Journal of Alpine Research | Revue de géographie alpine

96-4 | 2008

Recherche alpine : spécificité et devenir

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Electronic version

URL: <https://journals.openedition.org/rga/603>

DOI: 10.4000/rga.603

ISSN: 1760-7426

This article is a translation of:

Évolution de l'environnement alpin - URL : <https://journals.openedition.org/rga/596> [fr]

Publisher:

Association pour la diffusion de la recherche alpine, UGA Éditions/Université Grenoble Alpes

Printed version

Date of publication: 15 December 2008

Number of pages: 65-76

ISBN: 978-2-200-92503-1

ISSN: 0035-1121

Electronic reference

Philippe Schoeneich and Carmen de Jong, "Changes in the Alpine environment", *Journal of Alpine Research | Revue de géographie alpine* [Online], 96-4 | 2008, Online since 04 March 2009, connection on 08 December 2022. URL: <http://journals.openedition.org/rga/603> ; DOI: <https://doi.org/10.4000/rga.603>

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Changes in the Alpine environment

How will the Alpine environment be tomorrow and for what activities?

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Abstract : The way the Alpine environment will evolve in the 21st century depends upon climate change. This could lead to climates never before seen in the Alps, resulting in a major and lasting environmental crisis. In the face of these challenges, funding is still insufficient for specialised research on mountain environments. State funding often prioritises polar research at the expense of high altitude areas, whereas funding schemes from bodies such as Interreg do not sufficiently address the need for fundamental research, which is nevertheless a necessary first step prior to establishing scenarios. Over the last two or three years, there has been some progress towards transalpine network projects.

This article identifies the main challenges faced by the alpine environment research field and the capacity of research programmes to meet these needs. The first section, on climate change, is based on the following recent reports: the IPCC 2007 summary report (IPCC 2007), the IPCC Europe report (Alcamo *et al.* 2007), and the ClimChAlp programme summary report (Prudent-Richard *et al.* 2008). These contain full, detailed bibliographies. The second section analyses recent or current calls for proposals, and projects which have been selected for funding.

Keywords : mountain, environment, research, challenges, programmes.

One core problem: climate change

One clear observation can be made: all of the future challenges of the Alpine environment will directly or indirectly depend upon a central problem: climate change.

TEMPERATURE CHANGES

The best-known factor, the one which is best accounted for in models and which is easiest to imagine is temperature change. Studies so far have shown that warming in the Alps has been greater than the world average: a 0.9 – 1.5°C increase in the Alps since 1850, which is almost double the world average increase of 0.7 – 0.8°C. (Beniston, 2005; Casty *et al.*, 2005; Alcamo *et al.*, 2007; IPCC, 2007).

These changes are neither linear nor uniform:

– They vary according to the seasons: a greater increase in temperatures has been measured in winter and spring than in summer, except in France (Prudent-Richard *et al.*, 2008);

- Minimum temperatures have increased more than maximum temperatures (Dumas et Atunes, 2003);

- Values vary greatly over different areas.

This disparity in values illustrates some evident difficulties when dealing with averages, but does not give reason to doubt the phenomenon of global warming: the trend is the same and its effects are felt everywhere.

The most immediate and visible effects can be observed in the cryosphere: in snow, ice and glaciers, because, as we have mentioned, the temperatures which have risen the most are winter and minimum temperatures. This results in:

- a reduction in snow cover, in terms of both duration and depth of snow (Martin et Etchevers, 2005);

- glacier melt, which not only causes the glacier edges to recede, but for the last few years has also brought about a reduction in thickness up to the top of the accumulation areas (for a complete picture of recent glacier changes, see Francou & Vincent, 2007);

- permafrost thaw, which for the last few years has resulted in more frequent rock falls in high-altitude areas and in the appearance of new phenomena which had never previously been observed, such as the acceleration, or even cracking of rock glaciers (Delaloye *et al.*, 2008).

One less obvious effect is the fact that isotherm altitudes are creeping up, and consequently morpho-climatic and bio-climatic boundaries are also moving higher:

- areas of intense and/or maximum frequency of freeze/thaw cycles;

- the lower limits of the permafrost;

- the upper limits of forests, trees, and of all vegetation belts generally.

