cE3c
Centre for Ecology, Evolution and Environmental Changes

STRATEGIC PLAN 2018-2022

Towards a sustainable future

cE3c
centre for ecology, evolution and environmental changes

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Cover photo: cE3c Annual Meeting "Frontiers in E3" at Faculty of Sciences of the University of Lisbon. July 2018. PHOTO: Rúben Oliveira

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Message from the coordinator

Cristina Máguas. PHOTO: Rúben Oliveira

Welcome to the Centre for Ecology, Evolution and Environmental Changes (cE3c) of the University of Lisbon!

2015 was the starting point of a unique research centre focused on Ecology, Evolution and Environmental sciences (the 3Es of cE3c). Since then, cE3c has engaged in leading biological research, with particular focus on conservation and sustainability sciences.

cE3c is now a larger R&D unit, resulting from merging the Centre for Environmental Biology with the Azores Biodiversity Group and the Climate Change Impacts, Adaptation and Modelling group.

As coordinator of cE3c since 2018, I envision our Research Centre as a crucial player in a vital national strategy that consolidates outstanding research and invests in emerging research fields: cE3c will contribute knowledge to address present and future societal challenges, incorporating science into technical solutions and policies. For 2018-2022, we will ensure the continuity and consolidation of cE3c as a research centre of excellence on ecology, biodiversity, evolution, global changes, climate change, and ecosystem conservation, as well as a relevant contributor to the science-society interface. This consolidation phase requires a budget that increases funds allocation to human resources ensuring optimization of previous investments in equipment and infrastructures, as well as contributing to intensify cE3c's international networking. While we are a large unit, with several labs and facilities at different locations, I am committed to reinforce the centre's cohesion and an open, supportive environment for researchers and students. Indeed, the strong research training and diverse community outreach activities which have long been trademarks of cE3c, will continue unabated.

I am privileged to coordinate a research centre of such diversity and enthusiastic researchers, engaged in national and international scientific projects and networks, committed to a sustainable future and a better-informed society.

All together we will be able to build a bright and promising future!

Cristina Máguas

Timon lepidus.
PHOTO:
Telma Laurentino

I. Vision and strategy

I.I. cE3c VISION AND MISSION

cE3c is committed to a sustainable future. Our mission is to produce fundamental and applied science in Ecology, Evolution and Environmental Changes that integrates life and climate sciences.

Our research examines and integrates all levels of biological organization, from organisms up to ecosystems, both natural and anthropogenic. We will carry on our pursuit of tools to assess and monitor impacts of global change on biodiversity, health and well-being. Our combined expertise and unique databases constitute fundamental repositories of knowledge for Portugal, the Macaronesian Islands, other Portuguese-speaking countries in Africa and South America, and the European Union.

cE3c's mission recognizes that while producing knowledge is a crucial step to sustainable development, using this knowledge to effectively promote change is just as important. Our R&D will contribute to UN's Sustainable Development Goals. Thus, we will endure our praxis to combine research with education, outreach and knowledge transfer to the public and private stakeholders.

Pico island: high altitude semi-natural pastures with endemic trees and shrubs. Azores. PHOTO: Paulo Borges

1.2. cE3c STRATEGY

To contribute knowledge and action aimed at future sustainability, cE3c will intensify internationally recognized applied and fundamental science organized around six core thematic lines (see section 3): TL1 - Integrative ecological assessment of environmental change impacts on biodiversity; TL2 - Evolutionary processes that shape biodiversity and adaptation to environmental changes; TL3 - Sustainable management strategies for high-nature-value farmlands; TL4 - Green and blue infrastructures for urban sustainability; TL5 - Human health: linking evolutionary history, environment and physiology; and TL6 - Climate services.

Knowledge and expertise have been, and will continue to be during the next five years, leveraged by successfully integrating expertise between cE3c's 13 research groups, which published 106 inter-group collaborative papers between 2015 and 2018. Broadening international scientific collaborations is also a priority, expanding from our 41 recent and/or ongoing European projects and networks.

cE3c's contribution to future sustainability also involves transforming knowledge into action by offering advanced training, engaging in outreach, promoting knowledge co-production and transfer to stakeholders, innovation, and policy advice. cE3c will continue to: support the generation of independent and motivated scientists; address crucial points raised by International and European Agendas and Institutions (such as the UN's Convention on Biological Diversity, UN's 17 Sustainable Development Goals, and the International Union for Conservation of Nature); support and inform governmental agencies at regional and international levels; and contribute to industry and ecosystem services optimization (e.g. microbial driven processes for agriculture and greenhouse gas reduction).

We will continue to communicate science to non-specialist audiences, contributing to citizen-science programmes, exhibitions, and other broad-audience outreach activities.

Pico Gaspar in Terceira island: a Strombolian Vulcan with native forest in its caldera. PHOTO: Paulo Borges

PEOPLE AT cE3c

208 - Integrated researchers

13 - Research groups

124 - PhD researchers

84 - PhD students

30 - Technicians and research assistants

Contrarily to major trends, cE3c has a gender-ratio biased towards females: 0.6 for Integrated members; and 0.54 among PhD students.
Note: "Integrated researchers" are PhD holders and PhD students

Fieldwork at Sierra Nevada: Telma Laurentino takes a break and enjoys the view. PHOTO: Eduardo Marabuto

2. The Past
Achievements & internationalization

2.1. MAJOR ACHIEVEMENTS

DEVELOPMENT OF UNIVERSAL ECOLOGICAL INDICATORS

A global change trait-indicator framework based on lichens and biocrusts was designed to overcome the geographical constraints of classic species-based approaches.

Ecological indicators: the lichen *Pseudocyphellaria aurata* is an indicator of ecological continuity. Natural Park of Serras de Aires e Candeeiros. PHOTO: César Garcia

Biodiversity sampling methods were compared at global scale and universalised. A space-for-time substitution allowed us to measure the effects of climate change on biodiversity metrics, which was validated over time at selected locations.

The best biodiversity metrics were modelled using climate variables and remote sensing information to allow pattern upscaling to similar areas of the world.

RESEARCH LANDMARKS AND IMPACTS

Scientific contributions

Lichen traits responding to aridity
Matos *et al.*, 2015. *Journal of Ecology* 103: 451–458.

Seasonal patterns of Mediterranean evergreen woodlands (Montado) are explained by long-term precipitation
Ramos et al., 2015. *Agricultural and Forest Meteorology* 202: 44–50.

Grazing or not grazing: implications for ecosystem services provided by biocrusts in Mediterranean cork oak woodlands
Concostrina-Zubini *et al.*, 2017. *Land Degradation & Development* 28: 1345-1353.

Tracking global change using lichen diversity: towards a global-scale ecological indicator
Matos *et al.*, 2017. *Methods In Ecology and Evolution* 8: 788-798.

Which plant traits respond to aridity? A critical step to assess functional diversity in Mediterranean drylands
Nunes *et al.*, 2017. *Agricultural and Forest Meteorology* 239: 176-184.

Policy advising

- Global Change indicator presented at 12th UN Forest Forum, 2017;
- Definition of NH3 and N critical levels and loads in EU;
- Mapping of Ecosystem Services in EU;
- Chairman of the National Council for the Environment and Sustainable Development (CNADS) since 2017.
- National Climate Change Strategy for Biodiversity.

CRUCIAL KNOWLEDGE TO HALT BIOLOGICAL INVASIONS

We have contributed significantly to the field of Invasive Alien Species (IAS), providing knowledge of significant IAS impacts in Mediterranean and tropical ecosystems. cE3c was involved in international networks, led Group 1 of the ALIEN Challenge COST Action and participated in the FP7 INSPECTED.NET project.

Invasive species: Caldeira Funda, at Flores Island, is currently one of the most disturbed areas in the island due to invasive plant species *Hedychium gardneranum* and *Hydrangea macrophylla*. PHOTO: Paulo Borges

Studies about factors underlying the spread and establishment of IAS were undertaken: impact of Acacia species at an early invasion stage in association with its strategic use of nutrients (where trading nitrogen for phosphate may be a major component); islands vs mainland habitats resilience to invasion by harlequin ladybugs, the world most invasive insect; effects of emerging invasive pathogens on amphibians; and a rapid adaptation of native amphibians to an invasive predator, documenting the fastest known evolution in a tetrapod.

RESEARCH LANDMARKS AND IMPACTS

Scientific contributions

Rapid evolution of constitutive and inducible defenses against an invasive predator
Nunes *et al.*, 2014, *Ecology* 95: 1520-1530.

Warm vegetarians? Heat waves and diet shifts in tadpoles
Carreira *et al.*, 2016. *Ecology* 97: 2964-2974.

Natural regeneration of Pinus pinaster and Eucalyptus globulus from plantation into adjacent natural habitats
Fernandes *et al.*, 2016. *Forest Ecology and Management* 378: 91–102.

Impacts of climate change on the global invasion potential of the African clawed frog Xenopus laevis
Ihlow *et al.*, 2016. *PLOS One* 11: e0154869.

Impact of asynchronous emergence of two lethal pathogens on amphibian assemblages
Rosa *et al.*, 2017, *Scientific Reports* 7: 43260.

How to outgrow your native neighbour? Belowground changes under native shrubs at an early stage of invasion
Ulm *et al.*, 2017. *Land Degradation & Development* 28: 2380-2388.

Societal impacts

Support of eradication programmes in partnerships with the Portuguese Institute for Nature Conservation and Forests and the Azores Ministry of Environment.

Establishment of a partnership with Sousa Prado & Filhos: production of acacia green waste compost to ameliorate sandy soils.

SETTING AGENDAS IN ISLAND BIODIVERSITY CONSERVATION AND RESEARCH

Native species: the canopy native spider *Macaroeris cata*, is common in Azorean native forests. PHOTO: Paulo Borges

Using the most comprehensive standardized arthropod abundance database for an archipelago, novel theoretical research was produced in functional ecology, species abundance distributions and biogeography. This database enabled the creation and coordination of the Mid-Atlantic Island Invertebrate Specialist Group of the International Union for Conservation of Nature.

Our integrative research inspired a horizon-scanning approach that identified 50 fundamental questions for the development of Island Biology. New estimators of functional and phylogenetic diversity were created, and new hypotheses proposed for the role of native and exotic species on island functional diversity. Macroecological studies highlighted the importance of standardized sampling at plot level across islands to understand the role of scale in species distribution and abundance in island ecological communities.

RESEARCH LANDMARKS AND IMPACTS

Scientific contributions

A new frontier in biodiversity inventory: a proposal for estimators of phylogenetic and functional diversity

Cardoso *et al.*, 2014. *Methods in Ecology and Evolution* 5: 452–461.

Functional biogeography of oceanic islands and the scaling of functional diversity in the Azores

Whittaker *et al.*, 2014. *Proceedings of the National Academy of Sciences of the United States of America* 111: 13709–13714.

Dispersal ability determines the scaling properties of species abundance distributions: a case study using arthropods from the Azores

Borda-de-Água *et al.*, 2017. *Scientific Reports* 7, 3899.

Oceanic island biogeography through the lens of the General Dynamic Model: assessment and prospect

Borregaard *et al.*, 2017. *Biological Reviews* 92: 830–853.

A roadmap for island biology: 50 fundamental questions after 50 years of The Theory of Island Biogeography

Patiño *et al.*, 2017. *Journal of Biogeography* 44: 963–983.

A Global Island Monitoring Scheme (GIMS) for the long-term coordinated survey and monitoring of forest biota across islands.

Borges *et al.*, 2018. *Biodiversity and Conservation* 27: 2567–2586.

Societal and policy advise impacts

Multi-level evaluation of species extinction risk, contributing with assessments to the International Union for Conservation of Nature, IUCN Red List of Threatened Species.

Development of biodiversity monitoring programmes for lesser-known taxa, and information transference to conservation managers.

