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Scenarios as a tool for large-scale ecological research: experiences and legacy of the ALARM project

THE ROLE OF SCENARIOS IN GLOBAL CHANGE STUDIES

Scenarios can play a valuable role in providing coherence to studies of future global change, especially when such studies address multiple objectives and draw upon diverse disciplines and research traditions. The advantages of a scenario-based approach can include (Alcamo, 2001; Rounsevell & Metzger, 2010):

1. Offering a framework for representing uncertainties in future socio-economic and technological developments that are the driving forces of environmental change.

2. Providing an opportunity to integrate the key drivers of environmental change and their impacts and interactions within a common logic.

3. Raising awareness of future changes, all plausible, many contingent on human decisions, some seemingly unavoidable, others merely conceivable, but none predictable in a probabilistic sense.

4. Combining qualitative and quantitative information about the evolution of future environmental conditions.

5. Imposing consistency in characterizing future conditions across diverse studies spanning different sectors, regions, societies and scales of analysis, thus facilitating the direct intercomparison of results.

6. Allowing analysts to explore plausible future developments that may have important implications for current and future decision making.

There can also be disadvantages in adopting a scenario approach. For instance, selection of a few scenarios that are subsequently applied in all aspects of a study may impose constraints on the analysis that could result in too narrow or unrepresentative visions of the future. Furthermore, the credibility of results that rely upon scenarios will normally rest on the perceived legitimacy of the scenarios among those groups analysing and using them. To encourage 'buy in', extensive stakeholder involvement is usually required in the design and development of scenarios and storylines, a process that can be time-consuming and resource intensive (Alcamo, 2001).

SCENARIOS FOR ADDRESSING FUTURE RISKS TO BIODIVERSITY

Whilst acknowledging its potential difficulties, a scenarios approach appeared to offer the most promising basis in the ALARM (Assessing LArge-scale environmental Risks for biodiversity with tested Methods) project for exploring possible future risks to biodiversity and for integrating across diverse disciplines. ALARM involved more than 250 scientists from 68 institutions and 35 countries (see Settele *et al.*, 2005; Spangenberg *et al.*, 2012). Its central goal was to undertake an integrated large-scale assessment of risks to biodiversity in terrestrial and freshwater ecosystems, with a focus on the following four risk areas: climate change, environmental chemicals, pollinator loss and biological invasions. The project developed a set of risk indicators that can be related to various socio-economic drivers of biodiversity pressure, which are intended to support long-term policy-making on biodiversity conservation as well as offering a guide for monitoring the effectiveness of policy implementation.

A key scientific challenge of the project was to integrate the multiple disciplines, perspectives and scales represented by the consortium within a common research framework that could draw upon diverse disciplinary traditions, methods and tools, while adequately addressing issues of uncertainty. In this context scenarios were regarded as a potentially valuable tool, both as a method of integrating different strands of the project and as a means for addressing alternative future pathways that might have an important effect on biodiversity. Thus, the use of scenarios is aimed at:

1. Making the results more consistent across the project, and hence potentially more useful to the policy process than multiple independent analyses of future risks.

2. Stimulating multidisciplinary exchange and interdisciplinary learning.

3. Gaining the attention of key stakeholders with a set of coherent messages that contribute towards enhanced awareness of threats to biodiversity in Europe and beyond.

Scenarios are not predictions but rather a means to generate information by illustrating possible future developments under conditions of uncertainty (Alcamo, 2001; Spangenberg *et al.*, 2012). They deal with multivariable state changes, which cannot be analysed empirically in a laboratory or greenhouse setting while – as often also in economic theory – assuming that everything else remains constant. Unlike forecasts or predictions, to which probabilities can be attached, scenarios characterize future developments that are largely driven by human actions and are generally regarded, to all intents and purposes, as being impossible to predict or foresee (van der Sluijs, 2002). Thus, assumptions have to be made, constituting scenario narratives which are supported whenever possible by model simulations (Alcamo, 2001).

Scenarios can provide a comprehensive view of plausible (not necessarily probable) future developments, and they can deal

