THE STATE OF NATURE IN CATALONIA 2020

ÉS NATURA | ESTRATÈGIA DEL PATRIMONI NATURAL I LA BIODIVERSITAT DE CATALUNYA 2030

NATURAL HERITAGE AND BIODIVERSITY OBSERVATORY OF CATALONIA

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BACK COVER: Drylands of the Lleida plain. Photo: Víctor Sazatornil.
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FARMLAND AND GRASSLAND: Balaguer dryland. Photo: Joan Estrada Bonell.
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SEA AND COAST: Sampling violescent sea-whip Photo: Joaquim Garrabou.

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- Granollers Museum of Natural Sciences
- Aiguamolls de l'Empordà Natural Park
- Alt Pirineu Natural Park
- Cadí-Moixeró Natural Park
- Cap de Creus Natural Park
- Capçaleres del Ter i del Freser Natural Park
- Delta de l'Ebre Natural Park
- Montgrí, Medes Islands i El Baix Ter Natural Park
- El Montseny Natural Park
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- SEO BirdLife
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PROJECTS

- Assessment of changes in habitats in Catalonia
- Cartography of priority species for conservation (CARTOBIO)
- Cartography of Habitats of Catalonia (CHC)
- Meteorological stations of L'Estartit and Torroella de Montgrí
- Factors de Canvi
- Inventory of Sites of Geological Interest in Catalonia
- National Forest Inventory (IFN)
- Catalan Forestry Laboratory
- Land use and cover map of Catalonia
- Platform for tracking climate change in the Mediterranean (T-MEDNet)
- Study program on the ecological quality of rivers in the Province of Barcelona
- Monitoring program on the quality of water, mollusks and toxic phytoplankton in seafood production areas on the Catalan coast (PSQAM)
- Monitoring program on wild boar population in Catalonia
- Montseny brook newt monitoring program
- Monitoring and control program on bodies of water in the river basin district of Catalonia
- Global biodiversity monitoring program in Catalonia (SISEBIO)
- Specific biological monitoring in the natural parks of Catalonia
- Fauna and Flora Service specific biological monitoring
- Monitoring of amphibians and reptiles of Spain (SARE)
- Monitoring of measures implemented in managed estates in the eastern and western SPAs in the Segarra-Garrigues canal area.

REFERENCE RECOMMENDED

Brotons, L.; Pou, N.; Herrando, S.; Bota, G.; Villero, D.; Garrabou, J.; Ordóñez, J. L.; Anton, M.; Gual, G.; Recoder, L.; Alcaraz, J.; Pla, M.; Sainz de la Maza, P.; Pont, S. and Pino, J. (2020) *The State of Nature in Catalonia 2020*. Catalan Ministry of Territory and Sustainability. Government of Catalonia. Barcelona.

The work group for this document would like to express our gratitude for the information provided by the institutions, projects and people mentioned herein, especially the Government of Catalonia, as the leading Catalan public body in this field, but also local government bodies such as Barcelona Provincial Council and state and European authorities. We are particularly grateful for the work of hundreds of volunteers who helped compile the information on the projects mentioned here; it is impossible to list them all, but we wish to convey our appreciation, as without their help, all this information would not have been available to us.

This report was largely produced during a global health crisis that has affected our lives more than we could have imagined; the work group would therefore especially like to express our gratitude to our families (relatives and the people we live with), as without their support this report would not have been possible.

'FOR THOSE TO COME. WE HOPE THAT THE COUNTRY YOU FIND KNEW HOW TO CONSERVE YOUR NATURAL HERITAGE'

September 2020

PROLOGUE

The report in front of you is a landmark for the country and justifies the Catalan Government's investment over the last three years, including passing a Natural Heritage and Biodiversity Strategy, creating the Agència de la Natura de Catalunya (Catalan Nature Agency) and introducing specific funding for environmental policies, among other measures.

The figures on loss of biodiversity provided here, although lower than world figures, show clearly that our country has not escaped the global emergency that some have termed the sixth mass extinction of wildlife on Earth and which could have enormous economic consequences. The opportunity cost of failing to meet the European Union's 2020 goal for halting biodiversity loss (and we have failed to meet it!) is calculated at 50 billion euros a year. Hence, this is an issue that should concern everyone.

This report is a collective work that addresses the resolution by the Minister for Territory and Sustainability, of October 3, 2019, urging the publication of regular reports on the state of nature conservation and taking steps towards creating a Natural Heritage and Biodiversity Observatory. Indeed, this report is the embryo and calling card for the Observatory, a public-private partnership which we hope will soon be up and running, integrating research centers, universities and organizations working on the study of the environment, alongside the Government of Catalonia and other government bodies.

The Natural Heritage and Biodiversity Observatory is destined to become a key organization in obtaining, integrating, processing, accessing and disseminating information on Catalan natural heritage. It is not conceived as a center for documentation or an information repository, but as a space to generate knowledge for decision-making. Right from the start, it needs to look to provide answers, because only through seeking answers can we construct the information system we need. And for this reason, we preferred to produce the report before founding the Observatory.

Public policy, and the natural environment should be no exception, cannot be ideological or based on preconceived ideas, but founded on quantifiable indicators and scientific evidence. Future management must be adaptable, based on efficiency, cost-benefit ratio, efficacy; in other words, on results. This is why this study is so important: it provides figures, it quantifies, it sets out what we know and not what we think. It is also important because it analyzes the situation by areas and sectors of activity, forcing everyone to look at themselves, putting things into context and providing an incentive for action. The report not only addresses conservation policy, but also specific policies for the most important sectors in the country.

Finally, this work can be said to have arrived at just the right time. In early 2021, the governments worldwide and institutions concerned about nature conservation aim to take stock of the last decade and establish what might be termed the post-2020 strategy at the Conference of the Parties to the Convention on Biological Diversity. It could not come at a better time, because in Catalonia we are also taking stock of the situation and can thus participate in these debates from a position of knowledge.

This 2020 report is the first in what we hope to be a regular, on-going and growing monitoring program on the situation of our natural heritage and biodiversity. Making decisions requires historic data series and trend analysis. A film always provides more information than a snapshot. With more resources and more participation, the product can only improve; but for this to happen, we must take the first step.

The context in which this step was taken is an exceptional one, in the middle of a viral pandemic, with all its associated consequences. I would like to express my gratitude to all the people and institutions who have worked and helped in writing this report in such a difficult situation. Maybe this is no coincidence. The COVID-19 pandemic, which experts suggest arose out of human abuse of the Earth's natural resources and then spread around the modern, globalized world, should give us cause to reflect on our relationship with nature and on the world we want in the coming years.

Marta Subirà i Roca
Secretary for the Environment and Sustainability
Government of Catalonia

We live in a context of large-scale environmental and climate crises, with profound effects on biodiversity, the functioning of the ecosystems we need to sustain life and, consequently, the services they provide directly and indirectly to society.

The presentation in 2019 of the United Nations Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) made it clear that the global rate of species extinction and habitat destruction is accelerating. The goals set by the European Union for 2020 to halt biodiversity loss have not been met; and the latest reports on the application of the Habitats and Birds Directives in Catalonia (2013-2018) indicate that Catalonia is not immune to this loss. Overall, the figures show the diagnosis may vary considerably depending on scale and context; thus we need detailed knowledge on what is happening in our country if we hope to define an effective strategy to address the issue.

Today, no-one doubts that global biodiversity loss is the consequence of human activity, but clearly this involves a large number of factors linked to so-called global change. This makes diagnosing the problem a complex process requiring joint analyses of a large number of dimensions. The aim is to obtain an evidence-based overview of the changes we are observing in nature and the factors determining them, through a series of representative and robust indicators using the information available to us. We need to provide figures, orders of magnitude, speeds of change.

This report is a collective work and the result of much initial preparation. In Catalonia, a number of relevant documents are available to help understand how our society is affecting biodiversity. *Natura, ús o abús?. Llibre blanc de la gestió de la natura als Països Catalans* (1976, 1988 and 2018-2019) and the *Informe sobre l'Estat i les tendències del medi natural a Catalunya* (2010) by the Institute for Catalan Studies are part of this collection. But one should also bear in mind the effort put into collective analysis in recent years, already noted in the context of the IPBES Platform and the 6-yearly assessment on the application of the Habitats and Birds Directives conducted by the Government of Catalonia.

In recent decades, in Catalonia, an impressive network of people, groups and institutions has been developing, working from different angles to take the temperature of the natural environment around us. The information compiled in the context of this report is the result of the effort and hard work by this community of public and private actors. The report in front of you is the result of collaboration among 40 leading organizations in the study of nature and is based on data and scientific evidence collected by thousands of volunteers throughout the country. We would like to thank everyone who in one way or another has made this possible.

This report is in line with international and European reports, such as those assessing achievement of the Aichi Targets, the 2020 Living Planet Index, the State of Nature in the EU and others on a regional scale and focused on Catalonia. It provides a context for our specific situation and places us at the same level of more advanced countries in terms of identifying conservation priorities.

We wish to highlight the efforts involved in the summaries, graphic design and communication that make this report readable on different levels and generate its titles and conclusions, with no loss of scientific rigor. This report is not a denunciation, it is a scientific report, but which is also educational and accessible to all. It is a report that seeks careful consideration, even-handedness, based not on ideology but on evidence, debunking myths, not pointing the finger but stating only what can be backed up by data. And, finally, it is a report that breaks down the situation by habitat and sector of activity, so we can all identify our impact and the challenges that face us.

As you will see, the results show a general trend, common to all advanced countries, whereby Catalonia, in little under 20 years, has seen a 25% drop in its *Living Planet Index*, an index measuring abundance of wildlife. This is a major loss, but less than that 60% measured worldwide. You will also see that this biodiversity loss is not the same for all the main habitats; the figure is 54% for species in rivers, lakes and marshlands, 34% for farmland and grassland and 12% for forests and scrubland. In sea habitats, available data also indicate an unfavorable situation, although here the figures are not complete.

We hope this report proves useful, helps define our collective priorities more accurately and encourages us to take action as effectively as possible, based on a thorough understanding of the situation.

WORK GROUP

GENERAL STATE OF BIODIVERSITY IN CATALONIA

KEY MESSAGES

In the last 20 years, numbers among native vertebrate and invertebrate populations for which data are available have shrunk by an average of 25%.

The underlying cause of biodiversity loss is a socio-economic model that leads to ever more intense resource extraction in some areas and the abandonment of others, which had been used more sustainably.

The loss in population numbers is more than 50% for species living in rivers, lakes and marshlands, 30% for farmland and grassland species and 10% in forests and scrubland species. In the sea, available data also indicate an unfavorable situation.

Conservation measures have proved essential to reversing the negative situation among specific species, habitats and sites of interest, but have not halted the general decline.

Changes in land use are the main direct cause of biodiversity loss, although climate change and the arrival of invasive exotic species are having an increasing impact.

In general, the problems of biodiversity conservation in Catalonia are similar to those in Europe as a whole.

Biodiversity is the most widely used term to refer to the diversity of forms of life. This first section of the report quantifies changes in the state of biodiversity in Catalonia in recent years, analyzes the main impacts and describes the work under way to reverse negative trends in certain species and habitats. Finally, it discusses Catalonia's responsibility in conserving European and global biodiversity. The report also refers to geodiversity, defined as the variety of rocks, fossils, minerals and landscapes that make up the physical substrate for biodiversity.

The European roller (*Coracias garrulus*) in the Montgai dryland. **Photo: Joan Estrada.**

GENERAL DECLINE IN BIODIVERSITY

Catalonia is undergoing a steady, generalized deterioration in biodiversity. Data from vertebrate and invertebrate monitoring programs show a general decline in numbers. The average decrease between 2002 and 2019 was 25% (Figure 1, see also Boxes 1 and 2).

Globally, the average decline in wild vertebrate populations for the planet between 1970 and 2014 was 60% (Figure 2, see also Box 1).

Living Planet Index for Catalonia (LPI-Cat)

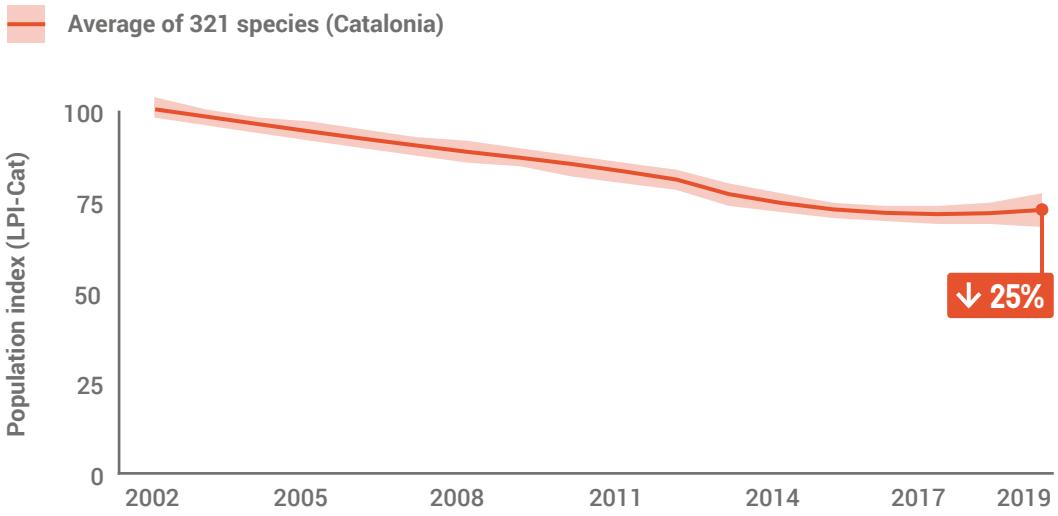


FIGURE 1. Living Planet Index for Catalonia (LPI-Cat). Average population trend in individual numbers of 321 native vertebrate and invertebrate species included in large-scale, long-term monitoring projects in Catalonia. The graph shows the average annual value and the 90% confidence interval. See Boxes 1 and 2 for an explanation of the graph. **Source: the authors.**

Living Planet Index (LPI)

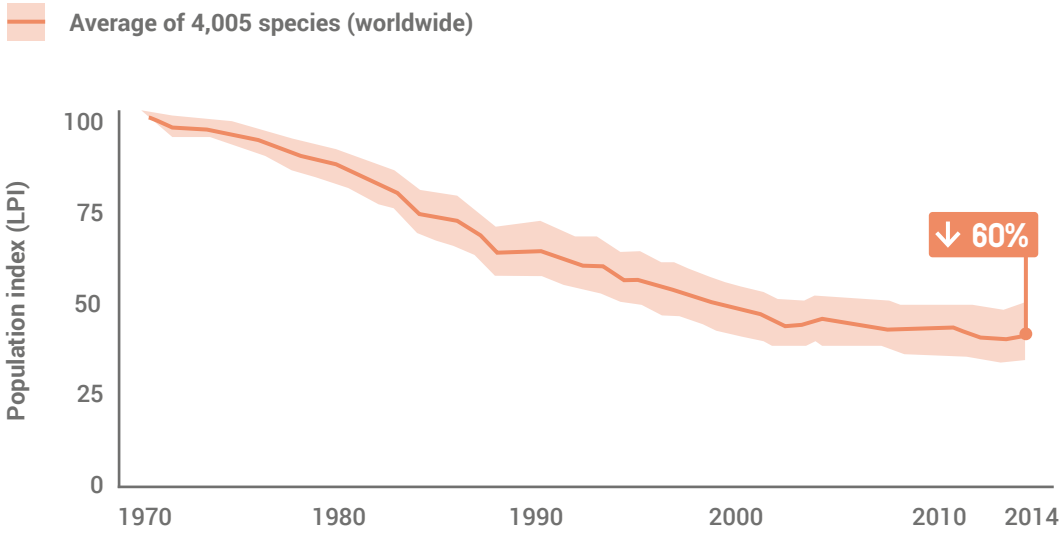


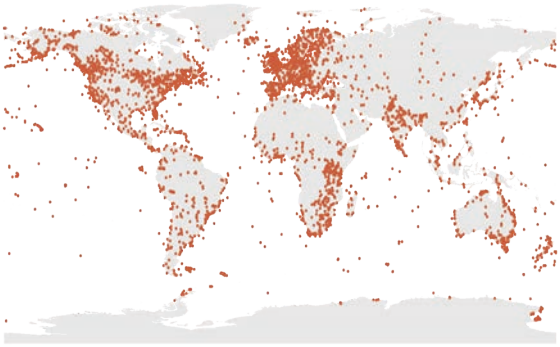
FIGURE 2. Living Planet Index (LPI). Average population trend in individual numbers of animal populations worldwide, calculated from monitoring data over time for a total of 4,005 vertebrate species during this period. The graph shows the average annual value and the 95% confidence interval. See Box 1 for an explanation of the graph. **Source: WWF/ZSL 2018.**

LIVING PLANET INDEX LPI

The **Living Planet Index** (LPI)[1] is an indicator used by the United Nations to monitor how far the global goal of maintaining the diversity of life on the planet is being achieved to contribute to people's well-being.[2] The index considers the planet as a whole, but LPIs are also produced for specific environments and regions.

The LPI is calculated as the average of all trends in the numbers of 4,005 species, each one calculated from individual, standardized counts, year after year, at thousands of locations around the planet. Currently, the LPI only counts data on vertebrates, but work is under way to extend it to other groups.[3]

The 2018 update to the LPI shows that vertebrate populations on the planet now have halved in numbers in the last 50 years.[4]



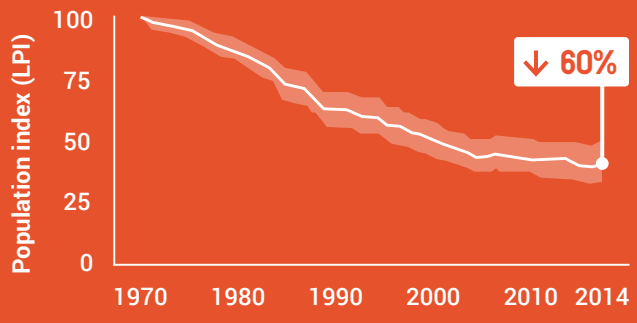
Sampling points in the species monitoring programs providing data to the LPI. **Source: adapted from www.livinplanetindex.org.**

HOW TO INTERPRET THE LPI GRAPHS

The Living Planet Index (LPI) assesses changes in numbers of animal populations in a region, considering only species for which large-scale, long-term monitoring data are available. It takes a reference value of 100 from the first year of assessment and compares other years to this value; thus a value of 95 means there has been an average 5% drop in the numbers of the species included in the index.

The graph shows the **average annual population value** (line) and **the 95% confidence interval** (shading around the line). This interval measures how certain we can be that the averages are accurate; the broader the shading, the higher the uncertainty.

For instance, in this LPI graph, the last value on the line indicates an average estimated loss of 60% and the shading above and below the value indicates that there is a 95% chance that the real value is somewhere between 43% and 50%.



For more information see:

1. LPI: https://www.livingplanetindex.org
2. Aichi 2020: https://www.cbd.int/sp/targets/
3. ZSL: https://www.zsl.org/global-biodiversity-monitoring/indicators-and-assessments-unit/living-planet-index
4. WWF: https://www.wwf.org.uk/updates/living-planet-report-2018

1970

Group of zebras (*Equus quagga*) in the African savanna. **Photo: Sergi Herrando.**

2018

Photomontage: Nora Soler, from the previous photo.

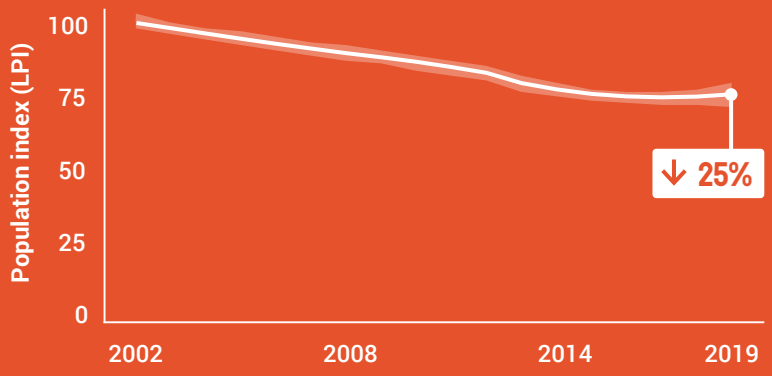
LIVING PLANET INDEX FOR CATALONIA LPI-CAT

The **Living Planet Index for Catalonia (LPI-Cat)** is an adaptation of the Living Planet Index to the figures for Catalonia. It uses the same basic methodology as the global index, but also includes information on invertebrates, as do other European countries. The LPI-Cat is currently calculated from data on trends in 321 species included in 7 large-scale, long-term monitoring programs.

BIOLOGICAL GROUP	NUMBER OF SPECIES	MONITORING PROGRAM
Butterflies	127	CBMS[1]
Fish	9	ACA[2], CHE[3]
Reptiles and amphibians	14	SARE[4]
Birds	153	SOCC[5], Specific monitoring[6]
Mammals	18	SEMICE[7], SOCC[5]

NOTE ON THE LPI-CAT GRAPHS

In the Living Planet Index for Catalonia (LPI-Cat) the shading around the line is a **90% confidence interval** (see also Box 1).



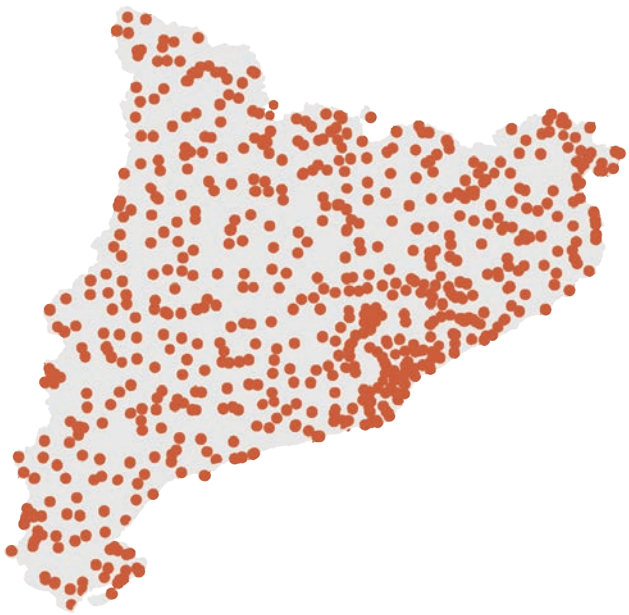
Species monitoring programs in Catalonia:

1. **CBMS**. Catalan Butterfly Monitoring Scheme. Monitoring program promoted by the Granollers Museum of Natural Sciences and the Catalan Ministry of Territory and Sustainability.
2. **ACA**. Catalan Water Agency monitoring programs.
3. **CHE**. Ebro Hydrographic Confederation monitoring programs.
4. **SARE**. Monitoring of amphibians and reptiles of Spain. Monitoring program promoted by the Asociación Herpetológica Española (Spanish Herpetological Society).
5. **SOCC**. Monitoring of common birds in Catalonia. Monitoring program promoted by the Catalan Ornithological Institute and the Catalan Ministry of Territory and Sustainability.
6. Specific monitoring programs. Monitoring programs for specific bird species of special interest promoted by the Catalan Ministry of Territory and Sustainability.
7. **SEMICE**. Monitoring of small mammals in Spain. Monitoring program promoted by the Granollers Museum of Natural Sciences and the Catalan Ministry of Territory and Sustainability.

Most of the data come from citizens' science projects, with the participation of coordinated networks of hundreds of mainly volunteer naturalists, linked to key institutions in each biological group.

LPI-Cat is promoted by the **Natural Heritage and Biodiversity Observatory of Catalonia** and all the associated monitoring projects. It is included in the Natural Heritage and Biodiversity Strategy of Catalonia 2030 (ESNATURA). Trends for each biological group are plotted by the corresponding biological monitoring projects, which are then all coordinated to produce this summary index.

The system for generating the LPI-Cat can also be used for specific environments or groups of species to provide a better understanding of mechanisms causing the decline in biodiversity. These variations to the LPI-Cat are contained in this report.



Sampling points in the species monitoring programs providing data to the LPI-Cat. **Source: the authors.**

2002

Group of house sparrows (*Passer domesticus*). **Photo: Raül Aymí.**

2018

Photomontage: Nora Soler, from the previous photo.

Bearing in mind that the monitoring programs obtain data from a representative sample of all species in the related biological groups (321 species including butterflies, fish, reptiles, amphibians, birds and mammals in the LPI-Cat), clearly the loss is not exclusive to a few species, but generalized. Some of the most alarming examples in Catalonia are the European eel (*Anguilla anguilla*) and the western marbled white butterfly (*Melanargia occitanica*), whose numbers have dropped by over 90% in the last 20 years (Box 3). However, biodiversity loss is not only detected by changes in wildlife populations. Changes in habitats, defined as units where plant species interact with the physical medium, can also provide relevant information[1] (Box 4).

The data indicate that biodiversity is not being lost everywhere. The situation is deeply concerning in aquatic environments (rivers, lakes and marshlands) and the losses are also striking in land environments with more open vegetation (farmland and grassland). However, in forest and scrubland the results show that, overall, the drop is on a much smaller scale (Figure 3).

Population trends in different environments

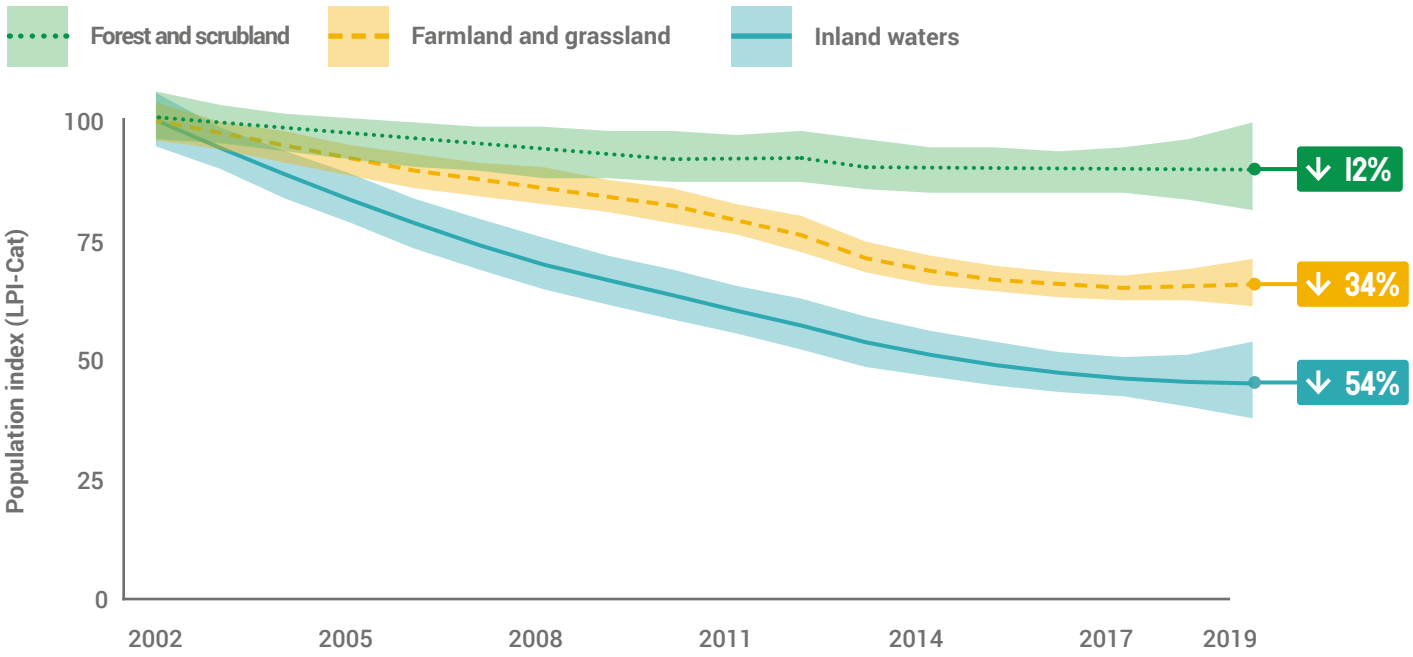


FIGURE 3. Average population trends (LPI-Cat) in different environments in Catalonia. These include the same taxonomic groups as in the LPI-Cat in Figure 1, but each trend line corresponds to a set of native species based on their environment: forest and scrubland (81 species), farmland and grassland (149 species) and inland waters (45 species). The graph shows the average annual value and the 90% confidence interval. See Boxes 1 and 2 for an explanation of the graph. **Source: the authors.**

1. Carreras *et al.* 2014

Nor is biodiversity loss equal for all species. Generalist species with less demanding requirements remain stable while specialist species, which are more selective and have more restrictive ecological requirements, are clearly in decline (Figure 4). This process, observed in several contexts around Europe,[1] indicates that a small number of generalist species are favored, to the detriment of most specialist species.

Finally, the available data indicate that numbers of butterflies (the only group of invertebrates for which a sufficiently long data time series is available) are decreasing much more sharply than for vertebrates (Figure 5). This matches data showing a large-scale, global decline in this insect group[2], suggesting that the global LPI, currently only calculated from data on vertebrates (Figure 2 and Box 2), would show an even more dramatic decline were data from invertebrates to be included.

