Ecological-economic modelling for designing and evaluating biodiversity conservation policies

ESF-exploratory workshop
in the Life and Environmental Sciences (LESC) section

Convenors

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Date and location

08-10 September 2004 at the UFZ-Centre for Environmental Research Leipzig-Halle in Leipzig, Germany

I. Executive summary of the workshop

Aims of the workshop

On a general level, the aims of the workshop were methodological reflections on ecological-economic modelling to better understand its potential for improving conservation policies, as well as problems that occur in such a model-based merger of the two disciplines ecology and economics. To achieve this general aim, the workshop was structured around the following themes and questions:

(I) The differences and common ground between ecological and economic concepts, theories and methods were explored with a particular focus on the potential for evaluating and designing biodiversity conservation policies through ecological-economic models.

(II) The main ideas and approaches used in the development of ecological-economic models were collected and compared addressing questions such as: What types of ecological-economic modelling approaches exist? What are the general similarities they share and what are the differences? What constitutes a 'good' ecological-economic model? What is the range of applicability of ecological-economic models?

(III) A comprehensive understanding of the differences and similarities between ecological and economic models as well as of the nature of ecological-economic models provided the basis to achieve the final aim: identifying how limitations and disadvantages of existing ecological-economic modelling approaches can be overcome and exploring the potential for the development of new approaches.

Structure of the workshop and scientific content

The three themes were addressed in three sessions:

1. Comparison Ecological and Economic Modelling: Two examples of biodiversity modelling where presented: one "typical ecological" and rather complex (in terms of parameter number) model (Andreas Huth) and a "typical economic" and rather simple one (Anders Skonhoft). Volker Grimm presented a review that compares the typical ecological and economic modelling approaches found in the literature.
2. Case studies where ecological and economic knowledge has been integrated: Five case studies were presented and discussed to demonstrate difficulties arising in ecological-economic modelling, obstacles and how they can be overcome. Case studies included the problem of reserve design (Hugh Possingham), management of invasive species and instruments for landscape design (Jason Shogren), grazing in semi-arid systems: resource management under uncertainty (Stefan Baumgärtner), design and implementation of marine reserves in fisheries (Claire Armstrong), and modelling for landscape planning (Jana Verboom). All presentations were followed by short comments of discussants to stimulate plenary discussion. The plenary discussions covered methodological (modelling) problems as well as institutional, political and economic obstacles for conservation and how to integrate such aspects in ecological-economic modelling.

3. Difficulties, limitations of ecological-economic models, how they can be overcome, and future potential of ecological-economic modelling: On the example of Lake Victoria, Charles Perrings presented and summarised the main arguments in favour of and challenges to ecological-economic modelling as well as the main barriers to "good" inter-disciplinary research. Christian Wissel summarised the workshop along the topics mentioned under Aim III above, which lead into a plenary discussion on these topics.

The main outcomes of all discussions can be arranged into four main themes:

i. Difficulties in linking ecological and economic models: Different modelling cultures, institutional barriers, model complexity

ii. Limitation of existing approaches: Model is often biased towards one discipline, disregarding important issues of the other (Ecology: e.g. species interactions, spatial heterogeneity, long-time scales; Economics: e.g. market conditions, property rights, asymmetric information).

iii. How to overcome difficulties: work ought to be problem-oriented, identify and concentrate on key components of the ecological-economic system studied, aim for generalisation of models.

iv. More communication between disciplines, ecologists consider economy more realistically, and vice versa.

Assessment of the results, contribution to the future direction of the field, outcome

The discussions revealed that ecological-economic modelling can facilitate true inter-disciplinary research. Analysing coupled ecological-economic systems by ecological-economic models leads to a better scientific understanding of the system as well as better policy recommendations as compared to mono-disciplinary approaches. It was felt that the number of practitioners of this methodology is reaching now a critical mass that allows the methodology to be established as a sound research field in the scientific community. A problem but also a chance in this kind of research is that ecologists and economists may view the same problem in a different manner and word the same things differently. To enhance co-operation between ecologists and economists communication has to be improved and each discipline should make better use of and respect the experience and knowledge of the other. A useful way of establishing such co-operation is problem-oriented research, accompanied by methodological reflections like those undertaken at this workshop. A valuable contribution to the scientific community may be summer schools on ecological-economic modelling that are planned for the future. Other outcomes of the workshop are the preparation of a joint publication on the central themes of the workshop, a special issue of presentations and the establishment of several joint research activities among workshop participants.

