January 1997

Proceedings of the 1997 National Cave and Karst Management Symposia National Cave & Karst Management Symposia NCKMS

Robert R. Stitt

Proceedings of the
1997 Karst and Cave Management Symposium
13th National Cave Management Symposium

Bellingham, Washington
and
Chilliwack and Vancouver Island, BC, Canada

October 7-10, 1997

Symposium Organizers

Robert R. Stitt and Paul Griffiths, Co-Chairs

Proceedings Editor

Robert R. Stitt

Layout and Design by

Robert R. Stitt

Our Sponsors

HOSTS: National Speleological Society American Cave Conservation Association Cave Research Foundation The Karst Waters Institute National Caves Association The Nature Conservancy U. S. Forest Service U. S. National Park Service U.S. Bureau of Land Management U. S. Fish and Wildlife Service

CO-SPONSORS: British Columbia Speleological Federation British Columbia Ministry of Forests Northwest Caving Association Oregon Grotto of the NSS Northwest Chapter of the ACCA Northwest Cave Research Institute BC Parks Bat Conservation International Washington Dept. of Fish and Wildlife Richmond Area Speleological Society Terra Associates Western Forest Products Limited MacMillan Bloedel Limited Canadian Forest Products Limited The Record (Gold River) Mount Tahoma Chapter of the American Association of Zoo Keepers

National Cave Management Symposium Steering Committee

David Foster, American Cave Conservation Association

Jennifer Jinx Fox, U. S. Bureau of Land Management

Roger McClure, Cave Research Foundation

Robert R. Currie, U. S. Fish and Wildlife Service

Jim Miller, U. S. Forest Service

Dr. Rane L. Curl, The Karst Waters Institute

Gordon L. Smith, Jr., National Caves Association

Ronal Kerbo, U. S. National Park Service

Janet B. Thorne, National Speleological Society

Gabby Call, The Nature Conservancy, Tennessee Chapter

Steering Committee Coordinator

Janet Thorne

Organizing Committee

Rob Stitt, U.S. Co-Chair; Paul Griffiths, Canadian Co-Chair; Libby Nieland, Treasurer; Tom Strong, Program Chair; Dick Garnick, Local Arrangements; Dave Klinger, Sponsorship and Volunteers; Mark Sherman, Publicity; Jim Nieland, Mt. St. Helens Field Trips; Donovan Whistler, Publications; Eric Larsen, Sponsorship; Reid Robinson & Sue Vessey; Martin Davis, Canadian Vendors; Steve Sprague, U.S. Vendors; Bill Marshall; Alisa Vanderberg; Mack Pitchford, Registration; Pat Shaw, Chilliwack Field Guide; Denis Moffatt, Phil Whitfield; Michael Compton; Rick Coles; Jim Baichtal, Alaska Field Trips; Karen Griffiths, Travel Arrangements; Sheryl Craig, Registration; Linda Heslop, Graphics Design; The rest of the gang: John Madsen, Rob Wall, Ken Langdale, Cam Brady, Len Titus, Hal Reveley, Gerry Still, Charlie Cornfield, Bill Bennett, Laura Friis, Scott Davis, Dave Hopf

Printed in the United States of America

Table of Contents

Opening Remarks

Rob Stitt, Paul Griffiths, and Janet Thorne

Rob Stitt, U.S. Co-Chair

On behalf of myself and the Organizing Committee, I'd like to welcome you to this Symposium, the thirteenth of an ongoing series that began in 1975 and has continued annually or biannually ever since. The symposia provide a valuable forum for the exchange of information on cave and karst management, and the published Proceedings represent the only comprehensive body of work on the subject. Traditionally this has been a **Cave** management symposium. On Vancouver Island, however, as in most cave areas, it has been necessary to consider not only the management of caves but the management of **karst**. As you'll see as we get into the program, cave managers in Northwestern North America have been at the forefront of at least thinking about the issues of integrated karst management. In other parts of the US, the deforestation of karst areas generally occurred in the last century, and by now the land has recovered as much as it can, leaving a cave and karst environment that in many cases is completely different than it was before the white man came. On Vancouver Island and in Alaska, we are observing history in real time, as the process of deforestation proceeds. And we have an opportunity to learn to manage these resources for the future. One of the purposes of the Symposium is to expose local managers to the National and International body of knowledge on karst and cave management, as well as to share local information with other researchers. I look forward to a week full of learning opportunities with all of you.

Paul Griffiths, Canadian Co-Chair

As Canadian co-chair of the Organizing Committee, I am very pleased to welcome you to the 1997 Karst and Cave Management Symposium. After 26 months of planning, we are delighted to have you here and we await your presentations with great interest. I'm sure that the week's activities will be both productive and fun. I would like to make two points about the organization of this symposium without going into great detail.

The first is the excellent working relationship of the bi-national planning committee—a reflection of the very close ties that exist between Canadian and US speleological organizations. My fervent hope is that the spirit of cooperation and friendship that was shown throughout the planning phase, will now spread further and infect every one of you this week. The very title of this symposium is also a sign of the strong desire of both countries to advance the goal of more fully integrating karst and cave management (at least where karst caves are concerned). By deciding to sponsor in this symposium, I believe we have already made great strides towards this goal.

As for the highlight theme—management of karst resources and caves in temperate coastal rainforests— it reflects a common interest that extends all the way from the West Coast of North America to "down under" (not a pun intended for the benefit of our Australian colleagues who are with us here today).

My second point concerns the role of the two key provincial government agencies with a mandated responsibility for managing karst and cave resources in my province - the British Columbia Ministry of Forests and BC Parks. Their co-sponsorship role is recognized and appreciated, as is their strong representation and desire to actively participate throughout the week.

Indeed, let's make full use of this opportunity to exchange information and learn from each other.

Janet Thorne

Thanks, Rob.

On my way here I was trying to remember how many Symposia I have attended, and I really couldn't. It was in the mid-80's that I started attending on a regular basis, but I was at the very first Symposium in Albuquerque in 1975. After the first few annual meetings, the Symposia have been conducted on a more or less regular schedule of every two years, and this is the 13th in the series.

Who here has attended a Symposium before?

Well, as those of you who have been coming for a few years know, the first Symposia were informally organized by the private interest groups and government agencies that are involved nationally with managing caves. In the late 1980's there was general consensus that more structure was needed, so the concerned organizations formed a Steering Committee for the National Cave Management Symposium. The NCMS Steering Committee is composed of representatives of each of the national organizations that are involved in some way with cave management. The representative of the National Speleological Society serves as the Coordinator of the Steering Committee, and currently I am that representative, which is why I'm standing before you now.

Let me introduce you to the other members of the Steering Committee. From the Federal government side, the Bureau of Land Management is represented by Jinx Fox, who works out of the Washington office. I guess in this state I need to say, 'Washington, D. C."! The Fish and Wildlife Service's representative is Dr. Robert Currie, a biologist from Asheville, NC. Jim Miller from Washington D. C., represents the Forest Service. The National Park Service is represented by Ron Kerbo, who is the agency's national cave specialist, working now in Denver.

From the private sector, representing the American Cave Conservation Association is Dave Foster, who lives in Horse Cave, KY. The Cave Research Foundation is represented by Roger McClure from Dayton, OH. The National Caves Association, which is an organization of show cave owners, is represented by Gordon Smith of Indiana, who was not able to attend this Symposium. Mark Ludlow of Florida Caverns State Park will be representing the NCA this week. And The Nature Conservancy, which undoubtedly is the private landowner with by far the most cave properties, is represented by Gabby Call of the Tennessee Chapter.

Finally, I'm pleased to announce that the Steering Committee this past summer added a new organization to its ranks. The Karst Waters Institute is an organization that conducts scientific research and education on a national level for cave and karst related issues. KWI has named Dr. Rane Curl as its representative; Rane recently retired from the University of Michigan at Ann Arbor.

These are the organizations and people who serve on the Steering Committee of the NCMS. Their primary responsibilities are to select the groups that will form the Organizing Committees for each Symposium, to encourage people within their own organizations to participate and present papers, and to ensure fiscal responsibility, so that all bills are paid and each new Organizing Committee has start-up funds for a coming Symposium.

If you have any questions about the Symposia in general, don't hesitate to ask one of the people I've introduced. The Steering Committee will hold its meeting on Wednesday afternoon at 4:30 p.m., and if you'd like to attend and see what we're up to, please feel free.

For those of you who haven't attended a National Cave Management Symposium before, I think you'll find that a tremendous amount of good and useful information will be presented during the week, both by the speakers and during the field trips. Please don't overlook the fact, however, that one of the greatest values of this Symposium will come from your having a chance to talk about any cave management problems you have with other people who are involved with cave management and perhaps have dealt with the same issues. Really, the interaction that takes place here is tremendously important.

Now, just to get that interaction started, I'm going to ask you to please turn to someone sitting near you whom you don't know, and introduce yourself.

Thank you. Now everyone in this room knows at least one other person here who also is concerned with the proper managing of caves. Please do try over the next few days to sit down with someone you don't know and introduce yourself. I've known of many occasions when someone in this group has a question or problem, and suddenly discovers that someone else is here who has dealt with the same issue and perhaps even has a solution!

So, I'm certain this will be a memorable week. Thank you for coming.

Role of the Epikarstic Zone in Temperate Rain Forest Management in Alaska

Tom Aley and Cathy Aley

The epikarstic zone is the weathered upper part of the bedrock. In the karst regions of southeastern Alaska the thickness and hydrobiologic functioning of the epikarstic zone varies dramatically. Where suitable lithologies exist, the thickness of the epikarstic zone is closely related to the amount of time since the last glaciation. As an example, in one area on the northern end of Prince of Wales Island, lands below elevations of about 400 feet are characterized by thin epikarstic zones because of recent glaciation. Lands with very thin epikarstic zones are less vulnerable to adverse impacts from timber harvest and road construction than are lands with thicker epikarstic zones. This relationship is one of several factors integrated into a karst land vulnerability strategy developed for the Ketchikan Area of the Tongass National Forest. The epikarstic zone is the region in which most bedrock dissolution, which is dominantly controlled by hydrobiological processes, occurs. A hydrologically integrated epikarstic zone provides lateral water movement to localized zones with enhanced vertical permeability. Turbulent water flow capable of transporting sediment and suspended organic materials is common in epikarstic zones developed beneath lands with at least moderate relief. Much of the sediment and suspended organic material transported through epikarstic zones ultimately discharges through springs to the streams of the region.

Application of a Karst Management Strategy: Two Case Studies from the Tongass National Forest, Southeastern Alaska The Challenges of Implementation

James F. Baichtal
Forest Geologist, Ketchikan Area, Tongass National Forest
Thorne Bay Ranger District, P.O. Box 19001, Thorne Bay, Alaska 99919
Phone: (907)828-3304 FAX: (907)828-3309
E-mail: mailto:/s=J.Baichtal/ou1=R10F05D04A@mhs-fswa.attmail.com

Abstract

Extensive areas of very pure carbonate, approximately 207,690 hectares (805 sq. miles or 515,000 acres), are found within the boundaries of the Tongass National Forest. The natives and local inhabitants of Southeast Alaska have long known of the presence of caves. The existence of well-developed cave systems was first reported in 1975 and mapping of the caves began in 1987. The existence of vast areas in which karst had developed was fully recognized in 1990. Though noted by early foresters and geologists, about this same time the interrelationship between timber production and highly productive forests atop the karst landscape became apparent. With the passing of the Federal Cave Resources Protection Act (FCRPA) in 1988, the Forest struggled with methods to protect the many caves throughout the landscape. At first, protection focused on only the large, significant karst features and cave entrances. Subsequent measures tended to look at entire karst hydrologic systems. These measures were limited by the need to provide timber for the long-term timber sale contracts that fed the pulp mills and wood-products industry in southeastern Alaska.

From 1993 to 1997, the Forest worked on revising the Tongass Land Management Plan (TLMP) that would guide the management of the nations largest National Forest for the next 10 to 15 years. One of the five "emphasis areas" identified in the TLMP revision was karst and cave resource management. Responding to the need for a management strategy, standards and guidelines were developed which provided for other land uses while taking into account the function and biological significance of the karst and cave resources within the landscape. This strategy has been developed during the last four years beginning with the recommendations of a karst and cave resource significance assessment completed by Aley et al in 1993 and combining the most current thinking on karst management issues. The Forest began adopting a land management strategy for the karstlands similar to "hazard area mapping" or "risk assessment". Referred to as "vulnerability mapping" or "karst vulnerability, this strategy assesses the susceptibility of the karst resources to any land use. Vulnerability mapping utilizes the fact that some parts of a karst landscape are more sensitive than others to planned land uses. The key elements of the strategy focus on the openness of the karst system and its ability to transport water, nutrients, soil and debris, and pollutants in to the underlying hydrologic systems. The strategy strives to maintain the capability of the karst landscape to regenerate a forest after harvest, to maintain the quality of the waters issuing from the karst hydrologic systems, and protect the many resource values within the underlying cave systems as per the requirements of the FCRPA.

This strategy has been applied to a number of areas in which timber harvest has been planned. This paper reports on the application of this strategy to the LAB Bay Planning Area on northern most Prince of Wales Island (POW) and to a salvage sale on Heceta Island, off the western coast of Prince of Wales Island. The Lab Bay Project Area comprises the northern 70,562 hectares of POW of which 33,903 hectares (48%) are carbonate. Heceta Island covers approximately 19,830 hectares of which 13,881 hectares (70%) are carbonate. Because of the geologic and climatic setting of these areas, it is assumed that karst has developed, to one extent or another, within all carbonate blocks. Discussed are the application process and assumptions, the on-the-ground implementation, and the shortcomings and/or challenges of implementation. From these experiences, the research needs are identified to help refine the process and make future implementation more meaningful and easier.

Introduction

The Tongass National Forest completed its revision of the Tongass Land Management Plan (USFS, 1997c) during the summer of 1997. The new plan incorporates a karst management strategy and associated standards and guidelines. This karst management strategy has been developed during the last four years combining current thinking on karst management issues, especially those focusing on timber production and associated activities (Aley and Aley, 1993; Aley et al, 1993; Blackwell, 1995; Eberhard, 1994; Griffiths, 1991; Harding and Ford, 1993; Herring, 1995; Huntoon, 1992a,b, and 1995; Kiernan, 1993; Lichon, 1993; Stokes, 1996; Stringer et al, 1991; Tasmania Forestry Comm., 1993). Also included in the development of the strategy were results of field studies specific to the Southeast Alaska karstlands (Aley et al, 1993; Baichtal, 1993 a, b, c, 1994, 1995; Baichtal et al., 1996; Baichtal and Swanston, 1996; Bryant et al, [In Press], Elliott, 1993; Lewis, 1995; Lewis and Baichtal, 1997; Streveler and Brakel, 1991; USFS, 1995a and b, 1996 a, b, and c, 1997 a and b).

As mentioned in the abstract, the Forest adopted a land management strategy for the karstlands similar to “hazard area mapping” or conducting a “risk assessment”. Referred to as “vulnerability mapping” or “karst vulnerability, this strategy assesses the susceptibility or sensitivity of the karst resources to any land use. Vulnerability mapping utilizes the fact that some parts of a karst landscape are more sensitive than others to planned land uses. The goal of the karst management strategy is to maintain and protect, to the extent practical, the natural karst processes and the productivity of the karst landscape while providing for other land uses where appropriate.

The major focus and intent of the karst management strategy is to identify and protect the karst systems and the caves and associated resources contained within, as per the requirements of the FCRPA. The Federal Cave Resources Protection Act is the primary U.S. law affecting caves. It requires protection of significant caves on Federal lands. A cave must possess one or more of the criteria outlined in 36 CFR Part 290.3 to be determined “significant”. Though “non-significant” caves may exist, most meet the criteria for “significant”. The intent of this act is to protect cave resources not karst resources. However, it is important to recognize that caves and associated features and resources are an integral part of the karst landscape. Karst must be managed as an ecological unit to ensure protection of the cave resources.

This karst management strategy has been applied within several proposed timber harvest projects across the Tongass: the Lab Bay FEIS on Northern Prince of Wales Island (USFS, 1995b, 1997a), to the Indian River and Whitestone Project Areas on Chichagof Island on the Chatham Area of the Tongass National Forest (USFS, 1996 a and c), to Tuxekan Island, west of northern Prince of Wales Island (USFS, 1995a), the Chasina Project Area, east-central Prince of Wales Island (USFS, 1997b), and to Heceta Sawfly Salvage Project on Heceta Island (USFS, 1996b). The karst management strategy applied in these projects was essentially the same as what is published in the new Tongass Land Management Plan (USFS, 1997c). At the time the strategy was applied within the above-mentioned projects, the strategy was considered interim direction and was evolving. Of the above-mentioned projects, the Lab Bay and Heceta Sawfly Salvage Projects contain some of the better developed karst areas and have a long history of timber production. After a brief summary of the projects, this paper will focus on the challenges and lessons of implementing the karst management strategy.