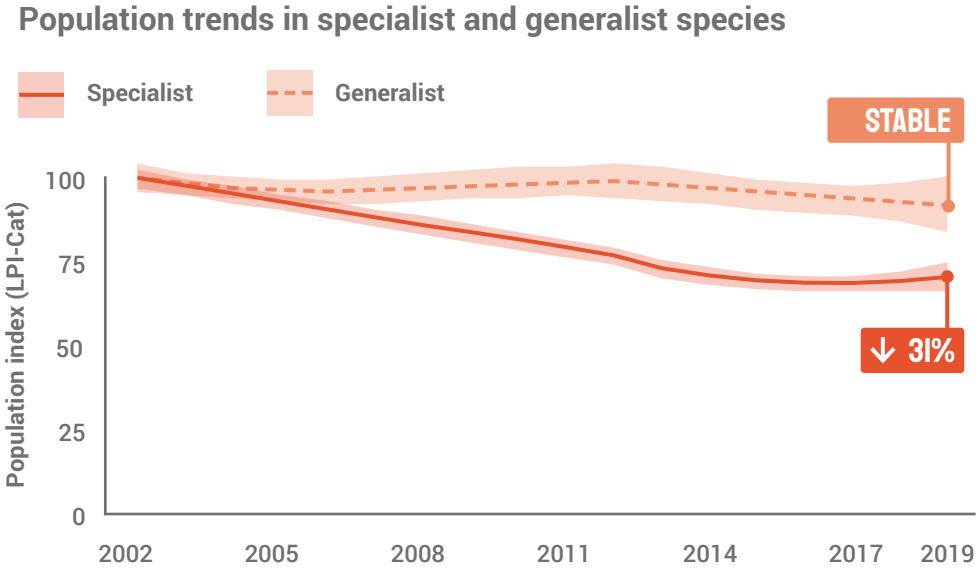


FIGURE 4. Average population trends (LPI-Cat) in specialist and generalist species in Catalonia. These include the same taxonomic groups as the LPI-Cat in Figure 1, but each trend line corresponds to a type of species: specialist (254 native species) and generalist (57 native species). The graph shows the average annual value and the 90% confidence interval. See Boxes 1 and 2 for an explanation of the graph. **Source: the authors.**

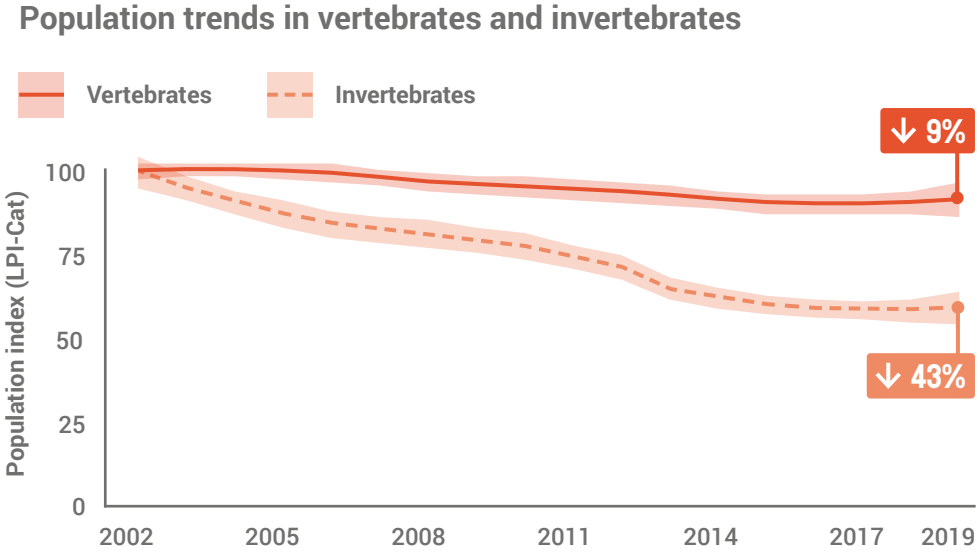


FIGURE 5. Average population trends (LPI-Cat) in vertebrate species (194 native species of fishes, amphibians, reptiles, birds and mammals) and invertebrates (127 native species of butterflies, the only group with data available for this report) in Catalonia. The graph shows the average annual value and the 90% confidence interval. See Boxes 1 and 2 for an explanation of the graph. **Source: the authors.**

1. Le Viol *et al.* 2012
2. Sánchez-Bayo & Wyckhuys 2019, Seibold *et al.* 2019

CAUSES OF BIODIVERSITY LOSS

There are various causes underlying most of these changes in biodiversity, the relative importance of each depending on the region of the planet under consideration.[1] Globally, the main causes of biodiversity loss are intensification of production systems (farming, forestry and fishing), fewer, deteriorating natural habitats, climate change, invasive species and pollution.[2] In Catalonia, the biggest cause is undoubtedly intensified natural resource use in different socio-economic sectors, as well as the abandonment of certain forms of usage in largely unproductive areas. Nor should one ignore the fact that resource requirements have risen along with population growth, which in Catalonia has increased by 20% in just 20 years.[3]

Thus, in the last two decades in Catalonia, there has been a notable abandonment of extensive arable and livestock farming, especially outside the main plains (Figure 6). Furthermore, in the context of the current globalized economic system, many areas with a harsher topography have largely become unprofitable, leading to general expansion of forest land (Figure 7). However, in many other areas, pro-

Changes in farmland use in Catalonia between 1997 and 2017

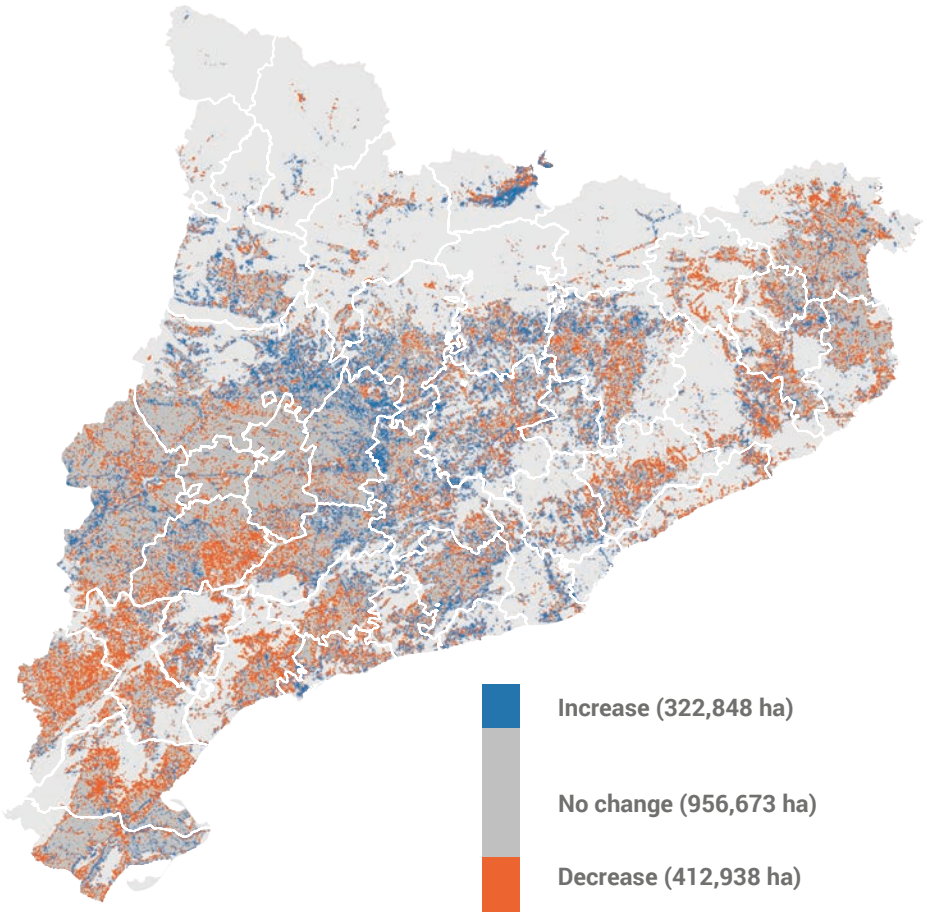


FIGURE 6. Changes in farmland use in Catalonia between 1997 and 2017. **Source: CREAF and the UAB-GRUMETS Department of Geography (2020), based on Catalan Ministry of Territory and Sustainability land cover and use maps.**

1. IPBES 2019
2. IPBES 2019; CDB 2020
3. IDESCAT 2020a

ductive activities such as forestry and farming have steadily intensified, thereby increasing production per unit of land. In the case of agriculture, this involves consumption of large amounts of materials from outside the farm (fertilizers, phytosanitary products, machinery, water, etc.) combined with improvements in farming techniques and greater crop variety, all of which has a significant impact on biodiversity. Furthermore, buildings and communication routes (Figure 8) have transformed many areas previously occupied by other environments (particularly farmland and grassland). This greater human pressure increases the impact on the natural environment (pollution, crowds, changes in water use, etc.) and reduces the connectivity between the remaining natural areas.[1] Finally, despite all the efforts made to improve efficiency in water use and reuse, intensive farming and growing urban demand make it an increasingly scarce resource, which also has a major impact on dependent natural systems. Most of these causes are common to the rest of western and Mediterranean Europe.[1]

Relating all these causes to spe-

Changes in forest land use in Catalonia between 1997 and 2017

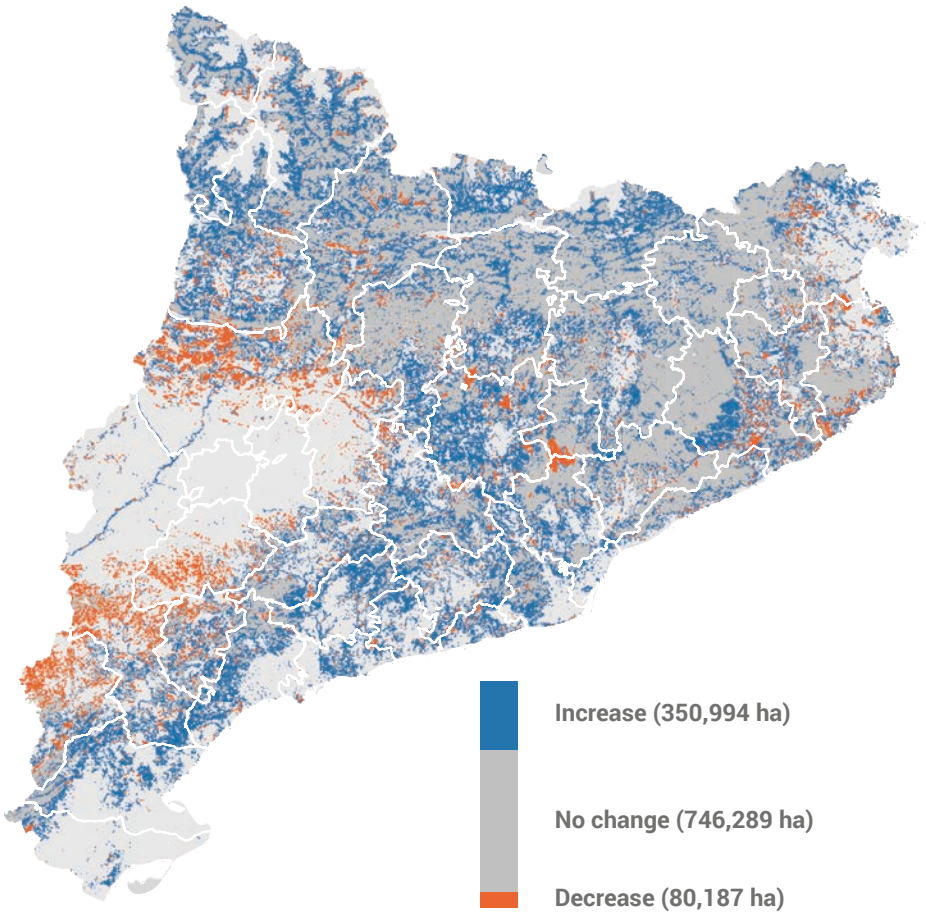


FIGURE 7. Changes in forest land use in Catalonia between 1997 and 2017. **Source: CREAF and the UAB-GRUMETS Department of Geography (2020), based on Catalan Ministry of Territory and Sustainability land cover and use maps.**

1. IPBES 2018

cific instances of biodiversity loss is not always simple, as there are usually several factors interacting at the same time. Nevertheless, it is safe to say that the abandonment of farmland in some areas and more intensive arable and livestock farming in others are closely related to biodiversity loss, as shown by the trend in farmland and grassland species in Figure 3. The same figure also shows that despite the expansion of forest land, there is no general recovery in species native to this environment. Finally, intensive and growing use of inland waters, as well as the sea and coast, mean these environments among the hardest hit in terms of biodiversity loss in Catalonia. All these issues are discussed in greater detail below, in the corresponding sections.

Changes in urban land use in Catalonia between 1997 and 2017

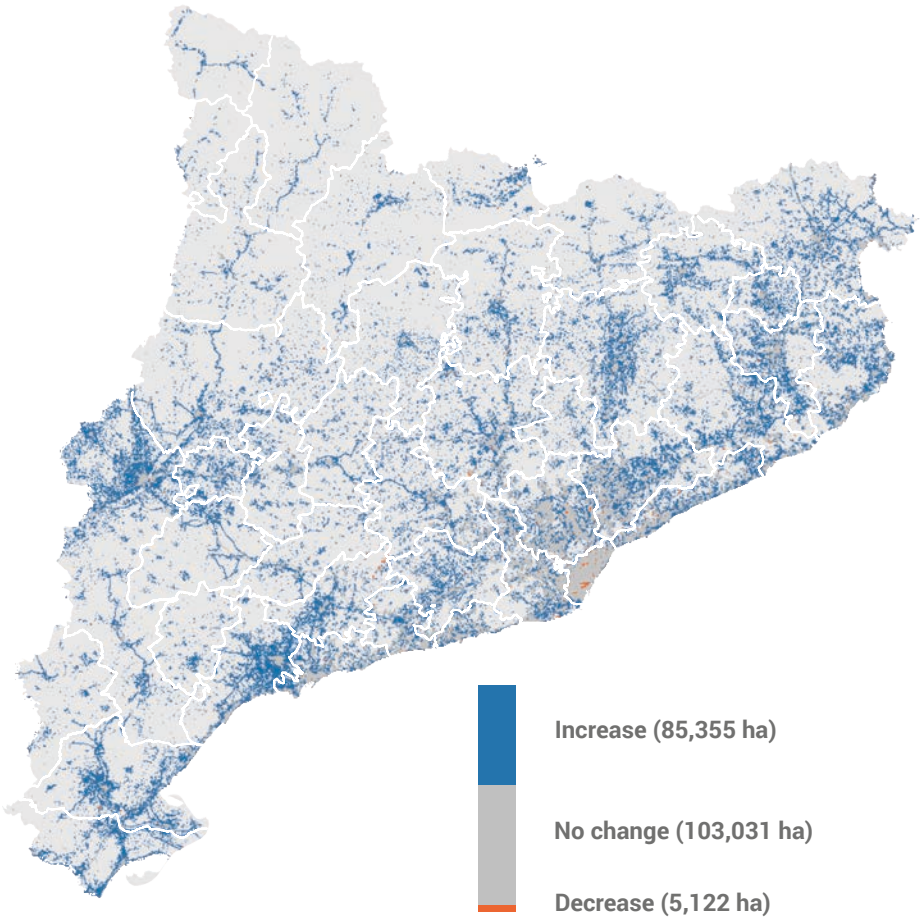


FIGURE 8. Changes in urban land use in Catalonia between 1997 and 2017. **Source: CREAF and the UAB-GRUMETS Department of Geography (2020), based on Catalan Ministry of Territory and Sustainability land cover and use maps.**

1. IPBES 2018

In Catalonia today, besides the intensification or abandonment of natural resource use and changes in land use, climate change and invasive exotic species also exert severe pressures on biodiversity. However, the impacts often only become visible after a delay[1], hence the negative effects of such pressures will probably become much more significant in the future.

In Catalonia, climate change is causing increasingly hot years and persistent droughts, interspersed by occasional rainy years (Figure 9). Changes in population numbers among species for which long, Europe-wide data series are available, such as birds, show their response to climate change. Species best adapted to the new conditions have increased their numbers since 1990 (coinciding with a general temperature rise in Europe), while others started to decline at the same time. In Catalonia, where data collection started later (2002), the differing reactions are also evident in species favored or harmed by climate change (Figure 10).

With regard to exotic species, in a society hyper-connected to almost everywhere else in the world, with transport of goods and people from almost any point on the planet, the

Annual climate anomalies in Catalonia compared to the period 1980-2010

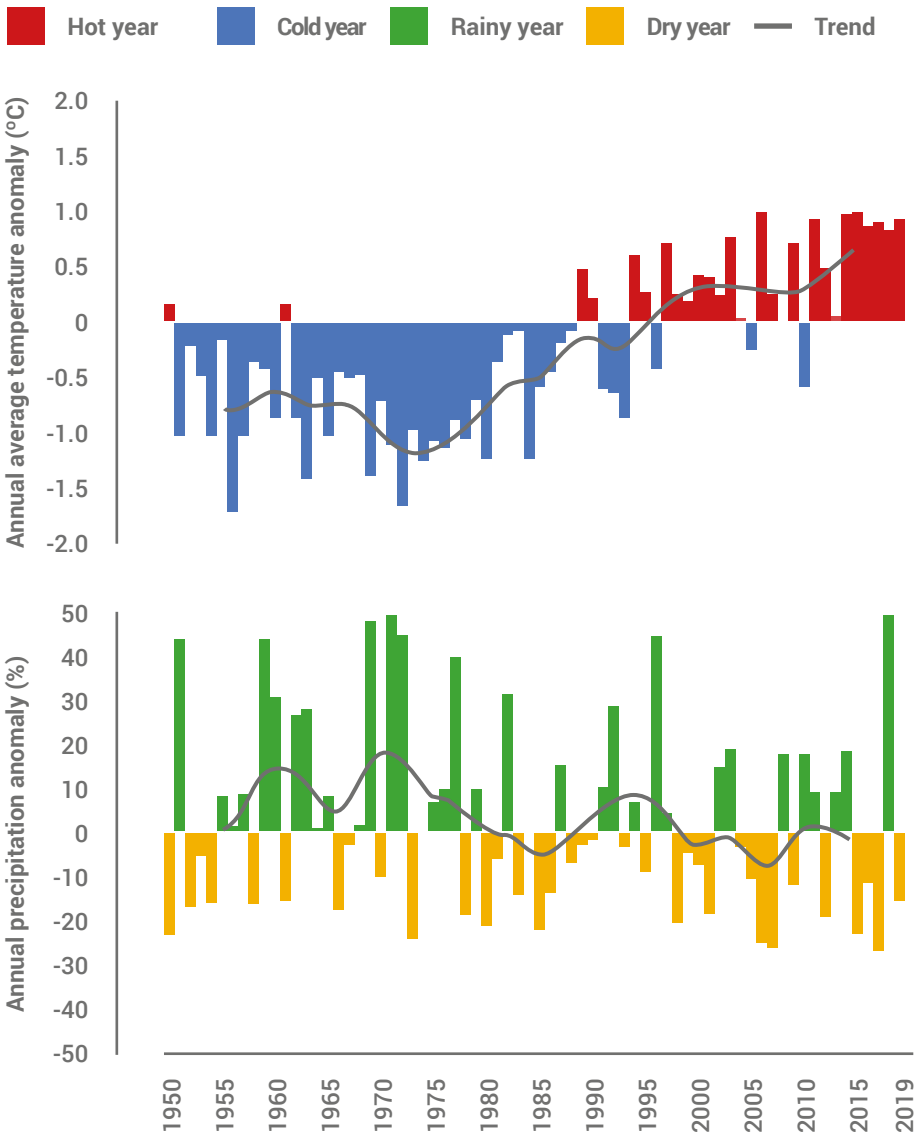


FIGURE 9. Anomalies in average annual temperatures (top) and annual precipitation (bottom) in Catalonia since 1950, compared to the average for the period 1981-2010. The annual average temperature in Catalonia has increased at a rate of +0.25 ºC/decade since 1950. Annual overall precipitation in Catalonia shows a slight downward trend since 1950, at around -1.6%/decade. **Source: Meteorological Service of Catalonia (SMC 2020).**

1. Devictor *et al*. 2012; González-Moreno *et al*. 2017

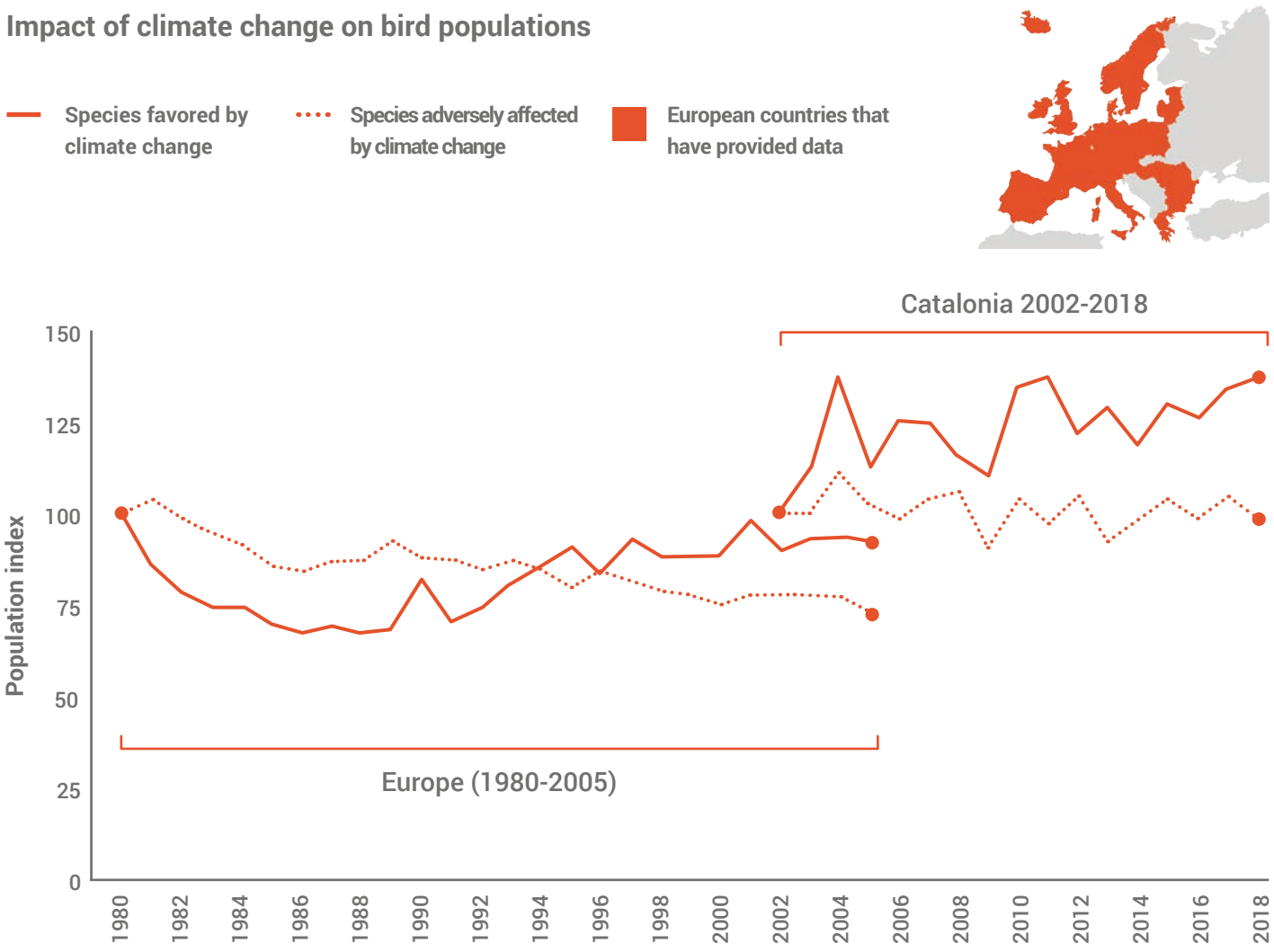


FIGURE 10. Change in the populations of bird species favorably and adversely affected by climate change in Europe (EEA 2020a) and Catalonia (ICO 2019). **Source: adapted from Gregory *et al*. 2009.**

arrival of species carried deliberately or accidentally by human activity from previously remote countries is now a new reality. Most such exotic species fail to become fully established, but some become invasive as they spread through the territory (Figure 11), posing a threat to native species and habitats, even to human activities. In 2019 there were 1,625 exotic species registered in Catalonia, 190 of which (mostly plants and invertebrates) were considered invasive.[1] The increase in the number of exotic species is continual; from 2013 to 2019, a further 204 species arrived.[1]

It should be stressed that conservation and sustainability policies in Europe have lessened some of the pressures affecting European biodiversity, yet at the same time, economic activities are relocated and cause major biodiversity loss in other parts of the world.[1]

1. EXOCAT 2020

Finally, it is worth mentioning that all these pressures on biodiversity not only interact with one another, but also have common causes arising from social values and behaviors, including consumption patterns, population dynamics, trade, technological innovations and governance. These are known as indirect causes of global change.[1] The current situation cannot be understood without considering them also.

Berries on the American pokeweed (*Phytolacca americana*), a toxic invasive plant in Catalonia. **Photo: J.Luis Ordóñez.**

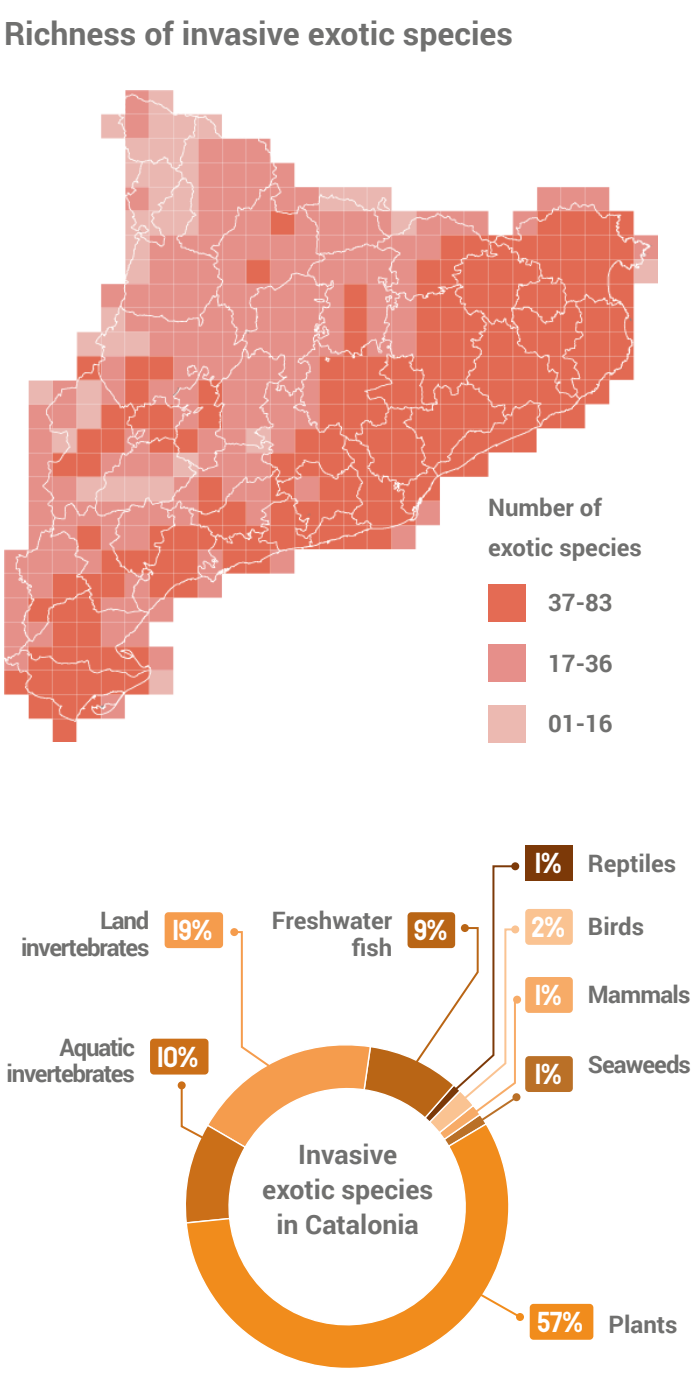


FIGURE 11. Invasive exotic species in Catalonia. Number of species per 10x10 km square (top) and percentage of each biological group (bottom). **Source: Catalan Exotic Species Information System - CREAF (EXOCAT 2020).**

1. IPBES 2019

PUTTING A STOP TO BIODIVERSITY LOSS

In Catalonia, like most European countries, specific conservation, restoration and control measures have been implemented to help mitigate biodiversity loss.

Successes in conservation are concentrated in the protection of specific areas (protected areas network) or species (conservation plans and actions) and in restoration projects for habitats and specific areas, including areas of geological interest.

One example of such measures are the threatened species catalogs, a legal instrument that covers plant and animal species whose survival is threatened to varying degrees and which require specific conservation measures to prevent their disappearance (Figure 12). In some cases, these are species that have been hunted or exploited in recent times and whose state of conservation has now greatly improved (Box 3).

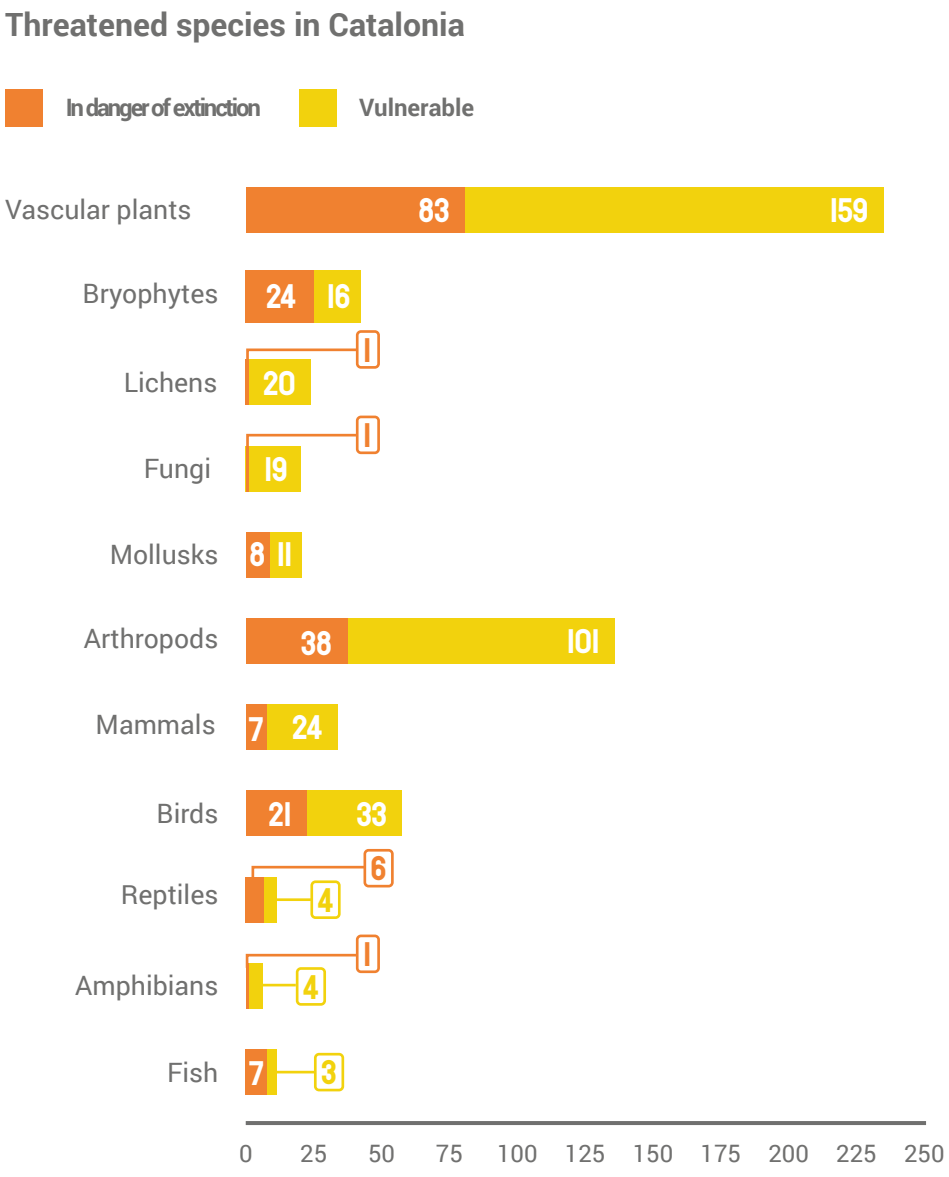


FIGURE 12. Number of species in each biological group included in the Catalog of Threatened Plants in Catalonia and the proposal for the Catalog of Threatened Animals in Catalonia (SFF 2019). The threat classification is based on common, standardized criteria used by all Spain's Autonomous Communities. **Source: the authors.**

PROTECTED NATURAL AREAS

Natural parks are natural areas with classified natural values, whose protection aims to make their conservation compatible with regulated use of their resources and their inhabitants' activities. In general, conservation goals are defined for these parks, which are met or maintained through conservation measures executed by a managing body, funded by the park. Monitoring programs assess their effectiveness and contribution to conserving natural heritage. Box 4 gives a number of examples of how protected natural areas have contributed to improving biodiversity.

Cap de Creus Natural Park. **Photo: Núria Pou.**

PLANT AND ANIMAL CONSERVATION ACTIONS

In the last three decades, a variety of actions, included in recovery and conservation plans and projects for threatened animal species, have been promoted and implemented, leading to the recovery of a number of species, some of which had even disappeared from Catalonia.

With regard to plants, in recent years work has been conducted on conservation planning, establishing regulations and ensuring their observance. However, recovery and conservations plans for threatened species still need to be approved and executed and more conservation actions promoted. Nevertheless, one-off management actions have been taken for a variety of threatened plant populations, especially in conjunction with the protected natural areas. Box 3 also shows some examples of these actions.

Petrocoptis pardoi, a protected endemic plant in Catalonia. **Photo: Artur Lluent.**

CATALONIA IS LOSING BIODIVERSITY...

1 **European eel** (*Anguilla anguilla*)

A fish eaten by numerous predators, including humans, which lives part of its life in rivers and the other part in the sea. Its population has decreased by over 90% since the start of the 21st century. **Source: ACA, CHE**

2 **Black-eared wheatear** (*Oenanthe hispanica*)

Bird found in bush and orchards, where it helps control pests. Its population has decreased by over 43% since the start of the 21st century. **Source: SOCC**

3 **Western marbled white** *Melanargia occitanica*

Butterfly endemic to dry Mediterranean grassland, where it pollinates numerous plants. Its population has decreased by over 90% since the start of the 21st century. **Source: CBMS**

4 **Mediterranean mouse** (*Mus spretus*)

Mouse found in open lowlands, which helps balance the populations of its numerous preys and predators. Its numbers fluctuate greatly from year to year, although the general trend is uncertain or negative. **Source: SEMICE**

5 **Algerian sand racer** (*Psammodromus algirus*)

Reptile found in numerous environments. Its numbers fluctuate from year to year, but the general trend is negative. **Source: SARE**

6 **Mirbeck's oak** (*Quercus canariensis*)

Tree with a highly restricted distribution The land surface it occupies has decreased in recent years. **Source: IFNs**

Projects and Leaders in Catalonia

CBMS. Catalan Butterfly Monitoring Scheme. Monitoring program promoted by the Granollers Museum of Natural Sciences and the Catalan Ministry of Territory and Sustainability; **IFNs:** National Forest Inventories. Program promoted by the Spanish Ministry of Agriculture, Fisheries and Food; **SARE**. Monitoring of amphibians and reptiles of Spain. Monitoring program promoted by the Asociación Herpetológica Española (Spanish Herpetological Society); **SEMICE**. Monitoring of common micromammals in Spain. Monitoring program promoted by the Granollers Museum of Natural Sciences and the Ministry of Territory and Sustainability; **SOCC.** Monitoring of common birds in Catalonia. Monitoring program promoted by the Catalan Ornithological Institute and the Catalan Ministry of Territory and Sustainability.

Institutions

ACA. Catalan Water Agency; **CHE**. Ebro Hydrographic Confederation; **DIBA**. Barcelona Provincial Council; **DIGI**. Girona Provincial Council; **DTES**. Government of Catalonia Ministry of Territory and Sustainability; **ZOO**. Barcelona Zoo.

