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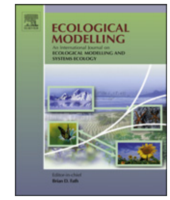

Common challenges for ecological modelling: Synthesis of facilitated discussions held at the symposia organized for the 2009 conference of the International Society for Ecological Modelling in Quebec City, Canada, (October 6–9, 2009)

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ABSTRACT

The eleven symposia organized for the 2009 conference of the International Society for Ecological Modelling (ISEM 2009) held in Quebec City, Canada, October 6–9, 2009, included facilitated discussion sessions following formal presentations. Each symposium focused on a specific subject, and all the subjects could be classified into three broad categories: theoretical development, population dynamics and ecosystem processes. Following discussions with the symposia organizers, which indicated that they all shared similar issues and concerns, the facilitated discussions were task-oriented around four basic questions: (1) key challenges in the research area, (2) generating and sharing new ideas, (3) improving collaboration and networking, and (4) increasing visibility to decision-makers, partners and clients. Common challenges that emerged from the symposia included the need for improved communication and collaboration among different academic disciplines, further progress in both theoretical and practical modelling approaches, and accentuation of technology transfer. Regarding the generation and sharing of new ideas, the main issue that emerged was the type of positive interactions that should be encouraged among potential collaborators. The usefulness of the Internet, particularly for the sharing of open-source software and conducting discussion forums, was highlighted for improving collaboration and networking. Several communication tools are available today, and it is important for modellers

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to use them more intensively. Visibility can be increased by publishing professional newsletters, maintaining informal contacts with the public, organizing educational sessions in primary and secondary schools, and developing simplified analytical frameworks and pilot studies. Specific issues raised in each symposium are also discussed.

Table 1
Symposia organized during the 2009 international conference of the International Society for Ecological Modelling (ISEM 2009).

Title	Organizers
1- Earth surface modelling and global ecology	Tian-Xiang Yue (China) Sven E. Jørgensen (Denmark) Guy R. Larocque (Canada)
2- Network modelling and systems theory: advances in network environ analysis	Caner Kazanci (United States) John Schramski (United States)
3- Individual-based models for conservation	Eliot J.B. McIntire (Canada) Danielle Marceau (Canada)
4- Ecological accounting	Bin Chen (China) Guogian Chen (China)
5- Forest simulation models for sustainable forest management under a changing environment	Changhui Peng (Canada) Guy R. Larocque (Canada) Daniel Mailly (Canada)
6- Ecological modelling for environmental flows	Zhifeng Yang (China)
7- Modelling the consequences of climate change on the agricultural landscape	Beata Novotna (Slovakia)
8- Modelling avian seasonal productivity	Matthew Etterson (United States)
9- Research perspectives in carbon cycle modelling to support sustainable terrestrial ecosystem management	Guy R. Larocque (Canada) Jagtar S. Bhatti (Canada) Jinxun Liu (United States) Alison Munson (Canada) Daniel Mailly (Canada) Andrew M. Gordon (Canada) Nancy Luckai (Canada) James C. Ascough II (United States) Louis Archambault (Canada)
10- Ecosystem modelling for decision support in water management	Peter Goethals (Belgium)
11- Static and dynamic approaches to modelling diversity and complexity	Madhur Anand (Canada)

1. Introduction

Eleven symposia on a variety of subjects were organized for the 2009 conference of the International Society for Ecological Modelling (ISEM 2009) held in Quebec City, Canada, October 6–9, 2009 (Table 1). In the year preceding the conference, the members of the organizing committee invited ecosystem modellers to submit proposals for the organization of symposia. The objectives of the symposia were to focus on a subject of interest to organizers and participants and provide a forum for constructive group discussions to develop new ideas or establish partnerships. Twenty-three ecosystem modellers from five different countries responded to the invitation. As indicated in Table 1, several subjects were discussed at the symposia, which can be classified into three broad categories: (a) theoretical development (1, 2, 4, 10 and 11), (b) population dynamics (3 and 7), and (c) ecosystem processes (5, 6, 8 and 9).

The format of the symposia consisted of formal presentations by guest speakers invited by the organizers (Appendix A), followed by a discussion period. As indicated in Appendix A, more than 75 communications by 269 authors were presented. In order to encourage all the participants to propose solutions and share ideas, the discussion sessions (which lasted between one and two hours) were led by facilitators who were trained to lead group discussions and highlight the main ideas in a concise manner. This type of facilitation in scientific conferences has proven its effectiveness and relevance in synthesizing the main ideas among large groups of participants (e.g., Larocque et al., 2009). The objective of this paper is to report the results of the facilitated discussions.

2. Methodology

The facilitators belonged to the Learning Organization Community of Practice (LOCOP) of Natural Resources Canada[1]. Before the symposia, a member of LOCOP, Mrs. Deidre Moore[2], interviewed the main organizer of each symposium to inquire about the specific objectives and subjects presented in the formal presentations. Following the interviews, the LOCOP came to the conclusion that the symposium organizers shared a common interest in the four following questions to be discussed among the participants:

1) What are the key challenges in this research area (ecosystem modelling)?
2) How can we generate and share new ideas?
3) How can we improve collaboration and networking?
4) How can we become more visible to decision-makers, partners and clients?

When the formal presentations ended in each symposium, the facilitators divided the participants into four groups. The participants in each group met together independently from the other groups to hold discussions on each question and propose answers. Then, at the end of the discussion period, all the participants gathered together and voted on the most important ideas, suggestions and solutions that came up during the discussions.

3. Results and discussion

3.1. Common suggestions and ideas

The initial data compilation phase indicated that many suggestions and ideas were similar in different symposia. To avoid redundancy in Section 3.2, this section describes the common outcomes from the symposia. During the subsequent data compilation phases, it was decided to classify the suggestions and ideas into different broad categories to allow readers to better understand the diversity of opinions expressed by the participants.

Regarding the identification of key challenges in ecosystem modelling (question 1), the suggestions and ideas from the different symposia were subdivided into five broad categories (Table 2). For information, society's needs and technology transfer, the key points that summarize the ideas and suggestions gathered are the importance of improved communication and collaboration among modellers from different academic disciplines, the difficulties inherent to conducting the work required to test new ideas, and the applicability of models by non-modellers to meet society's needs. There are still many challenges associated with the theoretical and practical aspects of model development, including

[1] http://wiki.nrcan.gc.ca/index.php/AFC_LoCOP.
[2] Library Manager, Natural Resources Canada, Laurentian Forestry Centre.

Table 2
Suggestions and ideas gathered during the facilitated discussion periods at the different symposia organized at ISEM 2009 to identify key challenges in ecosystem modelling (Question 1).