Lab Bay Project

The 70,590-hectares (174,357-acres) Lab Bay Project Area is located on northern Prince of Wales Island. Within the Project Area there are 33,903-hectares (83,773-acres) of karstlands. Of the 33,903-hectares of karstlands, 18,233-hectares (54%) were considered suitable timberlands of which 8,349-hectares (25%) have been harvested. The remaining 56 percent of the karstlands were within some protected land status or constitute many of the high ridges and alpine areas of the northern island.

During the summer of 1993, the Forest Service assembled an independent panel of karst specialists to assess the significance of the karst resources within the Ketchikan Area, to evaluate the effectiveness of current strategies for protecting karst resources, and to recommend appropriate changes to those strategies. The Karst Panel's primary recommendation was to develop a karst landscape vulnerability rating strategy (Aley et al. 1993). Subsequently, such a strategy was developed for the Lab Bay Project Area and implemented in 1994 as the Phase 1 and Phase 2 karst vulnerability assessments. (Harza Northwest, Inc. et al. 1994; USFS, 1995b.)

The Karst Panel also recommended a more comprehensive mitigation strategy that moved away from a karst feature protection strategy toward a more comprehensive karst systems protection approach. The Draft Karst and Cave Resource Management Forest-wide Direction and standards and guidelines (USDA Forest Service 1994) strived to achieve a systems management approach and was applied to the Lab Bay Project Area.

The Karst Vulnerability Assessment Report (Harza Northwest, Inc. et al. 1994) describes the Phase 1 vulnerability assessment of the Lab Bay Area. The Karst Vulnerability Assessment Report, Phase 2 Site-Specific Verification Study (USFS, 1995b) confirmed an overall accuracy of 92 percent for the Phase 1 assessment. The studies include descriptions of karst features and their distribution, and delineations of areas of low, moderate and high vulnerability classifications under different management activities. These resource values were incorporated into the vulnerability rating process that delineates a Project-wide classification of karstlands. Parameters used in the assessments include geology; elevation; slope; karst features such as caves, sinkholes, insurgences and resurgences; Class I and II streams; and non-carbonate watersheds draining to karst areas. Areas of high vulnerability are those areas that have the highest resource value and that are most sensitive to adverse impacts from management activities.

Protection measures described in the Draft Karst and Cave Resource Management Forest-wide Direction and standards and guidelines (USDA Forest Service 1994), were applied on a case by case basis to karst features identified in proposed logging units and road locations in the Lab Bay Study Area.

The final analysis defined 2,916-hectares (7,203-acres) of low vulnerability karstlands, 3,996-hectares (9,870-acres) of moderate vulnerability karstlands, and 27,004-hectares (66,700-acres) of high vulnerability karstlands. The original purpose and need identified for the Project planned to harvest approximately 85 million board feet of timber. The selected alternative is planned to harvest 42 million board feet of timber and is designed to avoid harvest on high vulnerability karst and minimize the impacts of road construction across karstlands. This is the first project to which the vulnerability strategy was applied.

Highly skilled resource specialists with an exceptional working knowledge of karst processes conducted the karst vulnerability assessment for the Lab Bay Project. Field reconnaissance of the Project Area continued for three field seasons. Resource specialists were trained to recognize karst features and the degree of karst development. Geologists, geomorphologists, wildlife biologists, foresters, and cavers were utilized in the initial karst resource inventories. Local karst management specialists worked with the contractors preparing the EIS to develop the Phase I vulnerability assessment during the winter field season. The following field season the Phase I assessment was verified and dye studies were conducted. The importance of local knowledge by the karst management specialists involved in completing the Phase I assessment is evidenced by the 92 percent accuracy of that assessment. This intimate knowledge of the karst landscape came not only from the resource specialists spending time afield but also from close coordination and good communication with the volunteer cavers inventorying within the Project Area.

Heceta Sawfly Salvage Project

The Heceta Sawfly Salvage Project is located north of Bald Mountain on Heceta Island. As proposed, the Project boundary covers some 2,425-hectares (5,989-acres) and plans to harvest approximately 15 million board feet of dead and dying timber defoliated by hemlock sawfly as well as approximately 25 percent associated green trees.

Assuming that to one extent or another, karst has developed on and within all carbonate substrate, all 5,989 acres of the Project Area are atop karst. Karst resources are very well developed within the limestones and limestone breccias of the Heceta Formation of the Project Area. Small drainages disappear along the margins of small peatlands developed on glacial alluvium, features are concentrated along fault traces, and sinkholes and other collapse features are numerous across the surface of the karst lands. Based on the criteria outlined in the applied karst management strategy (Baichtal et al., 1996, USFS, 1996b), it was modeled that 1,545-hectares (3,817-acres) of the Project Area are moderate vulnerability karst and 880-hectares (2,172-acres) are high vulnerability. There were no low vulnerability karstlands within the Project Area boundary.

The highly vulnerable areas are both discrete karst features and areas of intense epikarst development. Based on the evidence of the glacial history and the intensity of the karst development, the steepness of the slopes, and the shallowness of the soils, everything above 1,000 feet in elevation is considered high vulnerability karst. Soils are a mosaic of both mineral and organic. Mineral soils vary from shallow to deep, are well drained, and are of glacial origin. Organic soils are shallow and well drained. Karst topography and subsurface drainage systems are very well developed in the carbonate substrate. Few areas of southeastern Alaska show better karst development. Low numbers of caves were found within the Project Area, however extensive cave systems exist just outside the Project Area boundaries. Through dye tracing, the extensive cave systems outside the Project Area boundary have been shown to be hydrologically connected to features within the Project Area. Few streams exist on the carbonate areas and these only flow during large precipitation events. Based on previous harvest data on USFS lands, 49 percent of the forested karst lands on Heceta Island has been harvested, 38 percent of the forested karst lands within the Project has been harvested.

The Heceta Sawfly Project was designed so that there would be no timber harvest atop high vulnerability karstlands and to mitigate the impacts of harvest atop moderate vulnerability karstlands (Baichtal et al., 1996, USFS, 1996b). It was also intended that the areas that are defined through dye tracing, to contribute to the extensive cave systems outside the Project boundary be protected or carefully managed.

The karst management specialist working with the caving community conducted the initial karst vulnerability assessment for the Heceta Sawfly Project. Field reconnaissance and harvest unit design lasted for one field season. The final harvest unit design and vulnerability assessment were carried out by a seasonal geomorphologist with limited karst experience and other resource specialists and foresters somewhat familiar with karst processes and the vulnerability assessment. Dye studies were also conducted over one field season by the volunteer cavers on expedition within the Project Area. Because of other responsibilities given to the karst management specialist, field verification and spot-checking of the on-the-ground karst vulnerability classifications were not accomplished. Communication with the caving community and research partners also suffered because of the re-assignment of duties of the karst management specialist. Because of the experience level of the resource specialists field checking the proposed harvest units, it is possible that the karst management strategy was not fully implemented within the project area. Acting on concerns voiced by the cavers from the current year's expedition, the karst management specialist will be re-assessing the karst vulnerability within the Project Area. With the dwindling Federal budgets, it is a common theme that resource specialists are asked to take on added responsibilities that limit field time. The Forest has recently re-focused the emphasis of the karst management specialist seeing the need for such skills in karst resource inventory and application of the karst management strategy.

Application, Implementation, Challenges

The karst management strategy applied to these and other projects is relatively new. Acceptance of what the strategy is trying to achieve when applied on the ground has been a mixed bag. The author does not wish to dwell on the trials and tribulations of developing and gaining acceptance of the strategy as it now stands. The author realizes that the karst management strategy may not be quite perfect, however the author believes that the approach is sound. What the author wishes to share are his insight, observations, and opinions on how the process should work and where further work and research is needed.

The Karst Management Strategy has four phases: identification of potential karst lands, inventory of the karst resources, delineation of the karst hydrologic system(s) and catchment area(s), and assessment of the vulnerability of the karst terrain to the proposed management activity. These four phases are the basis for the following discussions. The discussions are based on the experiences gained in implementation of the two projects outlined above and other projects cited.

Identification of Potential Karst Lands: This is, for the most part, the easiest phase. Geologic maps exist for many areas where projects are proposed and the coarse geology is mapped. The intricacies of the outcrop patterns can be quite different however. Many of the inter-Island areas of southeastern Alaska have never been precisely mapped. Therefore, education of field going personnel is essential to identify possible karst areas where geologic information is sparse. Education should include carbonate rock identification and karst landform recognition. Also, proficiency in air-photo interpretation and recognition of the karst landforms and associated vegetative and stream patterns is a must. This can be challenging within the dense coastal rainforests of Southeast Alaska. In a relatively short time, the Forest has been able to increase the awareness of karst landforms and processes to the point that resource specialists can recognize karst areas most of the time. Education is an ongoing process, new areas are entered and personnel move or change positions.

Inventory of the Karst Resources: In the author's experience, this is the most important and time-consuming phase. The more intense the karst development, the more intense the inventory must be. Resource specialists or partners with experience and/or understanding of karst and cave resources and karst processes must complete inventories. Time must be allowed prior to decisions on management activities to complete the inventory. Ideally, a minimum of two years lead-time is needed on large-scale projects. Inventory is complicated by the remoteness of projects, access, terrain, weather, and vegetation. It is of utmost importance that both resource specialists and partners within the caving community become involved early. Communication needs to continue throughout the process both internally, within the Agency, and externally with partners and researchers. Results and implications of the inventory need to be clearly conveyed to interdisciplinary teams, decision makers, and external partners throughout the inventory phase. The caving community needs to be brought into the process to begin inventory and mapping of the caves discovered and to explore other karst features encountered. Their reports are the link between the surface features inventoried and the underground resources. Constant communication between all involved is paramount. Without this communication, misunderstandings, mistrust, and conflicts arise on all sides.

Delineation of the Karst Hydrologic System(s) and Catchment Area(s): Again, time must be allowed prior to decisions on management activities to complete the dye tracing necessary to define the karst hydrologic system(s). All insurgences and resurgences both within and proximal to the project area need to be noted during the inventory phase. Key karst features, which do not take surface flows, identified during inventory should be considered for die injection during testing. Time is the key element here. It takes time to grossly define the hydrologic boundaries between karst systems. Dye tests should be conducted during both high and low flow periods to help define the full complexity of the systems. With this information, cumulative effects, watershed assessments, and mitigation can be analyzed and defined. Catchment areas defined through dye tracing, to contribute to significant cave systems should be protected or carefully managed. The intent of the karst management strategy in catchment area protection is not to completely close the area to other land uses but to insure protection of the down-gradient karst resource values. Dye studies have shown that, without good, reliable dye tracing data, there is little chance of predicting neither the karst systems boundary nor where the waters flow. Without proper dye tracing to predict the karst hydrologic system(s) extent, mitigation and protection can only focus on feature protection and not system recognition. Partners can and should play a major role in helping to define and characterize the karst hydrologic systems and conduct the dye traces.

Assess the Vulnerability of the Karst Terrain to the Proposed Management Activity: Once the project area has been fully inventoried, surface and subsurface information compiled and the hydrologic information analyzed, determination of the vulnerability of the karst terrain can begin. As previously stated, the karst management strategy strives to maintain the capability of the karst landscape to regenerate a forest after harvest, to maintain the quality of the waters issuing from the karst hydrologic systems, and protect the many resource values within the underlying cave systems as per the requirements of the FCRPA. To make these determinations a fully interdisciplinary approach to the analysis must be made. Foresters, silviculturalists, fisheries biologists, soil scientists, logging system specialists, hydrologists, etc., working together with the karst management specialist are needed to determine vulnerability of the karst lands. Understanding and agreement of the intent and application of the karst management strategy is necessary if consistency in analysis is to be achieved. It is imperative that partners and researchers fully understand how the strategy is to be applied on the land so that concerns can be voiced. It is also desirable that the caving community and research partners trust that the karst management specialist will incorporate their inventories and research findings in an unbiased manner into the vulnerability determinations. It is essential that communication between land managers, resource specialists and cooperators such as the caving community remain open.

Research Needs

Based on the authors field observations and application of the karst management strategy, there are three research priorities which would further our understanding of the karst landscapes function and biological significance. It is suggested that research into the following be encouraged:

1. Research into the complexity of the karst hydrologic systems. Particularly into the effects of clear cutting and the increased availability of surface waters due to the loss of interception of precipitation by the forest canopy. What are the effects of certain harvest methods on the flows within the karst systems? If the systems experience increased flows, how does the chemistry, pH, and sediment carrying capability of the karst waters change? Answers to these questions would greatly help in determining the effects of timber harvest atop karstlands.

2. Research into how sedimentation rates have changed over time, i.e. pre-harvest and post-harvest periods. It is understood that sediment studies measuring the presence of lack of cesium have been used for measuring sedimentation rates.

3. Develop and maintain a monitoring strategy to determine the effects of land uses, specifically timber harvest and road construction on the karst landscape. As a minimum, karst hydrology, soil loss, forest regeneration, sedimentation, and debris transport should be monitored.

The recently completed revision of the Tongass Land Management Plan (USFS, 1997c) has identified the following information needs and research priorities. The order of the list is not by prioritization.

1. Develop an understanding of the paleoecology and prehistory of Southeast Alaska through studies of the geology, paleontology, and cultural resources within the karst landscape.

2. Determine the relationships between forest regeneration and position in the karst landscape.

3. Document and describe the biospeleology of karst systems.

4. Determine the relationship between karst development and soil erosion within harvested lands.

5. Determine the contribution of karst groundwater systems to productivity of aquatic communities.

6. Determine the influences of forest road construction on sediment and woody debris delivery to karst drainage systems.

7. Evaluate the effects of sediment and woody debris delivered to karst drainage systems on flooding, erosion, and surface discharge.

8. Define the relationship of peatlands to karst development.

9. Analyze the geochemistry of karst host rocks to better understand karst development and identify possible areas suitable for mineral development.

10. Determine differences in productivity of anadromous fish streams draining karst terrain.

Conclusions

The karst management strategy, if carefully applied, works well throughout southeastern Alaska. Similar management strategies have been applied on Vancouver Island, British Columbia Canada, in the forests of Tasmania, and in select areas within the continental U.S. These strategies are focused on the possible effects from surface disturbing activities adjacent to or within a karst landscape associated with timber harvest, forest road construction, and mining. The resource specialists implementing the strategy must have a clear understanding of karst processes. Education of field going personnel is essential to identify possible karst areas and to get a general understanding of the extent of karst development and the possible karst vulnerability. It is importance that both resource specialists and partners within the caving community become involved early. Communication needs to continue throughout the process both internally, within the Agency, and externally. Results and implications of the inventory need to be clearly conveyed to interdisciplinary teams, decision makers, and external partners throughout the inventory and assessment phase. Time must be allowed prior to decisions on management activities to complete the inventories, dye tracing necessary to define the karst hydrologic system(s), and the vulnerability assessment. The karst management strategy must be applied evenly and consistently to the karst landscape without bias. With good communication and consistent, well-understood, application of the karst management strategy, the balance between resource protection and other uses can be achieved with a minimum of conflict.

References

Aley, T. and C. Aley. 1993. Delineation and hazard area mapping of areas contributing water to significant caves. In: D.L. Foster (ed.): Proceedings of the National Cave Management Symposium, 1991. American Cave Conservation Association. pp. 116-122.

Aley, T., C. Aley, W. Elliot, and P. Huntoon. 1993. Karst and cave resource significance assessment, Ketchikan Area, Tongass National Forest, Alaska, Draft Report, prepared for the Ketchikan Area of the Tongass National Forest. 76 pp. + appendix.

Baichtal, J.F. 1993a. Management of the karst areas within the Ketchikan Area of the Tongass National Forest, Southeastern Alaska. In: D. L. Foster (ed.): Proceedings of the National Cave Management Symposium, 1991. American Cave Conservation Association. pp. 198-208.

Baichtal, J.F. 1993b. Karst and Cave Resources. In: Central Prince of Wales Final Environmental Impact Statement, U.S. Department of Agriculture, Forest Service, R10-NM-229a, pp. 179-200

Baichtal, J.F. 1993c. Karst Management Seminar Held in Alaska. In: American Caves, Spring 1993, American Cave Conservation Assoc. p 10.

Baichtal, J.F. 1994. Karstlands of Southeastern Alaska: Recognition, Exploration, and Appreciation. American Caves 7(1): p.5-7.

