Nationalpark O.ö. Kalkalpen Ges.m.b.H.
Nationalpark Allee 1
A-4591 Molln, 07584/3951, Fax 3654-291

ABSTRACT
of the Nationalpark Karst Research Program 1994 - 1997

Karst Program Part.Proj. 13/96

Harald Haseke
and partners

Annual report 1996/97

Nationalpark O.ö. Kalkalpen Ges.m.b.H.
Nationalpark Allee 1
A-4591 Molln, 07584/3951, Fax 3654-291

NATIONALPARK KALKALPEN (UPPER AUSTRIA) KARST RESEARCH PROGRAM

The Nationalpark Karst Program 1994-1997

Introduction

Karst landscapes represent an important facet of the Earth's geodiversity, and one of major management significance. The term karst denotes a distinctive type of terrain characterised by individual landform types and landform assemblages that are largely the product of rock material having been dissolved by natural waters to a greater degree than in most other landscapes.

Two essential characteristics of karst must be taken into account in developing protective policies:

- its integrity is intimately dependent upon maintenance of the natural hydrological system;
- karst is vulnerable to a distinctive set of environmental sensitivities.

From the system-analytical point of view, the conception "karst" means a range of themes whose investigation requires a multidisciplinary cooperation between several branches of bio- und geosciences. Karst research includes all aspects of landscape description and genesis, including knowledge on the kinds of dynamic processes from the past to the future.

As in many aspects of protected area management, the establishment of protected areas is not enough in itself. The management of karst demands specific interdisciplinary expertise and this is in the early stages of development in most countries. Management agencies should recognise the importance of this expertise and take advantage of inter-agency or international cooperation in order to enhance their own capabilities.

In Austria, a long and rich tradition in this field has allowed us to assume a leadership role with regard to karst hydrological topics.

Using this wealth of experience, the Nationalpark Kalkalpen has attempted to develop an exemplary karst program which could contribute to the exploration and management of karst National Parks worldwide.

The Nationalpark Kalkalpen area

The Nationalpark Kalkalpen ("National Park Limestone Alps") was established in 1990 in southern Upper Austria, between the Steyr and the Enns Rivers around the basin of Windischgarsten.

The first planning area consists of the "Sengsengebirge" and the "Reichraminger Hintergebirge" as characteristic parts of the Northern Limestone (Pre-)Alps, with an actually protected area of 180 km² north of Windischgarsten. The altitudes of the peaks do not exceed 2000 m asl. Large catchments (70%) of these mountains are deeply karstified and the main outcrops are Triassic and Jurassic limestones and dolomite rocks (Wettersteinkalk Limestone, Hierlatzkalk Limestone, Hauptdolomit/Main Dolomite).

The Northern Alpine Karst mountains have a very large water potential due to the high precipitation rates at the "bounce slope of Europe". From the valley grounds to the highlands and peak regions of the Nationalpark Kalkalpen, the precipitation rate increases from 1300-1500mm/yr to 2000mm/yr and more.

The mean area discharge represented by 792 identified springs (National Park and surrounding catchments) is around 30-50 l/s/km². The largest fountains release over 2000 l/s as average discharge and over 30 000 l/s during floods. In the National Park area, a total of 768 km of stream reaches, some of them intermittent streams, in 109 catchment areas has been mapped.

The great importance of such European resources makes it essential for the National Park office to be engaged in drinking water research.

The importance and vulnerability of Austrian karst areas

Northern Alpine karsts are major **water catchments** for domestic supplies. In Austria, nearly 50% of the inhabitants use karst fountain water for their daily needs. However, pollutants can be transported rapidly through subsurface networks. Proper management of karst is an essential element of water resources management.
Most of the alpine karst region is covered with forests. Human activities in the past have altered both the distribution and species composition of these forests. Firewood production to meet the energy demand of early industries resulted in huge clearcuts in the 18th and 19th centuries. In some cases afforestation led to monocultures of coniferous forests, in others forest land was converted to alpine pastures.
The "Reinertragslehre", a management concept of highest interest on forest capital investment also promoted monocultures up until the present time. Erosion and hydrological changes are a consequence of this intensive landuse. Secondary forests also show reduced stability against windthrow and bark beetle investations. Overstocking of alpine pastures caused degeneration of the vegetation cover and soil erosion. Although these pastures are now partly abandoned, the progress of secondary succession has been slow. In the past decades, construction of forest roads has had an additional impact on this sensitive landscape. Currently, browsing by game is inhibiting natural regeneration.
The area of the National Park is typical for such situations. Sengsengebirge and Hintergebirge are part of the "Eisenwurzen", an old industrial region famous for the production of iron and steel products. Altered interception and transpiration losses of the vegetation cover, increased surface runoff, a decrease in water storage capacity, and increased sediment transfer to the karst system are the most likely consequences and will be the focus of investigations.

Any perturbation in the **hydrological system** will threaten the karst and those caves which have a continuing relationship to the water levels. At the same time, any damage to the integrity of a karst system will have far-reaching hydrological impacts. It also needs to be recognised that groundwater divides and catchment boundaries may not coincide with surface divides. Pollution, whether by water-soluble compounds, microbial transmission, siltation or simply by dumping of large-scale wastes leads to a similar problem. The comparatively rapid transmission of groundwater flows in karst provides little opportunity for natural filtering or other purifying effects, and so problems such as disease transmission may arise much more readily than in other terrain.
To the life scientist, karst is also important for its **biodiversity**, harboring special plant and animal species and communities. Alpine karsts have served as refuges for species that have persisted underground through environmental changes in the Pleistocene which have eliminated their surface-dwelling relatives. In karsts, environmental conditions underground can be very constant and cave species may have little tolerance to subsurface environmental change. In many ways karsts are buffered against climate change and their biota are less vulnerable in climates characterised by high natural variability. Hence, karsts serve an important habitat function, and, given the specialised nature of karst environments, they are often a focal point with regard to endangered species.

National Park Research: The Karst Program

The interdisciplinary research program Karst dynamics is a cooperative project between the Federal National Park Office and the Federal Ministry of Environment. It is being carried out by a number of contractors working according to common guidelines and tight coordination. From 1997 to the future, the Karst Program will attempt to become more closely connected to the Austrian ECE Program “Integrated Monitoring Zoebelboden“, which is being carried out by the Federal Environment Agency - Vienna in the National Park area.

The conceptual study was drafted in 1993/94 by:

- Ralf Benischke, Dr. Hermann Stadler, Institute of Hydrogeology and Geothermics, Joanneum Research Graz,;
- Dr. Klaus Katzensteiner, Univ.Prof.Dr. Gerhard Glatzel, Institute of Forest Ecology, University of Natural Resources (BOKU University), Vienna;
- Dr. Harald Haseke, EIS Coordination office, Salzburg.

Nationalpark O.ö. Kalkalpen Ges.m.b.H.
Nationalpark Allee 1
A-4591 Molln, 07584/3951, Fax 3654-291

Scientific staff

Participant project	*Contractors*
1. Meteorology and Climatology	Mag. Manfred Bogner/ Thomas Lehner OEG m-bogner@ping.at Mag. Günther Mahringer guenter.mahringer@ccgate.austrocontrol.co.at
3.1. Assessment of watershed approach	DI Dr. Klaus Katzensteiner, DI Franz Mitterböck; katz@mail.boku.ac.at, mitter@h415.BOKU.ac.at
3.2. Soil, sediment and rock analyses	Dr. Franz Ottner ottner@edv1.boku.ac.at
4. Alpine meadows karstification	DI Dr. Klaus Katzensteiner, DI Josef Lechner katz@mail.boku.ac.at, lechner@h415.boku.ac.at
5.1. Pilot study carbonate soils	DI Dr. Klaus Katzensteiner, DI Nemesthoty katz@mail.boku.ac.at nemestot@woek.BOKU.ac.at
5.2.&2. Vegetation and soil hydrology	DI Dr. Klaus Katzensteiner, Prof. Dr. Gerhard Glatzel; katz@mail.boku.ac.at, Glatzel@woek.boku.ac.at
6. Geomorphological and hydrological mapping	Dr. Harald Haseke h-haseke@apanet.at
7.1. Karst spring monitoring, Event campaigns	Dr. Harald Haseke h-haseke@apanet.at
7.3. Karst spring documentation	Dr. Harald Haseke h-haseke@apanet.at
7.4. Supplementary water analytics	NPK Laboratory, Ing. E. Pröll elmar.proell@merlin.at
7.5.1. Microbial analytics I: Hygienical approach	Mag. Susanne Schmidt susanne.schmidt@kfunigraz.ac.at
7.5.2. Microbial analytics II: Soil bacteria	DI Peter Holubar holubar@mail.boku.ac.at
7.5.3. Microbial analytics III: Stygian bacteria (Myxobact.)	DI Benjamin Menne BIUS-BenMen@t-online.de
7.6. Spring ecology	Dr. Erich Weigand weigand@ubavie.gv.at, tockner@eawag.ch
7.7. Digital karst spring measurement	Ing. Max Wimmer, Fed. Hydrographic Office Linz, FAX +43 732 7720 2411
8.1. Discharge measurement, water balance	Ing. Max Wimmer, Fed. Hydrographic Office Linz, FAX +43 732 7720 2411
8.2. Hydrological data: statistics and evaluation	Ralf Benischke, Joanneum Research ralf.benischke@joanneum.ac.at
9. Intermittent stream research: Rettenbach	Mag. Gabriele Weigelhofer gweigel@pflaphy.pph.univie.ac.at
10. Speleological support	Ing. Josef Weichenberger Phone: +43 0732 307 571
11. Karst water tracing	Ralf Benischke, Joanneum Research ralf.benischke@joanneum.ac.at, h-haseke@apanet.at
12. Geographic Information System NPK-GIS	DI Andreas Gärtner, Norbert Steinwendner Federal NPK office, FAX +43 7584 3651
13. Scientific Co-ordination	Co-ordination office Dr. Harald Haseke h-haseke@apanet.at
14. National Park Research Center, scientific support	NPK Laboratory, Ing. Elmar Pröll elmar.proell@merlin.at

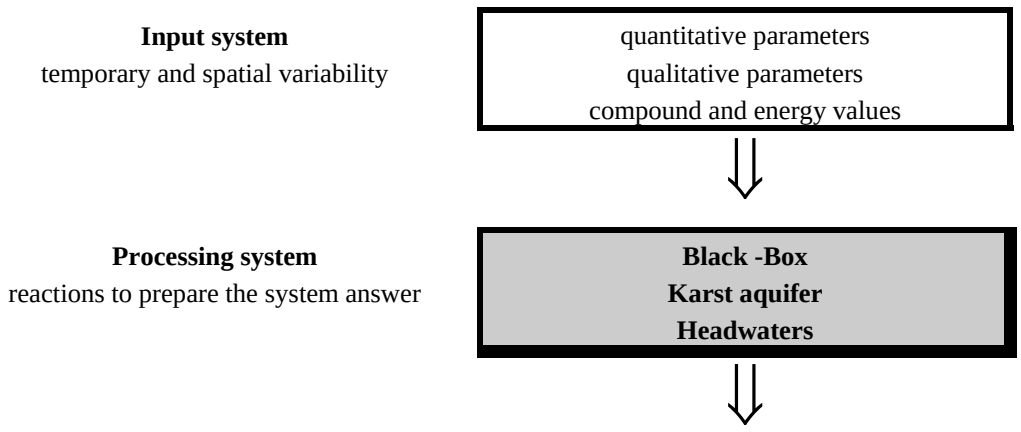
	Federal NPK office, Dr. Roswitha Schrutka
15. International investigations	I. Entner, R. Benischke, Joanneum Research ilse.entner@joanneum.ac.at ralf.benischke@joanneum.ac.at
00. Integrated Monitoring Zoebelboden	Federal Environment Agency - Austria DI Michael Mirtl, Dr. Martin Kralik mirtl@ubavie.gv.at, kralik@ubavie.gv.at

Tab. 1: Recent and ongoing participant projects and contractors to the Nationalpark Karst program. The reader can follow the headings to obtain more information on the projects and their links or can contact the contractors directly.

Fig. 1: Overview scheme to the principles and parts of Nationalpark Karst Research

The first program step is characterized as a “headwater study“, with the main effort being concentrated on the sampling and evaluation of basic parameters like the spatial analysis of geology, hydrology and geomorphology, along with investigations on meteorology, vegetation, regional benthic spring research, soil development studies, agricultural and forest uses, etc. Some primary data and regional overviews about the natural history of the National Park area are currently available, e.g. edited as an “Atlas of Geology“, “Atlas of Geomorphology“ and “Atlas of Hydrology“. These Atlases are on sale. GIS features like ARC-INFO have therefore been used for this purpose.

The second project stage, which is currently in effect (1996-1998), involves intensive investigations of small karst catchment areas, supplemented by strictly organized “Event Campaigns“. These inquiries take place along a large “transect“, i.e. a transverse section at the most elevated part of the Sengsengebirge mountain range (Nock Area, 600 - 1970 m asl). Two large springs are the ending points and output sites of this catchment area. These campaigns should allow us to decode the very complex relations and changing processes between the headwater and subterranean zone or, from the hypothetical perspective, between “biotic“ and “abiotic“ surroundings. Based on the stygofaunistic and microbiological evidence, however, we are convinced that the “abiotic environment“ in vadose and phreatic karst does not exist...



Output system
temporary and reduced spatial variability

quantitative parameters
qualitative parameters
compound and energy values

Fig. 2: Black-Box-Model as a simple research item for hydrology. While the input is spread spatially over the catchment areas, the parameters are manipulated and changed inside the "black box" karst. At the output locations, they can only be found as punctated information which is encoded. In this model, karst water is estimated as a "system answer" to various impacts and alterations in the catchment areas.

To classify the karst landscape, the term "hydrotope" is chosen in the field of hydrology to denote an area with homogeneous hydrological properties ("minimal catchment"). This is equivalent to the term physiotope as a characteristic part of the landscape or to the well-known term biotope. However, investigations revealed that such methods merely generated many analyzed single catchments without any homogeneity. The convergence approach postulates that all the information of the headwater area which occurs in the final exit of a catchment or in a spring is encoded. This must be decoded, e.g. with a discharge component segregation based on the quantitative hydrochemical or isotopic measurements.

