as methane or nitrous oxide are significant for climate change in the next few decades or century, but these gases do not persist over time in the same way as carbon dioxide'' (Solomon et al. 2009, p 1705).

Reasons for Concern

Reasons for concern about stabilizing greenhouse gases in the atmosphere that impact climate change are identified in the Third Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) (Smith et al. 2009). The risks after 1990 for each increase in temperature from 0 to 5 °C in global mean temperature are substantial: 1) risk to unique and threatened systems, 2) risk of extreme weather events, 3) distribution of impacts, 4) aggregate damages, and (5) risks of large-scale discontinuities (e.g., tipping points). Article 2 of the United Nations Framework Convention on Climate Change (UNFCCC) commits signatory nations to stabilizing greenhouse gas concentrations in the atmosphere at a level that ''would prevent dangerous anthropogenic interference (DAI) with the climate system'' (United Nations 1992; http://unfcc.int/resource/docs/convkp/convegn.pdf). ''The UNFCCC also highlights 3 broad metrics with which decision-makers are to assess the pace of progress toward this goal: allow 'ecosystems to adapt naturally to climate change,' ensure that 'food production is not threatened,' and enable 'economic development to proceed in a sustainable manner''' (Smith et al. 2009, p 4133).

The above metrics are very difficult assessment and management goals, especially because the present reasons for concern indicate that the perceived risks are significantly greater than they were in 2001. The changed perception of risks is quite understandable because much more data were available in 2009 than in 2001, but the methods and procedures for assessing risks during rapid climate change are, at best, in the early formative stages.

''As was true in the TAR (Third Assessment Report of the IPCC), the aggregation of risk across many different sectors, regions, or populations under a particular reason for concern is subjective and thereby introduces another source of uncertainty'' (Smith et al. 2009, p 4135). However, anthropogenic greenhouse gas emissions are still increasing substantially, and, as global mean temperature increases, carbon emissions in positive feedback loops from stored carbon (e.g., wetlands and tundra) are likely to increase as well, further exacerbating the problem.

Natural Capital and Ecosystem Services

Although the three broad metrics highlighted by the UNFCCC are persuasive, none will be achieved if the biospheric life support system fails. As a consequence, this potential failure dramatically increases the risks to which humankind may well be exposed in the near future. Little has been done to protect either natural capital or ecosystem services in comparatively robust economic times, so the prospects of any significant actions during a global financial meltdown seem dim. However, humankind is totally dependent on natural capital and the ecosystem services it provides, and, because Solomon et al. (2009) make a persuasive case for climate change being irreversible, substantive measures are required immediately to protect and nurture them. The consequences of small global temperature increases discussed by Smith et al. (2009) are not attractive at best and appalling at worst. Clearly, anthropogenic carbon dioxide emissions into the atmosphere must be reduced by 80% now because climate changes are already having very serious deleterious impacts in some parts of the world (e.g., Australia's ecological footprint is not changing, but its biocapacity is plummeting from the results of environmental changes [http://www.footprintnetwork.org/en/index.php/GFN/page/trends/australia/]). The required changes in lifestyle are distasteful, but the consequences of ''business as usual'' are unacceptable.

Ethical Considerations

Climate changes that have already occurred pose serious threats to future generations. Altered temperatures, rainfall patterns, and water shortages have already adversely affected agricultural productivity worldwide and, with 215,000 new mouths to feed daily (plus the approximately 1 billion people who go to bed hungry each night), further strains on the agricultural systems must be avoided. Finally, these changes are adversely affecting the millions of species with which humans share the planet, which, in the aggregate, constitute the biospheric life support system. Both environmental assessment and management will be more difficult due to irreversible climate change, but they must continue.

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INTEGRATING POPULATION MODELING INTO ECOLOGICAL RISK ASSESSMENT

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Current approaches to ecological risk assessment (ERA) are not sufficient to address environmental protection goals stated in current regulations in the European Union, North America and elsewhere. For example, the data used to estimate the likelihood of adverse ecological effects typically include responses of survival, growth, or reproduction of individuals measured under constant and typically favorable laboratory conditions. But these organism-level endpoints are far removed from the ecological features that the process aims to protect (i.e., the long-term persistence of populations of species in space and time under naturally varying field conditions and in the presence of other stressors). Ecological risk is most often characterized as a hazard ratio of predicted or measured exposure to predicted no-adverse-effect level expressed as a concentration or dose. It is widely accepted that such hazard ratios provide useful screening tools when exposure and no-effect levels are calculated using appropriately conservative assumptions. However, such ratios suffer from several disadvantages, not the least of which is that their relationship to the likelihood and degree of ecological impacts (i.e., risk) is unknown.

