Manual 13

EUROPARC-ESPAÑA series of manuals
English Version

Protected Areas
in the Face of Global Change
Climate Change Adaptation in Planning and Management

EUROPARC ESPAÑA

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Protected Areas in the Face of Global Change

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English Version

EUROPARC-Spain. 2020
Protected Areas in the Face of Global Change. Climate Change Adaptation in Planning and Management.
Ed. Fundación Interuniversitaria Fernando González Bernáldez para los Espacios Naturales. Madrid. 116 pp.

Edited by
Fundación Interuniversitaria Fernando González Bernáldez para los Espacios Naturales

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Editorial design and production
gráfica futura

Cover photo
Sierra de Guadarrama National Park.
Photo: José Antonio Atauri

ISBN
978-84-940457-8-3

The publication in English of this document has been carried out within the framework of the project "Co-Adaptation 2021: collaborative knowledge to accelerate adaptation to climate change "with the support of the Biodiversity Foundation of the Ministry for the Ecological Transition and the Demographic Challenge (call 2018).

This manual has been produced in the context of the projects:

Adaptation to climate change in the planning and management of protected areas in Spain, commissioned by the Spanish Office for Climate Change to the Fernando González Bernáldez Foundation and EUROPARC-Spain.

Promote adaptation to climate change in the management of protected areas in Spain. Call 2016 for the implementation of projects on adaptation to climate change of the Biodiversity Foundation, of the Ministry for Ecological Transition.

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Monfragüe Special Protection Area. Photo: Javier Puertas

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Peñones del Santo Natural Monument. Photo: Javier Puertas

Foreword

Protected Areas in the Anthropocene. Going Beyond Human-Caused Climate Change

Holocene is the name given by geologists for the recent 11,000 year period (approx.) in the history of the Earth in which the overall climate of the planet has been relatively stable, with the temperature fluctuating about 1°C. During this period, agriculture and human civilization appeared. However, since the industrial revolution 240 years ago, which represents 0.1% of the timespan of the human species, contemporary civilization has been built on an economy based on intensive use of fossil energy, primarily coal, oil and gas. As a result of this economic model the concentration of greenhouse gases in the atmosphere has increased considerably and alarmingly, causing an increase in global temperature of almost 1°C. Other consequences are ocean acidification, changes in water, carbon and nitrogen cycles, and loss of biodiversity.

The evidence - supported by empirical data - shows that we have entered a new geological period called Anthropocene, in which humans are modifying the global geochemical processes which drive the ecosphere, including the climatic system, to a greater degree than natural phenomena. Anthropogenic climate change is credible evidence of human capacity to influence ecological systems on a planetary scale.

In this context, the fifth IPCC report on Climate Change points out the difference between climate variability, or naturally occurring change, compared to anthropogenic climate change attributable to human activities. This is important, especially for Mediterranean systems, characterized by high biological diversity and complex socio-ecological resilience, because institutional climate change policies can disregard natural climate variability, the unpredictability of rainfall and susceptibility to drought, flood or fires affecting the integrity and resilience of ecosystems. Human beings, through a series of traditional socio-ecological practices, coupled with this natural climatic variability, have shaped Mediterranean cultural landscapes into an "adaptive dance" between the socio-cultural system and the biodiversity of ecosystems.

Often, and in order to control the increasing frequency of climate disturbances, strategies to "fight" climate change do not take into account naturally-occurring socio-ecological variability, and consequently propose policies based on short-term benefits (e.g. perverse subsidies that diminish or ignore local ecological knowledge), or technological solutions that diminish the resilience of ecosystems (as in the case of water management projects designed to control hydrological variability). When socio-ecological systems lose resilience they become more vulnerable, whereby even small disturbances can precipitate an undesirable change, adversely affecting biodiversity conservation and the health of ecosystems, consequently impinging upon the well-being of local communities. Adequate levels of ecological resilience, therefore, are essential in order to respond to severe disturbances associated with human-caused climate change. Thus, in climate change strategies, it is important to recognise natural climate variability which determines, in large part, the resilience of ecosystems. We should not forget that the history of life, of ecosystems and of human beings is the history of the climate of our planet.

During the Anthropocene, patterns or rhythms of change considered "natural" to the planet, including the climatic ones, have been modified, giving rise to an emerging and complex socio-ecological process called Global Change. Within Global Change the relationship between nature and society no longer happens just on a local or regional basis, but also at a planetary level. We cannot overlook that we live on a human planet.

Global Change is characterized by the so-called drivers of change. On the one hand there are the direct drivers, or sets of factors, of anthropogenic origin, which impact the essential processes of ecosystems, and therefore conditioning ecosystems' capacity to generate services that support human well-being.

Six direct drivers of fundamental change are considered: changes in land use, induced climate change, water, soil and atmospheric pollution, invasive alien species, changes in biogeochemical cycles and over-exploitation of geodetic and biotic components of ecosystems. In Spain, as in other countries where the United Nations International Millennium Ecosystem Assessment Project has been carried out, the most important direct driver of Global Change is not man-induced climate change - as popularly thought and denounced in many environmental forums - but changes in land usage demanded by economic growth. These changes, namely rural evacuation on the one hand and urbanization and agricultural intensification on the other, are factors which largely destroy and degrade ecosystems and, therefore, carry the greatest responsibility for loss of biodiversity. It is clear that changes in land use and induced climate change are mutually inter-related (for example, logging or burning forests for agricultural use will increase greenhouse gases in the atmosphere). In any case, both direct drivers are not perceived by society in the same way, since changes in land use act directly, visibly and in the short term, while induced climate change does so indirectly, less obviously, and in the medium or long term.

Direct drivers of change are mainly caused by six socio-political processes, called indirect drivers of change: economic, demographic, social, gender, science and technology and cultural policies. These policies act in a synergistic and diffuse manner, affecting one or more direct drivers of change, which generate environmental impacts affecting the conservation of ecosystems and their biodiversity. It is important when designing the effectiveness of conservation policies to differentiate between strategies or programmes that act on the effects or direct drivers of change, and those that affect the causes or indirect drivers of change. It is clear that if we seek to halt the loss of biodiversity, conservation policies should not only focus on minimizing the effects of direct drivers of change, but also on managing the causes of indirect drivers.

In this context, the number and extent of protected areas has increased almost exponentially in recent decades, and continues to grow today. However, this formal legal institution, which constitutes the cornerstone of conservation policies, is not effectively stopping the sixth mass extinction of species on the planet which is already underway. This can be explained by the fact that the application of various protection targets is an essential response to minimize the effects of the most important direct driver of global change: changes in land uses that degrade and destroy ecosystems. However, protected areas were not designed to manage the effects of economic or demographic policies which do not promote integrated territorial planning and which give rise to these destructive changes in land use. Only by the 'greening' of policies producing territorial impact can the destruction of ecosystems and loss of biodiversity, caused by this intensification of land use driven by economic growth, be halted. Thus, although protected areas play an essential role against the destruction of ecosystems, they are not usually enough to protect fundamental ecological processes: they do not manage to stop, in the medium and long term, the loss of biodiversity.

Global Change is characterised by promoting rapid, intense, nonlinear and globalizing changes that build uncertainty frameworks in which, generally speaking, neither individuals nor institutions, including protected areas, are equipped to face the management challenges linked to its two most important direct drivers of change: land use and induced climate change. Therefore the environmental and conservation problems associated with these direct drivers should be addressed from systemic and complex perspectives. In this context, static institutions with inflexible structures are more vulnerable to new patterns of change established by Global Change. This is the case of protected areas, whose rigidity is reflected in many management plans based on sectoral, reductionist or change-defiant analysis. It seems clear that the concept of protected area as it was created in the nineteenth century and developed in the twentieth century should be reviewed in the twenty-first century to embrace the new challenges posed by Global Change.

First of all it is important to bear in mind that the effects of induced climate change will be felt in the same way and with similar intensity within ecosystems and within biodiversity "inside" and "outside" of protected areas. This will pose new challenges for managers because, as the climate changes, fixed administrative boundaries will be unable to stop both the increase in the negative effects of intensive land use, as well as changes in the composition and diversity of biological communities, inside the protected environment areas. Many threatened species whose habitats are protected by law will move beyond the administrative jurisdiction of protected areas, increasing their risk of extinction. This shows that in the context of Global Change the problems of protected areas are increasingly social and transcend their administrative boundaries.

Secondly, and within so-called "natural solutions" to environmental problems, networks of protected areas are considered an essential tool to minimize induced climate change effects, by playing a key role in mitigation and adaptation processes. Regarding the mitigation process, protected ecosystems store large amounts of carbon in the vegetation and soil as well as capturing carbon dioxide from the atmosphere. As regards adaptation processes, protected area ecosystems sustain local climate and reduce the risk of disasters caused by extreme events such as floods, droughts, hurricanes, storms, tsunamis, etc.

The response from conservationists in the face of these new challenges posed by induced climate change, is to try to minimize the effects of displacement of protected species outside the established boundaries of natural spaces, and to enhance mitigation and adaptation processes within global, national and regional climate change strategies, and to continue increasing the network of protected areas both in number and area, despite the political, economic and social costs that this proposal implies. From the world of environmental administration the question arises, how much protected territory is enough? Who should bear the costs of this protection? These issues arise in a context in which Target 11 of the Strategic Plan for Biological Diversity 2011-2020 of the Convention on Biological Diversity has almost been met, which advocates the legal protection of 17% of terrestrial and inland water habitats and 10% of marine waters.

The strategy of focusing biodiversity conservation policies on creating more extensive and numerous protected areas, and of mitigating the effects of induced climate change within these areas, makes the surrounding territory invisible. This makes conservation programmes focus on the protected areas rather than managing the territory where they develop their objectives. This territorial myopia makes it politically easier and more profitable to declare new protected areas in order to minimize, in the short term, the adverse effects of intensive land use and induced climate change, rather than demand an integrated plan for the territory that addresses the causes of an unsustainable territorial model.


Posets-Maladeta Natural Park. Photo: Carlota Martínez


Peñones del Santo Natural Monument. Photo: Javier Puertas

Consequently, although protected areas can contribute to minimizing the undesirable effects of induced climate change, it is also essential to manage their causes, the indirect drivers of change, which should be reflected in structural changes of energy, infrastructure, transport, financial and industrial policies. Among policies which need most profound changes are those related to land use, which should aim to prevent degradation or destruction of terrestrial and aquatic ecosystems. Given the large area of protected territory that currently exists worldwide (13% of the continents) or at national level (more than 27% in the case of Spain), protected areas can play a fundamental role in coordination and collaboration to develop new cohesive and sustainable territorial models. From this perspective, protected areas would no longer be static isolated areas seeking to minimize the effects of unsustainable land use and induced climate change, but instead become means to coordinate and integrate the overall policies on managing the causes of intensive uses that destroy ecosystems and their biodiversity within the entire region. Under this framework, protected areas can play an essential role as the backbone of a territorial system with a socio-ecological basis, building resilient territories able to meet the challenges associated with global change discussed above.

Another recognized benefit of protected areas in the Anthropocene is to view protected ecosystems, and the biodiversity which they host, as natural capital which, if preserved, generates a rich and varied flow of beneficial outcomes, contributing directly or indirectly to human well-being. It brings an anthropocentric dimension to protected areas, beyond the intrinsic values of conservation of threatened species' habitats, to reconnect this legal entity with the local population, under the premise that there is no conservation without development, or vice-versa. With this approach protected areas would no longer be a means in which public resources are invested for the conservation of species and their habitats, and become increasingly a social product that also addresses cultural roots and the well-being of society. In the Anthropocene, conservation begins to be an increasingly social and participatory concept, and protected areas are closer to a socio-ecological than an ecological concept. They are conceptualized as an integrated system of humans in nature – socio-ecosystems - managed collaboratively between scientists from different disciplines, managers and the local population, via participatory processes.

From this new socio-ecological approach to protected areas for human well-being, it is essential to heed both the Aichi Targets of the Convention on Biological Diversity and the Sustainable Development Goals (SDGs) promoted by the United Nations. The 2030 Agenda aims for all countries and their societies to take a new path to improve their quality of life. Given that proposals to meet the targets of each SDG are developed locally, and that the global network of protected areas is extensive, it could be useful to cite different objectives for their fundamental role in the conservation of terrestrial (SDG15) and marine (SDG14) ecosystems, as well as to influence other goals, including the fight against climate change and its effects (SDG13).

But perhaps the most important challenge facing protected areas in the Anthropocene, to prevent them from becoming static legal institutions in a changing world, is to develop a new dynamic and adaptive governance system. Instead of creating isolated local areas attempting to minimise the effects of Global Change, a new system might focus on strategically managing the direction and conditions of an overall socio-ecological change, to avoid degradation of the essential ecological processes that determine the integrity and resilience of protected ecosystems. In short, management plans should respect the biophysical limitations of protected and unprotected ecosystems. Protected areas in the Anthropocene should learn to avoid the unmanageable and manage the inevitable. For this reason, new plans should embrace the inevitable changes within socio-ecological systems, explaining the stability of legal regulations instead of assuming legal stability and explaining ecological change.

In this context EUROPARC-España, with the support of the Fernando González Bernáldez Interuniversity Foundation for Natural Spaces, has launched a strategic document, entitled Society and Protected Areas. This document, addressed to public administrations and social and professional groups, includes the transversal principles and basic strategies to support a gradual and adaptive transition of Spain's network of protected areas towards the new socio-ecological context defined by Global Change in the Anthropocene in the general terms that have been explained.

Through a comprehensive conceptual framework integrating all the strategies included in this Programme, we seek to endorse systemic thinking and trans-disciplinary scientific knowledge to promote socio-ecological processes of creation, innovation, education and experimentation, so that protected areas evolve from being an end in themselves to becoming an essential tool in the development of an integrated territorial plan with a socio-ecological basis, whose aim is to promote the well-being of the local population. This objective justifies the Programme subtitle: "protected areas for human well-being".

The Programme presents Spain's protected areas as addressing the effects of induced climate change, not in an isolated way but in the context of the emerging Global Change process. A systemic vision of the management of direct drivers of change is proposed. This means that regional networks are prioritized in socio-ecological territory planning, and not solely in the management of the effects of induced climate change. It distinguishes between management efforts to minimize the effects of environmental impact on ecosystems and biodiversity, and the policies or causes which promote it. In this sense, unlike the general perception, induced climate change would not be the cause of degradation of ecosystems and the erosion of biodiversity, but the effect of unsustainable policies having a territorial impact. The Programme also seeks to manage the direct drivers of Global Change synergistically, requiring coordination of management programs of the six components (intensive land use, induced climate change, pollution, change in biogeochemical cycles and over exploitation of some supply services). Finally, it tries to focus management programmes not only on the components of ecological and social systems, but especially on the complex and binding relationships that exist between the two. It is in this context that Manual 13 of EUROPARC-España on "Protected areas in the context of global change" has been developed. "Climate Change Adaptation in Planning and Management" in its second revised and expanded version.

Two years remain to renegotiate the Strategic Plan for Biological Biodiversity (2011-2020). The new Goals that are proposed for the next decade should focus more on action and less on conversation. Beyond protecting the habitats of threatened species, actions aimed at accepting the new role of protected areas are necessary, highlighting their contribution to the well-being of local populations and society in general, their role in the integrated planning of the territory, and their contribution to the processes of mitigation and adaptation to induced climate change. But it is not enough to accept the new social and economic functions granted to protected areas which build high expectations in the world of conservation. It is necessary to support them politically and financially, so that these formal legal institutions can evolve with Global Change and not be victims of it in an environment full of disturbances, uncertainty and surprises. In short, if we do not make protected areas part of the territory and of society, who will protect them?

Carlos Montes del Olmo
President
Fundación Interuniversitaria
Fernando González Bernáldez

Sierra de Grazalema Natural Park. Photo: José Antonio Atauri

1 Executive Summary

Global change is a complex process, the result of the interaction of a number of factors affecting the operation of biophysical processes on a global scale. Land use changes, alterations in biogeochemical cycles, biological invasions, pollution and the over-exploitation of natural resources, as well as climate change, are the main factors driving global change and their effects are evident at both the global and the local scale.

The implications of climate change for the operation of ecosystems are already perceptible and extremely abundant evidence is available in the scientific literature. Chapter 2 shows that evidence has been collected on the effects of global change at all organizational levels: changes in genetic variability, in physiology, in demographic structure, in phenology and the lifecycles of many species, in distribution patterns, or in ecological processes such as productivity, material cycles and, in short, changes in the provision of services to society.

The evidence of global change, and of climate change in particular, has triggered a number of significant responses in the international arena, including those highlighted by the United Nations Framework Convention on Climate Change, which in turn has led many countries to adopt strategies and plans to address climate change.

Global climate models foresee that the decades ahead will see an increase in the overall temperature of the planet. The international community has established an increase of 2°C in the mean temperature across the globe above pre-industrial levels as an acceptable limit for the change by the year 2100. In order to face the effects of climate change two strategies are possible: mitigation (reducing the amount of CO_2 in the atmosphere) and adaptation, which consists in reducing the vulnerability of ecological and social systems to the impact of climate change by increasing their resistance or resilience (i.e. the ability to recover after disruption).

Insofar as they are inserted in a wider territory, protected areas are also subject to the effects of global change. The conservation targets for protected areas are in line with the adaptation goals as one of the main strategies to minimize the impacts of climate change on the ecosystems and biodiversity they accommodate. In this way, the maintenance of the ecosystems in good condition, namely with a high resilience and capable of supplying environmental services in the context of climate change, is considered to be one of the main pillars of this adaptation strategy in protected areas, known as "Ecosystem-Based Adaptation".

Nonetheless, the consideration of climate change in the targets for protected areas requires the reconsideration of certain criteria and a new management approach contemplating general recommendations, as set out in Chapter 5:

- Adopt a global, integrating perspective that considers protected areas and the territory in which they are located as a functional unit.
- Manage uncertainty by basing decision-taking on the best scientific information, constantly evaluating the outcomes of any actions taken.
- Incorporate change as a process that is always present and increase the ability of ecosystems to adapt to the new environmental conditions and their disruptions.
- Develop new governance tools for a new context, incorporating a larger number of agents, improving social support and sensitization on the effects of global change.

The various types of management plans are the tools in which the targets to be achieved in protected areas and how they are to be achieved are made explicit. They are therefore the main and most important tool in which to include criteria enabling a management style targeting adaptation.

However, while other drivers of climate change (changes in land use, invasive species or pollution) are well identified and habitually targeted in management plans, the attention shown to climate change is very scant, often non-existent. Chapter 6 develops how to consider climate change in all phases of the planning process:

- During diagnosis, where it is obviously important to count on good characterization of the climate as well as to have regionalized climate scenarios, so that forecasting adapts as closely as possible to the territory in question.
- In the phase for the identification of objects to be preserved, which must specify those most vulnerable to climate change.
- In the setting of targets, which may be explicit in terms of adaptation.
- In the measures proposed to achieve the targets, which will be aimed at increasing the resilience of the objects to be preserved.
- Moreover, the entire process must be based on the best scientific evidence available, foresee a monitoring and assessment system, and consider the importance of participation and communication processes.

When designing management actions, it is possible to consider adaptation criteria. For this purpose, these actions should have certain distinctive characteristics:

- Expressly bear in mind the new foreseeable climate scenarios.
- Contribute to the ecosystems' ability to recover (resilience) following the effects of extreme events derived from climate change.

- Be based on scientific evidence or on the best available understanding of the effects of climate change on the elements or processes on which action is taken.
- The outcomes, in terms of improvement in the ability to adapt to or mitigate the effects of climate change, must be demonstrable and quantifiable.
- The project must contribute to achieving the targets for the protected area and, therefore, be in line with the higher-level planning instruments.

In general, it can be said that adaptation measures, from the standpoint of Ecosystem-Based Adaptation, must aim to keep ecosystems in good conservation status, and so with the greatest resilience possible. These measures will be different depending on the local characteristics and specificities but, starting from existing case studies and scientific references, it is possible to offer general guidance by major types of ecosystem.

Alto Lozoya Special Protection Area. Photo: Javier Puertas

2 Presentation

The effects of global change are the result interactions between several simultaneous processes: changes in land uses (especially agricultural abandonment, changes in agricultural policies), biological invasions, pollution and overexploitation of some natural resources, and climate change. The first of these have always been the object of preferential attention in the planning and management of protected areas, and thus management plans tend to deal profusely with regulating changes in land uses, eliminating pollution problems, ensuring sustainable use of natural resources and, where they exist, control or eliminate invasive alien species.

However, climate change has not been the protected area manager's main focus, and plans that expressly consider it are scarce. As the effects of climate change are becoming evident, it is necessary to develop criteria that consider adaptation to climate change in the management of protected areas, so that international and national policies will begin to prioritize this issue, even with specific financial instruments (such as the Spanish Ministry of Fisheries, Agriculture, Food and Environment PIMA-Adapta Plan, which since 2015 has financed climate change adaptation action in the National Park Network and of ecosystem adaptation).

In this context the objectives of this document are:

- to offer a common conceptual basis and general principles for the development of adaptation to climate change in protected areas, and
- to provide a practical tool for consideration of criteria for adaptation to climate change in the design or evaluation of management plans and in the design of management measures.

This document contains, in addition to a review on the importance of climate change in protected areas, principles for general application to climate change issues in the management of protected areas, criteria to be followed in the process of drafting plans for management to consider adaptation to climate change, and recommendations for the identification of adaptation measures. In addition, an online tool and checklist have been developed to apply to drafted plans or during the participation or public information phase, which allows assessing the degree to which they address climate change. (http://www.redeuroparc.org/proyectos/adaptacion).

This manual is produced in the context of the Society and Protected Areas Programme, promoted by EUROPARC-Spain (EUROPARC-España, 2016). It aims to incorporate scientific and technical knowledge in the field of climate change into the planning and management of our protected areas, offering a practical tool to those responsible for drafting management plans and designing conservation action.