Baichtal, J.F. 1995. Evolution of Karst Management on the Ketchikan Area of the Tongass National Forest: Development of an Ecologically Sound Approach. In: D. L. Pate (ed.) Proceedings of the 1993 National Cave Management Symposium, Carlsbad, NM. pp. 190-202

Baichtal, J.F.; D.N. Swanston; and A. F. Archie. 1996. An Ecologically Based Approach to Karst and Cave Resource Management. In: Proceedings of the 1995 National Cave Management Symposium, 1996, October 25-28; Mitchell, In.: Indiana Karst Conservancy, pp. 10-27.

Baichtal, J.F.; and D.N. Swanston. 1996. Karst Landscapes and Associated Resources: A Resource Assessment. General Technical Report, PNW-GTR-383. Portland, Oregon: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 13p.

Blackwell, B. A. 1995. Literature Review of Management of Cave/Karst Resources in Forest Environments. Unpublished Report completed for Vancouver Forest Region, BC Ministry of Forests, Nanaimo, British Columbia, Canada. 19 pp.

Bryant, M.D.; D.N. Swanston; R.C. Wissmar; and B. E. Wright. [In Prep.] Salmonid populations in the Karst Landscape of Northern Prince of Wales Island, Southeast Alaska.

Eberhard, Rolan. 1994. Inventory and management of the Junee River karst system, Tasmania. A report to Forestry Tasmania

Elliott, W.R., 1994. Alaska's Forested Karstlands, American Caves, 7(1):8-12.

Griffiths, P. 1991. A resource user's perspective on cave management. British Columbia Caver 5(3). pp. 16-20.

Harding, K.A., and D.C. Ford. 1993. Impacts of primary deforestation upon limestone slopes in northern Vancouver Island, British Columbia. Environmental Geology 21:137-143.

Harza Northwest, Inc., Ozark Underground Laboratory, and J. F. Baichtal. 1994. Karst Vulnerability Report, for Lab Bay Environmental Impact Statement, Prince of Wales Island, Alaska. Prepared for the USDA Forest Service, Tongass National Forest, Ketchikan Area.

Herring, M. 1995, Karstlands: the world beneath our feet. Natural Areas Report, Vol. 7, No. 3, p.1-2.

Huntoon, P.W. 1992a. Hydrogeologic characteristics and deforestation of the stone forest karst aquifers of south China. Ground Water, Vol. 30, pp. 167-176.

Huntoon, P.W. 1992b. Deforestation in the south China karst and its impact on stone forest aquifers. In: Sauro, U.; A. Bondesan; and M. Meneghel, editors. Proceedings of the International Conference on Environmental Changes in karst areas; 13 Quaderni del Dipartimento di Geografia, Universita di Padova, Italy, September 15-27, 1991. pp. 353-360.

Huntoon, P.W. 1995. Upland Recharge Area Protection in Western North America Alpine and Sub-alpine Karsts. In: Proceedings of Mountain Hydrology, May 16-19, 1995, Vancouver, B. C. Canada. Canadian Water Resources Association, Cambridge, Ontario, Canada. pp. 55-63.

Kiernan, K. 1993. Karst research and management in the state forests of Tasmania. 10th Australian Conference on Cave and Karst Management: May 1993.

Lewis, S. W. 1995. Karst Ecosystem Protection in the Tongass National Forest. NSS News, Volume 53, No. 2. pp. 32-39

Lewis, S. W. and J. F. Baichtal. 1997. Protecting Caves, Karst, And Bats in the Tongass National Forest, Southeast Alaska. Conservation and Protection of the Biota of Karst, Extended Abstracts and Field-Trip Guide for the symposium held February 13-16, 1997, Nashville, TN: Karst Waters Institute, Special Publication 3. pp. 42-46

Lichon, M. 1993. Human Impacts on Processes in Karst Terranes, with Special Reference to Tasmania: Cave Science, Vol. 20, No. 2, Transactions of the British Cave Research Association, pp. 55-60

Stokes, T. 1996. A Preliminary Problem Analysis of Cave/Karst Issues Related to Forestry Activities on Vancouver Island. Unpublished Report completed for Vancouver Forest Region, BC Ministry of Forests, Nanaimo, British Columbia, Canada. 14 pp. + Bib.

Streveler, G. and J. Brakel. 1991. Cave lands of Southeast Alaska; an imperiled resource. A report to the Southeast Alaska Conservation Council by Icy Strait Environmental Services, Gustavus, AK. 39p. + appendix materials.

Stringer, J.W., B.L. Slover and T. Alley. 1991. Speleoforestry: Planning for an unseen resource. Journal of Forestry

Tasmania Forestry Commission. 1993. Forestry Practice Code for Karst Terrain. Tasmania Forestry Commission, Hobbit. 7 pp.

U. S. Forest Service, 1994. Draft Karst and Cave Resource Management Forest-Wide Direction and Standard and Guidelines. USDA Forest Service. Tongass National Forest.

U. S. Forest Service, 1995a. Final Karst Vulnerability Assessment Report, Tuxekan Island, Alaska. USDA, Tongass National Forest, Ketchikan Area, Thorne Bay Ranger District. 63 pp.

U. S. Forest Service, 1995b. Final Karst Vulnerability Assessment Report, Phase II Site-Specific Verification Study, Lab Bay Environmental Impact Statement, Prince of Wales Island, Alaska. Prepared by Harza Northwest, Inc. and Ozark Underground laboratory for the USDA, Tongass National Forest, Ketchikan Area, Thorne Bay Ranger District. 29 pp. + Append.

U. S. Forest Service, 1996a. Karst Vulnerability Assessment Final Report, Indian River Project Area, Chichagof Island, Alaska. USDA, Tongass National Forest, Chatham Area. 26 pp. + Append.

U. S. Forest Service, 1996b. Environmental Assessment, Heceta Sawfly Salvage Project, Heceta Island, Alaska. USDA, Tongass National Forest, Ketchikan Area, Thorne Bay Ranger District. 23 pp. + Append.

U. S. Forest Service, 1996c. Whitestone project Area Resource and Karst Vulnerability Assessment, Development of Karst Vulnerability Characteristic, Chichagof Island, Alaska. An Unpublished Report Prepared for the USFS by American Engineering Corporation and Ozark Underground Laboratory.

U. S. Forest Service, 1997a. Lab Bay Project Area Final Environmental Impact Statement, Ketchikan Pulp Company, Long-Term Timber Sale Contract, Volume 1: United States Department of Agriculture, Tongass National Forest R10-MB-321a, pp. 3-8 to 3-30.

U. S. Forest Service, 1997b. Chasina Timber Sale, Draft Environmental Impact Statement, Volume 1; In: Chapter 3, Geology, Minerals, and Karst Resources. United States Department of Agriculture, Tongass National Forest, R10-MB-333, pp. 107-120.

U. S. Forest Service, 1997c. Land and Resource Management Plan, Tongass National Forest: United States Department of Agriculture, Alaska Region, R10-MB-338dd, pp. 4-18 to 4-20 & Appendix I (22 pp.).

Wipfli, M. S. [In Prep]. Structure of Benthic Macroinvertebrate Communities Associated With Karst Landscapes on Northern Prince of Wales Island, Alaska, USA.

Wissmar, R.C.; D.N. Swanston, M. D. Bryant; and K. McGee. [In Prep]. Controls on Stream Chemistry Within a Karst Landscape, Southeast Alaska.

White, W. B.; D. C. Culver; J. S. Herman; T. C. Kane; and J. E. Mylroie. 1995. Karst Lands. American Scientist, Volume 83, Sept.-Oct., 1995. Pp. 450-459.

Karst Landscapes and Associated Resources: A Resource Assessment - Poster Presentation

James F. Baichtal

The Tongass National Forest contains world class karst features and the largest concentration of associated dissolved caves known in the State of Alaska. This poster will illustrate the many components of the karst landscape, describing the dominant karst forming processes, the controlling geologic and hydrologic characteristics, and the influence of the karst landscape on associated forest resources. The current Karst Resource Management Strategy being implemented on the Tongass National Forest will be highlighted. Printed copies of the Assessment will be available.

Karst Management in British Columbia

Address by

Bronwen Beedle
DEPUTY CHIEF FORESTER
BRITISH COLUMBIA

Good morning, everyone. I am very pleased to represent the British Columbia Ministry of Forests at this international gathering, along with a number of other specialists who are also here this week from the Ministry.

Deputy Chief Forester Bronwen Beedle has asked me to convey to you her disappointment and regrets at not being able to present her address to you in person today. As you are probably aware, B.C. is currently dealing with a number of high-profile forestry issues—not the least of which is the need to meet increasing management demands with decreasing budgets. As a result, she has been required to attend an executive meeting to help work out related strategies, and she's asked me to present her address on her behalf.

I am very happy and honoured to do that; my name is Gerry Still, and I am the Manager, Forest Practices Research, in the Ministry's Research Branch. What I'm going to present to you now is the address Bronwen would have made, had she been able to attend this symposium.

For me it is a real pleasure to be able travel "next door" as it were, and see what the neighbours are up to on current issues—and hopefully, in this case, what might be happening in other parts of the world as well. Some of our researchers are in regular contact with researchers in various areas of the United States. But it's always a benefit for me personally to meet our counterparts from other jurisdictions face-to-face and discuss our common concerns.

In situations like this I often find out we are not just dealing with similar issues of management and policy, we are also finding equally "interesting"—and by that I mean challenging and creative—solutions.

Karst management is no exception, in that it certainly has its own challenges needing resolution. So I am very pleased that our ministry is able to be a co-sponsor of this conference, and to host the field trips on Thursday to the north of Vancouver Island and in the Chilliwack area. I would like not only to thank, but also to congratulate, the organizing committee members for their hard work in putting together the complicated logistics for the conference. I know most, if not all of it, was private time donated by many committed individuals. If things go according to plan, and I am sure they will, this will be a very successful symposium.

My job this morning is to outline the management of karst environments in British Columbia, and I think I can do that best for you if I make some initial reference to the overall forest management context in British Columbia in which this takes place.

So I am going to first briefly discuss:

- our forest land base;
- what forestry means to B.C., in terms of its social and economic importance to the province;
- the scale of our environmental responsibility;
- and, some recent initiatives the provincial government has taken, in land-use planning and the regulation of forest practices, to try to integrate social, environmental and economic objectives on our forest land.
- Then, in that context I'll give an overview of karst in the province—the location, extent and character of these environments...

- followed by a historical perspective on the evolution of how we've managed—or in some cases *not* managed—karst in the past...

- and, finally, a description of our current initiatives for managing karst values today.

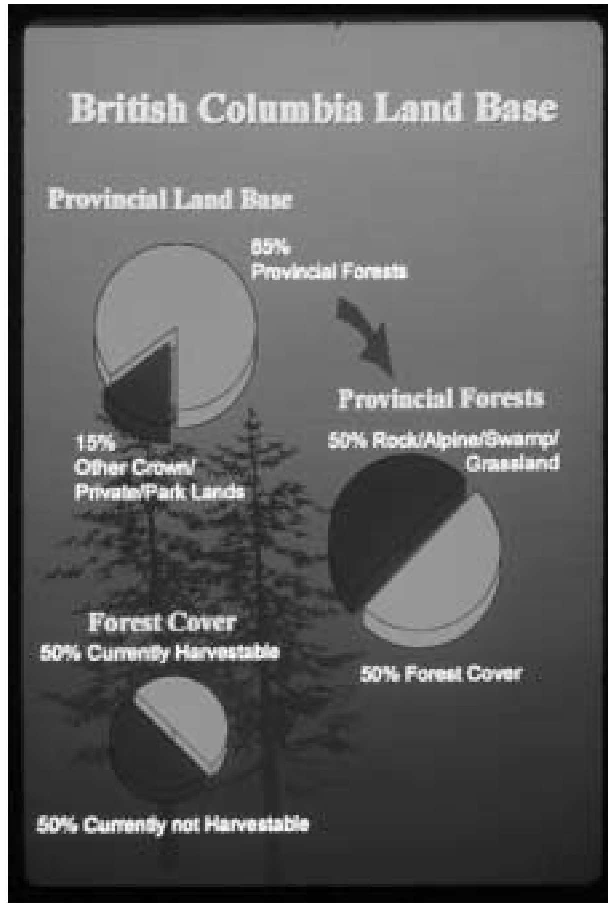
I would like to acknowledge the use in this presentation of a number of photographic slides, many of which were kindly loaned by Paul Griffiths, Jacques Marc, and Doug Herchmer.[1]

Slide 1: Ecological Map - "Biogeoclimatic Zones of B.C."

So I will start by very briefly reviewing the B.C. land base. First, and most obviously, B.C. has a very large area to manage. The province covers over 95 million hectares—or nearly 240 million acres. Over 94 percent of this is Crown provincial land, in other words, public land. This very large proportion of public land permits extensive government regulation in our forest management.

I note in passing that although the area of B.C. is comparable to that managed by the 35 000 or so employees of the US National Forest Service, our Ministry of Forests currently has only about 4000 employees—this implies more extensive management, and more reliance on periodic auditing, as compared to a more intensive monitoring, of harvesting activities.

The province has wide geographic and climatic variation, with an impressive diversity of both land- and water-based ecosystems, as you can see on this ecological map of the province. We currently have only about three-point eight million people, concentrated mainly in the Southwest corner of the province in Vancouver and Victoria, but the population is growing rapidly and has a great cultural diversity.



Slide 2: B.C. land-base breakdown.

Roughly half of B.C. is considered to support productive forests, and about half of this is considered to be harvestable. About one percent of the timber harvesting land base—usually less than 200,000 hectares or 500,000 acres—is harvested annually.

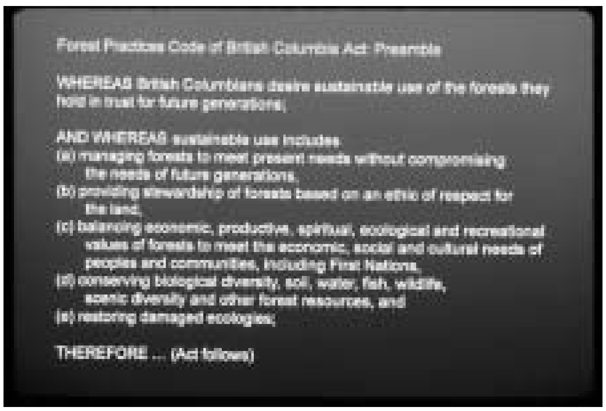
In contrast to many other constituencies around the world, we still have large areas of original forest, and these provide important planning options, and opportunities for conservation. At the same time, they present difficult management choices that we must resolve—under increasing world attention these days—to meet a broad spectrum of public demands and objectives.

These objectives include managing water quality, recreation, aesthetics, range and forage for domestic cattle, wildlife habitat, fisheries and riparian habitats;

[1] Note that these slides were included in the original speech, but only a representative few are used to illustrate this shorter version for the Proceedings.

maintaining employment levels and social structure in our many forestry-dependent communities; and producing a range of forest products including botanical forest products, as well as managing special features like the karst environments we are discussing today. I understand this spectrum of issues is not too different from that associated with public forest land in the US.

Through all the complex management this entails, we must keep in mind the need to protect biodiversity at both the forest stand and landscape levels. We are in fact *required* by our *Ministry of Forests Act* to balance and integrate the management of our forest resources and values, and by the *Forest Practices Code of British Columbia Act*, to do so sustainably.

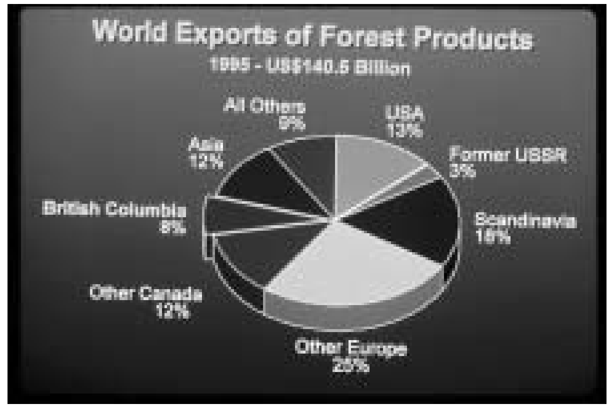


Slide 3: Preamble to *Forest Practices Code of British Columbia Act.*

This slide shows the preamble to the *Forest Practices Code of British Columbia Act*. The key concepts are: not compromising needs of future generations; an ethic of respect for the land; balancing a wide range of values; conserving biodiversity; and, restoring damaged "ecologies."