CHANGES IN PRECIPITATION

Changes in precipitation are not so well known and notoriously harder to predict using models. Although models predict a slight increase in terms of pluviometric figures, changes in precipitation patterns is the factor with the greatest potential consequences (see review in Prudent-Richard *et al.*, 2008):

- models predict a reduction in summer precipitation and an increase in winter precipitation,

- summer precipitation could take the form of less frequent, but heavier showers,

- winter precipitation will increasingly take the form of rain at ever higher altitudes.

However, these predicted changes in precipitation contain many factors of uncertainty.

Hydrological patterns will first be affected by changes in snow and glacier water retention. The amount of water stored in snow form will tend to decrease at mid altitudes, and the snow pack will thaw increasingly earlier. We can therefore expect:

- an increase in winter water flow rates
- an earlier and reduced snowmelt runoff peak.

Glacier melt will, for its part, have a two-stage effect (see several reports from the Alpine Glaciological Meeting 08):

- Initially, the thawing of the accumulated ice will release excess water and cause a rise in the volume of water flowing out;
- Subsequently, with insufficient stores of glacier ice, summer water flow will decline.

TOWARDS NEW MOUNTAIN CLIMATES?

Climate change is unlikely to be uniform, nor will it occur evenly across mountain areas.

The Alps currently encompass two main types of climate patterns: the Mediterranean climate of the Southern Alps of France and Italy, and a temperate climate with evenly distributed precipitation across the year in the rest of the Alps. This climatic boundary, which in France represents the traditional divide between the northern and southern French Alps, and which lies approximately on the border of the Isère *département* on the one hand, and the Drôme and Hautes-Alpes *départements* on the other, may begin to move northwards. If this were to occur, the Isère and Savoie *départements* could experience more significant climate change than other regions, with radical shifts in climate pattern. This hypothesis assumes that dry summers indeed become the norm in these areas. Otherwise, the trend will be different.

Climate is not determined by averages, but is the cumulative result of successive meteorological conditions (synoptic situations or weather patterns). This is particularly true for the Alps, which are affected by a range of very diverse situations. Yet the climate trend in the Alps will be largely determined by changes in the frequency and intensity of certain meteorological situations, in particular those which determine the greatest precipitation, or which can bring about long periods of drought. Two examples illustrate this idea:

- Winters at the end of the 1980s and beginning of the 1990s, which were affected by zonal circulation with alternating warm and cold fronts and Atlantic disturbances, causing alternating rain and snow fall in mid-altitude mountains, could point to the types of winters we will experience tomorrow;
- The lasting phase of south winds from the end of May to early June 2008, with a weather system coming from the east over France and heavy precipitation on the main ridge of the Alps, its lasting north foehn and exceptional levels of dust carried from the Sahara, could indicate future summer situations.

If situations such as these were to become more frequent and intense, entirely new climates could appear in certain regions of the Alps.

THE ENVIRONMENT'S RESPONSE

As mentioned above, vegetation is likely to respond to global warming by a shift in vegetation belts towards higher altitudes (Theurillat & Guisan, 2001; Walther *et al.*, 2005). In the case of forest stands, this upward shift should normally occur slowly. Indeed, although the spread of forest tree species depends heavily upon optimal reproduction conditions, once established, a forest can resist for a long time to conditions which have become adverse, as long as the change is progressive. Other determining factors can however be added to the equation, in particular, alterations in precipitation patterns, which may have the greatest effect on the vegetation trend.

It is important to take thresholds and climate extremes into consideration. Indeed, the distribution of vegetation is largely dictated by limiting factors, namely tolerance to cold and drought. Yet beyond the average progression, certain thresholds crossed during episodes of extreme weather are a key factor in the evolution of ecosystems.

The freeze which destroyed so many olive trees in 1956 is a good example. It shows that, even if temperatures increase and a Mediterranean climate becomes established in the Northern Alps, the olive tree is unlikely to grow at higher altitudes and latitudes for as long as extreme frost continues to occur, even if very rarely.

But extreme events will also play a crucial role in determining the capacity of today's ecosystems to maintain themselves. Such events are more likely to determine the survival of species than the gradual increase in averages. The 2003 heatwave and drought upset the balance of certain species, and this continues to be felt 5 years on. This event also recalls the drought of 1976 that had a medium-term effect and was largely responsible for the forest decline of the 1980s.

