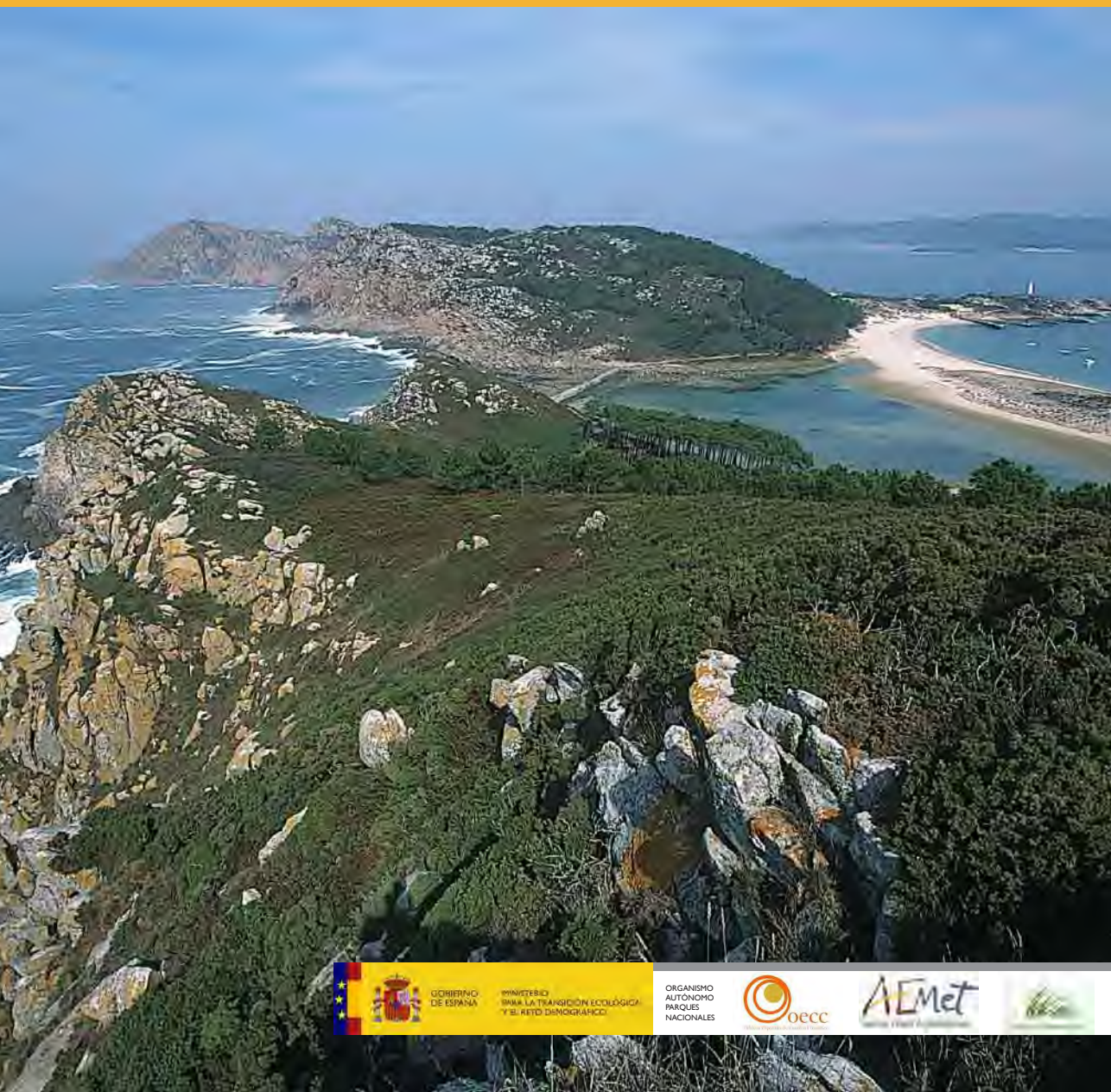
RED

global change

Nº8

NEWSLETTER OF THE GLOBAL CHANGE MONITORING PROGRAMME IN NATIONAL PARKS



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Editorial

This new edition of the Newsletter of the Global Change Monitoring Programme in National Parks coincides with a key moment in the development and implementation of national and international climate change adaptation policies and initiatives. An example of this is the recent (September 2020) passing of the second National Adaptation to Climate Change Plan (PNACC) 2021-2030[1]. This represents a response, as a country, to the challenge of coherently addressing all the measures aimed at alleviating the impacts, already evident, of an increasingly warm, extreme and uncertain climate. Intense efforts are being made in the EU to set out the new and more ambitious European Adaptation Strategy, approval of which is expected in the first quarter of 2021.

As part of the PNACC, the LIFE SHARA project has driven governance of adaptation to climate change in Spain since its inception in 2017, culminating in the conference held in November 2020 — *First Iberian Conference on Climate Change Adaptation, "Adaptes"*[2] — involving Spain and Portugal. This highlighted the importance of protected natural spaces and national parks in particular as preeminent places for observing change, bellwethers for the effects of global change and their important role as testbeds for experiences potentially capable of extrapolation to other regions.

The Atlantic Islands of Galicia Maritime-Terrestrial National Park, which is the focus of special attention in this newsletter, fulfils a series of characteristics that make it especially vulnerable to global change: the fragile balance of its marine ecosystems; being at the distribution boundary of many species, such as the park's colonies of seabirds; the significant impact stemming from invasive species; and the fact that it is home to groups of ectothermic vertebrates, such as reptiles and amphibians, subject to singular evolutionary processes and especially sensitive to climate change, all exemplify this vulnerability.

This new edition of the newsletter provides information about the progress made in the Park. What stands out is the importance of systematic and continuous monitoring of global change, using the meteorological observation network on the islands, which has developed and improved over time. Elsewhere, a range of research projects are described, each showing, among other things, the responses made to change by species, habitats and ecosystems, and providing a picture of the problems confronting the experts.

There is a need to continue acquiring in-depth knowledge of the elements and processes involved in the coastal, marine and island habitats that combine to form the Atlantic Islands National Park, as well as their application to adaptive management techniques. Transmitting this management knowledge and experience to the rest of the National Parks Network, to the scientific community and the general public will assist in the task of building a solid network of global knowledge and aid society's involvement in, and support for, the conservation of this protected space in the face of the threats of global change.

Editorial Committee

[1] https://www.miteco.gob.es/es/cambio-climatico/temas/impactos-vulnerabilidad-y-adaptacion/plan-nacional-adaptacion-cambio-climatico
[2] https://conferencia.lifeshara.com/

The role of protected maritime-terrestrial spaces in monitoring global change: the case of the Atlantic Islands of Galicia National Park

Vicente Piorno
Senior Conservation Officer at the Atlantic Islands of Galicia Maritime-Terrestrial National Park.

Conservation policies and measures taken in the fight against factors linked to global change have conventionally had a predominantly terrestrial focus. As far as protected marine spaces are concerned this has translated into a shortfall in terms of the surface area covered and the biodiversity represented within them compared to terrestrial spaces. In recent years, driven by the Convention on Biological Diversity, protected marine spaces have undergone major expansion. The push in this direction needs to be maintained however if this lack of representation is to be totally rectified.

The protection of the marine environment is the raison d'être of the Atlantic Islands of Galicia National Park. It is one of only two maritime-terrestrial national parks in Spain, together with the Cabrera Archipelago. Aimed at the protection of the coastal ecosystems and the Atlantic continental shelf, it is made up of four archipelagos (Cíes, Ons, Sálvora and Cortegada) sited off the Galician Rías Baixas and the surrounding sea. The marine environment accounts for 85% of its 8,480 hectares.

As part of this protection policy, the Park devotes considerable effort to monitoring global change. Such monitoring plays a key role in determining the priorities of intervention and the results of the activities carried out. Monitoring and research projects are thus carried out within the park both as part of the Global Change Monitoring Programme in National Parks and at the individual park level.

A basic aspect of monitoring global change is knowledge of the elementary meteorological and climatic variables. Here the National Park relies on a network of meteorological stations and oceanographic buoys with data series going back to 2005. This network was installed and is maintained by Meteogalicia, and is an essential instrument for understanding how biological systems respond to climate changes.

The marine environment represents a very important part of the monitoring work carried out. The Park monitors representative areas of the marine habitats on a periodic basis. There is also a network of stations that measure the quality of the water and other oceanographic parameters in the vicinity of the Park, working in partnership with Intecmar. Other specific projects in collaboration with research organisations involve the remote detection of intertidal macroalgae, the monitoring of kelp forests and the measurement of microplastics in the seawater. An acoustic telemetry network has also recently been installed to monitor fish species.

The Park is home to traditional fishing activity, which is also the subject of study. For example, research has been conducted into the impact of extracting mussel seeds for the aquaculture of the communities on the Park's rocky coast. Another notable initiative, involving a combination of outreach and monitoring, is a volunteer project that studies the interaction between seabirds, and fishing and leisure craft, in partnership with WWF Spain.

The seabirds are not only one of the Park's main conservation assets, they are also an indicator of the quality of the marine environment. This is why they are the focus of special attention. Annual censuses of breeding colonies and overwintering populations are thus conducted, and support is provided to research into their ecology, especially in partnership with the University of Vigo. There is also a long-term research project focusing on the organic pollutants in seagull eggs that has been running for the last 10 years.

As far as the terrestrial environment is concerned, as well as the network of monitoring activities run by the OAPN (monitoring common breeding and overwintering birds, the phytosanitary status of woodlands), at a park-wide level periodic monitoring is conducted of the conservation status of habitats of community interest and another of coastal lichens. Amphibians number among the park's most interesting species, owing to their ecological and genetic singularities and their role as bio-indicators in the face of climate change. Monitoring is therefore conducted of their breeding grounds. There are research projects under way for this group of species too, focusing on ecological, biogeographical and evolutionary aspects in partnership with the Universities of Oporto and A Coruña. The interaction between climate change and invasive species of flora, a major threat to the park, is also subject to research.

Volunteer projects are also carried out in the terrestrial environment, enabling not only awareness to be raised of global change but also information on this change to be collected. Notable for their long-term focus are the monitoring in partnership with BMS España and the ringing of passerines on autumn migration carried out by the Iberian Ringing Group, both undertaken in partnership with the OAPN.

Protected areas are fundamental tools in the fight against global change. The Atlantic Islands of Galicia National Park, together with the other parks in the network, form constitute authentic natural testbeds where change can be studied in detail to offset and adapt to its effects. In conclusion, two aspects are fundamental in this context. First, the need to maintain these monitoring activities over time. The shortage of resources and the reduced priority traditionally placed on data collection compared to other activities are a major limitation in this regard. But these efforts will only succeed in achieving their goal if they are maintained over the long term. Secondly, it is also very important to make society aware of the results obtained to garner its support and involvement. The national parks, with their ability to attract vast numbers of visitors, provide an exceptional platform in this respect.