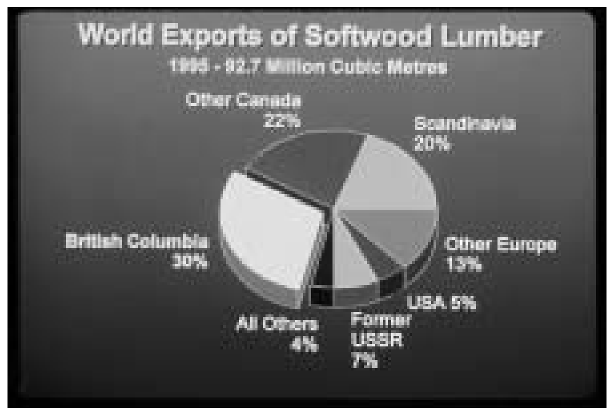
The preamble is followed by all the specific provisions of the *Code Act* and so predicates all our forest management on the requirement for sustainability.

This Forest Practices Code is still fairly new and was instituted to help achieve sustainable management after a history of development in the province, when timber harvesting was primarily an economic tool for developing social services and infrastructure. This was followed by an evolution into integrated resource management on forest lands. Today timber harvesting is considered to be one of a range of management objectives, as just noted. But our forest products industry is still an important player in the world markets and remains a primary generator of provincial revenues and export earnings.



Slide 4: World Forest products exports '95 (FAO)

In 1995, Canada was the largest single exporting country in the world for *forest products*. British Columbia provides almost half of Canada's forest products export value.



Slide 5: World softwood lumber exports '95 (FAO)

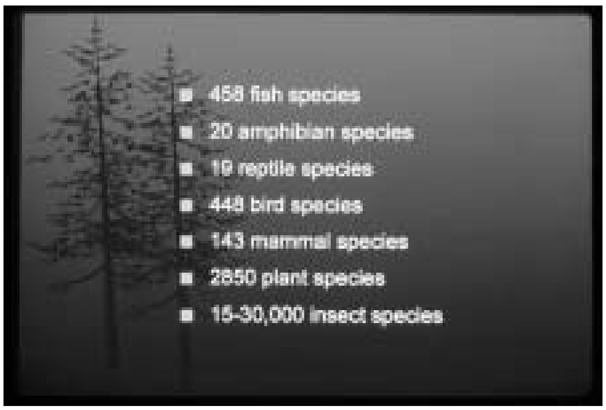
Also in *softwood lumber*, Canada is the largest single exporting country, accounting for more than half of the world's exports. In 1995 B.C. on its own accounted for about 30 percent of world exports.

In 1996, our total timber harvest of 75.2 million cubic metres produced manufacturing shipments worth 16.5 billion dollars, with government revenues of 1.67 billion dollars.

1995 statistics show that forest products supported approximately 106 000 direct jobs in B.C., and another 159,000 indirect jobs—together accounting for about 15 percent of total employment in the province; government currently has an initiative to substantially increase the number of jobs in the forest sector.[1] Many of our communities grew up around forestry operations, and still depend on them economically and for employment.

So, both socially and economically, forestry makes very active, important contributions to British Columbia today.

At the same time, due to the province's extensive and varied terrain, and the variety of climates and ecosystems, B.C. is also very rich and diverse *biologically*.



Slide 6: Plant and animal species in B.C.

B.C. is home to vertebrate species that include 458 fish, over 448 birds, 20 amphibians, 19 reptiles, and 143 mammals. We have at least 2,850 vascular plant species—69 percent of all those in Canada—and between 15 and 35 thousand insect species. And we have one of the most biologically diverse marine environments in the world.

These biological riches impose a heavy responsibility on us. The B.C. Ministry of Environment, Lands and Parks reports that 68 species of vertebrate animals and 224 vascular plants—like the *Corydalis scouleri* from the Nitinat Valley shown here—are threatened or endangered, or are potential candidates for these designations. Another 451 species are reportedly vulnerable or at risk.

This means our socio-economically important forest products industry is operating in a very sensitive natural environment. And our relatively short history of harvesting means that much of what we cut today is still harvested from old-growth forests. About 51 percent of the area harvested annually province-wide is covered by trees over 140 years old, and the figure is 87 percent on the coast. Province-wide, nearly 17 percent of the area harvested is over 250 years old. Our current age-class distribution shows that it will be several decades before second-growth forests contribute a major portion to the harvest, so we can't avoid harvesting in old-growth forests for some time to come, unless we are prepared to accept massive social and economic impacts.

Resolving issues of harvesting in old-growth forests has generated deep debates, both inside and outside B.C. I think it is fair to say that most people in our province have become well aware of the wide range of values on their forest lands. From this awareness, they have made it very clear that they want the land managed in ways that will balance and integrate the range of forest land values, and respect and conserve biodiversity for the future.

To help achieve this, the B.C. government—with extensive public input—has created a number of initiatives designed to do two things:

1) to carry out *responsible land-use planning*, which includes identifying some areas for protection and others for timber harvesting at various levels of intensity; and,

2) to ensure that where plans identify timber harvesting as an appropriate objective, only *sustainable operational practices* are allowed.

To do this we completely overhauled our land-use planning processes, with new initiatives, including our Protected Areas Strategy, improved Land and Resource Management Planning processes, the Forest Practices Code and other associated initiatives.

Strategic land-use planning with extensive public participation is now completed or underway for 75 percent of the province. The goal of this process—one not always realized—is to achieve consensus for approval by government at the Cabinet level.

[1] In 1996, these figures dropped to 101 000 direct jobs in B.C. and 152 000 indirect jobs, accounting for 14% of total employment in the province.

Slide 7: **Protected Areas Strategy Map for B.C.**

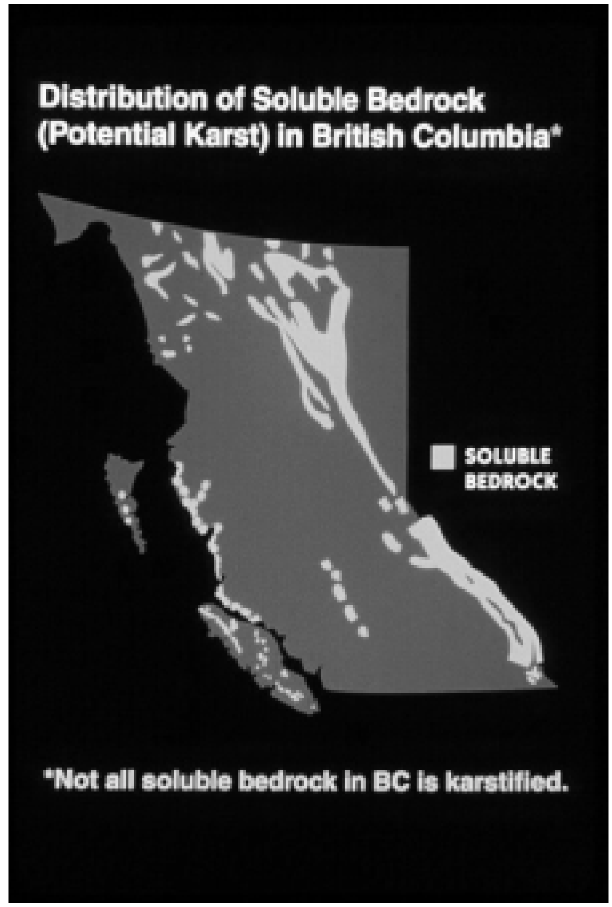
As part of this planning process, the B.C. government established the Protected Areas Strategy in July, 1993, and is committed to increasing protected areas to 12% of the provincial land base by the year 2000.

Currently, we have protected over 8.9 million hectares, (or 22 million acres) which is about 9.4 percent of the province, in the areas shown on the map here.[1] For comparison, that's a larger total area than ten Yellowstone Parks.

Land-use planning also identifies Crown or publicly owned land that is available for timber harvesting. Wherever this is the case, operational practices must meet the need for sustainability and the conservation of biodiversity. To achieve this, in June 1995 our Forest Practices Code was legislated to help protect the range of forest values. The Code consists of legislation, regulations and guidebooks, and threatens fines of up to a million dollars for non-compliance.

The preceding synopsis of our land-use planning and forest practices requirements in British Columbia indicates the complex context within which our karst environments must be managed.

So now let's look at where karst occurs in B.C., how much of it there is in the province, and what kind of features it has produced.



Slide 8: Map of karst occurrence in B.C.

B.C. has an abundance of karst environments that are as developed and interesting as anywhere in the world. Karst occurs on the west side of the province, particularly on Vancouver Island, on the Queen Charlotte Islands and along the coast, and also on the eastern side throughout the Rocky Mountains. There are also some smaller amounts in the Interior Mountain Ranges, in the Cariboo mountains, and in north-west B.C.

The Rocky Mountain karst along the Alberta border is spectacular in its own right, but it is the special relationship between karst and the temperate rain forest along B.C.'s coast that draws most attention, both locally and internationally. At least four percent of Vancouver Island's land surface is known to be underlain by karst terrain, and most of the 1500 or so caves that have been explored in B.C. to date are on Vancouver Island.

[1] By the end of 1997, these figures had changed to over 10 million hectares (or 24.7 million acres) of protected area in B.C., which is about 10.6% of the province.

Slide 9: The special relationship between karst and temperate coastal rainforest draws the most attention.

There is a larger than average proportion of privately owned land on Vancouver Island, and to the extent that this land encompasses karst there is less regulation of the resource. In addition, several environmental factors contribute to the extensive karst development on the coast.

The geology includes large areas of very pure carbonate bedrock, and abundant rain provides a steady supply of water. The topography is steep, which gives more force to the powers of erosion. Tectonic activity also helps by uplifting and tilting the limestone beds, and relatively frequent small earthquakes cause weaknesses in the rock that can then be exploited by water. The forest cover provides extensive organic matter that decomposes and increases carbon dioxide and carbonic acid levels in the soil. And a glacial history has released great quantities of water as well as remnant cobbles and pebbles to help erode the susceptible bedrock.

The resulting coastal karst in B.C. is quite special because of its unique association with the coastal temperate rainforest—the coastal western hemlock biogeoclimatic zone—in which most of the coastal karst occurs. The major tree species here are western hemlock and amabilis fir, with some western red cedar, yellow cedar and Sitka spruce. These coastal forest karst ecosystems are often characterized by large mature trees, diverse plant and animal communities, highly productive aquatic systems, well-developed sub-surface drainage, and extensive surface karst and underlying cave resources.

These conditions, where karst and temperate rainforest occur together, create cave and cavity habitat that's used by large carnivores for shelter and resting, by birds and small mammals for nesting, and by bats for roosting and hibernation. Elk and deer often bed down near cave entrances where the reasonably constant air temperatures feel relatively cool in summer, and warm in winter.

B.C.'s karst also has high archaeological and paleontological significance. The cool, temperatures, the alkaline conditions, the absence of light and the difficulty of access, often combine to allow archaeological sites to remain undisturbed, and to keep animal remains well preserved.

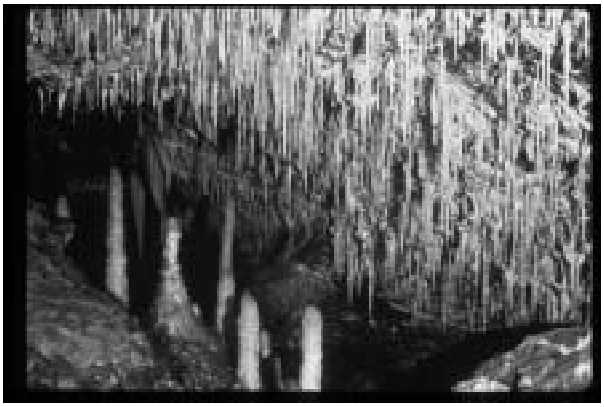
Slide 10: Karst conditions preserve animal remains well.

On northern Vancouver Island, for instance, mountain goat bones that were carbon-dated at 12,000 years old have been found in two karst caves. Mountain goats are not found on the island at all today. In other caves on Vancouver Island, 2500- to 8,000-year-old bones of the now endangered Vancouver Island marmot have been found where none live today, suggesting they once occupied a much wider, or different, range than at present.

Some of these marmot bones show cut markings that could only have been made by human tools. These are the first archaeological sites on the Northwest Coast to be found in the subalpine region, rather than in coastal lowlands.

Evidence suggests that, historically, karst played a significant role in the lives of aboriginal people. In some locations, aboriginals considered caves to be sacred as ceremonial and burial places. The productive terrain supplied large trees for aboriginals' dugout canoes and totem poles, as well as good growing sites for shrubs and herbs, and for food and medicines.

It is important to note that known archaeological sites in B.C. are legally protected under the *Heritage Conservation Act*, as are paleontological sites, which are also protected under the *Park Act* and other legislation.



Slide 11: Stalactites and stalagmites—Candlestick Cave

Today, B.C.'s unique karst features attract recreationists and cavers from around the world, particularly to the coniferous coastal temperate rainforest, since this is one of the last remaining areas in the world where examples of these conditions—at least in small areas—are still undisturbed.

Horne Lake Caves Provincial Park on Vancouver Island, for instance, now attracts over 55 000 visitors annually.

Because of increasing popular interest, B.C. is becoming better known for its extremely productive, interesting and vulnerable karst ecosystems. Since they were thousands of years in the making, they are truly a non-renewable resource. Any disruption to the delicate balance between soil, water, air, forest cover, and limestone bedrock can have far-reaching implications; industrial activities, like logging or quarrying must be properly conducted. If they are not, they can lead to excessive soil erosion, the destruction of surface and sub-surface karst features, changes in groundwater flows, and contamination, sedimentation or clogging of underground or surface streams.

Today, we recognize that when conducting forestry operations in karst-forest ecosystems, care must be taken to protect the karst values and forest productivity. We must also ensure that recreational pursuits in karst terrain are monitored, and if necessary managed or regulated, to avoid damage from overuse.

But how did we come to this realization?

In the 1960s, when small numbers of people were interested in caves on Vancouver Island and visited them for recreation on an individual basis, the wider values and ecosystem functions associated with karst were generally not well recognized.

In the early 1970s, some damage occurred to cave entrances from vandalism and sub-surface resource extraction—that is, the removal of interesting or marketable pieces of the underground environment—and conflicts over karst began to be an issue in the province, mainly in relation to caves.

In 1979 an Inter-Ministry Caves Committee was formed to co-ordinate government and public input into a provincial cave policy, and in 1980 a discussion paper entitled

Cave Resources in B.C. was published. After a protracted user dispute—during which an organized caving group was given permission to gate the Candlestick Cave on Vancouver Island against indiscriminate public use and potential vandalism—the Ministry of Forests released a management plan for the cave. This was a joint plan between the Ministry and the caving community, and it has been successful in controlling use for 17 years; MacMillan Bloedel, the local licensee, has never logged the area.

In 1981 the provincial government released its first cave policy paper, formally charging the Ministry of Forests with identifying, managing and protecting caves within provincial forests. The Ministry, drawing on work from New Mexico, developed a method of inventorying biophysical and cultural recreation features, with caves and karst resources being identified as landforms on the recreation inventory.

In 1983, the Ministry of Forests released a draft document called *A Method to Manage the Cave/Karst Resources within Provincial Forests*. This identified management processes and responsibilities for protecting karst resources. But the document was never officially adopted, and throughout the 1980s and early 1990s, impacts on karst from surface resource extraction continued to escalate.

In 1991, a cave management symposium was held in Campbell River to raise awareness and to revise the karst management document, as well as to consider revisions to legislation and policy and to develop an action plan for karst management. Symposium recommendations included long-term cave-management goals, and revisions to legislation, policy and practices.

At this time (1991) the Ministry's Recreation Manual was revised, to include:

- goals for cave environments with respect to balancing resource and recreational uses with protection,

- procedures for cave inventory and management,
- and information on rescue and safety.

At this time, too, the Ministry developed and released a management plan for the Artlish River area on Vancouver Island, in recognition of significant cave and karst values. This was successful in controlling timber harvesting, and the area is now protected.

In 1992, the ministry retained a consultant to review cave and karst legislation and policy and management issues, and to make recommendations. The study made several recommendations on legislative amendments, policy, planning, producing a handbook, and communication. While there was little immediate action on these recommendations, some of them have now been addressed through the biodiversity and soil conservation guidelines, and other aspects of the new Forest Practices Code.

Following this study, Bill 79 was passed amending the *Forest Act* to include a definition of recreation resources that included cave and karst resources. It also gave Forest District Managers powers to restrict, prohibit or attach conditions to recreation uses anywhere in the Provincial Forest, or to non-recreation uses at recreation sites.

In 1994, an overview of the karst inventory for Vancouver Island was undertaken.

In 1995, the *Forest Practices Code of British Columbia Act* was passed. The Code defines forest resources as including recreation resources that also encompass cave and karst features. The Code also formalizes the use of Resource Management Zones, Landscape Units, Sensitive Areas, and Sites and Trails as strategic planning elements, to help ensure forest resources are managed appropriately.