II. Scientific content of the workshop

Session 1: Comparison of ecological and economic modelling

1a. Andreas Huth: Biodiversity and ecological modelling - examples from the tropics

After an introduction on the global relevance of rainforests and the impact of humans on these ecosystems, Andreas Huth introduced as examples of ecological models the rainforest models FORMIX3 and FORMIND. These models can be used to analyse long-term impact of disturbances on rain forests (logging, fragmentation, El-Nino...), to evaluate forest management strategies (what is sustainable management?), to understand rain forest dynamics, to determine key processes, to calculate carbon balances for managed and unmanaged forests and to investigate general hypotheses on rainforest dynamics. The models presented are relatively complex and simulate the growth and interaction of individual trees. They have been used and validated in numerous parts of the world. A practical application presented was the linking of the rainforest model with multi-criteria analysis to identify logging strategies that are able to balance ecological and economic interests.

The discussion after the presentation focused on the following topics:

- the consideration of economic / market conditions in the analysis; the acceptance of management strategies by interest groups; the problem of time scales: short-term economic interest versus long-term conservation
- the problem of the generality of complex models vs. the practical applicability of simpler models and theories
- how to build an ecological-economic model: (1) start from ecology and then add economics, because biodiversity conservation is the ultimate goal, (2) start from economics, because humans are the main drivers of biodiversity loss, or (3) start simultaneously from both disciplines, including feedbacks in the discussion between ecologists and economists?
- "biodiversity-friendly" harvesting strategies vs. assignment of forest reserves

1b. Anders Skonhoft: Economic modelling approaches for biodiversity conservation

A mathematical model for wildlife management was presented. The background of the analysis are three basic driving forces that lead to species decline and the threat of extinction of wild living resources: biological and economic overexploitation, disinvestment in the biological resources and the institutional dimension. A case in sub-Saharan Africa was considered where conflicting interests exist about the wildlife as it is considered as both valuable and a pest. Next, the situation was analysed where there is an opportunity cost of protected land, and habitat area may shrink. Finally, the case of discrepancy between management and biological geography due to the fugitive nature of wild species was studied

The discussion started with a remark of a participant on the importance of using a language that both ecologists and economists can understand. Further topics included

- the biological realism of the presented model, followed by a discussion on the advantages and disadvantages of simple and complex models: Detailed ecological information can usually not be considered in simple equation-based models, but requires simulation which however makes the detection of general rules difficult.
- As economic models were perceived to be "simpler" than ecological ones, the question was raised whether and how the complexity of ecology and ecological models can be considered in a comparatively simple economic model – especially if the focus is on biodiversity which means consideration of a large number of species.

1c. Volker Grimm: Differences and similarities between ecological and economic modelling approaches

A review was presented that compared model studies related to biodiversity conservation that were randomly sampled from the literature, distinguishing ecological, economic, and ecological-economic models. It turned out that economic models tend to be relatively simple (in terms of number of model parameters), are formulated and analysed analytically. They tend to be used for the investigation of general questions, however often ignoring space, dynamics and uncertainty. Some of the ecological models sampled had the same properties as the economic ones, however, there was also a class of ecological models observed that are relatively complex and are analysed by simulation. These tend to be rather specific and often explicitly consider space, dynamics and uncertainty. The differences between ecological and economic modelling approaches were suggested to be a result of the historical development of the two disciplines of ecology and economics. Ecological-economic models were observed to lie in the middle between ecological and economic models, an important result being that they are not more complex than ecological and economic models (as one could have expected from naive "merger"), but have an intermediate complexity!

The discussion focused on the following topics

- Why are economic models simpler than ecological ones? One suggestion was that economists hesitate to model human behaviour beyond the two simple (and conveniently to model analytically!) classical axioms that actors maximise utility and are risk averse. Another suggestion was that policy makers when advised by economists ask for simple and handy models and guidelines.
- A simple model does not necessarily have less predictive power than a complex model. The complexity of a model is often not only determined by the complexity of the system described, but also by the modeler's understanding of the system.

Session 2: Case studies where ecological and economic knowledge has been integrated

2a. Hugh Possingham: The dynamic reserve system design problem and the general problem of conservation resource allocation in time and space

The presentation started with the somewhat provocative proposition that a common currency (which would require economic valuation of biodiversity) is useless, as the budget available for conservation is not determined by the pursuit for economic efficiency but by politics. Several reserve network design problems were presented. The basic objective in these problems was that certain conservation targets are achieved at least costs. Problems include the importance of space (e.g., shape and boundary length of a reserve determines costs), determination of protection costs in general, that objectives are often not clearly defined, socio-economic issues introduced too late, and that there are many conflicting objectives. A particular problem is that reserve networks need much time to build, which means that unprotected sites can be lost, affecting the ecological value of other sites in an uncertain manner. Still the selection plan or strategy has to be politically feasible. Simple theories are needed.