The global change monitoring programme in the Atlantic Islands of Galicia Maritime-Terrestrial National Park

Santiago Salsón Casado
Coordinator of the Observation and Climatology Area - MeteoGalicia

Marine-meteorological infrastructure constitutes a major part of the programme of monitoring the natural assets of the Atlantic Islands of Galicia Marine-Terrestrial National Park. The data that are collected help to determine the conservation status of the park and serve as an aid to decision-making in the face of possible changes that may arise. Moreover, in order to study the climate of any region it is necessary to have access to a range of relevant meteorological variables, such as the wind, rainfall and temperature, among others. The Park, which faces the Rías Baixas estuaries, exhibits a climate distinct from the nearby coastal areas, especially in terms of precipitation, because the weather fronts coming in from the Atlantic are unaffected by the topography, resulting in reduced rainfall.

The meteorological observation in the park has progressively evolved over the course of recent years, both in terms of the number of stations and the types of station in use.

The first weather station in the monitoring network was installed on the Cíes Islands in August 1998. This was a manual station that remained in operation until 2008 and featured a rainfall recorder and gauge, maximum and minimum thermometers, a sunshine recorder and a totalising anemometer for measuring wind direction and speed.

The data was recorded with the indispensable collaboration of the park wardens, who discharged their task as observers, manually collecting the data from each meteorological instrument on a daily basis.

Manual station on Cíes

The park's first automatic stations were installed in August 2005 on the north island in Cíes and on the island of Ons, next to the lighthouse. One year later, in June 2006 the Sálvora station came on stream, also in the vicinity of the lighthouse. The latter was transferred to the Pazo area in March 2019. These stations, powered by solar panels and featuring 4G communications, record wind, precipitation, temperature, relative humidity and solar radiation data every ten minutes. As well as broadening the range of recorded data and their accuracy over time, the introduction of these automatic stations aided and streamlined access to the data, which may be downloaded free of charge from the MeteoGalicia website.

http://www2.meteogalicia.es/galego/observacion/illasAtlanticas/plataformas.asp

These stations also form part of the network of weather stations belonging to the regional Environment, Territory and Housing Department, and have fulfilled the ISO 9001 quality standard since 2010. MeteoGalicia technicians are also responsible for the task of maintenance, in partnership with park staff who facilitate access to the stations.

The first sensor for measuring the brightness of the night sky was installed on Cíes in May 2014. These measures, among others, paved the way to the Park being awarded the status of a Starlight Reserve in 2017, in recognition of its perfect location for observing the night sky. Currently Cíes, Ons and Sálvora are all equipped with sensors of this type, enabling research to be conducted into light pollution and how it may be affecting the flora and fauna of the area.

With regard to oceanic-meteorological observation, in 2007 the first equipment was installed on the Cortegada platform and in 2008 the Cíes buoy was tethered in position, followed by the Ribeira buoy in 2011. These buoys record meteorological data, such as temperature, humidity and wind, and also oceanographic data, such as water temperature, salinity and currents. The data are recorded every 10 minutes and again may be downloaded from the MeteoGalicia website.

Ons station

This oceanic-meteorological network is part of the RAIA cross-border observatory, which brings together a large number of organisations in Galicia and Portugal undertaking significant activity in the operational oceanographic field.

Cíes buoy

In addition to the data collected by stations and buoys and in order to enhance maritime and terrestrial monitoring, webcams have been installed on the islands of Cíes (November 2016), Ons (February 2019) and Sálvora (March 2019), enabling observations to be made of the state of the sky and the ocean, as well as offering frequently spectacular views of incoming fogbanks, the formation of storms, sunsets and moonsets. On Cíes there is a camera near Rodas beach and another on the lighthouse. There are also two on Ons, one overlooking the port and the other the beach. The Sálvora camera is located at the weather station. These cameras provide an image every two minutes and a video of the current and previous day is also created.

Research

Research into the ecology of seabirds

Alberto Velando
Animal Ecology Group (GEA). University of Vigo.

Global change, the product of human activity, is causing major loss of diversity whose effects are particularly important on species' distribution boundaries. Seabirds comprise the most threatened group of birds on the planet and, owing to their role as apex predators, their local extinction brings about profound changes to the structure and functioning of the marine ecosystem. In this context, the seabird colonies of the Atlantic Islands of Galicia Maritime-Terrestrial National Park (PNMTIAG) constitute marginal populations on the limits of their distribution and studying them is particularly important for understanding how these organisms respond to the environmental challenges stemming from global change.

Since 1992, our research group (Animal Ecology Group, GEA, University of Vigo) has been studying the seabirds of the PNMTIAG, running and taking part in various projects funded both by the National Research Plan and the Regional National Parks Agency. Our research has focused on ascertaining the biology of the seabirds and the factors that impinge on their viability as a colony. The national park provides a unique laboratory for conducting studies into the basic biology of these organisms, enabling us to determine their response to environmental changes and develop strategies for their conservation.

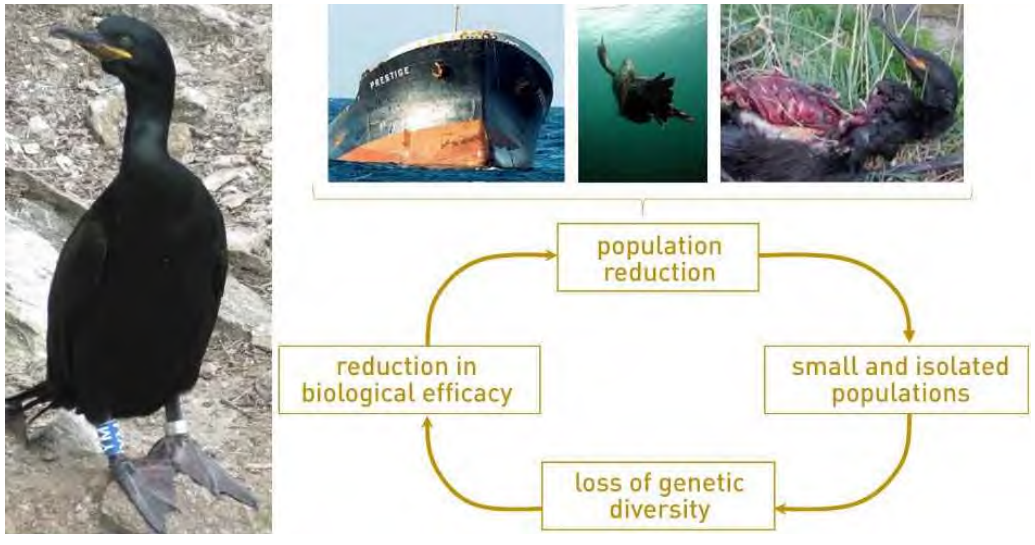


Figure 1.

The breeding population of the European shag (*Phalacrocorax aristotelis*) within the PNMTIAG constitutes one of the largest breeding colonies of this species, and is one of the Park's principal assets. Long-term monitoring of this population over the course of more than 25 years has enabled us to understand some of the factors that affect this colony, currently in decline. Studies of their movements and genetic analyses suggest that the Park's shags are isolated, comprising a genetic group that has little reproductive interchange with other populations in the north-western Iberian Peninsula. The park's population exhibits low genetic variability, partly owing to its demographic history – we believe that it suffered a "populational bottleneck" 100 generations ago, after which it expanded – but also owing to recent disturbances.

Scopoli's shearwater off the Cíes Islands. In 2007, Cristóbal Pérez, a researcher belonging to the GEA group, discovered Scopoli's shearwaters for the first time occupying burrows in the Cíes Islands' cliffs.

The findings of various projects suggest that the population has recently been subject to a range of threats stemming from human activity. The spill from the oil tanker *Prestige* in 2002 had various effects on the ecosystem that depleted the population.

This disturbance came on top of the negative effects brought about by mortality in gillnets and by the presence of exotic predators, such as the American mink (Figure 1). Fortunately, some of these threats have disappeared, but their effects linger on. Populations located at the limits of their distributions, like the European shag in the PNMTIAG, may be liable to extinction because anthropic effects exacerbate those caused by the low genetic variability of these isolated populations. Action needs to be taken on various fronts at the local level to ensure their conservation, and in the case of the European shag, this involves reducing the death rate of adults in the vicinity of the park.

Our group has also witnessed the creation of new colonies of Scopoli's shearwater (*Calonectris diomedea*) in Galicia, including within the PNMTIAG, which represents a notable expansion of the distribution range of this species. In order to determine their possible origin we created a genetic profile of the individuals who were colonising the Park and compared it to individuals in the possible source populations. Taken together the genetic data suggested that the colonising population was made up of a heterogeneous group of individuals originating from various highly distant colonies, which accounts for their high genetic variability. It is interesting to note that the genetic distance among the pairs in the new colonies is greater than that expected by chance. This

pairing pattern leads to an increase in genetic diversity that may favour the resilience of these populations over the long term.

The Island of Sálvora is a unique natural testbed enabling our group to study basic aspects of seabirds' reproductive biology. The yellow-legged gull (*Larus michahellis*) has a significant breeding colony on this island with little anthropic influence, providing an ideal opportunity for studying diverse aspects of its reproductive biology. For example, we have investigated the way in which the presence of exotic predators in the breeding colonies can have complex effects on the populations. Our studies suggest that the social stress caused by the presence of predators is transmitted by individuals, including during the embryonic development stage. The transmission of social information partly accounts for the persistent effects of exotic predators, which generate chronic stress by their mere presence, even among individuals that have not had contact with the predators.

The conservation of seabirds on the islands of the Rías Baixas estuaries in Galicia, in a context of global change, represents a difficult but not impossible task. The seabird populations of the PNMTIAG are of major importance to global conservation, but also to the conservation of the ecological processes in which these creatures are embedded. PNMTIAG is a unique site for studying these organisms in their natural environment, and it is our responsibility to bequeath this legacy to subsequent generations.

Researcher from the GEA group collecting data in the yellow-legged gull colony.

Research

The effect of climate change on an invasive species and on species endemic to sand dunes in the Atlantic Islands of Galicia Maritime-Terrestrial National Park

Rubén Retuerto Franco and Josefina González Campoy
Ecology Area,
Department of Functional Biology
University of Santiago de Compostela.

The distribution of plant species is predominantly determined by the climate, so it is to be expected that climate change will have a major impact on biodiversity. Plants' capacity to develop strategies to avoid, tolerate or escape from situations of stress is key to providing appropriate responses to the rapid and intense environmental changes that we face. Of all species, endemic species may be the ones most sensitive to climate change and consequently the most vulnerable to extinction. The phenomenon of the uncontrolled invasion of natural spaces by exotic species constitutes another of the main causes of biodiversity loss in the world, a circumstance that is exacerbated in habitats and ecosystems that are especially vulnerable in changing climatic conditions.