A proliferation of such events could severely upset forest ecosystems and cause an environmental crisis, particularly in the transition area between the Northern and Southern Alps.

Shifts in vegetation belts will have an effect on biodiversity, in particular on vegetation above the Alpine belt. In mid-altitude mountains, the extent of these vegetation shifts will be limited due to the height of the peaks. The zone above the Alpine belt, and its native species, could therefore eventually disappear from mid-altitude mountain areas. In terms of latitude, the Mediterranean biome should spread northwards.

This trend will have an impact on nature and biodiversity conservation strategies: the location and perimeter of certain protected areas may eventually prove to be inadequate, due to movements of protected species and habitats (Prudent-Richard *et al.*, 2008).

Nonetheless, environmental changes are subject to the dual influence of climate change and changes in anthropogenic pressure, and the role played by each is sometimes difficult to establish. Thus, the significant spread of forests in mid-altitude mountains is mainly due to the abandonment of agricultural, forestry and pasture activities. The issue of the revegetation of sub and periglacial scree slopes is more ambiguous, as a reduction in the intensity of the debris-forming process also plays a role (Arquès, 2005).

Methodological challenges

The capacity of Alpine communities to respond to these issues will very much depend on our ability to understand and anticipate the environment's future trends. However, these present a number of methodological challenges to science.

NO REFERENCES FROM THE PAST

One of the problems is the fact that we cannot draw from any similar situation in the past. Of course, glaciers have at times been smaller than they are today, indeed on several occasions throughout the last ten millennia (Hormes *et al.*, 2006), but today's glaciers are lagging behind in terms of climate change. If they were in balance with the current climate, they would undoubtedly be very close to the lowest levels of the Holocene. Tomorrow's climates will therefore be even warmer. Admittedly, the Holocene climatic optimum, which reached a peak between 8000 and 6000 years ago, was warmer and dryer than today. This situation was not however due to a more intense greenhouse effect, but to differences in the earth's orbit, resulting in an altered distribution of solar energy on earth. The earth was not hotter overall: the distribution of energy was simply different. Seasonal differences in the Northern hemisphere were heightened: it would have been warmer in summer yet colder in winter, and the higher latitudes were no warmer than they are today. The future will unfold in an entirely different context, so the Holocene climatic optimum cannot be used as a reference.

Therefore, forecasts (or predictions) cannot rely on modelling alone, with all of its typical problems: resolution of models, necessary simplifications, lack of knowledge about certain feedback phenomena and so on.

Nevertheless the main challenge remains without a doubt the prospect of a lasting ecological crisis, with no signs of stabilisation.

TOWARDS A PERMANENT ENVIRONMENTAL CRISIS?

Models showing the adjustment of systems to changes in framework conditions generally simulate a more or less rapid change from stable condition A to stable condition B, and demonstrate that systems react after a certain threshold has been crossed (which indicates the system's resistance to change) and, after a slight delay, progressively move towards a new more or less long-term state. From the starting point of one self-regulated stable state, another self-regulated stable state is eventually reached. The transition phase can lead to a crisis, depending on the magnitude and speed of the change in the framework conditions. This is how environmental crisis models are generally presented, whether these involve, for example, the biostasy/rhexistasy dichotomy or paraglacial adjustment (Ballantyne, 2002).

However, conditions in the 21st Century are entirely different: several centuries of continual climate change are being predicted, with no prospect of stabilisation for a long time. How will natural systems react in conditions of constant change? Are we moving towards a permanent environmental crisis?

In conditions of perpetual change, systems will indeed never be able to stabilise into a new state, so their future state is hard to predict. The evolution of glaciers is a good illustration of this state of constant imbalance: for 20 years they have been melting without “catching up” with the climatic conditions, and the concept of a glacier equilibrium line no longer means much today!

A further challenge presents itself in the domain of natural risk management. All of the traditional approaches to hazard assessment are based on a stationary-state hypothesis: either a series of historic events is used directly to calculate the probability of events of a given intensity, or trigger phenomena, matched to a series of measurements are inserted into physical-based models to simulate potential events. In a fast-changing climate, older data soon loses its relevance for anticipating the future. The design of all works and hazard zoning will therefore need to be reviewed, and it will no longer be possible to ensure protection objectives. Certainly, an endless amount of scenarios can be introduced into physical-based simulation models, provided that one is capable of hypothesising them.