2.1. Methodology

To produce this document, in parallel with a bibliographic review of the institutional context and scientific-technical literature, a survey of protected area managers and researchers was conducted in order to assess the importance attached to climate change and the most relevant aspects of it, and to identify cases of good practice. The survey was conducted online over two months (December 2015 - January 2016), compiling the responses of 70 managers and 85 researchers.

In addition, a content analysis of a representative sample of various management plans (natural resource management plans, management and use plans, and Red Natura 2000 management tools) was carried out, recording to what extent climate change in general, and adaptation in particular, were contemplated in these documents. A total of 60 management plans were analysed.

Progress in drafting the document has been shared with protected area managers and researchers on four occasions: two seminars in Valsaín (in April and December 2016) and a workshop in the Esparc Congress (Laguardia, June 2016), as well as in the Europarc 2017 Congress (Portugal, September 2017). These forums helped to identify cases of good practice, the compilation of adaptation measures by ecosystem type and the selection of criteria for including adaptation in the drafting of management plans.

During the participation process 22 adaptation projects in protected areas were identified, which have been included as demonstrative cases in the Database of Conservation Actions of EUROPARC-Spain (wikiconservacion.org).

The proposed procedure has been applied in seven pilot cases (only available in the full version in Spanish)

- Management plan of Sierra de Santo Domingo Protected Landscape (Zaragoza)
- Management Plan update of Teide National Park (Tenerife)
- Management Plan of the Bahía de Cádiz Natural Park
- Natura 2000 Management Plan for the Sierra Norte de Guadalajara Special Conservation Zone
- Natura 2000 Management Plan Urbasa and Andía Special Conservation Zone (Navarra)
- Management measures for the Río Milagros River Reserve (Segovia)
- Forest director plan of Monte de los Enebrales (Zaragoza)

Delta del Ebro Natural Park. Photo: Javier Puertas

Menorca Biosphere Reserve. Photo: Javier Puertas

3 Global Change and Climate Change

3.1. Global Change

The term “global change” includes the set of environmental changes produced by human influences, with special reference to changes in processes which determine the functioning of the Earth system (Duarte, 2009). Although the change is inherent to the functioning of ecosystems, two circumstances are unique in the current process of global change: its speed and the fact that the activity of a single species (the human being) is the main driver. It is also characterized by affecting the planet globally, although its effects manifest differently in different places.

Global change is the result of the interaction of factors that act directly on the biophysical processes of ecosystems and therefore affect the flow of services they provide, the so-called direct drivers (Duarte, 2009; Millennium Ecosystem Assessment, 2011):

- Land use changes, on the one hand artificialisation of land (urbanization) and agricultural intensification, and on the other hand abandonment of traditional practices and ecosystem management in rural areas, with consequences such as loss or degradation of habitats and fragmentation.
- Induced climate change: changes in precipitation and temperature patterns on a global scale, due to human action, with direct consequences on the functioning and distribution of species and ecosystems, and on the concomitant services provided from these to society.
- Pollution, especially of inland waters, and intensive exploitation of ecosystem supply services. Especially overfishing in the marine environment and overexploitation of aquifers, with serious consequences to wetland ecosystems linked to groundwater discharge processes.
- Invasions by exotic species are the second most important cause of biodiversity loss in the Mediterranean. The global translocation of species, linked to intense human activity, has profound effects on the functioning of ecosystems.
- Changes in bio-geochemical cycles due to the effects of human activity. In addition to the alteration of the carbon cycle (with an increase in the concentration of CO_2 in the atmosphere and oceans), human activity has accelerated the fixation of nitrogen, which in turn produces an increase of N_2O in the atmosphere, and has markedly increased concentrations of sulphur compounds, with implications for air, water and climate quality.

It is very important to keep in mind that direct drivers are actually the consequence of the so-called “indirect drivers” of change: socio-political factors and processes that act in a more diffuse way, altering the functioning of ecosystems through their action on direct drivers of change. The main indirect drivers of change are demographic, economic, socio-political, gender, science and technology, and cultural (Millennium Ecosystem Assessment, 2011).

Global change cannot be understood as a simple cause-effect phenomenon, but is due to multiple causal relationships, many of them nonlinear, that have effects at different spatial and temporal scales. That is why one of its characteristics is the difficulty of predicting its evolution. In practice, this uncertainty makes decision-making difficult for environmental policy managers. Therefore, as part of the strategies aimed at avoiding or limiting the consequences of global change, it is necessary to “build capacity for adaptation” in the face of global change in institutions, in planning processes and in decision-making. Protected areas need to adapt their management models to the changing world of the 21st century, in their social, economic and ecological dimensions, in order to continue offering society the rich and varied flow of services that contribute to its well-being.

3.2. Components of Climate Change

According to the results of the V Evaluation Report of the Intergovernmental Panel on Climate Change (IPCC), warming of the climate system is indisputable, manifested in a rise in the average temperature of the atmosphere and of the oceans, a decrease in the amount and extent of snow and ice masses, as well as the increase in sea level (MAGRAMA, 2014a).

Climate change is caused by imbalances in the Earth’s energy balance, by both natural and anthropogenic agents. This change in energy flows is known as radiative forcing (RF). Total anthropogenic RF is positive; it has a positive component (increase in

Intergovernmental Panel on Climate Change (IPCC)

The Intergovernmental Panel on Climate Change (IPCC) is the scientific-technical reference for decision-making in the negotiation processes of the United Nations Framework Convention on Climate Change. 195 countries are members of the IPCC.

The work of the IPCC is the result of voluntary contributions of thousands of scientists from all over the world, whose main product is the Evaluation Reports. The fifth report published in 2014, provides a synthesis and assessment of existing scientific and technical knowledge about climate change.

https://www.ipcc.ch/report/ar5/index_es.shtml

Climatic models

Global climate models are the main scientific tool for predicting future scenarios. These are mathematical models that predict climatic parameters by means of equations based on a series of variables (e.g. latitude and longitude, or insolation (incoming solar radiation) among others, and also the concentration of greenhouse gases).

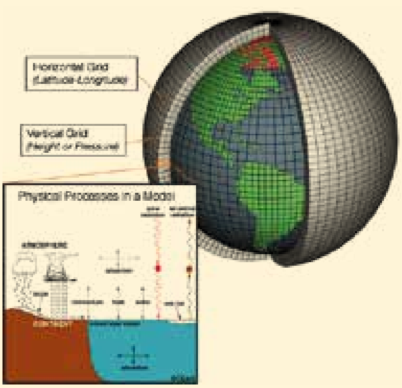
In these simulations, the planet is divided into a three-dimensional grid of cells in the order of hundreds of kilometres. Equations are applied to each cell, taking into account their interactions with adjacent cells.

These simulations are validated from long data series, so their reliability for past and current weather prediction can be quantified. Global models reliably simulate the main features of the current global climate on the planet and produce satisfactory results at hemispheric and continental levels.

To determine future climate scenarios, the simulators are loaded with hypothetical concentrations of greenhouse gases and other atmospheric variables, which represent possible future emissions of these gases. This gives a range of values for the different climatic variables analysed.

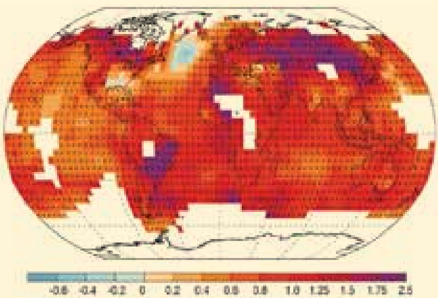
Global climate models, due to their low spatial resolution, are not suitable for carrying out detailed climate change studies since these require more definition, of the order of kilometres, or even information on specific locations. To solve this problem, the so-called “regionalization” or downscaling techniques have been developed, whose objective is to increase the resolution of global models.

Global atmospheric model scheme



Source: NOAA

Change in average annual temperature 1910-2012
Trend (°C in the period)



Source: MAGRAMA, 2014a

energy) of human origin, mainly due to the increase in the concentration of greenhouse gases in the atmosphere since 1750, and a much smaller negative one with a high degree of uncertainty, due to the cooling effect of aerosols and their interaction with clouds. Thus, greenhouse gases have contributed to heating between 0.5 and 1.3ºC in the period 1951-2010, while aerosols contribute to cooling between 0.6 and 0.1ºC.

Due to the great inertia of the climate system and the persistence of greenhouse gases in the atmosphere, all scenarios (including the one that assumes a reduction in CO_2 concentration) predict an increase in average global temperatures for the year 2100, from 1°C on average in the most favourable scenario, to 3.7°C in the least favourable.

In all scenarios, to varying extents, increases in average temperatures, greater frequency and intensity of extreme temperature events, increased frequency and intensity of heavy rainfall, and greater severity of extreme events are expected (floods, droughts, storms, fires). In the oceans, an increase in temperature and water acidification is expected, together with an increase in sea level and alterations in ocean circulation.

In any case, these effects will not occur homogeneously around the planet, but will differ in and within each bio-geographic region, with nuances at local level in which uncertainty in the prediction is greatly increased.

In the Mediterranean Region an increase in temperature above the global average is expected, more pronounced during summer months, ranging between 3.8ºC and 6.0ºC by the end of the 21st century, as well as a reduction in precipitation of around 12% in winter and 24% in summer. At the same time there will be an increase in the frequency of torrential rain (MAGRAMA, 2014a). In fact, increases in the frequency and intensity of extreme events such as heat waves or droughts, reduction of river flows and more forest fires are already experienced. From the point of view of the use of resources, there has been an increase in competition between different uses of water, with greater demand from agriculture. In the Atlantic Region, the changes already observed include, among others, an increase in very intense rainfall and winter storms (and associated damage), and an increase in the frequency and intensity of floods. Mountain regions report above-average temperature increases, loss of surface glaciers and an increase in distribution areas of many species (European Environment Agency, 2017).

3.3. Impact of Climate Change on Biodiversity

The effects of anthropogenic climate change on biodiversity are the subject of great attention by the scientific community, as evidence on a global scale is becoming very abundant, pointing to climate change at every level. The scientific literature

Climatic scenarios

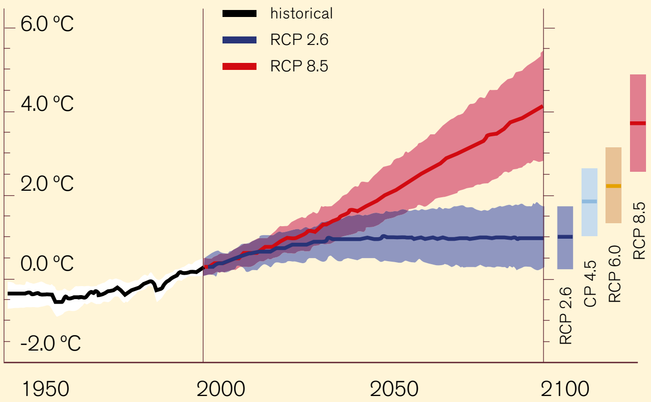
In order to evaluate future climate change projections, the IPCC has designed four scenarios with increasing rates of radiative forcing for the year 2100 (Representative Concentration Pathways or RCP), in which different alternatives are considered in greenhouse gas emissions, from increase to decrease.

	Radiative Forcing (RF)	RF Trends	[CO_2] in 2100
RCP2.6	2,6 W/m^2	decreasing in 2100	421 ppm
RCP4.5	4,5 W/m^2	stable at 2100	538 ppm
RCP6.0	6,0 W/m^2	growing	670 ppm
RCP8.5	8,5 W/m^2	growing	936 ppm

Using these emission scenarios, applied to global climate models, future climate scenarios can be predicted.

		2046 - 2065		2081 - 2100	
Variable	**Scene**	**Average**	**Probable range**	**Average**	**Probable range**
Average surface temperature change (°C)	RCP2.6	1.0	0.4 - 1.6	1.0	0.3 - 1.7
	RCP4.5	1.4	0.9 - 2.0	1.8	1.1 - 2.6
	RCP6.0	1.3	0.8 - 1.8	2.2	1.4 - 3.1
	RCP8.5	2.0	1.4 - 2.6	3.7	2.6 - 4.8

Evolution of the change in the global average temperature for different emission scenarios



Source: MAGRAMA, 2014a

records cases of changes in genetic variability and adaptive evolution processes or hybridisation, alterations in physiology (fertility changes, activity rates, sex ratio, resistance disease or survival) or even morphology (changes in colour or size in some species have been attributed to climate change). Changes in the phenology of many species are already well known (advance in bird migration, flowering and germination of plants or the dates of fish spawning), as well as variations in demographic dynamics (changes in profusion, in age distribution or recruitment of many populations). Variations in the patterns of distribution of species and habitats, following climatic changes, both in altitude and latitude, are among the most studied phenomena. The above changes sometimes trigger de-synchronization of relations between interdependent species (for example between predators and prey that do not co-exist in space or time), or new interactions due to the colonization of previously absent species (for example, by "tropicalization" or "borealization"). From the perspective of ecosystems, changes in primary productivity, marine biomass, erosion rates or material flows have been documented, as well as the impact on many services provided by ecosystems (Moreno, 2005; MAGRAMA, 2014b; Scheffers et al., 2016; Bellard et al., 2012; see Doney et al., 2012 for a review).

On a global scale, mountain, wetland and marine ecosystems formed by slower-growing communities (coral reefs, Posidonia meadows) as well as coastal ecosystems are identified as more vulnerable to climate change, due to the direct threat posed by retreating coastlines.

In Spain, evidence of the effects of climate change on biodiversity has been studied for years and the bibliography is constantly growing. Pioneering studies demonstrating the effects on the phenology of migratory birds can be cited, for example the decoupling between their life cycles and those of their prey (Sanz et al., 2003).

Another relevant issue has to do with changes in the distribution of some species, linked to shifts in climatic conditions for their continued existence. For example, changes in the altitudinal distribution of butterflies in the Central System have been documented (Wilson et al., 2005), or the colonization of summit areas by broom (Sanz-Elorza et al., 2003) or of bryophytes in the Canary Islands (Lloret and Gómez-Mancebo, 2011).

The compilation of scientific literature by Herrero and Zavala (2015) collates the available evidence of the effects of climate change on forests. Alterations in the phenology, physiology and demography of communities and ecosystems have been verified. There have been changes in the date of foliation, leaf fall, flowering and fruiting of several tree species in the north of the Iberian Peninsula, which are associated with the increase in temperatures. Precipitation reduction is associated with greater forest decay, which is characterized by a reduction in tree growth and higher mortality in some forest species and higher incidence of defoliation (Carnicer et al., 2011).

The high Mediterranean mountain ecosystems are most sensitive to climate change, due to their high proportion of endemic species, with small populations, specific habitat requirements and limited dispersal capacities. Abundant evidence of the effects of climate change, such as changes in productivity and abundance of some species, alteration in migratory patterns or changes in the area of habitat and species distribution, has been noted (Escudero et al., 2012; Zamora et al., 2015; OPCC-CTP, 2018).

In rivers and wetlands, changes in the hydrological balance and increase in average water temperatures will be key effects affecting the working of these ecosystems, especially in the upstream movement of cold water communities (CEDEX, 2012).

As for the marine environment, there is consensus amongst scientists that climate change is producing changes in the seasonal activity patterns of organisms and processes, acidification and increase in ocean temperature, increase in sea level and changes in the wind system which affect the processes of mixing and upwelling (e.g., lower intensity of upwelling in the peninsular NE), together with the disappearance of keystone species (Losada et al., 2014; Kersting, 2016).

These changes in the functioning of ecosystems have in turn effects on the flow of services they provide to society (Millennium Ecosystem Assessment of Spain, 2011).

3.4. The Role of Protected Areas in the Face of Climate Change

Ecosystems present in protected areas, just as everywhere else, are exposed to the effects of climate change, which effects are already evident. But since protected areas concentrate a territory's most valued natural resources, the negative effects of climate change on biodiversity can be considered qualitatively greater.

Considering all Spain's protected areas, the managers survey shows that 60% see enough evidence of the effects of climate change. Based on the responses received, this evidence can be grouped into: changes in the climate (meteorological parameters and frequency of extreme events), phenological changes (which are unequivocally linked to climate change), changes in the distribution of vegetation (with reference to a good number of specific and documented cases), changes in the distribution patterns of various species of fauna and flora, as well as their reproductive outcomes (lower regeneration, lower fruiting), as well as alterations in key biophysical processes such as soil formation, amongst others. Table 1 summarizes the different types of evidence cited in the survey, with some illustrative examples.

Table 1. Main evidence of climate change observed in protected areas, with illustrative examples provided in the survey of 70 managers of Spanish protected areas.

Changes in meteorological parameters

- Decrease in snow days
- Decrease in the permanence time of snow on the ground
- Fewer extreme cold days
- Alteration of summer temperature and rainfall patterns
- Decrease in annual average precipitation
- Temperature increase in the marine surface layer (0-50 m) marina (0-50 m)

Higher incidence of extreme weather events

- Longer droughts
- Increased risk of forest fire
- Increase of cold drop phenomenon
- Increase in flood frequency
- More frequent or intense sea storms

Phenological changes

- Delay in leaf loss of deciduous species
- Earlier flowering
- Changes in the reproductive seasons of birds and butterflies
- Changing habits of migratory birds
- Alterations in the pollination process

Changes in vegetation distribution

- Rising tree line. E.g.: Increase in altitude of pine forests of *Pinus sylvestris*, *Abies pinsapo*, and *Pinus nigra* ssp *salzmanii*
- Extinction (local) of high mountain species (for example, *Antennaria dioica*)
- Regression of deciduous forest (yew, *Sorbus*, etc.)
- Substitution by more xeric species (adapted to drier environment): loss of cork oak groves in favour of the olive tree; oak decay and replacement by *Phyllirea latifolia* and other species
- Expansion of invasive species and tropicalization of species in marine areas
- Proliferation of ivy (*Hedera helix)*
- Displacement or disappearance of humidity loving species and habitats (peat bogs).

Changes in wildlife distribution

- Rise in the lower distribution limit of 18 species of mountain butterflies
- Changes in the composition of *Rhopalocera* species
- Arrival of more southerly distribution species (very marked in odonates)
- Expansion of invasive species and tropicalization of species in marine areas

Changes in the reproductive success of species

- Some species' life cycle affected (e.g. decreased reproductive success of the European pied flycatcher (*Ficedula hypoleuca*) due to mismatch with biological cycles of its prey)
- Decreased fruiting in *Fagaceae*
- Reduction or difficulties in regeneration of tree species

Vulnerability to diseases and pests
- Higher incidence of forest pests (scolitids)
- Higher incidence of oak decline in dehesas
- Increase of diseases of wetland animal species
- Collapse in certain areas of artificial restocking and holm oak groves (drying and death in *Pinus pinaster*, and temporary drying in *Quercus ilex* groves on rocky substrate)
- Mass mortality of benthic communities
- Mass mortality (75%) of gorgonians (*Elisella paraplexauroides, Eunicella*) between 0 and -25 m depth

Alteration of biophysical processes
- Changes in hydrological functioning in lagoons
- Increasing salinity of fields
- Changes in the coastline and coastal erosion (rising sea level)
- River salt-wedge
- Loss and decrease in flow of water sources and springs
- Changes in the nutrient cycle and edaphic (soil) layer formation

In addition to verifying this evidence of climate change, 77% of managers considered that there are specific habitats and species populations that can be deeply modified as a result of climate change. Table 2 shows examples of habitats and species most sensitive to climate change cited in the survey. As can be seen, practically all the major habitat types appear (forest, pasture, steppes, wetlands, coastal/marine), with some characteristic species linked to them.

Table 2. Habitats and species identified as sensitive to climate change in the survey of 70 managers of Spanish protected areas.

Habitats and species in the altitudinal distribution limit
Subalpine forests and meadows, supraforestal habitats
Beech forests, *Quercus pyrenaica* forest, *Taxus baccata* forests, high mountain shrubs
Psychroxerophilic grasses, snowdrift and sedge vegetation
Fauna: European smooth snake, snowy partridge, partridge, grouse, ermine, *Parnassius apollo*
Flora: *Leontopodium alpinum, Diphasiastrum alpinum, Ranunculus amplexicaulis, Silene ciliata, Geranium cinereum, Ramonda myconi, Dryopteris mindshelken*sis

Relict formations linked to wet or cold conditions
Alpine tundra, mesophilic forests
Abies pinsapo
Macaronesian relict forests (laurisilva)
Species linked to humid micro-habitats in dry or sub-humid areas (e.g.: *Pinguicula vallisneriifolia, Narcissus longispathus*)

Forests at their distribution limit
Quercus ilex and *Quercus rotundifolia* oak groves
Mediterranean (southern) pine forests of endemic black pines

Aquatic or semi-aquatic habitats Flood meadows Peat bogs Riverine forests
Steptic type habitats and species
Habitats of anthropic origin Mown pastures and meadows, sub-atlantic grazing pastures Dehesas (open oak forests)
Coastal habitats and species Halophilic marshes, coastal lagoons, intertidal areas Coastal forests Dune habitats
Habitats and marine species *Posidonia meadows*, Maërl, *Cladocora caespitosa*, gorgonian reefs, benthic communities

Predicted changes in climate and the effects they are already having on ecosystems and biodiversity require rethinking the role of protected areas, incorporating climate change as one of their priorities (Araújo, 2011a).

By their very nature, protected areas present an opportunity to develop climate change response strategies. In the first place, due to their great extension and status: globally they comprise 20.6 million square kilometres of land and 12 million square kilometres of sea, representing 15.4% of the world's land area and 3.4% of seas and oceans. In Spain, protected areas represent 27% of the land area and 8% of the marine area (EUROPARC-España, 2017).