EVOLUTION IN FACE OF ENVIRONMENTAL CHANGES

cE3c's recognition in Evolutionary Biology is based on the proposal and testing of hypotheses using experimental evolution, and the pinpointing of adaptation in natural populations.

Experimental evolution showed that populations from contrasting European latitudes reared in the lab repeatedly converged at the phenotypic level but reached similar adaptive peaks by different genetic paths; and that evolution under different population structure results in different levels of sexual conflict. This research resulted in the first ERC-consolidator grant in Ecology and Evolution in Portugal, which will address how eco-evolutionary feedbacks shape competition and thereby species distributions - a key pending issue in Evolutionary Biology.

In natural populations, we found that human genomic diversity is consistent with a single dispersal out of Africa; we observed a high gene flow from Neanderthal in >30.000-year-old human samples; and we inferred past gene flow that accompanied the divergence of bonobos and chimpanzees.

Evolution and population structure: female-bias in patches of spider mites *Tetranychus* sp. PHOTO: Flor Zélé

RESEARCH LANDMARKS AND IMPACTS

Scientific contributions

Local Mate Competition Mediates Sexual Conflict over Sex Ratio in a Haplodiploid Spider Mite

Macke *et al.*, 2014. *Current Biology* 24: 2850-2854.

Integrating competition for food, hosts, or mates via experimental evolution

Rodrigues *et al.*, 2016. *Trends in Ecology & Evolution* 31: 158-170.

A genomic history of Aboriginal Australia

Malaspinas *et al.*, 2016. *Nature* 538: 207-214.

Chimpanzee genomic diversity reveals ancient admixture with bonobos

de Manuel *et al.*, 2016. *Science* 354: 477-481.

Predictable phenotypic, but not karyotypic, evolution of populations with contrasting initial history

Simões *et al.*, 2017. *Scientific Reports* 7: 913.

Ancient genomes show social and reproductive behavior of early Upper Paleolithic foragers

Sikora *et al.*, 2017. *Science* 358: 659-662.

Scientific recognition

Science's editorial selection for 'Breakthrough of the Year 2016', with the work co-authored by cE3c researcher V. Sousa.
Chair of the Outreach Initiative Committee of the European Society for Evolutionary Biology.

EDITORIAL BOARDS

Frontiers in Plant Science; Evolution, American Naturalist, Oikos, Journal of Evolutionary Biology, Journal of Genetics, Cogent Environmental Science, Cybium.

JURY OF INTERNATIONAL COMPETITIVE CALLS

ERC – EU, ESF, ANR, Swiss National Science Foundation, BiodivERsA, AXA Research Fund, Czech Acad. Sciences, Nat. Science Centre (Poland).

CLIMATE ADAPTATION SERVICES

cE3c's combination of research across natural and social sciences set it as the national reference for climate adaptation research. Through international networks and the organization of events and conference meetings we are establishing a European hub on climate adaptation services, including the provision of the required evidence for their efficiency.

Along with scientific results, the coordination of major multi-sectoral assessments and the response to requests for policy support prompted collaboration with decision-makers and stakeholders across key sectors in Portugal and Europe.

Climate adaptation services: delivering accurate information to policy makers, practitioners and other stakeholders. PHOTOS: Hugo Costa

RESEARCH LANDMARKS AND IMPACTS

Scientific contributions

The rise of demand-driven climate services

Lourenço *et al.*, 2016. *Nature Climate Change* 6: 13-14.

Understanding climate change policy and action in Portuguese municipalities: a survey

Campos *et al.*, 2017. *Land Use Policy* 62: 68-78.

Climate change scenarios for Angola: an analysis of precipitation and temperature projections using four RCMs

Carvalho *et al.*, 2017. *International Journal of Climatology* 37: 3398-3412.

Policy support and advice

Promoting interface between climate change research and society, agenda-setting and participating in international forums (e.g. IPCC – UN Intergovernmental Panel on Climate Change and ERA4CS – European Research Area for Climate Services); by contributing to technical publications at the EU level (e.g. European Environment Agency Reports) and developing decision-support platforms and tools (e.g., Climate-ADAPT).

Supporting decision-makers and stakeholders:

- National and Regional Adaptation Strategies,
- 30 Municipal Adaptation Strategies,
- Adaptation Plans for Water Utility,
- Insurance companies.

Recognition

Chairman of the National Council for the Environment and Sustainable Development (CNADS).

cE3c 2015-2017

TOP 5 PAPERS BASED ON JOURNAL IMPACT FACTOR

(Web of Science, 15-08-2018)

Ancient genomes show social and reproductive behavior of early Upper Paleolithic foragers

Sikora *et al.*, 2017. *Science* 358: 659-662.

Impact Factor 2017 = 41.06

Island biogeography: taking the long view of nature's laboratories

Whittaker *et al.*, 2017. *Science* 357: 1-7.

Impact Factor 2017 = 41.06

The rise of demand-driven climate services.

Lourenço *et al.*, 2016. *Nature Climate Change* 6: 13-14.

Impact Factor 2016 = 19.30

Integrating competition for food, hosts, or mates via experimental evolution

Rodrigues *et al.*, 2016. *Trends in Ecology & Evolution* 31: 158-170.

Impact Factor 2016 = 15.27

Oceanic island biogeography through the lens of the General Dynamic Model: assessment and prospect

Borregaard *et al.*, 2017. *Biological Reviews* 92: 830-853.

Impact Factor 2017 = 11.70

cE3c 2015-2017

TOP 5 PAPERS BASED ON CITATION NUMBER

(Web of Science, 15-08-2018)

The harlequin ladybird, Harmonia axyridis: global perspectives on invasion history and ecology

Roy *et al.*, 2016. *Biological Invasions* 18: 997-1044

Total citations 2018 = 59; Average citations/year = 19.7

Host identity is a dominant driver of mycorrhizal fungal community composition during ecosystem development

Martinez-Garcia *et al.*, 2015. *New Phytologist* 205: 1565-1576.

Total citations 2018 = 52; Average citations/year = 13.0

BAT - Biodiversity Assessment Tools, an R package for the measurement and estimation of alpha and beta taxon, phylogenetic and functional diversity

Cardoso *et al.*, 2015. *Methods in Ecology and Evolution* 6: 232-236

Total citations 2018 = 44; Average citations/year = 11.0

Handbook of protocols for standardized measurement of terrestrial invertebrate functional traits

Moretti *et al.*, 2017. *Functional Ecology* 31: 558-567.

Total citations 2018 = 33; Average citations/year = 16.5

Topography-driven isolation, speciation and a global increase in endemism with elevation

Steinbauer *et al.*, 2016. *Global Ecology and Biogeography* 25: 1097-1107.

Total citations 2018 = 31; Average citations/year = 10.3

cE3c PUBLICATION RECORD: 2015-2017

cE3c PRODUCTIVITY AT A GLANCE

604 - Papers in peer-reviewed journals

66 - Books and book chapters

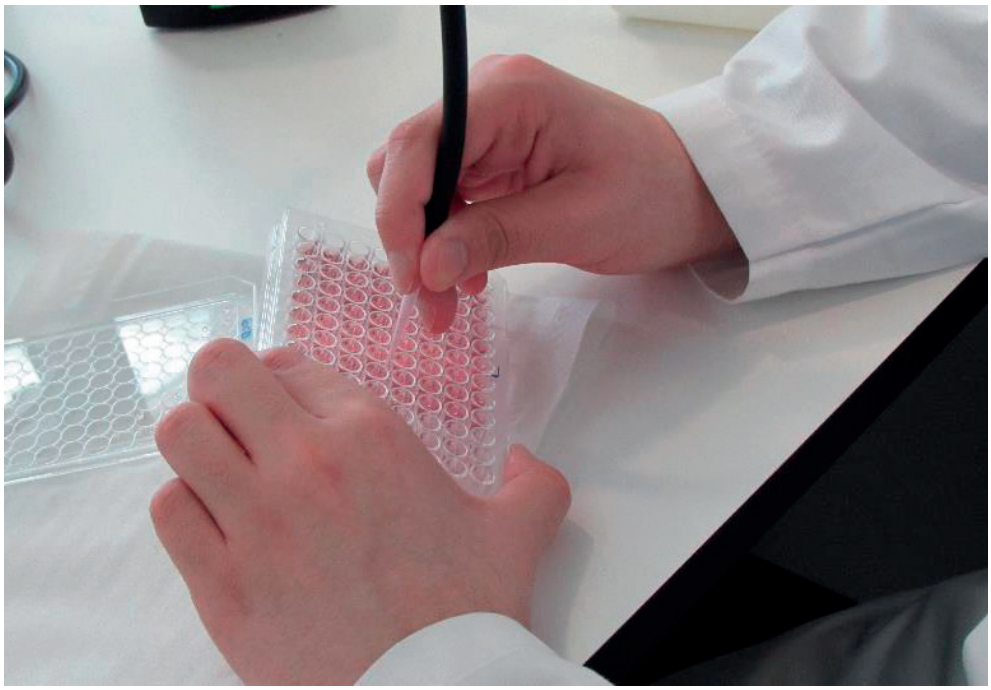
45 - PhD theses

106 - Other publications

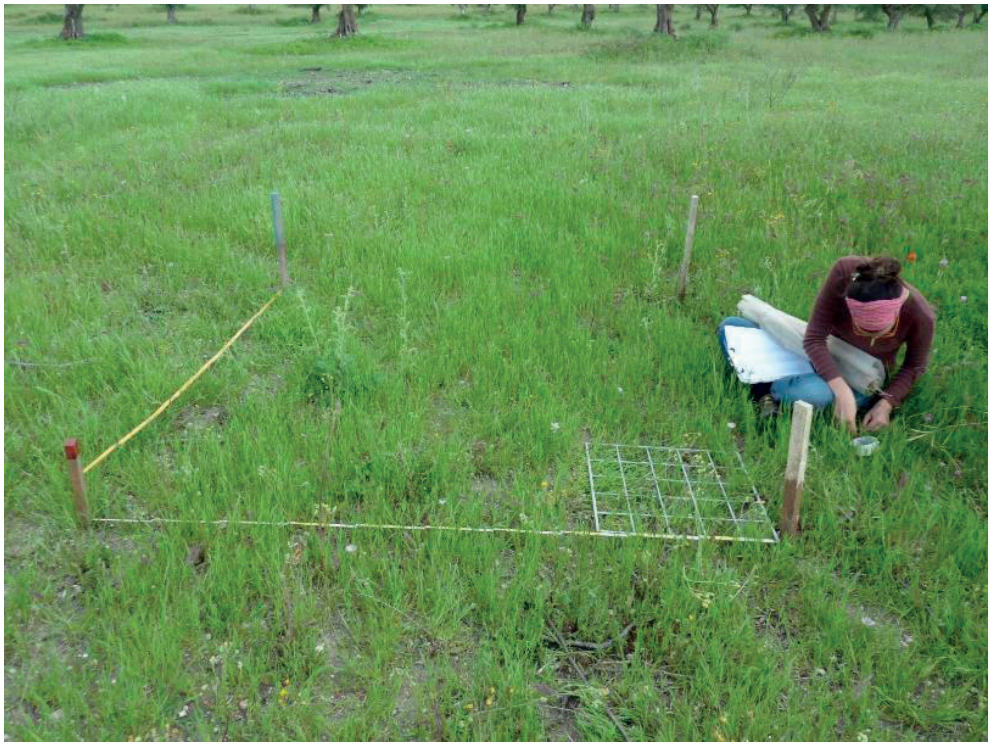
4.9 - Mean papers/PhD researcher

4.3 - Mean number of citations/paper

Note: Some authors use Department as affiliation rather than Research Centre or double affiliation, yielding incomplete results when using search engines such as Web of Science