Information, society's needs and technology transfer	
	Availability of model libraries
	New ideas are hard to work out
	Few colleagues in this field
	Fragmented and isolated research efforts
	Adequating needs, projects and models
	Finding balance in economic, environmental and social aspects of our work
	Adaptative management
	Improve scientific collaboration
	Ensure models are applicable to actual field scenarios
	More, better, and user-friendly software (maybe econet does this)
	Sufficiently trained users of models we create
	Linkages between predictive models and decision support tools
	Transfer information among scientists and from scientists to managers (from theory to practice)
Model development (theory and practice)	
	Elaboration of an accepted and widely used ecosystem theory, which can guide the modelling process
	Integration of hierarchical spatial and temporal (dynamic) models
	Merging ontologies
	Capture all ecosystem properties in our models
	Effectively work with large number of models and connecting modelling with biological processes (interdisciplinary)
	Dealing with different scales and dimensions
	How to calibrate models
	Gaps in knowledge
	Making the links between remote sensing and field data
	Promote interdisciplinary research linking for enhanced sustainability
	Estimating covariances among model parameters
	Getting a better handle on variance in Start/End dates. Minimizing estimate error/variance
	Competing risk issues
	Hierarchical models
	Quantifying spatio-temporal autocorrelation in vital rates
	Bayesian model averaging (weights)
	Non-probabilistic uncertainty analysis
	Is error so big that certain analyses are simply impossible
	Correctly integrating data from multiple sources
	Assessing commonalities compensating parameter
	Bridge the gaps between field experiments and modelling
	Practical multiscale methods and data sharing
	Bridge the gap between academic and practical approaches without reducing the complexity of models
Importance of data in modelling	
	Data limitations are still important
	Data quality
	How to get data for large-scale studies
	How to deal with large sample size requirements
	Data collection issues – scale VS scope
	Getting good/appropriate data for the model
	Open datasets – no analysis, just descriptions
Dealing with uncertainty and validation	
	Error estimation in models and methodology
	Validation procedures
	Estimating and communicating uncertainty
	Start collecting validation data. Find adequate datasets to validate models
	How to reduce uncertainty
	Link between lack of confidence and uncertainty about real systems
	Data uncertainty

a commonly accepted ecosystem theory, the integration of spatial and temporal scales, and the application of methodologies and calibration approaches. Despite the fact that many datasets are available, data quality and suitability for model development still remain a major issue in ecosystem modelling. The importance of dealing with uncertainty and validation was identified as a key challenge. In particular, it will be important for modellers to better communicate what uncertainty is all about. Another suggestion that can be summarized in one expression, *interdisciplinary science*, had the distinction of emerging as integral to the solution to all perceived challenges. When potential solutions were ranked, *interdisciplinary science* also appeared at or near the top with regard to the level of importance in each area of discussion. These findings agree with some of the latest efforts where research, conferences, and related publications in ecological sciences continue to address interdisciplinary science and management (Ewel, 2001; Leimu and Koricheva, 2005; Schramski and Gattie, 2009; Solidoro et al., 2009). While there is a need for new and innovative approaches to understand the complex structure of living systems, new mathematical problems arising from life sciences provide new opportunities to advance quantitative sciences, which have mostly dealt with physical problems over the last few centuries (Cohen, 2004). Clearly, these efforts and the findings from this symposium indicate that interdisciplinary collaboration is increasingly viewed as vital to the advancement of network modelling and systems theory as well as the mathematical and computational sciences used to support them.

The results of the discussion on the generation and sharing of new ideas (question 2) resulted in suggestions that were subdivided into six broad categories (Table 3). Even though long-recognized ideas were discussed, such as interdisciplinary approaches and enhanced communications, participants highlighted the fact that generating ideas is generally not a problem, but implementing them is the true challenge. Specific attitudes, such as respect among collaborators, will be strongly desirable to improve how ecosystem modellers work together to generate new ideas. The importance of publications, including scientific and review papers, was once again recognized. However, it was felt that it would be important to reduce the publication pressure by focusing more on quality, not quantity. This issue is in agreement with an editorial published in *Ecological Modelling*, in which it was mentioned that papers presenting further advances in ecological modelling, not only papers that use existing models with different datasets, were essential to increase the scientific value of *Ecological Modelling* (Jørgensen et al., 2006). It is believed that Internet utilities should be used more intensively for exchanges among ecosystem modellers, the sharing of open-source software and the organization of collaborative efforts.

For question 3, "How can we improve collaboration and networking", the suggestions and ideas gathered were also subdivided into six broad categories (Table 4). Several items had also been identified in question 2, but these were not necessarily overlapping because the ideas and suggestions originated from discussion groups that met independently from each other. The role of ISEM in the organization of meetings and the development of Internet utilities was highlighted. For communications and Internet use, several ways to meet formally were suggested and they all rely on existing tools. If these Internet communications tools are used more often, it will become possible for collaborators to reduce their carbon footprint. Also, the need for data and model sharing was once again identified, as well as the necessity to promote open access to scientific literature. Despite the fact that the use of these tools may appear to advocate formal communications, the need for informal discussions was also clearly identified. For collaboration and training, interdisciplinary approaches in student training and the establishment of exchange programs were advocated. For community actions, sharing data, methodologies and procedures as well as networking, several ideas identified in question 2 were repeated, which demonstrates their importance. However, some existing initiatives were identified as examples that could be used by the ISEM community, such as the National Center for Ecological Analysis and Synthesis (NCEAS), which provides funding, space and tools for proposals, or the USGS Northern Prairie Wildlife Research Center (NPWRC), which maintains an important databank. For networking, some additional elements relative to question 2 were identified, including the establishment of networks of research sites and measuring standards, common scientific questions and research framework. Several examples of existing networks of

Table 3
Suggestions and ideas gathered during the facilitated discussion periods at the different symposia organized at ISEM 2009 to answer the question on how to generate and share ideas in ecosystem modelling (Question 2).

Innovation	
	Apply theory to novel domains (like transportation)
	Establish on integrated theoretic framework for ecology (find out a general rule for ecology)
	Renew the models (e.g. dynamic models), don't always use same old formulas
	Present not only what works, but also what doesn't
Interdisciplinary approaches	
	Cross-fertilization from other fields that also use models (e.g. economics)
	Bring together field ecologists, modellers and decision makers
	Multidisciplinary groups
	Collaborative comparative model exercises in different ecosystems
	Summer school cross discipline
	Encourage co-ops and internships
	Modify undergrad teaching methods
	Require student research for graduation
	More student training (early, often, interdisciplinary)
Communications and publications	
	Workshops
	Use open source and public access journal. Every paper should come with data + model to produce reproducible science.
	Review paper; literature review (model types, model parameters, model sensitivities)
	Organize symposia: small focused workshops
	Generating special issues in journals
	Synthesis papers to identify "state of the art" in specific areas
	Speculative blue-sky presentations at conference
	Innovative and cross-discipline workshops + conferences
	Facilitate discussions at meetings/conferences
	More/smaller regional conference workshops
	Workshops at meetings
	Publish papers which DO NOT fail "repeatability" criteria
	Integrated brainstorming exercises – community-based participation – international project for collaboration and networking – more money (for conferences, visits between institutes, international exchanges) – increase collaboration and networking – listservers (bank of email addresses) – more cross – fertilizing across disciplines
	Balancing breadth and depth in academic training
	Involve undergraduate and graduate students in idea generation
	Engage more undergraduates in research (e.g. USNSF REU's)
Internet and Software resources	
	Open-source models & methods (transparency) and sharing of existing data & models - "Open source software" for ecological models (e.g. http://ecobas.org).
	Discussion forum and use of Twitter – using Internet tools to access other ideas (e.g. reading or creating blogs) – use technology (e.g. videoconferencing) more effectively (watch footprint) – chat line for ecological modelling
	Linking personal websites
	Online meta-data bank; data sharing
Networking	
	Facilitate research networks and/or fund participation to conferences
	Mediated institutionalized modelling
Desired attitudes	
	Respectful controversy generates ideas
	Better know each other
	Improve our communication skills
	Collaborate on generic tools, models and methods of wider use
	More joint research projects
	Collaborative modelling, apply everyone's models to common datasets