The passage of the Code and the requirement to manage karst resources appropriately have prompted a number of newer initiatives, outlined below.

A cave management handbook previously drafted is now being updated in a final review, and should soon be publicly available.

In addition, we have an interdisciplinary, interagency group that includes geological and karst experts from outside government, as well as representatives from the Ministry of Forests' regions, districts and Research Branch, and from BC Environment. This group is now working to develop interim karst management guidelines for B.C., which will be field tested and improved or modified as appropriate.

We also hope to develop karst inventory guidelines and standards, and undertake high priority research, but this is contingent on funding, and so far submissions to the Crown Corporation Forest Renewal BC for funding have not been successful.

When the interim management guidelines are completed, and the cave management guidebook is finalized, we expect to incorporate them into the Forest Practices Code. At that time, we plan to train foresters in their use, to ensure the guidelines are properly applied in forest planning and management.

We also plan to provide information to the public about the need for very careful management of these fragile resources. To this end we have produced a poster which we will distribute to all our regional and district offices, and an overview brochure for similar distribution.

Until the guidelines and guidebook are complete, under the general forest management context for B.C. that was outlined earlier, we do have a number of planning and regulatory tools that can help to ensure that karst and cave environments are properly assessed and considered during planning processes, either for protection or for management appropriate to their sensitivity.

Through the Protected Areas Strategy, for instance, we now have a number of areas protected on Vancouver Island specifically for karst values. These include the Artlish River as well as White Ridge, Clayoquot Plateau, and Weymer Creek karst. Together these areas make up over 50 square kilometres that are protected primarily for karst values, and in addition there are numerous other protected areas that also contain karst environments.

Cave and karst features are identified under the Forest Practices Code in the recreation feature inventory, and may also be assessed through specific cave and karst inventories.

Ministry of Forests' figures indicate that the availability of something like half a million cubic metres of harvestable timber is currently affected by karst, which indicates that the Forest Practices Code is providing opportunities for karst interests to be heard, and that there may be significant implications for local economies.

In summary then, our historical cave and karst management in B.C. may not have been exemplary, due to a former lack of awareness about the ecological significance of these environments. But we have learned a lot in recent years—thanks in part to groups such as yours. We are now moving to ensure that these resources take their rightful place in the consideration and careful management of all forest values and resources.

With that, I would like to thank you for the opportunity to address you this morning.

Salmonid Populations in the Karst Landscape of North Prince of Wales Island, Southeast Alaska

Mason D. Bryant, Ph.D., Douglas N. Swanston, Robert C. Wissmar, and Brenda E. Wright

Abstract

Karst topography is a unique and distinct landscape and its geology may have important implications for salmon productivity in streams. The relationship between salmonid communities and water chemistry and the influence of habitat were examined in a set of streams on north Prince of Wales Island, southeast Alaska. Alkalinity, pH, conductivity, and temperature were measured. Fish were counted during snorkel surveys, and habitat was identified on 500-1000 m reaches in each stream. Lengths were obtained from fish captured in minnow traps. Coho salmon (*Oncorhynchus kitsutch*) and Dolly Varden (*Salvelinus malma*) were the dominant species in all streams. Streams in karst landscapes showed higher alkalinities (1,500 - 2,300 µeq/L) than streams not influenced by karst landscapes (750 - 770 µeq/L). A significant positive relationship was observed between alkalinity and density of coho salmon parr. Backwater pools supported higher densities of coho salmon than did other habitat units. Both coho salmon fry and parr in karst-influenced streams were larger than those in non-karst streams. Although past timber harvest practices in the riparian areas of several of the stream appeared to influence stream habitat and water temperature, streams flowing through karst landscapes had a distinct water chemistry. Furthermore, these streams appeared to support more fish than non-karst streams.

[This paper was not actually presented at the Symposium because the presenters were unable to attend.]

Use of Dye Tracing and Recharge Area Delineation in Cave Protection and Conservation on Private Land

Gabrielle K. Call, Tom Aley, David L. Campbell, and John Farr

Gabrielle K. Call
Assistant Director of Stewardship
The Nature Conservancy, Tennessee Chapter
Nashville, Tennessee

Tom Aley
President and Hydrogeologist
Ozark Underground Laboratory
Protem, Missouri

David L. Campbell
Director of Science & Stewardship
The Nature Conservancy, Tennessee Chapter
Nashville, Tennessee

John Farr, GIS Technician
AEgis Services, Inc.
Clinton, Tennessee

Introduction

The Nature Conservancy has long been interested in the protection of biologically significant caves. TNC's mission to protect the lands and waters that support rare species, communities, and native biodiversity is well-suited to cave systems that contain high numbers of endemic and endangered species. A recent Defenders of Wildlife report naming caves as one of our nation's top 21 most endangered ecosystems (Noss and Peters 1995) supports the escalating need for cave and karst conservation on private land.

Since the early 1980's, TNC's Tennessee Chapter has worked with private landowners to bring the state's most biologically important and imperiled caves under some form of protection, including outright purchase as a TNC preserve and management agreements to build access barriers. These projects usually treated the caves' management problems directly at the mouth, and the popular solution was to construct a bat gate. Today, however, it is recognized that groundwater degradation and land use practices miles away from the entrance often wreak havoc on a cave and its inhabitants; to address these threats, some TNC cave projects now look beyond access control and approach cave conservation from a recharge area-wide perspective. A Tennessee example accomplished by TNC and Ozark Underground Laboratory (OUL) and funded by the U.S. Fish & Wildlife Service and the Tennessee Wildlife Resources Agency is the Herron Cave and Springs Complex project, which used dye tracing and recharge area delineation to create a comprehensive ecological site design for the Herron Cave system.

Herron Cave - A Tennessee Case Study

Herron Cave and Springs Complex (also known as Herring Cave) is located in Rutherford County, Tennessee on private land near the town of Lascassas (Figure 1). The Complex is so named because strong hydrologic interactions exist between the cave stream and two nearby water sources. The cave contains approximately 4,700 feet of passage and lies within Ridley Limestone (Wilson and Miller 1964). There is only one known entrance to Herron Cave, and a small perennial stream flows from the mouth into the adjacent cow pasture. The surrounding landscape is mostly agricultural (livestock pasture, row crops and hay fields), although residential housing developments are increasing in the area as Rutherford County's population continues to grow at a record pace—between 1980 and 1992, the county census increased by over 50% (U.S. Department of Commerce 1994). The lands within the vicinity of Herron Cave are pocked with many sinkholes, and a karst valley has formed to the east and southeast of the cave's entrance (Aley and Call 1997).

Figure 1 Project Area

TNC and other conservation interests consider Herron Cave biologically significant due to the site's suite of rare species. A small (<3,000 individuals) but consistent maternity colony of federally endangered gray bats (*Myotis grisescens,* G2G3) resides in Herron Cave during the spring and summer, and the cave stream supports Tennessee cave salamanders (*Gyrinophilus palleucus,* G2) and southern cavefish (*Typhlicthys subterraneus,* G3), both present on the State of Tennessee's rare vertebrates list (Division of Natural Heritage 1997).

Since the early 1990's, TNC has enjoyed a positive relationship with Herron Cave's owner, a long-time resident and cattle farmer of Lascassas. In 1994, TNC, the landowner, the United States Fish & Wildlife Service (USFWS), the Tennessee Division of Natural Heritage (DNH), and the Tennessee Wildlife Resources Agency (TWRA) signed a cooperative agreement allowing protection activities to occur at Herron Cave with the landowner's consent. TNC's subsequent grant award for cave conservation work, funded by USFWS and TWRA, resulted in the construction of a gray bat maternity gate in the summer of 1995.

Although the gate offered the gray bat colony further protection from disturbance, the issue of groundwater quality and its effect on Herron's aquatic vertebrates and invertebrates remained. TNC chose to undertake a dye tracing study at Herron Cave to delineate the system's recharge area, thereby expanding TNC's knowledge of which land uses in the entire Herron Cave and Springs Complex watershed were potentially degrading the cave stream. Once land uses, and consequently landowners, are identified within the recharge area, TNC may then target and prioritize protection actions such as management agreements and easements on private property.

Methods

To perform dye tracing in the Herron Cave vicinity, TNC and OUL followed methods described in Aley and Aley 1993. In March, 1996, TNC and OUL conducted field work in the vicinity of Herron Cave to identify sinkholes, sinking streams, surface streams, and springs that might supply water to Herron's cave stream. Seven dye recovery sampling stations were selected at water discharge sites within the study area, including the stream at the mouth of Herron Cave and other locations both upstream and downstream from the site.

Figure 2 Location of Sampling Stations

Sampling stations were located so that recovery of dye(s) at any station would help discern those sources contributing water to the cave stream (Figure 2). Activated carbon samplers, used to accumulate dyes and determine whether or not a dye reached a sampling station, were placed at each station by affixing two charcoal samplers to rocks or tree roots with fence wire.

Three fluorescent tracer dyes were used in this study: fluorescein, eosine, and rhodamine WT. Dye injection points such as sinkholes and crevices in losing stream segments were selected in six areas up-watershed of the cave. One-half to one pound of each dye was introduced per each of six total injections. Multiple traces were conducted to delineate the source-to-output geologic connections in the Herron Cave groundwater system.

Carbon samplers were collected from all sampling stations within seven to 14 days of a dye injection, depending upon rain events. Once removed from their anchors, samplers were stored in sterile, plastic bags labeled with station name, date, and time of collection. Collection bags were refrigerated and immediately shipped to OUL for analysis. Once arriving at OUL, samplers were washed to remove sediments and organic material and then eluted with 15 ml of standard eluting solution. After elution, the carbon was discarded, and elutant samples were drawn off with a pipette, placed in a spectrofluorometer, and analyzed for fluorescence peaks (*i.e.*, presence of tracer dye) using a synchronous scan of excitation and emission wavelengths.

Herron Cave's recharge area was delineated at OUL following the methods described in Aley and Call 1996. A polygon was mapped around the cave system that included all injection points where tracer dyes were introduced and then recovered at sampling stations in the Herron Cave and Springs Complex. All lands which are topographically tributary to any dye introduction point traced to the Herron Cave and Springs Complex were also encompassed in the recharge area.

OUL then completed a vulnerability assessment and hazard areas map following the methods detailed in Aley and Aley 1993. This assessment classified Extremely High Vulnerability, High Vulnerability, and Moderate Vulnerability lands within the Complex according to their potential for groundwater contamination.

Topographic and geologic quadrangle maps, landowner maps, aerial photograph and subterranean cave map were also collected for use in creating geographic information system (GIS) database layers on a Pentium 133 personal computer using ArcView 3.0 GIS software.

Results

Between March and October, 1996, seventeen successful dye traces were recorded, including seven total recoveries at Herron Cave's mouth and the two other sampling stations contained within the Herron Cave and Springs Complex. Based on the dye recovery results, a 1,463-acre (2.29 square mile) recharge area for the Herron Cave and Springs Complex was delineated (Figure 3). Most of this area contains primarily agricultural land and an occasional housing subdivision project and lies outside of the small topographic basin which shelters Herron Cave's entrance.

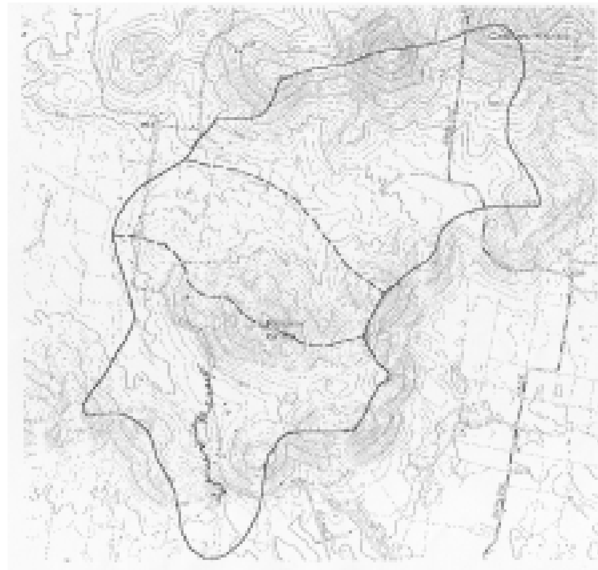


Figure 3 Recharge Area for Herron Cave/Springs Area

Six factors were identified during the vulnerability assessment that are related to the groundwater contamination potential of lands within the Herron Cave and Springs Complex:

- soil depth
- sinkholes and areas near sinkholes
- losing stream segments
- areas contributing most or all recharge water to the Complex
- areas overlying or near Herron Cave
- land use considerations such as trash dumps, agricultural activities, roads, and septic systems

By examining the locations of these factors in relation to the Herron Cave and Springs Complex, it was determined that 548 acres (37.5%) of the recharge area reside in Extremely High Vulnerability lands, 327 acres (22.3%) in High Vulnerability lands and 588 acres (40.2%) in Moderate Vulnerability lands (Figure 4). No lands within Herron's recharge area are considered of Low Vulnerability.

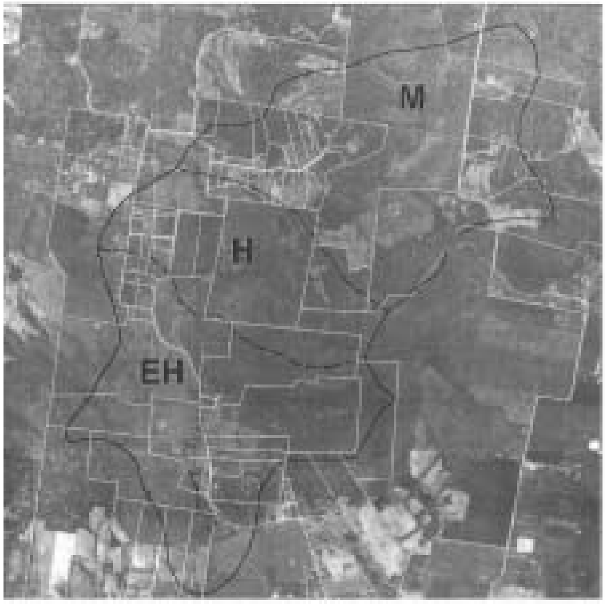


Figure 4 Vulnerability Levels

Herron Cave's recharge area polygon, vulnerability zones map, subterranean cave map, aerial photograph, topographic and geologic quadrangle maps and landowner maps were transformed into GIS databases at AEgis Services, Inc. Each database may be produced singly, or some or all layers displayed in an overlaid fashion to aid TNC in digital conservation planning and site analysis throughout the entire recharge area.

Discussion

The use of dye tracing to delineate Herron Cave's recharge area has provided TNC with a larger view of the cave's groundwater sources and has allowed for the analysis of potential threats from land uses. While the gate erected in 1995 offered protection from disturbance for the gray bat maternity colony, that management strategy ignored the water resource issues upstream that affect the overall health of the cave system, and, ultimately, its biodiversity.

Identifying landowners across the recharge area allows conservation work at Herron Cave to bridge the gap between conservation planning and local education and protection activities. The dominant sinking streams and sinkholes that transported the most dye to the cave stream are now linked to landowners and, more importantly, land uses such as cattle farming, row cropping, and home construction that would contaminate the system's groundwaters if not conducted under best management practices. The use of vulnerability zones further targets TNC's conservation actions on areas suffering the greatest impact, thereby focusing funds on the most critical tracts. Two educational programs for cub scouts and residents have already occurred to inform the local community of Herron Cave's biological assets and groundwater problems, as well as a sinkhole clean-up to begin eliminating a historic household dump from a large karst feature situated directly above the cave. Future activities in the recharge area will involve cooperative agreements between TNC and willing landowners whose land uses may be managed to decrease groundwater pollution.

TNC state chapters other than Tennessee now approach cave conservation from a watershed level rather than by simple access control as well. In West Virginia, TNC has access to dye tracing results provided by the West Virginia Association for Cave Studies, a group of spelunkers dedicated to utilizing caves for scientific study. The association's delineation of General Davis Cave's recharge area enabled TNC to write and implement a site conservation and management plan for that biologically significant system without spending limited conservation dollars on the dye tracing process. In Oklahoma, Ozark Underground Laboratory assisted the TNC chapter in a study similar to Herron Cave's by contributing recharge area information to Twin Cave's site conservation plan. Twin Cave is distinguished by TNC as having exemplary biodiversity, six rare, threatened, or endangered species and a host of aboveground threats.

Other TNC chapters across the southeastern and midwestern regions that have adopted ecosystem-level cave conservation projects include Maryland, Virginia and Missouri. In Maryland, TNC and Natural Heritage staff are working to protect Hogmaw Cave's entrance and recharge area, a system that shelters two federally endangered amphipods. Virginia's Unthanks Cave, home to several state- and federally listed species, is the focus of a major TNC protection initiative throughout the watershed. And in Missouri, a TNC project involving a significant Ozark cavefish (*Amblyopsis rosae*) cave has resulted in the watershed's delineation and pesticide screening.