The response of research programmes

In the face of such challenges, what is the capacity of research programmes to respond effectively to both the needs of the players in the field of Alpine development and of those of research?

THE GENERAL SITUATION

Compared with funding for high latitude (polar) research, high altitude (mountain) research remains meagre to say the least. There have certainly been significant developments since 2007, but these have provided few solutions to the issue of funding for fundamental research, and even fewer to that of interdisciplinary mountain research. Almost all existing funding programmes for fundamental research on, for example, mountain climatology or hydrology, or glacier melt, are national (ANR (French National Research Agency), *zones-ateliers* (special research areas) etc.) Obviously, the results are presented at key geosciences congresses such as that of the EGU (European Geosciences Union) which brings together researchers in this field whose work covers the mountains of Europe and the rest of the world. This conference demonstrates the imbalance between polar and mountain research. Even though the issues at stake are clear and the willingness to fund mountain research is developing, this is far too little to meet the needs of a fast-expanding scientific community. The following pages provide a summary of the different European funding options for mountain research. We can categorically observe that much more direct or indirect pressure must be applied to encourage funding for mountain research. Bodies that strive to stimulate and support the development of networks and projects have a key role to play in this context: some good examples are the MRI (Mountain Research Initiative) on a European scale, or the *Institut de la Montagne* and the *Pole Grenoblois Risque naturels* in France.

PROGRAMMES

Interreg

Currently, the best opportunities to obtain funding for applied Alpine research with the strong support of players are the Interreg “Alpine Space” or cross-border programmes. It must be emphasised however that applied research is not the main objective of Interreg, and its programmes only cover part of the mountain research fields. There are three key sections to the Alpine Space 2007-2013 programme: “competitiveness and attractiveness”, “accessibility and connectivity”, and “environment and risk prevention”. One of the most common reasons that projects submitted to Interreg’s Alpine Space are not selected is because they are overly scientific! Research must be applied and be applicable in practice. This therefore excludes basic research on climatological and hydrological predictions, glacial lake break-up, avalanches and ecology. In the current Interreg Alpine Space programme, only one true research programme has been selected for 2008 ñ 2011: the PermaNET project which aims to build a long-term permafrost observation and monitoring network across the Alps, bringing together 13 scientific and institutional partners from 5 countries. The largest programme selected in the environment section, Alp-Water-Scarce, is based around water management strategies to combat water shortages in the Alps. It involves hydroclimatological installations, modelling and developing scenarios, alongside the development of operational warning systems and strong input from those involved. Among the other projects selected, AdaptAlp (an extension of ClimChAlp) aims to develop adaptation strategies against natural risks in the face of climate change. The objective of ClimAlpTour, with over half of its project partners from university and research institutes, is to develop strategies for sustainable tourism in the Alps, based around the four seasons and climate change. Overall, only 12 projects (8%) were selected out of 138 proposals submitted.

In cross-border Interregs, there are many more opportunities for scientific and applied research work, for example basic research or training. In addition to the cross-border ALCOTRA project (France-Italy), there are further possibilities within the new France-Switzerland Interreg. Innovation, resource management, knowledge exchange across the network and in particular applicability and creation of employment opportunities are the underlying thrusts. “*The integrated management of the Haut Rhone River and its catchment area*” is an example of a cross-border project coordinated by scientists from both countries.

ESF (European Science Foundation)

The ESF contains 77 members from 30 European countries. Its objective is to promote high-quality research on a European level. It enables exploratory workshops (€15,000) and research network programmes (up to €120,000) to be organised, as well as facilitating collaborative research and conferences. Humanities, life and environmental sciences, engineering, social sciences, and polar and space sciences can all take part. “*Sustainable Development and Transboundary Co-operation in Mountain Regions*” is one such exploratory workshop. Another is the workshop on “*The Alpine and Carpathian conventions*” which took place in Budapest in September 2007 or the December 2005 SEDIFLUX

science meeting, in Durham, England. Moreover, networks exist such as PACE21 Permafrost and Climate in Europe, which seek to promote collaborative and interdisciplinary research on permafrost in the context of global climate change.