Table 4
Suggestions and ideas gathered during the facilitated discussion periods at the different symposia organized at ISEM 2009 to answer the question on how to improve collaboration and networking (Question 3).

Role of ISEM	
	Promote networking in specialized topics
	Society website (LinkedIn, Facebook, Skype, membership list, personal websites)
	Organization of meetings more often
	Space on ISEM website and increasing Web presence
	Use ISEM as a medium of communication
Communications and Internet	
	Internet forums, websites
	Establish a platform for data sharing
	Teleconferencing and Internet tools (e.g., Skype webcam for Tokbox)
	Create common open-source software and models
	Web conferences
	Directional website (to get information on the topic); Google wave
	Wiki pages; Silvics Wiki
	Data and software sharing
	Open access to all literature
	Video conferencing between field data collectors and model developers
	Open source software
	Global database
	Conferences where you can get feedback and have face to face communication
	Smaller "regional" or "topic" conferences
	Google/Facebook groups
	Create summary product following a workshop
	Reduce institutional barriers to meeting
Collaboration and training	
	Exchange of researchers and graduate students (internship across levels)
	Student activities (meeting mixers, listservs)
	Interdisciplinary student training
	Summarizing information
	EU networks of excellence and integrated projects
	Actively pursue/invite at all levels (take the initiative)
	Joint research program
	Meetings are important (especially for students)
	Work together for research project or student training
Community actions	
	Actively seek feedback and survey community
	Ecological data sharing across field
	Promote international projects
	Funding encourages collaboration
	Long-term funding commitments
	Possibility of feedback to published articles
	Publications with failures as well as successes
	Structured dialogue on infrastructure and interoperability along with feasibility of collaboration
	Stronger top–down management
	Technical workshops on methodological issues
	Create incentives to collaborate
	Getting a cross-disciplinary perspective
Sharing data, methodologies and procedures	
	Creating standard data storage and metadata protocols
	Common conceptual framework with sharing of database and metadata
	United standards of measurement
	Environmental flows (common terms, definitions, applications, case studies)
	Model comparisons
	Integrate research with on the ground applications
	Greater use of shared model platforms, model & data repositories
Networking	
	Setup networks of research sites and measuring standards
	Setup a common scientific question and research framework
	Multi-stakeholder workshops

interest were given as examples: Waterfowl brood/pair surveys, US Fish and Wildlife Service (USFWS), Canadian Wildlife Service (CWS), and the Black Dutch Joint Venture (BDTV).

Several issues were also debated for question 4, "How can we become more visible to decision-makers, partners and clients" (Table 5). The use of the Internet was discussed, but in a more proactive way with decision-makers and the public compared with the ideas and suggestions obtained for the other questions. For instance, the development of dynamic real-time websites was proposed. It was also suggested to use mass communication media to get closer to the public, such as being present on television shows. The importance of transferring information to the public in simplified terms was highlighted. It would also be advantageous to publish newsletters and professional papers. Education in primary and secondary schools was identified as an essential achievement to attract young minds. For decision-makers, it will be important to develop analytical frameworks based on scientific data to assist them during their reflection process for the analysis of model predictions. In addition, special efforts will be required by showing pilot studies and making user-friendly applications available.

Table 5
Suggestions and ideas gathered during the facilitated discussion periods at the different symposia organized at ISEM 2009 to answer the question on how to become more visible to decision-makers, partners and clients (Question 4).

Communications and Internet
Specialized courses
Press conferences with the media
Good institutional university websites with examples of models and applications
Documentation
Plan into research dissemination – outreach
Publish in management journals
Regular meetings among scientists, policy makers, clients, NGOs (non-governmental organizations). Invite them to conferences
"Open houses" – scientific institutions have special days when public and managers are invited
NGO to promote ecological modelling with end users
Influence funding calls to get buy in
Communication at different levels in the community
Be proactive to policy making process via mass communication tools (TV shows?)
Publish non-scientific (professional) papers as well as more high-quality papers (=sheer weight)
Education from primary schools
Create interest
Provide non science-heavy, non-tech. summaries; reduce scientific findings to lay language in report form; talk to decision-makers in their language; publish in agency, NGO, etc. newsletters
Dynamic real-time website
Generate press releases with a follow up with media
Use agencies as conduits
Organize debates on TV between scientists and laypeople (politicians?)
Build public relations (news releases, updates) into program structure
Use agencies as conduits
Using existing channels of publicity (e.g. other societies)
Package output in relevant language (communicate in basic language)
Communicate with decision makers to have their feedbacks or inputs
Media presence; Use models to help developing countries = media attention
Make sure concepts and ideas are communicated in terms that everybody can understand
Ecological modelling web pages
Simple models to drive home key points
Simple concepts (to facilitate communications)
Collaboration and training
Basic courses in academic programs
Emphasis on K-12 education
Developing framework for decision-makers based on scientific data
Community actions
Figure out and summarize who our decision-makers, partners & clients are
Attend structured decision-making workshops
Learn how to "market" results to decision-makers
Anticipate client needs 3–5 years ahead
Show that we are members of an active scientific society
Community-based participation
Invite local environmental or other citizen groups (stakeholders) to attend ISEM conferences
Public relations representative on executive council
Invite civil, architectural (etc.) firms to present their modelling projects
Determine how visible do we really want to be and to whom
Identify stakeholders at beginning of project; get client participation and buy-in at start of research project
Lobbying
Active participation in community initiatives
Repeated contact, follow up consultation
Grassroots efforts of members
Salesmanship (learn to "sell" research ideas to broader community)
Education to general public
More partnerships = more credibility
Laypeople become the bridge between modellers and politicians
Invite decision-makers, politicians and business for ecological analysis
Undergraduate training
Development and use of applications
Convincing pilot studies and applications
Well-explained case studies; showcases of applications
Added value of models
Ecological forensics/CSI (crime scene investigation)-style
Involve stakeholders in research project, ask them their needs
Dynamic three-dimension tools based on scientific data
Build up global projects that aim at linking existing models to provide decision tools for stakeholders
Present examples for new scientific innovations
Develop decision-making system based on scientific knowledge

3.2. Specific suggestions and ideas

In this subsection, specific issues that were raised in the symposia are discussed.

