

Limnology, Behavioural Research and the Environment

Heinz Löffler

Institute of Limnology

Need for reorientation

Limnology is the comprehensive study of the biological characteristics of inland waters within their physical and chemical environment. It has been pursued for roughly 100 years as an independent scientific discipline. As a sub-area of ecology, limnology traditionally investigates the interactions that determine the distribution and the frequency of organisms in inland waters, and the material and energy balance of the waters as a whole. The Institute of Limnology's present line of research is set out in the Medium-Term Research Programme 1996–2000 (MRP 1996–2000), and emphasizes this ecosystem-based approach. The objective was the *Research of aquatic ecosystems taking as example standing and flowing waters including groundwater*. The major issues laid down in the MRP 1996–2000 are the investigation of the following areas:

- Structure, function and long-term changes in the waters
- Autoecology of water organisms and their interaction with the environment, including their adjustment to changing environmental conditions

In the light of the existing infrastructure and personnel resources, the present lines of research have proven to be too general; the Institute has not been able to develop to the extent desired a common identity that would distinguish it from comparable institutions and university facilities, a criticism also raised by the assessors on the occasion of the last evaluation. The decision of the Academy to close the Lunz Section of the Institute of Limnology by 2003 at the latest, the appointment of a new director and the retirement of a number of academics in the medium term will in the near future also involve substantial personnel and structural changes that must be taken into account by means of a change in the line of research. A refocus also appears necessary in the light of the rapidly changing academic and social environment as we enter the new millennium.

The aim is to focus resources on a realistic and common objective. This will necessarily lead to cut-backs in existing research topics, such as the virtual abandonment of the research into flowing waters as a focal point of the Institute's work and indeed the sole focal point of the Lunz Section. Conse-

quently, the research programme described below essentially relates to the Mondsee Section of the Institute of Limnology.

Eco-physiology and evolutionary ecology as superordinate research topics

The previous approach is to be replaced by the *Eco-physiology and evolutionary ecology of aquatic organisms and symbiotic communities* as a new line of research. Limnological research is to address general ecological processes and principles and make greater use of limnology's specific advantages such as the comparatively easy experimental access to the subject matter of research and the short timescale of essential processes as compared with the neighbouring disciplines of marine and terrestrial ecology.

Within this new line of research, the *Creation and maintenance of diversity and complexity on the level of the individual, the population, the species and the ecosystem* has been selected as the focal point for the next five years. This specialization is intended to integrate the existing study groups' current and planned projects and to serve as the framework for new appointments.

Microorganisms as essential subjects of research

Since limnological research during the last century concentrated on those (higher) organisms that contribute less than 10% to the conversion of matter in water, one of the focal points of the Institute's research work in the future is to be those microorganisms (bacteria and protozoa) that are responsible for more than 90% of this process and are consequently incomparably more important for the biogeochemical cycles than macroorganisms. These investigations are to be linked with complementary studies on macroorganisms. Fundamental phenomena, such as the importance of clonal differences for the maintenance of genotypic and phenotypic diversity within a population that reproduces itself exclusively or primarily asexually, can be particularly well investigated using short-lived aquatic microorganisms. The – in evolutionary terms – old hunter-prey relationship between heterotrophic flagellates and bacteria has led to numerous adaptation strategies on both sides that are only now beginning to be understood, and while they are certainly not restricted to aquatic organisms, the latter can be used to investigate them in relatively simple suspension cultures. As the subject matter of the study

of biodiversity and evolutionary ecology, macro-organisms, such as those of the groundwater and the Danube, and the fishes and communities of fish species will continue to be investigated both as indicators of the ecological condition of lakes and as the object of behavioural physiology studies. The refocus involves an increased application of new methods deriving from molecular biology, hydro-acoustics and flow cytometry that permit the largely automatic recording of previously unquantifiable processes and structures on the levels of the individual and of the population. Causal-analytical experimental investigations are to be encouraged, while largely descriptive fieldwork is to take second place.

Priority in the future research of the Institute of Limnology is to be given to understanding limnology as a sub-area of ecology and to providing stimuli for the superordinate field of study. Aquatic organisms and ecosystems are to be used as relatively easily accessible objects in order to address general ecological and evolutionary biology issues. The primary objective is no longer to describe an aquatic ecosystem as completely as possible in all its variety, but instead to identify and analyze suprasystem key processes and structures. Account must be taken of the different timescales. Thus the objective of the Institute's paleo-limnological research is to analyse the importance of the historical environmental influences on the change of organism (communities) on the basis of selected organism groups (bio-indicators), and to be able to make predictions about the potential importance of climatic factors for future developments. Similarly, the groundwater crustaceans permit an analysis of the factors that caused the morphological adjustments of individual species and phylogenetic shifts in the biological community. In both cases, the reconstruction of historical processes should permit statements about the essential long-term factors, including those affecting recent symbiotic communities, that are not accessible to experimental manipulation. Medium-term processes including critical periods in the lifecycle of the species can be investigated using fish or macro-zoobenthic populations. The effects of short-term processes, including the important question of the physiological adaptation of organisms to short-term environmental changes (e.g. food surges, temperature changes) is to be investigated on different monocellular organisms by a number of study groups. Theoretical approaches from network thermodynamics will also continue to be pursued in order permit the analysis of the physiological adjustments of organisms as a complex interaction of energy-converting sub-systems in a cell. The coming years will focus above all on how a given adjustment event is determined by the organisms' previous history.