Nationally to date, at least two dozen TNC state chapters have brought biologically significant caves under protection. With the use of dye tracing and recharge area delineation, these private conservation initiatives will ensure caves a more complete defense against groundwater degradation throughout the ecosystem.

Literature Cited

Aley, T. and C. Aley. 1993. Delineation and Hazard Area Mapping of Areas Contributing Water to

Significant Caves. Proc. Natl. Cave Mgmt. Symposium, 1991. pp116-122.

Aley, T. and G. K. Call. 1997. Recharge Area Delineation and Vulnerability Assessment of the Herron Cave and Springs Complex, Rutherford County, Tennessee. A contract report prepared for The Nature Conservancy, Tennessee Chapter. Nashville, Tennessee. 43p + appendices.

Division of Natural Heritage. 1997. Rare Vertebrates List. Tennessee Department of Environment and Conservation. Nashville, Tennessee. 5p + appendices.

Noss, R. F. and R. L. Peters. 1995. Endangered Ecosystems: A Status Report on America's Vanishing Habitat and Wildlife. A report for Defenders of Wildlife. Washington, D.C.

U.S. Department of Commerce, Economics and Statistics Administration, Bureau of the Census. 1994. County and City Data Book, 1994, 12th edition.

Wilson, C. W. Jr. and R. A. Miller. 1964. Geologic map and mineral resources summary of the Lascassas Quadrangles, Tennessee. Tennessee Department of Conservation, Division of Geology. Map GM 315-NE and MRS 315-NE. 5p + map.

The Distribution of Troglobitic and Troglophilic Invertebrates in Southeast Alaska

Kent R. Carlson
Karst Biosciences
1155 King St., Christiansburg, VA 24073, USA

Abstract

Six islands in southeast Alaska (Prince of Wales, Dall, Coronation, Sumez, Heceta, and Baker) were sampled for cave-associated invertebrates between 1992 and 1995. Collections from over three-hundred cave and resurgence sites yielded at least five troglobitic and forty troglophilic invertebrate species. Many of these species, such as *Onychiurus n.sp.*, *Tomocerus n.sp.*, and *Stygobromus n.sp.*, have only just been discovered. A majority of the cavernicolous invertebrates were found to be associated with specific environmental parameters or habitats. Aquatic invertebrates such as *Stygobromus*, *Rhynchelmis*, and *Polycelis* were typically found in cave or resurgence sites with temperatures less than 8.5C. Terrestrial invertebrates such as *Robustocheles* and *Onychiurus* were also commonly found in the deep cave zone on low-activity drip pool surfaces. Larger patterns of invertebrate distribution were also seen. Cavernicolous invertebrate species abundance and richness was shown to decrease in collection sites as they progressed westward from the mainland. Abundance and diversity was also shown to decrease when progressing from north to south. This trend in distribution could have been created by past glacial events and their affiliated sea level changes. Geological evidence points out that Cordilleran glaciation overrode most of the coastal islands approximately 20,000 years ago, destroying many cave ecosystems. Rising marine tides coupled with glacial recession also undoubtedly wiped out many coastal populations of “karst-locked” cavernicoles. Both mechanisms could have contributed to the extant distribution of cavernicoles in southeast Alaska. Humans have had comparatively little direct impact on the distribution of cavernicoles in southeast Alaska. Anthropogenically introduced non-native species such as the collembolan *Willowsia* and Formicid ants may prove to have long term detrimental effects on cavernicole populations, however.

Atmosphere

The area encompassing southeast Alaska is commonly referred to as the Alexander Archipelago or Terrane. Southeast Alaska is roughly defined as the United States territory in between 54° 30' and 60° 15' latitude and west of 130° longitude. It is bounded by the Yukutat territory and the Hubbard glacier to the north and Cape Muzon, Cape Chacon, and Cape Fox to the south. Prince of Wales, Dall, Sumez, Baker, Heceta, and Coronation are the southernmost islands in the Alexander Archipelago and of importance in this report (see Figure 1).

Southeast Alaska's predominately maritime climate is due to the ocean's influence. Warm eddies and drifts from the Alaska current keep winters and summers fairly mild. The temperatures are also moderated by the amount of rain and fog it receives. On average, it rains 230 days and is cloudy 270 days a year. The constant cloud cover doesn't allow the earth or water to heat for long periods of time, so temperatures stay in a fairly narrow range (30 - 80°F). The amount of precipitation can range from 60 to 200 inches of rain a year (Harris *et al.* 1974, Condon 1961). Southeast Alaska's climate has allowed approximately 700 square miles of karst topography to develop in areas of limestone composition (Baichtal 1991). These systems have been modified extensively by tectonic activity and major glaciations. Many different varieties of invertebrate communities have evolved within these cave systems.

Invertebrate Diversity

The islands in southeast Alaska have been geographically isolated from one another for millions of years (Plafker and Berg 1994). Unlike the giant wetas of New Zealand (Wells *et al.* 1984), most of the invertebrate fauna in southeast Alaska has not undergone morphologic adaptive changes to fill empty habitats. This is probably due to the chronic population bottlenecks caused by glaciation.

Dozens of major glaciations in the last twenty million years have periodically wiped most of the southeast Alaskan coastal islands clean of indigenous fauna. Few epigean invertebrates are thought to have survived this onslaught. Instead, most were probably extirpated from the islands and immigrated back after glacial ablation.

Cavernicolous or cave-adapted fauna are perhaps the only invertebrate type that could have remained *in situ* during glaciation. Cavernicolous fauna are preadapted to highly resource restrictive and extreme environments (Howarth 1983, Hüppop 1985). Stable communities of cavernicolous invertebrates have also been demonstrated

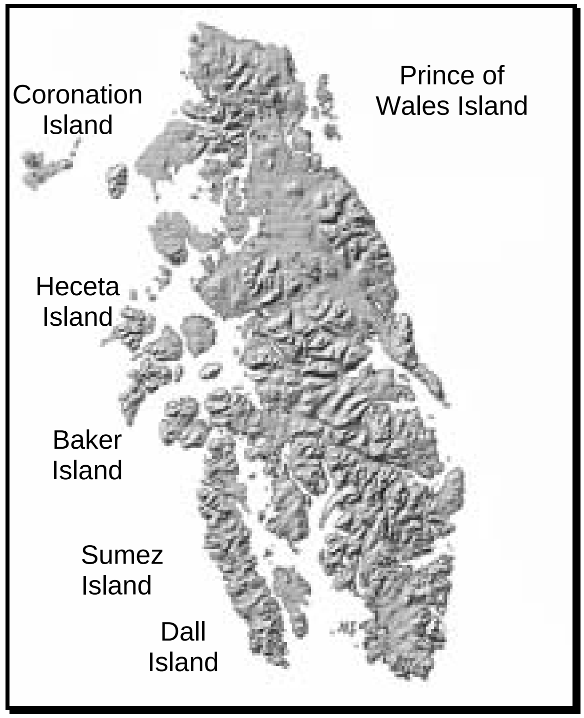


Figure 1. A Digital Elevation Map of the Southeast Alaskan Islands in the Study Area

in historically peri- or sub-glacial environments (Clifford and Bergstrom 1976, Holsinger *et al.* 1983, Holsinger and Shaw 1987, Holsinger *et al.* 1997, Campbell and Peck 1990). Surviving populations of cavernicoles probably re-radiated out from their refugia to repopulate the coastal islands after glacial recession.

The mechanism for achieving the current invertebrate distribution is not known, regardless of cavernicolous invertebrate potential to survive glaciation. The goal of this report is to provide evidence for these potential mechanisms of distribution.

Methods

Karst associated invertebrates were collected and identified from six islands in the Alexander Archipelago (see Figure 1). Abundance, the number of individuals within a species, and Richness, the number of different species, was recorded for terrestrial (*Rhagidiidae*, *Enchytraeidae*, *Opiliones*, *Tomocerus*, *Hypogastrura*, *Paranura*, *Isotoma*, *Neelus*, *Onychiurus*, *Arrhopalites*, *Dicyrtoma*, *Tricampa*, *Micropsectra*, *Parametriocnemus*, and *Bolitophila*) and aquatic (*Crangonyx richmondensis*, *Stygobromus n.sp. A*, *Stygobromus quatsinensis*, *Rhynchelmis*, *Planorbidae*, *Candona*, and *Polycelis borealis*) invertebrates with strong associations for the cave environment. These two diversity estimates were plotted against collection site locations. Data points organized east-to-west and north-to-south were then subject to linear and polynomial (X^6) regression in order to create easily interpretable trend lines.

Terrestrial Cavernicole Richness and Abundance, East-West Trends

Both measures of terrestrial diversity, abundance and richness, showed numeric decreases as collection sites progressed from east to west (see Figure 2). Species abundance decreased from 20 to 9, a loss of approximately 0.11 invertebrates per species per kilometer (55%). Species richness decreased from 3 to 1.7, a loss of approximately 0.013 species per kilometer (43%).

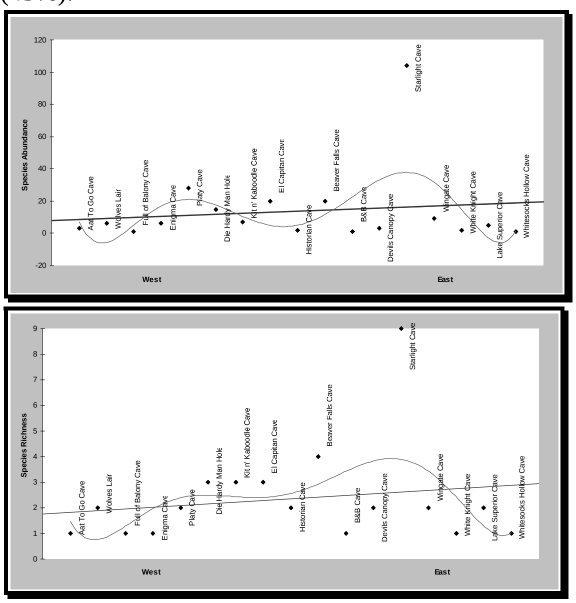


Figure 2. Terrestrial Species Abundance (upper) and Richness (lower) in Cave Locations Arranged East to West

Terrestrial Cavernicole Richness and Abundance, North-South Trends

Terrestrial species abundance and richness also decreased as the collection sites went from north to south (see Figure 3**).** Species abundance decreased from 26 to 1, a loss of approximately 0.15 species per kilometer (96%). Species richness decreased from 3.5 to 1.3, a loss of approximately 0.013 species per kilometer (63%).

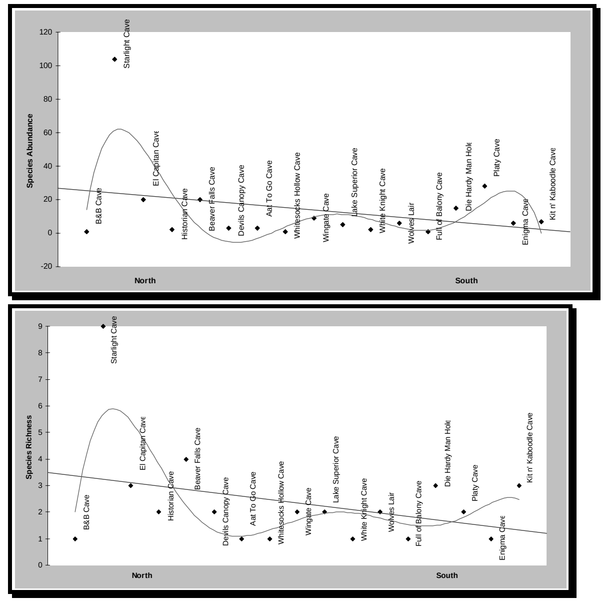


Figure 3. Terrestrial Species Abundance (upper) and Richness (lower) in Cave Locations Arranged North to South

Aquatic Cavernicole Richness and Abundance, East-West Trends

Aquatic invertebrate abundance and richness decreased as collection sites progressed from east to west (see Figure 4). Species abundance decreased from 18 to 8, a loss of approximately 0.1 species per kilometer (55%). Species richness decreased from 2.8 to 1.7, a loss of approximately 0.011 species per kilometer (39%).

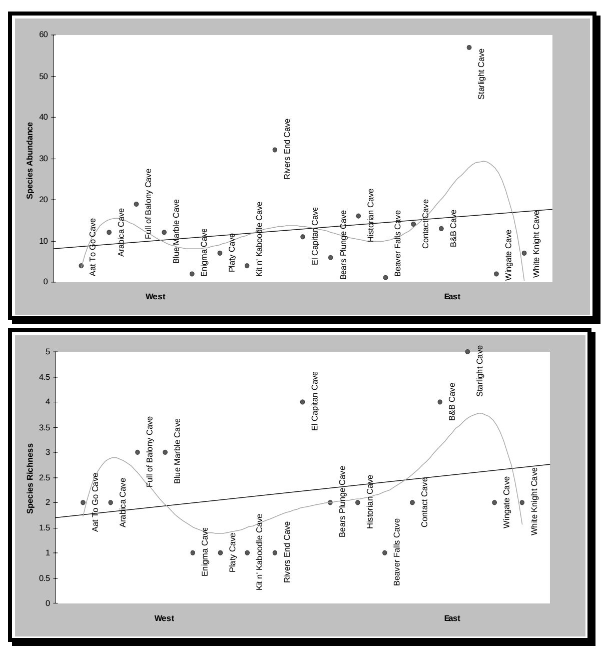


Figure 4. Aquatic Species Abundance (upper) and Richness (lower) in Cave Locations Arranged East to West

Aquatic Cavernicole Richness and Abundance, North-South Trends

Aquatic abundance and diversity decreased in a north to south trend (see Figure 5). Species abundance decreased from 23 to 2, a loss of approximately 0.12 species per kilometer (91%). Species richness decreased from 3.5 to 1, a loss of approximately 0.015 species per kilometer (72%).

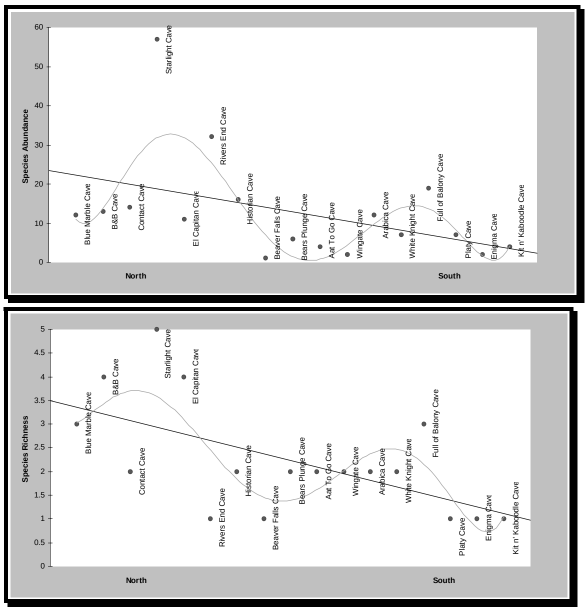


Figure 5. Aquatic Species Abundance (upper) and Richness (lower) in Cave Locations Arranged North to South

Invertebrate Micro-Distribution

Many of the troglophilic and troglobitic invertebrates of southeast Alaska have been shown to “prefer” particular habitats or environmental conditions (Carlson 1994, 1996, 1997). Aquatic cavernicoles such as *Stygobromus quatsinensis*, *Stygobromus n.sp. A*, *Polycelis borealis*, and *Rhynchelmis* have been significantly associated with 37.4-46.4°F freshwater cave or resurgence streams and pools. Other terrestrial cavernicoles such as *Robustocheles occulta*, *Onychiurus*, *Arrhopalites hirtus*, *Arrhopalites diversus*, and *Paranura colorata* have been significantly associated with entrance and deep cave drip pool or organic debris.

Invertebrate Macro-Distribution

As mentioned above, the current mechanism for cavernicole distribution is not known. Four distinct origins for these southeast Alaskan cave communities can be postulated: (a) The communities originated from invertebrates present on or within the glacial ice, (b) The communities originated from invertebrates that survived glaciation in ice-free or subglacial refugia, (c) The communities originated from invertebrates that migrated from unglaciated refugia back to exposed deglaciating areas, and (d) The communities originated from a combination of refugia and immigrational species.