3.2.1. Earth surface modelling and global ecology

The earth surface is the interface of the lithosphere, atmosphere, hydrosphere and biosphere. Earth surface modelling is generally defined as a spatially explicit digital description of an earth surface component or an ecosystem in terms of global ecology principles. The global-scale ecological unit of the biome has been extended to include the human influence on ecosystems, which comprises human population density, land use and land cover to describe anthropogenic effects on earth surface (Alessa and Chapin, 2008). Climate and geology have shaped ecosystems and evolution in the past, but human forces may now outweigh them across most of the Earth's land surface (Ellis and Ramankutty, 2008). Earth surface modelling cannot be conducted by dealing with global controls alone while ignoring local complications, or by treating local case studies separately from global factors. The key to a sustainable environment is to think globally and act locally; the key to understanding global ecology is to think globally and locally all at once (Phillips, 2002).

However, various problems remain in earth surface modelling. For example, no global models have yet achieved a satisfactory level of dynamic integration between the biophysical earth system and the human socioeconomic system. A global digital terrain model with high accuracy has yet to be completed or combined into related global models, and statistical transfer functions still need to be developed. An alternative means of solving these problems is to develop high-accuracy and high-speed methods for earth surface modelling, which could deal with huge amounts of data and multiscale issues in three dimensions, under consideration of a ground- and satellite-based global observation system with an optimal data-sharing mechanism (Yue, 2010).

3.2.2. Network modelling and systems theory: Advances in network environ analysis

Data collection, availability and uncertainty constitute a uniquely common and key challenge identified at the symposium. The search for novel ideas is a never ending venture. For example, the development of high throughflow experimental techniques (Fernandes, 1998), such as microarrays, has played an important role in recent advances in genetics, microbiology and medicine. Similarly, accurate and abundant data are required to model complex environmental phenomena for which feasible solutions usually involve both quantitative and experimental research. As such, advances in new experimental techniques and new quantitative approaches capable of dealing with incomplete and noisy datasets (e.g., stochastic methods, artificial intelligence, Bayesian approaches, etc.) are needed to advance network modelling and systems theory in environmental sciences (e.g., Bonavito et al., 1994; Aalders and Aitkenhead, 2006).

The need for interdisciplinary science is clear (Schramski and Gattie, 2009; Cohen, 2004). Building successful collaborations among scientists with different backgrounds, skills and interests is a key challenge. Derry et al. (2005) used cognitive science, "a field that attempts to promote cross-disciplinary integration of concepts, methods, epistemologies, language, data, and infrastructures for research and education on cognition, to shed light on the nature and complexity of interdisciplinary work." The facilitated discussion elicited several somewhat novel solutions, including interdisciplinary student training and specific engagement of undergraduate students in interdisciplinary research to facilitate the development of future scientists capable of communicating and working effectively across subject areas. Furthermore, it was noted that a commitment to ongoing and persistent interdisciplinary workshops, brainstorming sessions, and catalytic meetings can help researchers establish successful interdisciplinary collaborations.

3.2.3. Individual-based models for conservation

It has been recognized recently that conservation problems, such as restoration or preservation of critical habitats for wildlife species at risk, may be better addressed by modelling the individuals, since it is important to include mechanisms, i.e., the factors that drive the response of the animals to changes in their environment. Therefore, a critical component of individual-based models is often capturing animal movement. The challenge in simulating animal movement is to understand the interrelated factors (internal and external) that explain how and why an animal moves, which generates the observed patterns in nature.

Several algorithms of varying complexity and behavioural realism have been proposed to achieve this goal. A discussion occurred on the merits and limitations of different movement algorithms to adequately mimic animal movement. A consensus emerged on the necessity to compare algorithms for specific applications and obtain quality data for their validation. Another pervasive issue that was discussed was the qualitatively dissimilar models made by "ecologists" and "non-ecologists." For the former group, minimizing the number of parameters used is paramount, whereas the latter group focuses more on pattern-oriented modelling. This might cause parameter inflation, which is known to allow a better fit of models, but in general it reduces the power of prediction. Participants further discussed whether, at least conceptually, the modeller and the programmer should be separated. The model is conceptual and the programmer is the person who translates this concept into code. Some suggested the modeller and programmer should be different people as they have different skills; however, some particular experiences demonstrated that it may be more productive to combine these two types of expertise using programming tools, such as domain-specific languages. For example, NetLogo (ccl.northwestern.edu/netlogo/) is used by some, and was reported to be easy to learn to build relatively complex models. Repast (repast.sourceforge.net) is used by the "non-ecologists" and was reported to be powerful, but with a steep learning curve that may not be convenient for "ecologists." SELES (www.seles.info) is used by several of the ecologists, and is reported to have some strengths but also a steep learning curve. Several participants mentioned that research teams often lack people who could bridge the gap between the disciplines, resulting in models that are wildly "off" because the different groups are not able to understand the domain-specific language of the others. An important niche exists for people who can communicate across traditional disciplinary boundaries.

A last issue concerns granting agencies that often seem reluctant to fund research that involves using simulation models to test theory. It was concluded that perhaps it was a matter of maturity and demonstrations of success that could help change this attitude.

3.2.4. Ecological accounting

Various attempts have been made to describe the processes and responses of the growth and development of ecosystems (Fath et al., 2001; Jørgensen, 1997), among which ecological accounting serves as a necessary step to incorporate and quantify the contributions of social, economical and environmental issues. Different from conventional accounting and environmental accounting, the focus of ecological accounting is to develop practical models and methods to count the energy, materials and information flow and storage as well as structure of the ecosystem based on systems and thermodynamic perspectives to establish better strategies for environmental management (Chen et al., 2009). Its central defining characteristic is to be ecologically relevant and cost-effective in terms of biophysical metrics.

To quantitatively assess different socio-economic or compound ecosystems, holistic evaluation based on systems analysis and thermodynamics can be added to the body of knowledge on the poor coherence between economic profitability and ecological sustainability (Chen and Chen, 2006). Since many methods have been applied to ecological accounting, we need to integrate them into a self-consistent framework to evaluate the genuine wealth of nations and regions, which is not an easy task due to various principles, scales, orientations and, sometimes, even beliefs (Chen and Chen, 2009). Also, advances in modelling methodology, integrated socio-ecological models and eco-sustainability models must be included in ecological accounting to connect different sub-ecosystems and present more dynamic and holistic details that take into account the complexity of ecosystem evolution. Particularly, we need to provide a forum (e.g. websites, Facebook™ or Twitter™) for both researchers and practitioners who would like to exchange knowledge, perspectives and ideas for the application of ecological models in ecological accounting using a common platform and discuss the most recent advances in simulation models and assessment methods from both a theoretical and a practical perspective via suitable media.