The discussant, Martin Quaas, noted that conservation is an investment in species with the problem that human preferences (for conservation or other objectives) are uncertain, that extinction of species is irreversible and that they have a quasi option value, meaning that the extinction should (according to economic reason) be prevented at least until their value can be assessed.

The discussion was on

- The relevance of learning in the process of reserve selection, and more general, the relevance of education
- The necessity of generalisation, given that it is too time consuming and costly to construct a model for each individual species.

2b. Jason Shogren: Invasive species: management and incentive design

The presentation started with the note that ecological-economic modelling has to consider biological needs, political realities and economic incentives. Conflicts exist between property rights and the common good on the one side and between individual wants and social objectives on the other. A case study was presented about how to efficiently combat invasive species, i.e. whether resources should be spent to prevent invasion, eradicate or control invading species. The various risks were combined in a mathematical ecological-economic optimisation model. The choice of options depends on the preferences of the decision maker and the technologies at hand. Problems occurring are feedbacks, thresholds, determination of opportunity costs, determination of preferences, uncertainty and irreversibility. Another case study was a game-experiment on the effectiveness of compensation payments to generate a particular spatial allocation of reserves. This required co-ordinated action among the players

which was crucially influenced by the extent of communication allowed. With communication, the desired spatial structure was achieved quite rapidly. The presentation closed with some general guidelines for interaction among ecologists and economists, which include mutual respect and knowledge of each other's way of thinking. Integration may lead to more accurate and precise estimates of bio-economic phenomena, more comprehensive guidelines for policy makers, and a higher appreciation if diverse ideas and tools while one should not forget that it is important to keep rooted firmly in ones own discipline.

In appreciation of the results of the presented co-ordination game, the discussant, Mar Cabeza, emphasised that theoretically sound reserve design is needed instead of the currently usually practised ad-hoc approaches.

The discussion focused on

- The process of model building and the importance of communication between ecologist and economist
- The practical problems in the implementation of a co-ordinated auction process to achieve desired spatial habitat network structures, and alternative instruments
- The importance of education, which requires "advocates of science" rather than scientists

2c. Stefan Baumgärtner: Risk, insurance, and sustainability in the use of semi-arid rangelands

An ecological-economic model was presented for grazing strategies on a sheep farm in Namibia in the presence of uncertainty arising due to stochastic rainfall. The income of the farmer is dependent on the number of sheep on the farm which depends on the available vegetation biomass which in turn depends on the farmer's management strategy. The farmer can react on the present environmental situation and can choose between more risk-averse and more risk-tolerant grazing strategies. Being relatively simple but still capturing the essential elements, the model could largely be solved analytically. A main outcome of the study is that a risk-averse strategy is sustainable. The reason is that income variability, variability in the ecological good (vegetation biomass) and risk of degradation are all positively correlated, such that if the farmer wants to avoid income variability he automatically reduces degradation. In this way, the ecosystem acts as an insurance, with the consequence that if alternative (market-based) insurances were introduced, the farmer would choose a more risky grazing strategy – leading to faster degradation and less sustainability.

The discussant, Eloy Revilla, pointed to the problem that precipitation and wool price may be correlated, possibly reducing the farmer's options for reacting on unfavourable environmental conditions.

The discussion focused on

- The transferability of the model (results) to other regions, and possibilities to buffer variation in different systems
- Technical assumptions of the model and the level of model complexity
- Why there is currently no market in Namibia to insure farmers against low levels of rainfall

2d. Claire Armstrong: Ecological-economic modelling on marine reserves in fisheries

Only a small proportion of the oceans is currently under protection. Although there has been much ecological research on marine reserves, economic issues appear to be more critical, but are less well understood yet. The argumentation for or against marine reserves has been discussed in numerous studies. Scientific problems noted include missing economic realism in ecological models and vice versa as well as the consideration of non-commercial and/or non-use values. Important data to determine the carrying capacity of a marine area often are missing. In general, apparently there does not exist a clear answer to the question whether marine reserves are efficient instruments to protect marine biodiversity. Practical problems of reserve design include different interests of different fisher groups. Which areas to protect may depend on their representativeness, their productivity or how pristine they are. Uncertainty arises from missing information on the dependence of the carrying capacity on environmental variables.