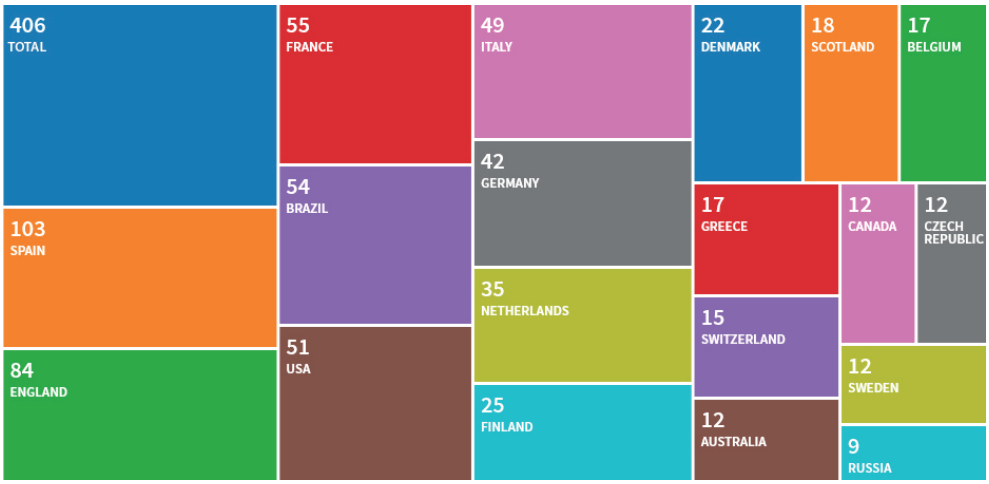
Exploring antitumoral activity *in vitro* using plant extracts from national flora. PHOTO: Maria do Carmo Barreto



Plant sampling in highly diverse olive orchards. Ferreira do Alentejo, Alentejo. PHOTO: Sergio Chozas

2.1. INTERNATIONALIZATION

A measure of the novelty, excellence and worldwide interest on our scientific contributions, and openness of our researchers is the level of internationalization we have achieved. Since 2015, 72% of our papers have been co-authored with foreign institutions and we delivered about 70 plenary talks at international meetings.



cE3c co-authorship publications by country (Web of Science search 2015-2017). Note: not all papers are included. Some authors use Department as affiliation rather than Research Centre or double affiliation

Since 2013, we have coordinated 18 and participated in 41 European projects and networks, including EU FP7, NETBIOME, H2020, BiodivERsA and Marie Skłodowska-Curie Actions.

Education also fostered internationalization: 54 international collaborations for MSc and PhD supervision since 2013. Advanced-training of international students was supported by specific funding to students from South Africa (Erasmus Mundus - AESOP project), Cape Verde (Fundação Calouste Gulbenkian) and Brazil (e.g. PUC-Rio de Janeiro).

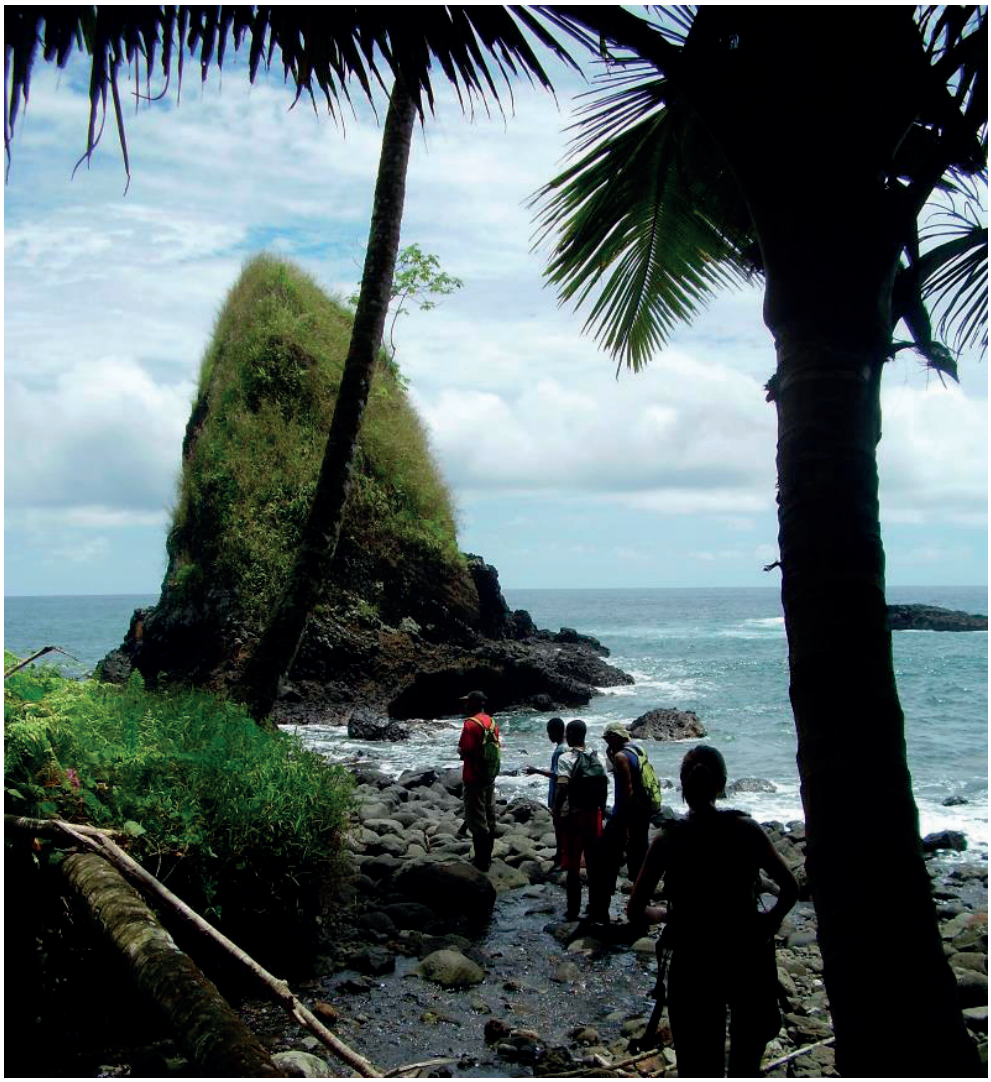
We serve on international scientific and advisory forums, including as national representatives at the International Long-Term Ecological Research network (ILTER), Vice-Presidency of the European Ecological Federation and members of International Union for Conservation of Nature (IUCN) specialist groups.

cE3c organized key international meetings, including the European Society of Evolutionary Biology, ESEB 2013 (over 1500 participants), the International Symbiosis Society 2015 (ca. 300 participants), Island Biology 2016 (over 400 participants), and the International Conference on Ecology and Management of Alien Plant Invasions, EMAPI 2017 (ca. 200 participants).

cE3c's researchers contribute to knowledge dissemination as editors and reviewers in 228 international journals, and as evaluators for international grants (e.g. European Research Council - ERC, The French National Research Agency - ANR, the UK Natural Environment Research Council - NERC, and the European network of funding organizations BiodivERsA).

We have successfully informed and advised sustainable development policies at the international level: defined EU's critical thresholds for nitrogen, advise conservation authorities in Portugal and Africa, and city planning in Europe and South America.

Measuring leaf reflectance at *a restinga* forest in Parque Estadual da Serra do Mar – Núcleo de Picinguaba, Ubatuba. São Paulo, Brazil. PHOTO: Cristina Máguas



Conservation: studying the impact of hunting on endemic pigeons, *Columba thomensis*, *Columba malherbii*, *Columba larvata simplex* and *Treron sanctitho*, of São Tomé & Príncipe. Bindá, S. Tomé & Príncipe. PHOTO: Ricardo Lima

2013-2017

HIGHLIGHTS OF cE3c INTERNATIONAL PROJECTS AND NETWORKS

FP7

OPERAS

Operational Potential of Ecosystem Research Applications

2012-2017

CIRCLE-2

Climate Impact Research & Response Coordination for a Larger Europe

2010-2014

GREENSURGE

Green Infrastructure and Urban Biodiversity for Sustainable Urban Development and the Green Economy

2014-2017

H2020

eLTER PROJECT

Integrated European Long-Term Ecosystem & Socio-Ecological Research Infrastructure

2015-2019

PLACARD

PLAtform for Climate Adaptation and Risk reduction

2015-2020

NETBIOME

ISLAND-BIODIV

Understanding biodiversity dynamics in tropical and subtropical islands as an aid to science based conservation action

2012-2015

SLAM

Long Term Ecological Study of the Impacts of Climate Change in the natural forest of Azores

2012-2017

MOVECLIM

Montane vegetation as listening posts for climate change

2012-2015

BiodivERsA

INVAXEN

Invasive Biology of *Xenopus Laevis* in Europe: Ecology, Impact and Predictive Models

2014-2018

3. The Future
Thematic Lines

Capitalizing on the success of our 2015-17 strategy, on recent promising scientific results and their application to policy on sustainable development, we will continue fundamental and applied research that integrates life and environmental sciences. The centre's 13 research groups (RG) diverse topics will interact to contribute to six Thematic Lines (TL): TL1 - Integrative ecological assessment of environmental change impacts on biodiversity; TL2 - Evolutionary processes that shape biodiversity and adaptation to environmental changes; TL3 - Sustainable management strategies for high-nature-value farmlands; TL4 - Green & blue infrastructures for urban sustainability; TL5 - Human health: linking evolutionary history, environment and physiology; and TL6 - Climate services.

TL1 to TL3 extend previous applied and fundamental research on biodiversity across biological levels, to address crucial points raised by International Agendas (UN's Sustainable Development Goal: SDG 15 - Life on Land). These lines study processes that create and maintain diversity, major threats affecting it, and the services it provides.

TL4 deals with green and blue infrastructures for urban sustainability, a field where cE3c is emerging significantly, arising from intensification of our work in urban ecology since 2015. This TL contributes to UN's SDG 11 - Sustainable Cities and Communities.

TL5 tackles human health, an incipient field at cE3c that intends to integrate ongoing research on climate science and methodologies. In doing so, this TL is expected to yield knowledge for environment-specific disease prevention policy and new therapeutic strategies. It responds to UN's SDG 3 - Good Health and Well-Being.

TL6 focuses on Climate Services, which addresses an international demand for climate adaptation, crucially required to respond to future climate and socio-economic changes. This TL fully encompasses UN's SDG 13 - Climate Action.