Finally, more professionals from universities, governments and the private sector should be responsible for, involved in or interested in ecological accounting as well as conventional accounting and environmental accounting to make effective comparisons, present and share new ideas, innovations, trends, experiences and concerns in environmental management so as to transform the green GDP into a 'greener GDP' or 'ecological GDP', based on which we could finally establish an important interactive (multi-agent) platform to make societal, economic and environmental developments in an 'ecologically profitable' way.

3.2.5. Forest simulation models for sustainable forest management under a changing environment

Forest simulation models are used to predict tree and stand productivity. This information is essential to ensure sustainable forest management. However, the changing environment creates new conditions that increase the degree of difficulty in model development. There are several key challenges in this research area. Overall, three ideas were prevalent, with the first being that the participants would like to have more opportunities to hold informal discussions about modelling, have more time to discuss and exchange new ideas and to hold more coordinated discussions. Validation procedures were quoted as important. To find adequate datasets to validate model processes is essential. However, there is confusion on the meaning of validation (Rykiel, 1996). Finally, estimating and communicating uncertainty of model simulations still remains a major challenge (Larocque, 2008; Larocque et al., 2008, 2011).

Among the other key challenges identified was the question of sustainable research funding from external grant organizations. Participants felt, however, that there is not much that can be done about it. This will remain an issue for the forthcoming years. Partnerships among different research teams may help to alleviate the problem of sustainable funding. Another issue identified was related to the connection of models with biological processes. Examining more biological causality may suggest taking new directions, i.e. towards process-based models and hybrid models (Kimmins et al., 1999; Peng et al., 2002). Finally, another issue was related to bridging the gap between field experiments and modelling, which implies that modellers and experimenters should communicate and work more closely together. In total, 60% of the challenges identified were methodological and communication initiatives.

The main idea proposed during discussions on the generation and sharing of new ideas was that it is important to present not only what works, but also what does not work for the models. It is also important to mention that this was recognized by a large proportion of the participants. A model or a research project that does not deliver the expected results may provide as good information as a model or research project that does. Science has evolved because many hypotheses, which were entirely logical, were rejected following testing and evaluation.

3.2.6. Ecological modelling for environmental flows

Determining environmental flows has become a fundamental issue around the world in dealing with water conflicts among industry, agriculture, energy production and ecosystem protection stakeholders. In recent years, more and more objectives have been added to environmental flow assessments. The complexity inherent to ecological responses to hydrological alteration has made it difficult to quantify the environmental flows required to maintain ecosystem health based on the demands of an individual species. Different types of ecological modelling exercises have been used in environmental flow assessments around the world because of their ability to represent the complexity and processes of ecosystems, and their relationship with human activities. Research on ecological modelling for environmental flows has only begun.

The main challenges faced in the modelling of environmental flows are the integration of different models with different structures and scales, and data scarcity for the establishment and calibration of integrated models. First of all, ecological modelling should not only focus on describing eco-hydrological processes when determining environmental flows; it should also be concerned with identifying the relationship between environmental flows and other sectors of water utilization. Second, environmental flows should be studied as part of an integrated system. Moreover, data scarcity seems to be an eternal topic in ecological modelling. Necessary information should be provided for model construction, validation, and so on. There should be a trade-off analysis in ecological modelling application between making a model more complex and detailed, which requires more information, and keeping it simple so that it becomes easier to be used in practice and requires fewer data, which often makes it less accurate. Data collection is a money and time consuming job, so developed regions should be responsible for helping developing regions, both technologically and financially.

Considerable work remains in the development of ecological modelling for environmental flows. Things we can do in the near future include the integration of new ideas from different disciplines, objectives from different stakeholders, models with different structures and scales, and complex and simple models for data requirements. Integrated ecological modelling will be helpful through its application in environmental flow assessment and decision-making. Connections that can be made between the different types of ecological models for describing complex ecosystems should be discussed at the next conference.

3.2.7. Modelling the consequences of climate change on the agricultural landscapes

Agricultural areas are among the landscapes most vulnerable to climate change. The long-term changes caused by climate change will affect natural environmental parameters which, in turn, can induce changes on the total water balance of river basins, soil water regimes, water movement through soil profiles as well as in plant production potential. Mathematical model applications have the potential to produce a prognosis of the future management of an agriculture landscape. During the symposium, hydrological models were discussed as suitable tools to study the impacts of climate change on hydrologic and water balance. The discussions can be summarized as follows:

- Spatial interpretation of the metrological input factors of river basins together with the application of geostatic methods improve the quality of output parameters.
- Regional interpretation of climate change impacts with respect to monthly components of individual elements of water balance and their variability provides the basis for effective implementation and adaptation measures.
- The analysis and quantification of the extreme phases of discharges within the soil, run-off, and snow submodels for the present and for future time horizons specify the probable course of extreme events.
- The evaluation of the different methodologies of nitrous oxide emission from arable soils under climate change conditions can be used to clarify uncertainty in the results in order to project and formulate adaptive measures more precisely.

The participants to the symposium agreed on the need to:

1) protect and rationally use water resources, with emphasis on the different aspects of soil exploitation and protection;
2) develop and adopt efficient mitigation measures in advance;
3) conduct feasibility studies and develop wide information tools to keep agricultural producers and stakeholders informed on the issue and its evolution.

3.2.8. Modelling avian seasonal productivity

Sustainable management of animal populations requires knowledge of how the natural environment and anthropogenic stressors together influence population persistence. The integration of such knowledge typically occurs through the application of demographic models that combine estimates of vital rates (e.g. survival, fecundity and growth) to estimate the growth rate of a population. However, in many cases, the vital rates themselves are not directly estimable and must, in turn, be estimated via a model. This is typically the case with avian fecundity.

What are the key challenges in this research area? Overwhelmingly, participants identified unifying methodologies as the most important challenge to further development and adoption of avian fecundity models, followed by collection of high-resolution field data. These topics were given priority in the resulting synthesis (Etterson et al., this volume, Sections 3 and 4). Five topics received two votes each, including distinguishing between pattern and process, estimating covariances among model parameters, estimating juvenile survival after fledging, and competing risks. A further eight topics received a single vote each, including getting models adopted by researchers, developing models for tropical birds, better understanding of start and end dates of the breeding season, renesting, hierarchical models, quantifying spatio-temporal autocorrelation in vital rates, estimating temporary emigration in long-lived birds, and discordance between seasonal and lifetime fecundity in long-lived birds.

3.2.9. Research perspectives in carbon cycle modelling to support sustainable terrestrial ecosystem management

The development of carbon cycle models for terrestrial ecosystems has been an active field of research for the last few decades.

These models share a common basic structure, which is the modelling of the carbon flow among the different compartments in terrestrial ecosystems. Several models of the latest generation are fairly complex and are increasingly used to address environmental issues, such as global climate change and effects of human intervention. Despite the fact that significant accomplishments have been achieved, several important challenges still remain.

