

— RESEARCH UPDATE —

Coordination Action for Research Activities on life in Extreme Environments – The CAREX project

CYNAN ELLIS-EVANS¹ and NICOLAS WALTER^{2*}
(on behalf of the CAREX Consortium)

¹ *British Antarctic Survey, High Cross Site, Madingley Road, Cambridge CB3 0ET, United Kingdom*

² *European Science Foundation, B.P. 90015-1, Quai Lezay-Marnésia,
67080 Strasbourg, Cedex, France*

Received: 14 May 2008

Accepted after revision: 2 June 2008

Life, as we know it, is constrained by various environmental parameters (physical and chemical) and these vary both in space and time. Combinations of specific ranges for each of these parameters within a particular area define biotopes or environmental conditions. Environments where one or more of these parameters show values permanently close to the lower or upper limits known for life are considered extreme environments. In 2003, the European Science Foundation (ESF) initiated a new research support activity “Investigating Life in Extreme Environments” (ILEE). The key event of this initiative was an interdisciplinary workshop held in November 2005 and attended by 128 European scientists. The headline conclusions of this initiative expressed the need for a more coordinated approach to improved future opportunities for funding research on life in extreme environments. It was emphasised that such an approach should be interdisciplinary. The CAREX project (Coordination Action for Research Activities on life in Extreme Environments) is an FP7 Coordination Action funded for three years (2008-2010) in the field of life in extreme environments. This interdisciplinary project will i) set up an interactive information platform, ii) develop open databases gathering information on life in extreme environments experts, research projects and specific infrastructures and technologies, iii) identify research priorities in order to define a European roadmap for research on life in extreme environments, and iv) promote the exchange of knowledge through the organisation of field trips, a laboratory seminar, a summer school and the award of short visit grants.

Key words: life in extreme environments, networking, coordination, research agenda, project.

OVERVIEW OF LIFE AT LIMITS

Life, as we know it, is constrained by various environmental parameters (physical and chemical) and these vary both in space and time. Combinations of specific ranges for each of these parameters within a particular area define biotopes, or sets of environmental conditions, which will be suitable for a given species. For most environmental parameters constraining life, specific limits have been established (but not definitively set) beyond which life, in its whole cycle, has

never been described to date. For example, the highest temperature currently known to allow the complete life cycle of an organism (the archaeon *Pyrolobus fumarii*) is 113 °C, the lowest is –18 °C. A wide range of parameters other than temperature can impose limits on life, including pressure, water availability, pH, osmotic potential (salinity) and radiation to name but a few. There may also be more than one parameter stressing an environment, e.g. marine hydrothermal vents have very high temperatures and pressures and very high concentrations of heavy metal sulphides, subglacial lakes have low temperatures, high pressures and very high concentrations of oxygen.

* Corresponding author: tel.: +33 (0)3 88 76 71 66, e-mail: nwalter@esf.org

The concept of the habitability of an environment has often in the past been defined in terms of the requirements for human existence. However, that part of the Earth's biosphere permanently inhabited by human is rather small and most of the planet, notably its deep core or mantle, will clearly never see a living organism. In between these two zones (inhabited and uninhabited), a great variety of environments exist where humans cannot live permanently, or which they cannot physically access, but a wide range of other organisms survive and flourish. Such environments, where one or more of the defining parameters show values permanently close to the lower or upper limits known for life are considered "extreme" environments.

Earlier technical limitations, as well as misconceptions as to the capability of life forms to colonise, initially restricted the search for life in these extreme environments. The discovery of the remarkable biota of mid-ocean ridge hydrothermal environments occurred only in the late 70's, the extent and diversity of deep sub-surface ecosystems was recognised only during the late 80's and early 90's and the first evidence of life in the giant subglacial Lake Vostok was reported only in the past decade. It is now recognised that, in terms of volume, extreme environments represent the most important part of the Earth's biosphere. They are inhabited by unique organisms that have evolved using adaptive mechanisms at the cellular and molecular level.

CAREX BACKGROUND

In 2003, the European Science Foundation (ESF) initiated a new research support activity "Investigating Life in Extreme Environments" (ILEE). The key event of this initiative was an interdisciplinary workshop held in November 2005 and attended by 128 European scientists. Presentations and discussions considered the issues of life in extreme environments in its broadest sense, covering various life forms (microbes, plants, animals and human) and various extreme environments (marine, terrestrial, polar and outer space) with the aim of expressing scientific and policy recommendations. The headline conclusions of this initiative were that (ESF, 2007):

- There is certainly a critical mass available to develop a pan-European community for researching Life in Extreme Environments (LEXEN). The workshop participants showed enthusiasm for a more coordinated approach that led to improved future opportunities for funding of LEXEN re-

search.