...BUT IS WORKING TO REVERSE IT

7 **Montseny brook newt** (*Calotriton arnoldi*)

Most seriously threatened amphibian in western Europe. The trend is mainly negative and its numbers are very low. Work is being done on its conservation in various areas (see Example 7). **Source: DIBA-DIGI, ZOO, DTES**

8 **Otter** (*Lutra lutra*)

In danger of extinction at the end of the 20th century. Despite the delicate situation in river systems, its reintroduction in 1995 has helped the species recover in many river basins. **Source: DTES**

9 *Cerinthe glabra*

Only known population in the Iberian Peninsula in the Alt Pirineu Natural Park. A number of conservation actions have been carried out: monitoring, elimination of invasive species, installing fences to prevent trampling, diverting paths and controlling intensive grazing. Even so, the trend is still not positive. **Source: DTES**

10 **Brown bear** (*Ursus arctos*)

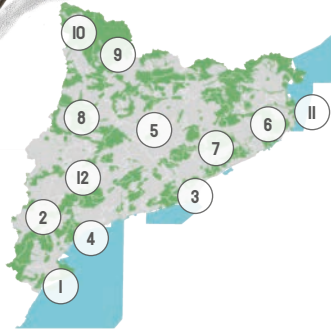
One of the large European mammals, carrion-eating, occasional carnivore and an important seed disperser. It disappeared from the central Pyrenees in the early 1990s. Its reintroduction in 1996, together with other actions, has helped the population to recover to up to 50 individual bears. **Source: DTES**

11 **Sea meadows of *Posidonia oceanica* and other seagrasses**

Seriously threatened communities. Very important for holding coastal sediments and because they provide food and refuge to many fishes and other animals. In the Montgrí, les Illes Medes i el Baix Ter Natural Park these meadows have been found to have improved in deep waters but have deteriorated in shallow waters. **Source: DTES**

12 **Lesser kestrel** (*Falco naumanni*)

In 1986, captive breeding of this species was started at the Torreferrusa Wildlife Recovery Center. The subsequent reintroduction program for the birds bred in captivity has increased the species' reproductive numbers. There are now 100 breeding pairs. **Source: DTES**



POPULATION TRENDS

- Increase
- Moderate decrease
- Notable decrease
- Change of trend

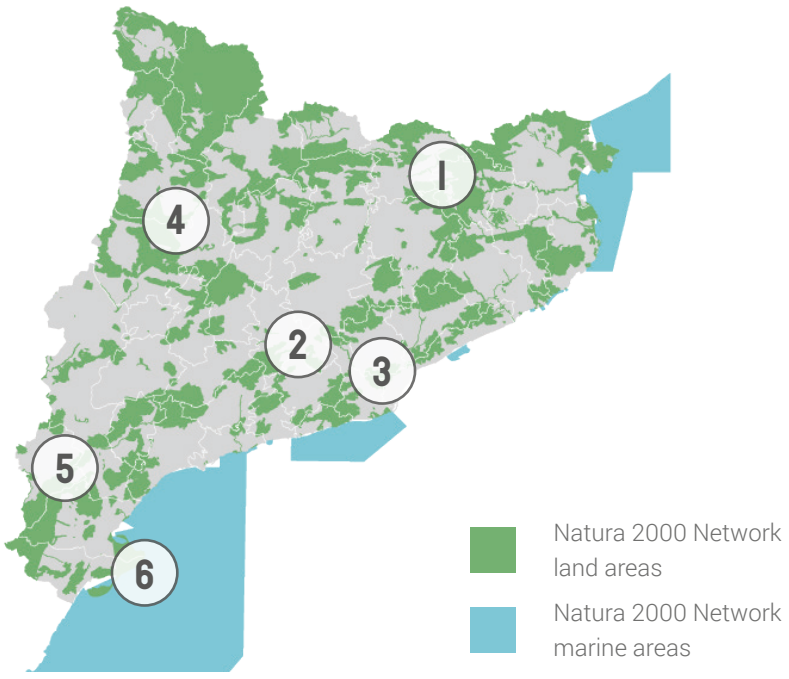
TYPE OF ENVIRONMENTS

- Forest and scrubland
- Farmland and grassland
- Inland waters
- Sea and coast

STATE OF HABITAT CONSERVATION

Habitats are ecological units defined mainly by their vegetation and the physical features of the environment (sunlight, altitude, climate, etc.), elements that determine how it functions and the lifeforms that inhabit it. Thus, their conservation is crucial to maintaining biodiversity.

In Catalonia, information on the surface area and location of land habitats is provided by habitat maps. The analysis of changes between the first two versions of the map (based on aerial photography in 1997 and 2008) shows that among the 248 natural habitats studied, 30% lost and 23% gained surface areas, while the rest remained stable.[1] In farmland, a number of habitats also lost surface area.Overall, in just 10 years, the trend in the surface area of natural habitats was downward, with direct consequences for biodiversity loss.



TYPES OF ENVIRONMENT

- Forest and scrubland
- Farmland and grassland
- Inland waters
- Sea and coast

CHANGE IN SURFACE AREA OF THE HABITAT FROM 1997 TO 2008

- Increase
- Moderate decrease
- Notable decrease

Project
Assessment of changes in habitats in Catalonia

Institutions
UB. University of Barcelona; DTES. Catalan Ministry of Territory and Sustainability.

1. Carreras *et al.* 2014

1 MESOPHYTIC AND XEROPHYTIC BEECH FORESTS -1.7% ▽

Beech forest. **Photo: Sergi Herrando.**

2 ALEPPO PINE WOODS RESULTING FROM COLONIZATION +15% ▲

Aleppo pine wood **Photo: Albert Ferré.**

3 SAVANNA-TYPE THATCHING GRASSLAND, ON SOUTH-FACING SLOPES IN MARITIME REGIONS. -1.7% ▽

Savannah-type grassland. **Photo: Albert Ferré.**

4 COMMUNITIES DOMINATED BY SEDGE ON LOWLAND WATER BANKS -1.7% ▽

Sedge surrounding a pond. **Photo: Albert Ferré.**

5 DRYLAND ORCHARDS -3.3% ▽

Dryland olive grove **Photo: Sergi Herrando.**

6 VEGETATION IN FLOODED COASTAL SALINE SOILS WITH LITTLE OR ABUNDANT MOISTURE -13.3% ▼

Saline soil vegetation. **Photo: Sergi Herrando.**

GEOLOGICAL HERITAGE AND GEODIVERSITY, THE FOUNDATIONS OF NATURAL RICHNESS

Geological substrate and topography of the terrain, what might be termed its physical matrix, is extremely important for understanding biodiversity. This matrix, in continual interaction with the climate, microorganisms, flora and fauna, goes toward forming the soil, which provides the foundations for the whole terrestrial ecosystem. Furthermore, topography (mountains, cliffs, cavities, etc.) plays a major role in shaping biodiversity in many different ways, including climate diversification and the formation of refuges for numerous plant and animal species. Catalonia has over 550 million years of geological history recorded in its rocks. Understanding and conserving this geological heritage will also provide a better understanding of natural heritage in general.

One of the main tools for understanding and conserving geological heritage and geodiversity is the Inventory of Sites of Geological Interest in Catalonia (IEIGC). This inventory, currently being updated and revised, establishes a selection of geological sites (currently 158), which, overall, bear witness to the geological history of the region. It covers 143,478 hectares, and 73% of the surface area falls within protected natural areas (Box 5).

Cliffs in the Portella hills, in the Origens Geopark. **Photo: Gonzalo Rivas.**

THE INTERNATIONAL IMPACT OF BIODIVERSITY LOSS IN CATALONIA

We are witnessing a global loss of biodiversity, and every country and region in the world is responsible to a greater or lesser extent.[1] In Catalonia, there are 173 species considered at risk of worldwide extinction.[2] Overall, these globally threatened species are just a small part of the biodiversity of the Catalan territory, although this is not the case for all groups (Figure 13). Over 10% of fishes, amphibians and reptiles in Catalonia are at risk of worldwide extinction.[2] Some of these species are restricted to a very small geographical area, such as the Montseny brook newt (*Calotriton arnoldi*) (Example 5), while others have a wider distribution and spend only part of their life in Catalonia, such as the European eel (*Anguilla anguilla*) (Box 3).

In the context of the European Union, biodiversity in Catalonia is also important. A total of 245 species and 99 habitats in Catalonia are considered of community interest and are included in the main European nature protection directives (Habitats Directive 92/43/EEC, and the Birds Directive 2009/147/EC). The case of birds is particularly striking, as in Catalonia, which makes up just 0.7% of the total European Union surface area, there are 89 bird species of community interest that are regularly present, representing 44% of the birds included in Annex I of the Birds Directive.

Every six years, it is obligatory to inform the European Commission of the state of species and habitats of community interest.[3] Thus, in the working context of the Habitats and Birds Directives, the Government of Catalonia provides this information to the Spanish Government, who pass it on to the European Commission, who integrates all the information from all European Union countries. These reports are a valuable insight into the state of nature.

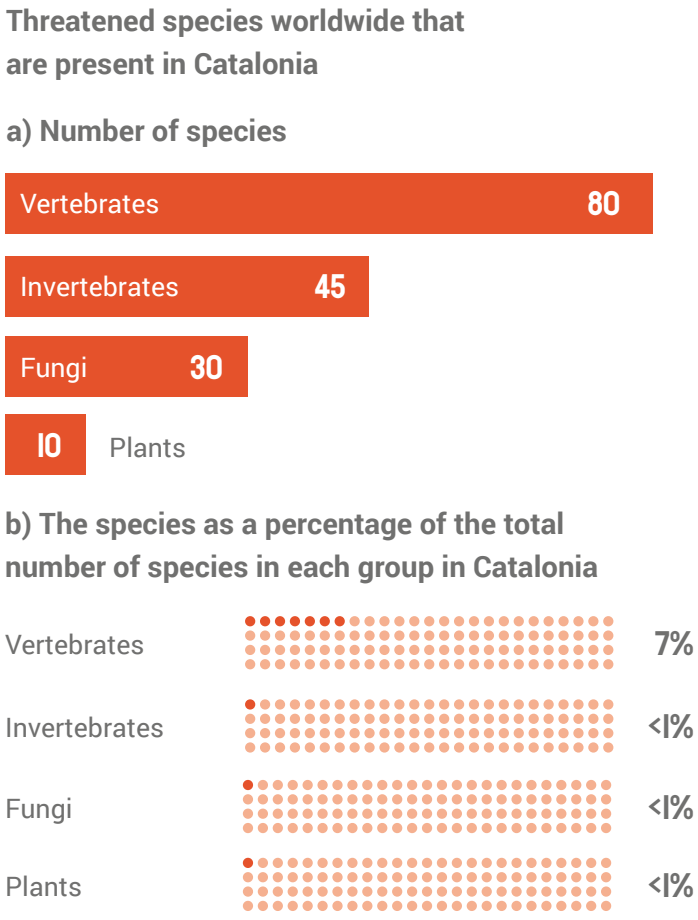


FIGURE 13. Number of species threatened worldwide that are found in Catalonia (a), according to data from the International Union for the Conservation of Nature (IUCN 2020). This includes species in the vulnerable, endangered and critically endangered categories. It also shows the percentage these species represent out of the total number of species in the same group present in Catalonia (b), according to the 2030 Natural Heritage and Biodiversity Strategy of Catalonia (GENCAT, 2018). **Source: the authors.**

1. IPBES 2019
2. IUCN 2020
3. DTES 2019a

The information provided in the latest report on the application of the Birds Directive in Catalonia shows that changes in the area of distribution of this biological group in the last 40 years are mostly positive (Figure 14).[1] These positive trends can also be seen in the European Union as a whole, although to a lesser extent.[2] The positive trends for birds are largely due to the success of the first regional, national and European biodiversity conservation policies (the Birds Directive was the first in its field) and a clear increase in public awareness of natural heritage over the same period. Nevertheless, in the last 12 years, this positive balance has shown signs of stagnating and the number of species increasing is virtually equal to the number in decline.

Bearded vulture (*Gypaetus barbatus L.*). **Photo: Albert Vila.**

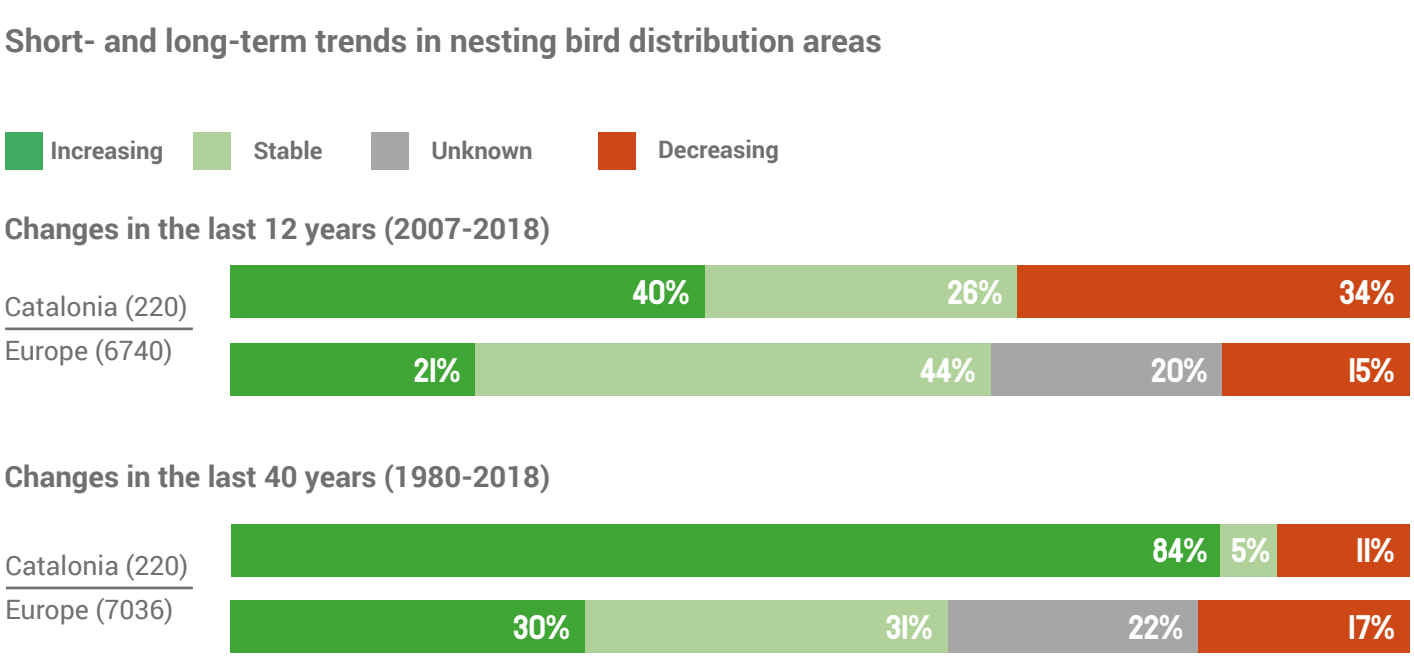


FIGURE 14. Short- and long-term changes in the size of the distribution area for nesting bird species of community interest in Catalonia and the European Union. The graph shows the percentage of species in each of the established change categories. The total species considered are shown in brackets next to each region. **Source: the authors, based on information from DTES 2019 and EEA 2020c.**

1. DTES 2019a
2. EEA 2020c

With regard to the latest information on the application of the Habitats Directive, which mainly focuses on the future viability of habitats of community interest, the assessment shows the state of the habitats is mostly unfavorable, both in Catalonia and in Europe as a whole (Figure 15). There are no major differences between environments, which means that in the medium term if nothing is done to prevent it, the viability of many of these habitats (37% of all habitats in Catalonia) cannot be guaranteed. However, it should be noted that there is still a notable lack of information in Catalonia on aquatic environments, thus hindering an accurate overview of the situation being obtained (Figure 15).

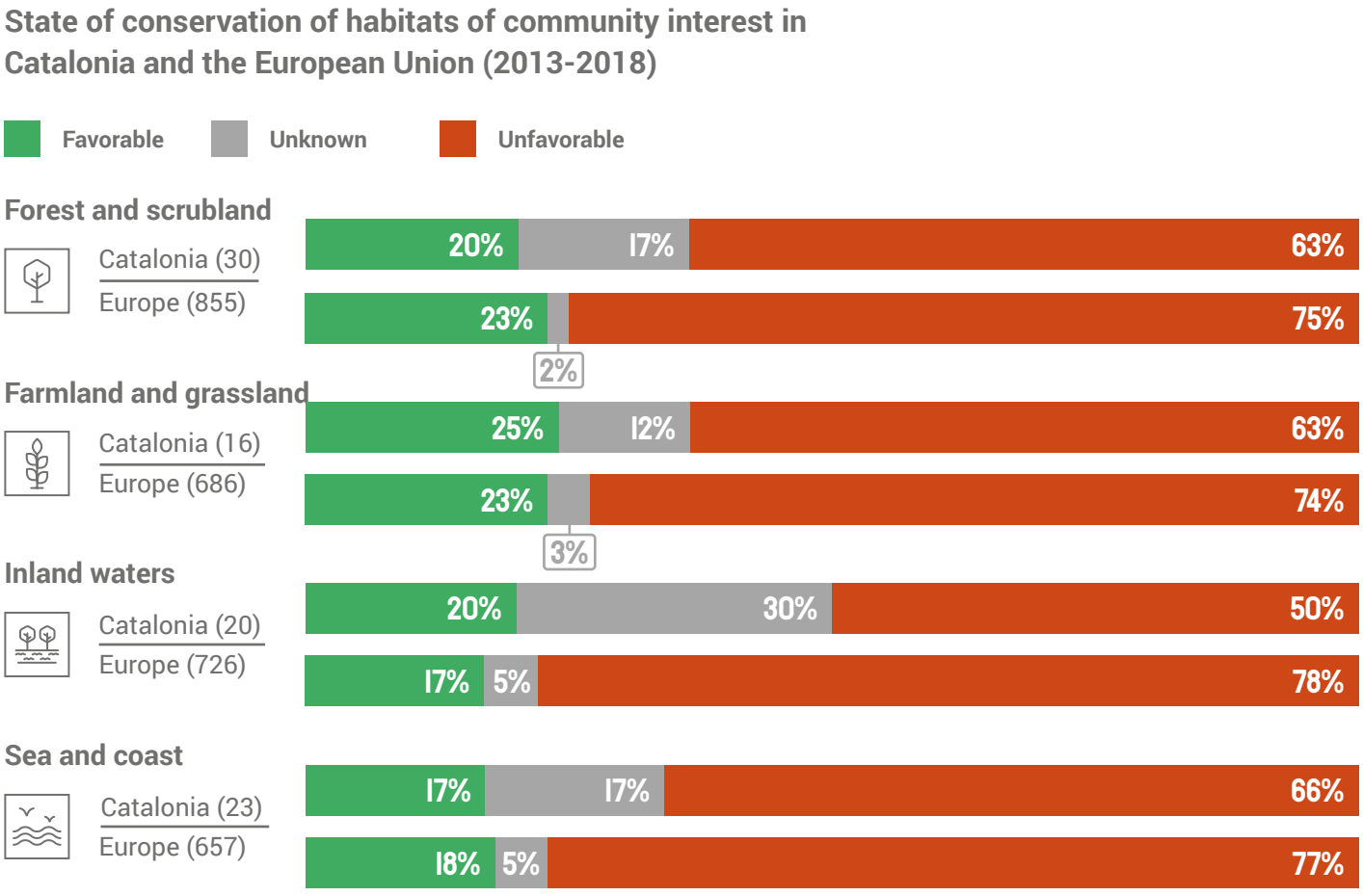
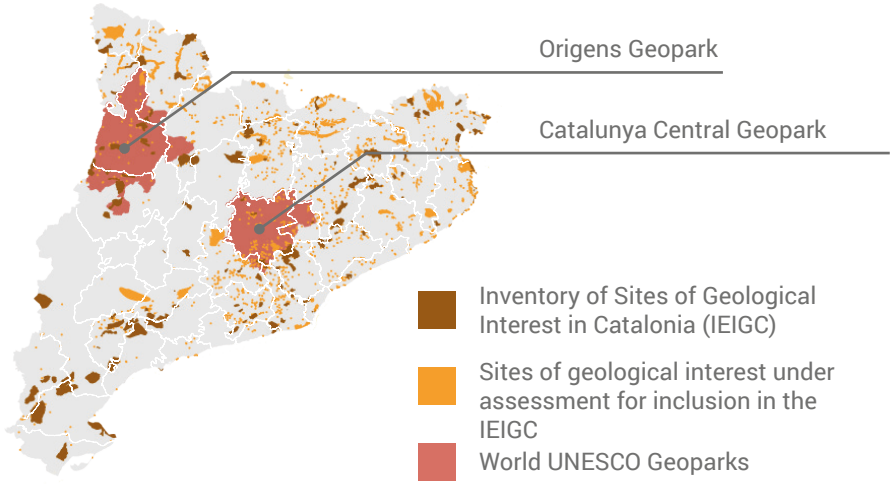


FIGURE 15. Conclusions on the state of surface area of habitats of community interest in Catalonia and the European Union in the period 2013-2018, based on information from the latest report on application of the European Union Habitats Directive. *Favorable*: viability is ensured in the medium term, as there is sufficient surface area to guarantee the habitat is maintained, its trend is not declining and there are no major threats to its viability. *Unfavorable*: the viability of the habitat is not guaranteed in the medium term as at least one of the above premises is not met. The total species considered are shown in brackets next to each region. **Source: the authors, based on information from DTES 2019 and EEA 2020d.**

STATE OF GEOLOGICAL HERITAGE AND GEODIVERSITY

Unlike biodiversity, which is recoverable in certain circumstances, impacts on geodiversity are almost always irreversible. This is why their prevention is essential to effective management of geological heritage.



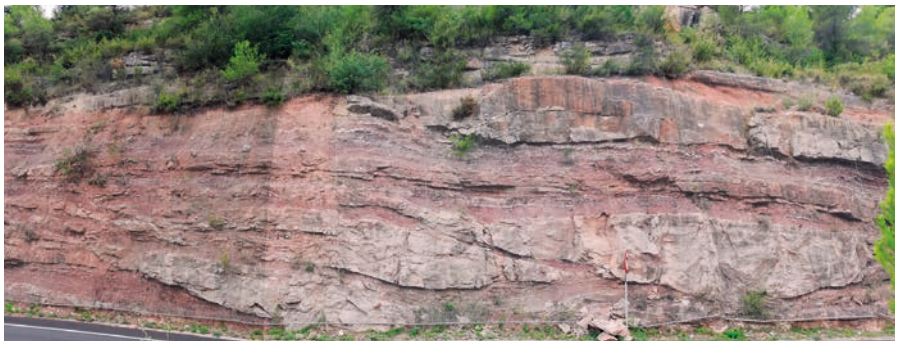
Source: Cartographic and Geological Institute of Catalonia (ICGC).

CAUSES OF THE LOSS

The main causes for loss of geological heritage in Catalonia are large infrastructures (such as highways, railroads and dams), industry (especially extractive industry) and urbanization.

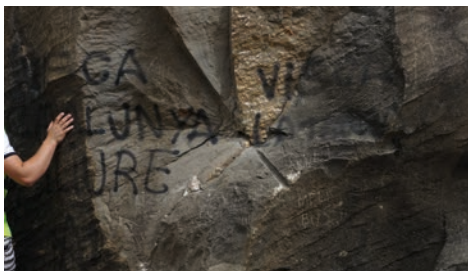
However, a paradox often arises here: many infrastructures that have damaged part of the geological heritage (such as an outcrop, fault or thrust), have also brought the heritage to light.

Plundering or vandalism of heritage elements, such as minerals or fossils, an activity with significant financial interests behind it, are also a severe threat to areas of geological interest.



Sandstone next to the Monistrol de Montserrat road. **Photo: Gemma Gual.**

El Guix fault in Sallent in the FGC railroad cutting, near the Botjosa mining facilities. **Photo: Joan Santamaria.**



Left: Rock from which a fossil dinosaur egg has been removed. **Photo: Pilar Casanovas**; Right: Graffiti on a Gres d'Areny outcrop, in Isona. **Photo: Josep Oriol Oms**.

CONSERVATION

In 2004, the first ever global diagnosis of the state of geodiversity conservation was conducted. In 2008, priority conservation areas were identified and the most urgent actions were defined.

Ensuring the conservation of Catalonia's geological heritage requires stronger preventive and active management and completion of the legal framework of its protection.

ACTIVE CONSERVATION

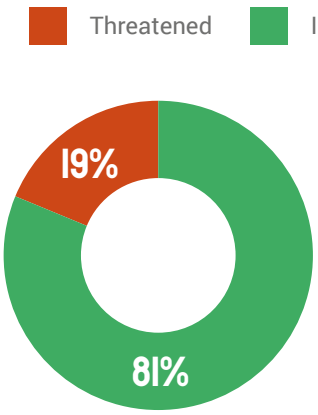
Some of the most emblematic conservation projects carried out in Catalonia are associated with programs to restore the impact of extractive industry, often in protected natural areas. A recent example is the preparation and construction of an interpretation center near the old Coll de Fumanya quarry (Fígols), within the Serra d'Ensija-Els Rassos de Peguera area protected by the Plan for Areas of Natural Interest (PEIN), where strata with titanosaurus footprints have been uncovered.

PREVENTIVE CONSERVATION

Current urban planning legislation in Catalonia stipulates that the Cartographic and Geological Institute of Catalonia must produce a mandatory report to assess the impact of actions on geological and paleontological elements of interest on land not designated for urban development. Since 2005, around 10,000 actions have been assessed, of which 400 were in sites of geological interest in the inventory (IEIGC).

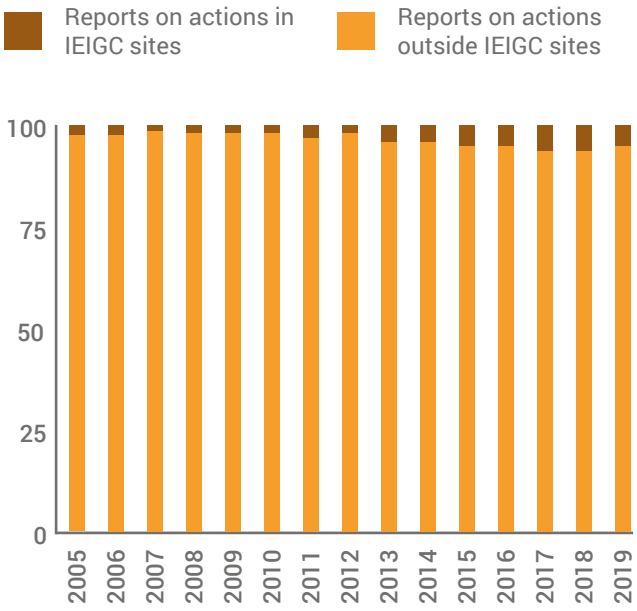
THE GEOPARKS

Geological heritage is an opportunity for local development. In this context, the international concept of the Geopark provides UNESCO recognition to regions for their local socio-economic development strategy, based on their internationally important geological heritage. The Catalunya Central and Origens Geoparks have been given this recognition.



The 2004 diagnosis found that 29 out of the 153 sites of geological interest in Catalonia (EIGC) in the inventory at that time were threatened. **Source: Directorate-General for Environmental Policy and Natural Resources (DTES).**

Fumanya Dinosaur Interpretation Center in the old open-pit mine. **Photo: Josep Oriol Oms.**



Percentage of reports issued yearly inside and outside inventory sites of geological interest (%). **Source: ICGC.**


FOREST AND
SCRUBLAND

KEY MESSAGES

The abandonment of pastures and fields has led to the spread of woodland and the quantity of vegetation in Catalan forests.

The increase in the volume of trees has not been offset by disturbances (natural or otherwise) or forest usage in the last 20 years.

Most Catalan forests are relatively young and lack almost all the features of maturity.

In general, forest animal life is stable or improving slightly, especially generalist species.

However, species endemic to mature forest or scrubland are clearly in decline.

In many cases, forest management and certain low-intensity disturbances have had a positive effect on biodiversity, especially for scrubland.

This is not the case when the impact of management or disturbance has affected mature forests.

FOREST AND SCRUBLAND

This chapter describes the general trends in the biodiversity of Catalan forest and scrubland and analyses the main factors involved. It includes habitats with significant tree cover and scrub and bush habitats that may by highly stable or instable over time. The latter are often the result of dynamics induced by certain disturbances, such as the regeneration of burnt forests.

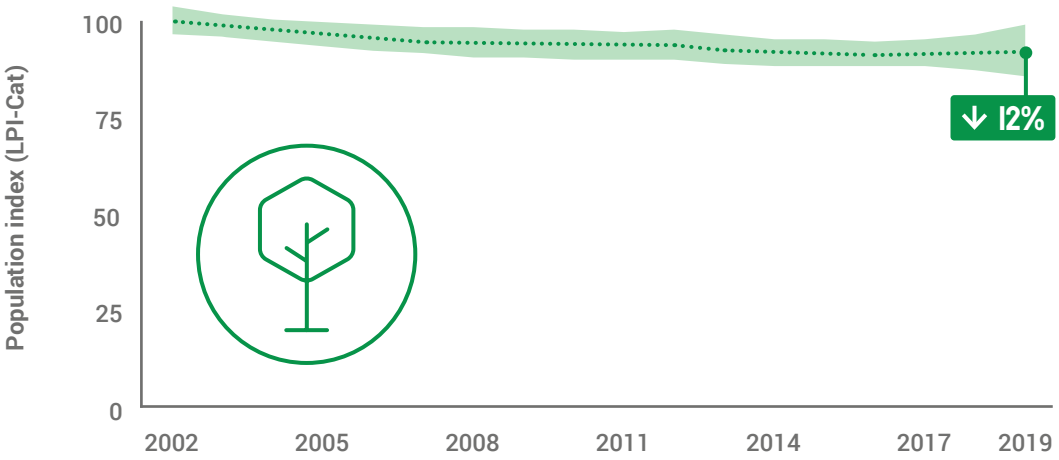


FIGURE 16. Average population trend (LPI-Cat) in 81 animal species associated with forest and scrubland in Catalonia. See Boxes 1 and 2 for an explanation of the graph. **Source: the authors.**

Aleppo pine (*Pinus uncinata*) forest in L'Alt Urgell. **Photo: Xavier Florensa.**

CATALAN FORESTS AND THEIR DYNAMICS

Catalan forests today reflect the socio-economic changes in the region through a variety of processes. Historically, forests were steadily replaced by crop and livestock farms in more productive areas and were subject to intense usage in other areas to supply local and regional energy and building needs. These processes resulted in a major reduction in forest land and significant impact of human activity on the structure of the remaining vegetation. In the mid-20th century, the introduction of new materials, fuels and industries led to the rapid abandonment of less productive farmland and the slow recovery in the average maturity of forests, as the pressures of forest use were generally outweighed by the capacity of forest growth.[1] The current state of forests is the legacy of these historical dynamics.

Beech (*Fagus sylvatica*) forest, El Montseny Natural Park. **Photo: Xavier Florensa**

1. Cervera *et al*. 2019

Thus, abandonment and changes in usage patterns are the two main factors to have affected Catalan forests in the last 20 years. Not only has the forest surface area generally continued to increase over this period (Figure 7), but also the comparison of forest inventories over the last 20 years shows the volume of trees in existing forests has increased considerably as well (Figure 17). This positive balance between growth and mortality (the latter combining both usage and natural mortality) is varies between different parts of the country. In the south, the positive balance is basically due to growth that greatly outweighs natural mortality. In the north, where forest areas are more productive and the forestry industry is more active, there is also a rise, despite the much higher use of forests (Figure 17).