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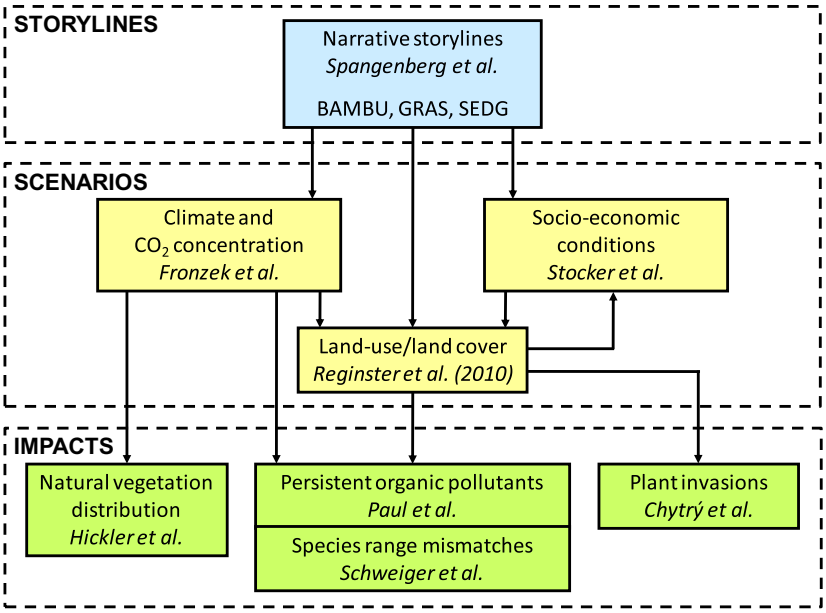

Figure 1 Relationships between the ALARM (Assessing LArge-scale environmental Risks for biodiversity with tested Methods) storylines and scenarios, and to their application in impact studies (arrows). Citations in italics are to papers in this Special Issue (undated) and to a published source (dated). BAMBU, 'Business As Might Be Usual'; GRAS, 'GRowth Applied Strategy'; SEDG, 'Sustainable European Development Goal'.

with complexity. This way they serve as a means to explore the possible future outcomes of decisions taken (or not taken) now. Within ALARM, scenarios developed are broad pictures of archetypical possible futures aiming to derive information on risks to biodiversity from a diverse range of factors during the 21st century. The three core scenarios are BAMBU ('Business As Might Be Usual'), an extrapolation of current policy trends, and two alternative policy options, GRAS ('GRowth Applied Strategy') simulating a policy of deregulation and globalization, and SEDG ('Sustainable European Development Goal'), a sustainable development policy scenario. To test the robustness of the scenarios, and as the future can be expected to diverge from simple trend extrapolation, three 'shock scenarios' (assuming unexpected events) were also developed. Further details on the development of these scenarios are provided in the opening paper in this collection (Spangenberg *et al.*, 2012). More information on the quantification of specific elements of the scenarios is given in Fronzek *et al.* (2012), Stocker *et al.* (2012) and Reginster *et al.* (2010). Figure 1 illustrates the linkages between these papers and with other papers in the Special Issue that describe applications of the scenarios.

APPLICATION OF THE ALARM SCENARIOS

So how can we judge the usefulness of the ALARM scenarios? Of course, they have served a purpose within the project itself, as evidenced from the papers in this issue and elsewhere (or yet to appear) that made use of them (cf. Fig. 1). Economic (GINFORS; see Stocker *et al.*, 2012) and land-use scenarios (MOLLUSC; Reginster *et al.*, 2010; see Spangenberg *et al.*, 2012) were harmonized and related to different IPCC Special Report on Emissions Scenarios (SRES) climate scenarios (A1FI, A2, B1; see Fronzek *et al.*, 2012), providing a reference base for the vegetation, plant invasion and chemical deposition scenarios (Chytrý *et al.*, 2012; Hickler *et al.*, 2012; Paul *et al.*, 2012) as well as species distribution models for the projection of species ranges and species richness under scenario conditions (e.g. Araújo *et al.*, 2006; Pompe *et al.*, 2010; Schweiger *et al.*, 2012).

However, a more lasting measure of their utility would be their continued adoption within the wider research community. They have already been adopted in other European Commission (EC)-funded projects like COCONUT[1], ECOCHANGE[2], MACIS[3], SCALES[4], and STEP[5], national research programmes like Mistra-SWECIA[6], and ISTO[7], as well as other research projects like LEGATO[8], CLIMIT[9], and PRONAS[10]. Further success here can only be evaluated at some future time, but would provide a judgement on whether the scenarios: (1) are comprehensible and readily accessible to the research community; (2) are regarded as credible, salient and legitimate (Cash *et al.*, 2003) by potential users; and (3) offer advantages over other comparable scenarios available from elsewhere.