- In part because of the interdisciplinary nature of research into life in extreme environments and its enormous diversity, fragmentation of existing European efforts and lack of coordination in extreme environment research are currently major constraints to pan-European capacity building.
- Larger and more frequent interdisciplinary endeavours are necessary to derive fuller data sets and provide the cross-disciplinarity needed to understand these environments. Again this needs more coordination.
- The workshop identified the desirability to adopt, where possible, an ecosystem-based approach to studying extreme environments and the value of potentially identifying model ecosystems and model organisms for coordinated research focus.
- Development of necessary technologies must parallel increased research interest in extreme environments, as it is often a pre-requisite for a significant step forward, and this technical requirement needs to be recognised by funding bodies.
- There is a clear need to develop a networking and information exchange capability for the scientific and technological community.

An extensive ESF report on the workshop has been completed and was published by ESF in May 2007.

CAREX CONCEPT AND OBJECTIVES

The CAREX project answers a FP7 call for Coordination Action in the field of life in extreme environments issued in November 2006. The Call text emphasised the need for a furthering of knowledge of extreme environments, the organisation of large scale multidisciplinary events to build and maintain a dynamic research community and the need to improve information exchange and networking of both the multi-national community involved as well as other relevant programmes and projects. These points essentially reflect key conclusions identified during the original ESF-ILEE initiative. The CAREX project has been selected for funding by the European Commission for a period of three years (2008-2010) and is active since January 1st 2008.

Extreme environments and their biota are a diverse topic that would challenge even a global consortium to fully address. However, significant progress to furthering knowledge of life in these environments through European contributions is entirely possible with the identification and prioritisation of the key

research areas and required technological support, alongside with trans-national coordination to bring together required disciplines, logistical capabilities and funding support. Much current LEXEN research is not based on a comprehensive assessment of the research urgencies across Europe but rather reflects national priorities and individual scientific interests. The challenge is then for the pan-European community to come together to develop a set of priorities that resonate with the national and European funding agencies and the science community in the manner of international programmes such as the International Polar Year 2007-2008. One of the main CAREX objectives is therefore to identify the European research priorities for LEXEN research. To address this issue, three large scale workshops are being organised to bring together science and technology experts across the LEXEN spectrum to debate the priority targets for European research and the technological developments needed to support this science. These workshops will be focussed on i) the identification of model ecosystems in extreme environments, ii) the identification of model organisms from extreme environments, and iii) identification of priorities for environment-specific technological developments and infrastructures to support the research. The results of these meetings would then be synthesised and presented as an expert report (outlining a strategic roadmap) to inform national and European funding organisations as a basis for future dialogue.

Whilst the identification and communication of priorities for research and technological development are clearly a major objective, there is also a need to establish a connected community to address the scientific and technological challenges more effectively. It was recognised at the ESF-ILEE workshop that, whilst Europe has internationally recognised research individuals and groups in the LEXEN field, fragmentation limits the ability of Europe to tackle the many research questions that require substantial interdisciplinarity and sophisticated infrastructure for both logistical access to sites and diverse complex analyses. Overcoming fragmentation will provide opportunities for networking, exchange of information, critical discussion and harmonisation of methodologies and approaches, all of which will contribute to improving knowledge of the topic.

The over-riding CAREX objective is to build the European LEXEN community and establish a robust framework that will continue after the end of the project because the community has realised the benefits

of greater interaction and wants to maintain connectivity and regular interaction. To consolidate the community that emerged through the ESF-ILEE initiative and the development of the CAREX network requires a commitment to establish even greater communication through networking at various forms of meetings, and, more particularly through tools such as a dedicated website, regular newsletters and promotional material.

The European LEXEN community also needs to know its place in the broader scheme and to interact externally, so CAREX plans a series of forums to promote LEXEN research to other research projects and programmes as well as stakeholders, such as national funding agencies, ministries and commercial sector organisations.

CAREX main objectives:

- Establish interactions, coordinate activities and promote a community identity.
- Identify the current status of research on life in extreme environments within Europe.
- Furthering the scientific knowledge of life in extreme environments on key issues.
- Identify the priorities for future research on life in extreme environments within Europe.
- Identify the environment-specific technological challenges and infrastructure necessary to support research priorities on life in extreme environments.
- Harmonise protocols and approaches used in research on life in extreme environments and promote knowledge transfer across the community.
- Promote the development of young career scientists.
- Establish an interactive information hub to support and develop a dynamic European community.

These objectives are addressed through four lines of development:

- i. Scientific Priority setting: CAREX's high level scientific workshops address the issues of Model Ecosystems, Technology and Infrastructures and Model Organisms in order to define a European roadmap for research on life in extreme environments.
- ii. Exchange of Knowledge: through the organisation of field trips, a laboratory seminar, a summer school and the award of 20 short visit grants, CAREX catalyses the transfer of knowledge and exchange of best practices among the scientific community and towards young researchers.

- iii. Information Hub: CAREX website (www.carex-eu.org) provides an interactive platform for the exchange of information, job and funding opportunities, news and events specific to research on life in extreme environments.
- iv. Databases: CAREX website hosts an open searchable directory of international experts, a database of research projects on life in extreme environments and a portfolio of specific infrastructures and technologies.