In brief, the framework of the Karst Program can be described as follows:

Meteorologists collect both regional and site-specific climate data as the highest system parameter. The network of measuring stations from different areas enables the weather conditions across the National Park to be described on a daily basis. Automatic instruments are employed to measure the climate directly at the scientific test sites; they record the minimum parameters precipitation, humidity and temperature.

Rainfall affects karstified surfaces that differ in altitude, vegetation and soil development. Bioclimatologists and soil ecologists are charged with studying the resulting transformation processes and the seepage of water into the subsurface zone.
In the bioclimatology and soil hydrology part of the study, interception losses of different vegetation covers (Norway spruce, European beech, clearcut regeneration, Mugo pine), transpiration of different tree species (Norway spruce, European beech), water storage in the forest floor and mineral soil, as well as the chemical changes of percolating water are investigated during the vegetation period. The bulk samples of precipitation, throughfall and stemflow (only in beech) are gathered weekly. Soil water is sampled with suction lysimeters below the forest floor and in the mineral soil; water of the unsaturated zone is gathered with funnels in nearsurface caves.

Geomorphological, hydrological and geological maps provide the underlying framework for the topographical representation; this is also available in the Geographic Information System (GIS).

The percolation water strings pass through the large black-box zone of the vadose karst and join within the semiphreatic watertable of the fountain caves and the spring areas.

Speleology contributes valuable data gained from subterranean exploration and measurements. Isolated tracer experiments have been and continue to be conducted in selected catchments to investigate drainage conditions.

A wide range of studies are being carried out in the water table zone of karst water and in the springs themselves. These include:

* Quarterly synoptic campaigns to determine karst water quality over the entire region (Karst Spring Monitoring, 35 to 40 springs),
* Intensive campaigns during certain situations at 2 to 3 selected springs: here, samples are taken at intervals of 3 to 6 hours over a period of several days; a hydrological profile at reference springs with different expositions (Event Campaigns),
* Automatic data loggers at several large springs,
* Monthly sampling of environmental isotopes at selected springs and precipitation stations: The investigations encompass hydrophysics, hydrochemistry, hydrobiological parameters and microbiology. A hydrologically oriented spring register was established to characterize those springs under long-term investigation; it contains the basic data on 792 springs and detailed data on approx. 65 springs.
* The limnofauna of the 40 most important springs was studied; 4 springs are the subject of intensive ecological research and permanent observations.
* A special program was designed to study the water-bearing Rettenbachhöhle. These include water level measurements (flooding phases) along with hydrochemical, sedimentological, macrobiological and, above all, microbiological programs (microbial colonisation of subterranean evacuations and interfaces, influence of carbonate lysis on karstification, or bioconservation).

Investigations at the “lowest system level“ include also discharge measuring campaigns at spring effluents (hypocrenale streams) and in the catchments as well as the limnological research at intermittent epirhithral karst streams.
All projects are permanently interlinked to exchange data and other information, including the time schedules of the various campaigns (synopses). All incoming data are evaluated and standardized using the specific methodologies of the respective subdisciplines in order to enable valid comparisons. As the local server of investigations, the National Park office maintains a Research Center with a well-equipped hydrological laboratory and computer data banks.

The Karst Program I (1994-1997) will be evaluated in late 1997, and we will do our best to always put the most recent information on the Internet. At the present time, the individual reports describing the specific projects only contain preliminary results.

Future project evaluations will develop and/or test well-established and innovative/experimental investigations in the field in order to build and discuss karst process models in an international frame.

METEOROLOGY AND CLIMATOLOGY: REGIONAL MEASUREMENT NETWORK

Nationalpark O.ö. Kalkalpen Ges.m.b.H.
Nationalpark Allee 1
A-4591 Molln, 07584/3951, Fax 3654-291

Meteorological Program 1993-1998 & Nationalpark Karst Program 1994-1997 Participant Projects: 1603-1.1 and 1.2.

a) Short description of the climate

The location of the National Park at the northern side of the Alps with heights reaching from 400 to 2000 m asl determines the climatic situation in the area, which is a moderate, humid climate with strong oceanic influences. In the frequent weather situations with northwesterly flow, precipitation is strongly forced by the lifting of the air. The mountain regions show a strong dependence on altitude and exposition regarding the climate elements temperature, precipitation, wind, snow cover and radiation.
Mean annual temperatures reach from 8°C in the valleys down to 1°C at 2000 m asl. The mean precipitation ranges from 1300 to 1800mm at the measuring stations, but is probably above 2000mm along the mountain crests. Although the climate is humid throughout the year, the highest precipitation occurs between June and August due to frequent thundershowers. The mean snow cover duration is 60 days/yr in the northern valleys (400 m asl), around 100 days/yr in the inner alpine valleys (600 m asl), and around 190 days/yr at an altitude of 1500 m asl, with great differences between northern and southern expositions. Sunshine duration ranges from 1500-1600 h/yr in the valleys up to 1700-1800 h/yr on the mountain, where less fog occurs between October and March.

b) Meteorological Observations and Documentation

The Nationalpark Kalkalpen is the site of interdisciplinary research projects focussing mainly on hydrological, biological and meteorological aspects. To achieve a better coverage of area, climatology measurement sites were established in this region; most of these are situated above 1200 m asl in order to obtain more information about phenomena in northern alpine regions. - Since 1990, a meteorological observation and research program has been conducted in the National Park. This program yielded all the existing data. Since early 1993, meteorological stations are being operated at the following locations:

- Schoberstein (1285 m) - Wind, Temperature, Humidity, Pressure, Radiation, Precipitation, Visibility, Cloud information, Weather.
- Hinterer Rettenbach (610 m) - Temperature, Humidity, Precipitation.
- Zöbelboden (900 m), as of 1996 Feichtaualm (1350 m) - Wind, Temperature, Humidity, Precipitation.
- Kogleralm (1240 m) - Temperature, Humidity, Precipitation.
- Feichtausee (1400 m) and Hagler (1590 m) - Precipitation totals.

Additional stations are temporarily operated during special campaigns of the Karst project. All stations, sensors and data are carefully checked. The routine work of meteorologists in the National Park consists of maintaining the stations as well as collecting, analyzing and interpreting all meteorological data of the region and its surroundings. The statistical evaluation of the climatological data comprises the description of the daily, monthly and long-term development of the weather situation combined with climatological and meteorological parameters.

This work is carried out at the request of other scientists who need these data for their projects.

Additionally, research studies are carried out to study phenomena such as:

* heavy precipitation events and their impact on the biosphere,
* to gain knowledge about detailed precipitation patterns within different types of weather simulations and
* to estimate precipitation input into catchments for research campaigns studying karst water flows in springs and stream reaches.

On the basis of data from precipitation measurement campaigns, a high resolution rain gauge network was designed to be operated during summer seasons. It consists of 30 stations and will be completed in May 1997, using self-designed RALO´s (Rain loggers) as easily portable, low-cost automatic stations. The total area covered by the network is about 200 km², with an average spacing of less than 3 km.

Another part of the METEO project is the

* study of duration and depth of the snow cover,
* the temperature distribution and
* the duration of sunshine at different National Park sites.

These elements are displayed in high spatial resolution using geographical information systems (GIS Arc/Info).

The Karst program provides a framework for additional measurements and documentation. Stations are operated seasonally at the research areas, measuring temperature, humidity, precipitation and ground temperatures in several depths. Bulk precipitation collectors are operated for chemical analyses. The detailed meteorological situation is documented prior to and during hydrological measuring campaigns to enable a correct evaluation of the findings.

Most recent activities:
A dense precipitation measuring network has been in operation since 1996. It will consist of 30 RALO stations by June 1997. This network yields very valuable information on detailed rain patterns with good areal representation, with the possibility to give reliable values even for small catchments. The average spacing of the stations will be 2-3 km, and many of the stations are located in high altitudes. Unheated conventional sensors developed by the team itself are employed; the system is operated every year between the May and October/November. The temporal resolution is 10 minutes. A documentation of heavy precipitation episodes is carried out after every season.
As supplements for the catchment soil studies in the Karst program, three additional stations have been exposed and evaluated.

Further activities:

The high resolution rain gauge network will be completed in May 1997; it will be fully equipped and operational during the first season.
Climate change will be an important theme for future research. The METEO project intends not only to investigate trends in the usual meteorological parameters like temperature, wind speed and precipitation, but also biologically relevant extreme situations like periods of drought and water deficit, floods, influence to the duration of vegetation periods and so on, which have to be defined in a close interdisciplinary co-operation. However, long-term observations and measurements must be available before good results can be expected.

Mag. Manfred Bogner/ Thomas Lehner OEG m-bogner@ping.at
Mag. Günther Mahringer guenter.mahringer@ccgate.austrocontrol.co.at

ASSESSMENT OF THE WATERSHED APPROACH FOR THE KARST RESEARCH PROGRAM

Framework: Nationalpark Karst Program 1994-1997
Participant Project: 1603-3.1.

Physiographical, geological and geomorphological maps, soil data of the environmental monitoring program, vegetation information from aerial photographs, and meteorological data are analyzed with GIS and statistical techniques to describe the properties of distinct watersheds.

The data are implemented in simple hydrological models to estimate rainfall interception, water storage and runoff for topographically determined watersheds negotiating karst-water pathways. These analyses are the basis for the comparison with measured runoff and the estimation of water pathways.

The results will be used for decision making about the establishment of long-term monitoring instrumentation in experimental watersheds.

DI Franz Mitterböck mitter@h415.BOKU.ac.at
DI Dr. Klaus Katzensteiner katz@mail.boku.ac.at

CHEMICAL AND MINERALOGICAL ANALYSES OF SOILS AND ROCKS

Framework: Nationalpark Karst Program 1994-1997
Participant Project: 1603-3.2.

This project part characterizes representative rocks, soil samples and drift particles in spring waters. In the first project part a number of typical soils, lithic Leptosols, rendzic Leptosols, chromic Cambisols and stagnic Gleysols of different origin (limestone, dolomite, marls) were

analyzed chemically and mineralogically. Based on diagnostic properties and analyses, soil genesis, filtering and buffering capacity, and hydraulic properties are evaluated.

The report contains detailed profile descriptions and the results of the analyses in tabular form. The results are compared with those of other studies like the Austrian forest soil survey. The analyses show the dominant influence of pre-Holocene soil-forming processes for the current situation: a major part of the soils are Paleosols. Additionally, loess covers can be found on leesides. These soils - if not too shallow - have a high water storage capacity and a very high buffering capacity (high pH and CEC).

On very poor limestone, where accumulation of pre-Holocene soil material was not possible, extremely shallow lithic Leptosols with pronounced accumulation of alpine mor are developed. These soils are very poor, both with respect to water storing capacity and to physico-chemical filtering capacity.

Current work:
Soil characterization of small experimental catchments,
Physical characterization of selected soil samples (pF-curves),
Mineralogical analyses of cave sediments and drift particles in selected karst springs.

Dr. Franz Ottner ottner@edv1.boku.ac.at
DI Dr. Klaus Katzensteiner katz@mail.boku.ac.at

KARSTIFICATION AND SUCCESSIONAL DYNAMICS OF ALPINE MEADOWS IN THE SENGSENGEBIRGE

Framework: Nationalpark Karst Program 1994-1997
Participant Project: 1603-4.

In former centuries the demand for firewood for early iron industries led to intensive anthropogenic pressure on the forests of the area. After clearing, alpine pastures were frequently established in former forests. In sensitive parts of the area, where rather shallow Paleosols overlayed pure limestone, denudation took place within a few decades.

Based on the study of historical documents, the stocking on the pastures and the grazing intensity was reconstructed and implemented in a GIS. Since 1880, legal regulations restrict this land-use practice to less sensitive sites. Four waves of decline in grazing intensity could be recognized: 1880, 1900, 1956-1960, 1976. Secondary succession was studied along two transects on selected abandoned alpine pastures. The regeneration history of the forest was reconstructed by analysing increment cores and stand structure.

Additionally, humus and ground cover vegetation showed a clear spatial gradient from the central parts of the former pastures to the edges.

Nationalpark O.ö. Kalkalpen Ges.m.b.H.
Nationalpark Allee 1
A-4591 Molln, 07584/3951, Fax 3654-291

DI Josef Lechner lechner@h415.boku.ac.at
DI Dr. Klaus Katzensteiner katz@mail.boku.ac.at

PILOT STUDY CARBONATE SOILS

Framework: Nationalpark Karst Program 1994-1997
Participant Project: 1603-5.

The aim of this project was to adapt ecological field methods for the investigation of complex sites in karst regions. The investigations started in November, 1994, and were completed by late 1995.
The first part of the project describes the soil series in the Mieseck-area, a flat hilltop in the Reichraminger Hintergebirge at an elevation of 1200 - 1300 m asl. An area of 80 ha was sampled in a 100x100 m point grid. The data were analyzed using multivariate statistical methods. The soil series range from extremely shallow lithic Leptosols, rendzic Leptosols, chromic Cambisols to stagnic Gleysols in sinkholes. In the second project part, the influence of logging on nutrient storage and soil bulk density was investigated. For this purpose, a clearcut with dense regeneration and ground cover vegetation was compared to an adjacent mixed spruce-beech-fir old growth stand. Both on the clearcut and in the stand the compartments forest floor vegetation, forest floor and mineral soil were sampled and analyzed.
The investigations show the importance of the compartments for the nutrient turnover in the plant-soil system: For some elements like potassium, the exploding vegetation on the clearcut is an important buffer, minimizing losses with seepage water. No significant influence of logging on soil physical properties could be identified. The high biological activity and bioturbation of the well base-saturated soils seem to reduce these impacts.
The last project part discusses methods for measuring water turnover on heterogeneous karst soils. TDR-technology proved to be well adaptable to measure the water content in shallow soils. Different suction lysimeter types were used to sample soil water for chemical analyses in several soil depths. There is a rapid enrichment of calcium and magnesium in seeping water, while potassium and nitrogen remain in the upper soil horizons and the vegetation, both in the old growth stand and on the clearcut. Percolating water in a nearby karst sinkhole already shows Ca-concentrations similar to those in the water from karst springs. The Mg-content increases steadily and reaches highest values in the springs after the passage through dolomitic rock series. The water pathways are described in project 11 (Tracer experiments).

DI Dr. Klaus Katzensteiner katz@mail.boku.ac.at
DI Nemesthoty nemestot@woek.BOKU.ac.at

INFLUENCE OF VEGETATION AND SOIL ON SEEPAGE WATER OF KARST SYSTEMS

Framework: Nationalpark Karst Program 1994-1997

Nationalpark O.ö. Kalkalpen Ges.m.b.H.
Nationalpark Allee 1
A-4591 Molln, 07584/3951, Fax 3654-291

NATIONALPARK KALKALPEN

Participant Projects: 1603 - 5.2.&2.