But in addition, due to their governance structures (legal framework, social participation mechanisms, participation instruments), the existence of planned management, greater means for monitoring and surveillance, and the presence of field technicians, they are scenarios where climate change response strategies can be developed (Dudley et al., 2010).

Protected areas can contribute significantly to the response to climate change by developing climate change response strategies in several complementary directions (IUCN-WCPA, 2004; Dudley et al. 2010):

- Prevent the loss of carbon that is already captured in vegetation and soils, (protecting, or restoring where appropriate, ecosystems with high carbon storage capacity, such as forests, peat bogs or sea grass beds among others), and avoid the degradation of natural ecosystems with higher rates of atmospheric carbon sequestration. Many of these ecosystems can go from being carbon deposits to net emitters, depending on their management methods.

- Maintain the capacity of ecosystems to cushion extreme disturbances (such as floods, storms, droughts or sea level rise), and maintain (or restore) ecological functions that provide essential ecosystem services to society, reducing the vulnerability of humans.
- Develop long-term monitoring systems for the effects of climate change and disseminate the results. Provide evidence of the consequences of climate change on the functioning of ecosystems.

Therefore, networks of protected areas, both for their extension and for the variety of ecosystems they include, can be an important instrument in the management of global change, offering one of the most effective 'natural solutions' against the climate crisis (Hansen et al., 2003; Dudley et al., 2010 The World Bank, 2009; Harley and Hodgson, 2008; Game et al., 2010; Lhumeau and Cordero, 2012).

Protected areas, scenarios for research and monitoring of climate change

Monitoring and evaluation of the effects of global change in the Spanish Network of National Parks includes a **Monitoring and Evaluation Plan and a Research Programme** (Bonache et al., 2015). Research carried out in this programme over the last decade has permitted documentation of very varied effects of climatic change, including the withdrawal of snowfields in Picos de Europa and Sierra Nevada, changes in the distribution limits of high mountain vegetation and fauna, the effects on physiology or behaviour in populations of mountain birds, reptiles and amphibians. In addition, changes in the aquatic systems have been revealed, for example in the composition of *Ephemeroptera* and *Plecoptera* species in the Aigüestortes rivers, increase of biomass in Daimiel or alterations in the carbon and nitrogen cycles of the mountain rivers of Aigüestortes, as well as impacts on marine ecosystems in Cabrera (García Fernández, 2017).

The **Sierra Nevada Global Change Observatory** (wiki.obsnev.es), linked to the natural and national park, already has enough data to start generating useful results for management. The effects of climate change detected in this protected area are consistent with those already observed in other places: a shorter duration of snow cover, phenological changes in flora and fauna, or altitudinal displacement of some species (Zamora et al., 2015).

Monfragüe National Park. Photo: Javier Puertas

4 Adaptation to Climate Change

4.1. Strategies Against Climate Change

The global climate models developed by the IPCC foresee that in coming decades the global temperature on the planet will increase, regardless of the greenhouse gas emissions scenario already considered. In the Paris agreement of 2015 the international community agreed that an increase in global average temperature of 2ºC above pre-industrial levels was an acceptable limit for the year 2100, but to persevere with efforts to limit that increase to only 1.5°C, recognizing that this would significantly reduce the risks and effects of climate change.

Beyond this it is considered that the risks associated with climate change could reach dangerous levels, with consequences too serious to be countenanced (UNFCCC, 2016). However, although different emission reduction policies will have tangible effects on the scope of long-term change, due to the inertia of the climate system the change will occur, even if emissions were to be completely eliminated.

To cope with this change by maintaining warming below the established threshold of 2ºC, and reducing risks as much as possible, two complementary strategies are proposed (IPCC, 2007):

- **Mitigation:** policies and actions aimed at reducing sources and emissions of greenhouse gases (substitution for goods and services with lower emissions, new technologies, improving the effectiveness of current ones, using renewable energy), and increasing the atmospheric carbon capture rates and their fixation in 'carbon stores' such as forests or peat bogs.
- **Adaptation:** reducing the vulnerability of ecological and social systems to the impact of climate change, increasing their resilience (or ability to recover after a disturbance).

The IPCC proposes in its latest Evaluation Report (2014) a varied mix of adaptation approaches to address the impacts of climate change, which include structural, institutional and social measures, among others. Table 3 summarizes these and presents some generic examples.

Table 3. Typology of adaptation measures and some generic examples.
Adapted from MAGRAMA, 2014

Adaptation options by categories		Examples related to biodiversity and ecosystems
Physical Structural	Engineering	Control, regulation, protection and stabilization structures; adaptation of infrastructure and equipment located in vulnerable areas; relocation
	Ecosystem based	Restoration and conservation of ecosystems; conservation of biological diversity; habitat creation; connectivity enhancement; green infrastructure; natural solutions based on ecosystem services
	Goods and services of the economic system	Adaptation of vulnerable systems and infrastructure associated with provision of local basic services (water, electricity, transport, communications) and public use and tourism
Social	Education, training	Integration in educational programmes; training and technical training; creation of information exchange platforms, learning and good practice; creation of cooperation networks; organization of seminars, workshops, conferences, conferences
	Information, Research	Mapping of danger, vulnerability, risk; compiling high resolution databases of indicators; early warning and response systems; climate services; evaluation and monitoring of ecosystem impacts; development of impact projections; development of new scenarios, creation of research networks
	Behaviour	Awareness-raising; volunteering; evacuation plans; diversification of activities in risk areas; changes in land use and public use
Institutional	Economy	Financial incentives including taxes and subsidies; insurance; economic evaluation of ecosystem services
	Laws and regulations	Territorial planning; sectoral planning; civil protection; building and construction codes
	Plans and programs	Management plans for protected areas; local adaptation plans; risk management programmes; concession management; integrated watershed management; integrated management of coastal areas; participatory management, intra and inter-administrative coordination

4.2. Adaptation to Climate Change on the International Agenda

Evidence of climate change has made it necessary to include it in the political agenda and in the development of the different sectoral policies, including those related to biodiversity and protected areas, especially in the international arena (for a review see Harley and Hodgson, 2008; CONANP, 2012; Dudley et a., 2010; Magrín 2015).

The United Nations Framework Convention on Climate Change (UNFCCC) aims to stabilize greenhouse gas concentrations in the atmosphere at a level that prevents dangerous anthropogenic interference in the climate system.

During the 16th Conference of Parties (COP 16; Cancun 2010), signatory States adopted the Cancun Adaptation Framework giving adaptation the same priority as mitigation. This Framework aims to improve action for adaptation through international cooperation and the active consideration of issues related to adaptation within the scope of the Convention. The Cancun Adaptation Framework promotes strengthening the resilience of socio-economic and ecological systems, through means such as economic diversification and sustainable management of natural resources.

The 21st Conference of Parties (COP 21; Paris 2015), which resulted in adoption of the Paris Agreement, was a milestone in the United Nations Framework Convention on Climate Change's international negotiations. The Agreement establishes, inter alia, to keep the increase in global average temperature below 2ºC compared to pre-industrial levels – but making an extra effort to keep this increase below 1.5ºC -, as well as counting on everybody's response to meet the challenge. The Agreement also includes a key aspect: the impacts of climate change are already being felt and will not stop increasing if greenhouse gas emissions are not stopped urgently. Therefore, it considers adaptation to climate change as a common objective for all countries. This objective seeks to strengthen resilience to reduce vulnerability to climate change. In addition, the Agreement also recognizes that mitigation and adaptation are two sides of the same coin in that the greater the reduction of greenhouse gases, the lower the need to adapt to the impacts of climate change.

After COP21, the Marrakech (COP22) and Bonn (COP23) Climate Summits, in 2016 and 2017, set a calendar for preparing the Paris Agreement Work Programme, which should be finalized in 2018 (COP24 Katowice)[1]. This Programme includes the rules with which to interpret each area of the Agreement.

The United Nations Framework Convention on Climate Change is the main international inter-governmental forum for negotiating the global response to climate change, but

1—After Katowice other COP have taken place developing the Paris Agreement

Sustainable Development Objectives (2015-2030)

Objective 13: Adopt urgent measures to combat climate change and its effects

Aims: Strengthen resilience and adaptive capacity to climate-related risks and natural disasters in all countries.

Incorporate climate change measures into national policies, strategies and plans.

Educate, raise awareness and improve human and institutional capacity to mitigate climate change, adapt to it, reduce its effects and provide early warning.

Implement the commitment made by developed countries to The United Nations Framework Convention on Climate Change to jointly mobilize $100,000 million annually by the year 2020, from all sources, to meet the needs of developing countries with the cost of mitigation and transparent application, and put into operation and capitalize the Green Climate Fund as soon as possible.

Promote mechanisms to increase capacity for effective climate change planning and management in least developed countries and small developing States, focusing in particular on women, youth and local and marginalized communities.

Strategic Plan for Biological Diversity 2011-2020 and the Aichi Targets

Strategic objective D: Increase benefits of biodiversity and ecosystem services for all.

Objective 15: By 2020, to increase resilience of ecosystems and the contribution of biological diversity to carbon stocks through conservation and restoration, including restoration of at least 15% of degraded land, thus contributing to climate change mitigation and adaptation, as well as the fight against desertification.

the fight against climate change is also amongst the priorities of other global forums and their strategic documents, as in the case of the Strategic Plan for Biological Diversity 2011-2020 of the Convention on Biological Diversity and also the Sustainable Development Objectives within the 2030 Agenda.[2]

With regard to protected areas, the Convention on Biological Diversity is the international reference, and its Work Programme on Protected Areas is one of the main tools for developing mitigation and adaptation strategies to climate change, prioritizing opportunities to use protected areas within the framework of climate change response strategies. The objective “Substantially improve the planning and administration of site-based protected areas” includes “Integrating climate change adaptation measures into

2—Under the auspices of the United Nations Environment Programme (UNEP), the Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES) works to strengthen the scientific-political interface on biodiversity and ecosystem services, in order to contribute to the conservation and sustainability of biological diversity, human well-being and development. It aims to identify, prioritize and evaluate the available scientific information, to generate the necessary knowledge to support decision-making and policy development (https://www.ipbes.net).

protected area planning, management strategies" (Secretariat of the Convention on Biological Diversity, 2004).

4.3. Adaptation to Climate Change in European Policies

Climate change and its effects on different sectors of activity are evident in the European Union, measurable and recognized in official documentation (European Environment Agency, 2017). In the EU, the process of defining adaptation policies began in 2007 with the implementation of the Green Paper on Adaptation, continued in 2009 with the White Paper on Adaptation, and culminating in 2013 with the European Climate Change Adaptation Strategy, with a 2013-2020 horizon (García et al., 2015). Objectives include promoting adaptation within Member States, the expansion and dissemination of knowledge about adaptation and promotion of adaptation in vulnerable sectors. It envisages initiatives to integrate climate change adaptation into biodiversity policies, including the planning and management of the Natura 2000 Network. As a complement to the adaptation strategy, the European Commission also has guidelines for the development of environmental adaptation strategies. (ETC/ACC. 2010; European Commission, 2013a).[3]

Adaptation also features in other sector strategies. Regarding conservation, the European Biodiversity Strategy 'Our life insurance, our natural capital: a biodiversity strategy of the European Union by 2020' should be highlighted, following commitments approved at the tenth meeting of the Conference of Parties to the Convention on Biological Diversity, 2011.

This Strategy aims to protect and improve Europe's biodiversity status over the next decade, and part of the premise is that the most efficient approach to loss of biodiversity and adaptation to climate change is based on maintenance and restoration of the integrity of ecosystems, and with it the services (supply, regulation, cultural) that they provide to society. The European Biodiversity Strategy underlines the importance of addressing climate change in the European Union, specifically through effective management of the Natura 2000 Network.

The strategy comprises six priority objectives that address the main factors of biodiversity loss, seeking to reduce the major pressures on nature and ecosystem services, and integrating biodiversity objectives into key sectoral policies. Among its goals are the contribution to mitigation and adaptation to climate change and the fight against invasive species.

3—Online tool for applying the guidelines for the development of environmental adaptation strategies: http://climate-adapt.eea.europa.eu/adaptation-support-tool/key-principles

On the other hand, the European Commission's Green Infrastructure strategy: improvement of the natural capital of Europe (COM (2013) 249 final), proposes biodiversity and the Natura 2000 Network as key elements in stimulating development of Green Infrastructure and its close relationship with adaptation to climate change[4].

On the subject of protected areas, in 2010 the European Environment Agency published guidelines for adaptation to climate change (ETC/ACC, 2010), and in 2013 a further document of guidelines incorporating mitigation and adaptation to climate change in Natura 2000 management (European Commission, 2013b) based on five general principles:

- Reduce existing pressures.
- Ensure the heterogeneity of ecosystems.
- Increase connectivity.
- Safeguard conditions for the abiotic environment.
- Manage the impacts of extreme weather events.

As a result of approval of the Strategy by the European Commission, some Member States have developed their own national strategies (Spain, United Kingdom, Denmark, France, Germany; see MAGRAMA (2016) for a review).

For its part, the latest global strategic document for biosphere reserves includes among its objectives the contribution to climate change mitigation and adaptation (UNESCO, 2016).

4.4. Adaptation to Climate Change in Spanish Policies

In Spain, the National Climate Change Adaptation Plan (PNACC) was adopted in 2006 as a national reference and coordination framework for initiatives and activities to assess impacts, vulnerability and adaptation to climate change. The key elements of the PNACC are summarized in (García et al., 2015):

- Integration of adaptation to national regulations and planning and management of sectors vulnerable to climate change.
- Development and dissemination of future climate projections in Spain, with regionalized climate scenarios.
- Strengthening of coordination between national, regional and local administrations.
- Establishment of alliances with public and private partners.

4—During the preparation of this English version the European Green Deal and the EU 2030 Biodiversity Strategy are under development

National Climate Change Adaptation Plan - Lines of action in the field of Biodiversity

Amongst measures, activities and lines of work for impact evaluation, vulnerability and adaptation related to Biodiversity to be carried out in the development of the National Adaptation Plan, the following can be mentioned:

- Assessment of impact of climate change on goods and services provided by different ecosystems.
- Assessment of vulnerability to climate change of key Spanish habitats and taxa: mapping the vulnerability of Spanish biodiversity.
- Evaluation of protected natural area networks (including Natura 2000 Network) in climate change scenarios: environmental connectivity, latitudinal and altitudinal gradients, establishing of 'reserve areas' aimed at reducing impact associated with climate change, etc.
- Evaluation of *ex-situ* conservation measures, in response to potential impacts of climate change.
- Incorporation of climate change as a variable to be considered in ecological systems restoration projects.
- Promotion of greatest possible genetic variability in ecosystems as the basis for adaptive capacity to climate change.
- Consolidation of long-term ecological monitoring networks and integration of data to detect the effects of climate change.
- Identification of a system of biological indicators of impacts of climate change, and definition of measurement protocols for a surveillance and early warning system.
- Evaluation of carbon balances for different types of ecosystems.
- Evaluation of the effects of climate change on invasive species.
- Development of predictive models based on responses of species and communities to change and projections of regional climate models.
- Evaluation of climate change effect on biodiversity in hydrological/aquatic environments; ecological water demands and resource allocations.
- Evaluation of activities aimed at promoting carbon sinks and their (positive or negative) effect on biodiversity.

The National Climate Change Adaptation Plan operates through Work Programs which have already produced results in its four areas of action - sectoral impact assessment, regulatory integration, mobilization of players and the establishment of a system of indicators - and its two basic pillars - administrative coordination and the strengthening of R&D&I oriented to the needs of the Plan.

The Third Work Programme of the National Climate Change Adaptation Plan 2014-20, currently in operation, explicitly states the need to integrate adaptation into planning of protected areas, by incorporating it into planning instruments as a scheduled activity. Literally, the Third Work Programme identifies among its lines of activity the following:

> 'Development of guidelines to integrate adaptation into the instruments of natural resource management and planning and management of protected areas. Pilot

trial in Natural Resource Management Schemes (PORN) and Master Plans for Use and Management (PRUG)'

The autonomous communities, in carrying out their competencies, develop and maintain planning frameworks and a series of initiatives in the field of adaptation to climate change (OECC, 2014). The development of strategies or plans to face climate change varies in the autonomous communities, as well as the degree of commitment implied, which is reflected in the regulatory range used to approve plans and strategies.[5]

Regarding nature conservation legislation, the Strategic Plan for Natural Heritage and Biodiversity 2011-2017 (Royal Decree 1274/2011, of September 16) approved in Law 42/2007 on Natural Heritage and Biodiversity, integrates the main lines of work of the National Climate Change Adaptation Plan, which are considered in the reference framework.

Adaptation to climate change is reflected in recent Spanish legislation on protected areas. Thus, Law 33/2015 of September 21, which updates Law 42/2007 of December 13, on Natural Heritage and Biodiversity contains an objective related to climate change: 'i) The prevention of problems emerging from climate change, mitigation and adaptation to it, as well as the fight against its adverse effects.' In addition, its development is envisaged as part of the 'State strategy for green infrastructure and ecological connectivity and restoration' (Art 15.2), currently under development.

In the particular case of national parks, the network's master plan (Royal Decree 389/2016) includes amongst monitoring measures the 'charter of a network for monitoring the disturbances associated with global change and developing early warning mechanisms, especially with respect to those caused by human activity', which is specified in a global change monitoring programme coordinated by the OAPN.

Likewise, the second Action Plan for Spanish Biosphere Reserves (OAPN, 2013) incorporates adaptation as one of the objectives.

5—See plans or strategies approved in each autonomous community on the AdapteCCA Platform
http://adaptecca.es/administracion-autonomica-local/comunidades-autonomas

Ordesa y Monte Perdido National Park. Photo: Carlota Martínez

Lagunas de Villafáfila Nature Reserve. Photo: Javier Puertas

5 Adaptation in Protected Areas

5.1. How Important Is Adaptation in Protected Areas?

Anthropogenic climate change is the subject of increasing attention in technical documentation on protected areas, for example in recommendations to embed climate change adaptation into management (WWF, 2003; Welch, 2005; Heller and Zavaleta, 2009; Dudley et al., 2010; CONANP, 2012; European Commission, 2013b), but its presence in practice is still very limited (Poiani et al., 2012).

Regarding planning of protected areas, the analysis of a large sample of planning instruments in Spain (PORN, PRUG and Natura 2000 management plans) show that few consider climate change explicitly, appearing only in some instances after 2013. This shows that the impact of climate change and the need for adaptation is a relatively recent concern in this area; it is more evident in the management plans of Red Natura 2000 or, in Master Plans for Use and Management (PRUG) recently approved, or in their drafting stage.

When it occurs, consideration of climate change is usually limited to general references to climate. It is rarer to find documents with regionalized scenarios of climate change or analyses of the vulnerability of conservation targets. This is probably very new information, not yet known or accessible to technical teams dedicated to protected areas.

In general, there are usually no explicit objectives in planning documents related to climate change or the need to adapt. This is independent of the fact that references to it exist in the diagnoses or remedies.

Regarding the type of climate change measures included in plans, the most frequent refer to improvement of knowledge. Managers probably perceive that there is not yet enough evidence on the effects of climate change to proactively intervene on specific species or habitats.

Explicit adaptation measures are scarce, and are usually found in forest management. In any case, many management measures have an adaptation component: most actions aimed at improving the conservation status of habitats or ecosystems, increasing heterogeneity or diversity of species, or reducing exposure to disturbances such as fire or floods are, in fact, contributing to greater adaptation to climate change.

5.2. What Kind of Adaptation Makes Sense in Protected Areas?

Developing the capacity to adapt to climate change in protected areas is one of the main strategies to minimize impacts of climate change on ecosystems and the biodiversity they host. Maintaining ecosystems in a good condition - maintaining high resilience and ability to provide environmental services in the context of climate change - is considered one of the main bases of this adaptation strategy in protected areas.

According to the Millennium Ecosystem Assessment (2011), in the last 50 years most of the ecosystems in Spain have suffered significant reduction in their ability to generate services. Due to the effects of global change - of which climate change is one of the main drivers - rivers and wetlands have less ability to provide quality water or to curtail the effect of flooding. Coastal systems are more vulnerable to storms, forests more vulnerable to drought or fire.

Ecosystem-based Adaptation is a strategy defined as 'the use of biodiversity and ecosystem services as part of a broader adaptation strategy, to help people adapt to the adverse effects of climate change. (...) Its purpose is to maintain and increase resilience and reduce the vulnerability of ecosystems and people.' (IUCN, 2009).

The principles of ecosystem-based adaptation (Lhumeau and Cordero, 2012) would be:

- Focus on reducing non-climatic pressures.
- Involve local populations.
- Develop strategies with multiple partners, aligning the interests of conservation, development and poverty reduction.
- Avail of existing good practice in natural resource management.
- Adopt adaptive management approaches.
- Integrate ecosystem-based adaptation into broader adaptation strategies.
- Communicate and educate.

5.3. General Criteria for Adaptation to Climate Change in Protected Areas

The collation of available evidence on causes of climate change and its effect on ecosystems into basic principles to guide management of protected areas in the context of global change is possible, despite uncertainties and shortcomings of knowledge in some areas. These principles can be formulated into general guidelines to be considered at regional level, as well as in networks of protected areas and specific places, in both short and long term.

These guidelines should enable protected area managers to incorporate global change into planning tools and management of ecosystems, habitats and species. Putting these general criteria into concrete measures requires a case-by-case consideration based on the ecological characteristics of each place and the available technical alternatives.