The discussant, Jane Jeppsen, emphasized that ecologists and economists strongly disagree in their opinions whether and where to implement a marine reserve, possibly due to different perspectives, the problem of characterising marine biodiversity, and too little economics in the development of criteria for reserve design.

The main discussion topics were

- Ecological factors affecting marine biodiversity, such as species interactions and top-predators
- Economic issues, such as how much compensation to fishers is fair and how to deal with the issue of property rights

2e. Jana Verboom: Quantitative ecological assessments in landscape planning and decision making

Major issues in the field of ecological-economic modelling for biodiversity conservation include cost-effectiveness, the assessment of compensation and mitigation strategies, and optimal spatial allocation of habitats and measures. An obstacle to inter-disciplinary research is missing interaction between researchers. It is nevertheless important to acknowledge that there is no single currency, but the disciplines have their own valid indicators to assess conservation strategies. These introductory remarks were followed by a presentation of the

EU project EURURALIS (European Rural Area Land Use Interactive Decision Support System). It integrates the different dimension of policy making. Analysis is based on four scenarios defined by the spatial scale of policy instruments and the degree of market liberalism. Various ecological, economic and social indicators are determined. A biodiversity indicator is considered that is composed of a species index, nitrogen level and level of disturbance to the ecosystem.

The discussant, Laure Ledoux, asked how an ecological-economic model can be defined as such and remarked that scenarios should also be defined by the assumed preferences of the considered stakeholders.

The discussion was focused on

- The different definitions of scenarios (as story lines or policy options)
- The coupling of modules in a complex land use model. It was emphasized that interactions between different modules have to be taken into account explicitly in the simulation of scenarios and that researchers must understand at least the basic functioning of each other's modules. Is a single model more suitable than a linked system of different modules?
- The importance of having a clear objective of the model

Session 3: Difficulties, limitations of ecological-economic models, how they can be overcome, and future potential of ecological-economic modelling

3a. Charles Perrings: Reflections on the nature of ecological-economic models: land-water interactions in Lake Victoria

The presentation highlighted the importance of feedbacks between ecological and economic agents as well as the importance of temporal and spatial scales within an ecological-economic system. Such system are often characterised by a sensitivity to initial conditions, path dependency, non-linearities and discontinuities, multiple equilibria, irreversibilities and hysteresis effects. The analysis of such a system was demonstrated on the example of eutrophication of Lake Victoria where land use affects eutrophication which affects the biomass of fish which affects the return of fishers. This again affects the agricultural activities in the surrounding regions which closes the loop. In a situation of uncertainty, modelling can enhance transparency. Simulation experiments may identify that certain actions lead to expensive and irreversible damages leading to the avoidance of such actions in the real system. Two major barriers to learning across disciplines in general and modelling in specific are (1) disciplinary, such that perceptions of the same problem may be different in different disciplines, and (2) institutional, e.g., caused by rivalry within or between departments of institutions.

The discussion highlighted the following issues:

- Transfer of knowledge to actors and the use of simulation games for education
- Consideration of multiple species in economic (fisheries) models
- Transparency of models: make the limitations explicit – at the risk of not being taken serious by politicians.
- Model complexity, possible to be reduced as systems are understood better

3b. Christian Wissel: Gaps in knowledge and promising new approaches to ecological economic modelling: summary and discussion of workshop results

Christian Wissel's summary and the following discussion went along 4 main themes:
a) difficulties/challenges in linking ecology and economy in models
b) limitations and disadvantages of existing ecological-economic models
c) how these can be overcome
d) in which way ecological-economic modelling should evolve

Ad a)

- Main difficulties are different ways of thinking, different modeling cultures, different vocabulary, institutional barriers. The problem selection is often different between the disciplines and it is not always clear in which order an ecological-economic model should be composed. Ecological systems often operate on longer time-scales than ecological ones and space often plays a higher role – leading to differences in modeling approaches.
- Regarding complexity there is a trade-off between understanding the unrealistic simplicity in simple models on the one side and the incomprehensibility of the realistic complexity in complex models on the other side.

Ad b)

- Often models are biased towards economics, disregarding important characteristics of ecosystems (diversity, species interactions, spatial heterogeneity and long time scales) or towards ecology, disregarding key economic constraints (market conditions, property rights, asymmetric information).