Irregularly structured beech tree (*Fagus sylvatica*) forest, with trees of different sizes. **Photo: Jordi Camprodon.**

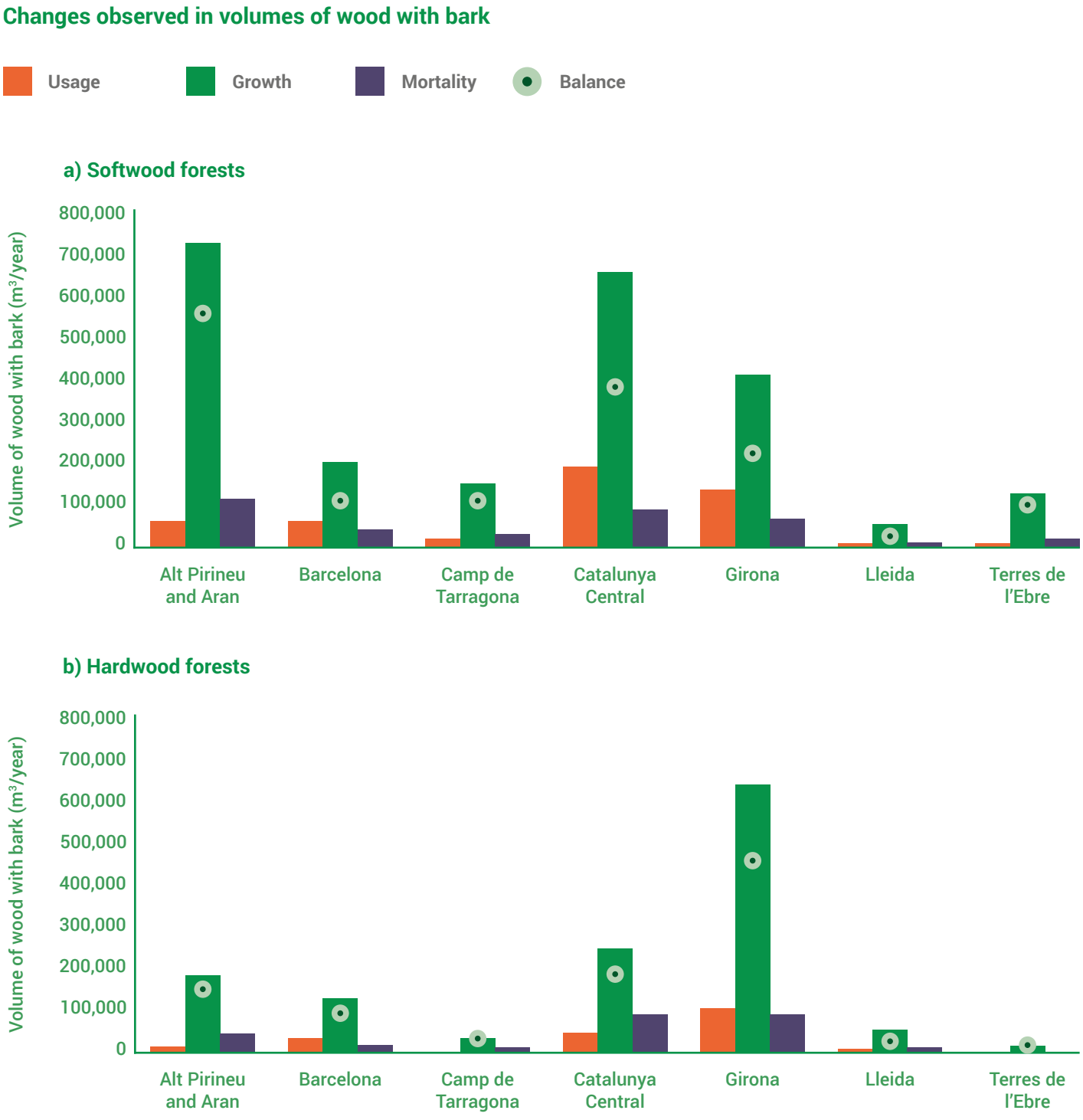


FIGURE 17. Changes observed in volumes of wood with bark in Catalan forests between the IFN3 (2001) and IFN4 (2014-2016) National Forest Inventories. The data are shown by major forest type: (a) softwood; (b) hardwood. The graphs show the absolute change in volume (m3/year) ,obtained by subtracting losses from forest use and natural mortality from the average annual growth. **Source: the authors, based on data from IFN3 and IFN4 provided by the Catalan Forestry Laboratory.**

Other factors for change repeatedly affect the dynamics of the country's forest. One of the most significant in recent decades are forest fires, which, since the 1980s, have had a significant impact on the most Mediterranean region of the country, although this impact that seems to have decreased since 2000 (Figure 18). Fires in Catalonia seem mainly to be associated with the spread of forest land, the increase in plant biomass and a steady rise in conditions favorable to plant combustion, associated with climate change (Figure 9). It should be borne in mind that fire plays an important role in the dynamics of forest systems. It has a direct, negative impact on plant and animal species in mature forests. However, it favors bushy vegetation in the affected zone, benefiting other species that are characteristic of these more open habitats (Example 1).

Other impacts in the country's forest areas that were relatively important in the past, such as episodes of acid rain in the El Berguedà region, no longer have any significant effect. By contrast, one sees a steady rise in forest areas influenced by urban and suburban land (Figures 7 and 8) and a significant impact from episodes of forest decay (higher than usual tree mortality, discoloration and loss of leaves) caused by (Figure 19) climate anomalies (Figure 9). This is especially relevant if one bears in mind that these events could become more serious and frequent due to climate change. Despite these impacts, which can be locally severe, the effects of fires and other disturbances to forests have fed rather than reversed their general spread.[1]

Stone pine (*Pinus pinea*) forests showing signs of forest decay caused by the combination of drought and forest pests. **Photo: J.Luis Ordóñez.**

1. Doblas-Miranda *et al*. 2017

Forest fires in Catalonia from 1986-2019

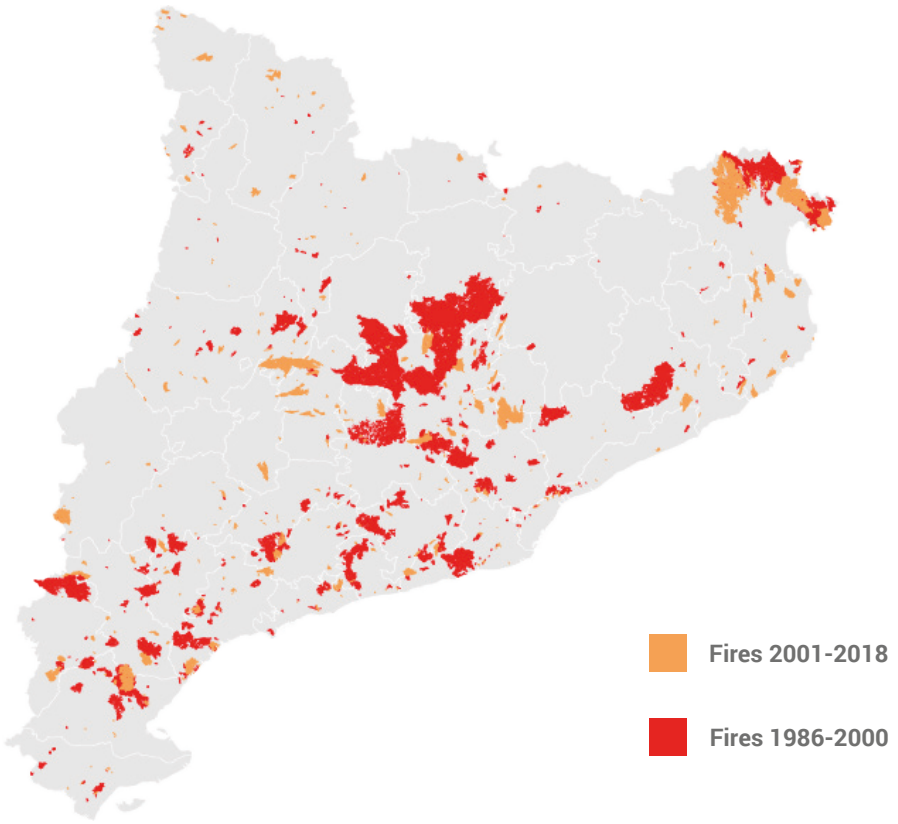


FIGURE 18. Map of forest fires in Catalonia in the periods 1986-2000 and 2001-2019. Areas burnt in both periods are shown in the color of the most recent period. **Source: the authors, based on data from the Government of Catalonia Ministry of Home Affairs.**

Annual surface area newly affected by forest decay in Catalonia

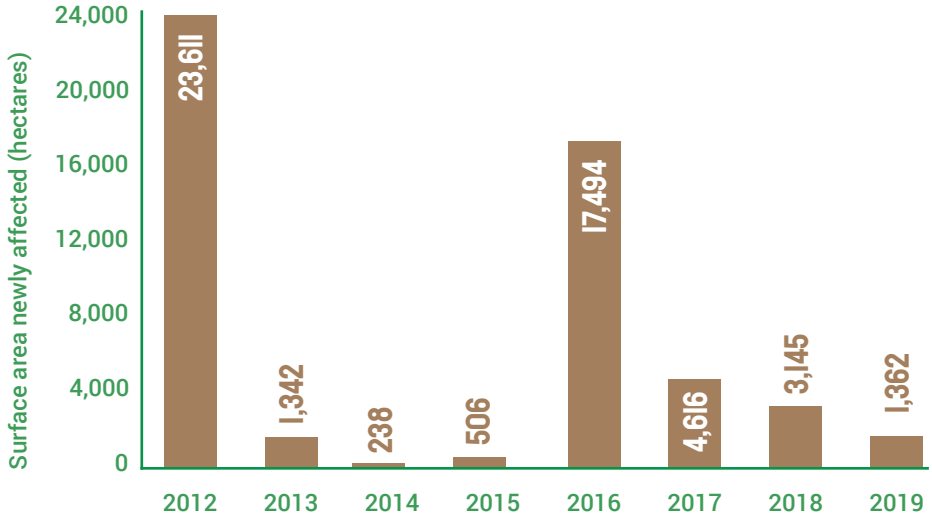


FIGURE 19. Annual surface area recently affected by forest decay in Catalonia (2012-2019). The graph shows the surface area of forest (in hectares) affected by decay due to drought and/or pests (other than pine processionary) each year. Both 2012 and 2016 were years with severe summer droughts, increasing cases compared to other years. **Source: DeBosCat project, Banqué et al. 2019.**

STATE OF BIODIVERSITY IN FORESTS AND SCRUBLAND

The trend towards recovery in Catalan forests has a complex effect on biodiversity. Firstly, the average maturity of forest habitats has improved (Figure 20) and forests show more features of mature forest cycle stages, such as dead wood, natural cavities and large diameter trees. This indicates that, as one might expect, the greater the growth of forests the greater the interest in their conservation, although in the general context such interest is still extremely low. The immense majority of Catalan forests are relatively young and lack almost all these elements (Figure 20 and Box 6).

Forest maturity in Catalonia

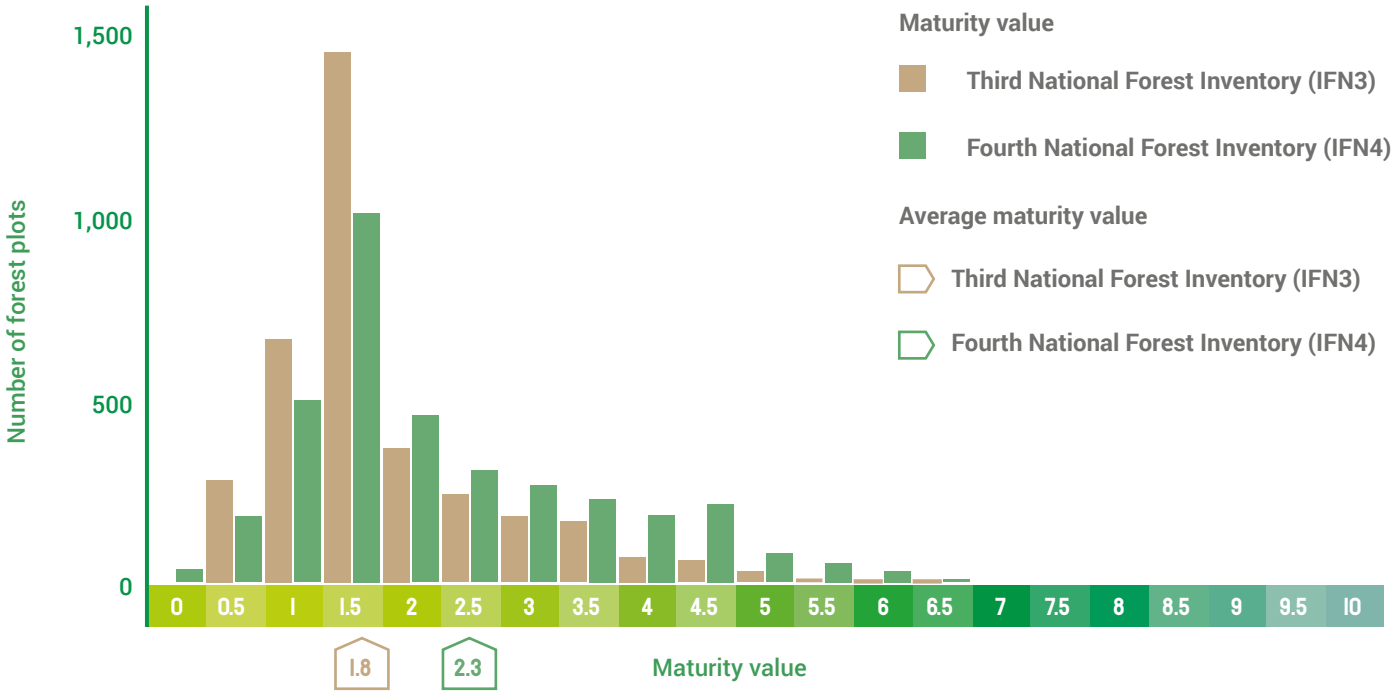


FIGURE 20. Distribution of plots in the IFN3 and IFN4 National Forest Inventories in Catalonia by maturity value. The maturity value characterizes different plots by their maturity based on a variety of indicators (baseline area, exceptional trees, diametric classes, tree species richness and proportion of dead wood); the higher the value, the more maturity features the forest plot contains. See also Box 6. **Source: CREAF, based on data from IFN3 (2001) and IFN4 (2014-2016), applying a simplified version of the methodology developed in the LIFE RedBosques project.**

Tree with natural cavities made by woodpeckers (*Dendrocopos sp.*) for nesting. **Photo: Jordi Camprodon.**

PHASES IN THE FOREST MATURITY CYCLE

Over its landscape, a mature forest contains all the phases of this cycle spread over different areas. This natural dynamic allows it to perpetuate itself over time, providing it is not affected by severe disturbance. In practice, it is a very difficult condition to reach.

CLEARING

A clearing opens in the forest, often due to the fall of dominant trees, knocking down other ones in the process. It is easy to find large sized dead wood.

REGENERATION

A new generation of trees starts to establish itself by occupying the space in the clearing. Remains of dead wood, both large and small, are still present.

OCCUPATION

The trees grow until their canopies touch each other and close the forest. Less vigorous trees die through competition and generate small sized dead wood.

EXCLUSION

The large trees also start to die through competition, especially species that are less tolerant of shade. The remaining ones reach their maximum volume of wood and base area.

MATURATION

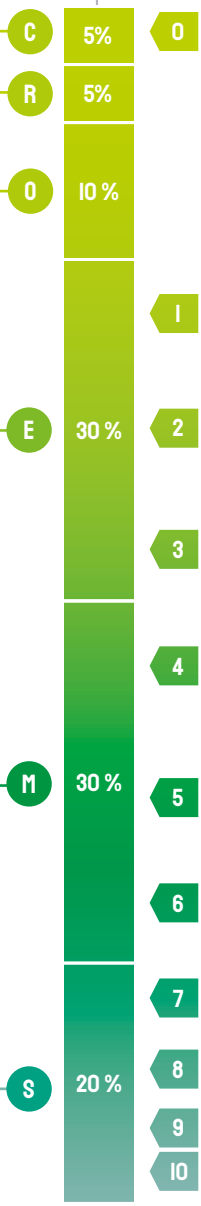
The trees have reached their maximum height and mainly grow in diameter. Those that reach their longevity limit start to die, generating large sized dead wood.

SENESCENCE

The forest has a highly complex structure and a chaotic appearance, with a large number of senescent or dying trees. Dead wood can exceed 25% of the total volume of wood.

TIME OF EACH PHASE

The earliest phases in the cycle are shorter than the later ones. The percentages indicate the proportion of time out of the total longevity of the dominant tree species in the forest.



MATURITY VALUE

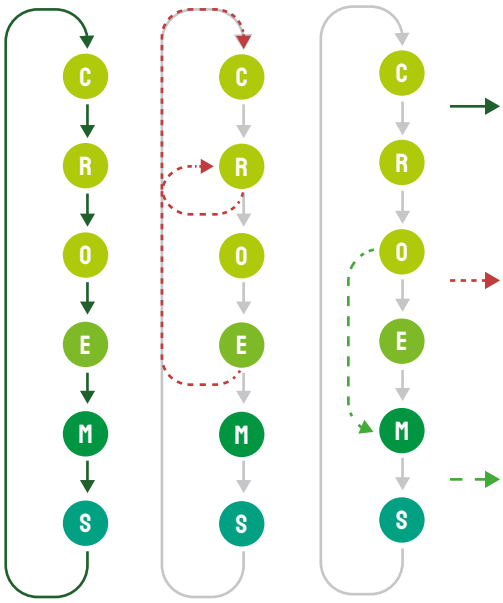
The maturity value is defined from six indicators that assess the structure and composition of the forest, its dynamics and other aspects related to the space occupied by the forest. Displaying maturity values alongside the time bar shows just how long it takes to reach adequate values. See also Figure 20.

IT TAKE A LONG TIME TO REACH MATURITY

The time it takes for a forest to reach maturity depends on the longevity of its trees. Forests with a predominance of long-life, slow-growing species take much longer than those with a predominance of short-life, fast-growing trees. However, in all cases, the forest must be free of severe disturbances for centuries to reach maturity.

LONGEVITY OF THE MAIN TREE SPECIES THAT FORM FORESTS IN CATALONIA (YEARS)

Holm oak (*Quercus ilex*) **800**	Oak (*Quercus* sp.) **1000**	Cork oak (*Quercus suber*) **500**
Aleppo pine (*Pinus halepensis*) **200**	Austrian pine (*Pinus nigra*) **600**	Scotch pine (*Pinus sylvestris*) **500**
Mountain pine (*Pinus uncinata*) **400**	Stone pine (*Pinus pinea*) **300**	Beech (*Fagus sylvatica*) **500**



FOREST MATURITY IS A CYCLE

When a tree reaches the limit of its longevity, it starts to decay, until it dies. On falling to the ground it allows others to occupy the space and the cycle begins again.

DISTURBANCES OFTEN RESTART THE CYCLE.

Major disturbances (such as fires, droughts, pests and snowfalls) usually take the forest back to a previous stage in the maturity cycle, never allowing it to reach the latter stages. Extraction of commercial timber and other human activities often have the same effect.

THE CYCLE CAN ALSO BE ACCELERATED.

Certain minor disturbances (such as low-intensity fires) can shorten phases in the cycle. Forest management can also accelerate the process, through measures such as favoring the presence of different species, sizes and ages of trees and generating large sized dead wood.

AS THE FOREST MATURES, ITS COMPLEXITY, QUANTITY OF DEAD WOOD AND BIODIVERSITY INCREASE

As the forest matures and some trees die off, the ecosystem becomes more complex and biodiversity increases. Large sized dead wood is extremely important in this process. Firstly, because dead trees generate new micro-environmental conditions that provide opportunities from many plant and animal species. Secondly, because dead wood is a habitat for many variety of fungi, insects and other animals. Species diversification improves wood decomposition, recycling of nutrients and pest control. Given that it is difficult to reach mature states of forest, this biodiversity is rare and vulnerable, and often given legal protection.

LARGE SIZED DEAD WOOD.

BIODIVERSITY

Changes to forest structure and degree of maturity help the recovery of many forest species populations. Seventy-seven percent of 53 tree species assessed in the National Forest Inventories and present in Catalonia show a clear increase in their cover. This rise can be seen in 25 out of the 26 most frequent species, such as the holm oak (*Quercus ilex*) and the Aleppo pine (*Pinus halepensis*), while among the 27 least frequent species, 16 increased and 11 decreased, as is the case with Mirbeck's oak *(Quercus canariensis*) and the sycamore maple (*Acer pseudoplatanus*). This means that the forest expansion and maturation process is favoring the most frequent species in particular, but there is also a significant group of less frequent trees whose presence in forests is steadily decreasing. With regard to characteristic animal life in forest and scrubland, the different taxonomic groups for which information is available have not recovered in the same way as trees and, overall, their numbers have declined slightly (Figure 3 or Figure 16). As for species that prefer forest, populations of butterflies have remained steady, while bird numbers have improved slightly[1] (Figure 21). By contrast, species that use more open areas or scrubland have suffered notable declines, especially butterflies (Figure 22). Thus, a dynamic exists whereby abandonment of agricultural and livestock farming leads to processes of vegetation growth that limit availability of open habitats, to the detriment of the species that inhabit them, only partially compensated by the temporary effect of fires (Example 1).

Iberian scarce swallowtail (*Iphiclides feisthamelii*), a common butterfly in open forest areas. **Photo: J.Luis Ordóñez.**

1. Herrando *et al.* 2016

Population trends in woodland species

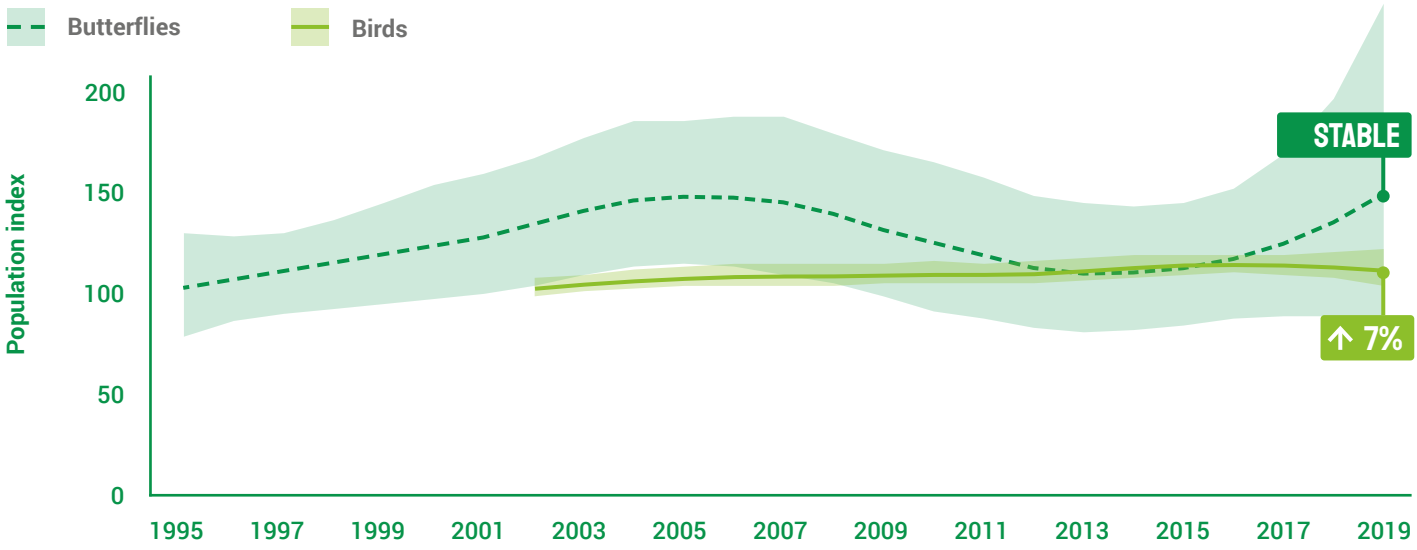


FIGURE 21. Average population trends in woodland birds and butterflies. There are 26 species in the bird indicator and 7 in the butterfly indicator. This graph is interpreted in the same way as the LPI graphs (see Boxes 1 and 2). **Source: the authors, based on data from the SOCC-ICO and CBMS-Museum of Granollers.**

Population trends in scrubland species

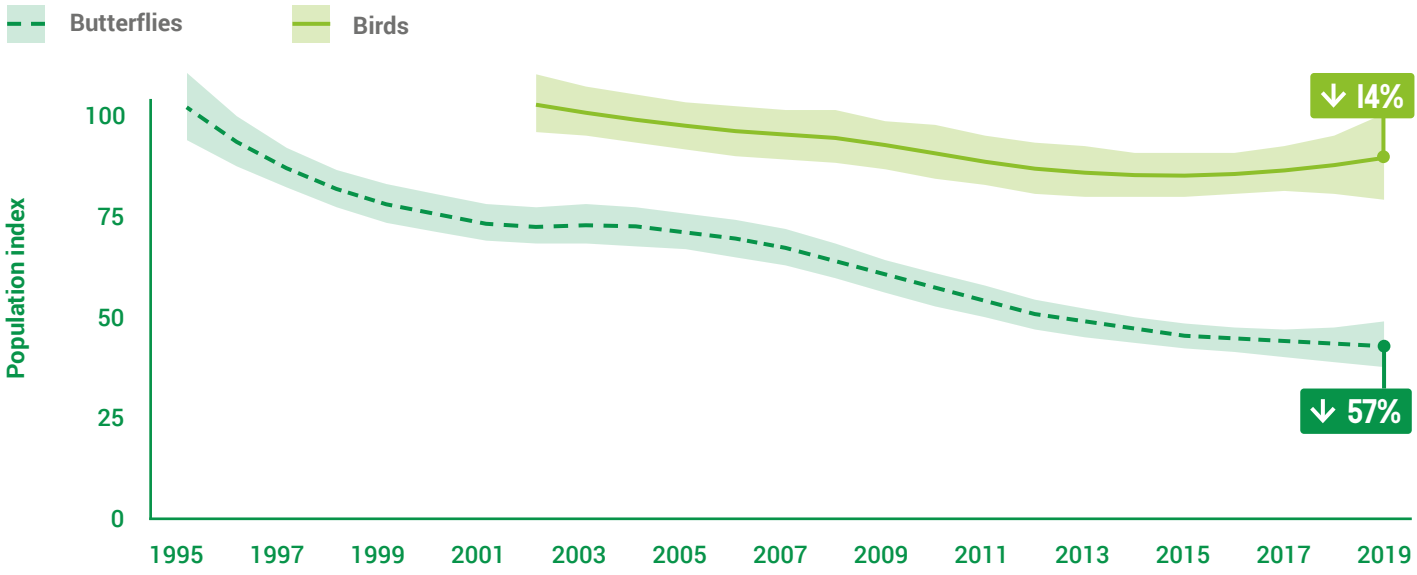


FIGURE 22. Trend in scrubland birds and butterflies. There are 11 species in the bird indicator and 9 in the butterfly indicator. This graph is interpreted in the same way as the LPI graphs (see Boxes 1 and 2). **Source: the authors, from the SOCC-ICO and CBMS-Museum of Granollers.**

Another of negative impact of global change on biodiversity is functional simplification of ecosystems,[1] where generalist species (which can live in a greater number of habitats, and which are more adaptable to change) expand, while more specialist species (more selective and restricted to fewer habitats) decline (Figure 4). As can be seen in Catalan forests, there are significant increases in generalist species that use the forest and additional resources from other habitats and while there is a significant decline in specialist species that require more specific forest resources, related to forest maturity. In many cases, the latter have declined due to the large proportion of young forests (Example 2). Among the generalist species, there has been a major rise in the numbers of wild boar (*Sus scrofa*) in Catalonia, mainly in forest habitats (Figure 23). The increase in wild boar and other hoofed species is also related to ecosystem simplification, lack of natural predators and possibly other factors, such as hybridization with domestic species.

Estimated wild boar density in Catalonia

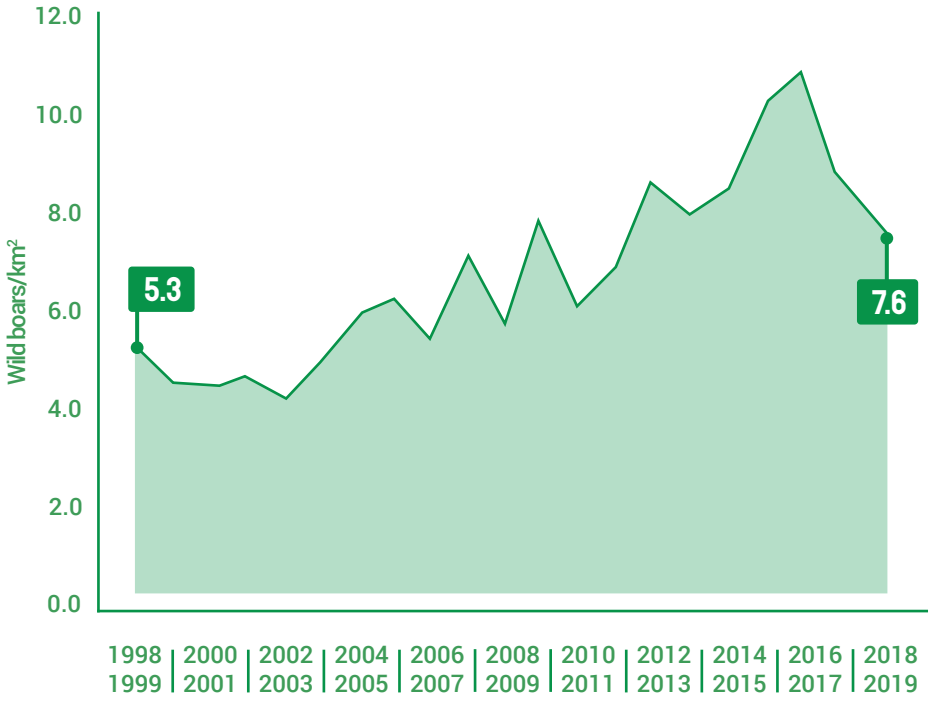


FIGURE 23. Change in average wild boar (*Sus scrofa*) population density in Catalonia (1998-2019). Trend obtained from the seasonal data of the observatories at L'Alt Empordà, El Cadí, Freser-Setcases, Garraf-Olèrdola-Foix, Montnegre-Corredor, Montseny, Els Ports, Sant Llorenç del Munt i L'Obac, the Collserola controlled hunting area and the La Garrotxa Volcanic Zone. **Source: Wild boar population monitoring program in Catalonia (2019). DARP, DIBA and Minuartia.**

Wild boar (*Sus scrofa*), a species favored by the expansion of woodland and lack of predators. **Photo: Vulpes_podšitá, via flickr.**

Some of the specialist species are included in the catalogs of animals categorized as vulnerable, such as certain forest bats, including the Mediterranean horseshoe bat (*Rhinolophus euryale*) and whiskered bat (*Myotis mystacinus*); beetles that require dead wood, such as the Alpine longhorn beetle (*Rosalia alpina*) and hermit beetle (*Osmoderma eremita*); and birds such as the western capercaillie (*Tetrao urogallus*). In the latter case, quantitative data are available showing that its numbers have declined between 31 and 34% in the last 10 years.[1] The state of conservation of forest species included in European directives also shows that drastic improvements are required, as over 80% of these species are at risk of no longer having viable populations in the future (Figure 24a). In terms of habitats, the situation does seem quite so negative, nevertheless over 60% of habitats are in unfavorable situations (Figure 24b).

Alpine longhorn beetle (*Rosalia alpina*), an endangered beetle in Catalonia. **Photo: Josep Maria Olmo.**

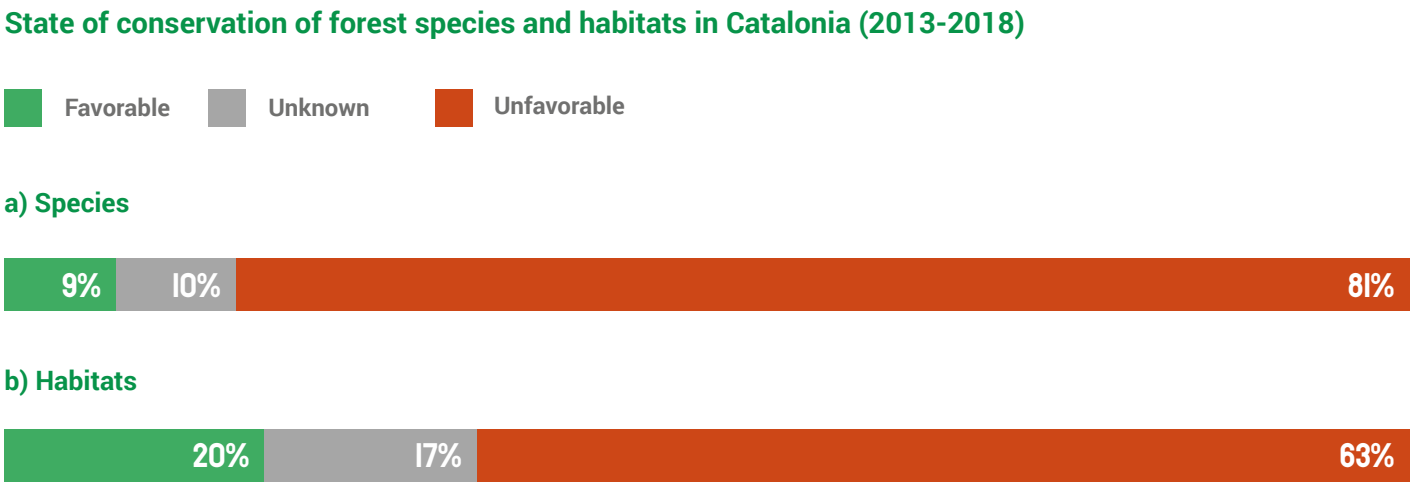


FIGURE 24. Conclusions on the state of conservation of 54 species (a) and 30 habitats (b) associated with forest and scrubland and included in European directives in Catalonia for the period 2013-2018. **Source: results from the reports on the application of the Habitats and Birds Directives in Catalonia 2013-2018 (DTES 2019).**

1. DTES 2017

EXAMPLE I

FOREST FIRES AND BIODIVERSITY

Forest fires are considered highly negative by society due to their impact on the landscape, materials and, unfortunately, sometimes also humans. In ecological terms, fires play an important role in the natural dynamics of Mediterranean forest systems. Large forest fires have a negative short- and medium-term impact on species that require more developed vegetation and trees, especially when they affect more mature forests; but they can have a positive impact for many invertebrate and vertebrate species that require open habitats (such as scrubland and meadows), which are currently regressing in Catalonia.