Some recommendations are proposed below for development of the ability to adapt to global change in protected areas, structured around five basic principles:

- **Consider the global perspective.** From protected spaces to networks, and territory as a system. Protected areas are a tool to manage global change, but by themselves they will not be enough. An integrative perspective is needed, on a global and long-term scale, which considers protected areas and the territory in which they are established as a functional unit.
- **Managing uncertainty:** the importance of research and monitoring. The uncertainties associated with predictive models make it essential that decision-making is based on the best scientific information, that monitoring systems are available which report the effects of global change, together with an adaptive management model that continuously evaluates the results of the actions undertaken.
- **Incorporate change** as always present in the planning and management of protected areas. Ecosystems are immersed in a process of constant change. It is necessary to have ecological succession as a natural process and not manage against it, and increase the capacity of ecosystems to adapt to new environmental conditions and disturbances.
- **Develop new governance tools** for a new context. It is necessary to develop new forms of governance of protected areas, incorporating a greater number of stakeholders, and define viable management models in the new socio-economic and environmental context.
- **Improve social support** and awareness of the effects of global change.

These five basic principles are developed below in guidelines for adaptation to climate change in protected areas, and are summarized in Table 5 (further below):

1. Consider the global perspective. From protected spaces to networks, and territory as a system.

The planning of protected area networks is a fundamental tool in managing the effects of climate change, if adaptation criteria are incorporated into network design, and in the delimitation and zoning of protected areas (representativeness, rarity, etc.) (EUROPARC-España, 2008; MAGRAMA, 2016). The global effects of climate change reinforce the need to plan from a perspective of networks and systems of protected areas.

The following is recommended:

- Consider the territory as a system: integrate protected areas into their territorial context. Incorporate conservation criteria in planning the territorial matrix outside protected areas.
- Managing a climate change scenario requires jointly considering different spatial (local, regional, global) and temporal scales (short, medium and long term).
- Incorporate social and economic aspects to the definition of planning models. Strengthen the role of protected areas as demonstrative examples of climate change management models that can be extrapolated to the whole territory.
- Strengthen the role of networks of protected areas: design and evaluate conservation objectives from the perspective of networks rather than individual protected areas.
- Use planning techniques that consider the uncertainty associated with climate change, and are capable of incorporating a wide variety of future scenarios.
- Promote connectivity at regional level: maintain or improve permeability for species and ecological processes. In this way, more opportunities are provided for movement of species whose strategy against climate change is to relocate to optimal habitats. Identify, preserve or restore corridors or areas of high permeability.
- Explicitly include in planning those degraded ecosystems whose restoration is viable.
- Identification of climate refuges; prioritize the identification and protection of areas less likely to suffer significant changes induced by climate change.
- Pay special attention to isolated populations or those at the limits of distribution of a species, which may constitute genetic reserves, of particular importance in a context of population mobility or habitat reduction due to climate change.
- It is important to incorporate monitoring systems into broader networks (LTER or others), in order to compare the data and interpret it in a regional context.
- Implement or revitalize participation in research networks such as GLOBIMED, as well as develop tools for transferring scientific knowledge to management.
- The effects of climate change can alter the areas of distribution of ecosystems and species. Provide mechanisms that allow the adaptation of networks of protected areas to new socio-ecological situations that may occur in the medium and long term.

2. Managing uncertainty: the importance of research and monitoring.

Given the importance of uncertainty associated with climate change and its interactions with other change processes, the improvement of knowledge and strengthening of research are fundamental pillars on which to build adaptive management capacity.

Scientific output on the effects of global change and climate change - particularly in the field of biodiversity conservation - is very abundant, but its incorporation into management is scarce. The review of research on global change carried out in Spain in the national park network until 2014 - based on analysis of scientific publications obtained from projects funded by OAPN - shows that most of them focus on gaining new knowledge (with an important bias towards certain areas of knowledge) rather than its application to management (Pineda et al., 2014).

There is therefore a real difficulty in implementing the recommendations of scientific reports, but at the same time a compelling need to kick-start action on the ground, in view of the effects of the drivers of global change on protected areas (changes in climate, land use, invasive alien species, etc.).

Therefore, it is essential to set up mechanisms for transferring scientific knowledge and academic proposals on global change, even of a very theoretical nature, to planning and management of protected areas. In addition to generating new knowledge, we must establish permanent bridges, collaborative flows between academia and practical decision-making. After several decades of accumulated research in protected areas, objective conditions exist for joint, collaborative and coordinated work between the scientific community and managing administrations. A topical example may be the

Research in the National Parks Network

The National Parks Autonomous Agency has been developing the **Research Programme in the National Parks Network** since 2002. The Research Programme, prepared with collaboration of a Scientific Committee, is the reference document for development of research within the National Park Network.

The research programme is developed through the Annual Call for Research Aid, which is tendered competitively by a large number of public research organizations. In the period 2007-2015, 142 research projects were funded, with an average allocation of €75,000 per project, of which 39 (27.46%) aimed at the effects of global change.

The transfer of new knowledge is effected through the annual Research Conference, where all beneficiaries of the call for aid gather to share their results with managers of national parks.

Dissemination of the results is carried out through of the National Parks Autonomous Agency publications, especially the 'Network Research' collection, which each year presents a summary of funded projects.

Spanish National Park Network Research Programme, which aims to apply scientific research to the resolution of management problems.

In addition to generating new knowledge and transferring it to management, it is necessary to maintain systems for monitoring the state of ecosystems and their responses to global change. In Spain, global change monitoring networks are scarce and at an early stage of development. At state level, the Spanish Network for Long-Term Ecological Research (LTER-Spain), aimed at long-term ecological and socio-economic monitoring, is coordinated by the Autonomous National Parks Organization, especially the Global Change Monitoring Network of the National Park Network (see box and Table 4).

Global Change Monitoring System within the National Park Network

Integrated into the National Parks Network Monitoring Plan is a permanent network of data acquisition stations in six national parks. Its main objective is to deliver "in situ" data acquisition, storage and processing infrastructure, in addition to exchange with the scientific community, which allows the development of a global change impact evaluation and monitoring system within the Spanish National Parks Network.

This is carried out via a collaboration agreement between the Autonomous Agency of National Parks, the Spanish Office of Climate Change, the State Meteorological Agency and the Biodiversity Foundation, with the collaboration of Ferrovial-Agromán.

www.mapama.gob.es/es/red-parques-nacionales/red-seguimiento/divulgacion.aspx

Parallel to these national networks, a multitude of monitoring initiatives exists in individual protected areas (Table 4). Generally, these are oriented to the needs of management, lending a certain heterogeneity to the monitoring parameters, although climatic parameters and monitoring of endangered species populations predominate. Sometimes there are long seasonal series of data, invaluable for monitoring global change, so it is necessary that the different monitoring platforms work in a coordinated manner.

Table 4. Monitoring initiatives in protected areas compiled by EUROPARC-Spain.

Description	Scope
Climate Change Monitoring Programme in the National Park Network	National Park Network
Monitoring of global change in forest areas in the National Park Network	National Park Network
Monitoring of phyto-sanitary status in forest areas in the National Park Network	National Park Network
Monitoring of ecosystems using remote sensing techniques in the National Parks Network	National Park Network
Monitoring and Evaluation Plan of the National Park Network	National Park Network
Sierra Nevada Global Change Observatory	Andalusia
Programme for monitoring natural resources and processes in Doñana Natural Park	Andalusia
Crane monitoring and censuses in Gallocanta Lagoon	Aragon
Moncayo Natural Park Ecological monitoring plan	Aragón
Salada de Chiprana Nature Reserve Ecological monitoring plan	Aragon
Galachos del Ebro Nature Reserve Ecological monitoring plan	Aragon
Iruelas Valley monitoring of the black vulture population	Castilla y Leon
Geographical distribution and phenology of butterflies in Alto Tajo Natural Park	Castilla-La Mancha
Regeneration, dynamics and eco-physiology of woody species in Alto Tajo Natural Park	Castilla-La Mancha
Flora monitoring in the Barranco del Cubillo lagoons	Castilla-La Mancha
Tordera Observatory	Catalonia
Alt Pirineu Natural Park Biological Monitoring Plan	Catalonia
Monitoring plan for butterflies in Catalonia	Catalonia
La Garrotxa Volcanic Zone Natural Park Monitoring Plan	Catalonia
El Poblet Natural Area of National Interest Monitoring programs	Catalonia
Alta Garrotxa open space recovery project	Catalonia
Network of constant effort ringing sites in Catalonia (SYLVIA)	Catalonia
Monitoring of common birds in Catalonia (SOCC)	Catalonia
Monitoring of fauna and flora in Ports Natural Park	Catalonia
Climate change monitoring in the Delta de l'Ebre Natural Park	Catalonia
Ecological monitoring in Aigüestortes i Estany de Sant Maurici National Park	Catalonia
Diputación de Barcelona Natural Parks Network standardized monitoring of threatened flora	Catalonia
Global change monitoring in the Columbretes Islands Marine Reserve	Valencia
Peñalara Natural Park monitoring	Madrid
Wetlands Monitoring in the Region of Murcia	Murcia
Monitoring plan of the natural parks of Álava	Basque Country

Finally, it is necessary to implement systems to evaluate the effectiveness of programs and projects. Only with systematic and rigorous knowledge of the effects of management actions and the degree to which planning objectives are achieved will it be possible to commend management to the new scenarios.

In order to ensure management in protected areas avails of the best available information, it is proposed:

- Design a research programme geared to strengthen the adaptive capacity of protected areas against climate change.
- Develop knowledge sharing and dissemination platforms for pilot projects and case studies.
- Promote monitoring and early warning networks of the effects of global change, taking advantage of and coordinating existing ones.
- Upgrade current monitoring programs to include climate change monitoring needs.
- Use existing standardized monitoring methodologies whenever possible.
- Merge available historical information into the monitoring systems so that long time series are available.
- Ensure that monitoring is viable in the long term. For this it is recommended to upgrade personnel training so they can carry out data collection and processing within work routines.
- Assess the potential of incorporating citizen participation in monitoring programs.
- Implement trans-disciplinary research and monitoring projects aimed at global change.
- Create and strengthen new professional profiles and train human capital to occupy a new interdisciplinary niche, between research, monitoring and management.
- Adopt adaptive management approach, with result evaluation systems that allow learning from what has been done and adjust management objectives dynamically.

3. Incorporating change as an ever-present process in protected areas

Conservation policies for species, habitats or ecosystems are usually based on the restoration of maintenance of an ecological scenario deemed optimal (known as 'favourable conservation status' in the Natura 2000 Network). However, we should acknowledge that natural systems are subject to a continuous process of change, that they may present more than one state of equilibrium, and that the variations that occur may be nonlinear and unpredictable. Occasionally, on crossing certain thresholds of change, it is no longer possible to return to the original state (Terradas, 2001).

The effects of climate change tend to produce changes in the distribution of species and habitats causing current policies -based on the maintenance of a given conservation status in certain locations - to lose effectiveness (Cliquet et al., 2009). Departing from the premise that establishing reference conservation conditions is a useful tool for improving management, it will also be necessary to recognise that these scenarios of reference are not static and may change in the future.

In the context of climate change, it is therefore a matter of promoting ecosystems that are resilient against extreme events, that is to say, that will revert to the ecological status deemed desirable after suffering from disturbance. But in addition, given that changes in climate are irreversible, it is necessary to ensure that during the process of change within ecosystems the services that these provide are not lost; management should therefore focus on boosting the ecological scenarios of greatest value in terms of the services rendered (regulation, supply and cultural features), rather than on maintaining a given balance of species (Lloret et al., 2015). Maintaining healthy ecosystems is seen as one of the most important forms of adaptaion (socioecological resilience). In this context, the restoration of degraded ecosystems is one of the most significant options.

To ensure that the integrity of ecosystems and of the processes that give them resilience is maintained, it may be necessary to modify some management approaches. Active ecosystem management in a global change scenario implies developing a flexible management approach, as current management styles may not be of use in the future. It is therefore necessary, to begin with, to identify climate change (and other aspects of global change) as a priority, and, to follow on, consider its effects throughout the stages of the management cycle, from the definition of objectives to designing actions. It will be necessary to adopt more agile and flexible planning instruments for managing changing scenarios, and to identify in explicit terms the scenarios that are desirable for the future (Palomo et al., 2012; 2017).

- Incorporate climate change to planning processes in explicit terms.
- Consider the maintenance of ecosystems in good conservation status as a tool to temper the effects of climate change. In this light, consider the importance of restoring degraded ecosystems.
- Promote mechanisms for resilience (heterogeneity, diversity, facilitation, etc.) in ecosystems as a form of adaptation to climate change.
- Promote spatial heterogeneity on a landscape scale, and structural heterogeneity within ecosystems. The greater the variety in landscapes and ecosystems, the less sensitive they will be to disruptions such as fire or plagues that may escalate in a global change scenario. Promote heterogeneity associated with environmental gradients.

- Minimize stress factors other than climate change; ensure good conservation of species and ecosystems as a way to better resist changes in environmental conditions.
- Establish measures to foster ecological connectivity for fauna, flora, habitats, etc. as well as processes, e.g., flood, runoff, sedimentation, etc.
- Assess the role of certain disturbances in generating heterogeneity, and therefore resilience, in ecosystems. Promote the most resilient structures in ecosystems to disturbances, e.g., fire, drought or floods.
- Promote diversity at all levels: ecosystems with greater species diversity, and genetically diverse populations may have more options to adapt to new climatic conditions.
- Adapt management techniques to promote adaptive capacity to change in ecosystems (for example, longer rotation forestry, clearing of forests to reduce water stress).
- Ensure that mitigation is performed in a manner compatible with conservation of biodiversity. Take advantage of the potential of this form of management to also achieve conservation objectives.
- Be prepared for changes in the specific composition of ecosystems due to changes in species distribution due to new environmental conditions.
- Monitor and control native species that have become over-abundant as a result of climate change (e.g. rabbit), preferably by considering the causes of their population increase.
- Develop protocols for early detection of invasive alien species and rapid information sharing, providing updated knowledge of their progress and the results of actions undertaken.
- Prioritize control or eradication of invasive alien species that impact primary conservation targets, either due to their importance or good state of conservation, and especially those species capable of invading less anthropic environments.
- Consider the role of translocations and *ex-situ* conservation measures as a last resort for threatened species, after detailed analysis of uncertainties, risks, legal conditions, technical feasibility, social acceptance and long-term sustainability.
- Keep track of projects carried out. Incorporate continuous evaluation systems in project design.
- Implement pilot schemes to draw conclusions applicable in other territories; document examples of good practice.

Planning of future scenarios in Doñana (Palomo et al., 2012)

Future scenario planning is a methodology that can be useful in identifying long-term patterns in ecologically and socially complex environments in a continuous process of change, in which management capacity is limited and the degree of uncertainty very high.

By this method, four possible long-term scenarios for the Doñana region have been specified, along with management strategies permitting them to be reached, in a participatory and agreed way, with a large group of stakeholders. These future scenarios allow a consensual diagnosis to be reached, a definition of the engines of change and modelling the future state of the territory, under certain assumptions that are also made explicit.

The following table summarizes the main characteristics of each of the four scenarios defined for Doñana and its surroundings:

	Scenario 1 **Doñana globalized knowledge**	**Scenario 2** **Doñana registered trademark**	**Scenario 3** **Arid Doñana**	**Scenario 4** **Adaptive Doñana: wet and creative**
Approach to sustainability	R&D&I: ecological production technology: eco-efficiency. Ecological Engineering	Sustainability is not sought. Economic growth: maximization of supply and consumption; fragmentary conservation of spaces and species.	Technological response to climate change; search for eco-efficiency; participatory research efforts.	Participatory eco-management of socio-ecosystem; technology/tradition symbiosis; cooperation and participation; education and training; equity and solidarity with other peoples.
Economic approach	Adaptation of uses to capacities. High development due to investment in new technologies.	Mercantilist and speculative globalization; European economic bloc.	Regulated and protective market economy of natural capital; Promotion of quality consumption.	Eco-friendly industrial fabric based on SMEs and cooperatives; regulated trade rules and respect for ecosystem and the community; redistributive taxation.
Social dynamics	Participation through ICT/Information and communication technologies. Responsible and trained citizenship. High levels of immigration.	Competitiveness and exclusion by economic status; conflict and repression, south-north migration exodus, countercultural movement.	Social conflict and unemployment; social orchestration; tradition as a social binder.	Cooperatives and mutualism; strengthening of cultural identity.
Main actors	Scientists and technologists. Local population Immigrants	Large economic corporations versus self-managed communities.	Agents and local population; NGOs; Scientists with socio-ecological approach.	Local population well supported by administration, NGOs and scientists.

4. Develop new governance models for a new context.

Protected areas as we know them today, as administrative structures, are designed with an essentially stable world in mind. However, the accelerated consequences of climate change require rethinking this model, making it more flexible and favouring adaptation to new realities (MAGRAMA, 2016).

The economic and financial crisis has revealed that this institutional stability was less than previously assumed. Measures put in place to remedy this have directly affected administrative structures responsible for conservation policies, mainly due to severe cutbacks in resources to protected areas. This reduction translates into significant decreases in public budgets, staffing cuts and reduction of administrative structures, with environmental departments merging into other non-environmental ones, and a loss of influence of protected area networks throughout the Administration.

This new reality requires rethinking the management of protected areas, in a much scarcer human, material and economic environment, identifying new forms of management. Based on the role of the Administration as ultimately responsible for conservation policies, the incorporation of different social agents involved in the territory and implementation of new financing models will be essential factors to achieve the region's protected area objectives in the context of global change (EUROPARC-España, 2016). The following is recommended:

- Include essential ecological conservation processes and ecosystem services explicitly in conservation policies.
- Consider integrating natural and human systems, taking into account the impact of climate change on functioning of socio-ecosystems.
- Create and strengthen inter-administrative coordination between departments with the capacity to develop adaptation strategies or actions, so as to avoid duplication of effort.
- Establish inter-sectoral coordination mechanisms to ensure inclusion of environmental criteria and adaptation to climate change in the set of policies with territorial impact.
- Assess the opportunity to create specific coordinating bodies for adaptation to climate change, both at local and network levels.
- Develop management models that favour synergies with other public sector entities (health, education).
- Encourage alliances that stimulate private participation in nature conservation.
- Explore new funding mechanisms for protected areas (charging for services, environmental tax, etc.).

Inter-sector coordination: LIFE-IP NADAPTA-CC project (2017-2025)

Climate change adaptation is a cross-cutting issue that concerns all sectors of society and requires action at multiple levels of government, from national to local agencies.

Within the European Commission LIFE Programme, Integrated Projects (IP) are distinguished by implementing large-scale territorial (at least regional), environmental or climate plans or strategies, with special attention on their integration into other sectoral policies. Within this philosophy of sectoral integration and regional scope, the LIFE-IP NAdapta-CC is the first integrated project of adaptation to climate change to be launched in Spain.

The main objective of the project is to increase the resilience of Navarre in the face of climate change by implementing adaptation measures in the territory, through collective work between different departments of the Regional Government of Navarre and public companies and promoting, in turn, that sectoral policies incorporate the fight against climate change into their programmes and projects.

The project includes 53 actions being developed, the majority in six key areas: water (demand management and extreme events), forests (development of new, more resilient forest management models), agriculture (implementation of more efficient innovative techniques), health (attention to new diseases derived from climate change), infrastructure and territorial planning (pilot actions in housing, public facilities and areas of economic activity), to which a transversal action of Climate Change Monitoring (control and alert systems) is added.

LIFE-IP NAdapta-CC actions are included in the Navarre CC Roadmap (HCCN) KLINA, so, through coordinated work, it will contribute to the implementation of all the actions included in it.

More info: lifenadapta@navarra.es

5. Improve social support and awareness of the effects of climate change.

A key aspect in the success of conservation policies is sufficient social support. Protected areas have proved useful for raising awareness and communication, improving social agreement and participation (EUROPARC-España, 2016). They are ideal scenarios for climate change education and awareness, bringing unique opportunities for communication actions in the field (Heras, 2016). They have a long tradition in programme delivery and design of equipment for dissemination, interpretation and environmental education, addressed to visitors and local inhabitants alike, in many cases providing guides and trained, specialized public service staff who can embed climate change messages into their activities.

In addition, they are generally better studied and recognized than other natural environments (sometimes they have valuable records) which, together with their low degree of artificiality, allows precise identification and recognition, on the ground, of some already visible effects of climate change (e.g., altitude displacement of vegetation). These effects can be observed directly by visitors, promoting a closer, local and real vision of climate change, moving away from the better-known and distant effects related to global change.

To promote ecosystems' services through adaptation in protected spaces.
Project LIFE AdaptaMed

AdaptaMed is a project led by the Junta de Andalucía and conducted in three protected spaces: Doñana, Sierra Nevada and Cabo de Gata. Its purpose is to improve the capacity to provide goods and services, by means of adaptive management measures, that involve the handling of habitats to increase their resistance and resilience against the effects of climate change and other disturbances. The aims of the project are the following:

1) To consolidate the follow-up programs launched at the three sites, generating synergies and proposing common targets in a shared conceptual framework,

2) To set in motion adaptive management projects in which scientific knowledge is applied to management, and the proposed management measures are assessed,

3) Social immersion of the project and citizen participation.

Dissemination activities are an important part of the project. In addition to a dedicated website providing a wealth of information, further communication materials are available and a presence is maintained in the social media. A number of local workshops, actions and material for teachers, exhibitions and volunteering work at the project sites and scientific dissemination for the general public are offered as tools to encourage citizens to take an interest in the project's objectives

More information at www.lifeadaptamed.eu

Protected areas constitute long-term social projects, where each generation can directly observe the legacy of previous ones and determine management decisions for future ones. Therefore, protected areas must not only highlight the problems and effects related to climate change, but should also identify ways forward, solutions and adaptation measures being implemented. Dissemination of projects for research, education and ecological restoration contributes to showcasing the value of protected areas in addressing climate change.