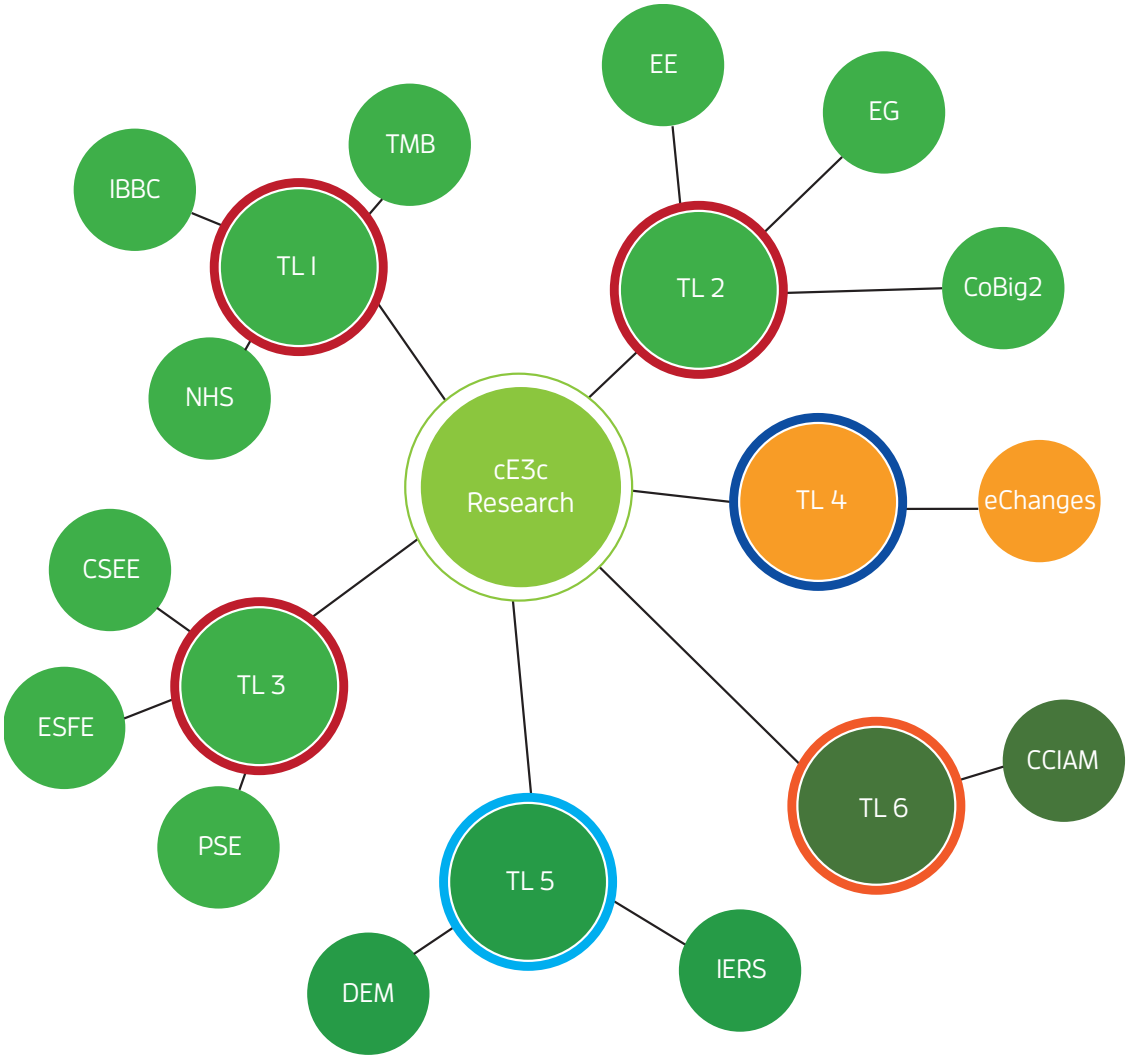
Monitoring species: the Azorean native land snail, *Columella microspore*, from native Azorean forests. PHOTO: Paulo Borges

THEMATIC LINES

TL I	Integrative ecological assessment of environmental change impacts on biodiversity
TL 2	Evolutionary processes that shape biodiversity and adaptation to environmental changes
TL 3	Sustainable management strategies for high-nature-value farmlands
TL 4	Green & blue infrastructures for urban sustainability
TL 5	Human health: linking evolutionary history, environment and physiology
TL 6	Climate services

RESEARCH GROUPS

CCIAM	Climate Change Impacts, Adaptation and Modelling
CoBiG2	Computational Biology and Population Genomics
CSEE	Conservation in Socio-Ecological Ecosystems
DEM	Development and Evolutionary Morphogenesis
eChanges	Ecology of Environmental Change
EE	Evolutionary Ecology
EG	Evolutionary Genetics
ESFE	Environmental Stress and Functional Ecology
IERS	Island Environmental Risks & Society
IBBC	Island Biodiversity, Biogeography & Conservation
NHS	Natural History and Systematics
PSE	Plant-Soil Ecology
TMB	Tropical and Mediterranean Biodiversity



Scientific Project 2018–22 at a glance: Thematic lines (TLs) and their core research-groups are indicated, as well as their alignment with main UN Sustainable Development Goals (SDGs)

TLI
INTEGRATIVE ECOLOGICAL ASSESSMENT OF ENVIRONMENTAL CHANGE IMPACTS ON BIODIVERSITY

TL1 will develop integrative biodiversity assessments to distinguish natural and anthropogenic environmental impacts on biodiversity at different scales. Specifically, it will use key native habitats to address the relative roles of spatial, historical and ecological processes driving taxonomic, functional and phylogenetic diversity patterns; and the utility of pattern metrics to track effects of global change and quantify ecosystem services.

To these goals, our research will:

- Follow-up long-term biodiversity monitoring using a multiple-taxa approach;
- Identify spatially explicit information on threats to biodiversity at different scales;
- Use an artificial intelligence framework for Big Data to develop sound indicators of change.

Biodiversity: Adrià *López*-Baucells sampling bats in a temporary lake in Central Amazon. PHOTO: Oriol Massana Valeriano

2018-2022

THEMATIC LINE I HIGHLIGHTS

24 PhD students pushing science forward

KEYWORDS

Biodiversity patterns and conservation; Human-nature interactions; In-situ and ex-situ conservation; Integrative taxonomy; Island biogeography; Macroecology; Management of scientific collections; Science communication; Taxonomic and functional diversity; Tropical ecology.

CONTRACT SERVICES

Collaborations with private and public stakeholders, including local and regional governmental institutions (Municipalities, Natural Parks).

Selected grants supporting future research

- DYNACOM – Dynamics of oceanic island arthropod communities in space and time. 2018-2020. Spanish Institutional funding.
- Facilitating MAES to support regional policy in overseas Europe: mobilizing stakeholders and pooling resources. 2018-2021. EU.
- AZORES NATURA – Active protection and integrated management of Natura 2000 Network in Azores. 2019-2023. LIFE-EU.
- Mid-Atlantic Island Invertebrates Specialist Group. 2015-2020. IUCN.
- SLAM - Long Term Ecological Study of the Impacts of Climate Change in the natural forest of Azores. 2012-2020. LTER.
- PORBIOTA – Portuguese E-infrastructure for Information and Research on Biodiversity. FCT permanent funding.

Selected recent research

A Global Island Monitoring Scheme (GIMS) for the long-term coordinated survey and monitoring of forest biota across islands.

Borges *et al.*, 2018. *Biodiversity and Conservation* 27: 2567–2586.

A global spatially explicit database of changes in island paleo-area and archipelago configuration during the late Quaternary.

Norder *et al.*, 2018. *Global Ecology and Biogeography* 27: 500-505.

Differential turnover rates and temporal beta-diversity patterns of native and non-native arthropod species in a fragmented native forest landscape.

Matthews *et al.*, 2018. *Ecography* 41: 1-10.

Functional traits of indigenous and exotic ground-dwelling arthropods show contrasting responses to land-use changes in an oceanic island, Terceira, Azores.

Rigal *et al.*, 2018. *Diversity and Distributions* 24: 36-47.

Land cover trade-offs in small oceanic islands: a temporal analysis of Pico Island, Azores.

Gil *et al.*, 2018. *Land Degradation & Development* 29: 349-360.

Successional convergence in experimentally disturbed intertidal communities.

Martins *et al.*, 2018. *Oecologia* 186: 507-516.

TL 2
EVOLUTIONARY PROCESSES THAT SHAPE BIODIVERSITY AND ADAPTATION TO ENVIRONMENTAL CHANGES

Knowledge produced at the intersection of ecology and evolution is essential to inform biodiversity and conservation studies leading to sustainable practices. In the face of man-driven environmental changes, can populations evolve quickly enough to ensure persistence? How much is the genetic composition of populations and their differentiation affected?

TL2 combines theoretical and empirical approaches to:

- understand how populations adapt to their environment;
- characterize populations' current genetic differentiation;
- reconstruct the evolutionary history of species.

We use tools such as: simulations and modelling; population genomics and transcriptomics; phylogenetic and phylogeographical analysis; and real-time evolution. Both lab model organisms and natural populations are studied.

Characterizing genetic differentiation across populations: polytenic chromosome of *Drosophlla subobscura*. PHOTO: Josiane Santos

2018-2022

THEMATIC LINE 2 HIGHLIGHTS

16 PhD students pushing science forward

KEYWORDS

Adaptation; Bioinformatics; Eco- and co-evolutionary dynamics; Evolution of biotic interactions; Genomics and epigenomics; Hybridization; Phylogenetics, phylogeography and speciation; Real-time evolution.

INNOVATION

Scientific software development for genetics/genomics data analyses. Concatenator, 4Pipe4, NCBI Mass Sequence Downloader, Structure_threader, TriFusion and pyRona are in broad community use.

Selected grants supporting future research

- ADAPTCLIMWARM – Real-time evolutionary response to climate warming: a multi-level approach in populations of contrasting biogeographical history. 2018-2021. FCT.
- COMPCON – Competition under (niche) construction. 2017-2022. EU-ERC.
- Keep Pace: Selection of trees keeping pace with fast environmental changes, a science-based approach for sustainable 21st century Oak forests. 2018-2021. FCT.
- MAPGenome – Mapping migration and adaptation in genomes. 2018-2020. EU – Marie Sklodowska-Curie.
- MICROEVOLD – Host-microbe interactions and the evolution of aging. 2018-2021. FCT.
- OCEANTREE – Mechanisms of reproductive allochrony in endemic Portuguese seabirds: implications for population divergence and response to climate change. 2018-2021. FCT.
- PATHOmics – Pathogenomics of coffee leaf rust to probe virulence mechanisms and diagnostic markers. 2018-2021. FCT.

Selected recent research

Different ecophysiological responses of freshwater fish to warming and acidification.
Jesus *et al.*, 2018. *Comparative Biochemistry and Physiology Part A: Molecular & Integrative Physiology* 216: 34-41.

Different genomic changes underlie adaptive evolution in populations of contrasting history.
Seabra *et al.*, 2018. *Molecular Biology and Evolution* 35: 549–563.

Ecology and evolution of facilitation among symbionts: causes and consequences
Zélé *et al.*, in press. *Nature Communications*.

Mate choice driven by genome in an allopolyploid fish complex.
Morgado-Santos *et al.*, in press. *Behavioral Ecology*.

Interspecific gene flow shaped the evolution of the genus Canis.
Gopalakrishnan *et al.*, 2018. *Current Biology*. Online First.

Novel insights on the colonization routes and evolutionary potential of Colletotrichum kahawae, a severe pathogen of Coffea arabica.
Vieira *et al.*, 2018. *Molecular Plant Pathology*. Online First.

The evolutionary history of Nebraska deer mice: local adaptation in the face of strong gene flow.
Pfeifer *et al.*, 2018. *Molecular Biology and Evolution* 35: 792-806.

The role of mate-choice copying in speciation and hybridization.
Varela *et al.*, 2018. *Biological Reviews* 93: 1304-1322.

TL 3
SUSTAINABLE MANAGEMENT STRATEGIES FOR HIGH-NATURE-VALUE FARMLANDS

Millennia of human activity transformed Europe's natural landscape, and many wild species currently depend on traditional low-intensity farming practices specific to local environmental conditions. The concept of high-nature value farming recognizes that biodiversity conservation in Europe depends on systems that link nature-value to environmental qualities and cultural heritage.

This TL aims at a better understanding of ecosystem processes and regeneration to inform management and conservation strategies for long-term sustainability at local to regional scales. It will contribute knowledge on effects of current and future droughts, overgrazing and tree mortality, and assess trade-offs in ecosystem services under various management scenarios, integrating cultural services.

Montado: a unique agro-silvo-pastoral ecosystem found only in the Mediterranean basin. Herdade da Coitadinha, Parque de Noudar, Barrancos, Alentejo. PHOTO: Pedro Pinho

2018-2022

THEMATIC LINE 3 HIGHLIGHTS

20 PhD students pushing science forward

KEYWORDS

Conservation management; Ecology in high nature value farmlands; Ecosystem-based research; Participatory research; Plant and pathogen genomics; Plant ecophysiology; Soil ecology; Stable isotope ecology; Spatial modelling; Sustainable intensification.