Within the framework of an interdisciplinary karst research program in the Northern Limestone Alps National Park (Austria), five small catchments were established in 1996 to investigate the alteration of precipitation water passing different vegetation covers and soils.

Two plots were located in the montane altitude: one pure European beech (*Fagus sylvatica*, 650 m asl) and one secondary Norway spruce (*Picea abies*)/ European larch (*Larix decidua*) stand (850 m asl). Both stands stock on rather deeply grounded colluvial soils with high content of coarse limestone debris. Stand composition has probably altered soil properties (beech: Rendzic Leptosol with Mull-humus and a mollic A-horizon of 70 cm, low bulk-density and well developed crumb structure; spruce: Rendzic Leptosol to Eutric Cambisol with stagnic properties in the subsoil, Moderhumus and a mollic A-horizon of 10-20 cm, high bulk-density and massive structure in the subsoil).
Three plots were established in the upper montane zone (1300 m asl): an old growth Norway spruce stand with single beech, an adjacent recent clearcut with initial vegetation, and a reforestation with larch and spruce with a dense ground-cover vegetation. A Moderhumus type called 'Alpenmoder' (alpine mor) between 5 and 20 cm thick with a mighty Oh-layer directly overlays the heavily karstified limestone ('Hierlatzkalk'). In the reforestation, the humus is partly mineralized.
An additional plot was established in the krummholz-(*Pinus mugo*) region on 'Wettersteinkalk' at an elevation of 1600 m asl.

All plots were equipped with precipitation samplers (automatic recording rain gauges on an open area at a short distance from the stands, throughfall samplers (10 gutters in each stand 1 m above ground, 10 gutters in the reforestation below ground cover vegetation, with a total of 1 m² sampling area for each setup) and stemflow samplers in the beech stand. Below the forest floor, ceramic plate suction lysimeters were installed; in the beech and the spruce stand on the deep soils, ceramic cup lysimeters were additionally established in a depth of 60 cm. Below the shallow soils, water of the unsaturated zone was gathered under rocks and in a karst sink hole ('Nadelöhr') 12 m below surface.

All samples were taken weekly during the vegetation period. Soil moisture was measured with TDR-probes and tensiometers on the deep soils; from the shallow Alpenmoder, undisturbed cores were taken to measure the moisture content. In the krummholz plot, no soil water samples were taken; precipitation and throughfall was only gathered during the measuring campaigns of the other project participants. Transpiration of selected trees on the old growth spruce stand in the upper montane zone was measured by the heat balance method. The interception losses of the old growth spruce stands lie between 24 and 27%, while the value in the beech stand was less than 19%. In the reforestation about 4% of the precipitation is intercepted by the canopy and 4% is intercepted by the ground cover vegetation.

The most significant changes of soil water composition take place in the humus layer and the upper soil horizons. While in the beech stand, pH values steadily increase from pH 6 to pH 8 when passing the crown cover and soil horizons, with a marked increase of HCO_3-contents in

50 cm soil depth (> 3 mg/l), in spruce there is a drop in pH to below pH 5 after passage through the forest floor. In 50 cm depth, the pH still has not reached comparable values of the beech stand. A similar decrease in pH was recorded under the shallow Alpenmoder; only in the reforestation did pH steadily increase after passing the canopy, the ground cover vegetation and the humus layer. Immediately after contact with solid limestone, the pH increases to above 7. Although the nitrate contents of seepage waters are generally low on all sites, there is some nitrogen mobilization on the clearcut, leading to a tenfold increase of nitrate values in seepage water. These values, between 5 and 10 mg/l, are still typical for a pristine area.

Except the krummholz plot, which drains to the 'Rettenbach' spring, all plots probably drain to the 'Steyern' spring. Both of these springs are the subject of intensive monitoring campaigns for chemistry, isotope analyses and microbiological parameters. Based on these parameters the link between watershed properties and karst springs will be modeled.

The soil hydrological modeling is currently in progress;
Chemical analyses are currently in progress;
The measurements will be extended to the end of the 1997 vegetation period.

DI Dr. Klaus Katzensteiner katz@mail.boku.ac.at
Prof. Dr. Gerhard Glatzel Glatzel@woek.boku.ac.at

MAPPING OF GEOMORPHOLOGY AND HYDROLOGY

Nationalpark Karst Program 1994-1997
Participant Project: 1603-6.

As early as the 1970s, the Enns Electric Power Group (EKW) undertook intensive investigations on the karstification in the northern foreland. Especially near the karst creek Krumme Steyrling, there are many recent and spectacular phenomena like "Caving in" (Wunderlucke - "Miracle pothole"). Some stream water disappears into the karstified rocks below the alluvions.
From 1990 to 1995, an intensive terrestrial mapping at a scale of 1:10.000 was done in the National Park zone 1 as well as in the surrounding regions. With regard to the hydrogeology, the boundaries of the mapping have generally been set in the receiving streams. The analysis of field data is supplemented with aerophotogrammetric and spot image research. For an integrated documentation in the National Park Research Center (Molln), the GIS-feature ARC/INFO is used. The mapping has been edited as an Atlas of Geology, an Atlas of Geomorphology, and an Atlas of Hydrology.

Sengsengebirge
The Sengsengebirge represents an entirely karstified limestone mountain based on its chain ridge type. Karst phenomena are typical for this formation. The Sengsengebirge is a large Triassic Wetterstein Limestone anticline, representing a west-east stretched barrier in the

North of the Windischgarsten Basin. The fold also features numerous tectonic structures: the north-south striking cleavages cause vertical dislocations, while the west-east disturbances seem to be recently activated, making them important for karst water tracing. All the valleys and stream patterns follow these structures.
Because of the great asymmetric anticline, the northern part of the Sengsengebirge forms large walls, while the southern hillside is less precipitous. The mountain tops are aligned in a long W-E chain (Hoher Nock: 1970 m asl). Thus, the alpine karst phenomena have evolved in relatively restricted areas. Only two positions can be interpreted as "Ancient Karst Landscapes": The cupola karst of the peaks (less karren, large dolines; 1700-1900 m) and the uvala karst valleys (large evolution of subcutane karren, irregular dolines, exhumed rock structures like "Karstgassen"; 1300-1500 m). The lower exposition boundary for the regular karren phenomena is ca. 1100 m asl, while the upper development exzends to the peaks (max. 1970 m). It should be noted that some of the main structures are asymmetric because of the exposition, e.g. due to the snow distribution.
The karstification and soil erosion on the upper parts of the Sengsengebirge is very high. It seems impossible today to establish meadows there, as was typical 50-80 years ago. In our opinion, pastures and hunting have, over the course of time, damaged the ecological system. Every type of cultivation on the Alpine Limestone Karst seems to have a severe environmental impact.
Hydrology: The highlands of the Sengsengebirge are like a rock desert. The karst water infiltrates the limestone and emerges as a number of mighty springs. It has been demonstrated that large karst springs are accumulated at the level of the "pre-Pleistocene valley niveau" (Rettenbach). On the other hand, karst water outputs often occur at lithologically induced expositions, for example at interbeddings, but they mostly have a restricted capacity. - The large alluvial groundwater field of the Hopfing, a very scenic meadowland near the National Park, is used today by the Austrian army as a wargame area. This is a serious threat to the natural resources.

Reichraminger Hintergebirge

The Hintergebirge is a typical pre-alpine landscape dominated by fluvial erosion. Having been a periglacial "tundra" during the Pleistocene, the total relief energy of the dolomitic and calcareous landscape extends to above 1000 m.
Geologically, the southern Hintergebirge is part of the Sengsengebirge fold, while the northern development consists of the "Reichraminger nappe". The main rock of this nappe is Triassic dolomite and, interfolded in it, abundant Jurassic and Cretaceous limestones and marls.
In the southern Hintergebirge, the ancient landscape is situated between 950-1300 m in dolomites and limestones, formed as a gentle Tertiary hill country. It bears a dense network of rugged Quaternary gorges and canyons. Only a few rocky peaks extend higher (Groesstenberg: 1720 m asl).
The hydrographic system has yielded well-karstified areas. This is more evident in the hydrogeology than the morphology. Karstified zones are well developed on the calcareous folds of the Sengsengebirge-Frenzberg-Anticline and the Ebenforst-Syncline, which are situated between large dolomitic areas. The presence of karst formations such as dolines, sink holes and lapies depends on the altitude and nature of the rock.

The hydrogeology is highly variable: Large karst springs are defined near the erosion base level, medium karst springs are situated between different beddings or caused by ancient karst piezometric levels. Large limestone sinks (ponors) like that in the "Hetzschlucht" have been also explored. In the pure dolomitic areas, the small springs mostly drain out large detrital accumulations, which are often clayey.
The spring pits, circular and V-shaped valleys and short gorge passages in the northern Hintergebirge are mostly developed in Triassic dolomitic rocks, also imbricated and folded. In spite of the reduced solution rate, subterranean water pads have locally reached the corrosive base level, which is often flat because of the deep regressive erosion. The large Ebenforst plateau is well karstified and because of this, erosion could not destroy the ancient landscape, which has been conserved there. Parts of this landscape are also found at Predigtstuhl and Zoebelboden, which lead to the northern forelands. The northern frontier of the Ebenforst syncline is surrounded by large rock streams. A number of gravel terraces in the various ravines of Großer Bach, which also shows gorge cuttings, are caused by backwater effects near the Enns River.
The future management of National Park natural zones will require closing certain Hintergebirge forest roads. Some of them destroy the ecological balance of both the morphology and hydrology and create too much disturbance.

Northern forelands ("Mollner Mountains")
The area north of the Wetterstein anticline features many lower calcareous mountains which are also karstified. They have an intensively folded structure containing dolomitic and Jurassic limestone rocks.
The forelands are generally situated in lower hillside and valley landscapes, which have been mainly developed at the coincidence of the Pleistocene glacial boundary and the dendritic drainage pattern of the "periglacial" zone. The morphology therefore appears to be young and active, as indicated by high rates of fluvial erosion and frequent rock falls or rock slides.
In the northern regions of the Sengsengebirge, the geology is defined by Triassic and Jurassic limestone in several folds and imbricated structures. This generates compact rock walls and mighty rock fall deposits. Gorge passages are not uncommon, and karstification phenomena often extend to the valley bottom. Some boulder walls might have been formed by recessional stages or by dead ice in late glaciation periods.
A speciality of the Sengsengebirge and Molln valleys are the interrupted creeks among the alluvium areas, infiltrating into karst ponors buried by Pleistocene and Holocene beddings. Because of avalanches and floods, small rivulets are often destroyed by stones and wood.

Southern forelands (Windischgarstener Basin, Dambach, Laussa)
These areas are generally situated in lower hillside and valley landscapes (400-1400 m), which have been mainly developed at the coincidence of the northeastern Pleistocene glacial boundary and the dendritic drainage pattern of the "periglacial" zone. The main processes in these regions are fluvial and gravity-caused erosion and deposition (rock falls, earth slips), related to the strong relief.
The geology of these areas is very complicated and variable due to the emergence of "unusual rocks" like the flysch facies, which has been overthrusted by the Northern Limestone Alps and has been transported by great fault movements such as the Teichl disturbance ("Win-

dischgarstener geological window“) to the surface. There are also irregular structures like the “Weyrer bends“, where the average trend of the Alps turns to N-S.

During the Pleistocene, the Sengsengebirge formed a barrier between the Windischgarstener Basin and the northern pediments (Alpenvorland). The glaciers of the later Quaternary period, coming from the Phyhrn pass and Totes Gebirge, were blocked in the basin; this gave rise to a large field of periglacial beddings. The large epigenetic canyons of Teichl creek, Steyr creek and the Rettenbach form a very strange and rare lanscape and are the most impressive highlights in the National Park valleys. The deep canyons in the diluvial pudding stone outcrop (“Nagelfluh“) are developed in the the Lower Terrace, which is the result of transported glacial deposits (congelifracts, moraines) by late glacial torrents.
Karst phenomena are less numerous than on the tops and plateaus of the surrounding Limestone Mountains, but they exist, especially as springs along the Teichl/Dambach and Laussabach valleys and as fields of lapiaz and sink holes on little catchments above the Laussa, Dambach, Teichl and Rettenbach creeks.

Most recent activities:
A GIS treatment of the maps has been prepared to allow quantitative analyses of the geophenomena .

Further activities:
GIS analyses are currently being conducted and will contribute to a physiography and water balance study of National Park area.
The mapping will be completed in stages, with the next step being work at other planning areas of the National Park projekt, e.g. the Haller Mauern or the Warscheneck group.

Dr. Harald Haseke h-haseke@apanet.at

KARST SPRING MONITORING AND EVENT CAMPAIGNS

Framework: Nationalpark Karst Program 1994-1997
Participant Projects: 1603-7.1. and 7.2.

The project “Karst Spring Monitoring“ is the task force for a series of specialized hydrological measurements in a synoptic and synergistic framework. The aims of Karst Spring Monitoring and Event Campaigns are as follows:

A) to gain knowledge about the hydrogeological and ecological status in the National Park headwaters by logging the outputs in their seasonal and long-term aspects and dynamics;
B) to explore the phenomena which occur during precipitation and flood events between the headwaters and the springs (dense interdisciplinary approach);
C) to provide some fundamentals on hydrophysics, hydrochemistry, organic contents and isotope hydrology, as well as advanced studies in crenal ecology, biodiversity and abundance of springs.