- Communicate the effect of climate change on protected areas, using every-day language. Emphasize the role of ecosystems as providers of services responsible for people's well-being.
- Encourage alliances with the media. Promote active communication policies.
- Emphasize the achievements of protected areas. Disseminate the good practices carried out in protected areas and areas of influence regarding climate change among the main co-responsible agents and society in general.

Table 5. Principles for adapting protected areas to climate change and summary of recommendations for each management capacity

	Global scale view	Manage uncertainty	Integrate the constant process of change	New governance model
Research	Promote research networks	Develop research programmes on the effects of global change		
Follow-Up	Integrate follow-up experience to global networks	Transfer follow-up results to management		
Network Design	Territory viewed as a system. Use of a territorial matrix	Identify climate refuges	Adapt planning to change (limits, new areas)	Integration of sectorial policies
	Network approach	Establish alternative scenarios	Management effectiveness assessment	Improve administrative coordination
Management of ecosystems	Guarantee connectivity	Develop adaptive management	Promote ecosystem resilience (heterogeneity, diversity)	Emphasis on ecosystems' services to social wellbeing
	Favour landscape heterogeneity	Limit all threats unrelated to climate change	Healthy ecosystems as a form of resilience	
Management of species	Facilitate the dispersion of species	Early warning systems	Control of alien invasive species	
		Conservation ex-situ and translocation as a last resort	Accept changes in the composition of species	
Administrative capacities				Update conservation policies Incorporate new stakeholders New funding channels New administrative structures
Dissemination				Alliances with the media

Sierra de Gredos Special Protection Area. Photo: Javier Puertas

6 Adaptation to Climate Change in Planning for Protected Areas

6.1. Planning in a Changing Environment. Cascade Planning

Incorporating adaptation to climate change in the planning process for protected areas implies overcoming the notion of isolated protected areas and embracing a broader territorial approach, which also requires changes in planning design. The contribution of protected areas, in terms of territorial adaptation, requires comprehensive planning incorporating the following three basic issues:

- climate change is a global phenomenon operating on a broad spatial scale. It is therefore pointless to address it from the perspective of each individual site, whereas it is essential to ponder the role of each site within its regional context.
- climate change is a long-term event, whose effects will persist over centuries, which calls for the design of strategic and long-term plans.
- judging by what we know at present of climate change, future climate scenarios will be different to those of today. We can state that change will surely come about, albeit with some uncertainty regarding its intensity and direction.

One possible solution to this need to plan for broad geographical contexts, with long-term horizons and variable scenarios, is 'cascade planning'. Cascade planning is a model in which planning instruments are integrated hierarchically, ranging from documents of a general nature for strategic objectives, to those of a more specific and operational nature (EUROPARC-España, 2008).

In this planning scheme, the lower echelons develop the targets set in the most generic plans, while the experience gained at the more specific planning levels provides information to reformulate the upper or more generic levels.

This type of planning allows integrated models to be developed for tiered management, from the regional to the local scale, enabling multidimensional and hierarchical coordinated management to be designed. It also allows the specific scope and the different structure and content of the various planning documents to be organised and adjusted.

System-planning instruments should therefore be strategic in nature, with long-range timelines and periodical target reviews, and on a large (at least regional) scale, providing the foundation for management plans that are more agile, operational and endowed with effectiveness assessment mechanisms that enable management results to be examined and scenarios to be altered as necessary.

With regard to adaptation, on the planning scale within the system, the planning instrument –the director plan or equivalent– should define as a minimum the following aspects:

- Assessment of vulnerability to climate change among different habitats and species from a regional or bio-geographical region perspective, enabling the identification of those at greatest risk (for instance, relict habitats or those on the fringes of their distribution area).
- Identification of the role played by each space within the system, in relation to the remainder of pieces forming the network, and their specific contribution in terms of adaptation, such as bioclimatic refuges.
- Identification of corridors, both linear and on the territorial matrix, permeable to the movement of species, propagules, etc., allowing the inter-connection between spaces and the movement of species in response to shifts in climatic niches.
- Evaluation of the representativity of the network of spaces, and its reassessment in the event of new climatic scenarios (redefinition of boundaries, declaration of new spaces, etc.).
- Definition of long-term adaptation targets, that may be evaluated in the short term. One option is to incorporate several successive temporal horizons.
- Integration and coordination with sectorial policies, especially with other instruments of sectorial planning.
- Transversal adaptation measures, on a scale encompassing the entire network (including, for instance, measures for improving knowledge, follow-up and technical training), and funding mechanisms for these measures.
- Specific governance mechanisms, if applicable, for instance to maximise coordination between administrations or to ensure citizens' involvement.
- The definition of a follow-up system based on indicators, allowing the effectiveness of measures to be assessed, that is realistic and applicable and enables targets to be reformulated as the management plans on the lower echelons are implemented.

6.2. Adaptation within the Management Cycle

Management plans, under their various forms (PORN, PRUG, Natura 2000 management plans, etc.) are instruments explicitly stating the targets to be reached within a given time interval, and the manner in which to reach them, i.e., the intended measures. These are therefore the principal and most important tool in which to include criteria and guidelines for the development of an adaptation management strategy, for which reason procedures and recommendations are being drafted for the purpose of including adaptation in the design of this type of plans (CONANP-FMCN-TNC, 2011; CONAP, 2012, WWF/Adena. 2012; European Commission, 2013b; SERNANP. 2015).

According to the most widely accepted planning scheme, we are speaking of a cycle commencing with the assignment of a number of general objectives for a given protected area (which are normally reflected in the declaration document), the identification of problems and opportunities detected in the territory in relation to the values to be preserved (or conservation objects), that are linked to explicit objectives described in the most specific terms possible, for whose achievement means are allocated and a number of measures are adopted. The cycle concludes with a continuous evaluation system that provides information on every action effectively performed, the results obtained therefrom, and the degree to which objectives were fulfilled, thus allowing the cycle to be restarted with a new diagnosis (Figure 1; EUROPARC-España, 2008).

Throughout the phases in the management cycle described above it is possible (and desirable) to incorporate criteria referring to climate change. Firstly, in the diagnosis, where it is important to establish an accurate climatic characterisation as the framework within which species, habitats and human populations interact, with reference to measured and forecast changes therein. For a proper definition of the desirable or foreseeable scenarios, it seems appropriate to establish baseline regional climatic scenarios from which to predict climatic models as closely adapted as possible to each territory in question. During the phase in which conservation objects are identified, it is necessary to determine which are

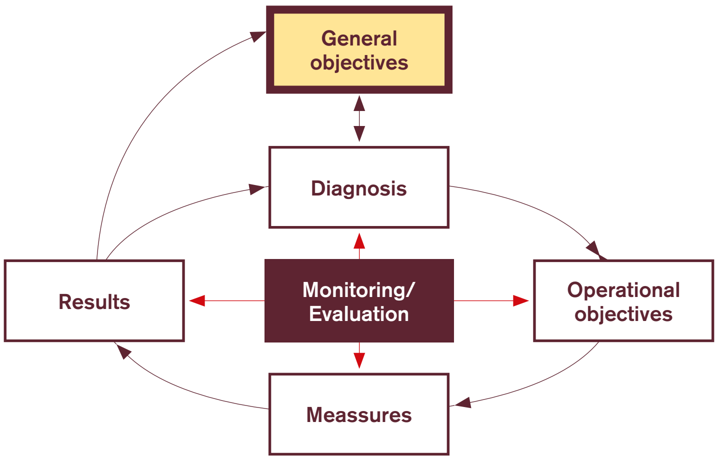


Figure 1. Phases in the planning and management process for a protected area (EUROPARC-España, 2008).

most vulnerable to climate change, specifying the importance of climate change in their conservation status.

Adaptation criteria may be present in the identified targets, as well as in the measures. Lastly, the follow-up system should include indicators on the efficiency of the plan as well as on the effects of climate change on the conservation objects (Figure 2).

Phases in the planning process		Aspects to take into consideration
General diagnosis	◄	Current climate and observed trends
Identification of conservation elements	◄	Elements that are sensitive to climate change (species, habitats, ecosystems, ecosystem services)
Definition of the reference (or desired) status	◄	Identification of future scenarios Regionalised climatic scenarios
Analysis of key factors, hazards, vulnerability	◄	Vulnerability to climate change among sensitive elements
Definition of objectives: —General —Operational	◄	Increased resilience against climate change Objectives that are explicit or implicit, but clearly linked
Management measures —Actions —Guidelines and regulations —Zonation	◄	Specific adaptation measures Emphasis on ecosystem functions and their capacity to generate services
Follow-up and evaluation —Programme for raising the level of knowledge —Climate change indicators —Review of measures effectiveness, fulfilment of objectives	◄	Evidence of climate change Monitoring variables of a climatic, phenological, etc. nature Management efficiency indicators

Figure 2. Phases in the management cycle to which climate change adaptation criteria may be incorporated.

Additionally, the entire procedure should be based on the best scientific evidence available, taking all existing information into account. Moreover, participation and communication processes throughout the procedure are essential to guaranteeing its effectiveness.

The spatial scale of the planning instrument will condition the nature of the objectives and measures to be adopted (these will be different on a network scale or a local scale). Owing to the global nature of climate change, the need for plans at a network scale that articulate and provide content to the plans for each individual space is unavoidable in the task of developing adaptation plans.

6.3. Criteria for Incorporating Adaptation in the Design of Management Plans

Detailed below are the criteria that should be taken into account in drafting the different phases in a management plan in order to adequately address adaptation to climate change. These do not include general criteria for drafting management plans, which may be consulted at EUROPARC-España (2008), but only those that are specific to adaptation, and were not taken into account in the above-mentioned handbook.

6.3.1. Legal Framework

In drafting a management plan, it is necessary to verify beforehand the legal framework it stems from, and its coherence with pre-existing adaptation plans or strategies on a national or regional scale. Occasionally there may be conflict between mitigation and adaptation objectives, which will need to be identified.

It is also necessary to ensure the coherence of any adaptation objectives or measures proposed within the plan with existing planning documents, whether these are sectorial plans or pertain to the protected space.

The instrument must be drafted according to the following, at least:

- National and regional adaptation strategies or plans. In these, the objectives and their coherence with the proposed adaptation objectives shall be identified.
- Planning documents for the protected area (PORN, PRUG, Natura 2000 Plan, species management plans, forestry master plans, etc.), identifying any possible synergies or contradictions.

6.3.2. Documentary Sources

To incorporate climate change criteria in the planning process, it is necessary to start from the best available information and to consult recent subject-specific information. Where local information is unavailable, national scale information should be sought. Consultation with local stakeholders may likewise be appropriate for incorporating unpublished information. These may include protected area staff and rangers, and also local experts and other agents (town councils, farming sector representatives, landowners, etc.)

The identification of missing information will be useful in the subsequent drafting of a diagnosis and, as applicable, in the definition of research measures to remedy this shortcoming.

- At least all the fundamental sources of nation-wide information should be consulted in reference to vulnerable species (fauna, flora), impacts on the coastline, rivers and wetlands, marine environment, forests, soil, ecological or geomorphological processes, etc.
- Insofar as they are available, bibliographic references on climate change and its effects should be consulted, in the greatest detail possible.
- Information specific to each area should be included, derived from consultations with experts on the local effects of climate change (scientists and managers, rangers and local agents).
- it should be expressly determined where information is lacking with regard to evidence of climate change or its effects (for instance, the lack of meteorological stations, data series, or scientific evidence of the effects on species or habitats).

6.3.3. Climatic Characterisation

The first step in considering climate change in the planning process is to give a precise description of the current climate in the territory being studied, on the basis of bibliographical and meteorological data from weather stations nearby. This description should be grounded on the variables that characterise climate (precipitation, mean, minimum and maximum temperature, duration and frequency of extreme events, etc.).

The existence of long data series often allows a simple and graphic display of some climate change indicators, such as rising temperature trends.

It must be borne in mind that climate variability is to some extent natural and that climate fluctuations -irregular precipitation, alternation between dry and humid periods- are an essential components in many ecosystems', particularly Mediterranean ecosystems. The availability of long data series is fundamental in order to differentiate natural variability from long-term trends in induced climate change.

In addition, the importance of each location must be evaluated from the bioclimatic standpoint with reference to bioclimatic zones and their relationship with the vegetation. This evaluation must consider the regional context: for example, whether the location represents a humid bioclimatic island within the dryer environment, or a relevant micro-climatic singularity.

- Describe the current climate briefly but precisely, with reference to the key variables that characterise it (mean, minimum and maximum temperatures, precipitation duration and frequency of extreme events).

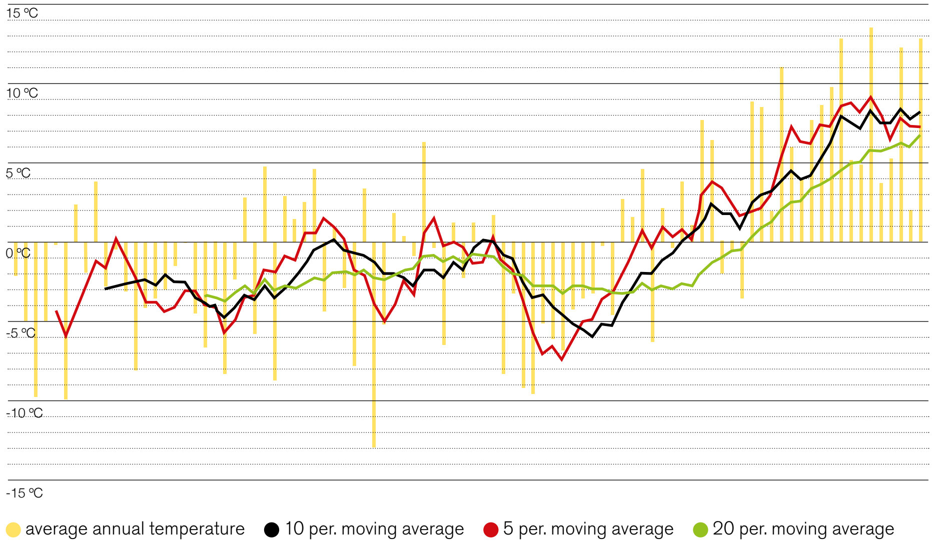


Figure 3. Forestry management plan at Monte Dehesa de los Enebrales, Daroca (Zaragoza).Difference in the annual mean temperatures compared to mean temperatures in the period 1920 to 2011 at the Daroca (Zaragoza) weather station

- Provide evidence to reveal climate change trends, particularly series over long periods registered at nearby weather stations.
- Provide recent evidence of climate change impact on the protected area (for instance, changes registered in phenology, species distribution areas, regeneration, etc.) from external expert knowledge.
- Describe the current climate from a bioclimatic perspective (relationship between climatic variables and the distribution of ecosystem or vegetation types).

6.3.4. Climatic Scenarios

The baseline in defining future scenarios is to consider global climatic change scenarios. However, these global scenarios may be adjusted to regional conditions, taking into account variables such as topography, distance to the seaboard and other variables, in models that allow the changes foreseen in climatic variables to be represented on a high-detail scale.

The process for generating regionalised climate change scenarios is subject to different sources of uncertainty, which are mainly associated to the baseline uncertainty inherent to the global model used, envisaged future greenhouse gas emission scenarios (that, in turn, are dependent on the development model adopted in coming years or decades), global climatic sensitivity (uncertainty due to insufficient precise knowledge of climatic responses to changes in external forcing), and uncertainty stemming from limitations in the regionalisation methods applied in the global models.

Nevertheless, the uncertainty that persists in forecasting climate up until the end of the century does denote ignorance but a range of possible and probable future scenarios that outline a common trend confined within uncertainty limits that are continually reviewed as scientific knowledge progresses. These are the scenarios that must necessarily be taken into account in planning and managing adaptation in each and every resource, system, sector and territory exposed or sensitive to climate change.

At present, some regions have developed regionalised climate change scenarios that are of great value in planning design. The Spanish Meteorological Agency and the Spanish Climate Change Office have developed an application for modelling regionalised scenarios on different scales, based on the latest available data.

Regionalised climate scenarios on the ADAPTECCA platform

In making use of regionalised climate change forecasts it is necessary to bear in mind the sources of uncertainty associated with the forecasting procedure, which include uncertainties regarding the future of greenhouse gas emissions and the limitations inherent to global models and regionalisation techniques. Adopting a cautious approach, it is advisable never to consider a single scenario or a single model, but rather sets of these that provide a balanced representation of the mentioned uncertainties.

The Spanish Meteorological Agency has developed an application for consulting regionalised climate change forecasts for Spain throughout the 21st century, following statistical regionalisation techniques.

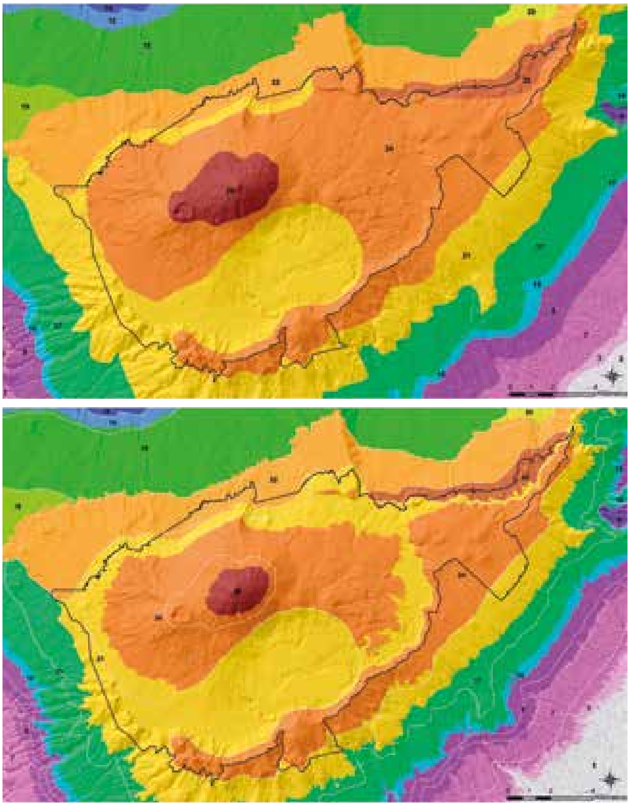
The online viewer for Climate Change Scenarios is designed to facilitate the consultation of data on statistical regionalised forecasts conducted by AEMET for a given geographical area, in a flexible format adapted to different users' needs.

http://escenarios.adaptecca.es/

Access to regional climate change scenarios allows modelling for the distribution of bioclimatic zones (that are defined as a function of temperature and precipitation) within the foreseen climatic scenarios. This enables a clear overview of the potential impact of climate change on the different types of vegetation or ecosystems within a given region.

Thus, as a final result of climatic characterisation, the importance of climate change can be established as a factor of change within the protected area.

Define in the most explicit terms possible the foreseeable climatic scenarios in the area studied. To this end:



7 Lower semi-arid thermomediterranean
8 Upper semi-arid thermomediterranean (-)
12 Subhumid Thermomediterranean
15 Lower semi-arid upper mesomediterranean
17 Dry lower mesomediterranean (-)
18 Subhumid lower mesomediterranean (+)
20 Wet lower mesomediterranean
21 Dry upper mesomediterranean
22 Subhumid Upper Mesomediterranean
24 Dry supramediterranean
25 Sub-humid supramediterranean
26 Dry Oromediterranean
(+) *With Alisio mists*
(-) *No fog from the Alisio*

Figure 4. Distribution of bioclimatic zones at present and in the B-2 scenario in Castilla-La Mancha. (Fernández et al., 2009).

- Take into account global climate change scenarios, as a minimum.
- Take into account the available regionalised climate change scenarios.
- If possible, model the effects of climate change from the bioclimatic point of view (changes in phytoclimatic zones).
- Draw up a global assessment of the importance of climate change as a factor of change that is relevant to the protected area.

6.3.5. Analysis of the Vulnerability of the Conservation Objects

A central phase in the planning process is the precise identification of conservation objects, that is, the values prompting the declaration of a protected area that are, therefore, the focus of preferential attention within the management plan.

In the Natura 2000 spaces the conservation objects are species and habitats, but other protected areas may cover a broader scope including ecosystems, landscapes, cultural features, uses or human activities that depend on the ecosystems within the conservation plan, etc.

Evaluation of the effects of climate change on Habitats of Community Interest. Management plan for the Sierra Norte de Guadalajara Special Area of Conservation

Conservation status of high Mediterranean mountain pastures (HCI 6160 y 8220)

Area in Natura 2000 site	Mediterranean high mountain pastures (6160) = 2,003.64 ha.
Description of the type of habitat in the Natura 2000 site and ecological requirements	Cryosubterranean psychroxerophilous grasslands are vicacious brown parrots, dominated by hemicriptophytes graminoids. They have low coverage and are physiognomically dominated by the root balls of *Festuca curvifolia*. They develop in the upper levels of the orosubmediterranean and cryosubmediterranean zones, in general above 2,000 m altitude. The casmophitic communities colonize the fissures of vertical rocks in which some soil can accumulate, they are characterized by the presence of *Saxifraga wilkommiana* together with *Alchemilla saxatilis.*
Trend	Since the habitats of this key element are located in the higher altitudes of site, global change and ascent of the lower limits of the climatic zones will lead to significant decreases in the potential distribution area.

In this case, it is necessary to provide explicit identification of the conservation objects likely to be affected by climate change and to what extent, that is, to evaluate their vulnerability in each case, so that specific effects on each conservation object may be identified and management measures may subsequently be prioritised in favour of the most vulnerable.

The scientific literature mentions different approaches for the assessment of vulnerability (Pacifici et al., 2015; Foden et al., 2016). In some cases, mathematical models are used to predict specific species' response to environmental change, for instance changes in their area of distribution (Felicisimo et al., 2011: Araujo et al., 2011b), although the main limitation to this approach is that a full set of initial data is required and species' capacity for persistence is often ignored or underestimated (Arribas et al., 2012). Other methods evaluate species' vulnerability by analysing their vital strategies (physiology, phenology, behaviour, etc.) and their capacity to respond to climate change ('trait based analysis' Bagne et al., 2011; Willis et al., 2015).

