish	Not implemented but planed for future	-
Visual census	3. Shift in species distribution	Periodic monitoring fish	Yes	-
OTHER PROTOCOLS				
Pinna nobilis	2. Episodic events	Mortality benthic species	Yes	

MONITORING PLAN FOR CLIMATE CHANGE THE MPA ISOLE PELAGIE				
Protocol	**Category of indicator**	**Indicator**	**Next 5 years**	**Next 10 years**
MPA-ADAPT PROTOCOLS				
Temperature	9. Physical & biochemical conditions	Seawater temperature	-	-
Mortality	-	-	-	-
LEK_1	10. Shift in species distribution	Historical trends fish	-	-
LEK_2	5. Shift in species distribution	Periodic monitoring fish	-	-
Visual census	3. Shift in species distribution	Warm/Cold affinity species	-	-

MONITORING PLAN FOR CLIMATE CHANGE THE MPA BRIJUNI				
Protocol	**Category of indicator**	**Indicator**	**Next 5 years**	**Next 10 years**
MPA-ADAPT PROTOCOLS				
Temperature	11. Physical & biochemical conditions	Seawater temperature	Yes	-
Mortality	12. Episodic events	Mortality benthic sponges/corals	upon funding	-
LEK_1	13. Shift in species distribution	Historical trends Fish	Yes	-
LEK_2	6. Shift in species distribution	Periodic monitoring fish	Yes	-
Visual census	4. Shift in species distribution	Periodic monitoring fish	upon funding	-
OTHER PROTOCOLS				
Pinna nobilis	2. Episodic events	Mortality benthic species	Yes	-
Invasive algae	3. Shift in species distribution	Settlement, presence, density presence	upon funding	-
Underwater caves	Inventory	Depth, shape, sp. list	No	-

Annex 4:

Vulnerability assessment training



REPORT ON CAPACITY TRAINING ON CLIMATE CHANGE VULNERABILITY ASSESSMENTS IN MEDITERRANEAN MPAs

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Photo: IUCN-Med

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