Increasing dependency on transitory open environments produced by fires has been observed among many species of high conservation value that occupy open spaces (**Figure 25**), given that forestation and intensive farming have reduced the availability of these stable open environments.[1] This has also been observed in highly endangered species, such as Bonelli's eagle (*Hieraaetus fasciatus*), whose distribution has expanded in some areas in the south of Catalonia due to the effect of forest fires at the end of the 20th century.

The effect of fires on bird species richness and their conservation value.

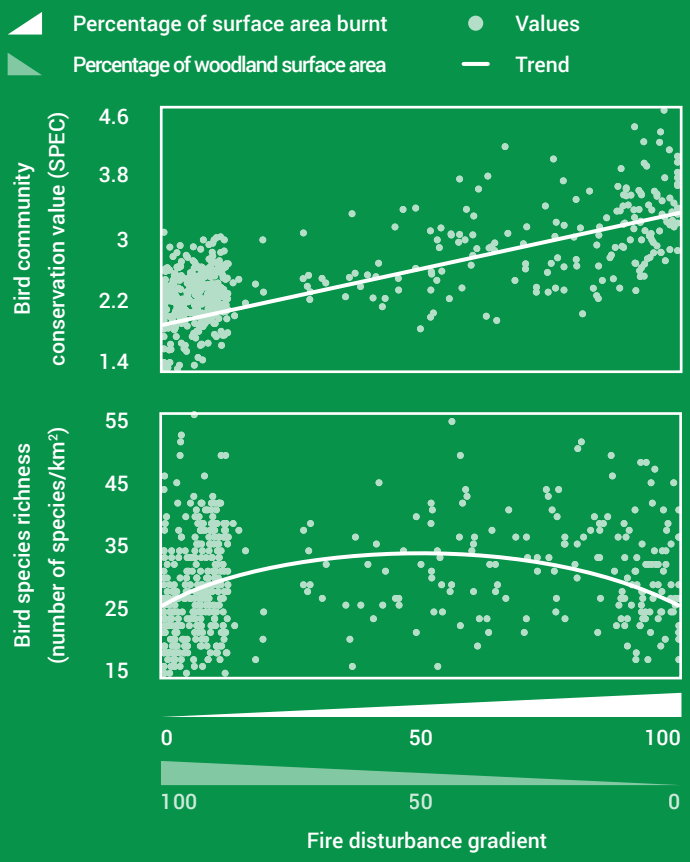


FIGURE 25. Relation between the combination of the effect of fire and resulting tree cover and bird species richness (number of species per km²) and the bird community conservation value (according to the SPEC: Species of European Conservation Concern). Graphs obtained from the analysis of 551 1x1 km squares in Catalonia. The fire disturbance gradient is a combination of the percentage of surface area burnt and percentage of surface woodland. The dots represent 1x1 km squares with their proportion of burnt zone and woodland area and their bird community. The average trend lines show a non-linear relation between each variable and the fire disturbance gradient. **Source: adapted from Clavero *et al*. 2011.**

1. Brotons *et al*. 2005

The forest fire in Ribera d'Ebre in 2019 left old crop terraces uncovered. **Photo: Lluis Brotons.**

EXAMPLE 2:

FOREST MANAGEMENT

Forest management is one of the main factors for change involved in the dynamic past and present of Catalan forests. In general terms, forest management extracts biomass from forests with a direct productive goal (as a source of energy or building materials) or an indirect goal (actions to favor certain forest structures). In ecological terms, forest management modifies the composition of tree and bush species and the forest structure, which can influence the composition and richness of other plant and animal species inhabiting it.[1] It is difficult to assess the magnitude of its impact on biodiversity because this depends on the context of the forest, specific direct actions and actions that are indirectly related (such as opening up roads and the levels of human presence).[2]

Actions based on systematic extraction of large trees and eliminating unproductive trees, such as dead or diseased ones, drastically reduce opportunities for finding natural cavities, as these generally form in trees of a certain age and diameter.

Natural cavities provide refuge and nests for various species of mammals and birds,[3] to the extent that the number of cavities per hectare of forest determines the number

Richness of nesting bird species in tree cavities

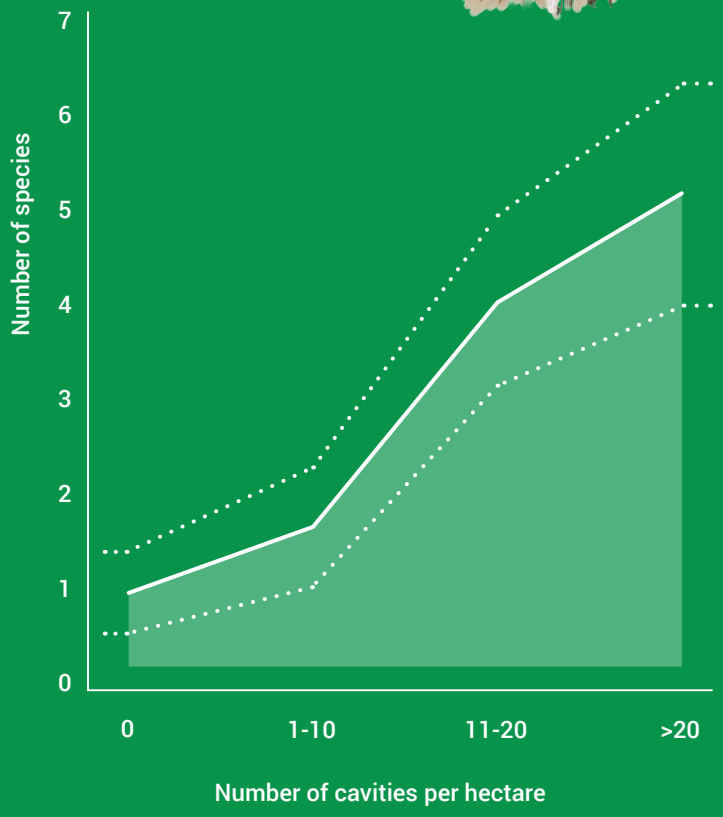


FIGURE 26. Richness of nesting bird species by number of cavities per hectare. The graph shows the average number of birds detected per sampling season (solid line) and the standard deviation (dotted line). The narrower the distance between the dotted lines, the more reliable the value calculated for the solid line. **Font: adapted from Camprodon *et al*. 2008.**

1. Camprodon 2013
2. Torras *et al.* 2012
3. Guixé and Camprodon 2018
4. Ameztegui *et al.* 2017

of these species found there (**Figure 26**). Furthermore, because large trees serve as a food substrate and refuge for many forest species, tree maturity also affects the abundance of birds (**Figure 27**) and forest bats.[4]

In young forests (such as those growing in abandoned farmland and mostly colonized pines), which characterize a large part of the country's woodland, actions that reduce tree density favor maturation and reduce the risk of fire. Furthermore, new open spaces in the forest created by these actions often allow forest species to enter.[4]

Whiskered bat (*Myotis mystacinus*), a species that occupies cavities in trees. **Photo: Laura Torrent.**

Richness of nesting bird species by type of beech forest.

FIGURE 27. Relation between the richness of nesting bird species in beech forests in the northeast of Catalonia and forest development. *Mature beech forests*: with features of mature forests (see Box 6); *Cleared forests*: with selective felling in full growth; *Deficient forests*: Poorly developed trees. **Source: adapted from Camprodon 2013.**

FARMLAND AND GRASSLAND

KEY MESSAGES

Catalan farming has undergone a process of has intensification and the abandonment of pastures and arable land in recent years.

These changes have led to a continual loss of biodiversity in these environments.

The most severely affected species are ones that depend exclusively on these environments, such as steppe birds and grassland butterflies.

The recovery of traditional practices and promotion of new, more sustainable production models could become tools among a range of options to halt and reverse biodiversity loss.

This chapter describes the main factors causing changes in recent years in farmland, grassland and pasture areas, which cover around 25% of Catalan territory. Because these are productive crop and livestock farming areas, they are heavily influenced by humans, while also having high natural richness, in some cases striking so, which is in general decline in Europe.

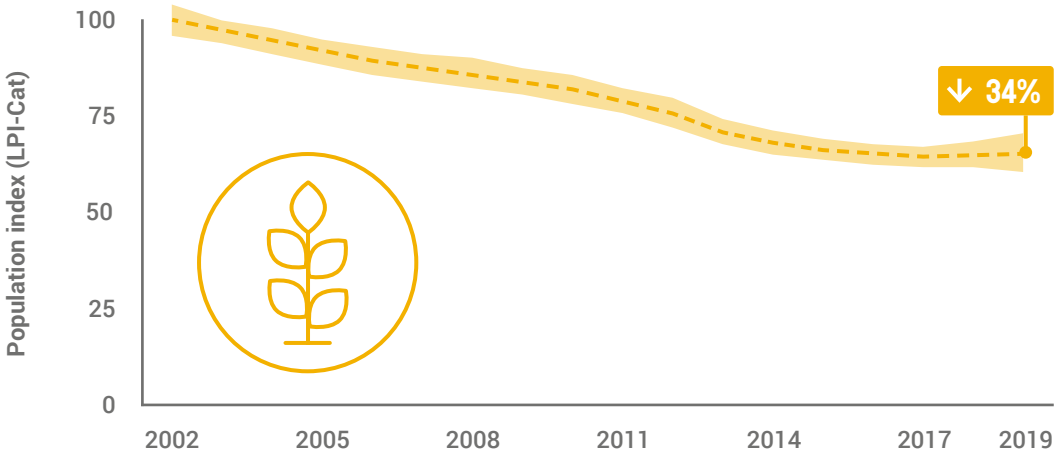


FIGURE 28. Average population trend (LPI-Cat) in 149 animal species associated with farmland and scrubland in Catalonia. See Boxes 1 and 2 for an explanation of the graph. **Source: the authors.**

DUALITY IN FARMLAND AND GRASSLAND: BETWEEN ABANDONMENT AND INTENSIFICATION

Due to the anthropic origin of farming areas, biodiversity conservation is closely linked to the persistence of certain extensive arable and livestock farming practices and preserving the microhabitats (such as fallow land and verges) associated with the farming landscape. These zones have for some decades been affected by a dual process in Catalonia. On the one hand, extensive arable and livestock farming has been steadily abandoned in less productive zones with harsher topography, as stated in other sections (Figure 6). On the other hand, in flatter, more productive zones, arable and livestock farming has been intensified, substantially increasing productivity per unit of surface area.

Bellpuig dryland. **Photo: Joan Estrada.**

Among numerous other changes, intensification has

led to a sharp rise in the use of phytosanitary products (mainly herbicides, insecticides and fungicides), up to as much as 13,528 tons a year,[1] a 100% increase over the last 14 years (Figure 29). In this context, spontaneous plant species, or weeds as they are commonly known, found in arable land are considered a good bioindicator of the state of the fields, as they are especially sensitive to and harmed by herbicide use. A comparison of the periods 1953-1988 and 2005-2007 in Catalonia shows there has been a 47% decline in weed species richness (Figure 30)[2]. This decline is even sharper for species considered rare and, therefore, in greater need of conservation. In addition fertilization based principally on use of slurry from intensive pig farming has a generally negative impact on the conservation of rare weeds,[3] bearing in mind that the number of pigs in Catalonia increased by 32% from 2000 to 2018, to the current figure of 7.5 million.[4]

Changes in annual consumption of phytosanitary products

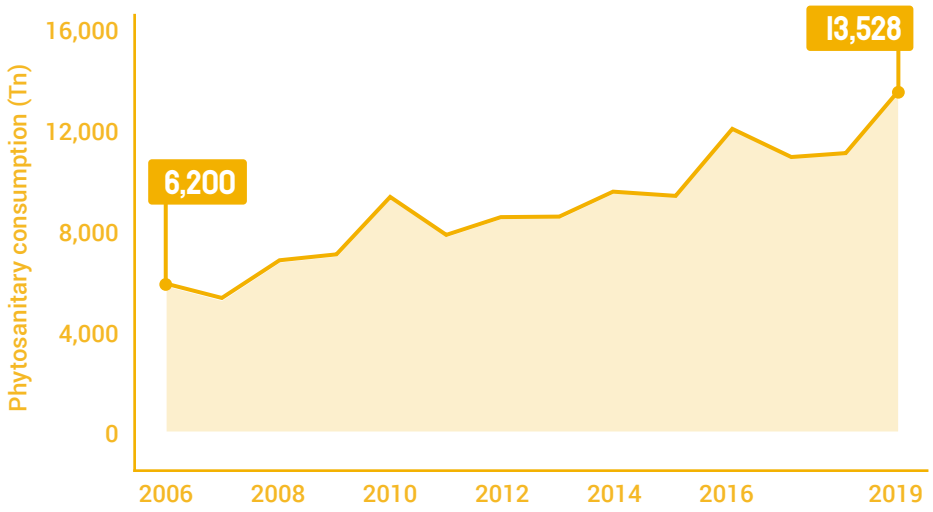


FIGURE 29. Changes in annual consumption of phytosanitary products (2006-2019). **Source: AEPLA 2020.**

Changes in the number of weed and rare weed species

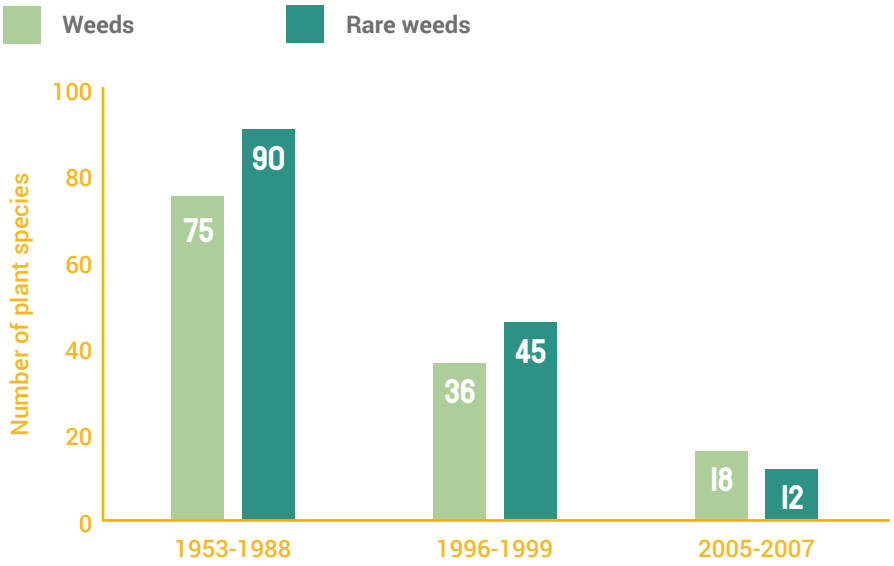


FIGURE 30. Changes in the number of species of weeds (common to arable land) and rare weeds present in cereal fields in Catalonia in the periods 1953-1988, 1996-1999 and 2005-2007. **Font Chamorro *et al* 2016.**

1. *et alet al*

In this context the LPI-Cat for farmland and grassland dropped by 34% from 2002-2019 (Figure 3 and Figure 28), which means the numbers of species dependent on these areas are suffering a serious decline. Birds in farmland areas are an official European bioindicator of the state of conservation of farming systems, using the Farmland Bird Indicator (1980-2017). This indicator shows a dramatic decline of 57% in European farmland bird populations, particularly sharp at the end of the 20th century.[1] In Catalonia, where the time series is much shorter (2002-2019) and after the period of major population decline observed in Europe, the trend in bird populations dependent on farmland and grassland has stabilized (Figure 31). However, in this group, the numbers of steppe birds, the true specialists of the Lleida plain drylands, dropped by 27% between 2002 and 2019 (Figure 31), one of the sharpest declines among bird groups in Catalonia.

Steppe bird populations depend on the maintenance of drylands (non-irrigated) and traditional farming practices, such as leaving fields fallow (leaving them unfarmed for a period).[1] The reduction in the surface area of fallow

Population trend in farmland birds and Catalan steppe dryland specialist birds

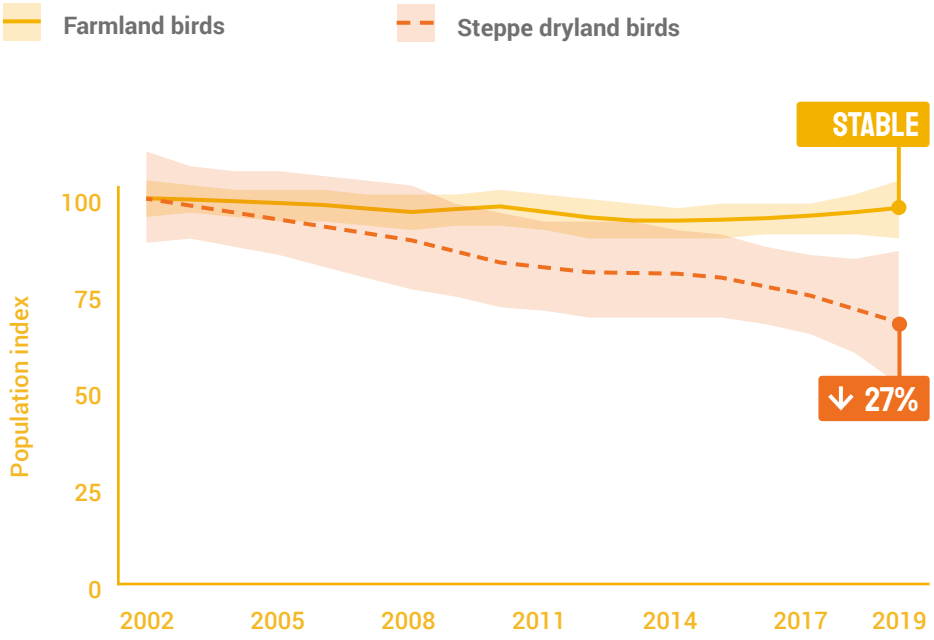


FIGURE 31. Average population trends of 42 specific of farmland birds and 11 species of Catalan steppe dryland specialist birds. The graph shows the average annual value and 90% confidence interval. This graph is interpreted in the same way as the LPI graphs (see Boxes 1 and 2). **Source: SOCC-ICO.**

Little bustard (*Tetrax tetrax*), a Lleida Plain steppe dryland bird. **Photo: Joan Estrada.**

1. PECBMS 2020

land in Catalonia (a 21% drop from 2009 to 2018; **Figure 32**) is another clear consequence of intensive farming and has led to the decline in number among these bird populations (**Example 3**). Another example of an affected species is the sooty orange tip butterfly (*Zegris eupheme*), which depends wholly on cruciferous plants that grow in fallow land. This butterfly has experienced one of the sharpest declines in numbers in the last 50 years, which is why it is classified as an endangered species in Catalonia. It previously occupied most of the Catalan Central Depression, even reaching the edge of the Catalan coastal region.[2]

In this context of intensive farming, certain organic farming practices have been shown to prevent a number of problems arising with modern agriculture. This difference is attributed mainly to banning the use of industrially synthesized phytosanitary products and quick-release chemical fertilizers and the use of more diverse crop rotation techniques. Currently, organic farming (excluding grassland, pasture and forage) covers more than 61,000 hectares (7.1% of total arable land in Catalonia),[3] and has clearly been rising in recent years (**Figure 33**).

Changes in fallow land surface area in Catalonia

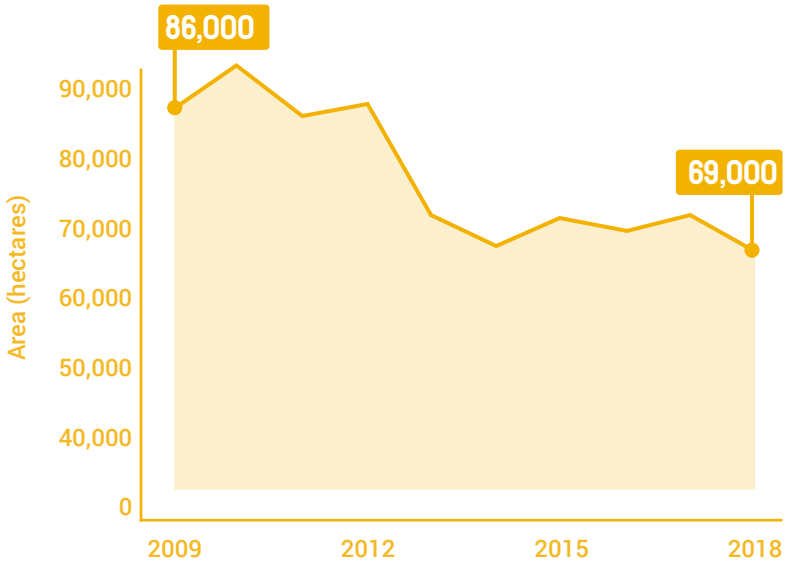


FIGURE 32. Changes in surface area of fallow land in Catalonia from 2009 to 2018. **Source: DARPA 2020a.**

Changes in arable land surface area in Catalonia

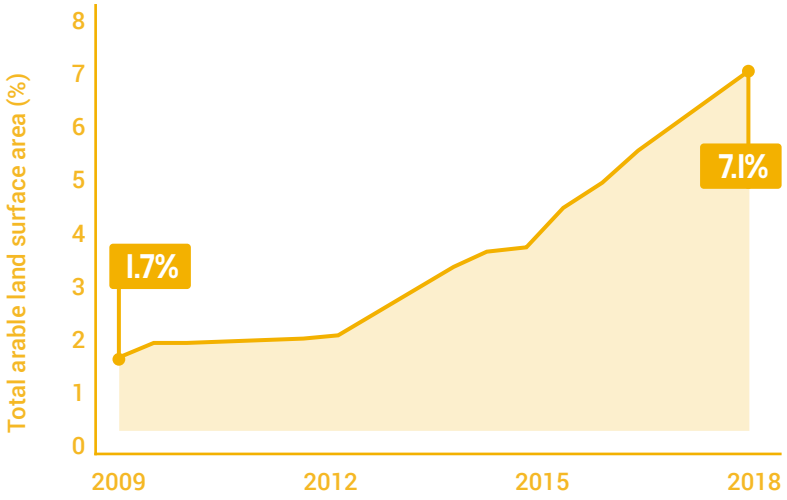


FIGURE 33. Change in the percentage surface area of organic arable land out of the total arable land for Catalonia. **Source: DARPA 2020b.**

1. Traba and Morales 2019
2. Vila *et al.* 2018
3. DARPA 2020b

The potential benefits of crops such as vines, cereals and olives can be seen in Catalonia among animal groups as diverse as birds,[1] bats,[2] insects[3] and weeds.[4]

Areas of grassland and pasture cover about 7% of Catalonia. The abandonment of traditional practices (mainly related to livestock farming) and the subsequent increase in woodland has had a particularly serious impact on the Mediterranean Basin.[5] Reforestation is causing changes in trends and the composition of butterfly communities associated with these open spaces. As observed in the rest of Europe,[6] their numbers are suffering a major decline, quantified as 71% from 1995 to 2019 (**Figure 34**). This general decline not only involves an alarming drop in numbers but also a rise in local extinctions of butterfly populations ecologically linked to grassland (**Figure 35**)

Population trend in butterflies associated with grassland

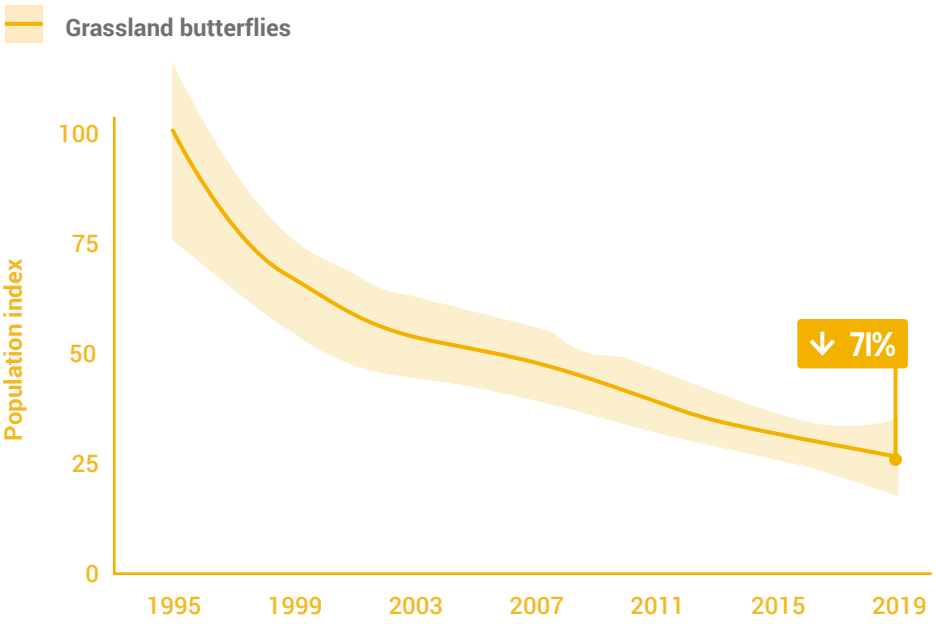


FIGURE 34. Average population trend in butterfly species associated with grassland in Catalonia. The graph shows the average annual value and the 90% confidence interval. This graph is interpreted in the same way as the LPI graphs (see Boxes 1 and 2). **Source: CBMS-Granollers Museum of Natural Sciences.**

Adonis blue (*Lysandra bellargus*), a typical grassland butterfly in Catalonia. **Photo: Xavier Florensa.**

1. Rollan *et al.* 2019
2. Puig-Montserrat *et al.* 2020
3. Puig-Montserrat *et al.* 2017
4. Chamorro *et al.* 2016
5. Doblas-Miranda *et al.* 2015
6. EEA 2020b

Distribution of population trends for four species of butterfly associated with grassland

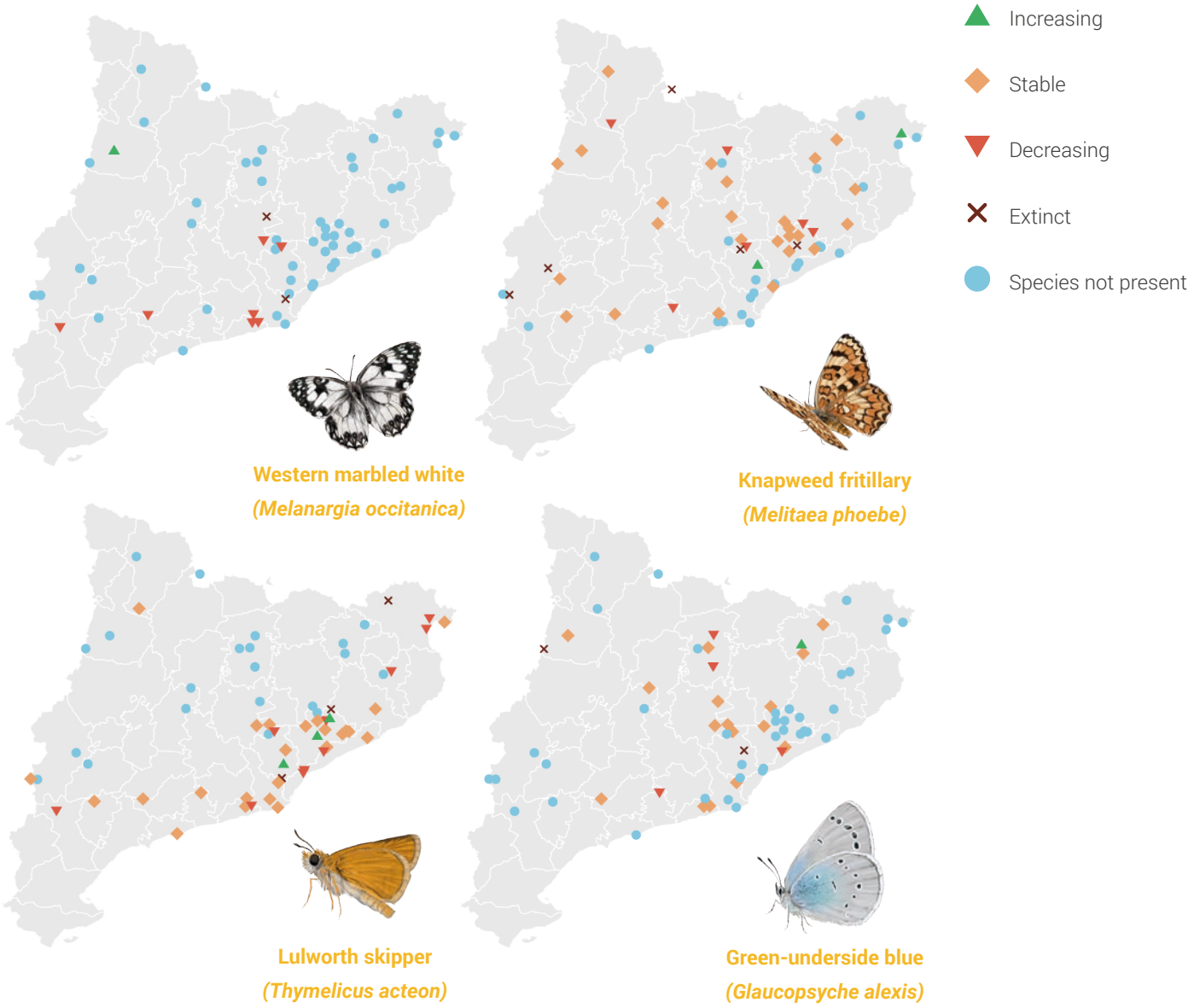


FIGURE 35. Maps of population trends in four species of butterfly ecological linked with grassland and pasture in the Catalan Butterfly Monitoring Scheme (CBMS) route network for the period 1995-2019. **Source: CBMS-Granollers Museum of Natural Sciences.**

STATE OF BIODIVERSITY IN FARMLAND AND GRASSLAND

Although less widespread and mainly in areas associated with livestock farming (such as pastures in the Vic plain and lower Pyrenean valleys), intensive farming processes (such as excessive fertilization, changes in pasture systems, introduction of ruderal species, etc.) have caused a loss of specialist plants, changes in plant communities and a reduction in biodiversity.[1] Loss of biodiversity in these environments is clearly shown by the results of the reports on the application of the Habitats Directive in Catalonia (2013-2018), as 85% of endemic farmland and grassland species mentioned in the directive are in an unfavorable state of conservation (Figure 36a). In relation to habitats of community interest in these environments, 62% are in an unfavorable state of conservation due especially to the reduction in their surface area in Catalonia (Figure 36b).

State of conservation of farmland and grassland species and habitats in Catalonia (2013-2018)

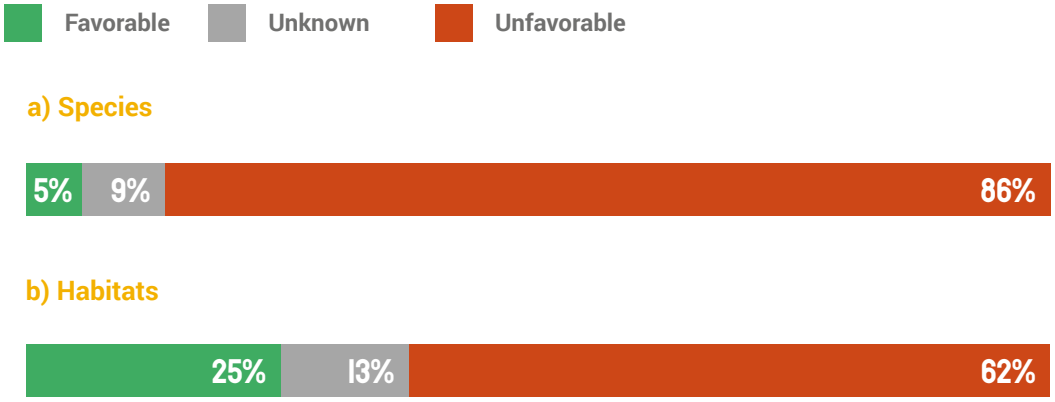


FIGURE 36. Conclusions on the state of conservation of 22 species (a) and 16 habitats (b) associated with farmland and grassland and included in European directives in Catalonia for the period 2013-2018. **Source: results from the reports on the application of the Habitats and Birds Directives in Catalonia 2013-2018 (DTES 2019).**

Black-bellied sandgrouse (*Pteroclis orientalis*) in the La Noguera drylands bird special protection area (SPA). **Photo: Joan Estrada.**

1. Palou 2016; Mercadal 2019

Fragrant orchid (*Gymnadenia conopsea*), an orchid found in moist mountain grasslands. **Photo: Xavier Florensa.**

EXAMPLE 3

RESPONSE OF THE PIN-TAILED SANDGROUSE TO FALLOW LAND MANAGEMENT

The pin-tailed sandgrouse (*Pterocles alchata*) has a reproductive population of around 100 birds in Catalonia, found in the western drylands of the Lleida plain. Its small numbers and long-term population trends mean it is considered a vulnerable species in Catalonia. Survival of this species, adapted to living in arid conditions, depends enormously on the presence of fallow land.[1]

For some years the DAPRA and DTES have been implementing different measures to increase the surface area of fallow land associated with steppe bird species. Mainly thanks to these measures, the reproductive population of the sandgrouse has seen a moderate increase (around 9% a year) from 2010-2019. This increase is particularly sharp from 2016, just after the largest increase in the number of hectares of managed fallow land (**Figure 37**). Furthermore, in the last four years, most of the evidence on species reproduction has come from estates managed for environmental purposes (**Figure 38**) while nest salvage protocols have been applied in the rest, in conjunction with the Rural Agents force. In conclusion, the increase in surface area of fallow land and good farm management is favoring the recovery of this species threatened by intensive farming.