Nationalpark O.ö. Kalkalpen Ges.m.b.H.
Nationalpark Allee 1
A-4591 Molln, 07584/3951, Fax 3654-291

The campaigns "**Karst Spring Monitoring**" in the area of the Nationalpark Kalkalpen (Upper Austria, southern part around Windischgarsten) were initiated in 1991 and are executed seasonally, recently four times p.a. The measurements integrate 35 to 40 larger fountains of various types from a sample of 792 recognized springs. The investigated area is approximately 200 km². These campaigns are conducted according to the Austrian "water quality collection order" (WGEV) coordinated by the Federal Ministry of Agriculture and Forestry.
The "**Event Campaigns**" were started in 1995. In this framework, the observations include only two or three important fountains of various types and their headwater areas during a short period, but in a dense rhythm of 3 to 6 hours. Recently, the following sources have been selected:

a) Rettenbach spring: headwaters of the type calcareous "rock karst" (approx. 1000-2000 m) with subalpine stands and abundant *Pinus mugo*. The investigations include a large cave system (Rettenbachhoehle) which corresponds with the shallow phreatic zone of the karst spring. In addition to the springs and downstreams, the participant project "Intermittent streams" is being carried out.
b) Steyern spring: headwaters of the type calcareous "green karst" (approx. 700-1500 m) with montane-subalpine forests and alps. When flooding occurs, the karst spring is highly polluted by sediments and microbes. In specially investigated catchments, the input into the vadose karst system is measured by standard methods employed in soil and forest ecology.
c) Weissenbach spring: headwaters of the type dolomitic "forest karst" (approx. 500-1100 m) with low montane forest stands. The water of the joint source is very clear. In the corresponding catchment Zoebelboden, the Federal Environment Agency runs a UN-ECE-Integrated Monitoring program (DI Michael Mirtl, mirtl@uba.ubavie.gv.at).
The campaigns of the National Park Research Center are carried out by automatic logging stations serviced by the Federal Hydrographic Agency and the Federal Environment Agency. These data loggers record the discharge of several springs; at three sites they additionally measure the temperature, conductivity, optionally the slurry und pH value (DKM**,** Digital Karst spring Measurement stations). Most of these stations were built in the framework of the Austrian water quality collection order (WGEV), but the recordings are available for National Park research.
Event campaigns are generally carried out in the case of floods, for example in a rain period or during snow melt. The following hydrophysical and hydrochemical parameters are measured by National Park laboratory and contractors :
Field data: Discharge, conductivity in µS/25°, temperature (0.1°), pH (0.01), REDOX-Pot., O_2
Hydrochemistry: Absorption 254, 285, 436 nm, total hardness, carbonate hardness, cations Ca, Mg, K, Na, anions NO_3, SO_4, Cl, DOC; only for specialized questions: NO_2, PO_4, NH_4;
Sediments: suspension matter value in TE, filter sludge: from 10 l of native water to high temperature drought glass fiber filters, determination of weight and grain size (coultercounter), from selected filters: heavy and clay minerals;
Organic contents and drift: DOC/Seston, colony-building Bacteria (culturing und directly counting), E. coli, coliforms, Enterobacteria; Myxobacteria, Streptomyceta, Agrobacteria.
Isotopes: ^{2}H, ^{3}H, ^{18}O.
At all the described spring sites, dense ecological investigations have taken place since 1994, including longitudinal descriptions of the eucrenal - epirhithral zone, exposition of emergency

traps and more. Results (interpreted until 1995): The hydrochemistry of the springs revealed a good drinking water quality from the calcium carbonate type, remaining far beneath the limiting values. Those parameters relevant to agricultural or industrial pollution are at a very low level. Only SO_4 occurs at considerable concentrations in some sources, but this is due to solution effects in gypsum-containing aquifers. The regional distribution of dissolved inorganic matter is not significant; also, it is not surprising that distinct types of catchments are associated with specific concentration levels of some parameters. Only the total hardness seems to be higher in the well-covered prealpine headwaters because of the higher solution rates by the biogenic CO_2. We recorded "organic" rates that were on a higher level than the anions and cations; this includes the absorption coefficients, the slurry index, the $KMnO_4$ consumption and the POC / clay rate. The peaks of CSB $KMnO_4$ reached nearly 35 mg/l, reported from springs with heavily utilized catchments, e.g. by forestry clear cutting or alpine meadows. Those springs characterized by disturbed catchment areas also showed comparably higher POC- and DOC-concentrations as well as enhanced concentrations of suspended solids. Caution should be exercised when drinking the water from these sources.
The microbial "pollution" of the National Park springs is also high. Within a sample of 28 permanently investigated MONITORING springs, only three sites turned out to be free of hygienically dangerous bacteria. Eighty-nine percent of the springs would not be appropriate as native drinking water, and nine springs (30%) have been identified as permanently polluted by human or animal faeces (e.g. waste water from huts, wildlife feeding, sinks in alpine pasture grounds). Seven of these springs have their headwaters in the inner National Park areas. We can identify certain human impacts as an important control system for microbial pollution in the catchments of the polluted fountains. Thus, the microbial impact clearly increases with the intensity of usage of the prealpine green karst catchment areas.

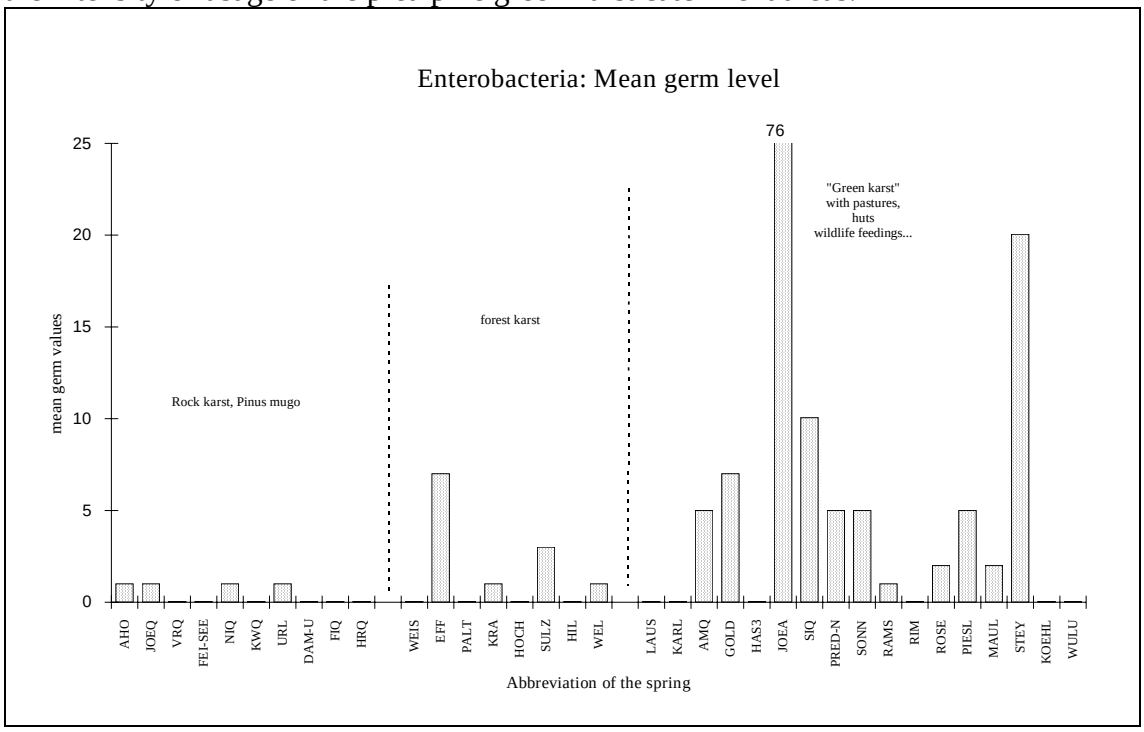


Fig. 3: Mean germ levels of *Enterobacteria*, sorted by different ecological types of spring catchment areas.

Most recent activities:
After several dry years since 1991, 1996 was cold and rainy. Some high-rated precipitations, mainly in late summer and autumn, yielded maximum flood discharges. The highest floods ever registered occurred at many hydrographic measurement stations.
The 1996 investigations included hydrochemical and hydrophysical measurements, environmental isotopes and hygienic microbiology (colony-building units, Enterobacteria, coliforms, E. coli) along with research on the macrozoobenthos, the eucrenal und stygobiotic limnology and ecology, extended microbenthic research on Myxobacteria, Agrobacteria, Streptomycetes, Rhizobiae, the organic carbon, suspended matter, sediments and other parameters. Four Monitoring tours and two event actions were coordinated. In addition, three measurement campaigns were organized into the vadose-shallow phreatic cave system of "Rettenbachhoehle", where intensive interdisciplinary research took place. The evaluation and summary of all results will be presented in BENISCHKE/HASEKE (1997).

Further activities:

25.-28.2.97: Winter campaign,
12.-15.5.97: Snow melt campaign,
14.-18.6.97: Precipitation campaign (Schafkälte, "sheep cold spell"),
10.-15.7.97: Drought campaign,
15.10.97: Final phase of laboratory measurements, evaluations,
15.12.97: Draft of Final Report.

The measurement campaigns are now more tightly linked to the Austrian Integrated Monitoring program at the Zoebelboden catchment (ECE, Federal Environment Agency; Dr. Martin Kralik, kralik@ubavie.gv.at).

Dr. Harald Haseke — h-haseke@apanet.at
Ing. Elmar Pröll (Nationalpark laboratory) — elmar.proell@merlin.at
Mag. Susanne Schmidt — susanne.schmidt@kfunigraz.ac.at

KARST SPRING DOCUMENTATION

Framework: Nationalpark Karst Program 1994-1997
Participant Project: 1603-7.3.

The Karst Program of the National Park Kalkalpen carries out periodic measurements at many karst springs (see part. proj. 7.1. and 7.2.). The documentation treatment includes all sites ever surveyed by the karst spring monitoring.

From 1990 to 1994, the hydrogeology of the whole National Park area (Sengsengebirge, Hintergebirge) and its environs was mapped (see part.proj.6.) The first information on 792 sources has been collected in a data bank (MS-Access) and several reports provided an overview of the hydrogeology of the headwaters. Also, an "Atlas of Hydrology" was published in 1996.

From 1994 to 1996, additional facts about 67 important spring areas were collected in several dossiers. These contain basic information like accurate logging position; lithology; stratification and tectonics; hydrological values; scientific reports, e.g. hypotheses on the headwaters of the springs; maps, photos and other supporting evidence. The spring register was conducted according to the recommendations of the Austrian water quality collection order (WGEV) coordinated by the Federal Ministry of Agriculture and Forestry.

Practical applications of the studies include:

* the possibility to estimate the native water resources of the National Park area,
* suitable references to the headwaters of the karst springs,
* facts about the ecology and vulnerability of closed karst catchments,
* a large geological and geomorphological basis for the hydrobiological and limnological statistics of the springs.

The tectonic mappings confirmed WSW-ENE directed fractures as the most important aquiferous structures (probably the key karst water tracing structure in the investigated area).

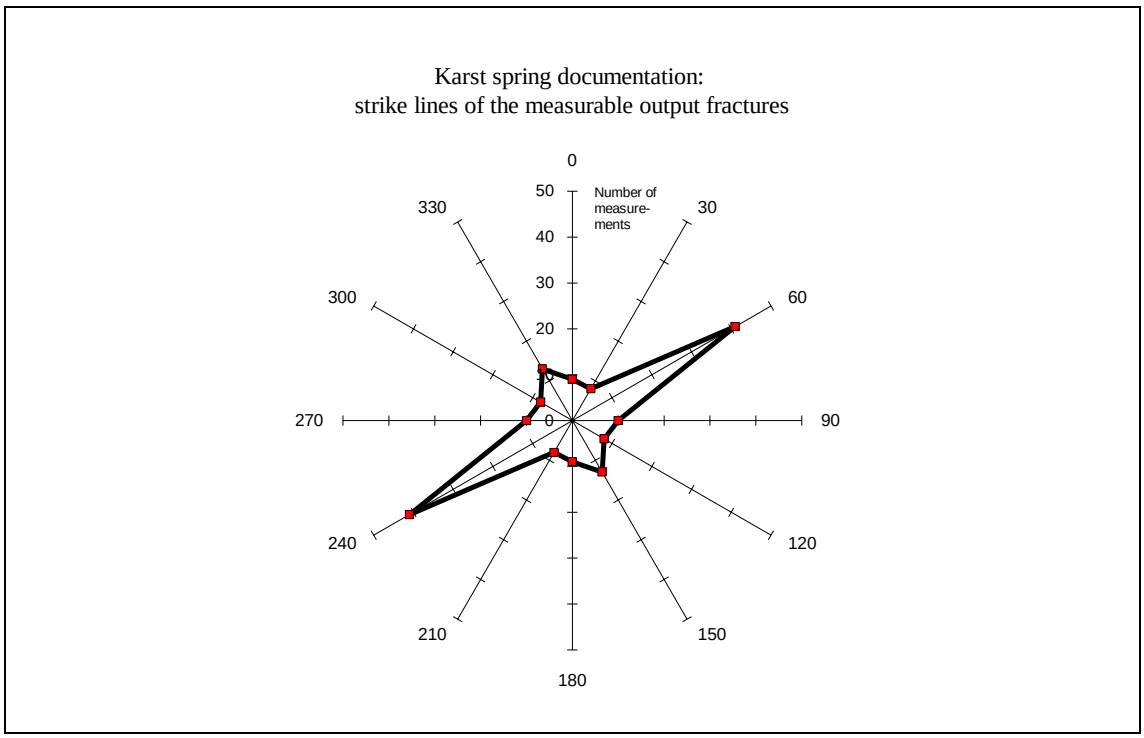


Fig. 4: A sample of the dominant strike lines of the measurable output fractures in some Karst springs at the Nationalpark area.

Most recent activities:
In 1996, the third phase of the Fountain Documentation selected 18 springs and ponors from a sample of 67 karsthydrological phenomena which are objects of scientific karst investigation in the National Park research effort. Seven springs are actually participants of the Karst

Spring Monitoring 7.1./96, 11 springs part of the Event Campaigns 7.2./96. Additionally, all the single vadose water streams and the shallow phreatic windows in the Rettenbach Cave were investigated and documented.

Further activities:
Approval has been given to complete the karst spring documentation with supplements to further 74 springs; this will enable the detailed registration of the last approx. 20% of the stock. These 74 sites are the objective of a comprehensive study (recently submitted) about the benthic fauna in the National Park springs (part.proj. 7.6.), which should be combined with hydrogeological and geomorphological data to formulate standard criteria for a hydro-benthic typology.

Dr. Harald Haseke h-haseke@apanet.at

Microbiological investigations based on Karst Spring Monitoring and Event Campaigns

Framework: Nationalpark Karst Program 1994-1997
Participant Project: 1603-7.5.1.