COLLABORATIONS

SFCoLAB - Smart Farm CoLab: a partnership with the Municipality of Torres Vedras, local producers/companies, and other research centres, to promote integrative high-tech solutions in horticulture-viticulture-fruticulture sector. 2018-2022.

Collaborations with private (e.g., Empresa de Desenvolvimento e Infraestruturas de Alqueva, S.A) and public stakeholders (e.g., Companhia das Lezírias S.A.), including local and regional governmental institutions.

Selected grants supporting future research

- Characterizing and monitoring cashew economically important diseases in West Africa as a prospective measure for sustainable production: a case study on Guinea-Bissau. 2017-2019. FCT.
- eLTER - Integrated European Long-Term Ecosystem & Socio-Ecological Research Infrastructure. 2015-2019, H2020, EU.
- LIFE-Montado-adapt (Portugal). Montado & Climate, a need to adapt. 2016-2021. LIFE-EU.
- MOVE - Facilitating MAES to support regional policy in OVerseas Europe: mobilizing stakeholders and pooling resources. 2018-2021. EU-FCT.
- R3forest – Using exotic biomass for post-fire recovery: re-use, regenretae and reforest. 2018-2021. FCT.

Selected recent research

Conventional farming disrupts cooperation among phosphate solubilizing bacteria isolated from Carica papaya's rhizosphere.

Melo *et al.*, 2018. *Applied Soil Ecology* 124: 284-288.

Estimating tree canopy cover percentage in a mediterranean silvopastoral systems using Sentinel-2A imagery and the stochastic gradient boosting algorithm.

Godinho *et al.*, 2018. *International Journal of Remote Sensing* 39: 4640-4662.

Genetic and genomic tools to asssist sugar beet improvement: the value of the crop wild relatives.

Monteiro *et al.*, 2018. *Frontiers in Plant Science* 9: 1-8.

Is research supporting sustainable management in a changing world? Insights from a Mediterranean silvopastoral system.

Leal *et al.*, 2018. *Agroforestry Systems* 1-14. On-line First.

Long-term monitoring of mediterranean socio-ecological systems.

Calvache *et al.*, 2018. *Agroforestry Systems*: 1-15. On-line First.

The effect of grazing exclusion over time on structure, biodiversity, and regeneration of high nature value farmland ecosystems in Europe.

Listopad *et al.*, 2018. *Science of the Total Environment* 610: 926-936.

The superior effect of nature-based solutions in land management for enhancing ecosystem services.

Keesstra *et al.*, 2018. *Science of the Total Environment* 610: 997-1009.

What is socio-ecological research delivering? A literature survey across 25 international LTSER platforms.

Dick *et al.*, 2018. *Science of the Total Environment* 622: 1225-1240.

TL 4
GREEN & BLUE INFRASTRUCTURES FOR URBAN SUSTAINABILITY

This TL takes UN and EU Agendas in recognizing cities green and blue infrastructure (GBI) as key to sustainability. This TL aims at understanding how to use biodiversity to create vibrant and healthy cities.

TL4 main topics are:

- Biodiversity as the key to support ecosystem services: using ecological indicators and functional traits to track the provision of ecosystem services by GBI.
- Adapt cities to the future: combining biodiversity with socio-economic and climate change scenarios to support cities adaptation strategies.
- Stakeholders engagement and support: communicating knowledge to authorities to promote the use of ecological approaches in urban management.

Urban green-infrastructures: studying the importance of biodiversity and vegetation structure in the provision of seed dispersal, carbon stock, air quality and microclimate regulation ecosystem services. Parque da Paz, Almada, Setúbal. PHOTO: Pedro Pinho

2018-2022

THEMATIC LINE 4 HIGHLIGHTS

5 PhD students pushing science forward

KEYWORDS

Cities resilience; Ecosystem services; Global change; Human well-being; Nature-based solutions; Urban ecology.

Selected grants supporting future research

- BIOVEINS - Connectivity of green and blue infrastructures: living veins for biodiverse and healthy cities. 2017-2020. BiodivERSA-EU (H2020).
- Implementing nature-based solutions for creating a resourceful circular city. 2018-2020. EU-COST Action funding.
- MedMossRoofs - Urban green covers based on mosses with no irrigation requirements under Mediterranean climate. 2016-2018. FCT.

CONTRACT SERVICES

Almada – Protocol with Almada Municipality (Portugal): monitoring flora and fauna of the municipality and of nature-based solutions to coastal protection and the urban heat-island effect. 2016-2018.

PIMQUER – Protocol with Loures Municipality (Portugal): monitoring the ecological quality of the riparian ecosystems. 2018-2019.

RIBoEIRAS – Protocol with Oeiras Municipality (Portugal) to develop an integrated monitoring plan of the riparian areas. 2018-2019.

Selected recent research

Changes in epiphytic lichen diversity are associated with air particulate matter levels: The case study of urban areas in Chile.

Varela *et al.*, 2018. *Ecological Indicators* 91: 307-314.

Chemical and magnetic analyses on tree bark as an effective tool for biomonitoring: A case study in Lisbon (Portugal).

Brignole *et al.*, 2018. *Chemosphere* 195: 508-514.

Ecosystem services: urban parks under a magnifying glass.

Mexia *et al.*, 2018. *Environmental Research* 160: 469-478.

Green spaces are not all the same for the provision of air purification and climate regulation services: The case of urban parks.

Vieira *et al.*, 2018. *Environmental Research* 160: 306-313.

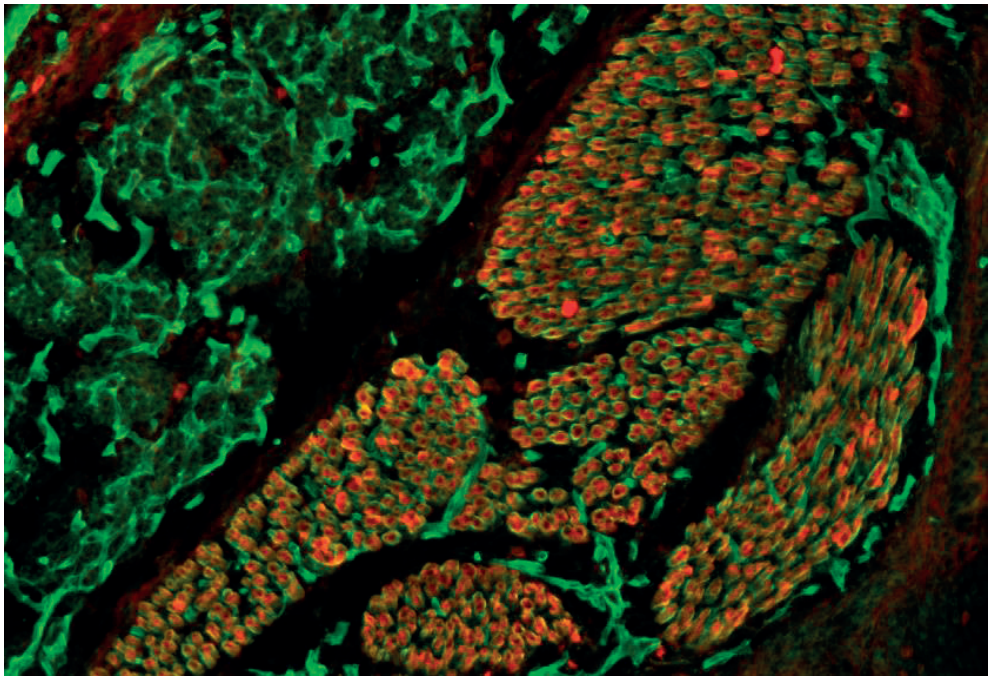
Production of moss-dominated biocrusts to enhance the stability and function of the margins of artificial water bodies.

Cruz de Carvalho *et al.*, 2018. *Restoration Ecology* 26: 419-421.

TL 5
HUMAN HEALTH: LINKING EVOLUTIONARY HISTORY, ENVIRONMENT AND PHYSIOLOGY

We will address how environmental exposure to anthropogenic and natural pollutants impact human health, to inform nature-based solutions to decrease it. Complex diseases are affected by the genomic background of each individual and processes at the cellular level. Hence, we aim to infer how recent evolutionary history affects genomic patterns and disease prevalence across populations, and characterize the cellular mechanisms that disfunction at disease onset.

We also investigate the interplay between aging, environment and disease, at molecular, cellular, tissue and organism levels. Combining this information will contribute to develop coordinated, multilevel strategies to understand and promote human health.



Development to disease: absence of laminin 2II isoform (green) results in mice born with smaller muscles (red). PHOTO: Andreia Nunes

2018-2022

THEMATIC LINE 5 HIGHLIGHTS

4 PhD students pushing science forward

KEYWORDS

Cell-cell and cell-matrix interactions; Citizen science; Environmental management; Health risk assessment; Island ecosystem services and health; Mechanisms of disease; Muscle development; Regenerative medicine.

CONTRACT SERVICES

Environmental monitoring of dioxins, furans and metals in the vicinity of a hospital incinerator. AMBIMED (Gestão Ambiental, Lda). 2014-2019.

LACTIS+: Environmental bioavailability of iodine and selenium in volcanic environments: soil, pasture and milk in S. Miguel Island, Azores, to UNILEITE milk cooperative. 2016-2017.

Selected grants supporting future research

- Instructive Surfaces and Scaffolds for Tissue Engineering Using Radiation Technology. 2014-2019. IAEA (Intern. Atomic Energy Agency).
- Understanding the developmental onset of muscular dystrophy in a mouse model of MDCIA. 2016-2018. AFM Téléthon (Assoc. Française contre les Myopaties).
- BIOINVENT - Generic bio-inventory of functional soil microbial diversity in permanent grassland ecosystems across management and climate gradients. 2017-2020. BIODIVERSA-EU (H2020).
- MACBIOBLUE - Development of new products & processes derived from macroalgae in the context of Macaronesian Blue Biotechnology & Transfer to Enterprises. 2017-2020. EU.

Selected recent research

Biological endpoints in earthworms (Amynthas gracilis) as tools for the ecotoxicity assessment of soils from livestock production systems.

Parelho *et al.*, 2018. *Ecological Indicators*. Online early.

DNA damage in oral epithelial cells of individuals chronically exposed to indoor radon (222Rn) in a hydrothermal area.

Linhares et al., 2018. Environmental Geochemistry and Health. Online First.

Evaluation of nanofibrous scaffolds obtained from blends of chitosan, gelatin and polycaprolactone for skin tissue engineering.

Gomes *et al.*, 2017. *International Journal of Biological Macromolecules* 102: 1174-1185.

Impaired fetal muscle development and JAK-STAT activation mark disease onset and progression in a mouse model for merosin-deficient congenital muscular dystrophy.

Nunes *et al.*, 2017. *Human Molecular Genetics* 26: 2018-2033.

Mapping exposure to multi-pollutants using environmental biomonitors a multi-exposure index.

Serrano *et al.*, 2017. *Journal of Toxicology and Environmental Health, Part A: Current Issues* 80: 710-718.

Mus musculus bone fluoride concentration as a useful biomarker for risk assessment of skeletal fluorosis in volcanic areas.

Linhares *et al.*, 2018. *Chemosphere* 205: 540-544.

Neonatal apex resection triggers cardiomyocyte proliferation, neovascularization and functional recovery in spite of local fibrosis.

Sampaio-Pinto *et al.*, 2018. *Stem Cell Reports* 10: 860-874.

Safety evaluation of fluoride content in tea infusions consumed in the Azores - a volcanic region with water springs naturally enriched in fluoride.

Linhares *et al.*, 2017. *Biological Trace Elements Research* 179: 158-164.