The *MRI (Mountain Research Initiative)* has made it possible for the WSL (the leading organisation) to submit a new FP7 Net-DYNAMO project (Network for integrated assessment of the dynamics of mountain catchments under global change). The aim of this research network programme is to produce integrated assessments and user tools for global climate change scenarios in selected mountain catchment areas, based on existing models. Currently, the project is being proposed to 20 other partner countries for co-funding.

The MRI is very active in distributing information on different funding options available, as well as organising information and exchange meetings.

ERC (European Research Council)

The ERC was created by the political institutions of the European Union to encourage the setting up of a common research area in Europe. It will be the first European agency for research into all fields of knowledge, from humanities and social sciences to life and physical sciences and engineering.

COST (European Cooperation in Science and Technology)

The work of COST is supported by the EU RTD framework programme. COST enables scientific consortia to be set up, but only covers travel, workshop and conference costs for short-term scientific projects (up to €150,000). Funding for in-depth research with scientific equipment is not included. COST currently only handles a single network concerning mountain areas: FP0601 “*Forest Management and the Water Cycle*” (FORMAN) which forms part of “*Forests, their Products and Services*” (FPS). The other possible field is the “*Earth System Science and Environmental Management*” (ESSEM) category. This includes hydrometeorological risk prediction and mitigation as well as environment and natural resource management. COST financed an initial meeting to define the final strategy in the field of “Global change and sustainable development in mountain regions” which took place in Innsbruck in April 2008.

FP7

The FP7 offers various possibilities, but other than the calls for proposals about vulnerable mountain regions in 2007¹ and Himalaya in 2008², no subject has been opened which has a broad yet specifically mountain-related scope. In terms of acceptance rate for the ENV 1.1.5.2 call for proposals, a large integrated project, 15 projects were submitted but only one selected (6%).

1 • ENV 2007 1.1.5.2. “*Climate change impacts on vulnerable mountain regions*”.

2 • ENV. 2008.1.1.6.1 “*Impacts of Himalayan glacier retreat and monsoon pattern change on the water resources in Northern India and adaptation strategies*”.

Among the new calls for proposals, there have been about eight which, without being specifically focused on mountains, are interesting due to the Alpine environmental issues they cover: such topics as climate, ecosystems, hydrology and remote sensing for example. On the theme of climate there is the programme “Climate dynamics and abrupt changes – analysis of the paleo record”³, which looks at the reconstruction, the integrated analysis and modelling of past conditions with a special focus on glaciers, multidisciplinary approaches, archives and especially biological processes and biogeochemical cycles. This covers a large geographical area, including Argentina, Chile, Canada, the United States, Russia, China and South Africa. The call for proposals on “climate change impacts and responses”⁴ seeks to facilitate collaboration between funding agencies and their research programmes on climate change. It supports transnational research activities including joint calls for proposals. ERA-NET projects are typically run by national agencies. The problem with these projects up until now was that they were focused on issues not specifically related to mountains, for example the Mediterranean in 2007. We hope that future projects will allow a greater scope for mountains. ERA-NET, 1.1.6.4, once it is formed, will logically be coordinated by the MRI, which will encourage national agencies to take part. The call for proposals “Climate change predictions in Sub-Saharan Africa, quantification of impacts and assessment of adaptation measures”⁵ aims to improve the quality of seasonal forecasts and decadal climate change predictions through better forecasting models and better understanding of the impacts of climate change in key sectors such as water resources and agriculture. Adaptation strategies with their costs benefits and the strong involvement of the African research community are required. The MRI is creating a “sub-consortium” on mountains in Africa.

As far as ecology is concerned, the call for proposals “Quantification and attribution of annual-to-decadal changes of carbon and GHG budgets in European terrestrial ecosystems to human and natural drivers and associated climate-carbon feedback”⁶ is based around the quantification of annual-to-decadal changes in the carbon and GHG budget of European terrestrial ecosystems, including forests, assess vulnerability of terrestrial carbon pools and risks of positive feedback in the climate-carbon system. These observations can be extended to southern Europe. This will allow researchers working on mountain forests to set up consortia and presents a real opportunity for researchers from eastern and southern Europe (Carpathians and Turkey). There are also “Wild fires in the context of climate and social change”⁷ and “Sustainable forest management as a tool to prevent unwanted forest fires”⁸: these calls for proposals aim to study, improve and integrate possible scenarios resulting from the effects of climate change, drought, heatwaves, and human, social and economic impacts to better manage future fire regimes and landscape solutions. Active participation

3 • ENV.2009.1.1.1.1 (large collaborative project, €7m).