In these models vulnerability is usually assessed as the result of three components, each of which may be evaluated separately, either with quantitative information, or by means of expert judgement, depending on the available information and the degree of detail required:

- Exposure to climate change (to changes in temperature, precipitation, sea level, etc.)
- The foreseen impacts on the conservation object (effects on populations, on the functioning of ecosystems, etc.)
- The capacity to respond to change, in turn conditioned by the capacity for dispersion, genetic variability, population size, etc.

A simple form of vulnerability assessment is to build a matrix in which the various components of vulnerability are expressly identified, from which a global evaluation is drawn that, in the absence of other information, may be qualitative (Table 6). This simple concept can be applied to species or types of habitat or ecosystems, or to ecosystem services or processes.

Table 6. Matrix for the evaluation of vulnerability to climate change in the different objects of conservation within a protected area.

Conservation object	Exposure	Impact	Adaptation Capacity	Vulnerability
Species, habitat, ecosystem	Components of climate change that affect the conservation object	Foreseeable effect of exposure to climate change on the conservation object	The system's inherent capacity to respond to climate change (by genetic variability, changes in behaviour)	Overall evaluation resulting from discounting the capacity for adaptation from the impact
(E.g.: aquatic invertebrates)	(E.g.: rise in water temperature)	(E.g.: migration up-stream)	(E.g.: migration curtailed by obstacles in the watercourse)	(E.g.: high vulnerability)

In the conservation objects prioritisation process that is usually present in management plans, it is necessary to include vulnerability to climate change among the prioritisation criteria, in explicit terms. Vulnerability assessment will thus expressly identify both the conservation objects most vulnerable and those most resilient to climate change.

The vulnerability assessment phase will allow us to identify to what extent climate change is a significant factor of change in how the protected area functions, in relation to other factors of global change (such as changes in land use), making it possible to prioritise management objectives in a later phase.

Finally, it is important not to overlook the scale on which climate change acts to appreciate the role played by location in conservation objects on a regional or national scale, (for example, whether these are a corridor, climatic refuge, etc.).

- Identify conservation objects (species, habitats, ecosystems, geology, cultural features, etc.)
- Identify the services provided by the ecosystems within the protected space and the key ecological processes to their functioning.
- Identify the most significant human activities within the protected space.
- Assess the vulnerability to climate change of the above items, including any envisaged impacts on them.
- Evaluate the effect of climate change on social aspects or local communities.
- Consider the importance of other components of global changes (changes in land use, invasive species). Identify the role of climate change as a factor of change for conservation objects.
- Include vulnerability to climate change as a conservation object prioritisation criterion.
- Identify conservation objects that are most vulnerable, but also those that are most resilient.
- Define the relative importance of location for conservation objects on a higher scale (bio-geographical region, state, regional) within the context of climate change.

Assessment of vulnerability to climate change at Monte Matagalls (Montseny Nature Park and Biosfhere Reserve)

Conservation Object	Exposition	Impact	Adaptation Capacity	Vulnerability
Communities with *Anagallis tenella* or other Atlantic plants, of edges of streams and wetlands, of the Mediterranean regions	Precipitation reduction and increased evapotranspiration	Disappearance	Very low, with hardly any displacement capacity	Very high
Acidophilic and mesophilic meadows with *Festuca nigrescens, Antennaria dioica, Deschampsia fleuxuosa* of the highest zone of Montseny	Temperature increase and precipitation reduction	Biogeographic singularity. Displacement of distribution area towards higher altitudes	Little possibility of displacement of distribution area, dependence on adequate livestock management	High

6.3.6. Definition of Adaptation Objectives

Every management plan must include a set of objectives that are sufficiently specific and appropriate to the temporal and spatial framework to render them measurable (EUROPARC España, 2008).

Objectives may be explicitly associated to adaptation, making the importance given in the plan to this aspect patently clear. However, they may also be implicit in other objectives which, ultimately, contribute to adaptation. From the perspective of Adaptation Based on Ecosystems, any objective designed to maintain or improve the conservation status of species, habitats or ecosystems may be considered as contributive to adaptation to climate change. Other more specific objectives, such as for instance promoting heterogeneity, diversity, connectivity, etc., are an essential part of adaptation strategies.

However, given that almost any objective can be considered related to adaptation, as mentioned earlier, it is desirable to state the link between objectives (especially if these are not climate-specific) and the problems deriving from climate change detected in the diagnosis as clearly as possible.

- ► Adaptation to climate change should be viewed as an objective in the management plan:
  —Define explicit adaptation objectives.
  —Include adaptation in other broader objectives.
- ► Make the link between these objectives and adaptation explicit.

Explicit adaptation objectives in the master plan project for Monte Dehesa de los Enebrales, Daroca (Zaragoza)

General objectives of this master plan:

1. To maintain forest to preserve its hydrological protection function and improve its adaptation to climate change

6.3.7. Adaptation Measures

Having defined the objectives, measures must be designed to achieve them. Normally these measures are of three types (EUROPARC-España, 2008), all of which may serve adaptation purposes:

- Regulation: ruling the activities allowed within the protected space.
- Management criteria: guidelines and orientations for third-party activities, ensuring these comply with the objectives for the protected area.

- Proactive measures: direct interventions on the physical, biotic or social environment. These will often consist of measures for enhancing knowledge (research and follow-up on the effects of climate change).

The range of possible measures is very wide and therefore they should be defined according to local specificities; the type of ecosystem involved and the environmental and social setting. At all events, measures should always follow the general principles stated in chapter 5.

Management criteria with reference to climate change in the Management Plan for Parque Natural Bahía de Cádiz

4.3.3. With regard to forestry activities

5. The management of forest stands will progressively integrate adaptive management strategies favouring the adaptability to the climate change scenarios forecast for Andalusia and the maintenance of climate change mitigation functions.

An important aspect to take into account in designing adaptation measures is the possibility that these might trigger unforeseen or undesirable effects, including some that may be contrary to the principle of adaptation, which is known as 'maladaptation'. The following are some examples of maladaptation (Barnett and O'Neill, 2010):

- Actions that increase greenhouse gas emissions.
- Actions that increase vulnerability in weaker social sectors.
- Approaches with social or economic costs that are disproportionately high.
- Alternatives that reduce the incentive for adaptation (for instance, those based on subventions).
- Alternatives that compromise instructions and/or capital in the long-term and that offer little or no capacity for change (for instance, major infrastructures).

Generally speaking it is considered that, given the uncertainties associated to climate change, adaptation measures should be of the 'no-regret' type. In other words, measures should imply an improvement in the conservation status of ecosystems and in the well-being of affected populations, even in the event that climate change does not materialise (IUCN, 2014).

- ► Develop management or regulatory criteria for adaptation.
- ► Define proactive measures with adaptation objectives.
- ► Proactive adaptation measures based on the conservation (or restoration) of ecosystems in good condition (natural solutions).
- ► Include research or follow-up measures on the effects of climate change on conservation objects.

- Evaluate the impact of adaptation measures and the compatibility of adaptation measures with other objectives or conservation measures or, as applicable, mitigation measures.
- Identify the available financial instruments to fund the adaptation measures foreseen in the plan.

Management measures that aim to maintain or recover the capacity for adaptation in the Pyrenean oak forests in Parque Natural del Moncayo (Zaragoza)

In the Aragonese Moncayo, the Pyrenean oak forests have been harvested for firewood for centuries, but woodcutting abruptly ceased from the 1960s to the 1980s. Toward the mid-1990s it became evident that the trees displayed signs of decline. With the aim of improving regeneration from seed and the capacity to resist drought, Pyrenean oak forests within the Natural Park were subjected to thinning works.

The remaining trees have developed structural changes in their wood that heighten their resistance to oak decline associated to hydric stress. Bearing in mind that the effects of climate change point to a certain thermal increase accompanied by a probable decrease in rainfall, works favouring resistance to drought should be a priority in the management of Pyrenean oak stands in order to ensure their adaptation.

The enhanced adaptability of culled forests was demonstrated in the Moncayo in late summer 2012, an exceptionally dry year throughout this Sierra. The stands of Pyrenean oak showed symptoms of early wilting, with their leaves turning yellow by mid August. However, stands that had been thinned in recent years retained green leaves until the usual time of the year for this species, demonstrating their resistance to drought.

Prioritisation of measures

After identifying a broad set of measures, it will be necessary to establish priorities as many of these will have a period of execution that extends beyond the term of a management plan (5 years for a natural park management plan, 6 years for Natura 2000 Network management plan, and in more ambitious cases, 10 years).

Prioritisation of measures in the Climate Change Road-map for Navarre (HCCN)

To implement adaptation measures a calendar of events may be established taking into account three temporal horizons: short-term (up to the year 2020), medium-term (up to the year 2025) and long-term (up to the year 2030). It must be determined which of these will exert the greatest influence considering a set of basic criteria employed in the HCCN, namely:

- Reduction of vulnerability to climate change
- Importance
- Urgency
- "No-regret"
- Co-benefits
- Sectorial acceptance

6.3.8. Funding

Management measures must be accompanied by a cost estimate and possible sources of funding (EUROPARC-España, 2008). The availability of financial instruments to promote adaptation in the European Union is an option to be taken into account in designing management plans.

The Rural Development Programmes co-financed by the European Agricultural Fund for Rural Development (EAFRD) offer funding measures for actions relating to adaptation to climate change within protected spaces, such as Measure 4 'Investment in Physical Assets', to finance non-productive investments linked to agricultural-environmental and climate-related objectives; Measure 8 'Investment in the development of forest areas and the improvement of forest viability'; Measure 9 'Reforestation and the creation of wooded areas'; Measure 10 'Agro-environment and climate': or Measure 15 'Silvo-environmental and climatic services and forest conservation'.

Another source of funding may be found in the Programme for the Environment and Climate Action (LIFE), which in its schedule for 2014-2020 contains, under Climate Action, the priority area 'Adaptation to climate change'.

In Spain, a specific financing instrument for adaptation is the PIMA Adapta, of the Spanish Ministry of Agriculture, Fisheries, Food and the Environment. The PIMA (Environmental Development Plan) aims to set in motion projects to reduce vulnerability to the effects of climate change, by anticipating the possible impacts. This is applicable to situations such as:

- Hydrological resources and the public hydraulic domain
- The coastline
- National parks
- Forest ecosystems

PIMA-Adapta Program in the network of National Parks

The PIMA for Adaptation to Climate Change in Spain (PIMA Adapta) was set in motion in 2015 as a pioneering initiative and to establish continuity, through specific projects for adaptation to climate change.

From 2015 to 2017, PIMA-Adapta dedicated over 2.8M€ to restoring habitats for amphibians, developing adaptive forest management works, establishing ecological corridors, studying habitat fragmentation situations, early detection of alien invasive species, and to developing an Amphibian Monitoring Plan within the Network of National Parks. In 2018 it is envisaged to define and apply protocols for monitoring lepidoptera in Canarian national parks and to enlarge the Network for Global Change Monitoring (RSCG) within the Network of National Parks, with 5 new land weather stations.

6.3.9. Monitoring and Evaluation

The need for a monitoring system enabling the efficiency of management plans to be assessed is a widely accepted aspect (EUROPARC-España, 2008). From the viewpoint of including the effects of climate change and the results of adaptation schemes, monitoring systems should include climate-related indicators (or the incorporation of the protected area to global climate monitoring networks), and indicators of the results obtained from adaptation schemes (MAGRAMA, 2016).

- Establish climate change monitoring indicators (temperature, precipitation).
- Establish monitoring indicators for the impact of climate change on conservation objects (phenology, regeneration, recruitment, etc.).
- Include indicators enabling the results of the envisaged adaptation schemes to be assessed.

Management monitoring indicators with reference to climate change in the Management Plan for Parque Natural Bahía de Cádiz

7.2. Indicators of the fulfilment of specific natural park objectives
In order to evaluate the fulfilment of specific aims set within the Natural Park, the following indicators were established:

- Number of reports on affection, actions and initiatives set in motion to prevent risks linked to climate change scenarios.
- Number of studies conducted to assess the effects of climate change in species, habitats and ecosystem services within the protected space and to analyse its ecosystems' resilience and adaptability.

6.3.10. Participation and Governance

Adaptation criteria must also be included in the mechanisms of governance and public participation (MAGRAMA, 2016, Hernández et al., 2018). The new climate scenarios and the magnitude of the changes to be addressed demand a transversal approach by the different government departments, the development of specific organs of collaboration, and an extra effort in dissemination to society.

Incorporating adaptation to participation processes in protected areas is a challenge, but at the same time an opportunity. On the one hand, it is a challenge owing to the diversity of stakeholders and social sectors interacting within these spaces (agriculture, livestock farming, fisheries, local populations, visitors, associations and NGOs, technicians, forest rangers, etc.), each with their own specific views and array of knowledge on climate change. And, on the other hand, an opportunity, as protected natural spaces are exceptional locations for setting up participation and decision-making mechanisms that also provide an individual and collective learning process on climate change and how to adapt to it.

- Incorporate climate change and adaptation to participation processes and communication material.
- Include the competent body for adaptation to climate change, in the central or regional government, in the process of participation or public information.
- Include adaptation measures in the existing intersectorial cooperation bodies.
- Identify local stakeholders likely to collaborate with the adaptation measures.
- Evaluate the possibility and feasibility of establishing specific or novel mechanisms for governance in relation to climate change (committees, forums, seminars, etc.).

Workshop on conservation and adaptation to climate change in the participative process for drafting the management plan for the Sierra de Santo Domingo Protected Landscape

As part of the participative process for drafting the management plan, a specific methodology was designed to identify adaptation measures. Two working panels were set up and participants (mayors, farmers, businessmen, NGOs, technicians, forest rangers, etc.) were asked to propose proactive conservation measures including, as appropriate, adaptation to climate change.

The panels dedicated a column for climate change, with the aim of inducing participants to reflect on this matter. Prior to commencing these panels, a presentation was given showing impacts of climate change on the Protected Landscape including proximate and concrete examples of species already suffering the effects of climate change.

Some of the difficulties encountered at this type of workshops are the 'uncertainty' attributed to climate change, and the 'doubts' regarding whether climate change is 'negative' for the Protected Landscape.

One learning outcome of the event was the need to work directly with the population to ensure that knowledge of climate change is more accessible and transversal for all individuals and sectors involved, and that each different moment of participation, dissemination and awareness-raising is dedicated to exploring new paths or models for decision-making and planning, focused on adaptation to climate change.

6.3.11. Dissemination

The Management Plan may envisage the incorporation, in communication materials, of content on the importance of the effects of climate change and adaptation measures taken in the protected area on the actions or communication content on the protected area, according to certain general principles (Heras, 2016).

- Offer a 'proximate' view of climate change: this is not a distant problem; its effects are evident on a local scale.
- Enable the understanding of key concepts and processes: changes, thresholds, adaptation, and mitigation. Whenever possible, use clear examples and field work.
- Combat the most frequent stereotypes: "we can reverse the problem", "we have time", "here it will have little effect", and "scientists cannot reach an agreement".

- Highlight the role of protected areas: the dissemination of projects for research, education and ecological restoration contributes to showcasing the value of protected areas in addressing climate change.
- Highlight personal responsibility in relation to the subject: a balance should be found between information on the risks and on the outcomes, discussing the existing responses and encouraging co-responsibility.

La Albufera de Valencia Natural Park. Photo: Javier Puertas

7 Adaptation measures

7.1. Characteristics of Adaptation Measures

In drafting a management plan, the greatest attention to precision and clarity must be given to designing management criteria with the aim of fulfilling adaptation objectives.

Given that adaptation based on ecosystems stems from the premise that healthy ecosystems are the best guarantee of their capacity for adaptation, ultimately any management measure taken for the conservation or restoration of healthy ecosystems can be viewed as an adaptation measure. As for all other management measures, guidelines may be followed for their design, implementation and follow-up (EUROPARC-España, 2011).

Nevertheless, adaptation schemes should contain some distinguishing characteristics, that should be formalised in action plans and projects. According to the prospective survey conducted among managers of protected areas (EUROPARC-España, 2016) and on the basis of a list of criteria provided by UICN-Med,[5] adaptation measures should conform to the following:

- Expressly take into account the foreseeable new climate-related scenarios.
- Contribute to ecosystems' capacity for recovery, i.e. resilience, from the impact of extreme events caused by climate change.
- Ensure that scientific evidence or the most reliable knowledge available is used to assess the effects of climate change on the elements or processes on which measures or actions are taken.
- Set explicit objectives for adaptation to climate change.
- Results must be proved and quantifiable in terms of improving adaptability or reducing the effects of climate change.
- Contribute to reaching the objectives set for the protected area, therefore complying with planning instruments and guidelines on a higher tier.

7.2. Adaptation measures in protected areas

Despite a lack of consideration toward adaptation regarding planning both on a network and a local scale, adaptation projects and actions are being implemented in a growing

5—IUCN-Mediterráneo conducted a survey in 2016 to identify adaptation actions, in the context of the project "Mejores soluciones basadas en la naturaleza en el Mediterráneo. Hacia el Congreso Mundial de la Naturaleza (Hawaii 2016)".

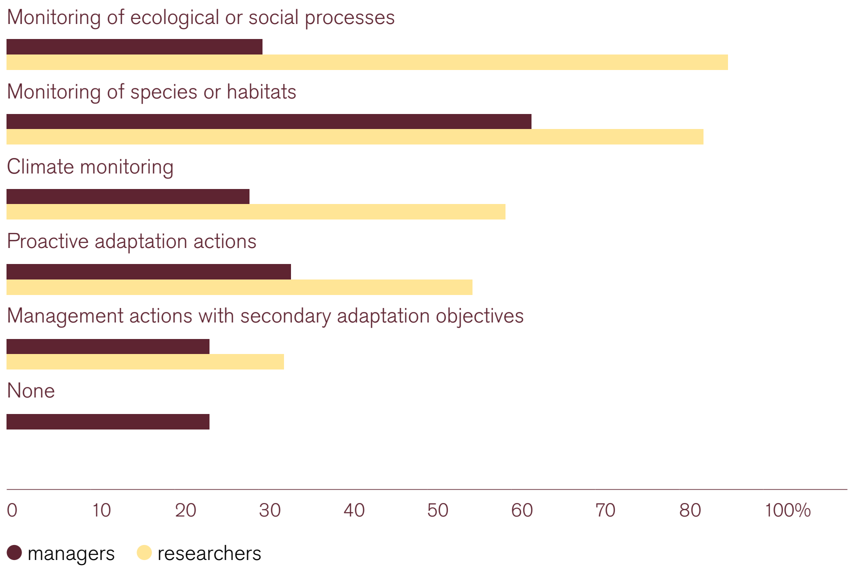


Figure 3. Adaptation measures to climate change viewed as an 'important' or 'highly important' priority by a sample of 70 managers and 85 researchers.

number of protected areas worldwide (for a review, see Berry et al., 2008; Harley et al., 2008; MAGRAMA, 2016).

Bearing in mind the importance granted by managers and researchers to adaptation measures, it is clear that proactive adaptation[6] measures appear to merit less importance than monitoring measures, which are by far more frequent. Measures deemed as 'priority' by the mentioned groups seem to be monitoring for ecological and social processes, species and habitats, as well as climate-related monitoring. A possible explanation is the perception that there is insufficient evidence of concrete consequences of climate change to warrant active intervention, while managers are still primarily engaged in gathering evidence. The implementation of adaptation measures is nonetheless viewed as a priority by 30% of managers and 50% of researchers surveyed (Figure 3).

A survey of possible adaptation measures viewed as a priority by respondents showed a preference for measures based on eliminating stress factors and restoring degraded ecosystems. More active intervention measures, aiming to modify those ecosystems' structure or function to heighten their resilience, are generally found appropriate for forest ecosystems with a long tradition on planning and silviculture.

6—Measures focused on species, habitats or the physical environment.

Adaptive management for stands of *Quercus pyrenaica* in Sierra Nevada toward global change processes, and the conservation and enhancement of *Juniper* thickets in Sierra Nevada: Adaptation to global change processes.

Some of the elements taken into account in planning and drafting these projects are:

- The use of facilitator species for seeding or planting. These are basically spiny species which protect young plants from herbivores, as well as protecting them from direct sun and reducing evaporation, thereby increasing the amount of water available in the soil.
- Use of indirect tools: Restoring traditional ditches and protecting natural water springs. In both formations (oak stands and juniper thickets) a direct relationship exists between their presence and favourable conditions involving edaphic moisture.
- Location and selection of enclaves offering optimal conditions at present and in the foreseeable future (moisture requirements, direct sunlight) for these plant formations to thrive. Seeding or plantation activities are planned exclusively at these selected sites.
- Elimination of occupant or opportunistic species that provide no facilitator effect for the selected species and which take up, through deterioration or anthropic action, these spaces identified as optimal habitats.
- Protection during the first stages of development against wild and domestic herbivory by removing this natural factor in order to guarantee the full initial establishment of the newly planted stands.
- The use of accompanying species in the new plantations to provide a substantially enhanced habitat and additional safeguards to the survival of plant communities.
- Application of the 'dispersal kernel' method consisting of creating enclaves that in the near future will function as seed-dispersal points.

Despite insufficient attention being given to adaptation in forestry planning, this type of intervention is beginning to be applied within protected areas.

7.3. Types of Adaptation Measures

Generally speaking, from the perspective of adaptation based on ecosystems, adaptation measures should aim for maintaining the favourable conservation status and maximum resilience of ecosystems (Shoo et al., 2013). More specifically, this refers to a set of measures that are common to all environmental types (Table 7)

These general adaptation measures can be further determined according to the environment or ecosystem type, the foreseeable effects of climate change and the available options for intervention. Below is a summary of the main types of adaptation measures.