TL 6
CLIMATE SERVICES

TL6 builds on previous work to establish cE3c as an international hub of excellence for research on Climate Adaptation Services. We will transform climate-related data and information into customised products and decision support tools (e.g., forecasts, socio-economic analysis, online platforms) to support solutions for climate adaptation, mitigation and disaster risk management.

We will interact to pursue novel areas of research:

- develop nature-based solutions to increase ecosystem resilience;
- model plant genetic properties as tools for mitigation and adaptation;
- use ecosystem indicators to evaluate the coping capacity of species and communities;
- assess potential impacts of climate change on the ecology of birds.

Climate services solutions developed with decision-makers, to support climate risk and vulnerability assessments in economic/societal sectors. PHOTOS: Virgílio Gomes, Hugo Costa

2018-2022

THEMATIC LINE 6 HIGHLIGHTS

14 PhD students pushing science forward

KEYWORDS

Climate adaptation services; Climate and global changes; Climate impacts; Risks and vulnerabilities; Socio-ecological system analysis.

CONTRACT SERVICES

SWELL - Shared Waters Enhancement and Loughs Legacy. Funded by Longline Environment Ltd. 2018-2019.

ETC-CCA - European Topic Centre on Climate Change impacts, vulnerability and Adaptation, Funded by European Environment Agency (EEA). 2019-2021.

Selected grants supporting future research

- CLIM2POWER - Translating climate data into power plants operational guidance. 2017-2021. Horizon 2020-EU.
- INDECIS - Integrated approach for the development across Europe of user-oriented climate indicators for GFCS high-priority sectors: agriculture, disaster risk reduction, energy, health, water and tourism. 2017-2020. Horizon 2020-EU.
- LIFE DESERT-ADAPT - Preparing desertification areas for increased climate change. 2017-2022. LIFE-EU.
- PROSEU - PROSumers for the Energy Union: mainstreaming active participation of citizens in the energy transition. 2018-2021. Horizon 2020-EU.
- SOCLIMPACT - 2050 and beyond: Downscaling climate impacts and decarbonisation pathways in EU islands and enhancing socioeconomic and non-market evaluation of Climate Change for Europe. 2017-2020. Horizon 2020-EU.

Selected recent research

Adaptation to Climate Change at local level in Europe: an overview.
Aguiar *et al.*, 2018. *Environmental Science and Policy* 86: 38-63.

Afforestation, subsequent forest fires and provision of hydrological services: a model-based analysis for a Mediterranean mountainous catchment.
Nunes *et al.*, 2018. *Land Degradation and Development* 29: 776-788.

Are European decision-makers preparing for high-end climate change?
Capela Lourenço *et al.*, 2018. *Regional Environmental Change*. Online First.

Assessing water contamination risk following vegetation fires: challenges, opportunities and a framework for progress.
Nunes et al., 2018. *Hydrological Processes* 32: 687-694.

Better models are more effectively connected models.
Nunes et al., 2018. *Earth Surface Processes and Landforms* 43: 1355-1360.

Health comparative comprehensive assessment of watersheds with different climates.
Hazbavi *et al.*, 2018. *Ecological Indicators* 93: 781-790.

The superior effect of nature based solutions in land management for enhancing ecosystem services.
Keesstra *et al.*, 2018. *Science of the Total Environment* 610-611: 997-1009.

Transferability of decision-support tools.
Street *et al.*, 2018. *Climatic Change*. Online First.

Outreach activity
at Serra de Sintra.
PHOTO:
Eduardo Marabuto

4. Transforming knowledge into action

4.1. SCIENCE-SOCIETY INTERFACES: POLICY, INNOVATION AND KNOWLEDGE TRANSFER

cE3c's commitment to a sustainable future frequently involves the process of advising stakeholders and of policy drafting. cE3c has successfully informed policy at the regional, national and European levels.

Societal contribution through policy drafting and advice will continue to be a major asset of the unit's strategic plan for 2018-2022. We will intensify these outputs, deepening the emerging field of green & blue infrastructures for urban sustainability, and exploring the incipient field of environmentally--specific strategies for disease prevention.

Advising conservation policy: *Conoceophalus chaves* is one of the most endangered insects in Azorean coastal habitats. PHOTO: Paulo Borges

POLICY DRAFTING AND ADVICE TOWARDS SUSTAINABILITY: HIGHLIGHTS

Advice in conservation & restoration

Co-authors of the "Montado Green Book", a policy-oriented report that reviews Montado current knowledge and highlights requirements to achieve its sustainability.

Long-term (since 1998) study of a restoration process in the SECIL limestone quarry.

Collaboration with IUCN to produce the European Red List of bryophytes and the Red List for Cabo Verdean endemic flora

Species assessments for IUCN: 240 Arthropoda (Azores); 56 Araneae (Madeira); 21 Pterydophyta (Azores); 176 Bryophyta (Macaronesia); 170 Bryophyta (Continental Portugal); ongoing assessment of extinction levels of Macaronesian endemic arthropods.

Definition of EU's critical thresholds for nitrogen.

Providing urban planning & services

Development of a novel framework that optimizes delivery of ecosystem services and their trade-offs in several EU and South American cities, contributing to urban planning.

Scientific coordinators of a campaign to eradicate the invasive African clawed frog (*Xenopus laevis*) in the Municipality of Oeiras, since 2010.

Addressing climate change

Presentation of a Global Change Indicator at the 12th United Nations Forest Forum (2017).

Membership of ENAAC National Climate Change Strategy.

Production of 30 Municipal Strategies for Climate Change Adaptation and Mitigation.

Participation in major international forums of Climate Change (IPCC, EGU, EASAC, JPI-Climate, ERA4CS).

Advising restoration programmes: long-term study of a restoration process in the SECIL limestone quarry. Serra da Arrábida, Setúbal. PHOTO: Paula Matos

Innovation and knowledge transfer to industry increased during the last years. We developed software (4Pipe4, NCBI-Mass Sequence Downloader, Structure_threader) and implemented two programs (Tryfusion; PyRona) for BigData genetic and genomic analysis, and created statistical applications for R (BAT and GAMBIN).

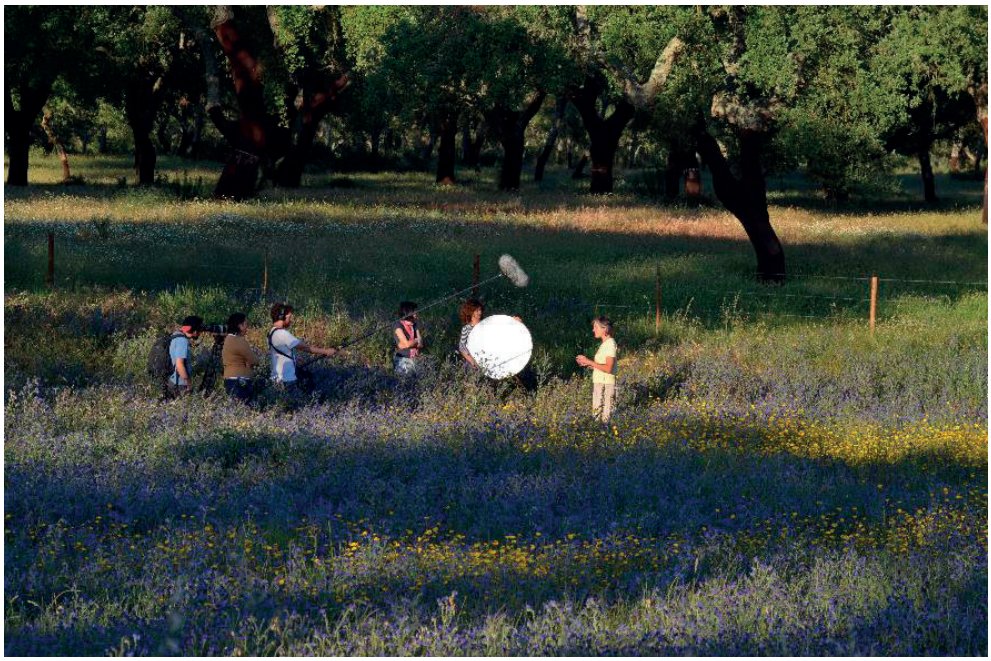
cE3c introduced two biofertilizers (BioClub and Novinoc), and developed a method for mycelium production (PNI 108840. IP 61/2017). We are currently working with the private sector on potential applications of acacia green waste compost (GWC) for poor agriculture soils.

Members of cE3c created Soilvitae, a startup, to pursue innovative R&D solutions, seeking bio-solutions for efficient agriculture with less environmental impact. Product design strategy is inspired by nature and based on scientific knowledge to stimulate communication, cooperation and complementarity among living organisms (mainly microbes and plants) and find tailored solutions for specific problems. Soilvitae received the "Agriculture-Green Project Award" in 2017.

4.2. OUTREACH

cE3c has significantly contributed to an informed and engaged society on sustainability, biodiversity and climate change issues. Moreover, the implementation of the Communication and Outreach Office in 2015 resulted from a strategic decision to promote activities in the realm of citizen science and to expand outreach efforts towards the general public, stakeholders, and policy-makers.

cE3c's contribution to a better-informed public included diverse activities and publications, namely broad-audience exhibitions, documentaries, and several books and articles for wide-circulation. We also collaborate with the Portuguese National Agency for Science Communication, Ciência Viva, on specific occasions (e.g., Ciência Viva School), and participate regularly on events such as the European Researchers' Night. We offer courses for secondary school teachers with lectures and demonstrations aimed at recycling and up-dating scientific knowledge to include new, emerging paradigms and tools.



Science communication to broad audiences: researcher Paula Gonçalves in Companhia das Lezírias, contributing to the long-feature documentary "Sons da Charneca". Lezíria, Santarém. PHOTO: Pedro Pinho

International Day for Biological Diversity, 2017: second-grade students identify plants using the *Guia de Campo – Dia B*, a field book for common, easily observed species edited by cE3c. Noudar, Alentejo. PHOTO: Patrícia Pereira

Promoting citizen-science: second-grade students at the Ribeira do Vascão Biodiversity Station. Their observations were reported to an online species-database platform. Alentejo. PHOTO: Rui Felix

OUTREACH HIGHLIGHTS

EXHIBITIONS & DOCUMENTARIES

Four broad-audience exhibitions, both outdoor (e.g. "Bugs and Society" in Azores) and indoor ("Insects in Order"", IiO). IiO was transformed in an itinerant exhibition that continues to travel across continental and insular Portugal.

Contribution to long-feature documentaries, including "O Cante da Terra").

BOOKS & FIELD-GUIDES

"Field Guide to the Bats of the Amazon" (2016) the only comprehensive guide of bat species and their ultrasonic calls for this region.

Field Guide: "Designing mobile interactive tools for place-based learning" (2018-2021, funded by FCT).

A comic book on climate change adaptation in Portugal: "Reportagem Especial - Adaptação às Alterações Climáticas em Portugal" (2016).

The ebook "What can we learn from islands? Perspectives from eight researchers", edited by cE3c.

EVENTS

Creation of the "International Day of the Microorganism", with UNESCO.

Co-organization of the International Biology Olympiads.