CAREX CONSORTIUM

The CAREX consortium shows a high degree of multidisciplinary. It involves:

- NERC – British Antarctic Survey, UK
- CNRS, France
- CNR – Istituto di Biologia Agro-ambientale e Forestale, Italy
- Deutsche Zentrum für Luft- und Raumfahrt (DLR), Germany
- European Science Foundation (ESF), France
- Ifremer, France

- Institute of Botany, Academy of Sciences of the Czech Republic
- INTA – Centro de Astrobiología, Spain
- MATIS – Prokaria, Iceland

In examining the CAREX core partnership one can see an agglomeration of various structures and scientific interests. As shown in Figure 1, this variety allows the project to cover the whole spectrum of domains and areas of interest for life in extreme environments, from microbial life to animal adaptation and considering marine, terrestrial, polar and space environments. Furthermore, in assembling national agencies, research centres and a pan-European research networking organisation, the CAREX consortium gathers information and knowledge of the whole research process, from data gathering to programme management and pan-European coordination and networking.

Whilst covering the broad spectrum of activities relevant to LEXEN research, the core partners are keen on consolidating the gathering of both knowledge and competencies through the commitment of

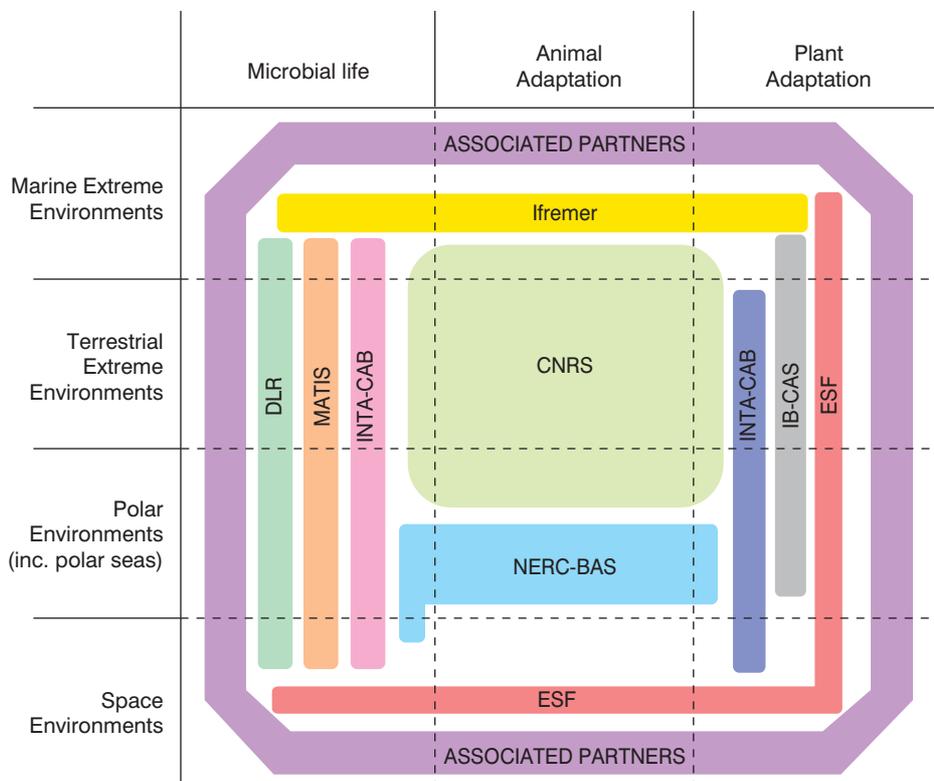


FIG. 1. The positioning of CAREX partner organisations relative to the type of organism and type of environment of interest for LEXEN research.

Associated Partners to the consortium. These Associated Partners provide additional insights and the highest level of European and international expertise to the project, enhancing further its disciplinary and geographical representativeness and providing the early backbone of the network to be further developed. CAREX has 46 Associated Partners from 16 European countries. In order to broaden the CAREX network and to establish links beyond the European countries, CAREX also has seven Associated Partners from six non-European countries (Canada, Chile, Israel, Japan, Ukraine, USA).

For CAREX to be successful and a dynamic LEXEN community to be established it is crucial that the potential participants in this community buy into the vision that such activities will bring tangible results and not simply be a set of “talking shops”. These benefits can be outputs such as steps to develop opportunities for future funding, practical comparisons

generating better methodologies or educational opportunities for early career scientists. But there can also be less tangible benefits such as an awareness of being part of a large related group beyond one’s own research area and that one can interact with people in these other areas (and possibly tackle larger questions beyond the capability of one’s own group). CAREX’s strategy involves a range of measures to define the community, make it aware of itself and its broader relevance, put in place resources/tools that the community can use or reproduce for its immediate and longer term benefit and involve the community in developing priorities.

REFERENCES

- European Science Foundation, 2007. *Investigating Life in Extreme Environments – A European perspective*. ESF, Strasbourg.