[1]http://www.coconut-project.net/
[2]http://www.ecochange-project.eu/
[3]http://www.macis-project.net/
[4]http://www.scales-project.net/
[5]http://www.step-project.net/
[6]http://www.mistra-swecia.se/
[7]http://www.mmm.fi/en/index/frontpage/adaption/isto.html
[8]http://www.legato-project.net/
[9]http://www.climit-project.net/
[10]http://www.ufz.de/index.php?de=17465

This was not the first EC-funded integrated project to develop and apply scenarios, so it would be instructive to point to earlier cases where scenarios developed for a specific application have been embraced more widely. Examples include the Fifth Framework Programme (FP5) ATEAM (Advanced Terrestrial Ecosystem Assessment and Modelling) scenarios, elements of which were developed in the parallel FP5 ACCELERATES (Assessing Climate Change Effects on Land use and Ecosystems: from Regional Analysis to the European Scale) project on European land use and subsequently adopted in ALARM, the FP5 PRUDENCE (Prediction of Regional scenarios and Uncertainties for Defining European Climate change risks and Effects) climate projections, which were used to frame the PESETA (Projection of Economic Impacts of Climate Change in Sectors of the European Union Based on Bottom-up Analysis) study of economic impacts of climate change in Europe, and the FP6 SCENES (Water Scenarios for Europe and for Neighbouring States) scenarios for the water sector in Europe (Kämäri *et al*., 2008), aspects of which have been adopted in the ongoing FP7 CLIMSAVE (Climate Change Integrated Assessment Methodology for Cross-Sectoral Adaptation and Vulnerability in Europe)[11] and MEDIATION (Methodology for Effective Decision-making on Impacts and Adaptation)[12] projects.

Other measures of the usefulness of scenarios are the citation rate of publications in which they are described, the breadth of disciplines represented by the citing articles and the frequency of downloads of the scenario data. For example, the heavy citation of the European climate dataset prepared for the ATEAM project (Mitchell *et al*., 2004) and subsequently adopted by ALARM (Fronzek *et al*., 2012), especially in ecological, agricultural and forest modelling articles, appears to be explained by a conjunction of factors, including:

1. The utility of combining historical climate data with future projections in a single, easily accessible, gridded dataset.

2. The salience of the scenarios, which are largely consistent with the core set described in the IPCC SRES (Nakićenović *et al*., 2000).

3. The variables represented in the dataset, which comprise those most frequently requested as input to models simulating plant growth and evapotranspiration.

4. The format of the data, which is ideally suited for application in ecological models, either as a whole (for running time-dependent, dynamic vegetation models), or as time slices in the past for which ecological data are available and can hence be matched statistically to the climate.

Moreover, a progressive annual growth in citations has been recorded, many of which are common between this dataset and the similarly well-cited land-use change scenarios prepared for the same ATEAM project (Rounsevell *et al*., 2005), especially concerning studies of multiple stresses on biodiversity in Europe.

Only time will tell whether the ALARM scenarios will succeed in offering useful insights to a wider constituency of users. The SRES scenarios are due to be superseded by a new set of global socio-economic, technological, land-use, emissions and climate scenarios developed by the international research community (Moss *et al*., 2010) ahead of the IPCC Fifth Assessment Report (AR5). However, this should not imply that the ALARM scenarios will become invalid; rather the new scenarios can be regarded as complementary, providing richer and more regionally specific socio-economic characterizations than the SRES, some of which are still perfectly consistent with the ALARM biodiversity-orientated information. An important task of the IPCC AR5 will be to assess how the new scenarios relate to SRES and to some other global scenario exercises. From this analysis it should then be possible to gauge the lasting value of the ALARM scenarios for continued application in the future.

[11]http://www.climsave.eu/climsave/

[12]http://mediation-project.eu/

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REFERENCES

Alcamo, J. (2001) *Scenarios as tools for international environmental assessments*. Environmental Issue Report No. 24, p. 31. Office for the Official Publications of the European Communities, Luxembourg.

Araújo, M.B., Thuiller, W. & Pearson, R.G. (2006) Climate warming and the decline of amphibians and reptiles in Europe. *Journal of Biogeography*, **33**, 1712–1728.

Cash, D.W., Clark, W.C., Alcock, F., Dickson, N.M., Eckley, N., Guston, D.H., Jäger, J. & Mitchell, R.B. (2003) Knowledge systems for sustainable development. *Proceedings of the National Academy of Sciences USA*, **100**, 14, 8086–8091.

Chytrý, M., Wild, J., Pyšek, P., Jarošík, V., Dendoncker, N., Reginster, I., Pino, J., Maskell, L.C., Vilà, M., Pergl, J., Kühn, I., Spangenberg, J.H. & Settele, J. (2012) Projecting trends in plant invasions in Europe under different scenarios of future land-use change. *Global Ecology and Biogeography*, **21**, 75–87 (this issue).

Fronzek, S., Carter, T.R. & Jylhä, K. (2012) Representing two centuries of past and future climate for assessing risks to biodiversity in Europe. *Global Ecology and Biogeography*, **21**, 19–35 (this issue).

Hickler, T., Vohland, K., Feehan, J., Miller, P.A., Smith, B., Costa, L., Giesecke, T., Fronzek, S., Carter, T.R., Cramer, W., Kühn, I. & Sykes, M.T. (2012) Projecting the future distribution of European potential natural vegetation zones with a generalized, tree species-based dynamic vegetation mode. *Global Ecology and Biogeography*, **21**, 50–63 (this issue).