In response to this biodiversity crisis, and given the urgency of minimising or reversing the losses, for more than six years the Functional Ecology of Plants group at the Biology Faculty of the University of Santiago has used the island of Sálvora, in the Atlantic Islands National Park, to study the effect of climate change on species of special interest to conservation, whether because they are more vulnerable to extinction, such as the endemic *Omphalodes littoralis* Lehm. subsp. *gallaecica* Laínz, *Alyssum gallaecicum* (S. Ortiz) Španiel, Marhold & Lihová and *Linaria arenaria* DC, or are responsible for the extinction of others, such as the invasive species *Carpobrotus edulis* (L.) N.E. Br., popularly known in Spanish as *uña de gato* ("cat's claw").

Thanks to grants obtained from two projects funded by the Ministry of Science and Economy (both co-funded by European ERDF financing), the Regional Government of Galicia, through funding an Invasive Species Network, and with the close partnership and constant support of the national park's management, this group has established an experimental plot on the island of Sálvora for monitoring the effects of climate change (figure 1).

The plot is equipped with open top chambers to increase the temperature of the site by approximately 2.5°C and a system of precipitation collectors to simulate the effects of rainfall reduction. It is also equipped with a system for recording environmental data, with air (temperature and humidity) and ground sensors (temperature, humidity and conductivity), which are sent by a telemetry system directly to the research group's lab oratory. It also has time-lapse cameras that take and store photographs at set intervals, recording plant growth,

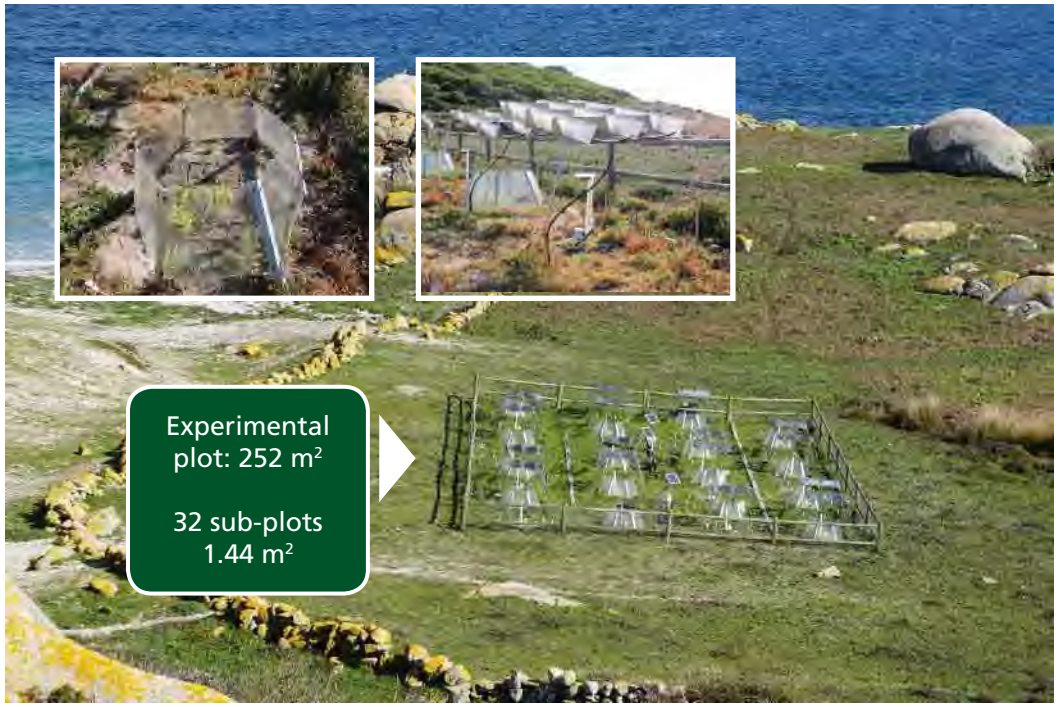


Figure 1. General view of the experimental plot on the island of Sálvora. It is shown in detail one of the eight Perspex chambers and the precipitation collectors, mounted on a post, one of the time-lapse cameras and the atmospheric sensors.

the pollinators that visit them and the dates of flowering.

One of the projects under way in the park, "Challenges in the management of the invasive plant *Carpobrotus edulis*: phenotypic changes in the course of the invasion, responses to global change scenarios and biological control", focuses on the effects of climate change on this invasive plant, originating from South Africa, which represents a serious threat to the biodiversity of coastal ecosystems throughout the world. Some of the results of this study are far from heartening, concluding as they do that the predicted changes in climate, especially the increase in mean temperature, may encourage the growth of this species by up to 16% (figure 2). Consequently, this invader may extend its range of distribution even further, thereby becoming an even greater threat to biodiversity than it already is. Other findings suggest that the physiological properties of this species, including pigments, antioxidants, photoprotectors and mechanisms for dissipating excess radiation, will enable it to out-compete other species in an increasingly warm and dry climate.

In this study, the differences observed in survival, growth and functional characteristics, comparing populations on the Iberian Peninsula and South African populations of *C. edulis*, make it evident that in the course of the invasion, the two population groups have undergone a process of evolutionary divergence. The research has thus also shown the extraordinary capacity of this species to improve its adaptation since it invaded the Iberian Peninsula more than 100 years ago.

In the project that is currently under way, "Endemic dunal species in the face of climate change: eco-physiology, genic expression and ecological niches", the group is using the experimental plot on the island of Sálvora to study the effects of climate change on three species endemic to our dunal systems, which are especially vulnerable owing to the threats they face.

The results obtained to date indicate significant effects of climate change on the survival, growth and reproduction rates of *O. littoralis* subsp. *Gallaecica*, *A. gallaecicum* and *L. arenaria*. The study has also shown that climate change will trigger surprising modifications to the onset and duration of flowering among these species as well as the existence of major intraspecies variability. This finding may provide a source of encouragement in a future scenario of climate change, given that in general, greater variability in a species indicates greater flexibility or capacity to respond to rapid environmental changes. However, the lack of understanding about the intensity and direction of the impact that climate change may have on plants and their varying degrees of vulnerability complicate predictions regarding how climate change may impinge on species extinction. The projects conducted in the Atlantic Islands National Park are thus essential for acquiring greater understanding of these processes and thereby helping to design appropriate strategies that offset the impact of climate change on biodiversity.

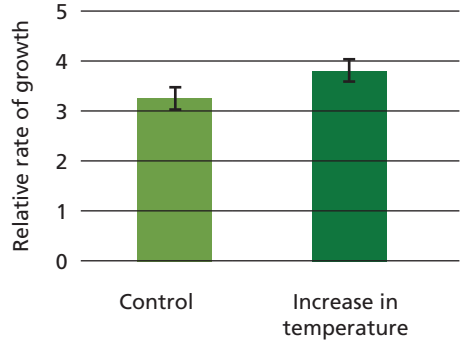


Figure 2. Shown on the left is the invasive species *C. edulis* growing inside a temperature chamber to simulate the effect of climate change and on the right the mean values (± standard error) of this species' relative rate of growth (day^{-1}) under the current climate (control) and the predicted climate at this latitude (temperature increase of 2.5°C).

Research

The biogeography and microevolution of the insular amphibians and reptiles of the Rías Baixas

Guillermo Velo-Antón
CIBIO-InBIO (Portugal).

The islands and islets that make up the Atlantic Islands of Galicia Maritime-Terrestrial National Park (PNMTIAG) offer a unique environment for studying recent microevolutionary, demographic and ecological changes, predominantly in flightless terrestrial species that have been isolated in these small areas. Unlike other insular systems (the Canary and Balearic islands), the origin of the islands in the Rías Baixas is very recent, coinciding with the rise in the sea level after the last ice age, which gradually cut off the highest parts of the former coastline. It is possible that many terrestrial species that inhabit these islands today became isolated when the islands were formed, although the proximity to the mainland could also have facilitated subsequent colonisations.

The amphibians and reptiles present on these islands and islets are undoubtedly the group of vertebrates attracting the greatest biogeographical interest on the islands. The ocean represents a barrier to the dispersion of these species, and therefore it is highly likely that each of the insular populations have been evolving independently since their isolation. Currently there are three species of amphibian (*Discoglossus galganoi*, *Lissotriton boscai* and *Salamandra salamandra*), and nine species of reptile (*Anguis fragilis, Chalcides striatus, Chalcides bedriagai, Coronella girondica, Natrix maura, Podarcis guadarramae, Podarcis bocagei, Rhinechis scalaris* and *Timon lepidus*) present in the PNMTIAG, exhibiting various patterns of distribution depending on their biogeographical origin, ecological requirements, interaction with other species and recent extinctions.

The insular populations of fire salamanders (*S. salamandra*) are a clear and unique example of recent evolution in insular systems, and still survive on the islands of Ons and San Martiño (extinct on the islands of Faro and Monteagudo). Their pueriparous mode of reproduction (giving birth to a small number of young on dry land), contrasts with the larviparous mode (giving birth to numerous larvae in streams and pools) present in mainland populations of the *S. s. gallaica* subspecies (to which it belongs), and that of the subspecies distributed throughout Europe, apart from the *S. s. bernardezi* subspecies, also pueriparous, and present in the north of Galicia and Asturias. This system therefore constitutes an exceptional case of reproductive polymorphism within the same species, and has persuaded us to monitor these island populations for the last 15 years, studying various biological facets (the genetic, morphological, reproductive and behavioural) in order to be able to understand the origin, causes and ecological and evolutionary implications of this change. This monitoring has not only shown that the origin of the pueriparity is distinct from the example that emerged in the Cantabrian Mountains, and is therefore very recent, and that the populations are completely cut off, but has also revealed other changes linked to their insularity.

Although *S. salamandra* is highly nocturnal and crepuscular, being mainly active on humid and rainy nights that enable them to maintain its physiological needs and gain access to prey associated with these conditions (for example, snails, slugs and worms), the San Martiño population exhibits significant daytime activity, shunning the more favourable conditions (humidity and prey) offered at night. Our studies suggest the possibility of predation by the black rat (*Rattus rattus*), which is highly common on the island and has crepuscular and nocturnal habits, as a possible cause of this behavioural change, although this hypothesis is still in the research phase. Other changes that we have observed in these salamander populations include smaller body size, possibly linked to their reproductive mode and/or an insular syndrome, and a tendency towards melanism on the island of Ons, although the causes underlying these morphological changes are still being investigated.

Using molecular techniques, we have been able to ascertain that these insular populations exhibit lower levels of genetic diversity than coastal populations, which may be linked to demographic processes (bottlenecks) that are common during the formation of islands, or the degradation of the habitat on the island of San Martiño, dominated by a eucalyptus plantation, coinciding with less genetic diversity in the population and reduced quantified corporal condition for the species. Although the change in the reproductive mode could also be linked to a reduction in the genetic diversity of these island populations, this seems unlikely given that we have observed differences between the pueriparous populations of *S. s. bernardezi* and larviparous populations of *S. s. gallaica* and, in the specific case of Ons, an increase in the levels of multiple paternity in the population may favour the maintenance or increase of genetic diversity.