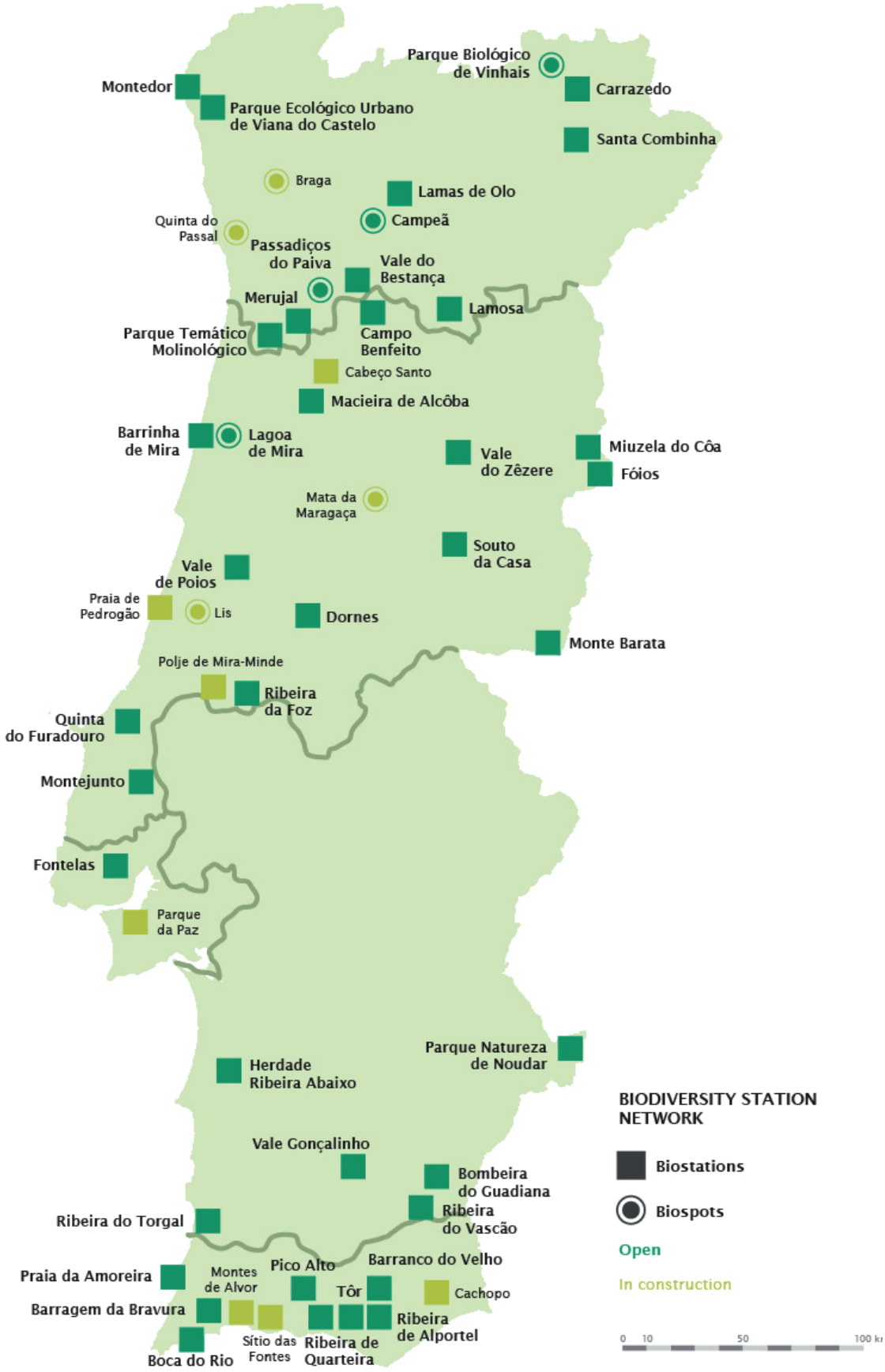
Participation in outreach events, including, MUHNAC's Science Fair, the JobShop Ciências Fair and European Researcher's Night.

MEDIA

Since 2013, 25 appearances on TV (e.g. *Biosfera*), 18 broadcasts on radio (e.g. *90 seconds with science*), and 407 appearances in written media (e.g. the newspaper *Público*).

Permanent communication in social media (Facebook and Twitter).

Citizen science has been increasingly recognized as a powerful mean to collect data and build robust databases, to stimulate public knowledge and awareness, as well as to reinforce the idea that science is a collective enterprise. cE3c is currently involved in two major initiatives: Biodiversity Stations Network (EBIO) and the platform Biodiversity4all. EBIO Network is composed of 41 pedestrian trails for biodiversity monitoring. Over 5000 observations have been registered. Biodiversity4all is an online database on biodiversity in Portugal to which citizens can contribute records of observations of fungi, plants and animals. Use of this database is free.



Promoting citizen science: EBIO stations in continental Portugal, an initiative of cE3c with Tagis – Centro de Conservação das Borboletas de Portugal in partnership with Municipalities. IMAGE: Tagis – CCBP

4.3. ADVANCED TRAINING

Advanced courses: intensive course on scientific writing and communication. PHOTO: Margarida Matos

Thanks to its robust R&D activities, cE3c has a supportive and exciting scientific environment for training young researchers. It hosts PhD programmes, MSc courses, advanced intensive courses, and seminars.

The Centre participates in 9 PhD programmes at Universities of Lisbon and the Azores, and coordinates 5, including, "Biodiversity, Genetics and Evolution" with Oporto University and "Climate Change and Sustainable Development Policies" with Nova University of Lisbon, and co-coordinates the recently-created "Sustainability Sciences" which involves 11 faculties at University of Lisbon. cE3c participates in nine MSc courses and coordinates MScs on "Conservation Biology", "Ecology and Environmental Management", "Bioinformatics and Computational Biology", and "Evolutionary and Developmental Biology".

Additionally, the Centre offers intensive advanced courses, targeting mainly first-year PhD students. Courses cover a wide range of topics and methods (e.g., "Practical course on Phylogenetics", "Urban Ecology: the green within the city", or "Scientific writing and communication"), some of which lectured by visiting foreign collaborators. Engaged young researchers took the initiative to promote short undergraduate courses, with high levels of participation.

High internationalization is guaranteed through Erasmus programmes, students co-supervisions, training schools and protocols in graduate programmes.

Advanced training: PhD field and lab work in coastal areas of the Azores Islands

32 - Advanced courses

2015 — **2018**

124 - MSc Theses

45 - PhD Theses

Conservation Biology MSc Program: fieldwork at Herdade da Ribeira Abaixo Fieldstation. Grândola, Alentejo. PHOTO: Rui Rebelo

cE3c'S PAST AND ONGOING ADVANCED TRAINING: A SELECTION.

PhD PROGRAMMES

BIODIVERSITY, GENETICS AND EVOLUTION

This PhD Program is a research-oriented program that awards a joint degree between the Universities of Oporto and Lisbon. It provides a solid scientific background in the fields of biodiversity, evolutionary biology and genetics.

CLIMATE CHANGE AND SUSTAINABLE DEVELOPMENT POLICIES

This PhD Program involves several schools of the University of Lisbon and the Nova University of Lisbon. The program also involves 9 international institutions from Brazil, Germany, Philippines and UK. This PhD program provides students with the necessary background to work on climate change and sustainable development policies.

SUSTAINABILITY SCIENCES

The programme will have its Ist edition in 2018-19. This new program is offered by II schools of University of Lisbon, spanning natural and exact sciences, social sciences and humanities, health and engineering.

INTERDISCIPLINARY MANAGEMENT OF THE LANDSCAPE

A joint PhD program involving the University of Azores, University of Lisbon (School of Agriculture) and the University of Évora, to link Landscape Ecology, Regional Science, Ecological Economics and Conservation Biology (with emphasis on island ecosystems).

MSc COURSES

NATURE MANAGEMENT AND CONSERVATION

This course is offered by University of Azores. It assumes an integrative approach to environmental problems, responding to the growing need for human resources in environmental management and conservation.

CONSERVATION BIOLOGY

The course is offered by University of Lisbon, and provides advanced training in Ecology, Mediterranean and tropical fauna and ecosystems, currently used methods and management techniques.

EVOLUTIONARY AND DEVELOPMENTAL BIOLOGY

This course is offered by the University of Lisbon. It provides training in fundamental biology allowing to develop skills in Developmental, Functional and Evolutionary Biology.

ADVANCED COURSES

SCIENTIFIC WRITING AND COMMUNICATION

This course aims at developing skills in communication and scientific publication writing.

URBAN ECOLOGY: THE GREEN WITHIN THE CITY

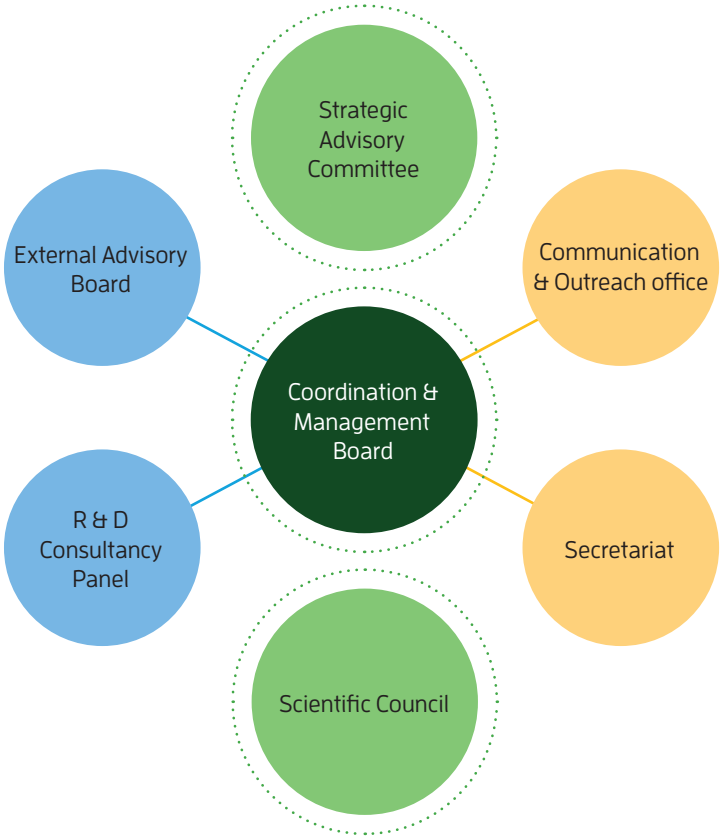
The goal of this course is to provide current and practical knowledge on urban ecology, including ecological and social aspects.

5. Organization and management

5.1. cE3c'S GENERAL ORGANIZATION STRUCTURE

cE3c's organization structure consists of six entities. The Scientific Council is the highest decision-making body. It integrates all PhD members and representatives of associate members, and elects cE3c's Coordinator. It meets bimonthly to discuss scientific and management issues. The Coordination and Management Board, headed by cE3c's Coordinator, oversees administration, research, advanced training, and infrastructures. Each Research Group leader and Thematic Line coordinator is a member of the Strategic Advisory Committee that is called by the Coordination and Management Board whenever needed to discuss strategic issues. Support to administrative and outreach activities is given by a Secretariat and a Communication and Outreach Office.

Four invited international researchers with recognized expertise on main scientific areas of cE3c constitute the External Advisory Board, which meets annually with cE3c members to analyse progress and advise on scientific strategies. The R&D Consultancy Panel, composed by experts from business, policy decision-making, NGOs and the media, contributes to align cE3c activities with national economic interests and societal needs.