Kämäri, J., Alcamo, J., Bärlund, I., Duel, H., Farquharson, F., Flörke, M., Fry, M., Houghton-Carr, H., Kabat, P., Kaljonen, M., Kok, K., Meijer, K.S., Rekolainen, S., Sendzimir, J., Varjopuro, R. & Villars, N. (2008) Envisioning the future of water in Europe – the SCENES project. *E-WAter*, 1–28. Available at: http://www.ewaonline.de/portale/ewa/ewa.nsf/home?readform&objectid=19D821CE3A88D7E4C12574FF0043F31E (date of upload 22 July 2008; accessed 4 October 2011).

Mitchell, T.D., Carter, T.R., Jones, P.D., Hulme, M. & New, M. (2004) *A comprehensive set of high-resolution grids of monthly climate for Europe and the globe: the observed record (1901–2000) and 16 scenarios (2001–2100)*. Tyndall Centre Working Paper 55. Tyndall Centre for Climate Change Research, University of East Anglia, Norwich, UK.

Moss, R.H., Edmonds, J.A., Hibbard, K., Manning, M., Rose, S.K., van Vuuren, D.P., Carter, T.R., Emori, S., Kainuma, M., Kram, T., Meehl, G., Mitchell, J., Nakicenovic, N., Riahi, K., Smith, S., Stouffer, R.J., Thomson, A., Weyant, J. & Wilbanks, T. (2010) The next generation of scenarios for climate change research and assessment. *Nature*, **463**, 747–756.

Nakićenović, N., Alcamo, J. & Davis, G. *et al.* (eds) (2000) *Emissions scenarios. A special report of Working Group III of the Intergovernmental Panel on Climate Change*. Cambridge University Press, Cambridge.

Paul, A.G., Hammen, V.C., Hickler, T., Karlson, U.G., Jones, K.C. & Sweetman, A.J. (2012) Potential implications of future climate and land-cover changes for the fate and distribution of persistent organic pollutants in Europe. *Global Ecology and Biogeography*, **21**, 64–74 (this issue).

Pompe, S., Hanspach, J., Badeck, F.W., Klotz, S., Bruelheide, H. & Kühn, I. (2010) Investigating habitat-specific plant species pools under climate change. *Basic and Applied Ecology*, **11**, 603–611.

Reginster, I., Rounsevell, M., Butler, A. & Dedoncker, N. (2010) Land use change scenarios for Europe. *Atlas of biodiversity risk* (ed. by J. Settele, L. Penev, T. Georgiev, R. Grabaum, V. Grobelnik, V. Hammen, S. Klotz, M. Kotarac and I. Kühn), pp. 100–105. Pensoft Publishers, Sofia and Moscow.

Rounsevell, M.D.A. & Metzger, M.J. (2010) Developing qualitative scenario storylines for environmental change assessment. *WIREs Climate Change*, **1**, 606–619.

Rounsevell, M.D.A., Reginster, I., Araújo, M.B., Carter, T.R., Dendoncker, N., Ewert, F., House, J.I., Kankaanpää, S., Leemans, R., Metzger, M.J., Schmit, C., Smith, P. & Tuck, G. (2005) A coherent set of future land use change scenarios for Europe. *Agriculture, Ecosystems and Environment*, **114**, 57–68.

Schweiger, O., Heikkinen, R.K., Harpke, A., Hickler, T., Klotz, S., Kudrna, O., Kühn, I., Pöyry, J. & Settele, J. (2012) Increasing range mismatching of interacting species under global change is related to their ecological characteristics. *Global Ecology and Biogeography*, **21**, 88–99 (this issue).

Settele, J., Hammen, V., Hulme, P. *et al.* (2005) ALARM: assessing LArge-scale environmental risks for biodiversity with tested methods. *Gaia – Ecological Perspectives for Science and Society*, **14**, 69–72.

van der Sluijs, J. (ed.) (2002) *Management of uncertainty in science for sustainability*. Copernicus Institute, Utrecht University, Utrecht.

Spangenberg, J.H., Bondeau, A., Carter, T.R., Fronzek, S., Jäger, J., Jylhä, K., Kühn, I., Omann, I., Paul, A., Reginster, I., Rounsevell, M., Schweiger, O., Stocker, A., Sykes, M.T. & Settele, J. (2012) Scenarios for investigating risks to biodiversity. *Global Ecology and Biogeography*, **21**, 5–18 (this issue).

Stocker, A., Omann, I. & Jäger, J. (2012) The socio-economic modelling of the ALARM scenarios with GINFORS: results and analysis for selected European countries. *Global Ecology and Biogeography*, **21**, 36–49 (this issue).