In all the above cases, fundamental biological phenomena and processes, which in all probability are not specific to aquatic ecosystems, will be investi-

gated in different time-frames in the light of the above-mentioned superordinate question. The conclusions, initially reached by the different projects independently of one another, will, when viewed together, possibly lead to the discovery of new more generally applicable rules that can explain the origin and/or the maintenance of diversity and complexity in (aquatic) ecosystems. The new line of research and the focal theme over the next five years correspond with the research priorities for limnological research in the 21st century that were recently adopted by leading authorities in the field.

Although the research topics are primarily to be ascribed to the field of basic research, there is no clear dividing line to applied limnology. This is the case for instance for the microbial ecology of the groundwater. The stocks of groundwater will become increasingly important for human water supplies in the 21st century, and microorganisms bear prime responsibility for the conversion of matter including the detoxification of harmful xenobiotics. Nevertheless, the genetic diversity and the physiological output of the groundwater microorganisms are largely unknown. The interaction between basic research and applied limnology also becomes clear in the assessment of the ecological functional capacity of the waters as required of the member states by the EU's Water Policy Framework Directive. The maintenance of diversity and complexity at the level of the ecosystem is an essential criterion, although the objective is not to undertake a causal analysis of the factors involved. Going beyond the individual case, our work should contribute to the causal understanding of the creation and maintenance of diversity and complexity on the various levels.

Konrad Lorenz Institute for Comparative Ethology

Main objectives

The work at the Konrad Lorenz Institute for Comparative Ethology (KLIVV) mainly concerns the comparative study of animal behaviour. It focuses on the adaptive value and evolution of behaviour. Therefore, the ecological context in which specific behaviours occur are investigated as well. Important research fields of the Institute, which holds a leading position in behavioural ecology, comprise research on reproductive behaviour and the role of ecological, morphological and physiological constraints on behaviour.

The research program for 2001–2005 will be based on the previously successful lines of research and be developed according to new scientific results and methods. Among these is the insight that parasites, including microbial diseases, profoundly influence survival as well as reproductive behaviour. The adaptive "arms" race between parasites and their hosts constitutes one of the main driving forces of

evolution. The spatial structure and differentiation of populations and species are increasingly recognized to be important for our understanding of their evolution. Here, molecular methods open up many new opportunities to test hypotheses about gene flow and local genetic isolation. They have also revolutionized our understanding of reproductive behaviour and are indispensable for many behavioural studies. Technological progress further allows us to measure signals relevant for optical and acoustic communication with great precision even under field conditions. Moreover, phylogenies derived from DNA sequences and new statistical procedures have led to an undreamed-of renaissance in comparative studies.

Studies relating to aspects of nature conservation, formerly an important component of the Institute's activities, will be limited to projects that are of general interest, have a theoretical or methodological link with other research activities and which stimulate interdisciplinary discussion at the Institute.

Mid-term empirical work has been consistently developed from the past programme and will be devoted to the general theme of conflict and cooperation in reproductive behaviour. Conflicts within the same sex arise from the competition over mates; conflicts between sexes result from the different optima that pertain to sex-specific behaviours related to mating, mate choice, and care of offspring. Cooperation pertains to the same functions. The actual amounts of conflict and cooperation depend on ecological and phylogenetic constraints. Questions of mate choice, mating systems, parental care, colony formation and sex-specific ecological, morphological and cognitive adaptations will be integrated into the general theme. This focusing of research will enhance internal cooperation and the efficiency of the projects to be carried out at the Institute.