We have also studied the biogeographical processes of Boscá's newt (*L. boscai*), showing that the populations present on the islands of Ons and Sálvora originated with the formation of the islands, ruling out subsequent colonisations from the mainland. We plan to extend this research to other species, such as the lizards (*P. bocagei* and *P. guadarramae*), widely distributed throughout the Park's islands and islets, and carry on studying the microevolutionary processes and the interaction of this interesting group of vertebrates with other species and with the environment they currently inhabit. Our hope is that such work will continue showing and disseminating the evolutionary interest inherent in these insular populations, and aiding in their management and conservation, preventing future extinctions such as those that befell some populations at the end of the last century. These islands are relatively small, just like many of the populations that inhabit them, and therefore extremely susceptible to such anthropic pressures as the transformation of the habitat (introduction of invasive species like the eucalyptus, which reduces the availability of prey and bodies of water), mass tourism (increasing interaction with wild species affecting their behaviour and activity, and the risk of transmitting emerging diseases that currently affect amphibians), as well as the negative effect of global change on ectothermic species, the category into which amphibians and reptiles fall.

Projects under way within the framework of the Global Change Monitoring Programme in National Parks

The table below sets out the research projects falling within the framework of the Global Change Monitoring Programme in 2020

PROJECT	ORGANISATION	NATIONAL PARK	FUNDING
HERBIVORES AND NATURAL REGENERATION IN MEDITERRANEAN SYSTEMS DOMINATED BY UNGULATES: IMPLICATIONS FOR SUSTAINABLE MANAGEMENT IN THE FACE OF GLOBAL CHANGE	MOUNTAINS, FORESTRY AND ENVIRONMENTAL ENGINEERING DEPT. (UPM)	NETWORK	OAPN
AUTOMATED GEOLOCATION OF FOREST FIRES VIA A SUSTAINABLE NETWORK OF LOW COST AND EASILY DEPLOYABLE SENSORS.	INSTITUTE FOR TECHNOLOGICAL DEVELOPMENT AND INNOVATION IN COMMUNICATIONS (ULPGC)	NETWORK	OAPN
IMPACT OF AGRICULTURAL ACTIVITIES ON THE FAUNA OF NATIONAL PARKS	INSTITUTE OF ENVIRONMENTAL DIAGNOSIS AND WATER STUDIES (CSIC)	NETWORK	OAPN
DEMOGRAPHIC EFFECTS AND REMEDIATION OF INFECTIOUS DISEASES AMONG AMPHIBIANS IN MOUNTAINOUS NATIONAL PARKS	NATIONAL NATURAL SCIENCE MUSEUM (CSIC)	NETWORK	OAPN
BELLWETHER LAKES OF GLOBAL CHANGE IN THE NATIONAL PARKS: MULTIDISCIPLINARY ANALYSIS OF THE LAST 6,000 YEARS	SCIENCE FACULTY (UGR)	SIERRA NEVADA N.P AND AIGÜESTORTES N.P. I ESTANY DE SANT MAURICI	OAPN
HIGH ALTITUDE AQUATIC ECOSYSTEMS: HIDDEN REFUGES OF BIODIVERSITY AND BELLWETHERS OF GLOBAL CHANGE	BLANES CENTRE FOR ADVANCED STUDIES (CSIC)	NETWORK	OAPN
HYBRIDISATION AS AN ENGINE OF BIODIVERSITY ALTERATION IN THE ERA OF GLOBAL CHANGE: AN EXPERIMENTAL AND PREDICTIVE PERSPECTIVE ON THE PHENOMENON	SCIENCE FACULTY (UGR)	NETWORK	OAPN
BELLWETHER LAKES OF GLOBAL CHANGE IN THE NATIONAL PARKS: MULTIDISCIPLINARY ANALYSIS OF THE LAST 6,000 YEARS	BIOLOGY FACULTY (UB)	SIERRA NEVADA N.P AND AIGÜESTORTES N.P. I ESTANY DE SANT MAURICI	OAPN
EVOLUTION OF THE BIODIVERSITY ON THE SEA FLOORS OF NATIONAL PARKS AFFECTED BY INVASIVE SPECIES AND CLIMATE CHANGE: GENETIC AND ECOLOGICAL MONITORING	BLANES CENTRE FOR ADVANCED STUDIES (CSIC)	CABRERA ARCHIPELAGO N.P. AND ATLANTIC ISLANDS OF GALICIA N.P.	OAPN
MONITORING AND MODELLING INTEGRATED INTO A CLIMATE VULNERABILITY WARNING SYSTEM IN MOUNTAIN FORESTS	AGR- CCT FORESTRY APPLICATIONS AND ECOLOGY RESEARCH CENTRE	AIGÜESTORTES N.P. I ESTANY DE SANT MAURICI AND ORDESA Y MONTE PERDIDO N.P.	OAPN
VIRTUAL MARITIME NATIONAL PARKS FOR MONITORING THE EFFECTS OF CLIMATE CHANGE	INDUSTRIAL AND TELECOMMUNICATION ENGINEERING DEPT. (UC)	CABRERA ARCHIPELAGO N.P. AND ATLANTIC ISLANDS OF GALICIA N.P.	OAPN
BELLWETHER LAKES OF GLOBAL CHANGE IN THE NATIONAL PARKS: MULTIDISCIPLINARY ANALYSIS OF THE LAST 6,000 YEARS. CLIMATE SUB-PROJECT	TOURISM AND GEOGRAPHY FACULTY (URV)	SIERRA NEVADA N.P.	OAPN
THE VULNERABILITY AND RESILIENCE OF MATURE FORESTS IN THE FACE OF CLIMATE CHANGE: IMPLICATIONS FOR FOREST MANAGEMENT IN THE NATIONAL PARKS	SUB-DIRECTORATE GENERAL FOR RESEARCH AND TECHNOLOGY (INIA)	NETWORK	OAPN
THE VULNERABILITY AND RESILIENCE OF MATURE FORESTS IN THE FACE OF CLIMATE CHANGE: IMPLICATIONS FOR FOREST MANAGEMENT IN THE NATIONAL PARKS	PYRENEAN INSTITUTE OF ECOLOGY (CSIC)	NETWORK	OAPN
VIRTUAL MARITIME NATIONAL PARKS FOR MONITORING THE EFFECTS OF CLIMATE CHANGE	SPANISH INSTITUTE OF OCEANOGRAPHY	CABRERA ARCHIPELAGO N.P. AND ATLANTIC ISLANDS OF GALICIA N.P.	OAPN
DEVELOPMENT OF ENVIRONMENTAL DNA TECHNIQUES AND NICHE MODELLING FOR THE CONTROL OF INVASIVE SPECIES AND THE CONSERVATION OF FISH SPECIES IN THE MEDITERRANEAN NATIONAL PARKS	NATIONAL NATURAL SCIENCE MUSEUM (CSIC)	CABAÑEROS N.P. AND MONFRAGÜE N.P.	OAPN

Outreach activities

Monitoring the post-breeding migration of passerines on the island of Ons

Miguel de Gabriel Hernando
Iberian Ringing Group.

In 2013 the Iberian Ringing Group, in partnership with the Atlantic Islands of Galicia Maritime-Terrestrial National Park, launched a project dedicated to monitoring the post-breeding migration of passerine birds on the island of Ons. The project seeks first to reveal the role of the islands as strategic stop-off points for the birds during the autumn crossing and secondly to contribute to monitoring migration at a peninsular level, focussing particularly on the implications of global climate change on this biological phenomenon.

The project is run each September thanks to the volunteer programme of the Autonomous National Parks Agency, which has so far attracted 90 participants originating from throughout the peninsula.

The volunteers have thus been able to discover the Atlantic Islands in the roles of researchers and involve themselves in the migration monitoring activities that have been organised. These include scientific ringing complemented by daily census walks carried out throughout the island's various habitats.

Since the project began, 3,147 individuals from 48 different species have been caught, and there have also been 1,361 recaptures which have enabled key data to be recorded such as the time birds remain on the island, the rate at which they gain weight and the variability in the size and physical condition of the various waves of migrants. The ringing activities and census results have also enabled the variability in the abundance of the species to be estimated in accordance with the habitat, the date and the meteorological conditions. Willow warblers, pied flycatchers, blackcaps and robins have been the most abundant birds during the autumn crossing, with recaptured examples of these migrants hailing from France, England and the Netherlands.

These results highlight the importance of the Atlantic Islands of Galicia as a strategic place of refuge and refuelling for the passerines that migrate southwards following the line of the Atlantic coast, acting as bridges to avoid the zig-zags of the tortuous Galician coastline. The monitoring programme also enables the impact of climate change on migration to be ascertained at the local level over the medium and long term, providing the scientific community with systematic data enabling the impact at a wider scale to be measured. With many natural habitats of the Atlantic Coast having been progressively degraded, the preservation and enhancement of habitats used by migrating birds in the national park may represent a major contribution to the conservation of migrating birds amid the impact of climate change.

Volunteer scheme to enhance the conservation of seabirds on the Atlantic Islands

Beatriz Nieto Novoa
Oceans programme. WWF Spain.

Seabirds are one of the main natural assets of the Atlantic Islands of Galicia Maritime-Terrestrial National Park which, being 80% covered by seawater, is home to six nesting species. This park provides the main breeding ground for the European shag (*Phalacrocorax aristotelis*) on the Iberian Peninsula and constitutes a place of special importance for migrating and overwintering species like the Balearic shearwater (*Puffinus mauretanicus*).

Hence, since 2018, the WWF has organised a volunteer scheme in partnership with the Atlantic Islands of Galicia National Park, to collect information about how the seabirds and human activities in the park's marine environment are distributed and the interactions that take place between the two.

The archipelagos that make up the park have historically been of great importance to the traditional fishing sector of the Rías Baixas owing to the wealth of stocks. Their waters form part of more than 12 shellfish management plans (clams, razor shells, goose barnacles and sea urchins) that involve more than 600 vessels. According to the results of a study carried out by WWF and the national park between 2016 and 2018, more than 200 distinct vessels operate in the park with passive fishing methods (creels, gillnets and baited hooks) aiming to catch octopus, velvet crab, spider crab and fish species such as sea bass, sargo and conger eel. Other active methods such as cord, net and purse seine fishing are also common in the park. Meanwhile, these waters are also much used for sailing and recreational purposes, tourism and shipping.

To date the volunteer scheme has attracted the participation of more than 100 people drawn from all over the Iberian Peninsula, with stays of 8-12 days. This year, affected by the Covid-19 pandemic, special steps have been taken to safeguard the health of all the participants.

During their stay, the volunteers are able to gain in-depth insight into the national park and see at first hand the difficulties of conserving marine species and their habitats in densely populated areas where apparently opposing interests may collide.

The volunteer programme aims to train the participants, as well as seeking a decisive contribution to the conservation of the park's assets. Over the lifetime of the scheme the participants have evinced a high degree of motivation, which has translated into firm commitment to the work undertaken.

This scheme relies on scientific advice for the analysis of the information collected and for the training of the participants. Equipped with binoculars and telescopes, the volunteers are posted to fixed points located on the main islands of the three archipelagos to observe how the seabirds use the environment and their interactions with human activities in the park's marine context.