Table 7. Proposed typology of proactive adaptation measures based on those viewed as a priority by the managers and researchers surveyed, with a few examples

Improve knowledge Research on the effects of climate change, vulnerability and capacity for adaptation Transfer scientific knowledge to management
Reduce non-climatic pressures Restore ecosystems Manage the impact from public use Manage livestock to prevent impact on vegetation Control alien invasive species Restrict intensive fishing methods Reduce pollution Eliminate weirs
Facilitate migration Create/restore corridors Eliminate barriers
Enhance heterogeneity Promote mixed forest masses Open up forest clearings Create landscape mosaics
Population management Reinforce or select the most resistant ecotypes Change interactions (facilitation, competition)(e.g. clearings to reduce competition) Increase/strengthen genetic diversity
Reduce water demand/enhance the hydrological cycle Hydrological improvement of lagoons (canal dredging, sluices, etc) Take action on water flows in regulated catchment areas Reduce water extraction Reduce forest densities Eliminate forest plantations with elevated water demand
Risk management Flooding management. Restore fluvial geomorphology. Remove dykes and mounds Fire management Prevent coastal storm damage. Restore dunes and coastal wetlands
Attend to ecosystem services Maintain basins to ensure water catchment and retention Improve land use (forestry, livestock, agriculture)
Attend to singular elements Assist the translocation of vulnerable species Recover threatened species populations Restore singular habitats (for example, peat bogs) Create singular habitats (for example, ponds for amphibians)
Monitoring Monitoring of climatic variables Monitoring of species or habitats Monitoring of phenological events Monitoring of ecological and social processes

7.3.1. High Mountain Areas

High mountain ecosystems are especially vulnerable to climate change (OPCC-OTC, 2018). On the one hand, they are highly diverse, as they contain within a small area a broad altitudinal range and topographical heterogeneity. Mountainous areas also often include genetically isolated populations, giving rise to a greater abundance of endemisms.

One of the forecast effects of climate change on high mountain areas involves the altitudinal displacement of climate niches, resulting in the reduction or loss of the higher bioclimatic zones and the progression of lower bioclimatic zones to a higher altitude. This, in turn, will cause the migration of species of flora and fauna to higher altitudes or to other more favourable mountains. This process will be strongly conditioned, on the one hand, by species' capacity for dispersal (frequently limited in high mountain species) and territorial connectivity, and on the other hand, by species' flexibility and local adaptability to changes (Garzón et al., 2011; Escudero et al., 2012).

Climate change is also expected to produce alterations in certain species' phenology and life cycles (Stefanescu et al., 2003; Donoso et al., 2016).

The disappearance of glaciers and the shorter duration of snow cover will affect habitats that are more specific to these conditions (snowfields), and cause hydrological changes with shorter lapses of time between precipitation and run-off, and decreased flow in rivers and streams (Price and Neville, 2002).

As these ecosystems' functioning is closer to nature, except those maintained through grazing, the options for intervention are fewer and should target the protection of singular features (such as peat bogs).

High mountain ecosystems	
Vulnerable elements	**Adaptation measures**
High mountain pastures	Ensuring local connectivity
Peat bogs	Allowing regional connectivity
Glaciers	Herbivory management (domestic and wild)
Snowfields, snow packs	Strict attention to singular features (psychroxerophile pastures, sheep pastures, peat bogs)
Alpine species	Assisted migration of critically endangered populations

7.3.2. Forests and Scrublands

Forests are probably the ecosystem type in which the effect of climate change has been studied most profusely. The probable impacts are affecting or are likely to affect every level in their organisation; eco-physiological processes, phenology, demography, the distribution and functions of plant species, causing changes in primary production, nutrient cycles and the hydrological cycle (Herrero and Zavala, 2015).

The most vulnerable elements will be the forests most closely linked to moister and cooler climatic conditions, those with limited distribution or at the limits of their area of distribution, forest patches of insufficient size or highly fragmented, and riparian forests. In addition, many - especially Mediterranean - forests suffering from prolonged drought may show signs of decay and become more liable to fire risk (Lloret, 2012). Forests that have become degraded or neglected as a consequence of intensive use or abandonment may likewise lose resilience, leading to lower adaptability.

The wealth of accumulated knowledge on silvicultural management, though destined in principle to timber production, may also be applied to achieving conservation targets (WWF España, 2012b; EUROPARC-España, 2013) and adaptation objectives. In this sense, forestry practices aimed at improving forest mass vigour (e.g. tree thinning), culling or clearing to increase structural heterogeneity, spacing to reduce competition and water dependence, or the establishment of more open canopies to curb their vulnerability to large-scale fires, may prove to be efficient adaptation measures within protected areas. (Vericat et al., 2102; Esteban, 2013; Doblas, 2013; Herrero and Zavala, 2015).[7]

Forests and scrubland

Vulnerable elements	**Adaptation measures**
Mesophilic habitats Habitats with restricted distribution Species at the limits of their distribution Fragmented wood and scrub masses Riparian habitats *Abies pinsapo, Juniperus thurifera, Pinus sylvestris, Fagus sylvatica, Quercus robur, Taxus baccata*	Increase the vigour of forests Optimise forest health condition Increase structural complexity; encourage mixed forests; enhance understory diversity. Facilitate genetic adaptation; increase genetic diversity Pay special attention to singular habitats Increase connectivity among forest fragments Increase resistance to drought Reduce the risk of major forest fires Reduce biomass; allow grazing for conservation purposes Decrease exposure to storms Locate and preserve mature stands; maintain old trees and dead biomass

7—The following may be consulted: "Database of nation-wide adaptation measures collected by working group 2 on adaptation, in the framework of the initiative COST FP0703 ECHOES (Expected Climate Change and Options for European Silviculture) (http://echoes.gip-ecofor.org/).

7.3.3. Continental Aquatic Ecosystems; Rivers and Wetlands

Spanish aquatic environments are extremely sensitive to climate, as the immense majority experience a very short or variable water permanence time, and are therefore dependent on annual or seasonal rainfall.

In general, base flow levels will diminish leading to an increase in temporary streams and in stretches of rivers carrying only seasonal flows. The levels and flows in most rivers, lakes, reservoirs and wetlands are very closely linked to short-term precipitation, and therefore winter and spring variations may be determinant for environments liable to temporality, whether lotic (for instance, streams, torrents and wadis) or lentic (e.g. lagoons in semi-arid areas).

Due to rising water temperature, we may expect modifications in biogeochemical and metabolic process rates, as well as an up-river biocenosis zoning shift.

The most vulnerable types of wetland are steppes, high mountain rivers and streams, coastal wetlands and those dependent on groundwater (Cobelas et al., 2005).

Rivers and wetlands are one of the most degraded ecosystems in Spain; agriculture, urban spread, flow regulation, morphological alterations - dredging and channelling - and invasion by alien species are tagged as having the greatest impact “MMARM, 2010). This situation, as mentioned earlier, acts as a stress factor aggravating the effects of climate change. Therefore, adaptation measures must aim first and foremost to restoring degraded ecosystems, by means of recovering connectivity throughout the river course and its banks, implementing water-saving and water quality policies, and applying conservation measures to the surrounding land habitats.

Rivers and wetlands

Vulnerable elements	Adaptation measures
Temporary and/or endorheic wetlands	Recover natural hydrodynamics; eliminate dikes and damns
Coastal wetlands	Recover natural flows
Peat bogs	Improve riverbank connectivity; restore geomorphology and riparian vegetation
Mediterranean temporary rivers	Maintain connectivity along river courses; eliminate obstacles (weirs, dams)
Riparian forests	Demarcate the public hydraulic domain in accordance with the new conditions
High-mountain rivers and streams	Water use efficiency
Ash groves	
Salt marshes	
Saline lagoons	

7.3.4. Extensive Farming Systems

Extensive farming systems, owing to their dependence on anthropic management, are especially vulnerable to land use changes (whether through intensification or abandonment) which, in turn, may be driven by changes in climatic conditions. Farming systems of interest for conservation purposes are characterised by their high heterogeneity and diversity. They are also particularly exposed, owing to the nature of the activities inherent to these systems, to invasion by alien species (Gelbard, 2003).

As these are husbanded ecosystems, adaptation options are more evident in these systems than in others. From a strictly agrarian perspective, these options include modifications in the species, cultivars and breeds of livestock, changes in crop rotations to optimise the use of water, more efficient water management strategies, or livestock density management (Mínguez Tudela et al., 2005). From the preservation of biodiversity viewpoint, measures should generally aim to maintain extensive land uses and to preserve features that ensure diversity; in the context of envisaged aridification, all water-related elements (lagoons, ponds, etc.) take on special significance.

Extensive farming systems

Vulnerable elements	Adaptation measures
Meadows (lignification, naturalisation)	Soil maintenance; reduce loss through erosion
Pastures (less water availability)	Increase habitat/species diversity
Riparian, shoreline and riverbank vegetation	Promote natural regeneration processes in dehesas
Temporary ponds	Preserve and increase livestock farming infrastructures (troughs)
Evergreen oak and cork oak	Grazing management. Prevent over-grazing in certain areas (section rotation, extensive grazing)
Amphibians	Attention to singular features (trees, ponds)
Species found in open spaces (steppe birds)	Protect hedgerows, shores and banks
	Restore natural hydrological processes in temporary lagoons
	Control alien invasive species
	Manage drought-resistant tree crops

7.3.5. Coastal Ecosystems

Coastal systems are particularly sensitive to the effects of rising sea levels and changes in wave patterns. The most sensitive ecosystems are low areas such as deltas, estuaries and marshes. Beaches and dunes are also particularly sensitive to coastal erosion due to changing wave patterns and the higher likelihood of storms, with a clear tendency toward regression (estimated at 2 to 3 metres by 2040). The pronounced deterioration of coastal ecosystems is a further hazard aggravating the effects of climate change (Losada et al., 2014).

Although in coastal areas adaptation options based on civil works are frequently found, space must be reserved, at least in protected areas, for adaptation based on the preservation of ecosystem functions and processes. Overall, in view of the high degree of urban development, many adaptation options will require the restoration of ecosystems such as coastal marshlands and dune ridges. Coastline environments are likewise highly sensitive to invasive alien species, whose proliferation is encouraged by climate change: their control thus becomes a further type of action to be prepared for.

Coastal ecosystems

Vulnerable elements	Adaptation measures
Inter-tidal and sub-tidal habitats	Control alien invasive species
Beaches and dune systems	Restore hydrological processes
Marshes	Coastal and hydrological planning
Estuaries	Maintain/restore dune ridges
Deltas	

7.3.6. Marine Ecosystems

Climate change in the marine environment is verified by a rise in the mean water temperature (between 0.2 and 0.7°C per decade), increased salinity in intermediate and deep waters, and lower pH which is more noticeable in waters in contact with the atmosphere. Verified consequences include higher sea level, changes in the intensity of upwellings in the Atlantic and in the deep water formation processes in the Mediterranean.

These changes in the physical environment have caused massive mortality among benthic invertebrates, regression of meadows of phanerogams and macro-algae in the Atlantic, and changes in the seasonality of phytoplankton cycles. Pinpointed as especially vulnerable are the coral reefs of *Cladocora espinosa*, coralligenous communities (in particular, gorgonias), the marine phanerogams (*Posidonia oceanica*, *Zoostera noltii* and *Zoostera marina*), meadows of macro-algae in the Atlantic and the reefs of *Dendropoma petraea*, as well as beds of rhodoliths and Maërl (Kersting, 2016).

The possibilities for developing direct intervention measures in the marine environment are slim, and are generally oriented toward monitoring and controlling other anthropic pressures (fisheries, pollution) in order to maintain the ecosystems in favourable conservation conditions. Habitat restoration activities may be of interest in certain situations but are usually pilot studies.

Marine ecosystems

Vulnerable elements	Adaptation measures
Seabed meadows	Control of alien invasive species
Coral reefs	Fisheries management
Coralligenous communities	Strict protection of certain zones
Meadows of phanerogams	Restoration of threatened habitats
Atlantic macro-algae	
Reefs of *Dendropoma*	
Beds of rhodoliths and maërl	

Acantilados de Maro-Cerro Gordo Natural Site. Photo: Javier Puertas

Posets-Maladeta Natural Park. Photo: Carlota Martínez

8 Final Considerations and Perspectives for the Future

The process of drafting this manual has allowed deeper study in such a complex and novel subject, both by the institutions and individuals involved in the planning and management of protected areas. Evidence of climate change, as part of the process of global change we are already immersed in, brings us new challenges of huge importance from the conceptual, institutional and instrumental points of view.

Protected areas, as tools for contributing to nature conservation in a broad sense rather than as an end in themselves, face the challenge of overcoming the limitations ensuing from applying sectorial policies. Unless the entire national territory is reached, if these actions are not coordinated with other, likewise decisive, policies for maintaining ecosystems' healthy status, any efforts made to enhance biodiversity and its benefits to society will be futile.

The implications of climate change further highlight this issue. Climate change is a global phenomenon that needs to be addressed on a global scale. Strong synergies with other processes of change, in particular changes in land use and the abandonment of rural areas, should lead us to work on the underlying causes of these processes of change. This is a complex question that, once again, affects our protected areas and demands a global, horizontal approach. Meanwhile, all the experience gained and developed within the protected areas (as territories endowed with specific legal and organisational tools) should be viewed as an excellent opportunity for the country as a whole.

At the World Parks Congress hosted by UICN in 2014, specific recommendations to governments were made for the incorporation of mechanisms in response to climate change. These included:

- To incorporate full recognition that biodiversity, ecosystems and, in particular, protected areas are the key to enabling countries to adapt to and mitigate the impact of climate change.
- To incorporate the concept of 'protected areas as natural solutions to climate change' to their nationwide efforts in planning, dissemination and financial strategies to build natural and social resilience.
- To improve their adaptation and mitigation strategies both within and without the boundaries of protected areas, by means of carbon management, long-term monitoring and full connectivity throughout the territory.

- Protected areas should adopt new planning and management mindsets, to ensure equitative social participation, especially among the younger generations, women, indigenous groups and local communities, on the basis of traditional knowledge and joint efforts to find solutions to climate change.
- Protected areas should adopt and implement innovative adaptation measures that are appropriate and specific to each context, to ensure that, faced with transformative climate change, they will continue to render their full range of values, functions and services to the population and to nature, including protection against climate-related factors and lower risks from natural disasters.
- New alliances should be forged and supported, inside and beyond national borders, to protect and connect marine and terrestrial landscapes as these transform and adapt to the climate.

From the experience gained in the process of drafting this manual, and through applying the recommendations to several pilot projects, at least the following lines of work have been identified as necessary in the short and medium term:

- To draw up and implement adaptation strategies on a territorial scale, forecasting the impact that alterations in the distribution of species and habitats may have on the representativity of current protected area networks and demands for further connectivity throughout the territory.
- To develop methodologies and procedures that will allow quantifiable identification of the effects of climate change on ecosystems' social and cultural features, and not only on their biodiversity components (species, habitats).
- To incorporate climate change adaptation schemes to planning and management strategies for protected areas that anticipate changes both in ecosystems and in human organisations.
- To develop practical tools, databases of good practices and mechanisms for exchanging knowledge and experience.
- To support training and research to increase knowledge on species' and ecosystems' adaptability, validating forecasting models with experimental results.
- To adapt and diversify governance systems that encourage greater social involvement and a broader spectrum of players embracing the adaptation measures as their own, to participate in developing instruments for declaring and planning these measures, and in monitoring and accountability systems.
- To strengthen institutional support permitting sound, replicable strategies to be developed, to promote protected areas' contribution as sites where adaptation to climate change is demonstrated.

Cadí-Moixeró Natural Park. Photo: Javier Puertas

Pedraforca Natural Site. Photo: Javier Puertas

9 References

Araújo, M.B., D. Alagador, M. Cabeza, D. Nogués-Bravo, W. Thuiller. 2011a. *Climate change threatens European conservation areas.* Ecology Letters, 14:484-492

Araújo, A., F. Guilhaumon, D. Rodrigues, I. Pozo, R. Gómez. 2011b. *Impactos, vulnerabilidad y adaptación al cambio climático de la biodiversidad española. 2. Fauna de vertebrados.* Ministerio de Medio Ambiente, Medio Rural y Marino.

Arribas, P., P. Abellán, J. Velasco, D.T. Bilton, J.M. Lobo, A. Millán, D. Sánchez-Fernández, 2012. Species vulnerability under climate change, a new challenge for biodiversity conservation. *Ecosistemas* 21(3):79-84. Doi.: 10.7818/ECOS.2012.21-3.10

Bagne, K.E.; M.M. Friggens and D.M. Finch, 2011. A System for Assessing Vulnerability of Species (SAVS) to Climate Change. Gen. Tech. Rep. RMRS-GTR-257. Fort Collins, CO. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 28 p.

Barnett, J. y S. O'Neill. 2010. Maladaptation. Global Environmental Change, 20: 211–213

Bellard, C., C. Bertelsmeier, P.Leadley, W. Thuiller and F. Courchamp. 2012. Impacts of climate change on the future of biodiversity. Ecology Letters, 15: 365–377. doi: 10.1111/j.1461-0248.2011.01736.x

Berry, P., J. Paterson, M. Cabeza, A. Dubuis, A. Guisan, L. Jäättelä, I. Kühn, G. Midgley, M. Musche, J. Piper and E. Wilson, 2008. Mitigation measures and adaptation measures and their impacts on Biodiversity - Deliverables 2.2 and 2.3: Meta-analysis of adaptation and mitigation measures across the EU25 and their impacts and recommendations how negative impacts can be avoided. MACIS Project. Environmental Change Institute, University of Oxford**.**

Bonache, J., G. de Mingo, J. Serrada, J. Amengual, J. Perales, R. Martínez. S. Rodado, E. Albornos. 2015. El seguimiento y la evaluación a largo plazo en la Red española de Parque Nacionales. Ecosistemas 25(1):31-48.

Carnicer, J., M. Coll, M. Ninyerola, X. Pons, G. Sánchez, J. Peñuelas .2011. Widespread crown condition decline, food web disruption, and amplified tree mortality with increased climate change-type drought. Proceedings of the National Academy of Sciences 108: 1474-1478. doi: 10.1073/pnas.1010070108.

CEDEX. 2012. Efecto del cambio climático en el estado ecológico de las masas de agua. Centro de Estudios y Experimentación de Obras Públicas, Madrid.

Cliquet, A., C. Backes, J. Harris and P.R. Howsam. 2009. Adaptation to climate change – Legal challenges for protected areas Utrech Law Review, 5 (1):158-175

CMNUCC. 2016. Informe de la Conferencia de las Partes sobre su 21 er período de sesiones, celebrado en París del 30 de noviembre al 13 de diciembre de 2016. Convención Marco sobre el Cambio Climático FCCC /CP/2015/10/Add.1 http://unfccc.int/resource/docs/2015/cop21/spa/10a01s.pdf

Cobelas, M.A., J. Catalán y D. García Jalón. 2005. Impactos sobre los ecosistemas acuáticos continentales. En: Moreno, J.M. (Coord.) Evaluación Preliminar de los Impactos en España por Efecto del Cambio Climático. Oficina Española de Cambio Climático, Ministerio de Medio Ambiente, Madrid.

COM (2011) 244 final. Estrategia de la UE sobre la biodiversidad hasta 2020: nuestro seguro de vida y capital natural. Comunicación de la Comisión al Parlamento Europeo, al Consejo, al Comité Económico y Social Europeo y al Comité de las Regiones. Bruselas.

CONANP. 2012. North American Protected Areas as Natural Solutions for Climate Change. North American Intergovernmental Committee on Cooperation for Wilderness and Protected Area Conservation.

CONANP-FMCN-TNC. 2011. Guía para la elaboración de programas de adaptación a cambio climático en áreas naturales. Comisión Nacional de Áreas Naturales Protegidas, Fondo Mexicano para la Conservación de la naturaleza, The Nature Conservancy; México.

Del Arco Aguilar, M.J. 2008. 4. *La flora y la vegetación canaria ante el cambio climático actual.* En Afonso-Carrillo, J. (Ed.), Naturaleza amenazada por los cambios en el clima. pp. 105-140. Actas III Semana Científica Telesforo Bravo. Instituto de Estudios Hispánicos de Canarias.

Doblas, E. (coord). 2013. Conservar aprovechando. Cómo integrar el cambio global en la gestión de los montes españoles. CREAF, Barcelona.

Doney, S.C., M. Ruckelshaus, J. Emmett Duffy, et al. 2012. Climate Change Impacts on Marine Ecosystems. Ann. Rev. Mar. Sci.. 2012;4(1):11-37. doi:10.1146/annurev-marine-041911-111611.

Donoso, I., C. Stefanescu, A. Martinez-Abraín and A. Traveset. 2016. Phenological asynchrony in plant-butterfly interactions associated with climate: a community-wide perspective. Oikos doi:10.1111/oik.03053

Duarte, M. (Coord). 2009. Cambio global. Impacto de la actividad humana sobre el sistema tierra. Colección Divulgación, CSIC, Madrid.

Dudley, N., S. Stolton, A. Belokurov, L. Krueger, N. Lopoukhine, K. MacKinnon, T. Sandwith and N. Sekhran (Ed.). 2010. Natural Solutions: Protected areas helping people cope with climate change, IUCNWCPA, TNC, UNDP, WCS, The World Bank and WWF, Gland, Switzerland, Washington DC and New York, USA

Escudero, A., R. García-Camacho, A. García-Fernández, R.G Gavilán, L. Giménez-Benavides, J.M Iriondo, C. Lara-Romero, J. Morente, D.S. Pescador. 2012. Vulnerabilidad al cambio global en la alta montaña mediterránea. Ecosistemas 21(3):63-72. Doi.: 10.7818/ECOS.2012.21-3.08

Esteban, M. 2013. Forest management of Mediterranean forests under the new context of climate change Building alternatives for the coming future. Nova Science Publishers.