Microbiological analysis of springwater in the NP-Kalkalpen started in 1993/1994. Over 30 different springwater samples have been collected 3-4 times every year. This monitoring program includes measurements in several different realms such as hydrochemistry, field data, sediments and isotopes. The microbiological samples detect the heterotrophic flora of bacteria (KBE at 22°C, coliform germs, facultative pathogenic bacteria; E.coli, Enterococcus). The samples were evaluated using hygienic parameters (Österreichisches Lebensmittelbuch, Kapitel B1).
However, these bacteria represent only a small part of the microorganisms inhabiting the water or cave and spring sediments. Many bacteria are attached to sediment particles. Investigations show that the hygienically dangerous E.coli is attached to particles. Thus, the survival time for these organisms could be longer than the estimated 30 days, which are often used for the demarcation of protected drinkwater areas. Only few E. coli germs are found in free water (see final report S. Schmidt, 1996).
The springwaters are also clearly contamined by microorganisms native to the headwater areas, which are brought in by animals and humans. The risk of damage from the surface is increasing for several reasons: farming, tourism, hunting, game (birds such as wild ducks) and so on. Nevertheless, the present results reveal only a glimpse of the overall microorganismic realm. A number of interesting quantitative and qualitative activities can be expected during different times of the year. In colder seasons there are a number of additional springs that could be evaluated for drinkwater quality.
As in other areas, the current investigation confirmed that fountain water contains less bacteria when emerging from deeper karst systems or from more highly exposed catchments of the rock-karst type. Spring water stemming from well-karstified, highly permeable and well-grown catchments closer to the springs is loaded with many more microorganisms, especially

with facultative pathogenic species. The jointing of the outcrop also clearly has a great influence to the microflora of spring water. Reversing the procedure, it was possible to estimate the borders of certain unknown spring catchments by analyzing the microbiological drift.

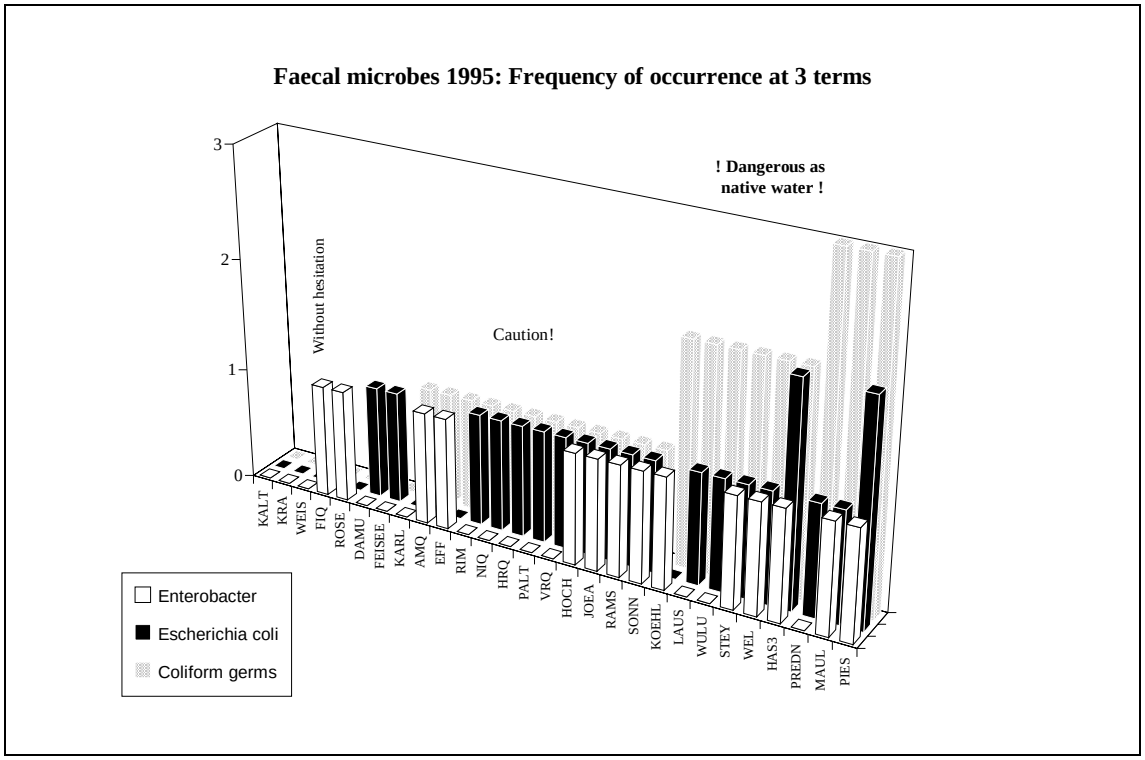


Fig. 5: The frequency of occurrence of faecal microbia, as an example in the year 1995. Other periods were similarly polluted by facultative pathogenic species.

Since 1996, samples have also been collected in the Rettenbach Cave (southern Sengsengebirge). In cooperation with B. Menne, who collected sediment samples for the investigation of myxobacteria stygofauna, we were able to determine that the quantitative distribution of the KBE (colony-building units) seems to correlate with myxobacteria due to the close dependence on the karstwater table. Many microorganism species found in the cave were probably percolated directly from the surface (E.coli...). Some investigated sites are apparently in contact with near-surface waters, polluted air, cave animals (bats), or even humans.

Further activities:
Spring Monitoring Campaigns 1997

Mag. Susanne Schmidt susanne.schmidt@kfunigraz.ac.at

Nationalpark O.ö. Kalkalpen Ges.m.b.H.
Nationalpark Allee 1
A-4591 Molln, 07584/3951, Fax 3654-291

EROSION MONITORING BY MEANS OF DETECTION OF SOIL-SPECIFIC MICROORGANISMS USING DNA-HYBRIDIZATION TECHNIQUES

Framework: Nationalpark Karst Program 1994-1997
Participant Project: 1603-7.5.2.

Soil erosion is a serious problem in karst systems. Steep areas used for agriculture can lose 30 tons of valuable soil per hectare (10 000 m²) and year. Only 1-2 tons of soil per hectare and year, that is 0.1-0.2 mm, are newly formed by fumigation processes. Monitoring erosion would therefore be very useful to describe erosion kinetics in karst systems. At the Institute of Applied Microbiology, investigations were carried out on erosion monitoring by detecting soil-specific microorganisms using DNA hybridization techniques on the basis of partial 16S rRNA. Sampling water from springs originating in the karst area and merely counting soil-specific bacteria should enable erosion rates to be estimated. - Strains used for this tests and their natural habitats:

Agrobacterium tumefaciens	soil bacterium, plant pathogenic (wine)
Agrobacterium rhizogenes	soil bacterium, plant pathogenic
Streptomyces griseus	soil bacterium
Streptomyces anulatus	soil bacterium
Rhizobium trifolii	soil bacterium
Rhizobium meliloti	soil bacterium
Enterococcus faecalis	contaminated or polluted water
Pseudomonas fluorescens	soil and water

Enterococcus faecalis and *Pseudomonas fluorescens* served as reference strains.
As a first step, hybridization probes were chosen to differentiate those species mentioned above. For these DNA probes, colony hybridization was optimised by changing denaturation temperature, salt concentration, washing conditions, dilution of antibody-enzyme-conjugate and exposure time to create stringent reaction conditions. Not using radioactively labelled probes makes it important to minimalize background signals from unspecific binding sites. As a result, fluorescine 11-dUTP labelled oligonucleotide probes were used instead of conventional biotin labelled probes. Lysis of microorganisms, especially the gram-positives, turned out to be a major problem at this point. To increase lysis efficiency, various lytic treatment procedures were tested. This approach allowed a protocol for complete lysis of all rel evant microorganisms to be developed. In addition to the DNA hybridization technique a number of strain specific culture media were tested. These media were used for plate counting microbial pollution of selected springs in the Nationalpark Kalkalpen. Within the monitoring program, these springs were sampled at different times. At this stage the analysis shows that the “Steyern-Quelle“ and the “Steyern-Quelle Überlauf“ were highly contaminated by soil-borne microorganisms, which indicates high erosion rates.

DI Peter Holubar holubar@mail.boku.ac.at

Nationalpark O.ö. Kalkalpen Ges.m.b.H.
Nationalpark Allee 1
A-4591 Molln, 07584/3951, Fax 3654-291

MYXOBACTERIA: SUBTERRANEAN DISTRIBUTION AS STYGO-FAUNISTIC BIOCOENOSES

Framework: Nationalpark Karst Program 1994-1997
Participant Project: 1603-7.5.3.

Since 1996, a total of twenty-two sediment samples were taken at two events in the Rettenbachhöhle (southern Sengsengebirge). The occurrence and distribution of the myxobacteria in the samples were examined. In addition, eight sediment samples from three small caves in the area of the "Eiseneck" at the northern borderline of Sengsengebirge were investigated. The first sample series concerned late-winter conditions, the second took place immediately after an important autumnal flood-event. Physical measurements completed the results.

Five different species of myxobacteria were identified.
Myxococcus fulvus was the absolutely dominant species overall. The presence of *Corallococcus coralloides* is also significant: it clearly indicates the degree of influence of the surface system. Further species are *Myxococcus virescens*, *Myxococcus stipitatus* and *Archangium gephyra*. The quantitative distribution of the myxobacteria proved to be strongly dependent on the position of the sample sites in relation to the karst watertable (vertical distance). A clear dependence on the sediment type (texture) was also evident. Sand was colonised preferentially. A very weak dependence on the pH-value exists. No correlation to the moisture content of the sediments was found. This result stands in contrast to other caves. We observed a large influence of the flood-event on the qualitative and quantitative composition of the myxobacteria biocoenosis.

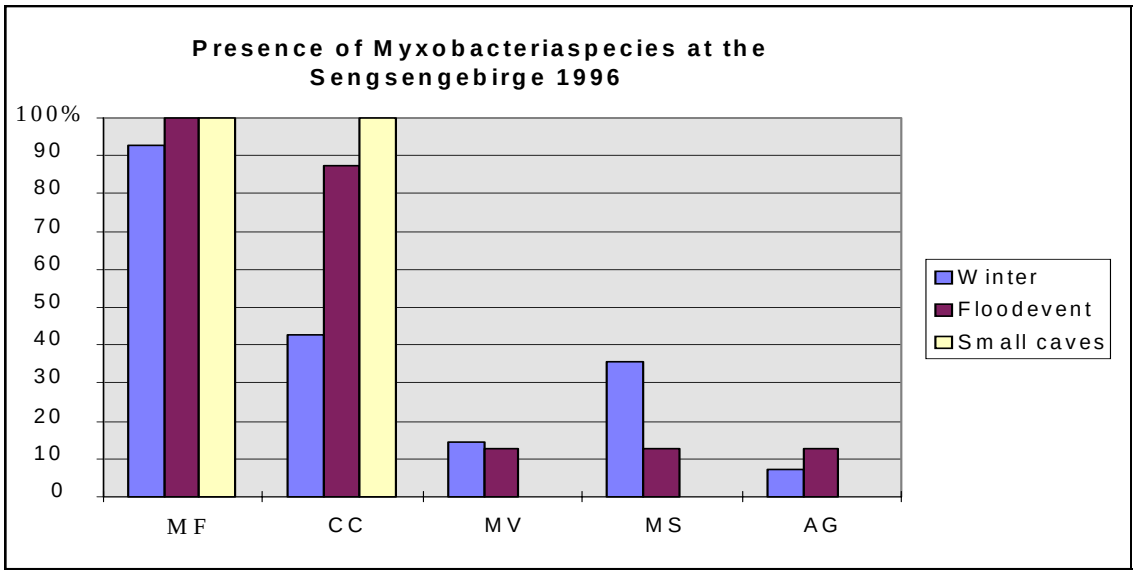


Fig. 6: Presence of Myxobacteria species at the Sengsengebirge 1996. - MF = *M. fulvus;* CC = *C. coralloides*; MV = *M. virescens*; MS = M. *stipitatus;* AG = *A. gephyra*

Nationalpark O.ö. Kalkalpen Ges.m.b.H.
Nationalpark Allee 1
A-4591 Molln, 07584/3951, Fax 3654-291

We also investigated micro-habitats. A common occurrence of magnetite and myxobacteria (as indicator organisms) raises questions regarding the microbiological formation of this mineral in the cave. A new attempt to biologically assess cave biotopes was made in the form of the "Oberflächenbezugsindex" (Surface connection index OBIX; this represents the chlorophyll content of the sediments after standard incubation). Much more important is the definition of the index PV1 , which refers to the quotient of the presence of *M. fulvus* and *C. coralloides*. The PV1 indicates the influence of the surface at a given cave site. The results of the Rettenbach cave are in agreement with those of the Wildpalfensystem (Hagengebirge, Germany).

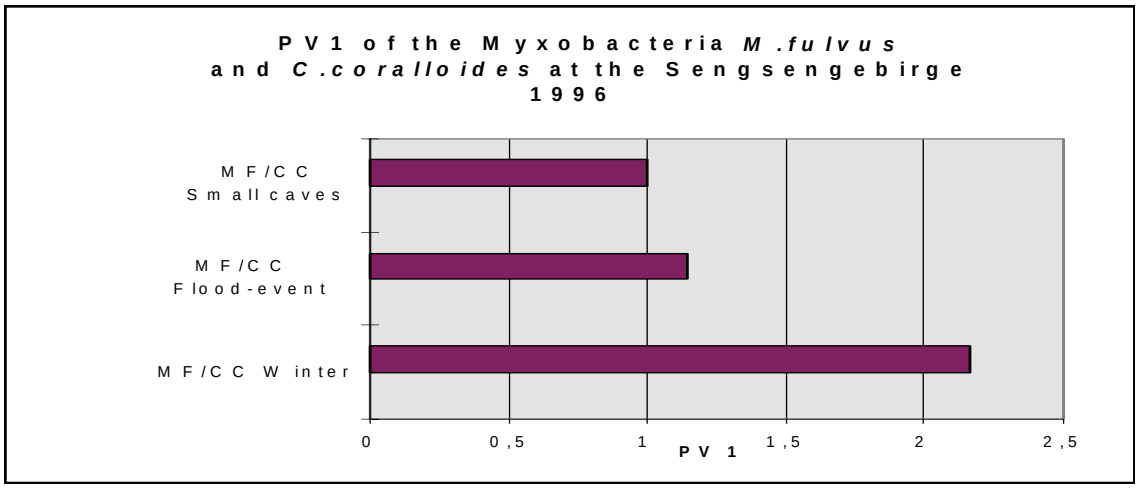


Fig. 7: PV 1 as the quotient of the presence of *M. fulvus* and *C. coralloide* in the Sengsengebirge 1996 -MF = *M. fulvus*; CC = *C. coralloides*

The myxobacteria investigations in the National Park area are discussed in the context of earlier observations at other caves. The result is a new biological division of the karstic limestone into four mainly vertical zones. These show various microbiological activity and heterogeneity: Subcutum, Epiklasal, Hypoklasal and Hydroklasal.