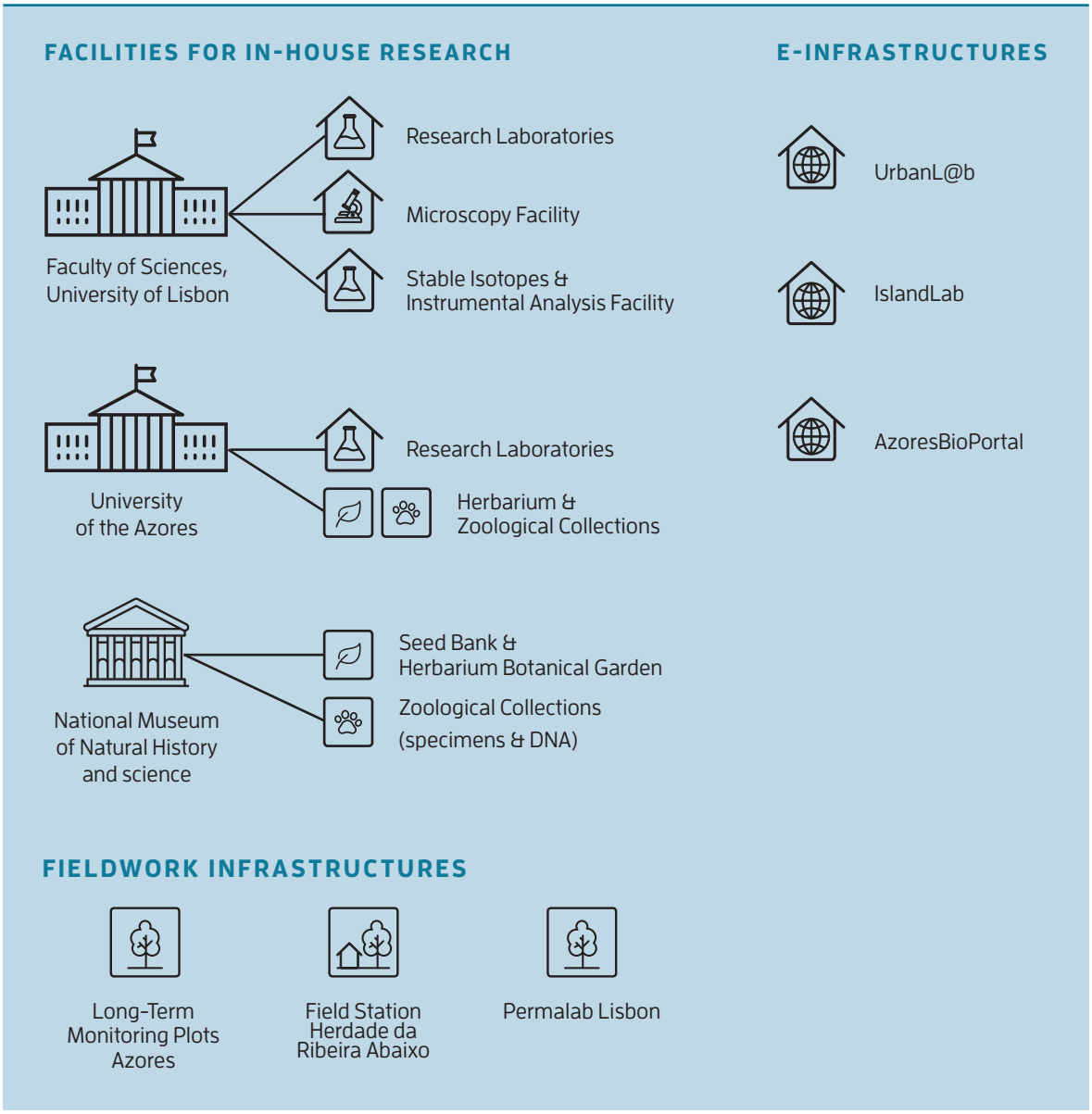


Management and organization structure

Greenhouse at the National Museum of Natural History and Science (MUHNAC). PHOTO: Celina Bellanger

Nine of cE3c's research groups are based at the Faculty of Sciences, University of Lisbon, two are based at the University of Azores, and one is based at the National Museum of Natural History and Science of the University of Lisbon. In addition, cE3c members developed and maintain state of the art laboratories and other infrastructures that support research. These include:

- Facilities and collections for in-house research
- Fieldwork infrastructures (Azores long-term monitoring plots, field station Herdade da Ribeira Abaixo, and Permalab);
- E-infrastructures (UrbanL@b, IslandLab, and AzoresBioPortal) to promote collaboration among peers and knowledge transfer.



cE3c infrastructures

FACILITIES AND COLLECTIONS FOR IN-HOUSE RESEARCH

cE3c facilities and collections for in-house research comprise a number of instrumental laboratories supporting research, training, contract services and outreach, located at Faculty of Sciences from University of Lisbon (FCUL), University of the Azores (UAc), and National Museum of Natural History and Science (MUHNAC). Shared facilities such as the "Microscopy Facility" for bioimaging and image analysis and the "Stable Isotopes Facility", a national reference laboratory, serve in-house research and supply services to the public and private sectors. Other shared facilities include Zoological Collections (specimens and DNA samples), a Seedbank and Herbarium associated with the Botanical Garden, and are located at the MUHNAC, in addition to an Herbarium and Zoological Collection located at the University of Azores.

cE3c's clean-plant rearing facility for spider-mite cultures. Faculty of Sciences, University of Lisbon. PHOTO: Inês Santos

Items from the Zoological Collection and the Seed Bank. National Museum of Natural History and Science (MUHNAC), Lisbon. PHOTOS: José Nuno Lamas

PhD student Patrícia Gomes de Almeida at the Microscopy Facility. PHOTO: Sólveig Thorsteinsdóttir

FIELDWORK INFRASTRUCTURES

A Field Station, Herdade de Ribeira Abaixo, located in Alentejo, is part of the a Long-Term Socio-Ecological Research platform devoted to the montado ecosystem (LTsER Montado), and integrates an Education Centre, lodging and lab facilities for students, researchers and visiting scientists. cE3c is the national representative of the LTER Portugal network, integrating the recently created European Research Infrastructure elTER ESFRI.

The Long-Term Monitoring Island Forest Field Plots is a network of 100 plots covering the native forests of seven of the nine Azores Islands. These sites monitor both the soil arthropods and flying insect fauna of Azorean native forests. In addition, bryophytes and vascular plants are also monitored.

The Permaculture Living Laboratory (PermaLab), located at the Faculty of Sciences, University of Lisbon, provides the space to experiment integrated sustainable nature-based designs and green infrastructures. Such experiments include, for example, storage and use of rain water, composting garden material and vermicomposting of food waste from local cantinas.

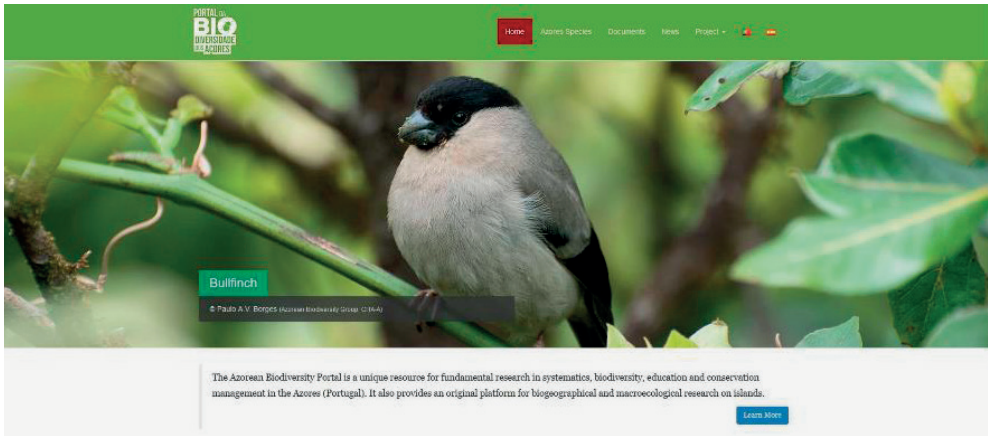
Herdade de Ribeira Abaixo Field station: this facility includes lodging and supports research, education and outreach activities. PHOTO: Rui Rebelo

PermaLab: students at the vegetable garden. Faculty of Sciences campus, University of Lisbon. PHOTO: Gil Penha-Lopes

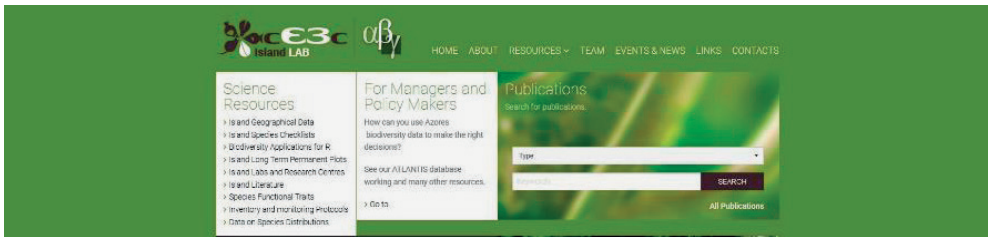
A SLAM trap in Faial Island: part of the project Long-Term Ecological Study of the Impacts of Climate Change in the natural forest of Azores. PHOTO: Paulo Borges

E-INFRASTRUCTURES

The centre's e-infrastructures, UrbanL@b, ISLAND LAB, and AZORESBIOPORTAL, work as virtual environments to promote collaboration among peers and knowledge transfer.



Azores Bioportal Database. http://azoresbioportal.uac.pt/



Island LAB. http://islandlab.uac.pt/

UrbanL@b. http://urbanlab.campus.ciencias.ulisboa.pt/

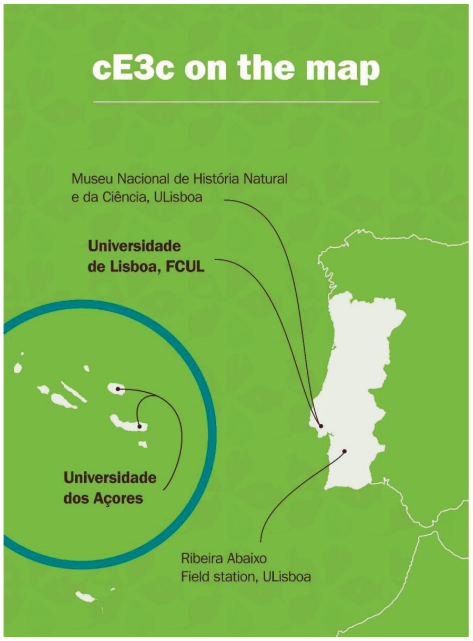
5.2. ENSURING SCIENTIFIC COHESION

Frontiers in E3 (2018): cE3c Annual Meeting. PHOTO: Rúben Oliveira.

All these infrastructures and facilities, located in Lisbon, Azores, and Alentejo, create a diverse and resourceful patrimony and expertise, which is a major asset of cE3c. However, spatial dispersion may affect integration, and therefore several measures were adopted to preserve the unit's cohesion, and facilitate continuous synergistic interactions among members, crucial to maintain excellence. These measures include:

- Science seminars by in-house researchers, "Encontros Scientia", broadcast to Lisbon and Azores. On these weekly seminars researchers present their latest findings in ecology, evolution and environmental changes (65 seminars, 2015-2017).
- Science seminars by external researchers, "cE3c Conferences", broadcast to Lisbon and Azores. Invited scientists share state-of-the-art research, thus promoting the debate and fostering new ideas and collaborations. (37 Conferences, 2015-2017).
- The annual scientific and team-building event, "Frontiers in E3: cE3c's Annual Meeting", which takes place in Lisbon or the Azores. In this event, cE3c researchers gather together to present and discuss their latest projects, scientific results, outreach initiatives, and explore novel ideas.

Interactions nurtured by these and other meetings, through research developed in converging topics, resulted in a significant increase of collaborative work. Since 2015, we published 106 papers authored by more than one Research Group of cE3c, which demonstrates our success in integrating expertise.



cE3c on the map: facility locations in continental and insular Portugal

5.3. cE3c's FINANCIAL MANAGEMENT STRUCTURE

To secure human resources and infrastructure support from member institutions, partnership agreements have been signed with the main management institution in Lisbon, Fciências.ID, which is also responsible for the Centre's overall financial management and its interaction with Fundação para a Ciência e Tecnologia (FCT). Given the significant number of members associated with Azores University (20% of integrated members), for operational and regional funding reasons, Fundação Gaspar Frutuoso (Azores) is a regional management unit that reports to Fciencias.ID, via the main Secretariat.

COMPETITIVE FUNDING AND ADMINISTRATIVE STRUCTURE (MAIN ENTITIES)