Management of fallow land leased for environmental purposes in the Lleida drylands. **Photo: Jordi Bas.**

1. Giralt *et al.* 2018

Trend in pin-tailed sandgrouse abundance

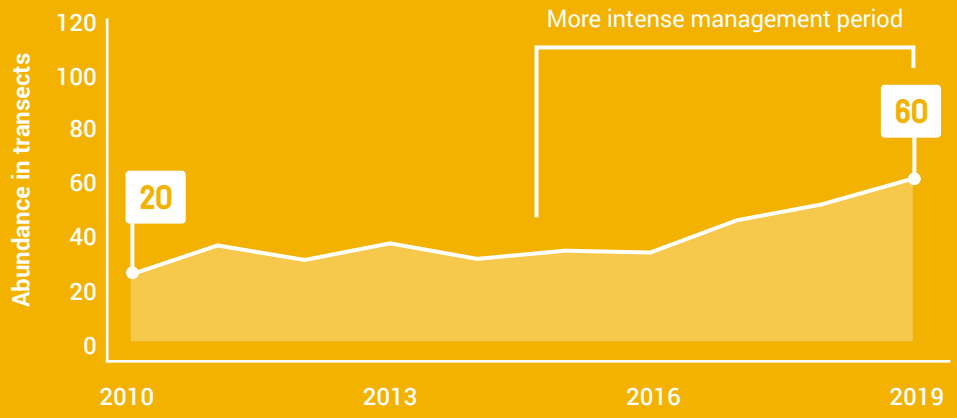


FIGURE 37. Change in the abundance of different census transects in the Lleida plain western drylands. The mark shows the most intense management period. **Source: Bird and habitat monitoring network in the El Segarra-Garrigues area (FARMDINDIS) - CTFC (Giral et al. 2020).**

Number of cases of pin-tailed sandgrouse reproduction detected yearly by type of estate

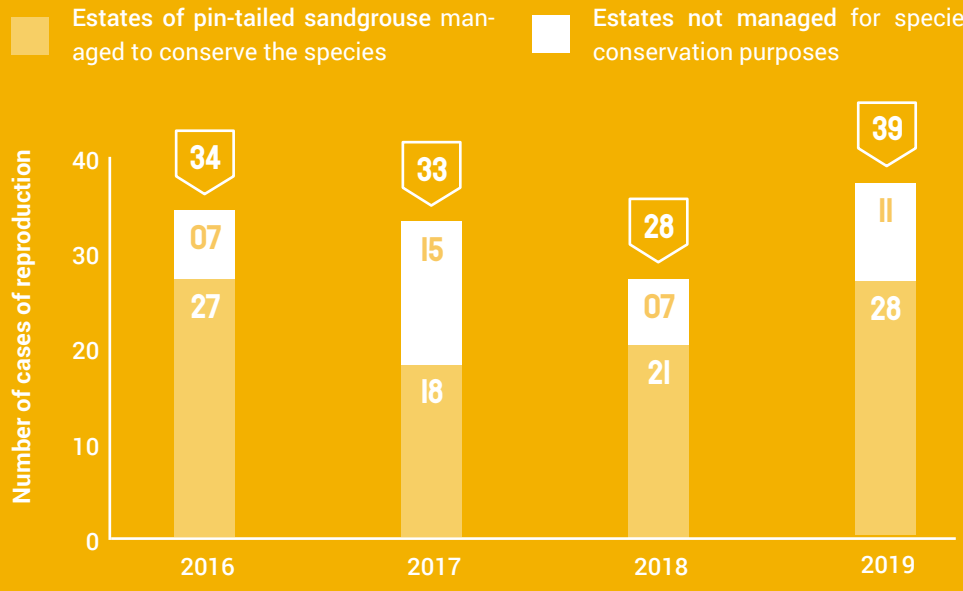


FIGURE 38. Number of cases of pin-tailed sandgrouse reproduction detected yearly by type of estate. The managed estates are fallow land estates in which actions have been taken to conserve the species. **Source: Management of the pin-tailed sandgrouse (Pterocles alchata) and black-bellied sandgrouse (Pterocles orientalis) in the Segarra-Garrigues area (CTFC 2019).**

INLAND WATERS

KEY MESSAGES

Inland water environments are subject to changes in the quantity and quality of water, the morphology of the riverbanks and the composition of the biological communities.

Despite recent improvements in the general quality of aquatic ecosystems, they are still in an unfavorable state of conservation and most of the species living in them are suffering major declines in numbers.

Only 40% of rivers and wetlands in Catalonia meet the quality standards set by the Water Framework Directive.

Loss of biodiversity and simplification of aquatic communities has heightened in recent decades due to the expansion of exotic species, only compensated occasionally by restoration actions.

INLAND WATERS

In Catalonia, inland waters are a scarce resource subject to sharp seasonal fluctuations and are home to unique ecological systems which are often subject to significant social usage. The broad environmental heterogeneity of the region is reflected in the diversity of existing aquatic ecosystems, which include rivers, brooks, streams and river beds, lakes, marshlands and coastal lagoons, permanent and temporary ponds, mountain lakes, wetlands and peatlands, as well as the aquifers and springs that feed them.

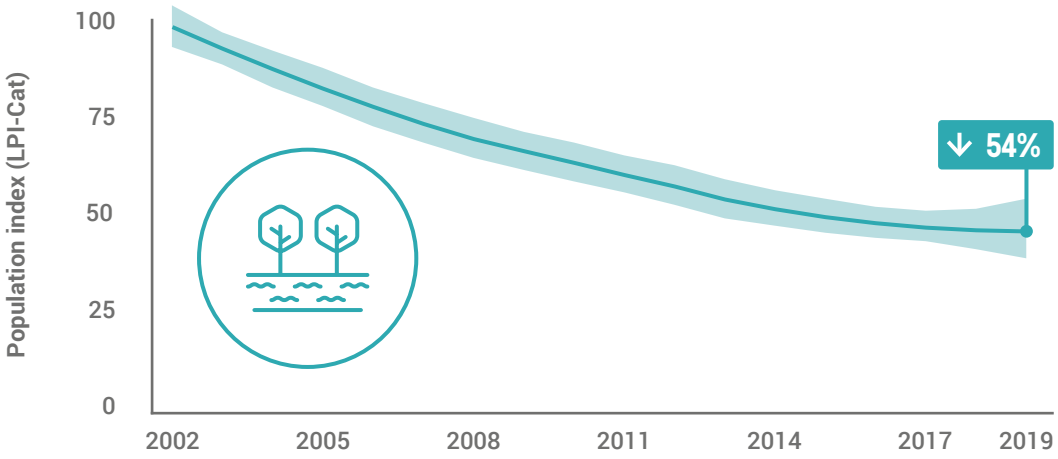


FIGURE 39. Average population trend (LPI-Cat) in 45 animal species associated with inland waters in Catalonia. See Boxes 1 and 2 for an explanation of the graph. **Source: the authors.**

Photo: Xavier Florensa.

INLAND WATERS ARE SUBJECT TO MULTIPLE HUMAN PRESSURES

Total demand for water for human consumption in Catalonia is 3,123 hm^3year, with 27% going to urban use (domestic and industrial consumption) and 73% to farm use (crop irrigation and livestock consumption arising from intensive farming).[1] Eighty percent of this volume comes from rivers and reservoirs, causing significant alterations to the volumes, structure and functions of rivers and their biological communities in 62% of watercourses (Figure 40 and Example 5).[2] The remaining 20% comes from groundwater, which affects 86% of aquifers, causing springs, wells and watercourses to dry out and rising salinity in coastal aquifers.[3] In addition to water catchment, river volume is also declining, with a sustained 8% loss of volume of water per decade, mainly due to lower rainfall and the spread of forest land due to the abandonment of traditional farming practices.[4]

Distribution of the impact level of human pressures on rivers, wetlands and lakes in Catalonia

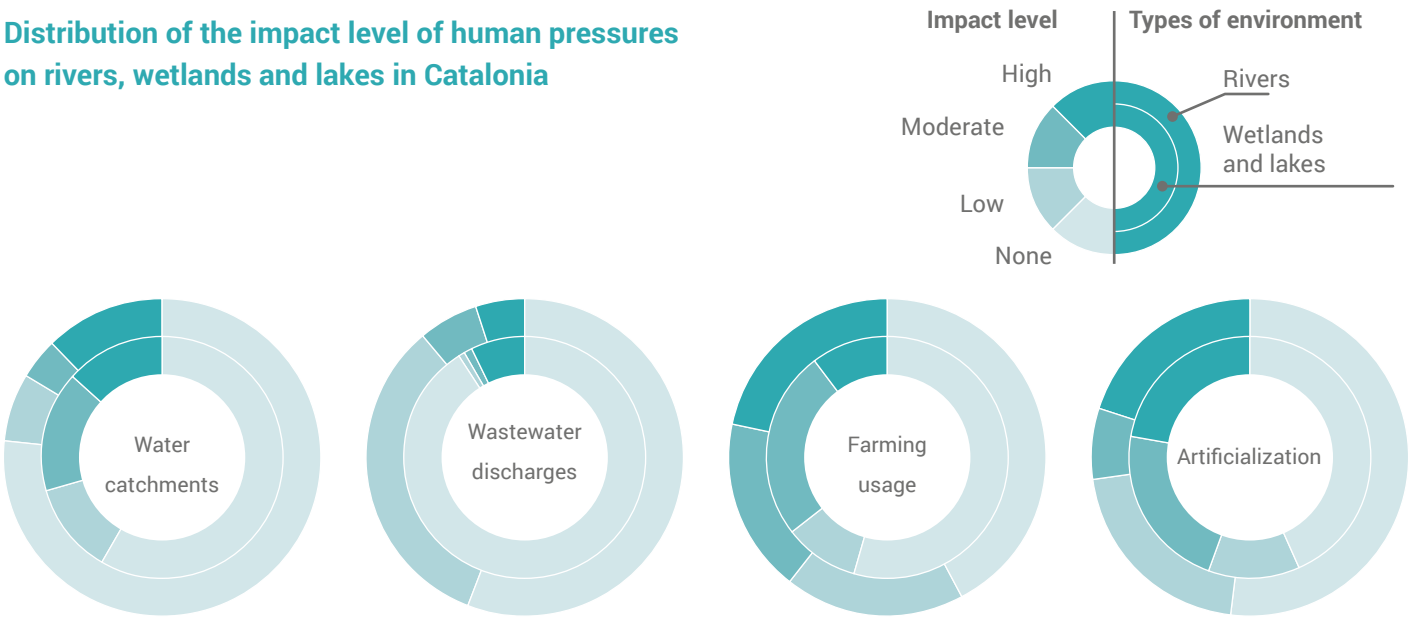


FIGURE 40. The level of impact on rivers, wetlands and lakes of certain pressures affecting water quantity (catchment), quality (wastewater discharges and agricultural use) and the morphology of aquatic systems (artificialization, understood as the loss of naturalness in land use in areas next to bodies of water). The percentages are calculated from all bodies of water studied in Catalonia in the impact pressure analysis of the Water Framework Directive, including the management areas of the Catalan Water Agency (248 rivers and 52 areas of wetlands and lakes) and the Ebro Hydographic Confederation (134 rivers and 15 areas of wetlands and lakes). **Source: redrawn from ACA (2019) and CHE (2017).**

1. ACA 2008a
2. ACA 2019; CHE 2017
3. ACA 2019
4. ACA 2019; Gallart 2011

With regard to water quality, in general, the aquatic invertebrate communities used as indicators have shown a markedly positive trend over the last 40 years, even in rivers such as the Llobregat, exposed to multiple impacts over its course (Figure 41). Nevertheless, urban, agricultural and industrial wastewater still cause pollution problems in 45% of watercourses (Figure 40), above all affecting rivers with low volumes receiving treated water discharges, which also alter the seasonal patterns of Mediterranean rivers, transforming temporary watercourses into permanent ones. In addition, 21% of rivers have registered the presence of hazardous or emerging pollutants (such as heavy metals, solvents, drugs and biocides), while mainly agricultural pesticides have been detected in 17% of rivers,[1] worsened by lower water volumes so they have less capacity to dilute such pollutants.[2] Wetlands are also exposed to diffuse entry of these kinds of pollutants, where moderate concentrations of phytosanitary products have been registered in 30% of them[3] (Figure 40). With regard to groundwater, excessive use of livestock waste and mineral fertilizers have caused nitrate and sulfate concentrations to rise in 43% of aquifers.[4] This is an extremely high level, which undoubtedly has a highly significant, indirect impact on biodiversity in aquatic environments.

Water quality in the Llobregat river

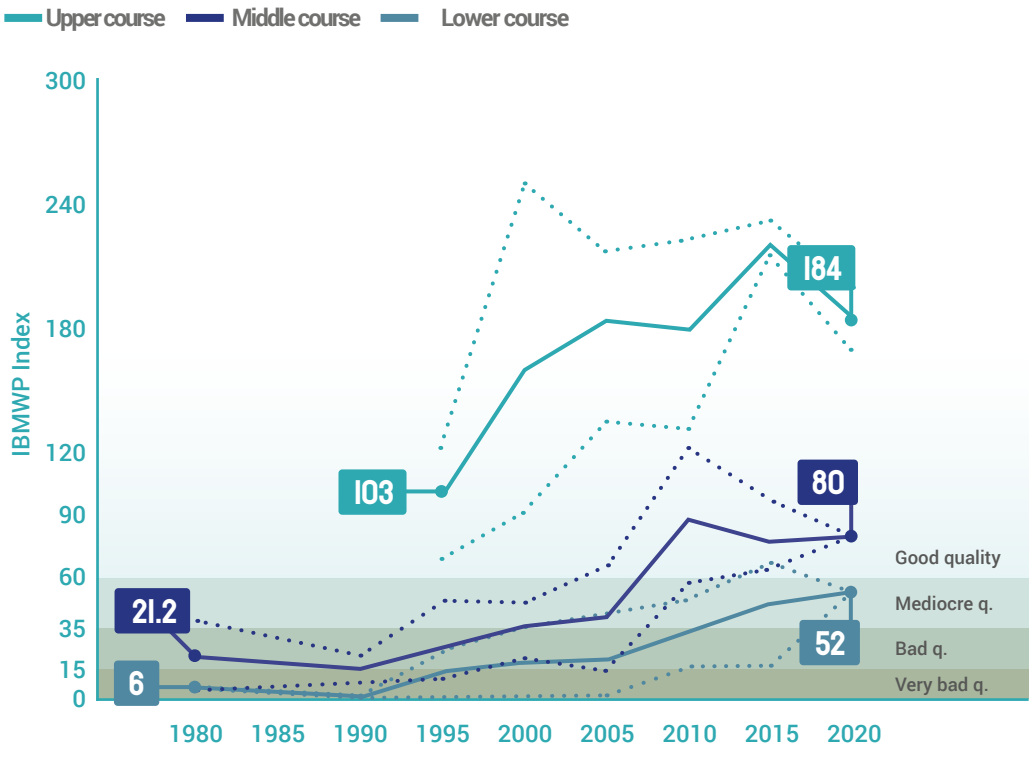


FIGURE 41. Change in water quality in the Llobregat river since 1980, divided into its upper course (Castellar de n'Hug with figures since 1995) middle course (Esparreguera, la Puda) and lower course (Molins de Rei). The graph shows the change in average values (solid lines) and minima and maxima (dotted lines) for the IBMWP (Iberian Biomonitoring Working Party) Index, which assesses the biological quality of the water based on the composition of benthic invertebrate communities. In the Llobregat, IBMWP values of over 60 in the middle and lower courses indicate the water is good quality, while values below this threshold indicate water is mediocre, bad (<35) or very bad (<15). **Source: Study program on the ecological quality of rivers in the Province of Barcelona - Barcelona Provincial Council and FEHM-Lab (UB-CSIC) (Fortuño *et al*. 2019).**

1. ACA 2019; CHE 2017
2. ACA 2009
3. ACA 2019
4. ACA 2019; Ladrera *et al*. 2019

Hydromorphological changes affect over half of rivers. These involve the occupation of floodplains and riverbeds and resulting loss of riverbanks and their habitats, a process exacerbated by modifications to natural courses and the constructions of dams, locks and similar structures.[1] (Figure 40). Furthermore, these 'barriers' disrupt connectivity along 27% of watercourses, affecting fish migration and other ecological flows (such as sediments and nutrients).[2] Loss or alteration of riverbank habitats also affects 57% of wetlands and lakes, 46% of which are in farming areas[3] (Figure 40). In these areas, habitat deterioration is accompanied by high human visitation affecting over 50% of water bodies, with the resulting disturbance to animal life, trampling of plant life and disruptions to the physical environment.[3] These impacts are especially serious in small wetlands, such as Pyrenean marshes or temporary Mediterranean ponds.[4]

Noguera Ribagorçana River flowing through the Congost de Mont-rebei gorge, at the start of the Canelles reservoir. **Photo: Xavier Florensa.**

1. ACA 2008b
2. ACA 2018
3. ACA 2019
4. Carreras *et al.* 2015; Boix *et al.* 2016

CONTRIBUTION OF EXOTIC SPECIES TO THE DEPLETION OF AQUATIC COMMUNITIES

Biodiversity loss and simplification of aquatic communities are the product of a long history of human impacts on the environment.[1] These have worsened in recent decades due to a sustained increase in exotic species (Figure 42), introduced mainly due to fish stock repopulation, fish farming and the market for pets, which in the aquatic environment find the ideal conditions for their establishment and propagation.[2] Currently, invasive exotic species are found in 64% of watercourses and 73% of wetlands[3] (Figure 43) and a total of 100 such species have been identified in the country as a whole.[4] Furthermore, unlike native species, invasive exotic species often show steady population growth (Figure 47). The most serious effects are the disappearance of native species due to competition, predation and the introduction of new diseases, and the simplification of aquatic communities[5] (Example 4).

Exotic species in the inland waters of Catalonia

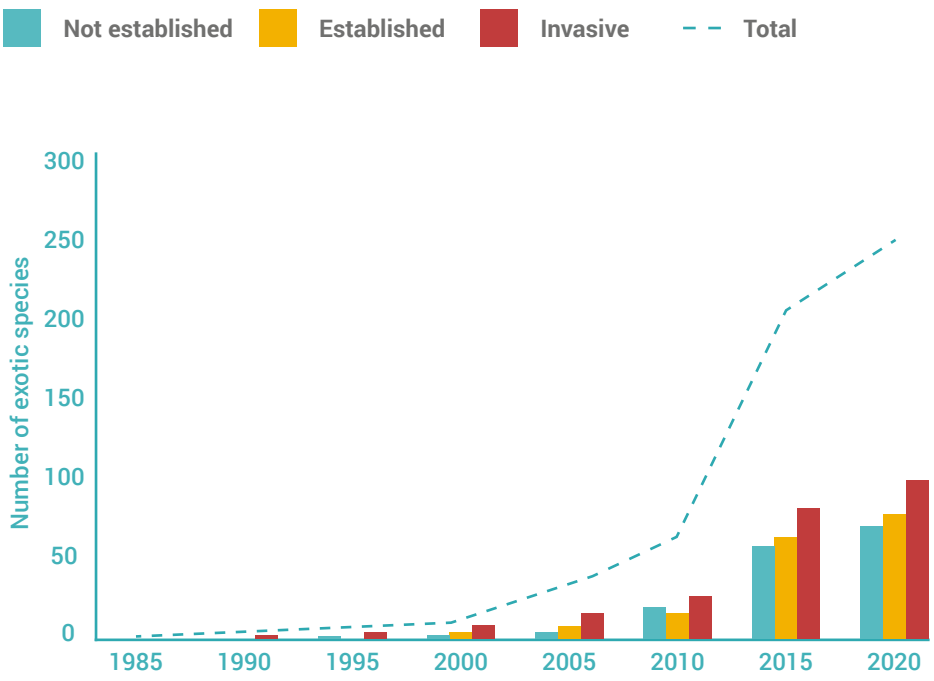


FIGURE 42. Change in the number of exotic species in inland waters registered in Catalonia in the period 1980-2020, divided into *unestablished* species (present but no evidence of self-sustaining populations), *established species* (self-sustaining populations but no territorial expansion or major impacts) and *invasive* species (territorial expansion and/or notable ecological or socioeconomic impacts). **Source: Catalan Exotic Species Information System - CREAF (EXOCAT 2020).**

1. Benejam *et al.* 2010; Hermoso and Clavero 2011; Romagosa 2000
2. ACA 2011; Maceda-Veiga *et al.* 2016; Miró and Ventura 2013
3. ACA 2019
4. EXOCAT 2020; Aymerich and Sáez 2019
5. ACA 2011; García-Berthou *et al.* 2007

Presence of invasive exotic species in the river basins of Catalonia.

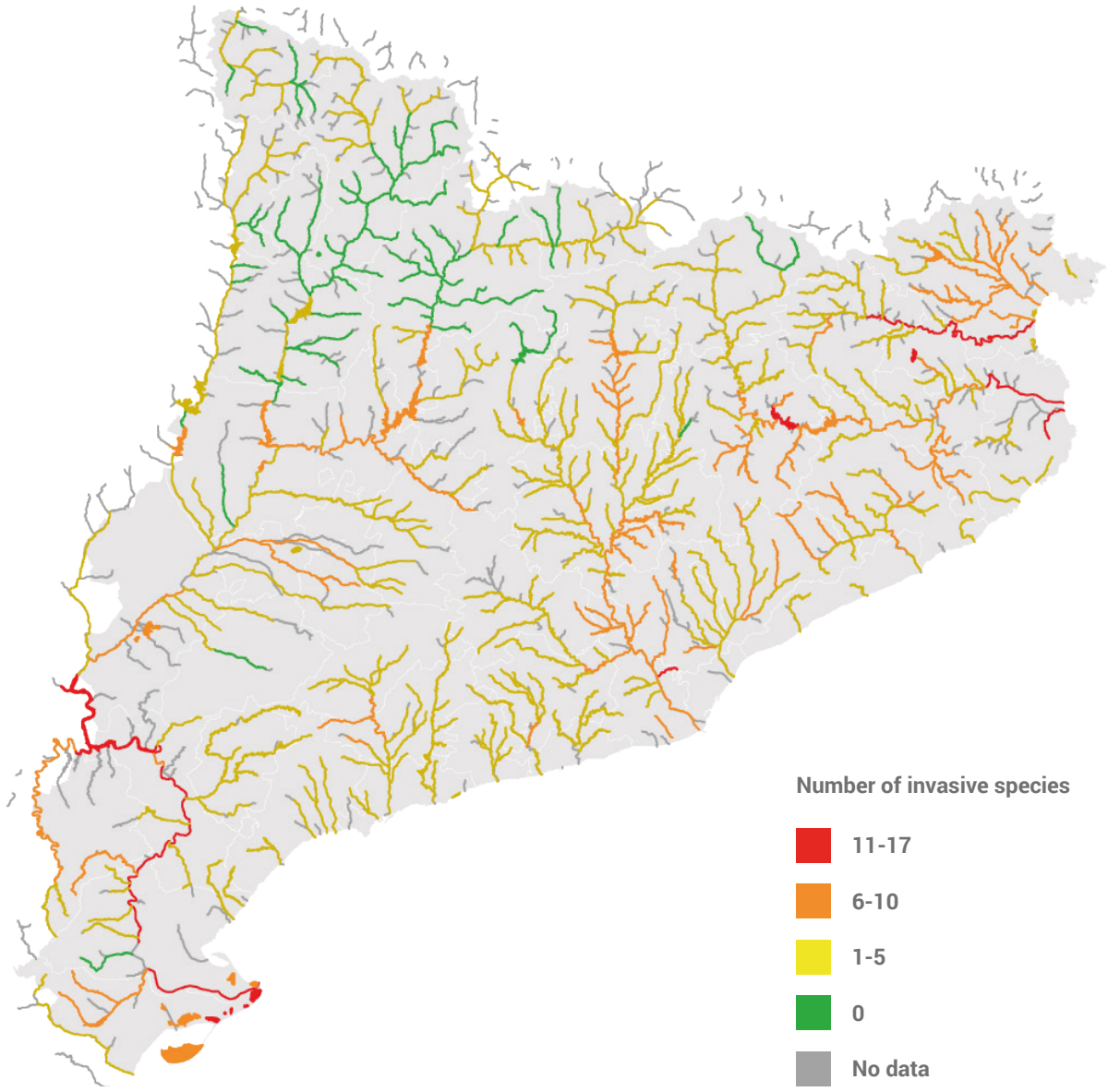


FIGURE 43. Map of the presence of invasive exotic species in the water basins and coast of Catalonia. **Source: Catalan Exotic Species Information System - CREAF (EXOCAT 2020).**

EXAMPLE 4

IMPACT OF THE INTRODUCTION OF FISH TO PYRENEAN MOUNTAIN LAKES

Most Pyrenean mountain lakes are ecosystems free of fish in their natural state, as numerous river barriers prevent their colonization. Nevertheless, today over half the lakes on the southern side of the Pyrenees have seen the introduction and proliferation of various fish species, mainly the brown trout (*Salmo trutta*), introduced for fishing purposes, and the common minnow (*Phoxinus phoxinus*), a species used as live bait.[1] **Figure 44** shows how the introduction of fishes into mountain lakes causes serious alterations to the whole ecosystem, due to the severe predation pressure fish exert on most native species in lakes (including amphibians, insect larvae and planktonic crustaceans).[2] This has consequences for other processes, such as the nutrient cycle, and for adjacent land habitats.[1]

Currently, work is being done on the ecological restoration of Pyrenean mountain lakes, in particular, eliminating introduced fish, so as to recover the original lake ecosystem relatively rapidly.[3] This work is coordinated by the LIFE+ LimnoPirineus project.

System for eliminating fish from a lake in the L'Alt Pirineu Natural Park. **Photo: Sorello, Aquatic Environment Studies.**

1. Ventura 2017
2. Miró and Ventura 2020
3. Sarnelle and Knapp 2004

Diagram of mountain ecosystems in their natural state and with the presence of fish

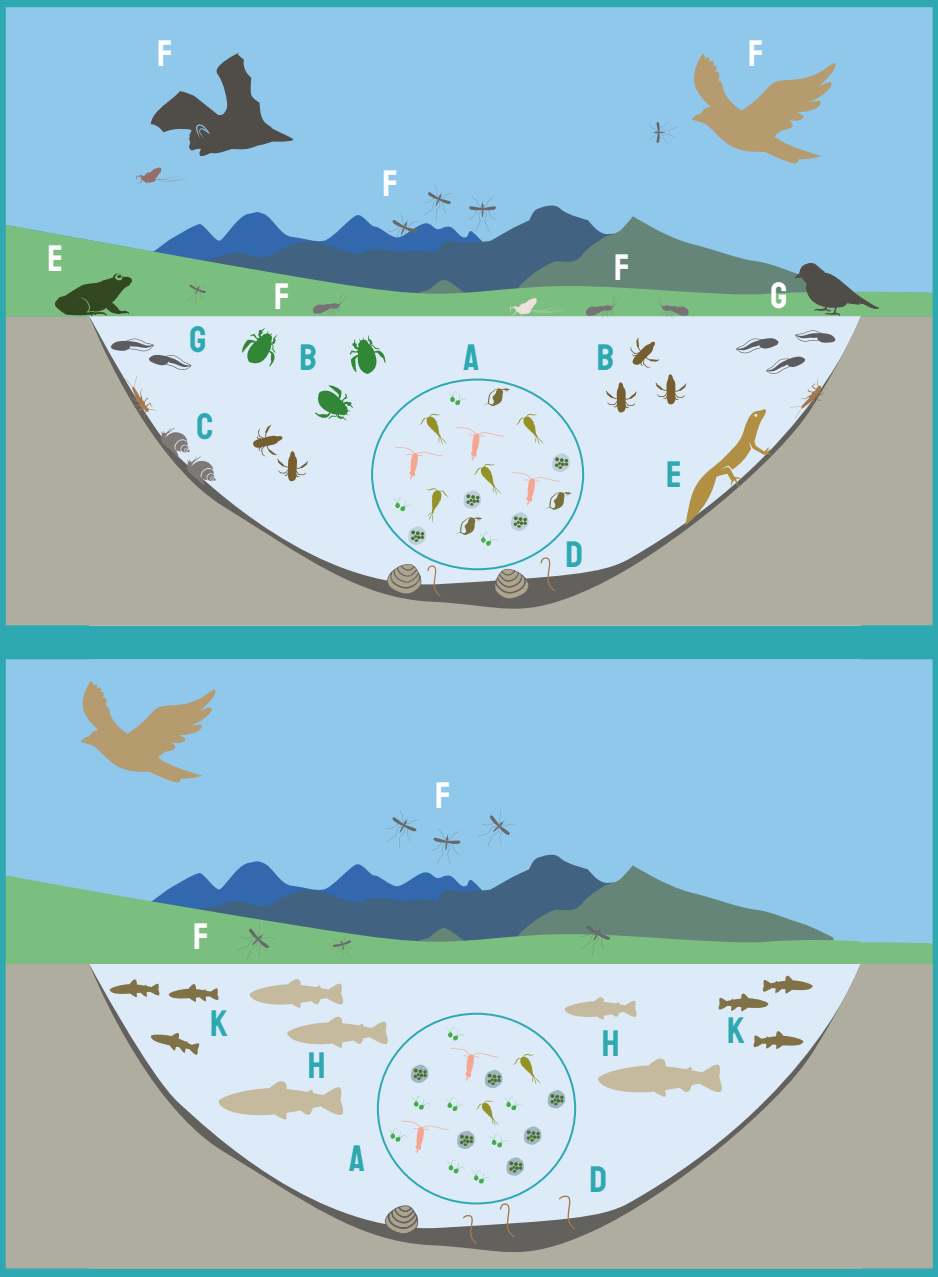


FIGURE 44. Diagram of mountain ecosystems in their natural state (top) and with the presence of fish (bottom). The presence of trout (**H**) and minnows (**K**) in mountain lakes results in a number of alterations to the ecosystem trophic network: direct predation on large planktonic crustaceans produces a change in the community and biomass of zooplankton and phytoplankton (**A**) and local extinction of nektonic (swimming) macro-invertebrates (**B**) and benthic (bottom-dwelling) invertebrates (**C**). In addition, macro-invertebrates that bury themselves in the bottom (**D**) do not suffer predation from fish and their populations are indirectly affected. The introduction of fish also frequently leads to the disappearance of amphibians (**E**) and exerts an indirect effect on adjacent land ecosystems, where the emergence of amphibians (**G**) and insects (**F**) is reduced. **Source: Redrawn from Ventura *et al*. 2017.**

STATE OF BIODIVERSITY IN INLAND WATERS

The information available on the state of conservation of these ecosystems shows the situation is far from satisfactory. Half the habitats of community interest in inland waters have an unfavorable state of conservation (Figure 45). Indeed, out of all the habitats of community interest in Catalonia, the ones at highest risk of disappearing are mostly in watercourses (Figure 46). With regard to species, aquatic communities are in an even worse situation than the habitats. Almost 80% of species assessed have an unfavorable state of conservation (Figure 45). In this context, of particular note is the sharp drop in native fish populations over the last 18 years, while exotic fish seems to have benefited, athough to a highly uncertain degree (Figure 47).