Most recent activities:
During November 1996, ten sterile, small containers were installed at different sites and with different vertical distance to the karst-water level. Every container is filled up with three sterile sand pockets to investigate the colonisation process of cave- and karst sediments.

Further activities:
- Participation at the Event Campaigns; Method-evaluation for the investigation of the joint plane biocoenosis.

DI Benjamin Menne BIUS-BenMen@t-online.de

Nationalpark O.ö. Kalkalpen Ges.m.b.H.
Nationalpark Allee 1
A-4591 Molln, 07584/3951, Fax 3654-291

SPRING LIMNOLOGY, BIOCOENOSES AND BIODIVERSITY IN FOUNTAIN ECOSYSTEMS OF THE NATIONALPARK KALKALPEN

Framework: Nationalpark Karst Program 1994-1997
Participant Project: 1603-7.6.

In order to investigate benthic communities in karstic outlets, 35 springs were sampled between 1994-1996. The main goals of these investigations were (1) to obtain an overview about species diversity in spring habitats, (2) to identify the main parameters controlling the ecology of springs and (3) to contribute to a general typology of springs based on physico-chemical parameters and on the composition of spring communities.
Spring habitats were sampled semi-quantitatively using pond-nets with a mesh-size of 100µm. More than 200 taxa were identified, and chironomids (non biting midges) were the most diverse group (67 taxa). Mayflies (Ephemeroptera) were represented by species which were very common to headwater systems and not only restricted to spring habitats. However, gastropods (spring snails) were dominated by species which were restricted in their occurrence to springs and subsurface areas (groundwater species like *Bythinella sp., Hauffenia sp., Belgrandiella sp.* and *Bythiospeum sp.*). About seven gastropod species were expected to be new to science. Hydro-geomorphically, most springs belonged to the so-called 'rheokren'-type. Therefore, they were colonised by both spring and rhithral communities.

A multivariate comparison of 40 spring areas by canonical correspondence analyses demonstrated a high dissimiliarity between the individual areas. Specific conductance, altitude (meters about sea level) and mean flow rate were identified as the main driving abiotic variables. Issues related to biodiversity and conservation of spring areas were discussed. In general, our knowledge about the ecology of springs is very limited, although springs harbour extremely endangered and diverse communities.
Measurements of POC-, DOC- and suspended solid-concentrations were carried out in 1995 in order to supplement previous investigations on the chemistry of spring outlets. Distinct differences between individual sampling sites were detected. In most outlets DOC-concentrations were higher than POC-concentrations (up to one order of magnitude). Those springs characterised by disturbed catchment areas (e.g. forest clear cutting) showed significantly higher POC- and DOC-concentrations as well as enhanced concentrations of suspended solids. Additionally, we intensified our investigation on organic matter and sediment dynamics in two contrasting outlets. “Hinterer Rettenbach” (HRQ) is characterised by a more pristine catchment area compared to the so-called “Steyernquelle” (STEY). On average, suspended solid concentrations were about five times higher in STEY than in HRQ and ranged from 0.64-5.63mg/l.
However, the organic proportion of the suspendeds was about three times higher in HRQ (33%). Proportions were negatively correlated with total suspended matter concentrations. Suspended matter concentration peaked during the increasing limb of the hydrograph (“hysterisis-effect”). DOC-concentrations averaged 2 mg/l. No relationship with water flow was detectable.
Springs which showed signs of organic pollution (high $KMnO_4$-, high organic matter concentrations) were expected to be less diverse than more undisturbed spring ecosystems. In fact,

we found a weak relationship between organic matter concentrations and species diversity, although other parameters, as mentioned earlier, modified this pattern (data: Weigand & Tockner, 1996).

Most recent activities:

(1) Distribution of benthic spring communities at the microscale (microhabitat) .
(2) Altitudinal zonation of the spring fauna (transect mapping: 600-1550 m asl).
(3) Seasonal emergence patterns of selected heterotopic insects.
(4) Taxonomic description of new species (Hydrobiidae, Mollusca) and autecological considerations.
(5) Preliminary investigations of the groundwater fauna (stygobiotic species).
(6) Classification of the spring fauna according to geographical distribution. Delineation of biocoenotic regions (Stygal, Krenal, Rhithral).
(7) Distribution of Amphibia in the Krenal.

Further activities:

Our results demonstrated a high turnover of species across space, meaning that each spring was colonised by a unique community. Therefore, further investigations are required. It is planned to sample approx. 20% out of a total of 792 springs (National Park area) in order to obtain an overview about spring biodiversity on a landscape scale. Additionally, an international collaboration with partners form several EC countries is proposed. This work should be carried out between 1998-2000 and will be part of an international spring ecology network named "Limnological typology of European spring regions" (Dr. Claus Orendt, orendt@rz.ufz.de).

Four selected springs will be monitored to demonstrate temporal patterns in geochemistry, suspended sediment transport and organic matter output.

Dr. Erich Weigand — weigand@ubavie.gv.at
Mag. Michaela Panzenböck — micha@pflaphy.pph.univie.ac.at
Dr. Martin Haase (spring snails) — haase@ubaclu.unibas.ch
Dr. Klement Tockner — tockner@eawag.ch

HYDROGRAPHIC RESEARCH: HEADWATER BALANCE, SPRING DISCHARGES AND MEASUREMENTS IN THE PHREATIC BLACK-BOX ZONE

Framework: Nationalpark Karst Program 1994-1997 &
Federal Hydrographic Agency - DKM
Participant Project: 1603-8.1.

The karst campaigns of the National Park Research program are supported and carried out by the Federal Hydrographic Agency. This institution carries out the following measurements, mostly connected with the Karst Spring Monitoring and the Event Campaigns:

1. Point discharge recordings at 20-25 springs using a hydrometrical vane;

2. Permanent discharge recordings by automatical gauge logging at the runoff of the springs: Piessling Ursprung, Vordere Rettenbachquelle, Hintere Rettenbachquelle, Teichl Ursprung (in preparation: Steyern Quelle);
3. Digital Karst spring Measurement stations **(**DKM**)** as automatic logging stations. These data loggers additionally record the temperature and conductivity, optionally the slurry und pH value. The Vorderer and Hinterer Rettenbach stations were built in the framework of the Austrian water quality collection order (WGEV); data loggings from the Hintere Rettenbachquelle were made available by the Federal Environment Agency. Piessling Ursprung and Steyern Quelle are in preparation.
4. Catchment discharge campaigns: The runoff of 73 well-defined hydrographical catchment areas in Nationalpark Kalkalpen is periodically measured. The campaigns take place in various hydrographic situations, e.g. autumnal drought, melting water or summer precipitation. The area discharge levels are very widespread, contingent on the geology and karstification of the individual catchments.

As an independent contribution to the National Park Research program, the Federal Hydrographic Agency FHA built a karstwater station inside the Rettenbachhöhle (Hinterer Rettenbach). The Rettenbach cave (“Devils hole“) is surveyed to a length of 1500 m and corresponds with some vadose and phreatic reaches. This truly unique work records the shallow phreatic karstwater table ranges at two positions and the submerging of the cave galleries, using a system of pressure-sond gauges. In the case of exceptional floods, the water table rises more than 45 m and nearly all the hollows are storaged with water, which emerges from the entrance with a estimated discharge of 8.000-10.000 l/s.

A second autonomous research site of the FHA is the Vordere Rettenbachquelle, where a very rare phenomenon is being permanently recorded: In the case of low discharge, the spring begins to “pulse“ in slow intervals. These pulses begin immediately with a downwelling at a well-defined discharge value and become faster if the discharge declines further. The mechanisms behind such occurrences are still unknown.

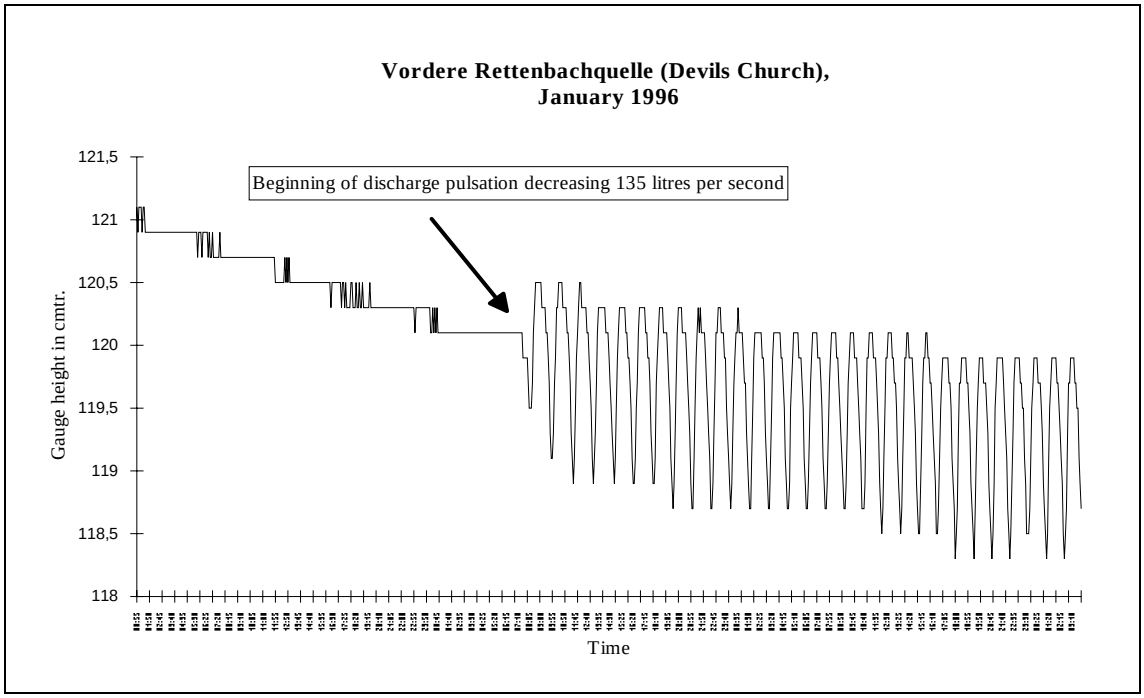


Fig. 8: The „intermittent spring“ Vordere Rettenbachquelle (Sengsengebirge), discharge pulsation at January 1996, as an example of the phenomenon.

Further activities:
The Steyern Quelle and the Piessling Ursprung will gradually be equipped with DKM stations for permanent data recording (Steyern Quelle will be installed at July, 1997). In the Rettenbach Cave, a third pressure-sond is in preparation to log data from the deepest karstwater level, which communicates directly with the spring system of Hinterer Rettenbach.
The results of the catchment discharge campaigns are ready to be evaluated with GIS technology.

Ing. Max Wimmer, Fed. Hydrographic Office phone +43 732 6584 248, FAX +43 732 7720 2411

HYDROLOGICAL DATA: STATISTICS AND EVALUATION

Framework: Nationalpark Karst Program 1994-1997
Participant Project: 1603-8.2.

Within the research program on "Karst Dynamics", one of the objectives is to study hydrological and hydrochemical processes and their interpretation in order to better understand the dynamic links between different parts of a karst system.

Starting from this general statement it was at first necessary to establish a well-structured research program with top-notch projects in all fields dealing with the karst phenomenon. Whereas any karst system can be treated as a black box from hydro(geo)logical point of view, it is ultimately necessary to draw conclusions about intersystem links such as: the influence of vegetation on water quality, on the retention of possible contaminants, or the influence of the aquifer substrate on hydrochemical constituents, or general properties of an aquifer. Thus almost all projects produce large scientific data sets, which have to be evaluated and to be classified for internal consistency and reliability for the entire research program.

The project entitled "Hydrological Data: Statistics and Evaluation" is one part of the karst program; it is charged with evaluating hydrochemical data from springs and mountainous streams as well as data about environmental isotopes. The applied evaluation includes plausibility control of hydrochemical analyses and statistical tests.
Another approach to study aquifer characteristics and their dynamic behaviour is the use of environmental stable and radioactive isotopes such as tritium, deuterium and oxygen-18 (cooperation with GSF-Munich). They are important components of the hydrological cycle and react very sensitively to changes of the hydrological regime or, more generally, of the climatic conditions. Such data can improve our knowledge about recharge conditions of specific catchment areas and their altitudinal delimitation. From the National Park area, many isotope data are available from earlier projects in the 1970s and also from monitoring springs within the karst program in this decade. This will provide an opportunity to compare these data and to derive information on storage characteristics of the aquifers.

The ultimate goal is to provide a consistent data base for all partners in this field of interdiscplinary research.

Ralf Benischke, Joanneum Research ralf.benischke@joanneum.ac.at
Ing. Elmar Pröll (Nationalpark laboratory) elmar.proell@merlin.at

INTERMITTENT KARST STREAMS IN THE NATIONALPARK KALKALPEN

Framework: Nationalpark Karst Program 1994-1997
Participant Project: 1603-9.

Since 1991, the ecology and dynamics of natural intermittent karst streams have been investigated in the "Hinterer Rettenbach" (HRB) and the "Fischbach" (FB) in the National Park. The present study focuses on the ecological significance of the hyporheic zone for the biocoenosis of these two streams during disturbances (floods, drying).
The HRB and the FB are characterized by a rapid change of unpredictable, sudden floods and more or less prolonged drying periods in which reaches of the FB fall dry down to a sediment depth of at least 40 cm. The upper part of the intermittent zone is characterized by a large downwelling site where surface water is lost to the underlying karst body (negative vertical hydraulic gradient). The lower part of the intermittent reach is characterized by an upwelling of karst water through the sediments; this is documented by a positive vertical hydraulic gradient, lower water temperatures and the presence of *Niphargus sp.* on the sediment surface. The interstitial water of the hyporheic zone of both the upwelling and downwelling site, and of the perennial stream reaches, shows similar values of conductivity, temperature and oxygen content, but slightly higher nutrient concentrations than the surface water.
Hyporheic and benthic density and distribution patterns of aquatic organisms are heterogeneous and dynamic; they vary according to the discharge of the respective stream reach and the character of the water exchange between surface and subsurface water over the hyporheic zone. Whether a stream reach falls dry or not is an especially important factor for the abundance and composition of the fauna of different reaches. Perennial stream sections are characterized by high abundances of organisms on the sediment surface (5300 ind./m^2) and in the hyporheic zone (10-40 ind./l interstitial water). Dominant groups are aquatic larvae of Ephemeroptera, Chironomidae and Plecoptera, with additional high quantities of Harpacticidae in the sediments. Intermittent stream reaches show low abundances on the sediment surface (1000-1200 ind./m^2) and in the sediments (0-10 ind./l) and are dominated by Collembola, Chironomidae and Oligochaeta, especially during low water conditions.
Biological interactions between perennial and intermittent stream reaches in the FB are complicated and manifold. During floods the highest quantity of organisms in the hyporheic zone can be found at or below 30 cm depth in perennial reaches and at downwelling sites of intermittent stream parts, while upwelling sites show the highest abundances in the first 10cm of the sediments. Macrozoobenthic densities decrease in all parts of the stream during floods.