1. How to handle and reduce uncertainty. This issue still remains to be addressed in more depth. Very few carbon cycle process-based models provide uncertainty estimates due to the lack of understanding of several processes, the presence of many sources of uncertainty (model structure, measurement errors, temporal and spatial scales, and imprecise evaluation of natural variability), the limited availability of mechanistic equations to represent processes, and unknown errors associated with parameters (Larocque et al., 2008). The use of carbon cycle models is increasing in importance to evaluate the impacts of climate change on the dynamics of terrestrial ecosystems. For policy making and adaptation, it is essential that carbon cycle models provide answers on the potential long-term effects on net primary productivity, carbon partitioning and potential for carbon sequestration. However, carbon cycle models are still in their infancy. Significant progress must be achieved to improve their predictive capacity. While research efforts continue, it is important for model users to understand the limitations of available carbon cycle models, and providing uncertainty estimates along with predictions would be a significant step in the right direction.
2. Bridge the gap between academic and practical approaches without reducing the complexity of models. The majority of carbon cycle models are characterized by complex structures. Their development is conducted mainly in academic circles where the main objective is to better understand the mechanisms that govern the dynamics of terrestrial ecosystems. In general, running these models requires a lot of data to provide initial estimates of the different pools and parameters, which are not necessarily easy to obtain for application to actual field scenarios. For effective use in policy making, it will be important to find ways to simplify model initialization without compromising model complexity.
3. Better linkage between field experiments and modelling. Field experimentation and model development are often performed independently. For many ecologists and decision-makers, field experimentation is merely considered as a simple step to collect data for parameter estimation. In reality, field experimentation can provide important information on the biological consistency of the structure and representation of processes and contribute to better dealing with uncertainty. For instance, soil carbon pools and below-ground processes are still poorly characterized. Estimates of soil carbon contents in field experiments are usually reported as a single number. In reality, soil carbon consists of many complex organic compounds with different chemical properties and turnover rates. The majority of soil carbon cycle models partition soil carbon using only three different classes. Given the complexity of soil organic matter, it is not evident that using three pools is sufficient to represent the complexity of soil carbon dynamics.

3.2.10. Ecosystem modelling for decision support in water management

The management of water resources must deal with several issues, such as pollution, habitat deterioration or invasive species (Boets et al., 2010). Ecosystem modelling may contribute to better capturing the quantitative insights in the interactions between the components that are involved.

Specific ideas and suggestions on the key challenges included the integration of habitat suitability (HSM), food web and spatial-explicit dynamic models, a better capacity to work effectively with a large number of models (development of a large set of models combined with user-oriented evaluation and selection) and the evaluation of models based on a more diverse set of criteria: specialized versus parsimonious, development and calculation time, data needs for training and simulation, model band width (predictive range and potential of extrapolation, e.g., Goethals et al. (2007)), ecological relevance, complexity and transparency (Mouton et al., 2009), user-convenience for training, validation and simulation. Multidisciplinary research was particularly discussed to generate and share new ideas, but also to integrate ecological models with hydrological, environmental, and other models as illustrated for instance in van Griensven et al. (2006). The participants felt that cross-fertilization from other fields was essential to make progress, both from a theoretical as well as an applied perspective.

3.2.11. Static and dynamic approaches to modelling diversity and complexity

Various static and dynamic approaches are available to model diversity and complexity in ecological systems. Static approaches are characterized as addressing one point in time, one spatial location and/or one organizational scale, while dynamic approaches generally involve temporal fluctuations, several spatial locations or spatial scales (e.g. local, regional, global), and/or several organizational scales (e.g. individual, populations, communities). Definitions of diversity and complexity have seen recent extensions and thus should include not only measures such as richness and Shannon diversity but also measures that incorporate spatial structures/configurations, fractals and connectedness in line with suggestions recently made by ecologists attempting to apply complex systems science tools and methodologies (Anand et al., 2010). However, improvements from information-theoretical as well as graph-theoretical approaches can still be made in helping to improve our definitions of ecological diversity and complexity.

One theme that emerged with respect to the efforts to link static and dynamic methods was the sampling methodological issues required to move across scales. Several papers presented novel statistical methodologies which incorporate scale, space and/or time, moving away from traditional static approaches. The other theme pertained to modelling issues that try to link spatial patterns with dynamics (statistical, computational and mathematical). It was concluded that static measures of diversity and complexity could depend greatly on temporal structures and in particular that spatiotemporal interactions needed to be better understood as these interactions could result in critical behaviour and/or regime shifts in ecosystems. Similar calls have been made recently in the literature (White et al., 2010). Areas of application in which linking static and dynamic approaches were shown to be particularly useful were restoration ecology and conservation biology. However, key challenges in this research area include: (1) linking statistical approaches and modelling approaches and (2) linking theoretical and applied approaches. The participants felt strongly that much insight can be gained by increasing communication between the statistical ecology and ecological modelling communities. We suggest having further session devoted to this topic.

4. Conclusion

Several ideas and suggestions were discussed at the different symposia that took place during the 2009 conference of the International Society for Ecological Modelling (ISEM 2009). As indicated by the synthesis of the discussions in this paper, common as well as different trends emerged, and this is normal for a conference such as ISEM 2009. The large number of common trends suggests that modellers from different disciplines related to terrestrial and water ecosystems face similar challenges and problems, despite the fact that they have to deal with specific issues related to their own disciplines. A major advantage of a scientific conference such as ISEM 2009 is to provide an invaluable opportunity for delegates coming from different parts of the world to explore and appreciate various points of view, discuss and exchange different ideas, theories, concepts or methodologies, and establish long-lasting relationships that may generate good collaboration. We believe that this was one of the great achievements of this conference.

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Appendix A. List of symposium presentations at ISEM 2009.