4 • ENV.2009.1.1.6.4 ERA-NET (€2 million).

5 • ENV.2009.1.1.5.1 (small to medium collaborative projects €3.5 million).

6 • ENV.2009.1.1.3.1 (large collaborative project, €7 million).

7 • ENV.1.3.1.1 (Large Collaborative Project, €7 million).

8 • ENV.2009.2.1.6.1.

in Mediterranean and North African countries is required, as well as countries with extensive experience in fire research.

For hydrology there is call for proposals “Water management and climate change impacts in the long term perspective”⁹, which looks at long-term water management and the effects of climate change. Long-term assessment and modelling of the impacts of climate change on hydrochemical, hydrological and ecological processes and the dynamics of river basins and their wetlands will be carried out. The effects of climate change on wetland and freshwater biodiversity, water quantity and quality, ecological thresholds for different water body types under various land use and management regimes will be addressed. Ecological indicators and methodologies for analyzing vulnerability to climate change will also be covered. Mountain headwater areas can be examined in terms of water quantity and timing of release. Coordination between mountain hydrologists is required. The call for proposals “Climate induced changes in water resources in southern Europe and neighbouring countries as a threat to security”¹⁰, seeks to study the impacts of climate change on water resources and extremes conditions in southern Europe and neighbouring countries which are threatening national food security. Modelling capabilities will be improved by integrating meteorological and climatological aspects. This will require the involvement of vulnerable regions of southern Europe and one or several North African countries as well as Mediterranean and Middle-Eastern partners. The consortium needs two European and two North African, Mediterranean or Middle-Eastern regions. Mountain hydrologists from Spain, Morocco, Italy, Greece, Turkey and other countries will be invited to participate, and the *Institut de la Montagne* has already created a consortium for the latest call for proposals which it is planning to issue again.

The last call for proposals in the environment programme which is of interest for mountain research concerns remote sensing: “Further structuring the European approach to Earth Observation”¹¹. This aims to facilitate collaboration between pan-European organisations involved in Earth observation using both in-situ and space systems, and coordination and collaboration between national and regional programmes in atmospheric and oceanographic monitoring.

Conclusion

Clearly, the challenges are huge, and after many years of essentially national or cross-border funding, environmental research is starting to be structured on an Alpine or even European scale. There will be many future calls for proposals, and the new challenge facing researchers will be to build structured projects supported by solid Alpine networks. Networking bodies, such as the recently established MRI Europe, are starting to play a role as a forum for meetings and exchanges, and are fostering new projects.

Translation: Accent mondial

9 • ENV.2009.2.1.2.1 (Large Collaborative Project, €7 million).

10 • ENV.2009.1.1.5.2 (small to medium collaborative projects, €3.5 million, coordinated with Theme 8: Socio-Economic Science and Humanities).

11 • ENV.2009.4.1.2.1 (€1 million).

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Organismes de “networking” cités :

MRI - Mountain Research Initiative - MRI Europe : <http://mri.scnatweb.ch>

Pôle Grenoblois Risques Naturels : www.risknat.org

Institut de la Montagne : www.institut-montagne.org

Principaux programmes et projets de recherche cités :

Interreg Alpine Space: www.alpine-space.eu

ClimChAlp: www.climchalp.org

AdaptAlp: http://www.alpine-space.eu/the-projects/running-projects/?tx_txrunningprojects_pi1%5Buid%5D=4&tx_txrunningprojects_pi1%5Bview%5D=singleView

PermaNET: www.permanet-alpinespace.eu

Alp-Water-Scarce www.alpwaterscarce.eu

ClimAlpTour: http://www.alpine-space.eu/the-projects/running-projects/?tx_txrunningprojects_pi1%5Buid%5D=9&tx_txrunningprojects_pi1%5Bview%5D=singleView

FORMAN – “Forest Management and the Water Cycle.” Action COST FP0601: www.cost.esf.org/index.php?id=143&action_number=FP0601