ETC/ACC. 2010. Guiding principles for adaptation to climate change in Europe. ETC/ACC Technical Paper 2010/6. European Topic Centre on Air and Climate Change. Bilthoven. The Netherlands.

EUROPARC-España. 2008. Planificar para gestionar los espacios naturales protegidos. Ed. Fundación Fernando González Bernáldez. Madrid.

EUROPARC-España. 2011. Guía para la aplicación del estándar de calidad en la gestión para la conservación en espacios protegidos. Ed. Fundación Fernando González Bernáldez. Madrid.

EUROPARC-España. 2013. Proyectos de ordenación de montes. Herramientas para la conservación en los espacios protegidos. Ed. Fundación Fernando González Bernáldez. Madrid.

EUROPARC-España. 2016. Conclusiones del Congreso Esparc 2016. Laguardia, 7-10 de junio 2016. Fundación Fernando González Bernáldez, Madrid.

EUROPARC-España. 2016. Programa Sociedad y Áreas Protegidas 2020. Ed. Fundación Fernando González Bernáldez, Madrid.

EUROPARC-España. 2017 Anuario 2016 del estado de las áreas protegidas en España. Ed. Fundación Fernando González Bernáldez. Madrid.

European Commission. 2013a. Guidelines on developing adaptation strategies. SWD(2013) 134 Final.

European Commission. 2013b. Guidelines on Climate Change and Natura 2000. European Union.

European Environment Agency. 2017. Climate change, impacts and vulnerability in Europe 2016. An indicator-based report. EEA Report No 1/2017. Publications Office of the European Union. Luxembourg.

Evaluación de los Ecosistemas del Milenio de España. 2011. La Evaluación de los Ecosistemas del Milenio de España. Síntesis de resultados. Fundación Biodiversidad. Ministerio de Medio Ambiente y Medio Rural y Marino, Madrid.

Felicísimo, A.M. (coord.) 2011. Impactos, vulnerabilidad y adaptación al cambio climático de la biodiversidad española. 2. Flora y vegetación. Oficina Española de Cambio Climático, Ministerio de Medio Ambiente y Medio Rural y Marino. Madrid, 552 pág.

Fernández González, F., R. Pérez Badía, S. Sardinero, R.A. Rodríguez Torres and G. Crespo. 2009. Espacios naturales protegidos y cambio climático en Castilla La Mancha. En: A. Rodríguez Torres, H Fernández Castro e I Rojano Saura (Coords). 2009. Impactos del Cambio Climático en Castilla-La Mancha. Primer Informe. Oficina de Cambio Climático de Castilla-La Mancha.

Foden, W.B. and B.E. Young, (eds.). 2016. IUCN SSC Guidelines for Assessing Species' Vulnerability to Climate Change. Version 1.0. Occasional Paper of the IUCN Species Survival Commission No. 59. Cambridge, UK and Gland, Switzerland: IUCN Species Survival Commission. x+114pp.

Game, E. T., C. Groves, M. Andersen, M. Cross, C. Enquist, Z. Ferdaña, E. Girvetz, A. Gondor, K. Hall, J. Higgins, R. Marshall, K. Popper, S. Schill, and S.L. Shafer. 2010. Incorporating climate change adaptation into regional conservation assessments. The Nature Conservancy. Arlington, Virginia.

García, C., R Garza y J.R. Picatoste. 2015. Marco normativo de la adaptación al cambio climático en España. En: Herrero A. and Zavala M.A. editores (2015) Los Bosques y la Biodiversidad frente al Cambio Climático: Impactos, Vulnerabilidad y Adaptación en España. Ministerio de Agricultura, Alimentación y Medio Ambiente, Madrid.

García Fernández, J. 2017. Observar de cerca el cambio global en los parques nacionales españoles. Síntesis de la actividad de investigación desarrollada en el marco de la Red de Seguimiento del Cambio Global. Oficina Española de Cambio Climático, Madrid. *Inédito.*

Garzón, B.M., R. Alía, M. Robson and M.A. Zavala. 2011. Intra-specific variability and plasticity influence potential tree species distributions under climate change. Global Ecol. Biogeogr. 646: 1-13.

Gelbard, J.L. 2003. Grasslands at a crossroads: protecting and enhancing resilience to climate change. En: WWF. Buying time: a user's manual for building resistance and resilience to climate change in natural systems. WWF Climate Program, Berlin.

Hansen, L.J., J.L. Biringer and J.R. Hoffman. 2003. Buying time: A User's Manual for Building Resistance and Resilience to Climate Change in Natural Systems. WWF.

Harley, M. and N. Hodgson. 2008. Review of existing international and national guidance on adaptation to climate change: with a focus on biodiversity issues. AEA report presented to the Bern

Convention's 'Group of Experts on Biodiversity and Climate Change' at their meeting in Strasbourg on 11 September 2008.

Heller, N.E. and E.S. Zavaleta. 2009. Biodiversity management in the face of climate change: a review of 22 years of recommendations. Biological Conservation 142:14-32.

Heras, P. 2016. Education in times of climate change facilitating learning to build a culture of climate-proteccion. MÈTODE Science Studies Journal (2015). University of Valencia. DOI: 10.7203/metode.85.4220

Hernandez, Y., Â. Guimarães, P. Barbosa. 2018. Resilient futures of a small island: A participatory approach in Tenerife (Canary Islands) to address climate change. Environmental Science and Policy,80:28-37. doi:10.1016/j.envsci.2017.11.008.

Herrero, A. and M.A. Zavala (editores). 2015. Los bosques y la Biodiversidad frente al cambio climático: impactos, vulnerabilidad y adaptación en España. Ministerio de Agricultura, Alimentación y Medio Ambiente, Madrid.

IPCC. 2007. Cambio climático 2007: Informe de síntesis. Contribución de los grupos de trabajo I, II y III al cuarto Informe de evaluación del Grupo Intergubernamental de Expertos sobre el Cambio Climático [equipo de redacción principal:Pachauri, R.K. y Reisinger, A. (directores de la publicación)]. IPCC, Ginebra, Suiza.

IUCN. 2009. Ecosystem-based Adaptation (EbA) Position paper. UNFCCC Climate Change Talks, 28th September – 9th October 2009 Bangkok, Thailand

IUCN. 2014. Ecosystem based adaptation: building on no regret adaptation measures. 20th session of the Conference of the Parties to the UNFCC and the 10th session of the Conference of the Parties to the Kyoto Protocol, Lima, Perú, 1-12 december 2014.

IUCN-WCPA. 2004. Securing Protected Areas in the FACE of Global Change. IUCN, Switzerland.

Kersting, D.K. 2016. Cambio climático en el medio marino español: impactos, vulnerabilidad y adaptación. Oficina Española de Cambio Climático, Madrid.

Lhumeau, A. and D. Cordero. 2012. Adaptación basada en Ecosistemas: una respuesta al cambio climático. UICN, Quito, Ecuador.

Losada, I., C. Izaquirre and P. Díaz. 2014. Cambio climático en la costa española. Oficina Española de Cambio Climático. Ministerio de Agricultura, Alimentación y Medio Ambiente, Madrid. 133 p.

Lloret, F, J.M. González-Mancebo. 2011. Altitudinal distribution patterns of bryophytes in the Canary Islands and vulnerability to climate change. Flora Morphol Distrib Funct Ecol Plants. 2011; 206(9):769-781. doi:10.1016/j.flora.2011.04.007.

Lloret, F. 2012. Vulnerabilidad y resiliencia de ecosistemas forestales frente a episodios extremos de sequía. Ecosistemas 21(3):85-90. Doi.:10.7818/ECOS.2012.21-3.11

Lloret, F.; A. Escudero, J.M. Iriondo, J. Martínez-Villalta, F. Valladares. 2015. Mecanismos de estabilización y resiliencia de la vegetación frente a eventos climáticos extremos. En: Herrero A. and M.A. Zavala (editores). 2015. Los bosques y la Biodiversidad frente al cambio climático: impactos, vulnerabilidad y adaptación en España. Ministerio de Agricultura, Alimentación y Medio Ambiente, Madrid.

MAGRAMA. 2014a. Cambio Climático: bases físicas. Guía resumida del Quinto Informe de

Evaluación del IPCC. Edita Fundación Biodiversidad, Oficina Española de Cambio Climático, Agencia Estatal de Meteorología, Centro Nacional de Educación Ambiental.

MAGRAMA. 2014b. Cambio Climático: impactos, adaptación y vulnerabilidad. Guía resumida del Quinto Informe de Evaluación del IPCC. Edita Fundación Biodiversidad, Oficina Española de Cambio Climático, Agencia Estatal de Meteorología, Centro Nacional de Educación Ambiental.

MAGRAMA . 2016. La Red Natura 2000 y el cambio climático: situación actual, retos y directrices para un marco conjunto de actuación en España. Dirección General de Calidad y Evaluación Ambiental y Medio Natural, Minsiterio de Agricultura, Alimentación y Medio Ambiente, Madrid.

Magrín, G.O. 2015. Adaptación al cambio climático en América Latina y el Caribe. Comisión Económica para América Latina y el Caribe (CEPAL); Naciones Unidas, Santiago de Chile.

Mínguez Tudela, I, A. Ruiz Mantecón and A. Estrada Peña. 2005. Impactos sobre el sector agrario. En: Moreno, J.M. (Coord.) Evaluación Preliminar de los Impactos en España por Efecto del Cambio Climático. Oficina Española de Cambio Climático, Ministerio de Medio Ambiente, Madrid

MMARM. 2010. Bases de la Estrategia Nacional de Restauración de Ríos. Ministerio de Medio Ambiente y Medio Rural y Marino, Madrid.

Moreno, J.M. (Coord.) 2005. Evaluación preliminar de los Impactos en España por efecto del cambio climático. Oficina Española de Cambio Climático, Ministerio de Medio Ambiente, Madrid.

OAPN. 2013. Plan de Acción de Montseny 2009-2013 de la Red de Reservas de Biosfera Española. Oficina del Programa MaB de la UNESCO en España, Organismo Autónomo Parques Nacionales (OAPN).

OECC, 2014. Tercer informe de seguimiento del Plan Nacional de Adaptación al Cambio Climático. Oficina Española de Cambio Climático.

OPCC-CTP. 2018. El cambio climático en los Pirineos: impactos vulnerabilidades y adaptación. Bases para la estrategia pirenaica de adaptación al cambio climático. Observatorio Pirenaico de Cambio Climático-Comunidad de Trabajo de los Pirineos, Jaca.

Palomo, I.; B. Matín-López; C. López-Santiago, C. Montes. 2012. El sistema socio-ecológico de Doñana ante el cambio global: planificación de escenatios de eco-futuro. Ed. Fundación Fernando González-Bernáldez. Madrid.

Palomo, I., M. Múgica, C. Piñeiro, B. Martín-López, J. Atauri, C. Montes. 2017. Envisioning protected areas through participatory scenario planning: Navigating coverage and effectiveness challenges ahead. PARKS. 23. (1) 29-44. DOI (10.2305/IUCN.CH.2017.PARKS-23-1IP.en).

Pacifici, M. 2015. Assessing species vulnerability to climate change.; Nature Climate Change 5:215-225. doi:10.1038/nclimate2448.

Pineda, F., M.F. Schmitz, B. Acosta-Gallo, M.F. Fernández Pastor, C. Arnáiz, P. Díaz, D. Ruiz Lablourdette. 2014. Evaluación y síntesis de la actividad investigadora desarrollada en el marco de la Red de Seguimiento del Cambio Global en los parques nacionales españoles. Universidad Complutense de Madrid.

Price, M.F and G.R. Neville. 2003. Designing strategies to increase the resilience of alpine/montane systems to climate change. En: WWF. Buying time: a user's manual for building resistance and resilience to climate change in natural systems. WWF Climate Program, Berlin.

Poiani K.A., R.L. Goldman, J. Hobson, J.M. Hoekstra, K.S. Nelson. 2011. Redesigning biodiversity conservation projects for climate change: examples from the field. Biodivers Conserv, 20:185–201 DOI 10.1007/s10531-010-9954-2

Sanz, J.J., J. Potti, J. Moreno, S. Merino, O. Frías. 2003. Climate change and fitness components of a migratory bird breeding in the Mediterranean region. Global Change Biology, 9: 461–472. doi:10.1046/j.1365-2486.2003.00575.x

Sanz-Elorza, M., E. Dana, A. González, E. Sobrino. 2003. Changes in the High-mountain Vegetation of the Central Iberian Peninsula as a Probable Sign of Global Warming. Annals of Botany 92: 273-280, 2003. doi:10.1093/aob/mcg130.

Shoo, L.P., A.A. Hoffmann, S. Garnett, et al. 2013. Making decisions to conserve species under climate change. Climatic Change, 119:239-246. doi:10.1007/s10584-013-0699-2.

Scheffers, B.R., L. De Meester, T.C.L. Bridge, et al. 2016. The broad footprint of climate change from genes to biomes to people. Science (80-). 2016;354(6313).

Secretaría del Convenio sobre la Diversidad Biológica .2004. Programa de Trabajo sobre Áreas Protegidas (Programas de trabajo del CDB) Secretaría del Convenio sobre la Diversidad Biológica Montreal. 34 pp.

SERNANP. 2015. Planes maestros de áreas naturales protegidas que incorporan el factor climático. Servicio Nacional de Áreas Naturales Protegidas por el Estado – SERNANP; Lima, Perú.

Stefanescu, C., J. Peñuelas, and I. Filella. 2003. Effects of climatic change on the phenology of butterflies in the northwest Mediterranean Basin. Global Change Biology, 9: 1494–1506. doi:10.1046/j.1365-2486.2003.00682.x

Terradas, J. 2001. Ideas actualmente dominantes sobre comunidades y ecosistemas. En: Ecología de la vegetación. Ediciones Omega, pp 83-115.

The World Bank. 2009 Convenient Solutions to an Inconvenient Truth: Ecosystem-based Approaches to Climate Change. The World Bank, Washington DC.

UNESCO. 2016. Plan de Acción de Lima para el Programa sobre el Hombre y la Biosfera (MAB) de la UNESCO y su Red Mundial de Reservas de Biosfera (2016-2025). Programa sobre el Hombre y la Biosfera, Organización de las Naciones Unidas para la Educación, la Ciencia y la Cultura.

Vericat, P., M. Piqué, R., Serrada. 2012. Gestión adaptativa al cambio global en masas de Quercus mediterráneos. Centre Tecnològic Forestal de Catalunya. Solsona (Lleida). 172 p.

Wilson, R.J., D. Gutiérrez, J. Gutiérrez, D. Martínez, R. Aguido, V.J. Monserrat. 2005. Changes to the elevational limits and extent of species ranges associated with climate change. Ecology Letters, 8:1138-1146.

Welch, D. 2005. What should protected área managers do in the face of climate change?. The George Wright Forum, 1(22):75-93.

Willis, S.G., W. Fode, D.J. Bake, et al. 2015. Integrating climate change vulnerability assessments from species distribution models and trait-based approaches. Biol Conserv.;190:167-178. doi:10.1016/j.biocon.2015.05.001.

WWF. 2003. Buying time: a user's manual for building resistance and resilience to climate change in natural systems. WWF Climate Program, Berlín.

WWF/Adena. 2012a. Adaptación al cambio climático en proyectos de conservación. WWF/Adena, Madrid.

WWF-España. 2012b. La gestión forestal responsable como herramienta de adaptación al cambio climático. recomendaciones para mejorar la capacidad de adaptación de los estándares españoles de gestión forestal para la Certificación FSC. WWF Informe 2012. Madrid.

Zamora, R., A.J. Pérez-Luque, F.J. Bonet, J.M. Barea-Azcón, y R. Aspizua, (editores). 2015. La huella del cambio global en Sierra Nevada: retos para la conservación. Consejería de Medio Ambiente y Ordenación del Territorio. Junta de Andalucía. 208 pp.

Sierra de Santo Domingo Protected Landscape. Photo: María Muñoz

10 Annex

Check-list to Management Plan

For the evaluation of management plans in the participation phase or the public information phase, the criteria provided in the form of a checklist on the following self-assessment table should be considered. It allows verifying compliance with the criteria quickly and easily, according to the following steps:

1. Fill in the self-evaluation form, indicating by checking the corresponding box if each criterion is met, not met, or not applicable (due to the specific characteristics of the plan).

2. Indicate, in the corresponding section next to each criterion, the physical document that verifies that the criterion is met, and its location.

The analysis of the criteria not met can serve as a guide to improve the treatment of adaptation to climate change in the document analyzed.

Name of protected area		
Legal designation		
Competent administration		
Approval date of plan		
Type of plan	▪ Network Plan ▪ Management Plan ▪ Natura 2000 managent plan ▪ Other	▪ Technical draft ▪ Participatory phase ▪ Public informatio phase ▪ Pending publication

Criteria	Yes/no
Legal Framework	
The specific legal framework of climate change has been consulted, at the national level, as well as regional or local action plans or strategies	
Possible synergies or contradictions have been identified with other plans or actions to mitigate climate change	
Possible synergies or contradictions have been identified with the protected area planning documents and other sectoral planning instruments (forests, waters, coasts ...)	
Sources of Information	
The basic documentary sources on climate change have been consulted, at least at national level	
The scientific and technical information relevant to the work scale have been consulted	
Experts have been consulted on the local effects of climate change (scientists, managers, rangers, local agents ...)	
The lack of existing information regarding the evidence of climate change or its effects have been expressly identified	
Climate Characterization and Evidence of Climate Change	
The current climate has been described, with reference to the key variables that characterize it	
Current evidence of climate change in the protected area is provided	
The global climate scenarios described (biogeographic region) have been described	
Climate scenarios at regional level are described	
The current climate has been described from a bioclimatic perspective (relation of climatic variables with the distribution of the types of ecosystems or vegetation) and the expected bioclimatic changes from the climate change scenarios	
Climate change has been explicitly identified as a relevant change factor for the protected areas	
Analysis of the Vulnerability of Conservation Objects	
The objects of conservation in the protected space have been identified	
Ecosystem services and key ecological processes in the protected area have been identified	
The most relevant human activities in the protected area have been identified	
Effects of climate change in the protected area have been identified	
The vulnerability to climate change of conservation objects, processes, services, and human activities has been assessed	
The effect of climate change on social aspects or local communities has been assessed	
The importance of other components of global change in the observed changes has been assessed	
Vulnerability to climate change has been taken into account in the prioritization of which conservation objects should be acted upon	
The relative importance of the protected area for objects of conservation at a global scale (biogeographic region, state, regional...) has been defined	
Definition of Operational Objectives	
There are explicit adaptation goals	
Adaptation to climate change is taken into account in the definition of the plan's objectives, and the relationship of the objectives to this adaptation is clear	
Management Measures	
Management criteria or regulations for adaptation have been included	
Proactive measures with adaptation objectives have been included	
Proactive adaptation measures are based on the conservation (or restoration) of ecosystems in good condition (natural solutions)	
The compatibility of adaptation measures with other conservation objectives or measures (or where appropriate, mitigation) have been evaluated.	
Available financial instruments (European, national, regional funds) have been identified for the financing of adaptation measures	
Monitoring and Evaluation	
Research or monitoring of the effects of climate change on conservation objects have been included	
Climate change monitoring indicators are selected	
Climatic variables (temperature, precipitation, ...)	
Effects of climate change on conservation objects (phenology, regeneration, displacement, etc.)	
Indicators have been selected to evaluate the results of the plan's adaptation actions	
Governance / Public Participation	
Aspects of climate change and adaptation have been incorporated into participation processes or communication materials	
The body responsible for adaptation to climate change in the central or regional administration has been included in the participation or public information process	
The inclusion of adaptation measures in existing intersectoral cooperation agencies is planned	
Local actors that could collaborate in adaptation measures have been identified	
Specific or original governance mechanisms in relation to climate change are planned (committees, forums, seminars, ...)	
Communication	
Contents on the importance of the effects of climate change on the protected area, are included in communication materials	
Communication measures are included in all adaptation actions	

Verification source	Comments
Legal Framework	
National Adaptation Plan, regional plans and strategies	
PORN, PRUG, Natura 2000 management plan, forest management plans, etc.	
Sources of Information	
	Climatic scenarios (State Meteorological Agency or regional agency), vulnerable species (fauna, flora), coasts, rivers, marine environment...
Climate Characterization and Evidence of Climate Change	
	Minimum, maximum, and average temperatures, precipitation, duration and frequency of extreme events
	Changes observed in climatic parameters from data series of nearby weather stations
	E.g. Foreseeable changes in the distribution of phytoclimatic types in the study area
	If climate change is not a relevant change factor, the process stops here.
Analysis of the Vulnerability of Conservation Objects	
	Depending on the nature of the protected area these objects may be plant or animal species, habitats, ecosystems, elements of geological heritage, cultural heritage, land uses...)
	Assess costs of provisional, regulatory, and cultural services
	Impact of uses, economic activities (tourism, agriculture, livestock, etc.)
	E.g. Changes recorded in phenology, species distribution area, regeneration, etc.)
	Vulnerability is defined by exposure to climate change, its impact, and adaptation capacity
	Possible effect on infrastructure, property, mobility, access to resources, etc.
	Assess other components of global change (land use changes, pollution, etc.)
	Identify both more vulnerable and resilient conservation objects
	For example role as corridors, climate shelters
Definition of Operational Objectives	
Management Measures	
	Avoid adaptation actions based on civil works or similar
Monitoring and Evaluation	
Governance / Public Participation	
	Request report from the national agency for climate change or regional equivalent
Communication	
	Only in plans of a certain entity
	Only in plans of a certain entity

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