With this information we have been able to draw up a map showing the risks of interactions between birds and human activities, determining zones of conflict where there is a negative effect on the distribution and behaviour of the seabirds, ascertaining the spatio-temporal pattern of the interactions and the species most effected, gaining a better understanding of the human activities that take place in the Park's maritime environment and the distribution of the seabirds and the use they make of the area. Recommendations and proposals have been drawn up based on all this to ensure an appropriate state of medium and long-term conservation for the seabird populations. The species that suffer most disturbance from the movement of shipping, one of the principal impacts, are by order of frequency: the yellow-legged gull (*Larus michahellis*), the European shag (*Phalacrocorax aristotelis*), the Balearic shearwater (*Puffinus mauretanicus*), the northern gannet (*Morus bassanus*), Scopoli's shearwater (*Calonectris diomedea*) and the lesser black-backed gull (*Larus fuscus*).

This research is an element of the partnership that the WWF has had with the Park since 2010 to collect information that supports management based on scientific knowledge and on the establishment of forums of dialogue and trust with the parties involved.

The management perspective

Interview with Vicente Piorno González, José Antonio Fernández Bouzas, Montserrat Martínez Morán and Emilia Castro Villaverde.

Technical team of the Atlantic Islands of Galicia Maritime-Terrestrial National Park.

From the management and research perspective of the Atlantic Islands of Galicia National Park, what is the value of participating in the Global Change Monitoring Programme, and in particular the maritime equipment?

It's of very considerable value. Research and monitoring are two of the legally-defined purposes of the national parks, so we give it great importance at the Atlantic Islands. The global change monitoring programme is an excellent opportunity to this end, enabling us to work on a fundamental aspect for conservation in a coordinated way with all the Spanish parks. Given its design it also appropriately complements the Park's own equipment and monitoring. The marine equipment is especially important for this park, considering our maritime-terrestrial nature. There is an historic deficit in the knowledge and conservation of natural resources in the marine environment that the Park is striving to remedy. The programme is a great help in this context.

Which species, habitats, systems and ecological processes do you think are most sensitive to climate change on the islands? What are the main problems associated with the marine environment?

Perhaps the Park's most important ecological process is the phenomenon of coastal upwelling. The existing system of winds and sea currents in the Rías Baixas causes a periodic rising of nutrient-bearing deep water that is responsible for the great productivity and biodiversity of the Park's marine environment. This system of water circulation is highly sensitive to the climatic conditions. There is scientific evidence that this process is threatened by the oceanographic changes associated with global change.

On a more global scale, there is also evidence of the impact of changes in the North Atlantic Oscillation (NAO) related to global change. Scientists who work in the park have documented the effect that this impact has on the productivity of the marine environment and its vicinity, and the population of seabirds that use it for nesting.

What are the most striking effects of global change, and of climate change in particular, on the status of the natural systems and species?

We are recording certain changes in the park for which there are major signs of links with global change. For example, some of the park's most sensitive habitats to climatic and oceanographic alterations are beaches and dunes, kelp forests and maerl beds. Scientists at the University of Vigo have shown the effects of change in wave and wind patterns on the beach-dune-lagoon system at Lago dos Nenos, a system that houses habitats and species of immense conservation importance. There are also data that show a decline in the kelp forests, the maerl beds and the breeding rates of various seabirds that nest in the park. We are also concerned by the catalyst effect that global change may have on other threats, such as colonisation by invasive species and other processes involving the disappearance of flora and fauna.

In which areas is it important to investigate further in order to improve scientific knowledge about the impact of global change in the national park?

As we mentioned earlier, there is a major gap in our knowledge about aspects related to the conservation of biodiversity in the marine environment. A full description of the Park's ocean floors, for example, is very recent. Working in the marine environment is more difficult and expensive, but keeping this effort going over the long term is fundamental to ascertaining the effects of global change. Areas that will have significant repercussion on the Park will include the impact of changes in the wave, current and wind patterns on sedimentary systems and the effect of oceanographic parameters on the sea floors, especially kelp forests and maerl beds. Also the effects of global change on the marine trophic networks, with regard to fishing and seabirds.

What are the most important parameters for monitoring climate and global change in terms of managing the Park?

From our viewpoint, one of the most important aspects for proper monitoring of the effects of global change is to ensure the continuity of the long-term temporal series, especially as far as basic monitoring data are concerned, for example meteorological and oceanographic variables and data regarding the conservation status of species and habitats of special conservation importance. In this context, the Park is fortunate to have data series of very high quality, for example those stemming from the partnership with Meteogalicia and Intecmar, and those relating to the populations of breeding seabirds collected by the park and the University of Vigo. As noted earlier, the foundations have been laid for the long-term monitoring of sea floors, in an effort that must be maintained. Monitoring traditional fishing activity and the trends of invasive species are also of significant interest to the Park.

How should policies designed to protect natural spaces adapt to the effects of climate change?

It seems to us that climate change should be one of the issues around which the management of protected spaces should revolve in the immediate future, and that adaptation to it should be part of practically all aspects of management. In our specific case we place particular importance on issues like reducing the impact of certain coastal infrastructure and offsetting the effect of other threats catalysed by climate change, such as the impact of biological invasions and fishing. Nor should we forget that national parks attract a very large number of visitors, who pay close attention to the way we manage these spaces. We therefore have a duty to prioritise exemplary practices of sustainability in our management and to raise awareness about the causes and consequences of global change in our educational and outreach activities.

The research perspective

Interview with Pablo Ramil Rego

Institute of Agrarian Biodiversity and Rural Development (IBADER) of the University of Santiago de Compostela.

From the management and research perspective, what is the value of the Atlantic Islands of Galicia National Park being a member of the Global Change Monitoring Programme?

The priorities in environment policy and the lines of enquiry in environmental R&D&I converge in the concept of global change. Natural spaces, and especially the National Parks Network, should be capable of setting up partnership mechanisms with the public and private organisations involved in research into natural systems to maintain and improve monitoring systems over the long term for ecosystems, habitats and populations of protected and exotic species. These are data that are tremendously useful in managing national parks, but also serve as support in designing other initiatives that can be undertaken within the context of other protected area networks (the Protected Area Network of the OSPAR Convention, the Network of Wetlands of International Importance, the Network of Biosphere Reserves, the Natura 2000 Network, etc).

Can conclusions be drawn about the effects of climate change on the Park's characteristic ecosystems?

Climate change has constituted one of the main modifying factors in the configuration of the ecosystems of the archipelagos that make up the Atlantic Islands of Galicia Maritime-Terrestrial National Park over the course of the Pleistocene and Holocene epochs. The anthropic activity carried out over the course of the last millennium has been extremely intense, and the processes of direct human intervention (modification of plant cover, introduction of exotic species, unsustainable exploitation of resources, repeated use of fire, etc) have probably had greater impact on the conservation status of the ecosystems than those stemming from global warming. Nevertheless, the effects of such warming are not insignificant and manifest themselves both in changes in the hydrological duration of certain types of habitat (temporary pools and puddles) and consequently on the biological cycle of the species that depend on them, and in the processes that favour the naturalisation and expansion of exotic invasive species. And here again we find the difficulty of distinguishing between phenomena caused by climate change and phenomena caused by human behaviour.

Which components of global change (climate change, changes in ground use, pollution, biological invasions…) are most important in the islands?

In the terrestrial environment, the consequences of the developmental models implemented mid-way through the 19th century are still evident, characterised by large areas of intensive forestry dominated by pine, eucalyptus, acacia and other exotic species. The creation of planted forests came at the expense of significantly reducing the surface area occupied by natural and semi-natural habitats. The reversal of this situation being carried out by the Park is a slow and delicate process that will repay dividends for the conservation status of the ecosystems and their diversity. The management of fish and shellfish extraction has also undergone major changes compared to the situation prior to the designation of national park status, but it still needs to be strengthened and consolidated on the basis of a rational and sustainable use of a singular and delicate ecosystem.

What are the top priority areas needing further investigation to improve scientific knowledge of the impact of global change in the case of the Atlantic Islands?
What are the most obvious signs of the effects of climate change on the Atlantic Islands?

The signs are the same as those recorded on the Atlantic coast, although they are accentuated here owing to the characteristics of the islands. Prominent among them are the seasonal decoupling of the temperature and precipitation conditions compared to the historic data. Thus, while rainfall maintains its annual level, it has changed its monthly distribution, being concentrated in the winter months, reducing or disappearing for the greater part of the spring and summer period, with a knock-on effect on habitats and the flora and fauna connected to them. The absence of cold spells in winter and the increase of maximum summer temperatures are other factors that may be seen as abnormal climatic conditions.

Which species, habitats, systems and ecological processes do you think are most sensitive to climate change in the National Park? What monitoring and/or adaptive management measures need to be adopted as a matter of priority?

It is difficult to find a habitat of public interest within the Atlantic Islands of Galicia Maritime-Terrestrial National Park that is not significantly affected by changes in seasonal climatic conditions. Although the greatest impact falls on the wetlands, whether the Lago dos Nenos coastal lagoon or the small seasonal wetlands that used to form in the midst of the sand dune systems, the heaths. By the same token, the dunal systems may be more resilient to temperature increases and the irregular distribution of rainfall, but this attribute cannot be applied to all the species that inhabit them, because many of them are highly sensitive to the phenological modifications of their habitats.

As mentioned earlier, the reduction in the area of intensive forestry plantations and their replacement by natural and semi-natural habitats constitutes a unique opportunity for strengthening the presence and distribution of singular habitats (small temporary pools and ponds, humid heaths, scrub on dunes, humid intradunal depressions, etc) which contribute to offsetting the effects of climate change on certain components of biodiversity.

As far as management measures are concerned, initiatives to control and mitigate already-established invasive exotic species need to be increased, both in the marine and in the terrestrial environments, establishing mechanisms for the swift control of new exotic elements.

The National Park benefits from a good network for monitoring climatic parameters (weather stations) which need to be complemented by continuous measurement sensors sited in particular kinds of habitat (caves, dunal ecosystems, scrubland, woodland, etc), deploying sensors both in the heart of the biocoenoses and in the aquatic and edaphic environments.

Can you suggest a small number of key impact and vulnerability indicators for the Atlantic Islands ecosystems?

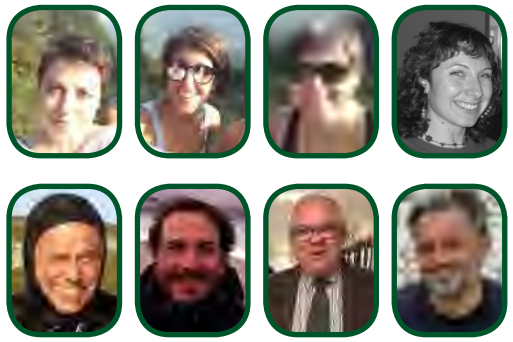
Climate indicators:

- Total recorded precipitation/ Total normal rainfall
- Percentage of surface area with lower than normal precipitation
- Number of days without rain / Number of days with rain
- Total hours of sunshine / Normal total hours of sunshine
- Duration of frost period / Normal duration of frost period
- Standardised drought index
- Normalised difference vegetation index/ normal normalised difference vegetation index
- Etc.