Mountain lake, Monsent del Pallars. **Photo: Xavier Florensa.**

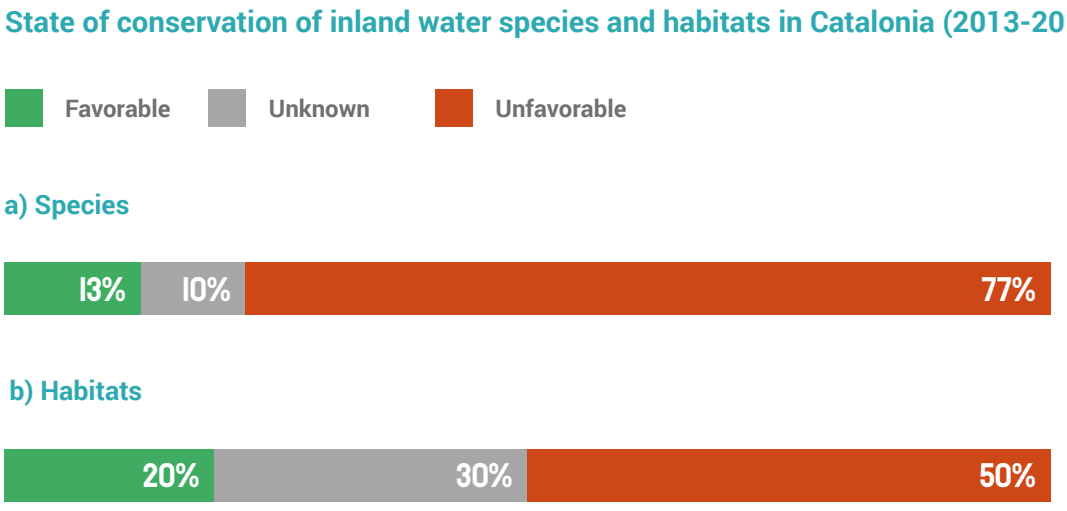


FIGURE 45. Conclusions on the state of conservation of 39 species (a) and 20 habitats (b) associated with inland water environments and included in European directives in Catalonia for the period 2013-2018. **Source: results from the reports on the application of the Habitats and Birds Directives in Catalonia 2013-2018 (DTES 2019).**

Habitats of community interest at greatest risk of disappearing

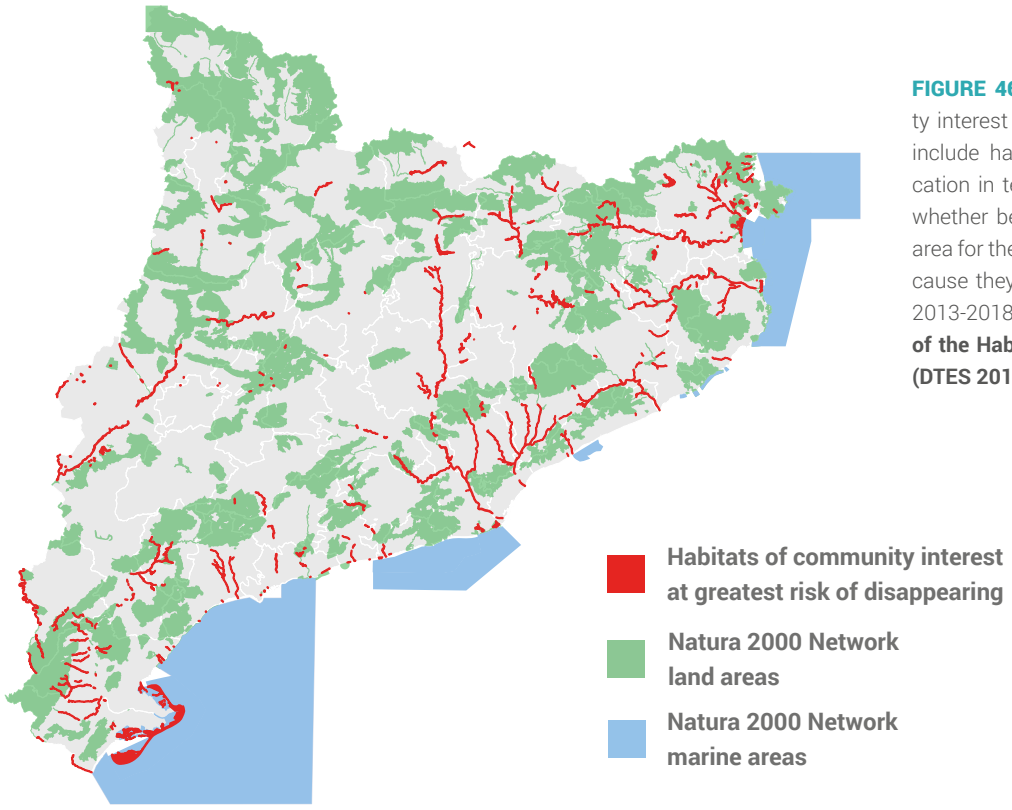


FIGURE 46. Distribution of habitats of community interest at greatest risk of disappearing. These include habitats with a unfavorable/bad classification in terms of their surface area in Catalonia, whether because they lack the minimum surface area for the long-term survival of the habitats or because they showed a negative trend in the period 2013-2018. **Source: Reports on the application of the Habitats Directive in Catalonia 2013-2018 (DTES 2019).**

Population trend in inland water fish

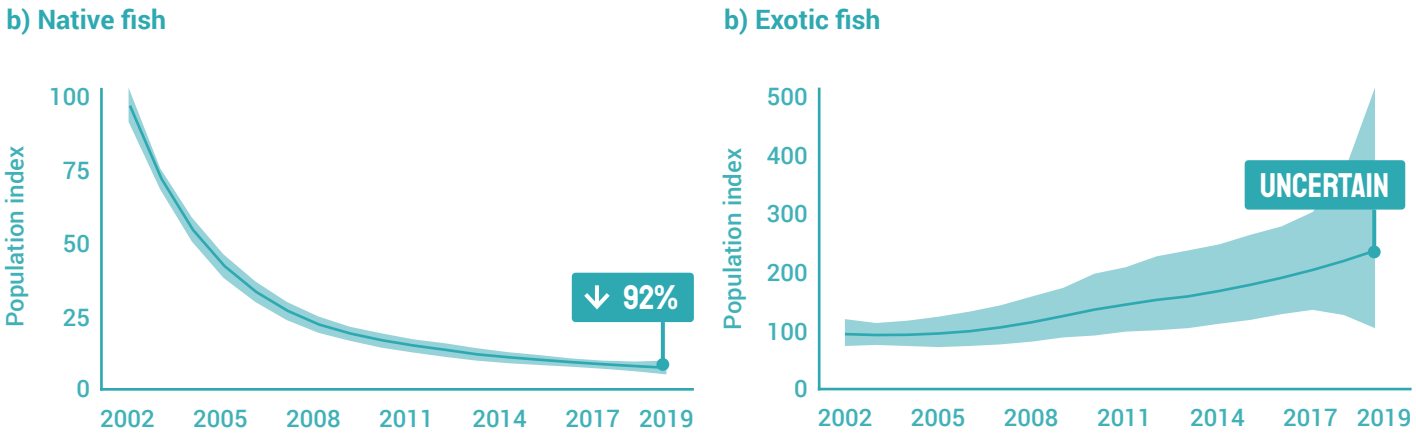


FIGURE 47. Average population trends in a) native and b) exotic fish in Catalonia from 2002-2019. The graph shows the average annual value and the 90% confidence interval. This graph is interpreted in the same way as the LPI graphs (see Boxes 1 and 2). **Source: the authors, based on data from the ACA and CHE.**

With regard to the state of the environment, the Catalan Sanitation Plan[1] has substantially improved the quality of water in rivers over the last 40 years (Figure 48) and there are currently 526 treatment plants in operation. Nevertheless, recent reports indicate that 43% of Catalan rivers (out of the 6,450 km of watercourses assessed) and 38% of wetlands and lakes (out of a total of 112 assessed) are in a bad chemical, ecological and hydromorphic state, thus the ecosystems in them are structured or functioning inadequately.[2] Only 45% of rivers and wetlands in the inland basins comply with the sustainability goals set by the Water Framework Directive.[3] This is because, as in most of the Mediterranean Basin, freshwater is a limited resource and subject to strong human pressure, which affects all aquatic ecosystems, causing changes to water quantity and quality, to the morphology of ecosystems and to the composition of the biological communities living in them.[4]

Chemical state of bodies of water in Catalonia

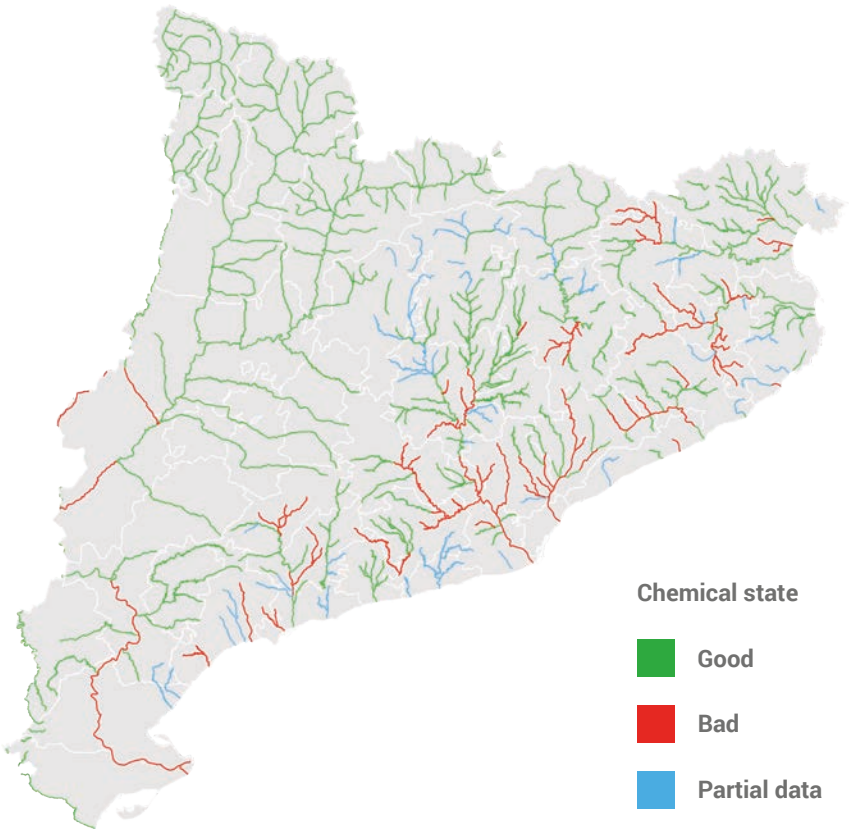


FIGURE 48. Map of the chemical state of bodies of water in Catalonia. The chemical state is diagnosed by compliance with a number of environmental quality standards for a list of priority and preferential substances established in Directive 2008/105/CE (hydrocarbons, pesticides, organic solvents, heavy metals, etc.). **Source: ACA (2019) and CHE (2017).**

1. aca.gencat.cat
2. ACA 2019; CHE 2017
3. ACA 2019
4. Bonada *et al*. 2019; Munné *et al*. 2019

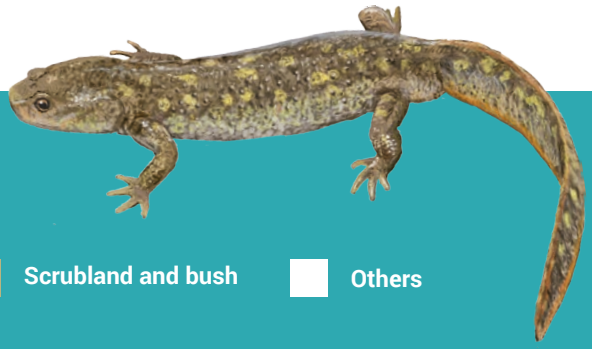
Riera de les Gorges, Osona. **Photo: Xavier Florensa.**

EXAMPLE 5

MONTSENY BROOK NEWT, A UNIQUE SPECIES IN THE WORLD

The Montseny brook newt (*Calotriton arnoldi*) is endemic to the Montseny massif and has a world population estimated at 1,500, living in just 3.5 km of little streams at the head of the Tordera river. This amphibian lives in cracks and holes in the rocks and is adapted to cold, voluminous waters flowing through riverbank woods of beech and holm oak. Thus, the species is highly sensitive to changes to the water and forest land lining the watercourses.[70]

The delicate situation of the species is caused by the fact that almost 75% of known populations live in private estates with large water catchments and practically 80% of habitats that border their streams are used for forestry (**Figure 49**). Water catchment dries out the streams and reduces the habitat available to the species while forest use reduces water quality. Loss of trees raises water temperatures, while replacing native mature forest with young forest or plantations increases forest evapotranspiration and causes alterations to the chemical composition of the water and erosion processes, filling the holes where the species lives with sediment.



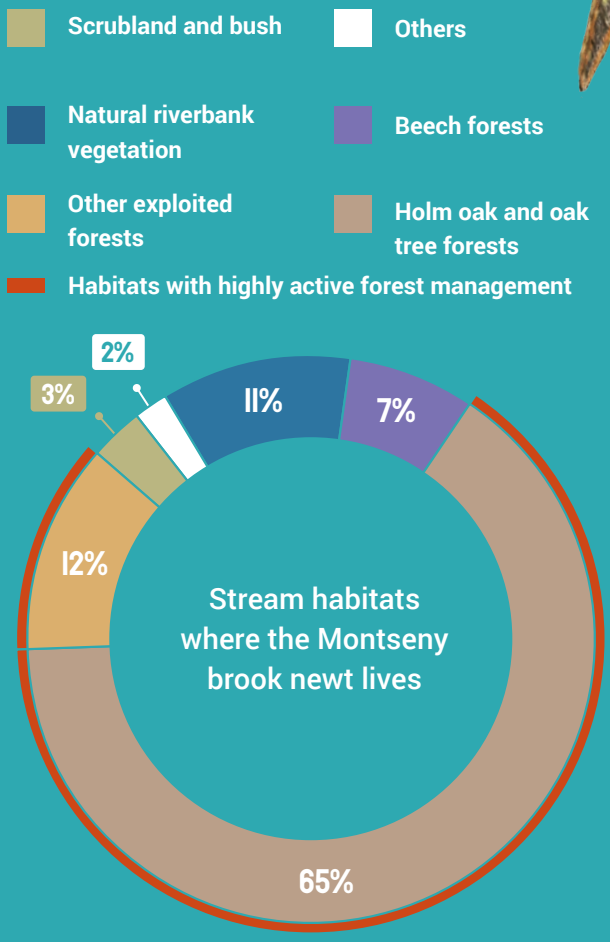
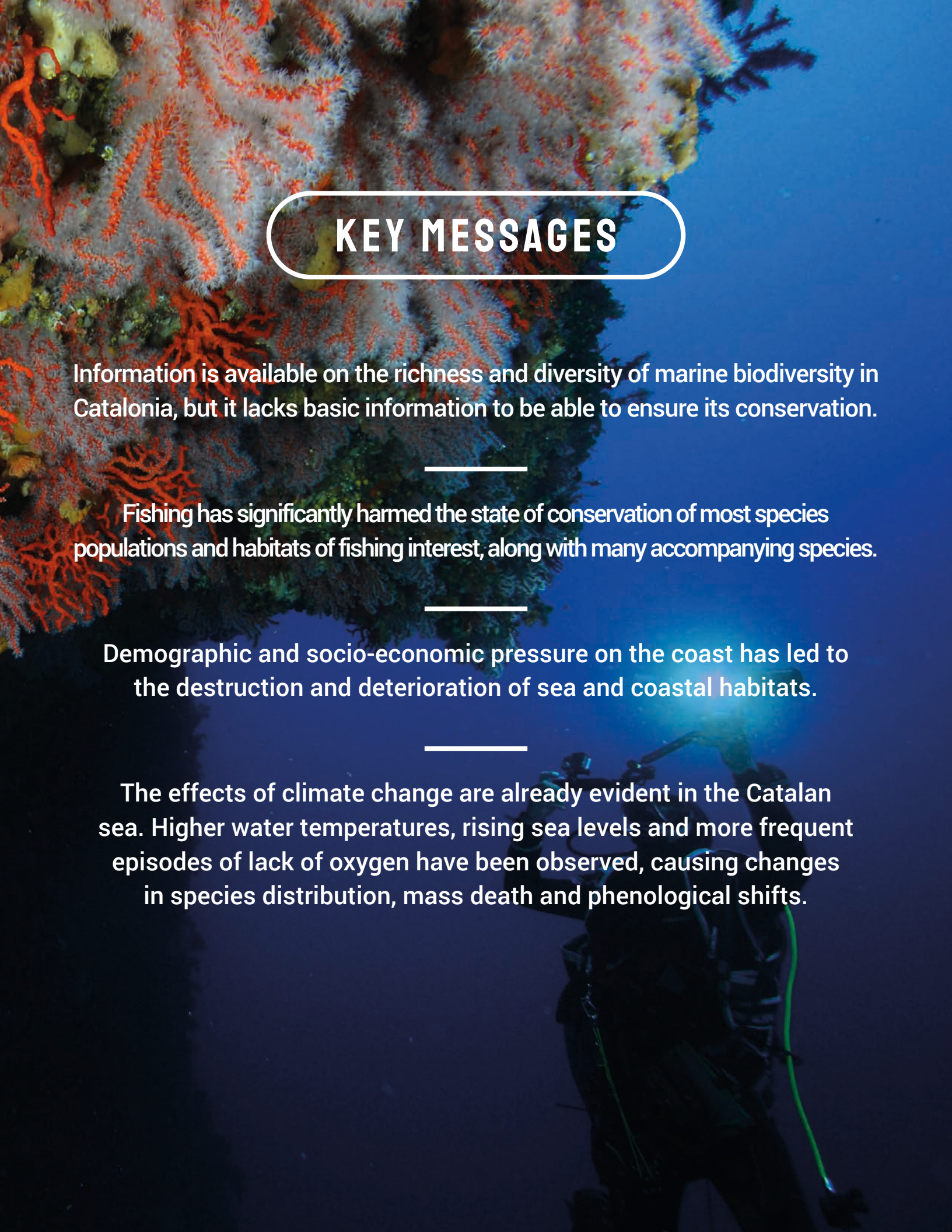


FIGURE 49. Composition of the stream habitats (as a percentage surface area) where the Montseny brook newt lives. Habitats favored by the species are streams bordered by natural riverbank vegetation and beech forest. Holm oaks forests are subject to highly active forest management, as are others, such as chestnut forests and soft-wood and hard-wood plantations. The calculation is based on a detailed map (1:2,500 scale) of habitats along a 50-m strip on either side of the streams (Pié 2017). **Source: El Montseny Natural Park, Barcelona Provincial Council and Girona Provincial Council.**

1. Ledesma *et al.* 2019

Montseny brook newt (*Calotriton arnoldi*) preying on a fire salamander larva (*Salamandra salamandra*). **Photo: Fèlix Amat.**

MARINE AND COASTAL ENVIRONMENT



KEY MESSAGES

Information is available on the richness and diversity of marine biodiversity in Catalonia, but it lacks basic information to be able to ensure its conservation.

Fishing has significantly harmed the state of conservation of most species populations and habitats of fishing interest, along with many accompanying species.

Demographic and socio-economic pressure on the coast has led to the destruction and deterioration of sea and coastal habitats.

The effects of climate change are already evident in the Catalan sea. Higher water temperatures, rising sea levels and more frequent episodes of lack of oxygen have been observed, causing changes in species distribution, mass death and phenological shifts.

This section focuses on marine biodiversity along approximately 580 km of Catalan coast, where there are a number of different environments: beaches, dunes, cliffs and marshes that stretch out to sea with rocky, shingly, sandy and muddy beds. Such a variety of environments means Catalan seas have a wide diversity of habitats and species.

A DIVERSE, INSUFFICIENTLY KNOWN SEA

The Mediterranean is home to a high level of marine biodiversity; although it represents less than 1% of the planet's sea surface, it contains 10% of all marine species, 30% of which are endemic.[1] Catalonia is in a region of the Mediterranean with high levels of biodiversity, in terms of both plants and animals.

The Catalan coast, with its geomorphic diversity and physico-chemical gradients, has a high diversity of marine habitats. According to the European Nature Information System (EUNIS),[2] there are 122 marine habitats, 38% of which are habitats of community interest and protected by the Habitats Directive (92/43/CEE). This diversity of habitats includes 94 marine species (among them, birds, cetaceans, turtles, sharks, seaweed and corals) protected by European, state and autonomous community legislation and a number of international conventions and treaties (Figure 50). The Catalan coast is also home to a wide range of plants endemic to this environment, including 27 threatened and protected species, and has habitats that are essential to the animals that nest in them, such as Audouin's gull (*Larus audouinii*), the Kentish plover (*Charadrius alexandrinus*) and the loggerhead sea turtle (*Caretta caretta*).

Recently hatched loggerhead sea turtle (*Caretta caretta*). **Photo: Aïda Tarragó.**

1. Bianchi and Morri 2000; Coll *et al.* 2010
2. Ballesteros 2019

Number of marine species in Catalonia protected by law or international conventions

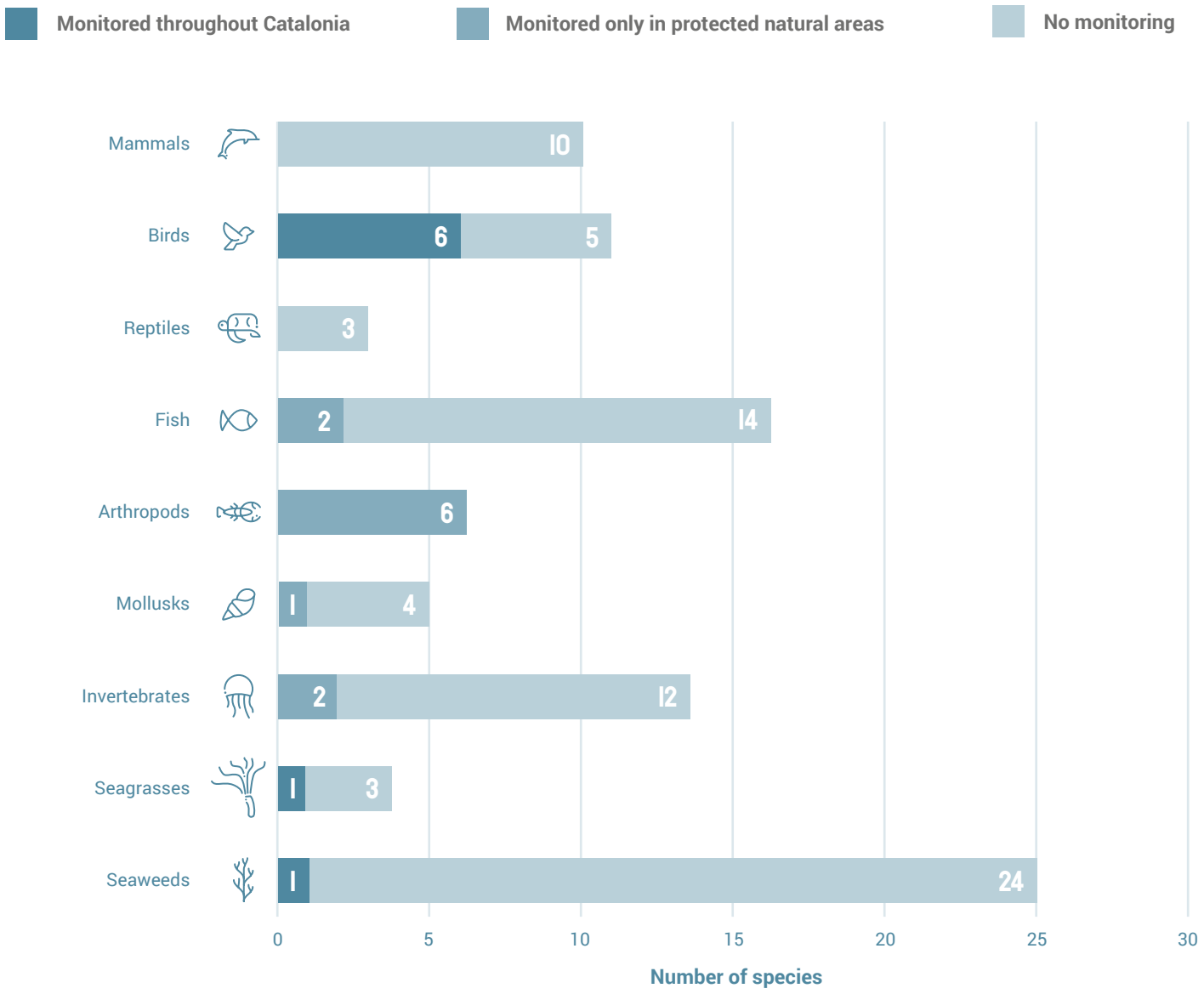
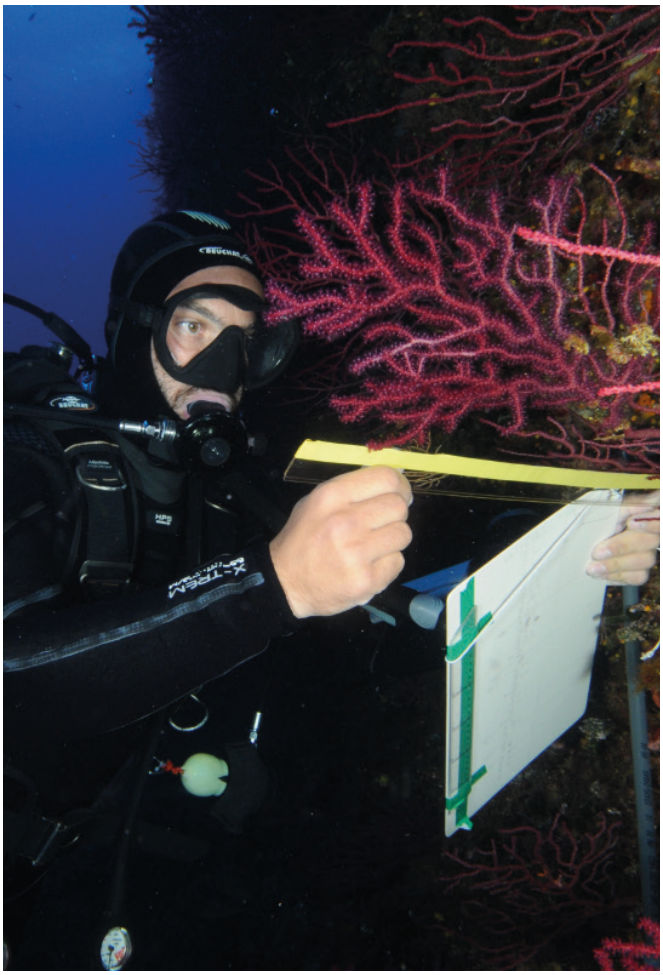


FIGURE 50. Number of marine species in Catalonia protected by law or international conventions. All those in international conventions ratified by Catalonia and those in the European Directive or state or Catalan law are counted. For each taxonomic group, the number of species monitored in some form throughout Catalonia or in protected natural areas and those that are not monitored is given. **Source: the authors, based on information from the Berne, Barcelona, Bonn, Ospar Conventions, CITES, the Habitats and Birds Directives, the national catalog of threatened species and the proposed Catalog of Protected Fauna of Catalonia presented for public exhibition on 29 March 2019.**

STATE OF BIODIVERSITY IN THE MARINE AND COASTAL ENVIRONMENT

Among the coastal and marine habitats of community interest, only 17% have a favorable state of conservation, the rest are considered unfavorable (65%) or unknown (17%) (Figure 51b). For the marine and coastal environment, Catalonia only has maps of coastal habitats, located from sea level to a depth of one meter. There is still no complete map for deeper habitats.

With regard to marine or coastal species protected by the Habitats Directive, 70% are in a state of unfavorable conservation while the state is unknown for the rest (Figure 51a). Indeed, there is no information available for most protected species on their precise distribution on the Catalan coast (Figure 50) and only 8% are subject to monitoring programs throughout Catalonia. This monitoring focuses on birds, certain types of seaweed, used to assess coastal water quality and seagrasses (e.g. *Posidonia oceanica*). Therefore, information currently available on marine species and habitats is insufficient to provide a general picture on their current situation and trends in Catalonia; and the species and habitats for which there is information mostly show unfavorable states of conservation (Figure 51).



Sampling violescent sea-whip (*Paramuricea clavata*)**. Photo: Joaquim Garrabou.**

State of conservation of species and habitats in coastal and marine systems in Catalonia (2013-2018)

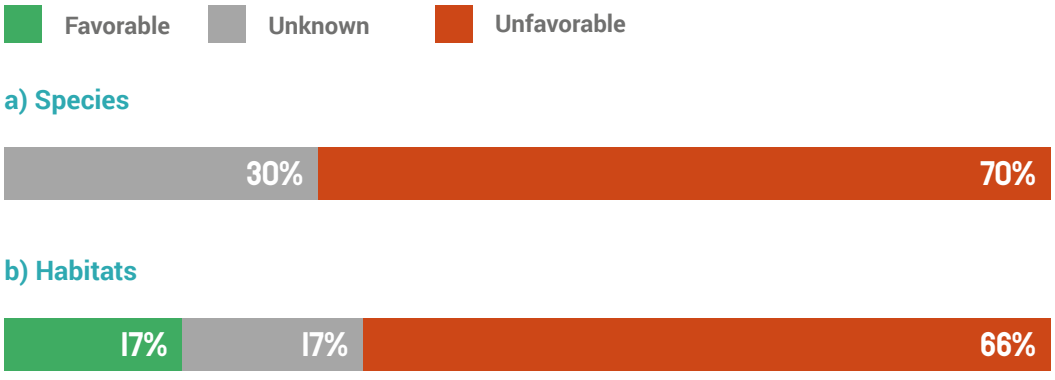


FIGURE 51. Conclusions on the state of conservation of 10 species (a) and 23 habitats (b) associated with coastal and marine systems and included in European directives in Catalonia for the period 2013-2018. **Source: results from the reports on the application of the Habitats and Birds Directives in Catalonia 2013-2018 (DTES 2019).**

FISHING, A MAJOR IMPACT

Worldwide, fishing activity is considered one of the main threats to the conservation of marine biodiversity.[1] In 2015, it was estimated that 33.1% of fish populations around the world showed clear signs of overfishing and that in the Mediterranean and Black Seas, most of the populations of other species of commercial interest, such as shrimp and cephalopods, were over-exploited.[2] Furthermore, fishing also has indirect impacts on accidentally caught, or bycaught, species (Example 6); in the case of trawling, a non-selective form of fishing, 33% of the fish biomass caught on the Catalan coast is thrown back.[3]

These impacts especially affect species with long lifespans, as their vital characteristics (slow growth rates, low fertility) makes them highly vulnerable to fishing (Example 7). This is the case of certain cartilaginous fish: in Catalonia 65% of sharks and 42% of rays are considered in danger of extinction,[4] while overall 18% of these species are threatened.[5]

When fishing methods reach the seabed, especially trawling and other lesser used methods, they cause the destruction of marine habitats[6] and a significant loss of the biodiversity associated with them. Morphological comparison of the seabed in fishing grounds with largely unfished areas shows the degree of transformation associated with trawling, where beds become uniform and lose morphological complexity.[7]

The blue shark (*Prionace glauca*) has been affected by trawling. **Photo: Gonzalo Jara.**

1. Pauly *et al*. 1998; Lotze *et al*. 2006; McCauley *et al*. 2015
2. FAO 2018; Fernandes *et al*. 2017
3. Sánchez *et al*. 2004; Tsagarakis *et al*. 2014
4. Bianchi and Morri 2019; Coll *et al*. 2013
5. IUCN 2020
6. Estes *et al*. 2011; Worm *et al*. 2011; Puig *et al*. 2012; Garrabou *et al*. 2017
7. Puig *et al*. 2012

EXAMPLE 6

BYCATCH OF MARINE SPECIES

Accidental catch (known technically as *by-catch*) is one of the main threats facing a number of marine species (birds, cetaceans, turtles, sharks, etc.). Its impact varies greatly with species, fishing method, time of year, type of bait, type of target fish and time of day of fishing. With regard to sea birds, although there is currently no monitoring program in place, the data indicate a clear impact on certain species, the most severely affected being the Balearic shearwater (*Puffinus mauretanicus*), the yelkouan shearwater (*P. yelkouan*) and Scopoli's shearwater (*Calonectris diomedea*). Other seriously affected species include the common shag (*Phalacrocorax aristotelis*) and Audouin's gull (*Larus audouinii*) (**Figure 52**).[1]