When the water level falls, population densities on the sediment surface increase in perennial stream reaches and decrease in intermittent reaches.
Hyporheic organisms of intermittent reaches are mainly represented by Oligochaeta, Chironomidae and Collembola and can be found deep in the sediments. Recolonization of the sediment surface of those reaches occurs rapidly after rewetting and is, again, dominated by the above-mentioned groups.

The investigations can be briefly summarized as follows:
* Drying periods largely depend on the complex and dynamic interactions between subsurface and surface waters and can occur in all seasons. Thus, adapted life cycles of stream organisms seem unlikely.
* Perennial and intermittent stream reaches show great differences in the benthic and hyporheic abundance of macrozoobenthic organisms.
* The process of drying and rewetting of stream reaches has little or no effect on the macrozoobenthic abundance of the respective stream reach. The pre-drying status can be established within a few hours or days after rewetting. Therefore, refugia must exist to which organisms migrate actively or passively.
* Potential refugia in the studied streams are:

a) Perennial reaches (increased abundances of organisms during low water conditions; increased drift densities during rewetting)
b) The hyporheic zone of intermittent stream reaches (deeper maximum abundances in the early drying phase; dominance of Oligochaeta, which are not represented in the drift, before and after rewetting)
c) Pools

Further activities:
In 1997, sampling of benthic organisms will be carried out in perennial and intermittent stream reaches with different drying frequencies (riffles with longer and shorter drying periods, perennial pools within dried stream sections) in dependence on the water level (high, medium and low). Especially the early drying period and the rewetting phase will be sampled, if possible. Furthermore, field experiments (e.g. prevention of drift with nets, artificial drying of stream parts) will be conducted during the 1997 study.
In the following years, investigations on the movement of macrozoobenthic organisms using benthic and/or hyporheic traps are planned.
The project has been submitted to a EU-TMR action under the title “European comparison of intermittent streams“ (Tania Schellenberg, tschell@uni-muenster.de), which should be carried out during 1998-2000.

Mag. Gabriele Weigelhofer gweigel@pflaphy.pph.univie.ac.at
Dr. Klement Tockner tockner@eawag.ch

Nationalpark O.ö. Kalkalpen Ges.m.b.H.
Nationalpark Allee 1
A-4591 Molln, 07584/3951, Fax 3654-291

SPELEOLOGY AND CAVE EXPLORATION

Nationalpark Karst Program 1994-1997
Participant Project: 1603-10.

The planning area of the Nationalpark Kalkalpen also includes the "Totes Gebirge" (Dead Mountains), which has been one of the most famous playgrounds of speleology in Austria for many years. We note for example that the Raucherkar Cave has been explored over a total length of more than 60 km, making it the 2nd largest cave in Austria.

The 1st planning area, in which the Nationalpark Karst Program is currently being carried out, is less well known and the caves are comparatively few and small. Furthermore, speleological research in this region has been infrequent. On the other hand, many catchments in the Sengsen- and Hintergebirge are well karstified and we are aware of "cave parks" where exploration seems to be promising. No speleology has been carried out by the National Park itself, but the efforts of the speleo groups at Linz and Sierning have been supported and the Karst Program has attempted to gain an overview of all the subterranean karst phenomena by cooperating with speleologists as contractors.

More than 70 caves are currently known in the designated Nationalpark Kalkalpen area. Most of them are developed in the Wetterstein Limestone fold of the Sengsengebirge and Hintergebirge, where the deepest and longest caves have been registered: The Groesstenberg shaft has an overall vertical distance of more than 409 m; the Rettenbach Cave near Windischgarsten has recently been explored over a length of nearly 1500 m. The entrances of the caves and pits are situated between 450 and 1890 m asl. At some positions in the Sengsengebirge, it seems theoretically possible to reach the -1000 m point by exploring pits and shaft systems. More than 35 caves are mainly vertical pits.
The highest density of caverns has been registered at the Gireralm Area (eastern Sengsengebirge) in the Wetterstein Limestone karst and at the Feichtau-Eiseneck Area (northern Sengsengebirge) in outcropping Hierlatz Limestone.

Special features include 4 ice-caves and 7 active water-caves, some of them connected with large springs. Two caves are protected by law and have been declared Natural Monuments. Two caverns contain interesting archeological and paleontological material, and in many pits we found skeletons, bones and other residua of various fauna. A distinct cave fauna has only been investigated at Rettenbach Cave, where endemites either among the terrestrial troglofauna or in the phreatic stygofauna are still under exploration.

A very interesting hydrological phenomenon is the intermittent pulsing karst spring of the "Teufelskirche" abri (Devils Church, southern Sengsengebirge). When the water flow decreases to 135 l/s, the oscillation starts with a lowering effect and with 12 pulses a day. When the discharge decreases further, the oscillation increases up to 24 daily pulses or one per hour. It is unknown which kind of hydraulic effects might cause such phenomena.

Most recent activities:
Single actions of speleologists at Gireralm catchment (shaft explorations), in Rettenbach Cave (diving, climbing, surveying) and in Maulaufloch ("Mouth open hole") spring cave: climbing, siphuncle pumping; National Park cave research at Feichtau-Eiseneck and in the Nock-Merkenstein area; intensive research in Rettenbach Cave: subterranean gauge stations, cave ecology, stygofauna, microbiology, sedimentology, water analyses.

Further activities:
Prolongation of the Rettenbach Cave investigations, further exploration of Maulaufloch and other spring caves, efforts to continue speleology in promising catchments.

Ing. Josef Weichenberger ☎ +43 0732 307 571
Landesverein für Höhlenkunde in Oberösterreich ✉ Landstrasse 31, A-4020 Linz

KARST WATER TRACING

Framework: Nationalpark Karst Program 1994-1997
Participant Project: 1603-11.

In 1995, a karst water tracing experiment was carried out at Reichraminger Hintergebirge between the Steyr- and Enns valleys. The investigation sites were located at Mieseck (1270 m), near the northern slope of the Ebenforst upland area. The inquiry supported the pilot study "Carbonatic Soils", which was part of the karst program 1994/95.
The Mieseck ("Stubbed corner") is a Norian block built of Plattenkalk and Hauptdolomit, part of the northern section of the "Ebenforst syncline" as a component of the "Reichraminger nappe". This block is well karstified and a little pit enabled the sampling of subsurface water at the entrance of narrow vadose patterns. At this point, the tracing experiment was carried out.
Around the Mieseck, many small vadose springs contributing to Ebenforst creek, Weissenbach creek and Wildergraben creek have been mapped and it was expected that the tracer would drift to one of them. On a larger scale, two bigger karst springs also exist at the contribute stream level near the Reichraming stream und the Krumme Steyrling stream.
Unexpectedly, the injected tracer URANIN contaminated exclusively the large phreatic spring "Predigtstuhlquelle" in the base level of Reichraming creek, 690 m below and nearly 4 km away from the injection point. The period from injection to detection was approx. 11 days, the distance rate approx. 14 m per hour. This proved that the area is deeply karstified and that the local spring areas have only small vadose karst catchments or drain coarse detritus beddings.

Further activities:

In 1997, a large tracer experiment has been commissioned in the Sengsengebirge; it will contribute to the hydrology of Rettenbach Cave and springs, and is coordinated by the Federal Hydrographic Agency, 3 tracers).
Also in 1997, a small One-tracer-action will be carried out at the western corner of the National Park, motivated by the advance heading for the PAB highway tunnel project.
In 1998, a karst water tracing program will take place at the border karst on "Zoebelboden", coordinated with the ECE-Integrated Monitoring team (Federal Environment Agency, Vienna).

Dr. Harald Haseke h-haseke@apanet.at
Ralf Benischke, Joanneum Research ralf.benischke@joanneum.ac.at

MANAGEMENT GUIDELINES FOR PROTECTED KARST AREAS

All the interdisciplinary studies should maintain close links to the National Park management in order to provide guidelines on how to handle the very sensitive alpine karst landscapes either in nature reserves or in "past-effective" areas. We recognize that it will be necessary to rebuild large parts of the forest plantations and to repair damage caused by roads and clearings.

According to the **CNPPA** Working Group on Cave and Karst Protection (**IUCN**), the Interdisciplinary National Park Karst Group formulates guidelines on how to handle the following issues:

* Human uses of karst areas should be planned to minimise undesirable impacts and monitored in order to provide information in future decision-making processes.
* While recognising the non-renewable nature of many karst features, good management demands that damaged features be restored insofar as is practicable.
* Where possible, total catchment areas should be included within the protected areas boundary.
* Where such coverage is not possible, consideration should be given to the use of environmental controls or total catchment management agreements under planning or water management legislation to safeguard the quantity and quality of water inputs to the karst system.
* Land managers should identify karst areas not included within protected areas and give consideration to safeguarding the value of these areas by such means as planning controls, public education programs, heritage agreements or covenants.
* Catchment boundaries commonly extend beyond the limits of the rock units in which the karst has formed. The definition of the whole karst drainage network depends on planned water tracing experiments and cave mapping. The boundary of this extended catchment can fluctuate dramatically according to weather conditions.

Nationalpark O.ö. Kalkalpen Ges.m.b.H.
Nationalpark Allee 1
A-4591 Molln, 07584/3951, Fax 3654-291

BIBLIOGRAPHY

ANGERER, S.. et al (1996): Atlas der Hydrologie 1:20.000, Nationalpark Kalkalpen - 1. Verordnungsabschnitt. - 21 Teilblätter, allgemeiner Teil. Texte: H. Haseke, Molln, Mai 1996.

BENISCHKE/GLATZEL/HASEKE/KATZENSTEINER/STADLER (1994): Projekt Karstdynamik im Nationalpark Kalkalpen. - A) Zusammenfassung (HASEKE, H.): 41 Seiten, Grafiken und Abb. - Molln-Graz-Salzburg-Wien März 1994. - B) Fachbereich Hydrologie und Hydrogeologie (BENISCHKE, R. und STADLER, H.): 50 Seiten, Grafiken und Abb. - Graz, März 1994. - C) Fachbereich Bodenkunde und Ökologie (GLATZEL, G. und KATZENSTEINER, K.): 26 Seiten, Grafiken und Abb., Wien, März 1994.

BENISCHKE, R. (1996): Teilprojekt 1603-8.2.1./94: Aufbereitung hydrologischer Meßdaten und hydrologische Zusatzarbeiten, Teil I. - 21 Seiten, zahlr. und umfangreiche Tabellen und Auswertungen. Graz, Juli 1996. - Unveröff. Studie, NPK 1996.

BOGNER, M. und MAHRINGER, G. (1994): Tageswetterlagenbeschreibung für Karstprogramm 1994. - Beilage zu HASEKE (1994c), Linz-Wien, 1994.

BOGNER, M. et al. (1995): Topoklimatologische Charakteristik der Testfläche der Pilotstudie Karbonatböden. 48. S., Tabellen. - Linz/Wien, Dezember 1995.

BOGNER, M. und MAHRINGER, G. (1995): Tageswetterlagenbeschreibung für Karstprogramm 1995. - Beilage zu HASEKE (1995d), Linz-Wien, März 1996.

Bogner, M. & Lehner, T. & Mahringer, G. (1996): Topoklimatologische Charakteristik des Geländeprofiles zwischen Steyernquelle und Rettenbach. - Kampagnenbezogene Tageswetterlagen 1996. 73 S., Tabellen und Diagramme.- Endbericht Karstprogramm 1603-1.2./1996, Linz, Dezember 1996.

BROZEK, S. et al. (1991): Limnologische Charakteristik der beiden Feichtauer Seen anhand von morphologischen Daten. - NPK 1991.

FABER, H., JERSABEK, C. et alt. (1990): Limnologische Erstcharakterisierung stehender Kleingewässer im Sengsengebirge. - 19 S., unveröff. Studie, NPK 1990.

GÄRTNER, A. et al (1994): Atlas der Geologie 1:20.000, Nationalpark Kalkalpen - 1. Verordnungsabschnitt. - 21 Teilblätter, allgemeiner Teil. Molln, September 1994.

GRIMS, F. (1993): Karstquellen-Monitoring: Moosaufnahme. NPK 1993. Beilage zu: HASEKE (1993a).

HASEKE,H. (1990): Hydrologie und Karstmorphologie des Sengsengebirges. - Nationalpark Kalkalpen, Forschungsprojekt 2.1.-1990. - Molln-Salzburg 1990.

HASEKE,H. (1991a): Hydrologie und Geomorphologie des Reichraminger Hintergebirges. Im Auftrag der Planungsstelle Nationalpark Kalkalpen, Molln 1991.

HASEKE,H. (1991b): Forschungsprojekt Karstquellen-Monitoring 1991. Synoptische Wasseranalysen. - 54 Seiten, 54 Abb. und Diagramme, 1 Tafel, 20 Fotos. - Bericht für den Nationalpark Kalkalpen, Molln-Salzburg 1991. -

HASEKE,H. (1992): Forschungsprojekt Karstquellen-Monitoring 1992. Wasseranalysen 11/91-5/92. 26 Seiten, einige Abb., Beilagen. - Bericht für den Nationalpark Kalkalpen, Molln-Salzburg Dez. 1992.

HASEKE,H. et al. (1993a): Forschungsprojekt Karstquellen-Monitoring 1993. 24 Seiten, Beilagen (Einzelberichte zu speziellen Themen). - Bericht für den Nationalpark Kalkalpen. Molln--Salzburg März 1994.