Habitat indicators. Comparative analysis of high-resolution orthophotographs every 5–10 years, combined with data collected *in situ.*

- Modification of the surface area of the main types of habitat (environmental units)
- Modification of the surface area occupied by invasive exotic species
- Modification of the biocoenosis surface / structure / composition of wetlands
- Modification of the biocoenosis surface / structure / composition of the beach-dune system
- Modification of the biocoenosis surface / structure / composition of the beach-dune-lagoon system
- Reduction in the surface area of forest systems
- Modification of the environmental parameters in cave systems (grottoes)

Studying the coastal biology of the Atlantic Islands of Galicia Maritime-Terrestrial National Park (PNMTIAG) in the era of global change



Cristina Piñeiro-Corbeira, Sara Barrientos, Pilar Díaz-Tapia, Viviana Peña, Ignacio Bárbara, Sergio Roiloa, Javier Cremades and Rodolfo Barreiro
BioCost Group, Science Faculty and Centre for Advanced Scientific Research (CICA) of the University of A Coruña.

Marine ecosystems provide human beings with goods and services but have for decades been subjected to various impacts stemming from human activity. In this context, protected areas such as national parks acquire special importance by enabling a representative sample of the marine ecosystems to be maintained in the place where they grow in appropriate conditions of conservation. The coastal biology research group BioCost, from the University of A Coruña has been studying the coastal environment of the PNMTIAG for over a decade.

Fig. 1. Maerl beds (Photo: Ignacio Bárbara)

One of the first projects undertaken was an in-depth study of the distribution and frequency of maerl beds and their associated flora, thanks to which 47 maerl beds were located covering 16 km^2 (Fig. 1). We were subsequently pioneers in using molecular tools to unravel the diversity of the calcareous algae that make up these beds. This led us to describing a species of maerl that was new to science: *Phymatolithon lusitanicum.*

In 2012 we carried out a multi-disciplinary study to design underwater routes aimed at revealing the depths of the Cíes archipelago to visiting

Fig. 2. Underwater scene around Cíes (Photo: Ignacio Bárbara)

Fig. 3. Intertidal impacted by cheek collection (left) and intertidal without impact (right)

snorkellers. To this end we developed a tool for quantifying the quality of the underwater seascape and we surveyed visitors to discover their knowledge of the subject. The results demonstrated the quality of the underwater seascape around Cíes (Fig. 2) and snorkelling's potential for raising awareness of the attractions of the ocean.

Despite being a protected area, the PNMTIAG still permits certain extractive activities with a major impact, a case in point being the collection of mussel seeds. We quantified the impact of this activity in the intertidal area of Cíes, Ons and Sálvora in 2016 and 2017. We also experimentally assessed the efficacy of certain methods that could reduce the impact of the extraction and we drew up a best-practice guide. The results showed the considerable impact of this activity on intertidal communities, which are incapable of recovering during the officially stipulated closed season (Fig. 3).

Kelp forests are one of the main marine habitats of the national park. A dramatic disappearance of the species that comprise it (*Laminariales: Laminaria ochroleuca, L. hyperborea* and *Tilopteridales: Saccorhiza polyschides*) has however been observed (Fig. 4). This is especially concerning for the Laminariales, because they are perennial species forming consolidated forests that provide a home, refuge and food for other species of socio-economic importance. We are currently researching the state in which the forests now find themselves and the possible reasons for their decline.

Fig. 4. Taking samples in a kelp forest (Photo: Pilar Díaz Tapia)

Long-term monitoring of diurnal butterflies in the Atlantic Islands of Galicia Maritime-Terrestrial National Park

Saba González Lorenzo
BMS España.

The diurnal butterfly monitoring programme in the Atlantic Islands of Galicia National Park was launched in 2015 within the framework of the Spanish National Parks Network's Long-term Monitoring Network. It also forms part of the European eBMS network, turning this programme into the largest insect monitoring network in Europe.

What is the goal of monitoring butterflies over the long term? Butterflies are excellent biological indicators of the conservation status of ecosystems, and because of their short life-cycles they respond rapidly to any change. As well as ascertaining the state of their populations in the national park and trends over time, it enables us to observe any adaptations and changes triggered by impacts on the habitats under study.

51 species of butterfly have been recorded in this protected natural area, a relatively high number for island ecosystems. Here it should be borne in mind that the archipelagos are located near to the mainland, and are of recent formation in geological terms, originating with the rise of the sea level caused by the last ice age some 12,000 years ago, when certain parts of Galicia's coastal mountain ranges were cut off from the rest of the continent.

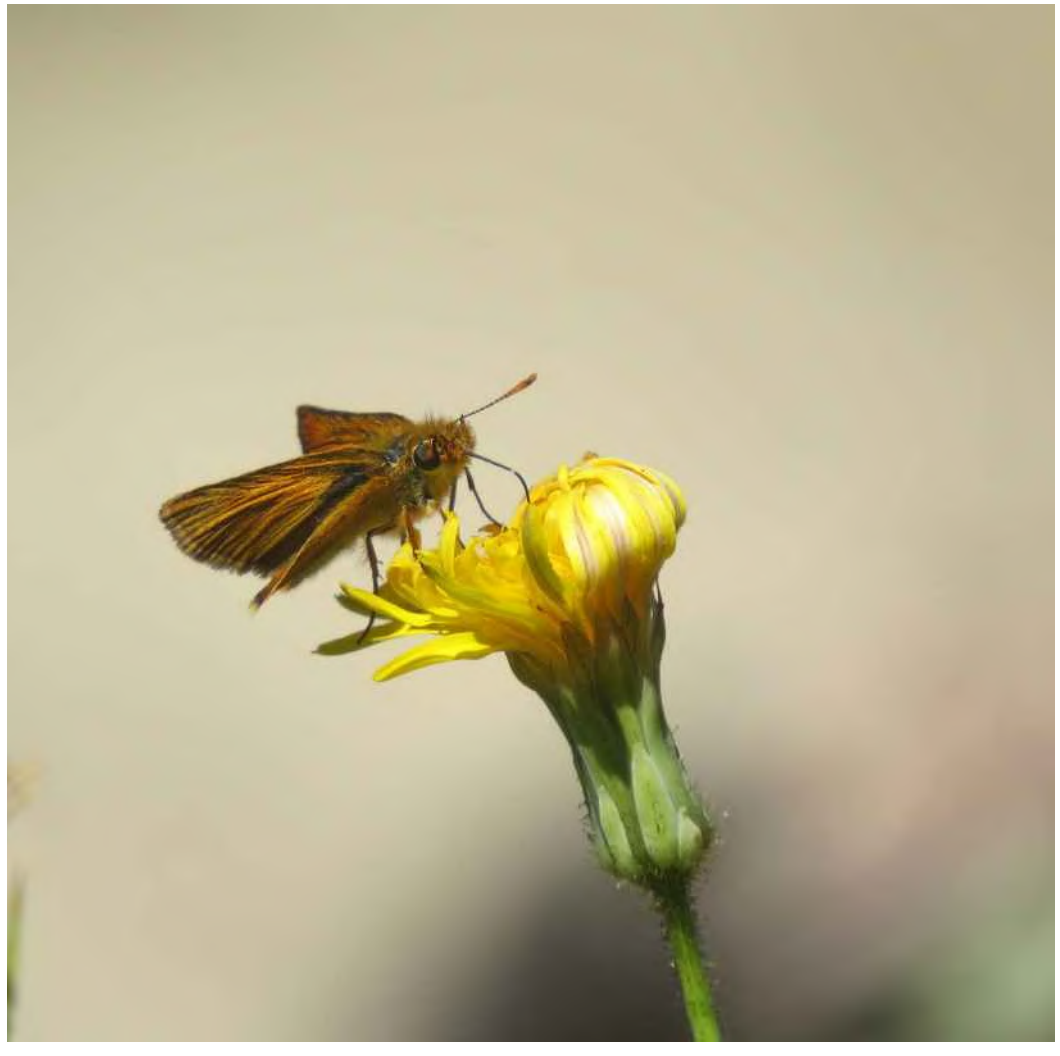
In terms of archipelagos, Ons and Cortegada have the highest recorded diversity of species (32), followed by Cíes with 25 species. The island of Sálvora joined the BMS in 2020 and was found to have a total of 21 species.

The censuses are carried out using a common and simple protocol that starts with designing a transect. The transects are made up of distinct sections in which distances and a representation of the archipelago's habitats are adjusted, to ensure that the observations are representative. The censuses are shared out between a group of 15 volunteers on the Park's main islands in the season when the insects are on the wing, which usually runs from March to September-October.

As far as data are concerned, more than 15,000 observations have been collected in just five years of censuses, with an average of 8-10 visits to each island per season. We have recorded new species for the park, such as *Apatura ilia* on Cortegada and *Argynnis pandora* on Monteagudo, Cortegada and Sálvora, and added new recordings of species for individual islands.

Although it may be premature to talk of population trends, the data collected has started to indicate where our attention should be focused: the abundance of certain species suggests the need for more in-depth scientific studies. Alterations in the populations of some butterfly species due to slight changes in their habitats have also been noted, as has the fact that the islands are stop-off places for some butterfly species, both in long and partial migrations.

Recording butterfly populations in the Atlantic Islands of Galicia National Park, despite any difficulty, is proving far from monotonous and is undoubtedly yielding startling results. And the data collected will help to manage this protected area to ensure that its ecosystems remain protected, something that is necessary amid the global impact of biodiversity loss.



Monitoring microplastics on Rodas beach

María Plaza Arroyo and José Luis Buceta Miller
Ports and Coasts Study Centre (CEDEX).

Seaborne litter is a global problem affecting all the world's oceans, stemming from bad practice in the management of solid waste and indiscriminate human behaviour. Such refuse is composed of a wide range of materials, with plastic waste being the most abundant. Notable among the plastic category are microplastics, referred to as such because of their size, below 5 mm, which may derive from various sources, primary sources being those manufactured with this size for direct use and secondary those that emerge from the fragmentation of larger sized plastics as a consequence of exposure to sunlight and other physical-chemical processes.

The goal of the Marine Strategy Framework Directive (2008/56/EC) is to achieve and maintain Good Environmental Status for the marine environment, with marine litter being an indicator of this status (Descriptor 10). To characterise this descriptor, indicator 10.1.3 refers to the presence of microparticles throughout the marine environment, with microplastics being the most significant factor within this indicator.

Since 2015, the current Directorate General of Coasts and Seas (DGCM), with the support of the CEDEX Ports and Coasts Study Centre, has been engaged in monitoring microparticles on beaches within the Monitoring Programmes of marine strategies (sub-programme BM-6). This sub-programme began in October 2016, and currently has a sampling network made up of 14 beaches throughout Spain, among them being Rodas beach in the Atlantic Islands of Galicia National Park.