Earth surface modelling and global ecology	Network modelling and systems theory: advances in network environ analysis	Individual-based models for conservation	Ecological accounting
YUE-HASM based ecosystem scenarios on global level.	Network mutualism in ecological and trophic networks.	Predicting spatial and temporal recolonization of large carnivore populations: wolves in the Italian Alps.	Ecological accounting based on exergy
Yue, T. X. and Z. M. Fan	Fath, B.D. and U.M. Scharler	Marucco, F. and E.J.B. McIntire	Chen, B.
Self-organization of tropical seasonal rain forest in southern China.	Comparative storage network environ analysis of a seven-compartment model of nitrogen flow in the Neuse River estuary: time series analysis.	An agent-based model to investigate the impact of increased levels of human presence on wolf behaviour in Banff and Kootenay National Parks, Canada.	Ecological economic evaluation of Beijing urban ecosystem based on emergy as embodied cosmic exergy: historical prospective stuty 1978–2004.
Lin, H., M. Cao and Y. Zhang	Whipple, S.J., S.R. Borrett and B.C. Patten	Morshed, A. Sk., M. Musiani, G. McDermid, M. Hebblewhite and D. J. Marceau	Jiang, M. -M., G. -Q. Chen, B. Chen and Z. -F. Yang
Modelling and mapping topographic variations in forest soils at high resolution: a case study.	Dynamic network analysis: throughflow, storage, cycling and indirect effects.	Moving through complex landscapes: the bane and promise of individual based models.	Effect of anaerobic fermentation residues on a chromium-contaminated soil-vegetable system.
Bhatti, J.S., P.N.C. Murphy, M. Castonguay, J. Ogilvie and P. Arp	Kazanci, C., Q. Ma, B. Tollner, L. Matamba, J. Schramski and B. Patten	McIntire, E.J.B., C. Schultz and E.E. Crone	Duan, N., X. Liu and C. Lin
Modelling sediment-deposition patterns of a flash flood in a residential area using Erosion 3D.	Evidence for the dominance of indirect effects in trophically-based ecosystem networks.	Individual-based models, functional connectivity conservation and performances of ecological networks: the TenLamas project.	Network calculation of embodied cosmic exergy and their consumption for Chinese economy 2005: an input–output analysis.
Arévalo, S.A., J. Schmidt, W. Schmidt and A. Michael	Salas, A.K. and S.R. Borrett	Baguette, M., A. Coulon, V.M. Stevens, A. Chaput-Bardy, C. Turlure, J. Clobert, D. Schmeller, C. Bleay, J.M.J. Travis, S. C.F. Palmer, T. Hovestadt and K.A. Barton	Chen, Z.-M., B. Chen and G.-Q. Chen
Modelling spatial structure in ecological data using eigenfunction-based spatial filtering methods.	Reconnecting environs to their environment.	How to achieve generalization in conservation models: Applications to individual-based modelling.	Ecological design and evaluation for the new industrial district of Caofeidian.
Blanchet, F.G.	Borrett, S.R., M.A. Freeze and A. K. Salas	Latombe, G., L. Parrott and D. Fortin	Li, C. and Y. Yang
Validation and uncertainty analysis of an ecosystem model for wheat-maize double cropping system over the North China Plain.	Sufficient conditions for threshold insensitivity of network environ analysis dominance indicators to boundary input.	Biased correlated random walk vs foray loop: which movement hypothesis drives a butterfly metapopulation?	Research on the risk assessment of Green Manufacturing decision-making unit and its application.
Mo, X.	Freeze, M.A., S.R. Borrett and A.K. Salas	Rompré, G. and E.J.B. McIntire	Tan, X., L. Cheng and Y.Y. Wang
Using spatial statistics and landscape index to quantitatively analyze the spatial characteristic on simulation image.	Do implicate forces in nature keep systems at or near steady states?	Supporting ecosystem management using agent-based modelling of whalewatching activities in the St. Lawrence estuary.	Emergy and exergy synthesis of four forest restoration modes in low subtropical China.
Wang, J.H., Y. He and W. Ren	Patten, B.C.	Landry, J.-A., L. Parrott, C. Chion, C. Cavalcante de Albuquerque Martins, P. Lamontagne, S. Turgeon, R. Michaud, D. Marceau, N. Ménard, G. Cantin and S. Dionne	Lu, H.-F., Z.-H. Wang and B. Chen
Modelling and simulating ecosystem services? a brief summary of recent state of the art and example applications for ecosystem management.	Structural and functional decomposition of ecological networks and their system-wide properties.	Analysis of emerging primary and secondary patterns for the selection and validation of a spatially explicit agent-based model.	An analysis of the urban metabolism of Bejing based on emergy synthesis.
Seppelt, R.	Gaff, R. and C. Kzzanci	Chion, C., P. Lamontagne, S. Turgeon, L. Parrott, J.-A. Landry, D. Marceau, C. Cavalcante de Albuquerque Martins, R. Michaud, N. Ménard, G. Cantin and S. Dionne	Zhang, Y., Z. Yang and B. Chen

Earth surface modelling and global ecology	Network modelling and systems theory: advances in network environ analysis	Individual-based models for conservation	Ecological accounting
	Finding important sub networks in ecological network analysis: finding coefficient vectors using flux decompositions. Luper, D., J.R. Schramski, C. Kazanci and H.R. Arabnia		
	Conservation laws: interdisciplinary modelling lessons in engineering and ecological compartment analysis using first principles and a case study of ecosystem energetics. Schramski, J.R., E.W. Tollner, D.K. Gattie, B.C. Patten, and J. Jambeck		
Forest simulation models for sustainable forest management under a changing environment	**Ecological modelling for environmental flows**	**Modelling the consequences of climate change on the agricultural landscape**	**Modelling avian seasonal productivity**
Modelling forest growth, productivity and carbon dynamics under a changing environment using hybrid modelling approach. Peng, C.	Environmental flow requirements for the habitat of Chinese shrimp (*Penaeus chinensis*) in the Yellow River Estuary, China. Sun, T.and Z. Yang	Assessment of climate change impacts on water balance in an agricultural river basin. Novotná, B., E. van Bochove and B. Viliam	Seasonal fecundity models: Critical assessment of questions and direction. Grzybowski, J.A. and C.M. Pease
Effects of climate change and CO_2 fertilization on water use efficiency of terrestrial ecosystem of China. Jiang, H., Q. Zhu, C. Peng and J. Liu	The effects of environmental flows regulation on food webs in the Baiyangdian wetland. Chen, H. and Z. Yang	Model evaluation of nitrous oxide (N_2O) emissions from arable soils of Slovak Republic in condition of climate change. Horák, J. and B. Šiška	Which life history components determine breeding productivity for individual songbirds? A case study of the Louisiana Waterthrush. Mattsson, B.J.
Challenges in the development and application of forest simulation models under a changing environment: Using different model types to answer resource management questions. Larocque, G.R., L. Archambault, C. Delisle, N. Luckai and S. Adhikari	Seasonal environmental-flow demand calculation of reed community (*phragmites australis* var. baiyangdiasis) under different meteorological conditions in the baiyangdian lake, China. Wang, Q., Z. Yang and J. Liu		Markov chain estimation of avian seasonal fecundity Etterson, M.A., R.S. Bennett, E.L. Kershner and J.W. Walk
Simulating the effects of pre-commercial thinning on forest growth of jack pine stands under two scenarios of climate change using a process-based model. Wang, W., X. Zhou, C. Peng, G.R. Larocque, D. Kneeshaw, X. Lei, T. Zhang and J. Sun	Estimation of dynamic environmental flows of Baiyangdian Lake, a shallow freshwater lake. Yang, W. and Z. Yang		Retrospective estimation of breeding phenology of American Goldfinch (*Carduelis tristis*) using pattern oriented modelling. Potvien, A., M. Etterson and R. Regal
The evolution of a growth model: Prognosis[BC]. Marshall, P.L., A.-A. Zumrawi and V.M. LeMay	Study on sustainable water use based on ecological network analysis with the consideration of environmental flow using ecological network analysis. Li, Y., Z. Yang and B. Chen		Food limits annual fecundity of a migratory songbird: an experimental study. Nagy, L.R. and R.T. Holmes
IVY: An individual-tree growth model for complex-structured stands.	Development of an inexact optimization model for water resources management with the consideration of uncertain environmental flows.		Calculations on the back of an envelope model: Applying seasonal fecundity models to species' range limits. Olsen, B.J., M.A. Etterson and R. Greenberg