HASEKE,H. (1993b): Kartierungsprojekt Ergänzungen: Hydrogeologie und Geomorphologie Sengsen - und Hintergebirge. 18 Seiten, 16 Fotos. - Bericht für den Nationalpark Kalkalpen. Molln--Salzburg März 1994.
HASEKE, H. (1993c): Exkursionsführer zum Workshop "Karstprogramm". - Gebiete: Steyern-Feichtau-Eiseneck und Vorderer Rettenbach-Kogleralm (Sengsengebirge). Kurzmonographien, Fotos. Molln, Juli 1993.

HASEKE,H. (1994b): Atlas der Geomorphologie und Hydrologie 1: 20.000. - Erstellt im Rahmen des Projektes "Karstdynamik" i.A. des Nationalparkes Kalkalpen. - Textteil, Legende und 22 Teilblätter, Originale 1: 10.000. Stand: 31.12.1994.

HASEKE, H. (1994c): TP 1603-7.1./94: Forschungsprojekt Karstquellen-Monitoring 1994. 46 Seiten, Diagramme, Tabellen und Beilagen (Einzelberichte zu speziellen Themen). - Bericht für den Nationalpark Kalkalpen. H. Haseke, Molln-Salzburg, Februar 1995.

HASEKE, H. (1994d): TP 1603-7.3./94: Quelldokumentation Teil I im Nationalpark Kalkalpen, Planungsabschnitt 1. - Hauptbericht 27 S., 17 Quelldossiers (Mappen) mit zahlr. Beilagen, 17 Meßstellen-Stammdatenblätter. - H. Haseke, Molln-Salzburg, Februar 1995.

HASEKE, H. (1994e): TP 1603-6./94: Hydrologie und Geomorphologie des Nationalparkes Kalkalpen, Planungsabschnitt I;Teil 4: Aussenzonen und Randgebiete. Bericht für den Nationalpark Kalkalpen. - H. Haseke, Molln-Salzburg, Februar 1995. 67 Seiten, Kartenteil im Atlas der Geomorphologie.

HASEKE, H. (1994f): Fels und Karst. - Natur im Aufwind7/94, Nationalpark Kalkalpen, Leonstein 1994: 12-19.

HASEKE, H. (1995a): TP 1603-3.3.&11./95: Hydrologie und Markierungsversuch zur Pilotstudie Karbonatböden am Mieseck (Hintergebirge) im Nationalpark Kalkalpen. - Karstprogramm 1995, Teilprojekte Nr. 1603-3.3./95 und 1603-11./95. - 20 Seiten, Tabellen, 1 Kartenbeilage. - H. Haseke, August 1995.

HASEKE, H. (1995b): TP 1603-13./94&95: Zwischenbericht der Koordination 1994 - 1995 zum ersten Abschnitt der "Einzugsgebietshydrologischen Studie. Statistische Angaben I zu den Einzugsgebieten.- Nationalpark - Karstprogramm, Teilprojekt Nr. 1603-13./94 und 1603-13./95. - 120 Seiten, 7 Tabellenbeilagen. Oktober 1995.

HASEKE, H. (1995c): TP 1603-7.3./95: Quelldokumentation Teil II im Nationalpark Kalkalpen, Planungsabschnitt 1 und Randgebiete. - 1 Hauptbericht, 34 Quelldossiers (Mappen) mit zahlr. Beilagen, 34 Meßstellen-Stammdatenblätter. Molln-Salzburg,, Dezember 1995.

HASEKE, H. et al. (1995d): TP 1603-7.1.&7.2./95: Forschungsprojekt Karstquellen-Monitoring 1995. 89 Seiten, zahlr. Diagramme, Tabellen und Beilagen (Einzelberichte zu speziellen Themen, Karte). - Bericht für den Nationalpark Kalkalpen. H. Haseke, Molln-Salzburg, Jänner 1996.

HASEKE, H. (1996b): Quellen und Höhlenwässer. - Natur im Aufwind 16/96, Nationalpark Kalkalpen, Leonstein 1996: 22-25.

HASEKE, H. (1996c): TP 1603-7.3./96: Quelldokumentation Teil III im Nationalpark Kalkalpen, Planungsabschnitt 1 und Randgebiete. - 1 Hauptbericht (37 S.), Quelldossiers (Mappen) mit zahlr. Beilagen,. Unveröff. Studie i.A. des Nationalparkes Kalkalpen, Molln-Salzburg, Dezember 1996.

HASEKE, H. et al. (1996d): TP 1603-7.1.&7.2./96: Forschungsprojekt Karstquellen-Monitoring und Ereigniskampagnen 1996. - 73 S., Beilagen. Unveröff. Studie i.A. des Nationalparkes Kalkalpen, Molln-Salzburg, Dezember 1996.

HAUSER, E:, WEISSMAIR, W.(1992): Biospeläologische Untersuchungen zur Fauna der Rettenbachhöhle bei Windischgarsten. - Unveröff. Studie i.A. des Nationalparkes Kalkalpen, Linz 1992.

HOLUBAR, P. und HEURITSCH, S. (1995): Teilprojekt 1603-8.2.2./95: Hydromikrobiologische Zusatzarbeiten, "Konzeption und Test spezieller mikrobiologischer Methoden zur Erkundung der pedogenen Organismenmobilität im Karstwasser". - 13 S., 31 Blots (Kopien). Unveröff. Studie, Wien, Juli 1996.

HOLUBAR, P., HEURITSCH, S und SEPER, C. (1996): Teilprojekt 1603-7.5.2./96, "Konzeption und Test spezieller mikrobiologischer Methoden zur Erkundung der pedogenen Organismenmobilität im Karstwasser ". 32 S., Abb. und Grafiken. Unveröff. Studie, Wien, Dezember 1996.
JERSABEK, C. et al. (1991): Taxonomisch-ökologische Erhebung der Rotatorien- und Crustaceenfauna stehender Gewässer des Sengsengebirges. - Unveröff. Studie i.A. des Nationalparkes Kalkalpen, Molln-Salzburg, 1991.

JERSABEK, C. (1992): Chemismus und Biologie der Feichtauer Seen. - Unveröff. Studie i.A. des Nationalparkes Kalkalpen, Molln-Salzburg, 1992.

KATZENSTEINER, K. (1995): Pilotstudie Wasserhaushalt und -chemismus von Karbonatböden im Rahmen des Projektes Karstdynamik im Nationalpark Kalkalpen. Einrichtung der Versuchsflächen (...) AZ: 1603-5.1./95. - 13 S., Abb., Grafiken, Tabellen, Karte. Unveröff. Studie i.A. des Nationalparkes Kalkalpen, Wien, Oktober 1996.

KATZENSTEINER, K. (1996a): Pilotstudie Karbonatböden, Abschluß und Auswertung. Im Rahmen des Projektes Karstdynamik im Nationalpark Kalkalpen. AZ: 1603-05./95 und 1603-06/94. - 33 S., zahlr. Abb. und Grafiken. - Unveröff. Studie i.A. des Nationalparkes Kalkalpen, Wien, Dezember 1995.

KATZENSTEINER, K., Nemesthoty, K. und Ottner, F. (1996): Analyse karstrelevanter Boden- und Gesteinsproben von repräsentativen Standorten des Nationalpark Kalkalpen. . Im Rahmen des Projektes Karstdynamik im Nationalpark Kalkalpen. AZ: 1603-3.2. 32. S., Tabellen und Grafiken. - Unveröff. Studie i.A. des Nationalparkes Kalkalpen, Wien, Oktober 1996.

LECHNER, J. (1996): Sukzessionsdynamik und Oberflächenverkarstung ausgewählter Almen im Sengsengebirge: Multitemporale Luftbildauswertung und Geländekartierungen. Karstdynamik 1603, Teilprojekt 4.1. Almnutzung und Sukzession, Teilprojekt-4.2. Multitemporale Luftbildauswertung. 107 S., Tabellen, Grafiken, Fotos, Karten. - Unveröff. Studie i.A. des Nationalparkes Kalkalpen, Wien, Oktober 1996.

MENNE, B. (1996a): Myxobakterien in der Rettenbachhöhle. Eine karstmikrobiologische Studie. - 19. S., unveröff. Studie i.A. des Nationalparkes Kalkalpen, Mühlacker (BRD) August 1996.

MENNE, B. (1996b): Carbonatolyse und Biokonservierung als Mechanismen der Verkarstung und Speläogenese. - Manuskript vor Veröffentl., Mühlacker 1996.

MENNE, B. (1996c): Manganhaltige Ablagerungen in der Rettenbachhöhle (Kat.Nr. 1651/1, OÖ) und ihre Zusammenhänge mit mikrobiologischen Prozessen.- Manuskript vor Veröffentl., Mühlacker 1996.

MENNE, B. (1997a): Myxobakterien in der Rettenbachhöhle und in einigen Kleinhöhlen des Sengsengebirges. Eine karstmikrobiologische Studie - Ergebnisse 1996. - 29.S., Abb. und Tab. - Unveröff. Studie i.A. des Nationalparkes Kalkalpen, Mühlacker, Februar 1997.

MENNE, B. (1997b): Myxobakterien in der Rettenbachhöhle. Eine karstmikrobiologische Studie. - Mitt. des Landesvereines für Höhlenkunde in Oberösterreich, 43.Jg.-1997/1, Gesamtfolge 102. Linz 1997: 11-26.

REINIGER, B. (1991): Feuchtigkeitskartierung Feichtau. - Unveröff. Studie i.A. des Nationalparkes Kalkalpen, 1991.
SALFELNER, T. (1991): Aufnahme und lagemäßige Kartierung von Höhlen im Sengsen- und Reichraminger Hintergebirge. Entnahme von Wasserproben. - Unveröff. Studie i.A. des Nationalparkes Kalkalpen, 1991.

SCHMID, P. und TOCKNER, K. (1990): Faunistisch-ökologische Untersuchung ausgewählter Fließgewässer im Sengsengebirge. - Unveröff. Studie i.A. des Nationalparkes Kalkalpen, 1990.

SCHMIDT, S. (1996a): Mikrobiologie der Quellen 1995. Teil 1: Verteilung in den Quellen des Monitorings 1995. Graz, Jänner 1996 - Teil 2: Konzeptive Weiterentwicklung des Nationalpark-Labors und versuchsweise analytische Behandlung. Graz, Mai 1996.

SCHMIDT, S. (1996b): Teilprojekt 1603-7.5.1./96, “Mikrobiologische Beprobung, Analyse und Auswertung der Quellwässer sowie Installation neu angewandter Methodiken für weiterführende mikrobiologische Analysen im NP-Labor.“ 60S., Abb., Tabellen und Grafiken. - Unveröff. Studie im Auftrag des Nationalparkes Kalkalpen, Graz, November 1996.

TOCKNER, K., Steiner, K., Schmid-Araya, J. & Schmid, P.E. (1990) Faunistisch ökologische Untersuchung ausgewählter Fließgewässer des Sengsenberg. Verein Nationalpark Kalkalpen Eigenverlag, Kirchdorf, 35 pp.

TOCKNER, K., Fesl, C. & Weilguni, H. (1991) Limnologische Studie Hinterer Rettenbach. Zur ökologischen Stabilität von Reinwasserreserven: Konzeption und Ausarbeitung einer Langzeitstudie zur Dokumentation und Prognose ausgewählter Umweltparameter im Ökosystem “Hinterer Rettenbach“. Verein Nationalpark Kalkalpen Eigenverlag, Kirchdorf, 187 pp.

TOCKNER, K. (1993) Limnologische Studie “Hinterer Rettenbach“ (Nationalpark Kalkalpen, Sengsengebirge, Oberösterreich). Ein Beitrag zur Limnologie eines Karstfließgewässers unter besonderer Berücksichtigung der ökologischen Relevanz hydrograohischer Extremereignisse. Verein Nationalpark Kalkalpen Eigenverlag, Kirchdorf, 197 pp.

TOCKNER, K. (1994) Ausgewählte Untersuchungen zur Ökologie eines Karstfließgewässers (Fischbach und Hinterer Rettenbach; Sengsengebirge). Verein Nationalpark Kalkalpen, Eigenverlag, Kirchdorf, 91 pp.

TOCKNER, K. (1996): Teilprojekt 1603-7.6./95: Schwebstoffe und organische Kohlenstoffverbindungen in ausgewählten Quellen des Nationalparkgebietes “Nördliche Kalkalpen“. 29 S., Taballen, Grafiken. Zürich, Oktober 1996. . - Unveröff. Studie i.A. des Nationalparkes Kalkalpen.

VEREIN NATIONALPARK KALKALPEN (1990): Jahresforschungsbericht 1990.

WEICHENBERGER, J. (1991): Systematische Dokumentation der unterirdischen Karstformen. - - Unveröff. Studie i.A. des Nationalparkes Kalkalpen, Linz 1991.

WEICHENBERGER, J. (1992): Speläologische Bearbeitung des Transekt-Gebietes Sengsengebirge. - - Unveröff. Studie i.A. des Nationalparkes Kalkalpen, Linz 1992.

WEIGAND, E. und TOCKNER, K. (1996): Limnologische Charakterisierung ausgewählter Karstquellen im Nationalparkgebiet Nördliche Kalkalpen. Teilprojekt 1603-7.6./94 im Rahmen des Programmes "Karstdynamik". - 105 S., zahlr. Tab., Abb., Fotos. - Unveröff. Studie i.A. des Nationalparkes Kalkalpen, Wien, Mai 1996

WEIGELHOFER, G. (1996): Teilprojekt 1603-9./96, Die ökologische Funktion der Bachbettsedimente in intermittierenden und perennierenden Karstgewässern. - 57 S., Abb., Fotos und Tabellen. - Unveröff. Studie im Auftrag des Nationalparkes Kalkalpen, Wien, Dezember 1996.

WIMMER, M. (1995): Bericht über hydrographische und karsthydrologische Beobachtungen in der Rettenbachhöhle. - Mitt. d.Landesvereines für Höhlenkunde in Oberösterreich, 41.Jg.-1995/1, Gesamtfolge 100. Linz 1995.

WIMMER, M. (1997): Neues aus der Rettenbachhöhle (Kat.Nr.1651/1) in Zusammenhang mit den hydrographischen Forschungen- Mitt. des Landesvereines für Höhlenkunde in Oberösterreich, 43.Jg.-1997/1, Gesamtfolge 102. Linz 1997: 27-36.