Research programme

Differences between the sexes are an obvious consequence of conflict and cooperation and this theme links the various research projects. Sexual dimorphism is an ideal model for studying the different influences of ecology and behavioural mechanisms on the evolution of reproductive behaviour. One of the central problems of evolutionary biology is to explain the immense diversity in the behaviour and morphology of organisms. Since behaviour rarely leaves traces in the fossil record, that is particularly challenging for behavioural studies. Special methodological approaches are thus required. They incorporate phylogenetic trees of species and populations that are generated from DNA sequences. When these trees are combined with information on as many extant species as possible, one can reconstruct the evolution of certain traits. Furthermore, comparative statistical analyses can account for the bias introduced by phylogenetic dependen-

cies. Comparative methods will be applied to questions concerning the evolution of parental care, mating systems, and particularly sexual dimorphism, and these should complement and contribute to the other projects at the Institute. Suitable examples will be taken from birds, the group of organisms about which the most comprehensive information is available. The role of behavioural flexibility and aspects of spatial differentiation of behaviour have to be included as well. There are conflicting results as to the evolution of sexual dimorphism. Several comparative analyses have shown that the differences closely relate to ecological conditions and that they vary interspecifically mainly because of differences among females. Detailed single case studies, however, have shown that variation within a species mainly affects males. This is consistent with the theory of sexual selection according to which female choice is linked with variation among males; interspecific differences, however, have not yet been explained convincingly.

Conflict between the sexes occurs particularly when females mate with multiple partners. Why females do so is still unclear. Females of some bird species (quails, blue tits) observe interactions between males and later mate with the winner. Which of the males actually fertilized the eggs can be determined with modern molecular techniques. Together with experimental manipulations of male quality, this may yield information about the criteria females use in their choice. In particular, research on the role of immuno-competence for mate choice has many interesting prospects. Immunological methods are very useful for characterizing specific qualities and the condition of individuals. Experiments need to be carried out that clarify whether signals directed to partners or competitors also reveal something about the immune system, and how the effort needed to maintain immune defence compromises courtship and care of offspring. One of the most important aspects in this context is that in several species zygotes and young originating from extra-pair fertilizations have greater chances of developing fully. Whether and how females influence this is still a complete mystery and will be investigated experimentally in bearded tits, a species studied intensively at the Institute for years. Special emphasis will be on an interdisciplinary project on the possible role of hormones transferred to the egg by the female.

Habitat structure influences the conflict between the sexes because it determines, among other things, the degree to which partners can watch and check each other. Most studies to date were conducted in cluttered habitats in which males could hardly guard their mates. For this reason species that live in open habitats will be the focus of future studies. Females may profit from joining breeding aggregations like colonies because they can easily approach different males. Projects related to this idea will take advantage of the fact that in species

that breed in nest boxes spatial arrangement as well as visibility can easily be manipulated. Ongoing research on colonial species in which colony size varies will naturally be continued. It is expected that this long-term research will generate valuable data with respect to the role of cooperation and conflict between and within sexes. A further programme is intended to elucidate the mechanisms – especially those pertaining to sexual selection – behind breeding aggregations and social systems. This work relates to a general theory stating that coloniality is the by-product of sexual and habitat selection and of information extracted from conspecifics. Corresponding data will be collected in experiments with fish (cichlids) at the Institute and in work on bird colonies in the field.

The sexes co-operate in raising the young in many species. Several studies have shown that parental care, mating system, and mate choice are intimately linked. Many problems and unsolved questions remain, however. On the one hand, certain taxonomic groups, such as songbirds, have been disproportionately studied. On the other hand, environmental influences have often been neglected. Another deficit in our knowledge concerns the sex-specific cost-benefit relations of parental care and the reasons for parental co-operation. Waders are ideal to study in this context because they are not related to songbirds and because they exhibit a high diversity of mating systems, parental care, and morphological differentiation of the sexes.

Commission for Interdisciplinary Ecological Studies

The Commission for Interdisciplinary Ecological Studies was established as a research unit of the Academy on 11th October 1996 and covers a large, highly topical area within the biological sciences. This ranges from recording and documenting biodiversity, the diversity of all micro-organisms, fungi, plants and animals as the biological resources of our planet, evolutionary research, biogeography and terrestrial ecology (including population biology, ecosystems research, and so forth), to human ecology and questions of sustainable use of our biosphere. The commission agreed to focus on biodiversity research and multi-disciplinary long-term terrestrial studies within Austria.

Catalogues and checklists of Austria's organisms

Several catalogues and checklists have already been published (rust fungi, true mosses), some are about to be finished (smuts, *Cortinarius* mushrooms, lichens, liverworts), many more, including various animal groups, are in preparation. To continue and complete this first comprehensive documentation of all organisms, which comprise the total biological resources of this country, constitutes one of the fundamental and most important activities of the Commission. The information about the distribu-

tion, ecology, indicator value, status and other details forms the basis for more exhaustive research within the biological sciences and for any sustainable use by humans.