Four years of cave and karst invertebrate collections in southeast Alaska indicates that glacial fauna probably did not remain behind after glacial recession. No species with glaciological associations have been collected in any of southeast Alaska’s karst areas. It is probable that indigenous glacial fauna migrated with ablating ice sheets back to the perennial glaciers in the Coast Mountains. Some glacier-associated invertebrate species such as the ice worm *Mesenchytraeus solifugus* are found on or within those coastal glaciers today (Bowers 1992).

An increasing amount of evidence is being uncovered that supports the possibility of invertebrate survival in refugial ice-free or subglacial southeast Alaskan habitats. In 1995, a tiny new species of troglobitic amphipod, *Stygobromus n.sp. A*, was collected in two cave sites historically covered with glacial ice (Holsinger *et al.* 1997). Collection of another troglobitic amphipod, *Stygobromus quatsinensis*, also indicates possible glaciological effects on distribution. This species has only been found on the outer islands of southeast Alaska (Dall, Coronation, Heceta, Baker, Sumez) and Vancouver island in British Columbia, areas that would have experienced decreased glaciation during the last ice age. These two occurrences support the hypothesis that cavernicoles could possibly have survived glaciation *in situ*. Re-radiation into new habitats probably occurred following glacial recession.

Other trends in invertebrate distribution can also give an idea of how the cavernicole communities became established. By observing the diversity of species over distance, one can determine the direction of migration. In southeast Alaska, invertebrate migration from the inner to the outer islands would present as a decrease in richness as one went from east to west. This is because fewer and fewer species would be able to pass migrational barriers such as mountains and open water as they moved westward. In addition, westward populations that did establish themselves would lag behind eastern populations in habitat colonization and expansion. This effect would manifest itself as a east to west decrease in abundance.

Results from trendline data support the above arguments. Terrestrial species abundance decreased from east-to-west and north-to-south by 0.11 and 0.15 species per kilometer, respectively. Aquatic species abundance decreased in the same directions by 0.1 and 0.12 species per kilometer, respectively. The same trend was seen with richness data. Terrestrial species richness decreased from east-to-west and north-to-south by 0.013 and 0.013 species per kilometer, respectively. Aquatic species richness decreased in the same directions by 0.011 and 0.015 species per kilometer, respectively.

The east-to-west decrease in richness and abundance indicated that most or all of the cavernicole populations analysed in this study were probably distributed due to re-immigrative mechanisms.

The north-to-south decrease in terrestrial and aquatic cavernicole abundance and richness is most easily explained as an artifact of the sample site locations. In this study most of the outer islands were also the southernmost islands. Since these islands had a decreased east-to-west abundance and richness, this would also be displayed as a decrease in north-to-south abundance and richness. The data, however, could also reflect the possibility that re-population of the outer islands happened in a north-to-south moving trend. This possibility has yet to be explored.

Overall evidence from discrete collection locations and general distributions have revealed that both re-radiative and re-immigrative mechanisms are probably involved in current cavernicole distribution. As more information is revealed about specific invertebrate species, a better picture of how the islands evolved biotically will undoubtedly be generated.

Acknowledgments

I would like to thank Kevin and Carlene Allred, Jim Baichtal, Peter Branson, Dee Casey, Bill Elliott, Mark Fritzke, Dave Heron, Rob Knotts, Marcel LaPerierre, Zack LaPerierre, Steve Lewis, Dave Love, Karen Marks, Amy Russell, Pete Smith, Mark Sowa, and Suzanne West for their help in collecting invertebrates. I would also like to thank Dr. Kenneth A. Christiansen, Dr. Robert Hershler, Dr. Richard Hoffman, Dr. John R. Holsinger, Dr. Masaharu Kawakatsu, Dr. Ken Stewart, and Dr. Miloslav Zacharda for identifying select specimens from those collections.

References

Baichtal, J.F. 1991. Management of the Karst Areas Within the Ketchikan Area of the Tongass National Forest, Southeastern Alaska. The Alaskan Caver. 11(6):10-21.

Bowers, H. 1992. Alaska's Ice Worms. The Alaskan Caver. 12(3):21.

Campbell, J.M. and S.B. Peck. 1990. *Omalonomus relictus*, an Unusual New Genus and New Species (*Coleoptera*: *Staphylinidae*, *Omaliinae*) of Blind Rove Beetle; A Preglacial (Tertiary?) Relict in the Cypress Hills, Alberta-Saskatchewan, Canada. The Canadian Entomologist. 122:949-961.

Carlson, K.R. 1994. Inventory and Assessment of Ecological Relationships Between Cavernicolous (Cave-Associated) Invertebrate Species and Their Interactions in Representative Karst Ecosystems on Carbonate Terrain in the Ketchikan Area National Forest: Part I. Dall Island. Karst Biosciences. Christiansburg, Virginia. 60pp.

Carlson, K.R. 1996. Inventory and Assessment of Ecological Relationships Between Cavernicolous (Cave-Associated) Invertebrate Species and Their Interactions in Representative Karst Ecosystems on Carbonate Terrain in the Ketchikan Area National Forest: Part II. Coronation Island. Karst Biosciences. Christiansburg, Virginia. 93pp.

Carlson, K.R. 1997. Invertebrate Habitat Complexity in Southeast Alaskan Karst Ecosystems. 1997 Cave and Karst Symposium, Bellingham, Washington. Karst Biosciences. Christiansburg, Virginia. 8pp.

Clifford, H.F. and G. Bergstrom. 1976. The Blind Aquatic Isopod *Salmasellus* From a Cave Spring of the Rocky Mountains' Eastern Slope, with Comments on a Wisconsin Refugium. Canadian Journal of Zoology. 54:2028-2032.

Condon, W.H. 1961. Mineral Resources of Alaska: Geology of the Craig Quadrangle Alaska. Geological Survey Bulletin. 1108-B:B1-B43.

Harris, A.S., Hutchison, O.K., Meehan, W.R., Swanston, D.N., Helmers, A.E., Hendee, J.C., and T.M. Collins. 1974. The Forest Ecosystem in Southeast Alaska : 1. The Setting. Pacific Northwest Forest and Range Experiment Station, U.S. Department of Agriculture, Forest Service. USDA Forest Service General Technical Report PNW-12. 40pp.

Holsinger, J.R., Mort, J.S., and A.D. Recklies. 1983. The Subterranean Crustacean Fauna of Castleguard Cave, Columbia Icefields, Alberta Canada, and its Zoogeographic Significance. Arctic and Alpine Research. 15(4): 543-549.

Holsinger, J.R. and D.P. Shaw. 1987. *Stygobromus quatsinensis*, a new Amphipod Crustacean (Crangonyctidae) From Caves on Vancouver Island, British Columbia, with Remarks on Zoogeographic

Relationships. Canadian Journal of Zoology. 65:2202-2209.

Holsinger, J.R., Carlson, K.R., and D.P. Shaw. 1997. Biogeographic Significance of Recently Discovered Amphipod Crustaceans (*Stygobromus*) in Caves of Southeastern Alaska and Vancouver Island. Proceedings of the 12th International Congress of Speleology, La Chaux-de Fonds, Switzerland. 3:347-349.

Howarth, F.G. 1983. Ecology of Cave Arthropods. Annual Review of Entomology. 28:365-389.

Hüppop, K. 1985. The Role of Metabolism in the Evolution of Cave Animals. NSS Bulletin. 47(2):136-146.

Plafker, G. and H.C. Berg. 1994. Overview of the Geology and Tectonic Evolution of Alaska. In Plafker, G. and H.C. Berg (ed). The Geology of North America. Volume G-1, The Geology of Alaska. The Geological Society of America. 989-1021.

Wells, S.M., Pyle, R.M., and N.M. Collins. 1984. The IUCN Invertebrate Red Data Book. IUCN, Gland, Switzerland. 632pp.

Invertebrate Habitat Complexity in Southeast Alaskan Karst Ecosystems

Kent R. Carlson
Karst Biosciences
1155 King St., Christiansburg, VA 24073, USA

Abstract

Starlight Cave is a model karst system for studying invertebrate interactions in complex cave habitats. It represents a small fraction of a larger karst ecosystem that includes areas around Sinkhole Lake, Thunder Falls Cave, Whispering Canyon Cave, and Carcass Cave in the north-central region of Prince of Wales Island. Starlight Cave has at least two distinct hydrologic zones, both of which are interconnected in various underground locales. The uppermost aqueous habitat has colder water (3.5-5C / June 1995) with low flow rates. Ironically, the lowermost level of the cave has warmer streams (14-15C / June 1995) with high flow rates. These streams are thought to originate from epigean habitats around Sinkhole Lake. A variety of stenothermal troglophilic and troglobitic aquatic invertebrates occupy the colder upper level waters. Fauna present in the lower level streams probably wash in from the margins of Sinkhole Lake. At least one species of aquatic invertebrate from the upper level pools (*Stygobromus n.sp. A*) has only recently been discovered. Starlight also has a complex terrestrial invertebrate distribution. This is primarily due to numerous karst windows and collapse pits. These openings predispose upper level subterranean habitats to invasion from epigean invertebrates. Terrestrial epigean invertebrates also wash into the lower regions of the cave on stream and flood debris. This results in a heterogeneous mix of epigean and hypogean invertebrates in most terrestrial habitats. Starlight Cave is one of the most extensively studied cave ecosystems in southeast Alaska. Further investigations into other cave systems will undoubtedly reveal increasingly more complex networks of habitats and invertebrates.

Southeast Alaska's Starlight Cave System

Southeast Alaska's temperate climate and abundant rain have created ideal conditions for the development of karst topography. The inclement weather has produced a regional limestone dissolution rate four to eight times greater than most areas in the contiguous United States (Aley et al. 1993). This has led to the development of an extraordinary number of caves and karst features in approximately 700 square miles of carbonate rock (Baichtal 1991). The Starlight Cave system is one such cave and karst feature.

The Starlight Cave system was one of the initial karst features discovered on Prince of Wales Island. Serendipitously, it was also one of the more developed subterranean areas in southeast Alaska. Starlight is characterized by immense collapse pits and pirated surface streams (see Figure 1). It has also been shown to be of phreatic origin and developed along a northwest to southeast trending fault (Allred 1992). Collapse pits expose a significant amount of the system to environmental and biological conditions present on the surface. Pirated surface streams also disturb the homogeneity and atmospheric stability of the system. Surface water input drags allochthonous material into the cave and thermally and ionically influences lower level aqueous passages on a seasonal basis. Descriptions of the system have been printed in a series of technical and cave trip reports by Kevin (1988, 1992) and Carlene Allred

(1988, 1992).

Starlight Cave was first explored and documented in 1988 by Kevin and Carlene Allred. Thick forest and minimal manpower delayed the discovery of the upstream components of the system, Whispering Canyon and Thunder Falls Cave until 1992. Currently, Whispering Canyon and Thunder Falls Cave have been linked together via traversable passage. Starlight Cave, however, has only been linked to Whispering Canyon and Thunder Falls Cave via thermal hydrologic profiles (see Environmental Parameters).

Fluorescein dye has been used to determine the water flow of the Starlight Cave system. In one study, it was injected into the Thunder Falls Cave stream in order to reveal potential resurgence locations. Dye traces subsequently showed up in the 108 Creek resurgence, 4800 linear feet away, twenty-four days after initiation (Aley *et al.* 1993). Water samples were not taken from Starlight Cave's lower level stream passage during this study, however, so dye confirmation of the systems hydrologic connections was not achieved.

Overall, the Starlight Cave system has a variety of distinct habitat types, each with its associated invertebrate community. Terrestrial and aquatic organisms share three general habitat designations, epigean (surface), entrance (or resurgence and insurgence), and the deep cave. Sinkhole Lake's influence makes the inclusion of a secondary aquatic deep cave habitat necessary. This is because the environmental parameters in areas affected by Sinkhole Lake's insurgent water are appreciably different than those present in other aquatic habitats in the system (see Environmental Parameters).

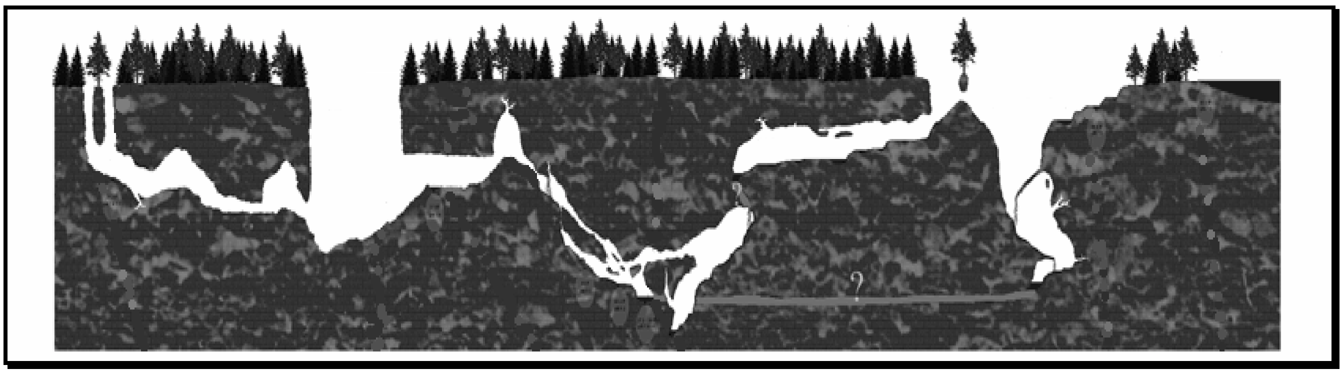


Figure 1. Starlight (S), Whispering Canyon (WC), and Thunder Falls (TF) Caves

Data Collection

Invertebrates present in epigean, entrance, resurgence, and deep cave environments were collected during the summer months from 1992 to 1995. All of the invertebrates were catalogued and identified. The identification data was then combined for all habitats to yield invertebrate composition charts for each environment. Temperature and pH readings were also taken at select aquatic habitats during the summer of 1995.

Environmental Parameters

Temperature and pH readings were documented for many of the aquatic habitats associated with the Starlight Cave system. This was done in order to assess the potential environmental influences of insurgent water.

Insurgent waters with large amounts of decomposing organic debris (muskegs and Sinkhole Lake) were found to be more acidic (pH 7.6-7.7) than water in cave drip pools (pH 7.9-8.1), cave streams derived from the water table (pH 8.2), and cave streams derived from distant epigean sources (7.9-8.0). An increased level of acidity in these waters is probably from the combination of rainwater and the bacterial metabolism of carbon-based detritus. It is very probable that the surrounding carbonate rock is already buffering these surface waters to some extent, since other muskeg runoff streams in southeast Alaska have been shown to have pHs as low as 2 (Aley *et al.* 1993).

The decreased pH in insurgence waters is important for the Starlight Cave system's structural development. Free hydrogen ions in low pH waters can combine with bicarbonate ions to produce carbonic acid. Carbon dioxide in the atmosphere also combines with water to produce carbonic acid. The carbonic acid can then dissolve calcium carbonates in the surrounding limestone and bring them into solution as bicarbonate ions, resulting in an increase in limestone conduit diameter and cave growth (Cole 1983, Palmer 1991).

The pH difference is probably not of biological significance. Most aquatic organisms function normally in waters with pHs ranging from 6.5-8.5 (Rand 1995). Cave-adapted organisms may require a narrower pH range than epigean ones, however. Details for this speculation have not been published at this time.

Streams originating from Sinkhole Lake underwent a decline in temperature as the sample areas progressed from the lake (63.5°F) to the Thunder Falls insurgence (60.8°F) and then to deep cave sites in Starlight Cave (57.2-59°F). This temperature decrease was due to passage through limestone channels that stay at or near the ground's ambient temperature of 40 to 45°F. Cave streams and pools that originated from groundwater release had much lower temperatures with less variation (37.9-41°F) than those from Sinkhole Lake. These lower temperatures were important for the maintenance of a distinct set of stenothermal cavernicolous organisms.

Water resources in the Starlight Cave system show a distinct separation into two different ecotypes; those originating from Sinkhole Lake, and those originating from ground water reserves. These physical parameters were found to greatly influence the invertebrate compositions in both habitat types.

Invertebrate Distribution

Invertebrates can be partitioned into discrete habitats according to their specific environmental needs. The invertebrates within each habitat type usually have similar life history characteristics as well. For example, most deep cave species have comparatively extended life spans, longer generation times, slower growth rates, poorer colonizing abilities, fewer trophic levels, lower species richness, and higher distributional patchiness when compared to epigean relatives. This discrete partitioning allows one to classify certain invertebrate communities by habitat type (Carlson 1991).

Invertebrates from a variety of families were collected and identified in order to create an total composition list (see Appendix A) for eight different habitat types in the Starlight Cave system. These habitats and their respective invertebrates are presented below.