Ad c)

- To overcome disciplinary barriers: work problem-oriented so researchers from both disciplines share the same overall goal.
- To solve the complexity problem: Select the key processes and use simple models for general understanding. Use complex models to identify key processes (much of this can be done separately in each discipline, leaving the rest of complexity to describe the feedbacks between ecological and economic systems).

Note: Linking *existing* models may be difficult, because they may have been developed for different purposes that are not compatible with the new purpose!

Ad d)

- For the future, economists should give the issue of space and non-equilibrium more attention and further develop the use of agent-based models to better include behavior and socio-economic complexity.
- Ecologists should try to simplify their relatively complex models and if possible translate them into mathematical formulas that are compatible to mathematical economic models.
- Keep an open mind and have the right tool to solve the problem which means that researchers should be proficient in a variety of problem-solving tools and concepts.

III. Assessment of the results, contribution to the future direction of the field, outcome

III.1 Assessment of results

The workshop has shown that there is now a critical mass of researchers interested in and able to carry out ecological-economic modelling on a high scientific level and relevant for policy making. We would like to emphasise that ecological-economic modelling is a tool that allows interdisciplinary research in a really integrated manner beyond research where different disciplines are just tacked together without real connection. The main results of the workshop may be summarised in the following statements:

- The successful design and implementation of biodiversity conservation policies and strategies (often) requires that ecological and economic aspects are taken into account in an integrated manner, and ecological-economic modelling is a highly useful methodology to do this.
- Similarly, a better understanding of ecological-economic systems and processes (often) requires an integrated modelling approach.
- Whether an integrated approach is useful depends on the underlying research/policy question. However, due to various reasons, so far research has been carried out largely in a disciplinary manner, suggesting that marginal benefits of integrated approaches are likely to be large.
- Even issues that are traditionally approached by one particular discipline (e.g. reserve selection by ecology and cost-effectiveness by economics) can often be better approached when relevant aspects of the other discipline are taken into account.
- The appropriate modelling approach depends on the underlying research/policy question. However, one should be aware that economists and ecologists have different perspectives and will identify different research questions when looking at the same conservation problem.
- Technically the integration is possible because both disciplines use formal methods and deal with problems of similar structure (e.g. optimisation problems). However, one should

be aware that economists and ecologists have often something else in their mind when they use the same words (e.g. models), leading to communication problems.

- Economic models tend to be simpler and more general than ecological models, economic models tend to be formulated and solved analytically whereas ecologists often work with specific models, using a variety of modelling techniques.
- The issues of time and space have different degrees of importance between the two disciplines and are (often) modelled differently in economics and ecology.
- Researchers should be aware of the richness of approaches in the other discipline and avoid simplified views (ecologists sometimes assume that when they integrate cost into a model then they have a fully integrated ecological-economic model, economists often are unaware about developments in ecology and use outdated ecological knowledge in their models).

III.2 Contribution to the future direction of the field

The workshop results regarding the future direction of ecological-economic modelling may be summarised as follows:

- When integrating ecological and economic knowledge in models it is important to make full use of the rich knowledge of the other discipline. While some ecological-economic modelling has been done, many central concepts and questions investigated in the individual disciplines have not been considered in ecological-economic modelling.
- The compatibility of ecological and economic models and modelling philosophy (regarding spatial and temporal scales, level of model complexity, etc.) should be improved.
- For a good integrated approach one should stay firmly grounded in ones own discipline and have an open mind regarding the other discipline.
- With respect to capacity building young researchers at the workshop have expressed an increasing interest in learning more about ecological-economic modelling. Summer schools about ecological-economic modelling are a good option to satisfy this interest.

III.3 Outcome

Tangible benefits in terms of future collaboration

- A joint publication in an international journal based on the presentations; arguing for the importance of ecological-economic models for designing biodiversity conservation strategies and policies and summarising main themes of the workshop.
- A special issue in an international journal about the workshop theme including (some of) the presentations and other invited contributions fitting into the theme.
- (At least) two ESF Eurodiversity proposals with participants of the workshop.
- Planned: a summer school on ecological-economic modelling (2005 or 2006), possibly proposed with ESF.

Intangible benefits

Besides concrete plans for future projects there were also several discussions among participants about ideas for future collaborations related to project proposals and to joint papers. These discussions took place among Europeans but also included the two participants from Australia and the USA. After the workshop all participants expressed that they had learned a lot about the issue of integrating ecological and economic knowledge in models. We would like to emphasise that these included a group of younger researchers (PhD Students or Postdocs) which had been selected and invited via a call for a grant to participate in the workshop.