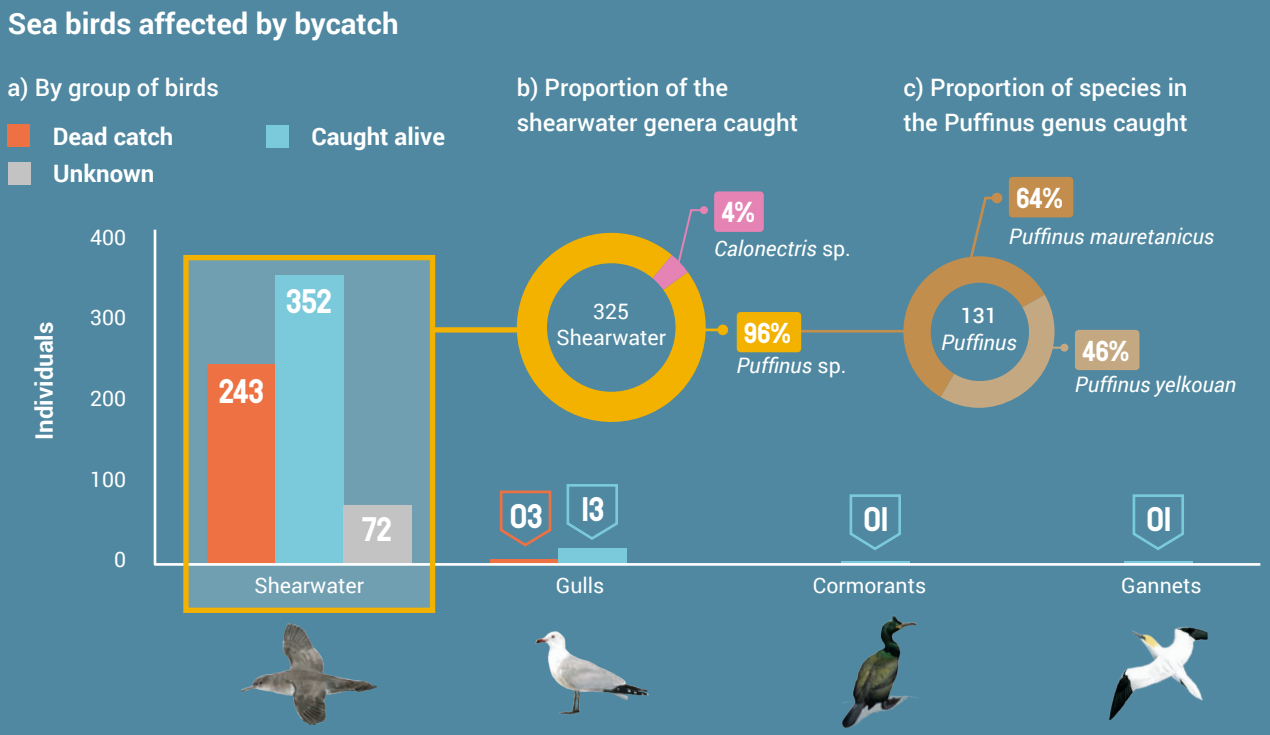
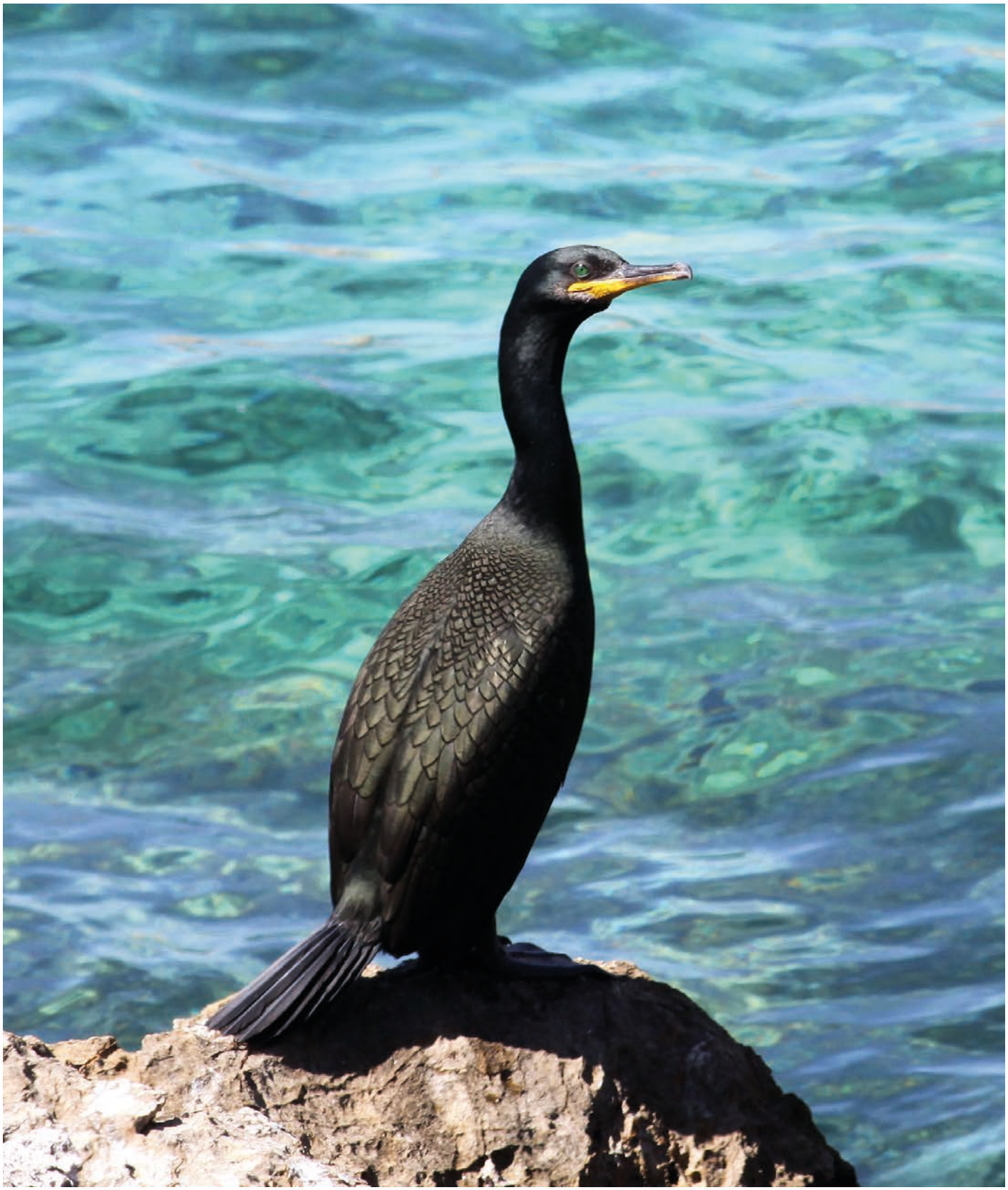


FIGURE 52. Sea birds affected by bycatch in the 13 boats that participated in the pilot study between the end of April and start of July, 2017. The diagram shows the numbers caught in four groups of birds (a). It shows whether the birds were caught dead or alive, when known. Shearwaters are counted jointly in the bar graph, as the specific species of the dead birds could not be identified. The data is separated in the bar graph, depending on the fate of each bird: death, life or unknown. Also shown are relative catch frequencies for both shearwater genera (*Puffinus* and *Calonectris*) (b) and the relative occurrence of both Puffinus species (*P. mauretanicus* and *P. yelkouan*) (c). **Source: Modificat de Tarzia *et al*. 2017.**

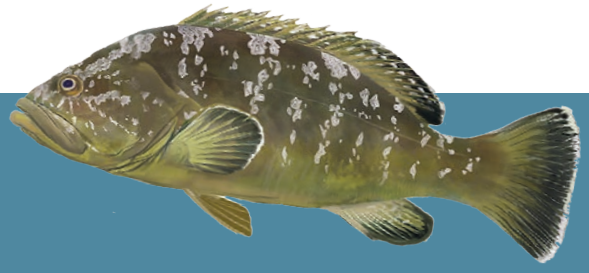
1. Tarzia *et al.* 2017; García-Barcelona *et al.* 2010



European Shag (*Phalacrocorax aristotelis*). **Photo: Giannis Markianos - HOS BirdLife Greece.**

EXAMPLE 7:

THE EFFECT OF FISHING ON FISH IN THE MEDES ISLANDS



The Montgrí, Medes Islands i El Baix Ter Natural Park has protection figures going back to 1983 which are used to regulate different forms of fishing (among other activities). Monitoring work conducted since 1992 shows the impact of fishing on fish species highly vulnerable to the activity, such as the dusky grouper (*Epinephelus marginatus*), the common dentex (*Dentex dentex*), the zebra sea bream (*Diplodus cervinus*), the European bass (*Dicentrarchus labrax*), the gilt-head bream (*Sparus aurata*) and the brown meagre (*Scieaena umbra*).

For some years, in the Les Medes Marine Partial Nature Reserve, where fishing is completely forbidden, numbers of these fishes have been much higher than in other protected areas where some form of fishing is permitted (**Figure 53**).

The effect of protection is especially evident with more sedentary species, such as the dusky grouper and brown meagre, which are rarely observed outside the Medes Islands environment. Some vulnerable, but more mobile species, such as the common dentex, guilt-head bream and zebra sea bream, also show a clear response to protection measures, to the extent that they are sporadically found on the Montgrí coast[1].

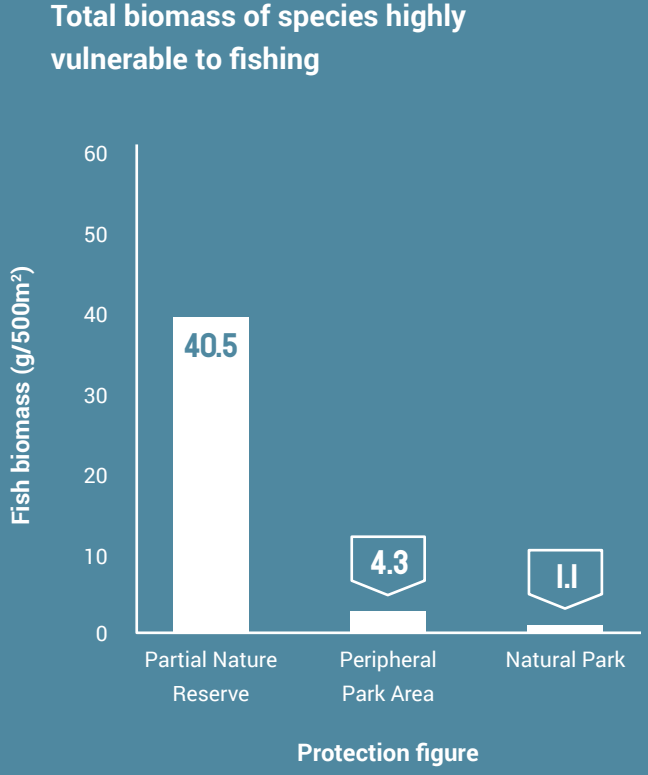


FIGURE 53. Total biomass of species highly vulnerable to fishing by degree of protection in the Montgrí, Medes Islands i El Baix Ter Natural Park in 2018. Fishing is prohibited in the Partial Nature Reserve; limited recreational rod and traditional fishing is permitted in the Peripheral Protection Area and fishing, excluding trawling, is permitted in the Natural Park. **Source: Monitoring of the marine environment in the Montgrí, Medes Islands i El Baix Ter Natural Park - UB (Aspillaga *et al*. 2018).**

1. Aspillaga *et al*. 2018

Dusky grouper *(Epinephelus marginatus).* **Photo: Eneko Aspigalla.**

COASTAL OVERCROWDING

From 2001, the population of Catalonia grew from 6.3 million inhabitants to over 7.7 million in 2020.[1] This growth is mostly concentrated on the coast, where 43% of the Catalan population currently live (Figure 54). Furthermore, demographic pressure on the coast increases in summer, due to Catalan tourism models based on season and high concentrations of people in coastal areas (Figure 55).[2]

The resulting urban development on the coast is more than obvious (Figure 8) and currently 26.8% of the land surface is urbanized in the first 2 km from the coast (49.9% in the Barcelona metropolitan area).[3] This process has also occupied the sea itself, with the construction of 47 ports[4] which, together with docks and breakwaters, alter coastal sediment dynamics,[2] so that sediment naturally settling on beaches is insufficient to counter erosion. Furthermore, maintaining the ports and palliating erosion involves adding and extracting sand along 60% of the Catalan coastline,[5] altering both the habitats from which sand is taken and where it is deposited.

Demographic pressure also affects the

Municipal population in Catalonia in 2019

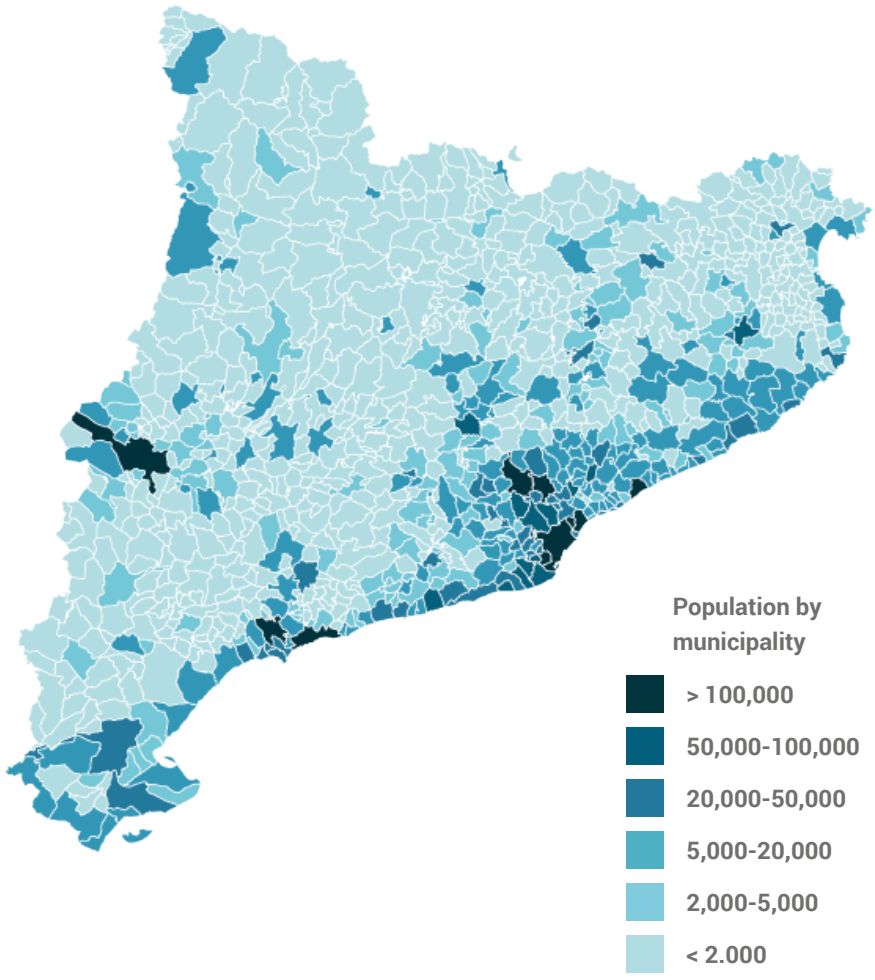


FIGURE 54. Municipal population in Catalonia in 2019. **Source: the authors, based on IDESCAT 2020c.**

1. IDESCAT 2020a
2. Pintó *et al* .2018
3. Nel·lo and Checa 2019
4. DTES 2019b
5. ACA 2019

quality of coastal waters, into which 60% of treated urban wastewater from the Catalan inland river basins is discharged[1], while 27% of the coastal water bodies are in an inadequate biological or ecological state, especially on the Barcelona and Tarragona coast.[1] Finally, marine ecosystems also receive land waste; for instance, in 2019, the 214 fishing boats participating in the MARVIVA project collected 58 tons of rubbish from the sea on the Catalan coast.[2]

These demographic and socio-economic dynamics also have consequences for coastal and marine habitats, either causing their direct destruction or profound transformation.[3] For instance, the presence of pollutants in the water affects the composition of coastal seaweed communities, where more sensitive seaweed is replaced by other species more tolerant to pollutants.[4] Pollutants also cause temporary episodes of mass growth of harmful or toxic microscopic algae, which change the color of the water. However, the lack of maps and comprehensive monitoring programs impede quantification of the scope of the impacts.

Number of tourist places by region in 2019

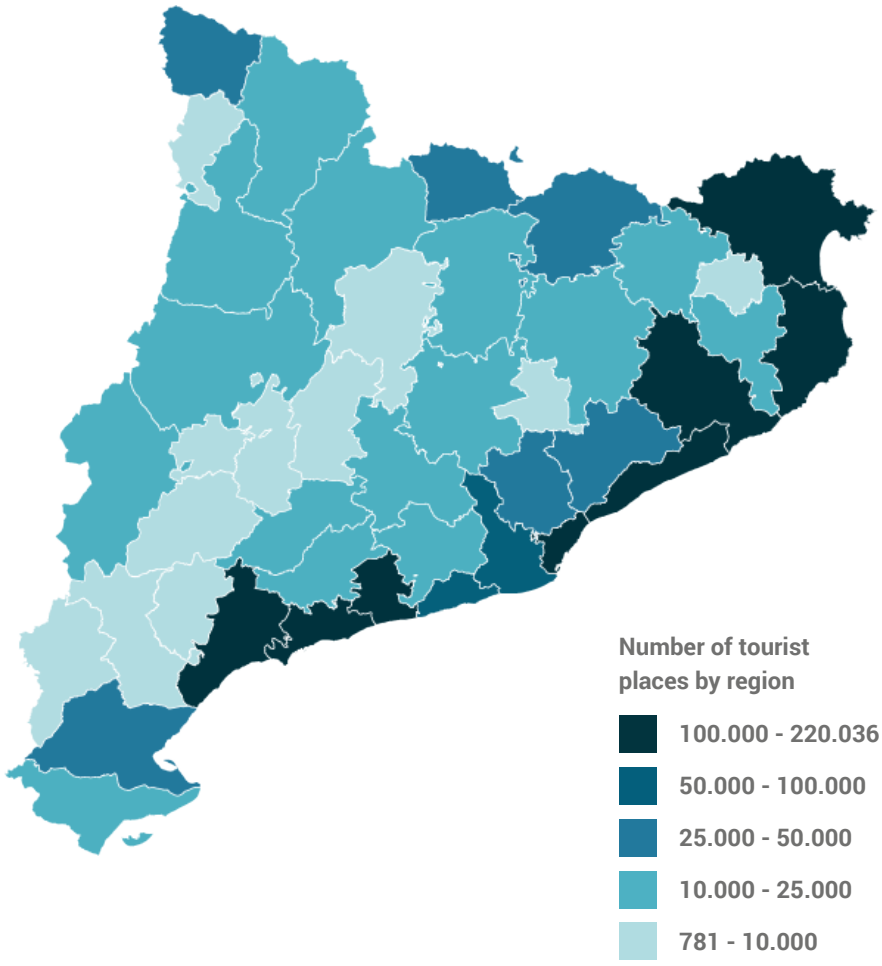
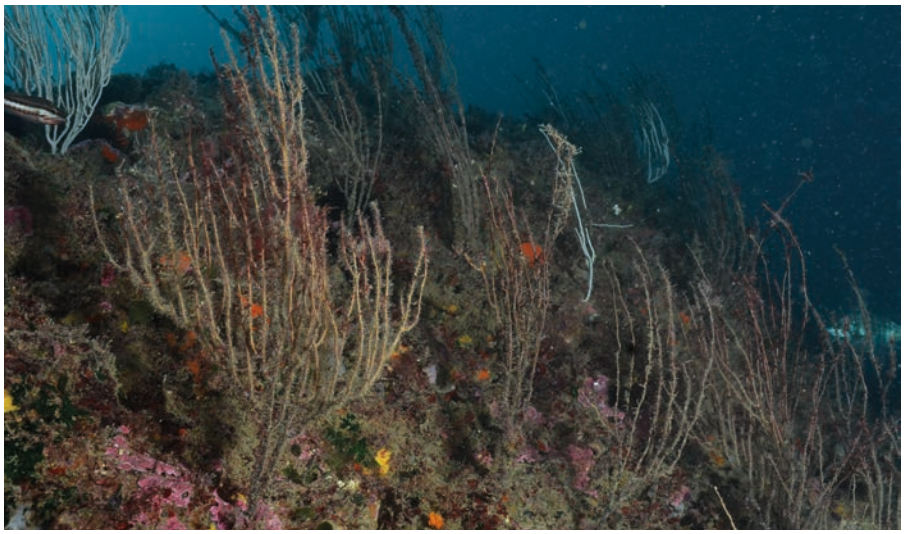


FIGURE 55. Number of tourist places by region in 2019. This includes numbers for tourist establishments (hotels, camp sites and rural tourism) and second homes (considering an average occupation of 3 people per home). **Source: the authors, based on data on tourist places (IDESCAT 2020d) and second homes (IDESCAT 2020e).**

1. ACA 2019
2. GenCat 2020
3. Ballesteros *et al*. 2007; Micheli *et al*. 2013; García-Lozano and Pintó 2018; Pintó *et al*. 2018
4. Arévalo *et al*. 2007

THE IMPACT OF CLIMATE CHANGE IS ALREADY EVIDENT ON THE CATALAN COAST

The impact of climate change on marine biodiversity on the Catalan coast is already evident. There has been a significant rise in water temperatures from the surface to depths of 80 meters[1] (Figure 56). In the western Mediterranean, the Catalan coast has even higher temperature rates (50% more at some depths). There has also been a rise in marine heatwaves (periods of extreme sea temperatures that last five or more days and can stretch for thousands of kilometers).[2]



Mass deaths of white gorgonian (*Eunicella singularis*), a species that is highly sensitive to rises in temperature. **Photo: Joaquim Garrabou**

The average annual sea temperature at different depths in L'Estartit

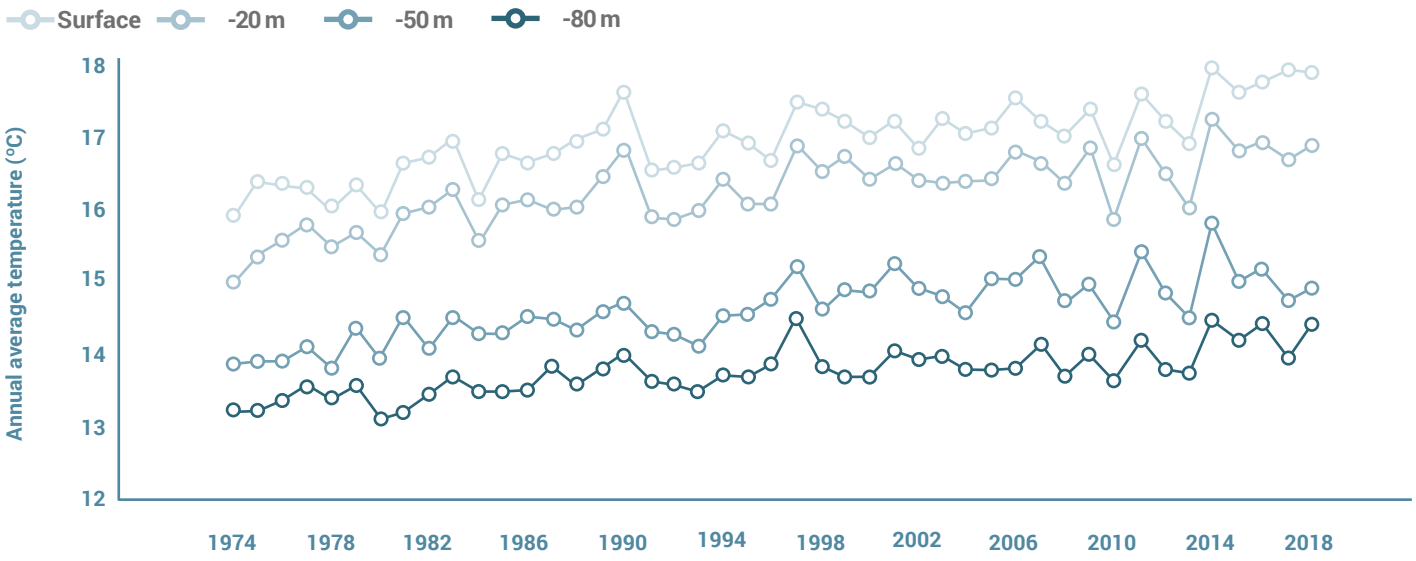


FIGURE 56. Changes in sea temperature in L'Estartit at different depths from 1974 to 2018. The average sea temperature has increased significantly at depths from 0 to 80 meters since 1974. **Source: Meteorological Service of Catalonia (SMC 2020b).**

1. Salat *et al.* 2019
2. Bensoussan *et al.* 2019

Rising water temperatures and marine heatwaves are associated with a variety of impacts on marine species and habitats, such as changes in the geographic distribution of both native and exotic species, over-abundance of species (jellyfish, filamentous algae), episodes of mass death (Figure 57 and Example 8) and phenological shifts in species.[1]

In addition, rising sea levels (Figure 58), together with the increase in frequency and intensity of storms (such as storm Gloria) are contributing significantly to the erosion of beaches.[2]

Impact of mass mortality events on the Catalan coast (2003-2015)

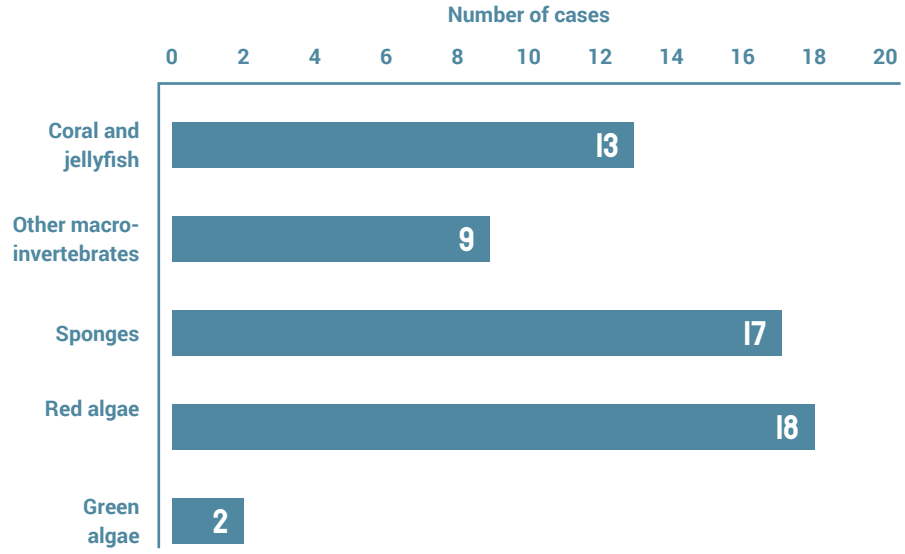


FIGURE 57. Number of mass death events studied on the Catalan coast from 2003 to 2015 by taxonomic group. **Source: the authors, based on data from the platform for tracking climate change in the Mediterranean (T-MEDNet) (Garrabou *et al*. 2019).**

Change in average monthly sea levels (1990-2015)

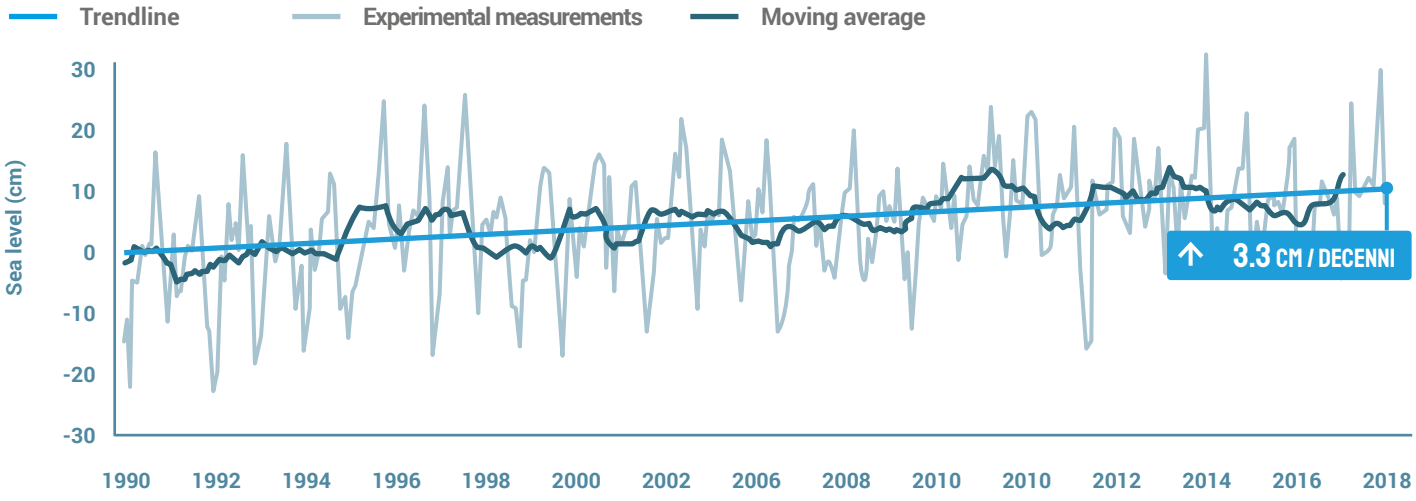


FIGURE 58. Change in average monthly sea levels in L'Estartit from 1999 to 2018. The dotted line shows the trendline, the lighter line indicates experimental measurements and the dark blue line is the moving average, a statistical calculation that smooths out short-term fluctuations to show long-term trends more clearly. **Source: Meteorological Service of Catalonia (SMC 2020b).**

1. Azzurro *et al*. 2019; Calvo *et al*. 2011; Garrabou *et al*. 2009; Ruiz *et al*. 2018
2. ICM 2020

EXAMPLE 8:

MASS MORTALITY OF MUSSELS IN THE EBRO DELTA

In the bays of the Ebro delta, episodes or marine fauna mortality occur during heatwaves in some summers. The bays are used for fish farming, where the Mediterranean mussel (*Mytilus galloprovincialis*) is the main species farmed. Although it is a Mediterranean species, water temperatures in shallow coastal areas on the Mediterranean are very close to the limit for its survival,[1] and in these bays, temperatures over 28 °C for more than one week have been observed to product mass death of mussels followed by a drop in oxygen concentration.[2] These episodes also occur in other parts of the Mediterranean, such as the Thau lagoon, in the south of France.[3]

The frequency of these events is increasing.[4] Records from the program for monitoring water quality in mollusk areas show that from 1990-1999, the water temperature exceeded 28 °C for 37 days in the Alfacs bay and 8 days in the Fangar bay. In the last 10 years (2010-2019), there were 54 days in the Alfacs bay and 34 in the Fangar bay. The drop in oxygen concentration starts when the water temperature exceeds 28 °C (**Figure 60**). This has forced modifications to some fish-farming management practices to prevent mass deaths of mussels in the summer months, but the rise in temperatures is expected to make conditions even more difficult for this species in the future.

Maximum temperature and minimum concentration of oxygen in the Alfacs Bay

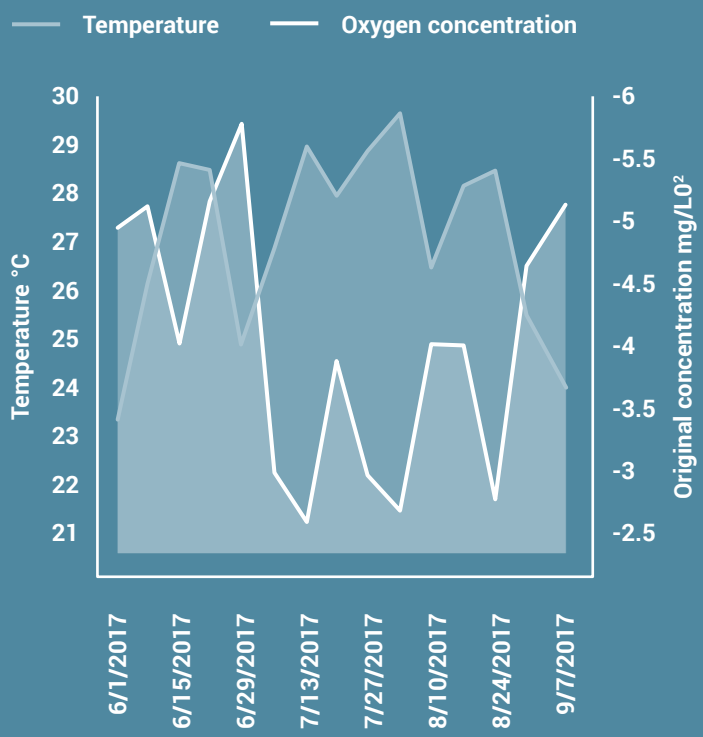


FIGURE 60: Maximum temperature and minimum oxygen concentration measured in the Alfacs Bay during the summer of 2017. **Source: Monitoring program on the quality of water, mollusks and toxic phytoplankton in seafood production zones on the Catalan coast (PSQAM) and the Directorate-General of Fishing and Maritime Affairs (DGPAM), executed by IRTA.**

1. Anestis *et al.* 2007
2. Ramón *et al.* 2007
3. Harzallaha and Chapelle 2002
4. Fernández-Tejedor *et al.* 2010

Mussel farm in the Alfacs Bay. **Photo: Margarita Fernández.**

A

ACA (2008a) *L'aigua a Catalunya: diagnosi i propostes d'actuació.* Agència Catalana de l'Aigua, Departament de Medi Ambient i Habitatge, Generalitat de Catalunya.

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ACA (2011) *Avaluació de l'estat i el risc d'invasió per espècies exòtiques dels ecosistemes aquàtics de Catalunya.* Agència Catalana de l'Aigua, Departament de Territori i Sostenibilitat, Generalitat de Catalunya.

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