Multi-volume critically revised flora of the vascular plants (ferns and flowering plants) of Austria

In contrast to many taxonomic groups of lower plants, fungi, and invertebrates, the more than 3000 species of vascular plants in Austria are relatively well known. Nonetheless, the present project comprises the first attempt to treat this group of plants in Austria within its present political borders, and to present the latest state of our knowledge about distribution, ecology, phenology, indicator value, status and phylogenetic relationships as accurately as possible. With the Commission's support, the manuscripts for the first parts of this multi-volume work are nearing completion and are due to be published in the near future. Considering the fact that practically all our neighbouring countries already possess such modern and critically revised floras of vascular plants, continuation of this Austrian standard work of reference with the support of the Commission has high priority.

List of the vascular plants of Central Europe

A third edition of this list, which is essential for Central European floristic botany, is in preparation. It contains all currently valid names, the most important synonyms, general country-by-country data about distribution, revised information about recent publications, and a numerical code to facilitate both incorporation in biodiversity-related databases and in the production of atlases. The completion of this substantially improved list is most important with respect to a project, commencing in 2001, concerning the treatment of all vascular plants in Europe and the Mediterranean (Euro-Med Plant-Base).

List of chromosomes of the ferns and flowering plants of Austria

This handbook presents for the first time all available information, compiled from many thousands of publications, about the chromosomes in these plants. This work was supported by the Commission and was published in 2001.

Multidisciplinary and DNA-based studies on the temporal and spatial origin of vascular plant lineages

In the field of biodiversity research, today one of the most topical scientific disciplines worldwide, the question about the origin of biodiversity is central. Research in this field uses state-of-the-art DNA analysis. The Commission has supported a number of such Austrian projects at the cutting edge of research. To date, papers have been published in international and peer-reviewed journals, for example on the economically important rue family, native oaks,

so important for forest formation and forestry, and the globally distributed herbaceous genus *Anemone*. Studies on selected groups of the madder family containing more than 10,000 species are under way. Similar experimental studies on the origin of biodiversity will continue to be supported with the Commission's limited funds.

Habitat Vienna

This multidisciplinary large-scale project commences in 2001 and is intended to run for three years. Its goal is to produce two comprehensive volumes (I: *Landschaft und Ökologie im Raum Wien [Landscape and Ecology in Vienna]*, II: *Umweltgeschichte der Stadt Wien [The History of Vienna's Environment]*) that treat our present knowledge about the environment, the city, people, and their mutual interrelations. This is a joint project of research units at the Academy (Commission for Interdisciplinary Ecological Studies, Institute for Urban and Regional Research, Institute for Research into the Daily Life and Material Culture of the Middle Ages and the Early Modern Period) and will be carried out by two teams of experts and authors. The Commission is responsible for Volume I.

Long-term monitoring at the glacier apron in the Rootmoos valley, Tyrol

The Commission has supported this multidisciplinary long-term ecological project that includes research on plants and animals at the glacier retraction zone of the Ötztaler Alps since 1996. In the meantime, this research enterprise has earned international recognition and produced high-quality publications. It documents the settlement of microorganisms, plants and animals on older and more recent moraines and reveals how increasingly complex ecosystems form.

Long-term studies on the population biology of amphibians

The Commission has supported multidisciplinary studies on ecological niche-establishment and the behavioural ecology of amphibian populations since its inception. These field studies utilized and continue to make use of radiotelemetric methods (via transponders). The results of the first series of studies on Vienna's "Danube Island" have been published (Stapfia 51). Further work on amphibian populations, partly accompanied by vegetation analyses,

is currently being carried out in the Alps and will continue to be supported.

Establishment of centres for biodiversity research and ecological long-term research in Austria

In connection with the work on checklists, catalogues and faunas and floras of all organisms in Austria, the Commission has grown into the most important and most comprehensive institution for the research on the biological resources of the country and their documentation. This justifies the Commission's role as the official link to the international parent organization DIVERSITAS (International Programme of Biodiversity Science within UNESCO). This is also true for long-term ecological research. Centres that serve as nodes for corresponding information networks will be established within the Commission in the near future.

Workshops, symposia, congresses

The Commission has organized several workshops and symposia within the past years (e.g. *Databases for Biodiversity Research*, held on 12th December 1997, *Presentation and Discussion of New Methods for the Recording and Documenting of Taxonomic Diversity*, which took place on 8th March 1999, and *The Value of Biodiversity*, held on 5th November 1999), and has contributed to the organization and budgets of several other workshops, symposia and congresses. Beginning in 2001, annual workshops on topical questions of long-term research will be held. All these activities represent an opportunity to present the Commission's research results and in turn offer numerous impulses for its own work.

Representation in expert bodies

Several members of the Commission represent its interests, particularly those related to biodiversity and long-term ecological research, in a great variety of national and international bodies. Among these are, for example, the MaB National Committee, the committee on Global Change, the National Biodiversity Committee at the Ministry of the Environment, DIVERSITAS, IUBS, IGBP, LTER, and so forth. This generates an essential and highly valuable information transfer in both directions. For this reason these activities will be continued and even intensified.