Every year since 2016 two six-monthly campaigns have been conducted on this beach (in spring and autumn). The samples are taken at the high-tide line; using a 50 x 50 cm frame, a 1 cm-thick surface layer of sand is removed by park employees, in accordance with the guidelines provided by the CEDEX Ports and Coasts Study Centre, the organisation responsible for running the sub-programme, and which was present in autumn 2016. The samples are processed and analysed at the CEDEX Marine Environment Quality Laboratory, following an analysis protocol developed by this laboratory in 2015 on the basis of the methodologies recommended by the European Union's Marine Litter Technical Sub-group (TG-ML).

Figure 1 shows the average concentration (in particles per kg) found at the various beaches studied since the start of the sub-programme. Particularly notable are the very high concentrations found at El Ámbar beach (LAM, Lanzarote), sampled for the first time in 2019, with up to 881 particles per kg of sand, followed by Cabo de Gata (CGA, Almería), La Pineda (PIN, Tarragona) and Famara (FAM, Lanzarote). The concentrations found at Rodas beach were far below those at El Ámbar, but the autumn levels were not far from those recorded at Cabo de Gata, Pineda and Famara, with an average of 27.5 particles per kg in the three campaigns carried out up to 2019 (figure 2). The latter graph shows the variability in concentration, which ranges between 0 and 44 particles per kg.

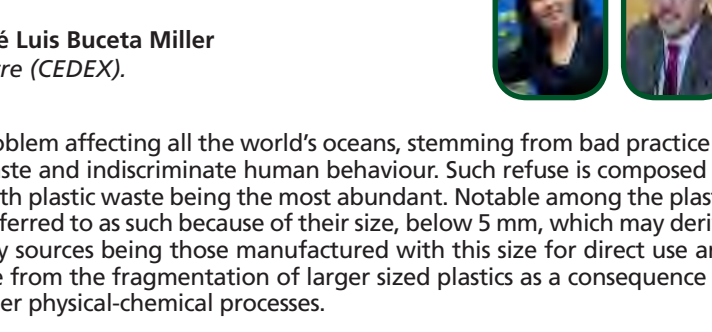


Figure 1: Mean concentration of N° particles per kg by beach and season

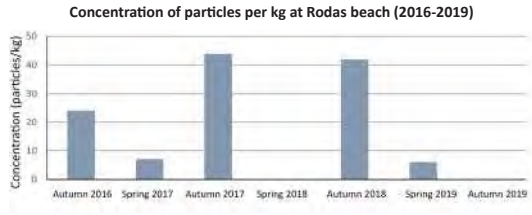


Figure 2: Concentration of microplastics (particles/kg) found at Rodas beach over various campaigns (2016-2019)

As well as the total concentration of microplastics, the monitoring programme provides a measurement of complementary data such as the size of each particle, its shape and colour. The left-hand panel of figure 3 shows the results obtained throughout Spain for all the particles analysed since 2016 (rather more than 11,000), from which it is evident that the most frequent size is smaller than 200 µm, accounting for approximately 43% of the total.

For the other categories of size, and despite the considerable concentration of pre-production pellets occasionally detected at some beaches, the differences are not particularly pronounced, with the particles being distributed homogeneously. In the case of Rodas beach (right-hand panel of figure 3), the predominance of particles smaller than 200 µm is also notable, as is the virtual absence of sizes greater than 1 mm, the category corresponding to pre-production industrial pellets, which indeed have hardly ever been found during sampling activities at Rodas.

With regard to the types of particle found over the course of the campaigns that have been conducted at Rodas beach, 60% of cases were granular fragments, while 38% were fibres or filaments.

Lastly, with regard to the trends that have been observed, the quantity of data collected is still relatively low, and for the time being no significant trend has emerged, therefore making it advisable that the monitoring activity continues. In this context it is worth stressing the effort being made by the DGCM, with the support of CEDEX, in monitoring microplastics at our coastal beaches, Spain being one of the few European countries to have implemented this kind of routine monitoring of its beaches.

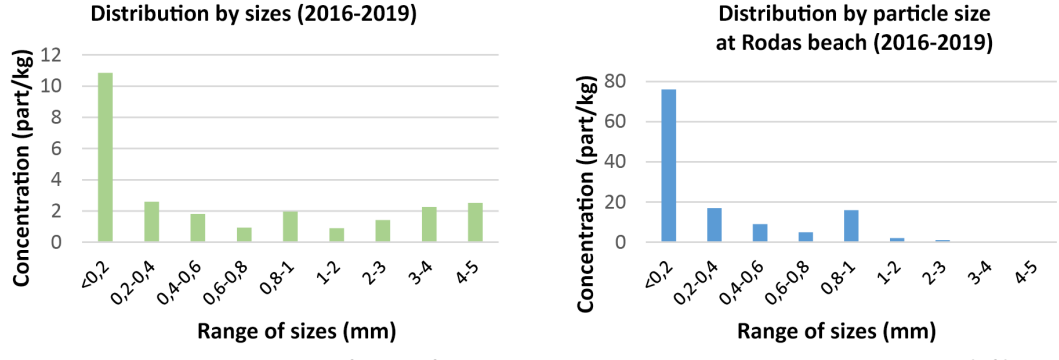


Figure 3. Mean concentration by size of particle for all samples analysed during 2016-2019 at Spanish beaches (left) and at Rodas beach (right)

Monitoring persistent organic pollutants in the eggs of yellow-legged gulls in the Atlantic Islands National Park

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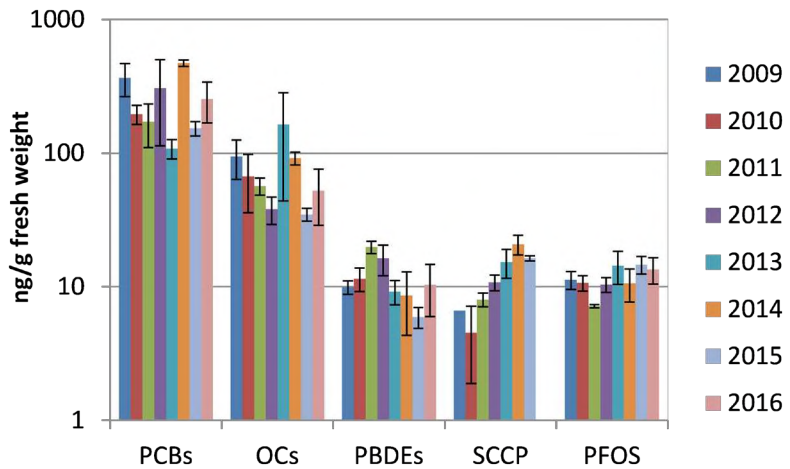
Persistent Organic Pollutants (POPs) are persistent compounds with the capacity to bioaccumulate and biomagnify over the length of food chains and exhibit considerable toxicity. They are regulated by the Stockholm Convention, which aims to protect human health and the environment by running monitoring and control programmes.

In 2009 we launched a partnership with the Atlantic Islands of Galicia National Park aimed at investigating POP pollution using the eggs of yellow-legged gulls (*Larus michahellis*) as a bioindicator, specifically collecting fresh eggs from the colonies on Cies, Ons and Sálvora. To our surprise, all the samples contained high concentrations of polychlorinated biphenyls (PCBs) and organochloride pesticides (DDTs, dieldrin and lindane, among others), and trace levels of brominated flame retardants from the polybrominated diphenyl ether family (PBDEs), short-chain chlorinated paraffins (SCCPs), dioxins and furans, and perfluoroalkyl substances (PFAS). Their presence was associated with the indiscriminate use of these substances and their discharge into the environment during the 1970s, until being prohibited in the 1990s and 2000s. This is when the opportunity arose of applying for project funding under the auspices of the Autonomous National Parks Agency. Thanks to the Agency's projects 2009/038 and 2012/768, from 2009 up to the present day we have run an annual monitoring programme of the levels of all the POPs covered by the Stockholm Convention in gull samples on Cíes, Ons and Sálvora with the goal of evaluating the presence, evolution and impact of these pollutants and proposing action plans for the conservation of protected natural areas.

The current records comprise data from an uninterrupted 12-year series (2009-2020). The results show that gull eggs are excellent bioindicators of the pollution emanating from POPs. PCBs comprise 70% of total pollutants, stemming from their extensive use in the 1970s in electric condenser and transformer fluids and as additives in many industrial products. Occupying second place are organochloride pesticides (20% of all pollutants detected), with DDE the most abundant compound owing to DDT use in agricultural and fumigation activities in the district. PBDEs, SCCPs and PFOS each account for 3% of total pollutants. It has been found that all the samples subjected to analysis were contaminated, which shows that the Atlantic Islands National Park is currently affected by the historic use of these persistent and hard-to-eliminate substances. During 2009-2016 (Figure 1) there was evident stability in the levels of all POPs except the SCCPs, the concentration of which increased significantly. The presence of SCCPs may be attributable to the growing use of flame retardants (replacing PBDEs) and plasticisers, as well as additives in many industrial fluids (replacing PCBs). The restrictions on using PCBs, OCs and PBDEs account for the fact that the concentrations recorded have not increased over time and it is to be hoped that at a certain point, the levels will exhibit a downward trend. With regard to the PFOS, it is evident that there are no significant differences either between the three colonies or over the course of the period under study, which indicates base levels of contamination attributable to the extensive use of these compounds in fire-fighting foams, in the production of Teflon and on a massive scale in mountain and hiking gear, such as impermeable boots and clothing. All these compounds are bioaccumulable, a fact that causes acutely harmful effects over the long term, given that they are teratogenic, neurotoxic and may affect levels of thyroid and reproductive hormones.

The non-invasive sampling protocol and our developed and validated analytical method has enabled a system that monitors more than 80 POPs included in the Stockholm Convention to be implemented systematically. Over the course of the 12 years of fruitful partnership with the staff of the Atlantic Islands of Galicia National Park we have been able to show that contamination by POPs remains a problem even in highly-protected areas and that it is necessary to join forces to identify the sources of pollution and to propose effective management tools in the face of environmental contamination. In addition we have created a valuable bank of samples that may help us provide retrospective information about other families of pollutants. The goal is to continue with the sampling to have a complete series enabling determination of the geographical distribution of the POPs, the main sources of pollution and the temporal trends over the long term (>10 years).



Average concentration of each family of POPs over the course of 2009-2016 (n=3) in the Atlantic Islands of Galicia National Park.

Monitoring fish species using acoustic telemetry

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The Atlantic Islands of Galicia Maritime-Terrestrial National Park (PNMTIAG) is located in one of the areas of greatest productivity anywhere on the Galician coast, with considerable socio-economic activity linked to fishing. A primordial goal of PNMTIAG, and the other maritime parks in the national network, is the conservation of marine biodiversity, and in particular of vulnerable species with low levels of resilience, within their borders, and by extension within their areas of influence, rendering compatible both the natural and environmental assets of the park and the sustainable use of the marine environmental heritage, promoting the integrated management of the ecosystem.