Earth surface modelling and global ecology	Network modelling and systems theory: advances in network environ analysis	Individual-based models for conservation	Ecological accounting
Groot, A.	Cai, Y. and G. Huang		Annual productivity in Greater Snow Geese: which fecundity parameter is the best predictor and why? Gauthier, G., C. Juillet, J. Bêty and M. Morrissette
Adapting a spatial forest simulation model for new management practices: approach and challenges. Mailly, D.			Seasonal fecundity of the common Loon. Evers, D.
Sensitivity of forest landscape models to individual growth rate functions: do small scale processes matter for large scale question? Elkin, C., C. Temperli, B. Reineking and H. Bugmann			Shifts in predation risk at camera-monitored Northern Bobwhite nests as a result of meso-mammalian predator removal in the southeastern U.S.A. Ellis-F., S.N., M.J. Conroy, W.E. Palmer, and J.P. Carroll
The importance of using the correct tree architecture in structural-functional process-based models. Schneider, R.			Non-linear patterns of parasitism and nest survival: implications for estimating avian productivity. Post van der Burg, M., L.A. Powell and A.J. Tyre
Modelling diameter growth in response to varying silvicultural treatments within mixed-species stands located in coastal British Columbia. Rathbun, L.C., V. LeMay and N. Smith			Modelling the effects of chemical exposure on avian seasonal productivity: Importance of differences in breeding strategies. Bennett, R.S. and M.A. Etterson

Research perspectives in carbon cycle modelling to support sustainable terrestrial ecosystem management	Ecosystem modelling for decision support in water management	Static and dynamic approaches to modelling diversity and complexity	
Modelling carbon budget in fire-prone ecosystems: Translating across scales from global to landscape. Mouillot, F.	Applications of habitat suitability models in marine management and research Willems, W.M.M., S. Degraer, V. Vanlancker, E. Verfaillie, M. Vincx and P.L.M. Goethals	What structures beetle communities in boreal forest? Blanchet, F.G.	
Data-model fusion approach in global carbon cycle research: recent development and future challenges. Peng, C.	Inverse analysis of the structure of the Venice Lagoon ecosystem. Brigolin D., C. Savenkoff, M. Zucchetta, F. Pranovi, P. Franzoi, P. Torricelli and R. Pastres	Regional pattern design for ecosystem restoration: a case study. Ma, K., M. Anand, G. Li and B. Fu	
Quantifying the uncertainty of the carbon dynamics of Canada's managed forest. Metsaranta, J., W.A. Kurz, G. Stinson, E.T. Neilson, G.J. Rampley, C. Smyth and C. Shaw	Plugging the holes in Lake Victoria: Summarising what is known about it and what has yet to be studied. Downing, A.S., W.M. Mooij, E.H. van Nes, J.H. Janse and M. Scheffer	Evolutionary biogeography improves biodiversity prediction in the Brazilian Atlantic rainforest. Carnaval, A.C. and C.C. Moritz	
Modelling carbon stocks in unmanaged forests in northeastern Ontario, Canada. Ter-Mikaelian, M., S.J. Colombo and J. Chen	Application of decision trees to analyze the ecological impact of invasive species in Polder lakes in Belgium Everaert, G., P. Boets, K. Lock and P. Goethals	Multifractal analysis of forest spatial distribution pattern over time. Zhang, Y., K. Ma and B. Fu	
Using the Carbon Budget Model of the Canadian Forest Sector (CBM-CFS3) to examine the impact of harvest and fire on carbon dynamics in selected forest units of the Canadian Boreal shield. Luckai, N., G.R. Larocque, L. Archambault, D. Paré, R. Boutin, A. Groot and A. Innerd	Species abundance patterns in benthic macro-invertebrate communities in steams in response to disturbance. Cho, W.-S., T. Van Nguyen and T.-S. Chon	Assessing mortality across habitat amount and configuration using individual based models. Ribeiro, M.C., A.C. Martensen, M.-J. Fortin and J.P. Metzger	

Earth surface modelling and global ecology	Network modelling and systems theory: advances in network environ analysis	Individual-based models for conservation	Ecological accounting
Simulations show deteriorating carbon balance of Rocky Mountain forests in the next century.	Validation of ecological models to support water management: integration of mathematical, ecological and management-oriented criteria.	Modelling impacts of disturbance on diversity using a markov model of succession in the boreal forest.	
Boisvenue, C. and S.W. Running	Goethals, P. and A. Mouton	Richardson, M.J., M. Anand and H.J. Eberl	
Simulating the dynamics of forest vegetation diversity under clear cutting and natural development at different climate change scenarios in central European Russia.		Fire feedbacks with vegetation and the spatial structure of savannas	
Khanina, L., M. Bobrovsky, A. Komarov, A. Mikhailov, V. Shanin and S. Bykhovet		Beckage, B. and C. Ellingwood	
Modelling carbon and nitrogen sequestration in boreal forest ecosystems of central Russia under different climate change scenarios and forest management regimes.		Facilitation and the emergence of community structure in metacommunities.	
Shanin, V.N., A.S. Komarov and S.S. Bykhovets		Filotas, E., M. Grant, L. Parrott and P.A. Rikvold	
Effective use of an experimental design in balsam fir (*Abies balsamea* (L.) Mill.) and black spruce (*Picea mariana* (Mill.) B.S.P.) forest ecosystems located along a climatic gradient for the development of a carbon cycle process-based model.		A model study of storm surge effects on a mangrove - hardwood hammock ecotone	
Larocque, G.R., D. Paré, R. Boutin, L. Sarr, V. Lacerte and C. Ansseau		DeAngelis, D.L., Teh, S.Y. Su and .L da Silveira Lobo Sternberg	
Modelling soil carbon dynamics under different traditional systems of agriculture and forestry in European Russia.			
Bobrovsky, M., A. Komarov and V. Shanin			
Dissolved organic carbon and N dynamics in forest streams, in relation to geospatial and hydrothermal controls.			
Castonguay, M., T.A. Clair and P.A. Arp			
Modelling of elements dynamics in mineral and organic forest soils: the Romul model expansion.			
Komarov, A., O. Chertov, Y. Khoraskina, S. Bykhovets, A. Larionova and M. Bezrukova			
Modelling the decomposition and N mineralization in ramin wood dowels (*Gonystlylus bancannus*) using a common climate function for the LIDET sites across the USA.			
Smith, A.C., J.S. Bhatti, M.E. Harmon and P.A. Arp			
Estimating California forest biomass change using process model and land cover disturbance data.			
Liu, J., J.E. Vogelmann, Z. Zhu, C.H. Key, B.M. Sleeter, D.T. Price, J.M. Chen, M.A. Cochrane, J.C. Eidenshink, S.M. Howard, N.B. Bliss and H. Jiang			
Effects of climate, age and stand origin on the above ground NPP (ANPP) of jack pine stands along the boreal forest transect case study (BFTCS).			
Bhatti, J.S., T. Varem-Sanders and M. Wang			

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