IV. Final programme

Wednesday 8 September 2004

Evening	Arrival
19:00	Bus-transfer to the restaurant „Thüringer Hof“ in Leipzig Get together and dinner

Thursday 9 September 2004

8:30	**Georg Teutsch** (Scientific Director of UFZ) **Frank Wätzold** (UFZ) Welcoming word **Rudy Rabbinge** (Standing Committee for Life and Environmental Sciences) Presentation of the European Science Foundation (ESF)
9:00	**Andreas Huth** (UFZ, Germany) Ecological modelling approaches and their role for biodiversity conservation
10:00	**Anders Skonhoft** (Norwegian University of Science and Technology, Norway) Economic modelling approaches for biodiversity conservation
11:00	Coffee break
11:30	**Volker Grimm** (UFZ, Germany) Ecological and economic modelling approaches: differences and similarities
12:30	Lunch at UFZ
13:30	**Hugh Possingham** (University of Queensland, Australia) The dynamic reserve system design problem and the general problem of conservation resource allocation in time ans space Discussant: Martin Quaas (University of Heidelberg)
14:30	**Jason Shogren** (University of Wyoming, USA) Invasive species: management and incentive design Discussant: Mar Cabeza (University of Helsinki)
15:30	Coffee break
16:00	**Stefan Baumgärtner** (University of Heidelberg, Germany) The use of ecosystem services under uncertainty. An ecological-economic model of a semi-arid rangeland system Discussant: Eloy Revilla (Estación Biológica de Doñana)

18:00	Bus-transfer to the „Krystallpalast“ in Leipzig Social event and dinner

Friday 10 September 2004

8:30	**Claire Armstrong** (Norwegian College of Fishery Science, Norway) Ecological-economic modelling of marine reserves in fisheries Discussant: Jane Jeppsen (NERI, Denmark)
9:30	**Jana Verboom** (ALTERRA, The Netherlands) Quantitative ecological assessments in landscape planning and decision making Discussant: Laure Ledoux (Macaulay Institute, UK)
10:30	Coffee break
11:00	**Charles Perrings** (University of York, UK) Reflections on the nature of ecological-economic models
12:00	Lunch at UFZ
13:00	**Christian Wissel** (UFZ, Germany) Gaps in knowledge and promising new approaches to ecological economic modelling: summary and discussion of workshop results
14:30	Discussion about potential co-operations
15:30	Coffee break End of workshop

V. List of participants (support staff included)

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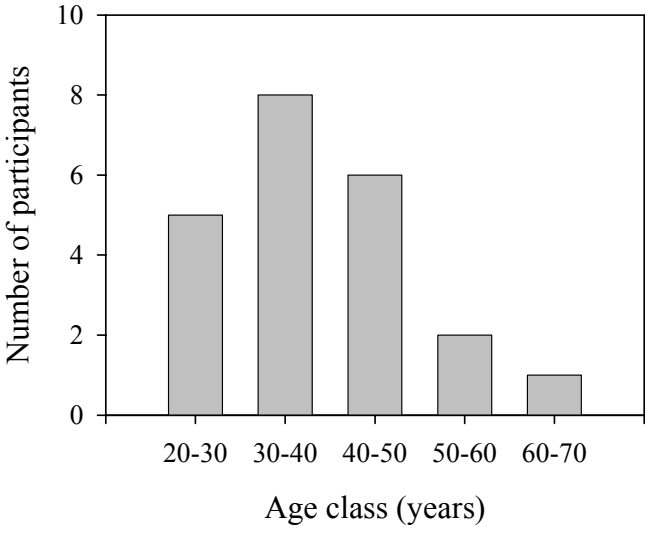
VI. Statistical information on the participants:

The total number of workshop participants was 33 with 22 of these being invited participants and 11 being support staff from UFZ. The latter chaired sessions, took notes and supervised the technical infrastructure to ensure a smooth flow of the workshop. The following statistics refer to the 22 invited participants only.

The participants came from 13 different countries:

Country	No. of participants
Australia	1
Britain	2
Denmark	1
Estonia	1
Finland	1
France	2
Germany	7
Ireland	1
Netherlands	2
Norway	1
Slovakia	1
Spain	1
USA	1

The age structure of the participants reflects a good mixture of young and experienced researchers.



In accordance with the aims of the workshop, about half of all participants came from each of the two disciplines, ecology and economics (13 and 9 participants, respectively).