Animals move around for a variety of reasons, such as searching for food, avoiding predators, engaging in reproductive behaviour, searching for shelter, etc. By means of such movements, many exhibiting a seasonal pattern, transport of nutrients, biomass and energy takes place through various habitats and even between ecosystems. Such movements are in turn directly or indirectly affected by variations in the environmental conditions and the physiological, endocrine and energetic status of the individual. In the final analysis, all this determines the structure of populations and ecosystems, maintaining their function and their productivity. In this context, understanding and quantifying the spatio-temporal patterns of movement and distribution, their affinity with different kinds of habitat and their relationship with environmental variability is of great importance for a proper description, evaluation and monitoring of the species that inhabit an area of special interest such as a national park at a time of global change. All this information needs to be borne in mind when it comes to designing the most appropriate management strategy.

The TAC project, using acoustic telemetry to monitor the behaviour of coastal species and to evaluate the protection given by protected marine status, in partnership with the Biodiversity Foundation through the Pleamar Programme, co-funded by FEMP and with the collaboration of the PNMTIAG, is based on the application of acoustic telemetry techniques for monitoring the movement and behaviour of coastal fish species in the area around the archipelago of the Cíes Islands. A fixed network for observing the movement and behaviour of marine organisms in the PNMTIAG has been created with this project, turning the Park into a unique natural laboratory for experimentation. This network will form part of the European Tracking Network research initiative (ETN, http://www.europeantrackingnetwork.org/), which brings together the continent's acoustic networks and facilitates access to the data generated.

Extended residence in relatively small areas is a typical behaviour among fish species associated with reefs and has been documented among many different fish families. The results of the TAC project confirm the sedentary behaviour of the ballan wrasse, *Labrus bergylta*, previously suggested in other studies. For the first time, prolonged periods of residence during the summer months have also been documented for the undulate ray, *Raja undulata*. Whereas *L. bergylta* remains in the study area throughout the year, the studies conducted in the Park indicate residence of a markedly seasonal nature for *R. undulata*. These findings have major implications in terms of the role that PNMTIAG can play in aspects related to the spatial protection of these species.

Both species (*L. bergylta* and *R. undulata*), which are of commercial interest to the traditional fishing fleet, have habitats that are well defined in terms of space usage. The ballan wrasse limits its movements to rocky reefs whereas the undulate ray makes more use of sandy and mixed depths. Ballan wrasses also move within a small range, to the extent of exhibiting highly territorial behaviours at certain times of year, during their breeding season. As far as *R. undulata* is concerned, the TAC project has identified a place where this species congregates in a very specific area of the park to which it is faithful from the end of spring to the beginning of autumn, information of great value for managing this resource. The research findings suggest that the PNMTIAG (and the Cíes Islands specifically) may play a significant role in the life cycle of *R. undulata.*

This fixed monitoring network represents a unique opportunity for understanding the role the archipelago plays in the spatial ecology of some of the most emblematic coastal fish species in Galician waters.

New remote detection technologies for mapping and managing of biodiversity in protected marine areas: the Cíes Islands as an experimental testbed

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Macroalgae provide important ecosystemic services, such as food and habitats for a range of marine species, carbon capture, the regulation of change in oceanic pH and the oxygenation of the marine environment. Macroalgae are threatened by global warming however, which involves rises in global temperature and an increase in the frequency and intensity of heatwaves. In the north of the Iberian Peninsula, the rising water temperature of recent decades has been linked to declines in their abundance and distribution. The negative effects of warmer water on intertidal macroalgae may be accentuated at low tide, when exposure to high temperatures and intense sunlight are critical for their physiology and survival, especially if there are heatwaves when low tide coincides with midday during the summer.

To determine whether global warming is affecting the distribution of macroalgae in the Atlantic Islands of Galicia Maritime-Terrestrial National Park (PNMTIAG) it is necessary to ascertain their current distribution and to conduct temporal monitoring, efforts that can be optimised by harnessing remote detection techniques.

The overall aim of the Alganat2000 project was to contribute to the sustainable management of protected marine areas with fishing activity and to the monitoring and maintenance of marine diversity by means of the development of new methodologies enabling macroalgae to be mapped and their physiological and conservation status to be assessed.

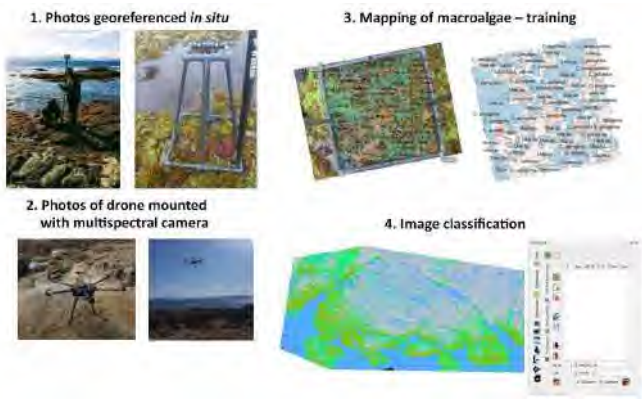

Figure 1. Field (1, 2) and cabinet (3, 4) methodology used to create the semi-automatic spatial classifier.

The project was carried out in the rocky intertidal zone of the Cíes archipelago, part of the PNMTIAG. The algae chosen as the study's target species were the most abundant in the intertidal zone: *Asparagopsis armata, Bifurcaria bifurcata, Colpomenia peregrina, Cystoseira tamariscifolia, Saccorhiza polyschides, Sargassum muticum, Ulva spp*. and *Codium spp.*

In order to create the classifier of macroalgae spatial coverage, data were collected between June and October 2019 in order to encompass the various phases of their development. The project team took photographs of the coverage of the macroalgae in the intertidal zone and georeferenced the position. Flights were also conducted with an unmanned aerial vehicle (UAV) equipped with a multispectral camera. Subsequently the macroalgae species were classified in the georeferenced photographs and the multispectral images obtained with the UAV were used to train the semi-automatic classifier (Fig. 1).

In order to share our results, an online classification viewer (SIGWEB) was created, which shows the macroalgae coverage from the data taken by the drone's multispectral camera. This tool enables information about macroalgae coverage in the study zone to be obtained remotely and is available at: http://193.147.83.216/alganat/map.phtml (Fig. 2).

The results of our study indicated that the semi-automatic classification method performed well as a means of rapid large-scale identification of macroalgae coverage in the intertidal zone. Meanwhile, a complementary laboratory experiment was conducted which assessed the effect of increasing the temperature of air at low tide and the temperature of water on photosynthetic efficiency, the growth and mortality of macroalgae. It was found that the increase in air temperature was critical for the correct physiological functioning and survival of the three species under study, whereas the effects of increases in the water temperature were sub-lethal.

In conclusion, an increase in air temperature is critical for intertidal macroalgae. The results indicate that if there is an increase in the intensity of heatwaves, the distribution and abundance of these macroalgae may be affected, and underlines the need for monitoring their populations.

The classification tool that has been developed (SIGWEB) needs to be supplied with new data. It would be advisable in future studies to carry on with continuous recordings of air and water temperature, and the coverage of the various algae in the PNMTIAG, to provide managers of protected marine areas with ongoing data series that help in decision making for adapting to global warming.

Figure 2. ALGANAT project SIGWEB viewer.

Basic guide to the seabirds of the Atlantic Islands of Galicia National Park and the Rías Baixas

This publication covers the 16 most frequently-observed seabirds in the Atlantic Islands of Galicia Maritime-Terrestrial National Park and its zone of influence, the Rías Baixas. Their breeding colonies have transformed the vegetation to the extent that, without them, the island landscape would be very different from what it is today.

The Park is very important for seabirds because a majority of the seabird species found on the Iberian Atlantic coast nest in its islands. Moreover, maritime zones around the islands, and in general all the Rías Baixas, comprise a zone of special importance for other species that visit us during their migrations or overwinter here.

It is very hard to appreciate anything one does not know about. Hence it may be said that the chief goal of this publication is to raise awareness of the fascinating world of birds.

https://cies.gal/wp-content/uploads/guia_avesmarinas_es.pdf

Mardeaves. Portal for the seabirds of the Rías Baixas.

This is an internet portal with the aim of collecting and sharing with the public existing knowledge about the seabirds in the Atlantic Islands of Galicia Maritime-Terrestrial National Park and its zone of influence, the Rías Baixas.

Here you will find a wealth of scientific and technical publications, many of them open-access and ready to be download in pdf format. In addition, there are data tables with seabird population censuses and other data of interest and a description of the biology and ecology of the commonest seabird species in the national park and the Rías Baixas.

https://mardeaves.org/

Climate change scenario viewer. AdapteCCa.

Developed within the framework of the PNACC (National Adaptation to Climate Change Plan), this viewer is designed to aid access to appreciate, visualise and download the most up-to-date forecasts for Spain's future climate.

Here you can consult the regional climate change projections for Spain based on the global projections contained in the Fifth Assessment Report of the IPCC (Intergovernmental Panel on Climate Change) within the framework of the PNACC Scenarios initiative and specifically, the 2017 PNACC Scenarios collection.

The available data come mainly from two sources: one-off forecasts from the Spanish Meteorological Agency (AEMET) and grid projections from the international Euro-CORDEX initiative.

http://escenarios.adaptecca.es

Publications

National Parks Network newsletter. Diurnal lepidoptera: learning about climate change with butterflies.

Issue number 63 of the National Parks Network newsletter, the first to be published in 2020, heralds a change of focus whereby issues of the newsletter will henceforth be devoted mainly to monographs related to the projects undertaken in the national parks and the network.

In specific terms, this edition focuses on butterflies, one of the groups of species that plays the clearest role as indicators of climate change and the conservation status of ecosystems. The contents of this publication are closely linked to the goals of disseminating, conserving and monitoring the highly prized assets of the National Parks Network. Indeed, the articles were written by the participants at the 9th seminar on the long-term ecological monitoring of the Network, held at CENEAM (Valsaín) in September 2019 and specifically devoted to diurnal butterflies.

https://www.miteco.gob.es/es/red-parques-nacionales/boletin/boletin_63_tcm30-507853.pdf

National Parks Network newsletter. Conservation and monitoring of amphibians in the National Parks Network. Adapting ourselves to change.

Amphibians are the most threatened group of vertebrates on the planet. In fact, the most recent data available suggest that more than half of species are threatened. Furthermore, this is a global phenomenon affecting the entire planet, and is even occurring in places that are theoretically well protected, such as the National Parks. The main threats looming over them are the loss, degradation and fragmentation of their habitats, emerging diseases, invasive exotic species, pollution, the increase in ultraviolet radiation, their exploitation and trade and, not surprisingly, climate change.

27 species of amphibian are present in the National Parks Network according to data collected in 2015. This diversity, combined with the special character of the National Parks from the perspective of their protection, makes the Network a very appropriate framework for establishing a long-term monitoring programme, enabling information to be obtained about the various species, not only in each individual national park but also across the entire Network.

https://www.miteco.gob.es/es/red-parques-nacionales/boletin/boletin_64_anfibios_tcm30-510343.pdf


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