Risk assessments only make sense if they inform management decisions about if, how, and how much we need to intervene in economic activities such as the production, use, and disposal of chemicals, to protect nature. The ecological protection goals are specified imprecisely in the legal instruments implementing environmental protection policies and are supposed to reflect public preferences, i.e., what the public values. Because environmental interventions invariably involve restrictions to economic activities, they involve costs; it is, therefore, important to judge these in terms of the value put on the ecological systems and related ecosystem services saved by the intervention. These kinds of socioeconomic analyses are mandated in chemicals legislation in the European Union, North America, and other jurisdictions.

Yet risk assessments carried out under these instruments have been unsuccessful in informing socioeconomic analyses as part of risk management. As described above, hazard ratios have dominated risk assessment, and these are impossible to translate into ecological values. The connection between these ratios and protection goals is far from straightforward and usually relies on expert judgments that often need to be carried through into decisions about what the ratios mean in terms of the type and extent of management. The values of experts therefore dominate decisions about interventions. Moreover, the analyses used to calculate hazard ratios are often overly conservative, potentially leading to unnecessary restrictions, which wastes economic resources. Whether the costs associated with a given risk management decision are reasonable cannot be judged if the ecological benefits arising out of the intervention are not made explicit. Thus, there is a need to make the benefits more explicit and to express them in a way that can inform management decisions. Given that ecological protection goals are often closely related to the protection of populations of key species and/or biodiversity in general, we should be developing approaches that more directly and explicitly quantify impacts on such entities.

Appropriate population models can provide a powerful basis for expressing ecological risks in a way that better informs the environmental management process. For this reason, a group of approximately 30 stakeholders from industry, government regulatory bodies, and academia met for a 2-day workshop in Roskilde, Denmark, at the end of August 2009 (RUC09). The aims of the workshop were to review the current state of population modeling and agree on what needs to be done in the future to develop population modeling so that it can be used in risk assessment by industry and be understood and accepted by regulators. A major motivation behind this initiative is that, for the sake of more transparency and better risk communication, ecological risks need to be expressed in more relevant (value-relevant) units than hazard ratios—and these units will often be at a population level.

The workshop identified several ways that population modeling can add value to ERA by incorporating mechanistic linkages between suborganism and population-level responses. For example, it can reduce uncertainty in the extrapolation of standard test results to ecologically relevant impacts and, thus, produce outputs that are more closely related to protection goals; it can help to identify high-risk scenarios for which testing efforts can be prioritized; it can provide mechanistic understanding of ecological impacts, which can aid development of management actions; it can provide the kind of outputs (i.e., value-relevant units, such as changes in population density and/or size/age structure) that are essential for choosing among management alternatives and for facilitating cost-benefit assessments; and it can reduce the use of animal testing in a more ecologically sound manner than relying on in vitro methods or quantitative structure activity relationships

Whereas population modeling has been used extensively in conservation biology and other types of ecological management, its use in chemical risk assessment has been minimal. However, both industry and regulators are showing increasing interest in exploring the potential of such models in a risk assessment context as evidenced in several of recent initiatives (e.g., Munns et al. 2008; Forbes et al. 2009; Grimm et al. 2009; Preuss et al. 2009). There are several reasons that the timing is right to integrate population modeling into ERA. Although the new European legislation, REACH, will provide many challenges for industry, it also provides the opportunity for industry to define its own approach to address higher-tier risk assessments. For highly important chemicals that fail the standard risk assessment thresholds defined in REACH, cost-benefit analyses will be needed, and population models can be developed that provide exactly the kind of information required for socioeconomic analyses (e.g., risk of population decline or extinction). Also, the USEPA is currently rethinking its ERA Paradigm (Munns et al. 2008), which could provide exciting opportunities for improving the way in which risk assessments are approached. Finally, monitoring programs around the world, especially those focusing on sediments, are picking up the presence of some emerging contaminants (e.g., fragrance materials, personal care products, pharmaceuticals), and this will challenge industry to demonstrate that presence does not necessarily mean relevant ecological risk.

A full report of the RUC09 workshop conclusions will be published in 2010, and presentations from the workshop are being prepared for upcoming SETAC conferences. The aims for the future are to consolidate on the understanding that has been achieved in previous work and to move toward a more focused research program that will further demonstrate the importance and limitations of population modeling in the development of relevant ERAs. The output from the workshop will be used to develop a prioritized set of research proposals that will address the most pressing issues needed to facilitate the implementation of population modeling in ERA in a way that clearly adds value to the process. Watch this space!

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