Aquatic Epigean Habitat

Sinkhole Lake's aquatic epigean habitat is the most structurally diverse aquatic habitat in this report. It has a food-resource rich organic matter substrate, moderately warm temperatures (63.5°F), a comparatively acidic pH (7.6-7.7), and a low flow rate. The biotic diversity at this site is high and is comparable to that found in the lower level aquatic cave habitat.

Most of the organisms present at this site have general feeding strategies. Specifically, the site has filter feeders (*Musculium*, *Megadrili*), detrital collectors (*Paraleptophlebia*, *Chironomidae*, *Krenopelopia*), and predator-scavengers such as *Hyalella*, *Crangonyx*, and *Zoniagrion* (see Figure 2). The filter feeding clams and worms, along with the larval mayfly and fly collectors, serve as the base of the food web in this habitat. Amphipod and damselfly larvae undoubtedly scavenge or prey upon these species when encountered.

Crangonyx has been collected in other epigean and cave habitats on Prince of Wales island. It is the only species in this group with any morphological adaptations towards cave life, such as functionally reduced eye structure and a lack of pigmentation.

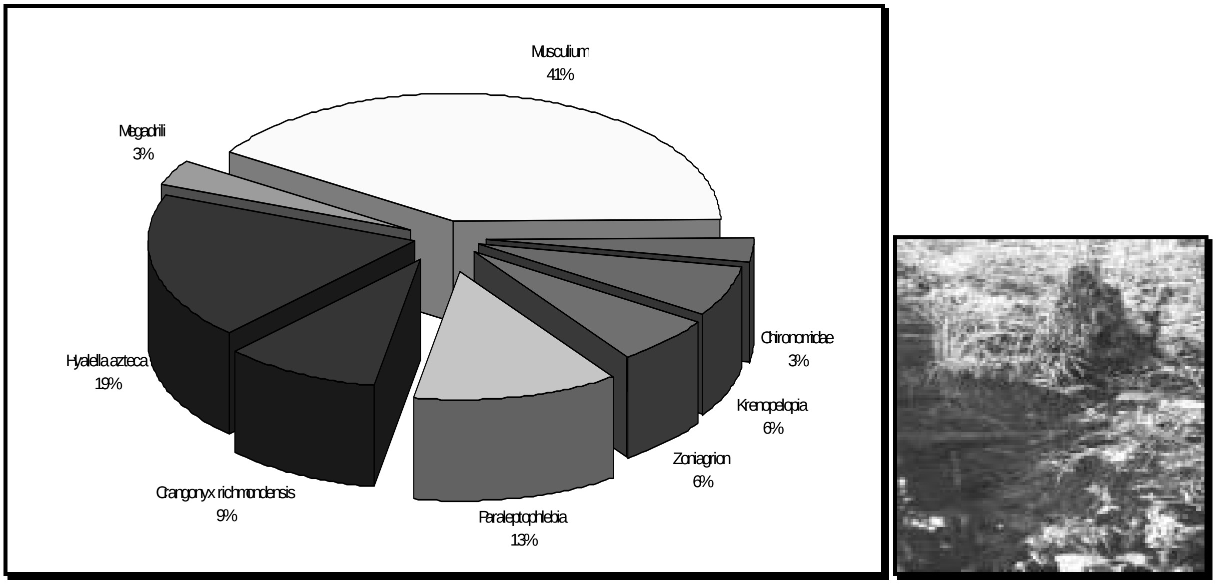


Figure 2. Invertebrate Composition Chart and Photograph of the Aquatic Epigean Habitat

Aquatic Insurgence Habitat

It is rare for a source stream to differ biotically from its insurgence point to any great extent This is the case with the insurgence from Thunder Falls Cave, however. The insurgence stream has narrowed and become channeled into a limestone canyon, increasing the flow rate dramatically. The substrate has also changed from organic to gravel-and-block and the light level has decreased to approximately half of that in the epigean site. The amount of organic debris has decreased by at least 90%, the pH has increased 7.9, and the biotic diversity has also decreased. Only the temperature (60.8°F) has remained fairly near that of the aquatic epigean site. This is probably due to the proximity of both sites.

Substrate attachment is the major factor that determines the species composition in this habitat. Most of the invertebrates found here excel at clinging or attaching to the bottom (*Wormaldia*, *Rhyacophila*, *Zapada*, and *Simulium*) or live within the substrate itself (*Enchytraeidae*, *Candona*). The overwhelming majority of the species at this site are collectors and filterers of bacteria and organic debris. *Rhyacophila*, a trichopteran, is the only predator at this site. Its negligible abundance means that it probably has limited effect on any of the other species at the bottom of the food web (see Figure 3).

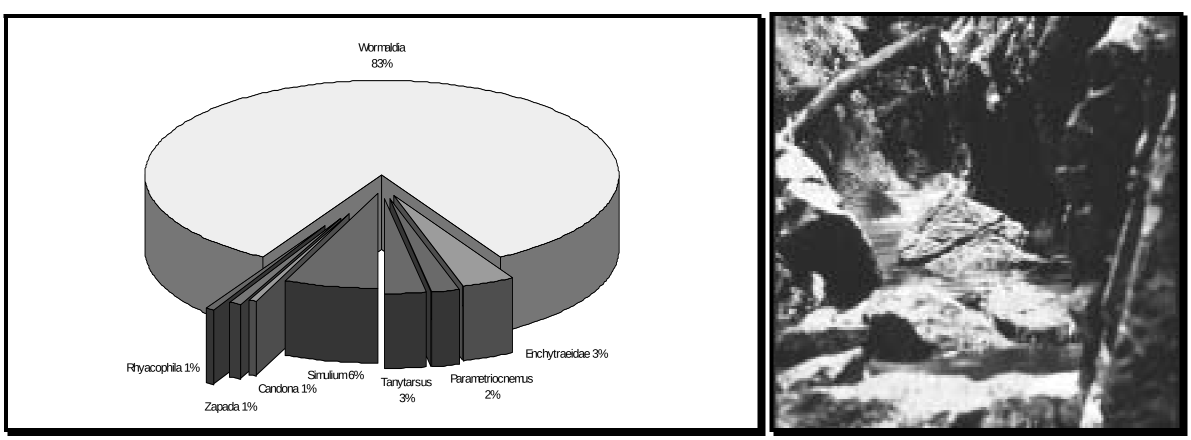


Figure 3. Invertebrate Composition Chart and Photograph of the Aquatic Insurgence Habitat

Aquatic Lower Level Cave Habitat

This habitat is atypical for a southeast Alaskan aquatic cave habitat in that it has increased water temperature (57.2-59°F) and increased biotic diversity. Other characteristics, however, such as a complete lack of light, a moderate flow rate, low amounts of organic matter, a gravel-sand-mud substrate, and pH (7.9-8.0), are typical aquatic cave parameters.

Wormaldia is still of primary abundance at this site (see Figure 4). The decrease in its percent composition probably reflects the fact that the collected organisms have washed into a habitat unsuitable for maintaining the large populations seen in insurgence environments. The drastically reduced occurrence of the clam *Musculium* at this site also supports this speculation. Approximately 73% of the invertebrates present at this site are filterers, collectors, or scrapers. None of these species have any cave adaptations, so they probably have an ephemeral existence which is dependent on washed in food resources, inter- and intraspecific competition, and predation. The composition chart shows that these lower level invertebrates support a healthy population of predatory *Gammarus* amphipods. Although these amphipods have no cave adaptations either, a constant supply of washed in weakened and damaged prey items probably sustain their population levels.

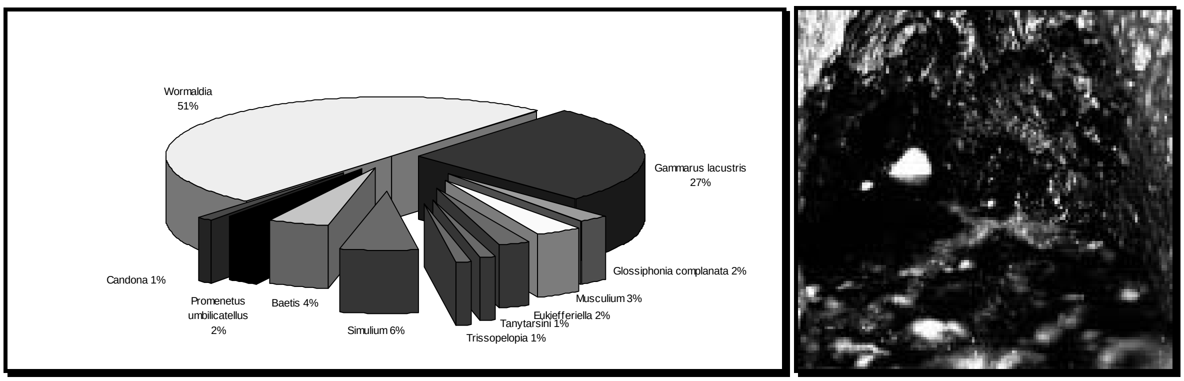


Figure 4. Invertebrate Composition Chart and Photograph of the Aquatic Lower Level Cave Habitat

Aquatic Resurgence Habitat

The resurgence for water flowing through the Starlight Cave karst system is located approximately 4800 linear feet from its insurgence point at Thunder Falls Cave (Aley *et al.* 1993). It has a moderate flow rate, mossy-gravel-block substrate, moderate amounts of organic debris, tannic coloration, a pH of 7.6, temperature of 45.5°F, and an extremely reduced biotic diversity. Downflow portions of the resurgence stream inexplicably display the same biotic and abiotic characters. The tannic coloration, acidic pH, and increased temperature of the resurgence water indicate that there are insurgences other than the Thunder Falls insurgence that contribute to its flow. This is because these characteristics were not observed in any of the other aquatic sites originating from the stream at Sinkhole Lake. In addition, if the water was only from subterranean sources the pH would be much higher (8-8.2) due to carbonate buffering and the temperature lower (around 38-40°F).

After many attempts, only one invertebrate species, an Enchytraeid worm, was collected at the resurgence site (see Figure 5). This reduction in species diversity and abundance could be linked to the large extent of pre-resurgence underground passage and its poor food resource state. Invertebrates washed into the system would find it increasingly difficult to find food as they drifted farther from the insurgence into the karst system. The journey from insurgence to resurgence could easily starve any invertebrate to death since it took a freely mobile fluorescein dye a staggering 24 days to make the trip. It is difficult to explain why there was no colonization of the resurgence by upstream migration of mobile aquatic invertebrates. Stream sections below the resurgence were equally reduced in fauna when sampled. This indicates that there might be a potential problem (tannins, dissolved toxins) with the resurgence water itself.

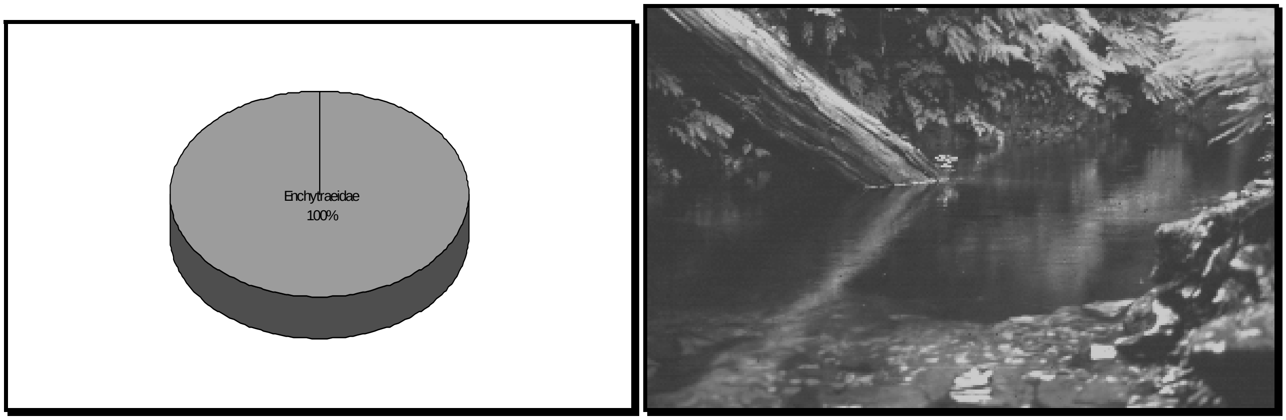


Figure 5. Invertebrate Composition Chart and Photograph of the Aquatic Resurgence Habitat

Aquatic Upper Level Cave Habitat

This habitat is the only "true" aquatic cave habitat yet discussed. It has a low flow rate, low amounts of organic matter, a mud-limestone substrate, absolute darkness, a temperature profile resembling that of the ambient ground temperature (37.9-41°F), pHs that are more indicative of carbonate buffering (7.9-8.2), and a reduced biotic diversity that is compositionally very different from habitats associated with Sinkhole Lake.

Most of the invertebrates collected in this environment are true cavernicoles and not washed in epigean varieties. *Candona*, a ubiquitous burrowing ostracod is the most numerous invertebrate at this site (see Figure 6). This may be due to a general reduction in other species' abundances or an actual preference for aquatic cave habitats. In the epigean and insurgence habitats, *Candona* comprised 1% of the total community abundance. *Rhynchelmis*, a proboscid worm, also had increased abundances at this site. *Rhynchelmis* and *Candona* form the base of the food chain for this habitat. *Stygobromus n.sp. A*, a newly discovered troglobitic amphipod (Holsinger *et al.* 1997), is also in great abundance in these pools. *Stygobromus*, the larval beetle *Hydaticus*, and the flatworm *Polycelis*, are the primary predator-scavengers found in the upper level cave pools. Comparatively, this habitat has a greater proportion of predators than any other in the Starlight Cave system.

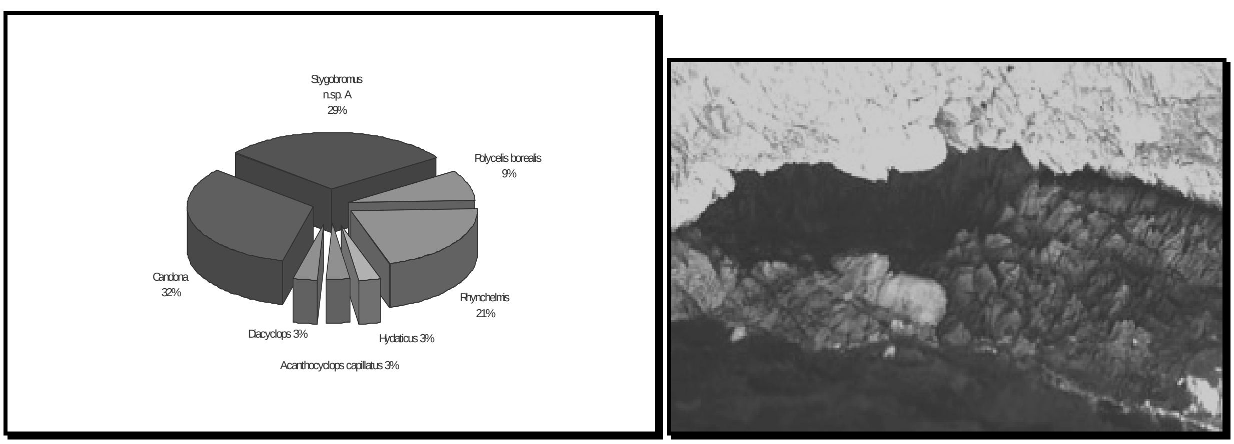


Figure 6. Invertebrate Composition Chart and Photograph of the Aquatic Upper Level Cave Habitat

Terrestrial Epigean Habitat

The terrestrial epigean habitat displays the greatest environmental variation of all the habitat types. Seasonal fluctuations in temperature, precipitation, wind, and organic matter substrates determine the location of many of its indigenous invertebrates. In addition, epigean environments typically exhibit the most diversity and abundance of organisms.

An immense variety of invertebrates colonize terrestrial epigean environments. As shown below (see Figure 7), collembolans (*Tomocerus* to *Dicyrtoma*) are the most abundant species in this habitat. Mites (*Orbatida* and *Rhagidiidae*), Spiders (*Araneae* and *Opiliones*), and Flies (diptera) follow substantially behind in percent of total community abundance. Detritivores such as the collembolans and flies constitute the bulk of the habitats community (approximately 85%). Predatory species such as the spiders, some mites, ants, beetles, and pseudoscorpions, make up the remainder.

Many invertebrate types found in terrestrial epigean environment are seemingly adapted for cave life as well. These species have modifications that are useful in the aphotic, humidified, regions of deep organic matter deposits. Flooding undoubtedly carries some of these species and their organic matter habitats into the cave system. This deposition creates a biotically heterogeneous terrestrial cave environment. Washed in species do not have a large effect on most cave habitat invertebrate compositions, however, since these organisms are quickly selected against by the cave's harsh environmental conditions.

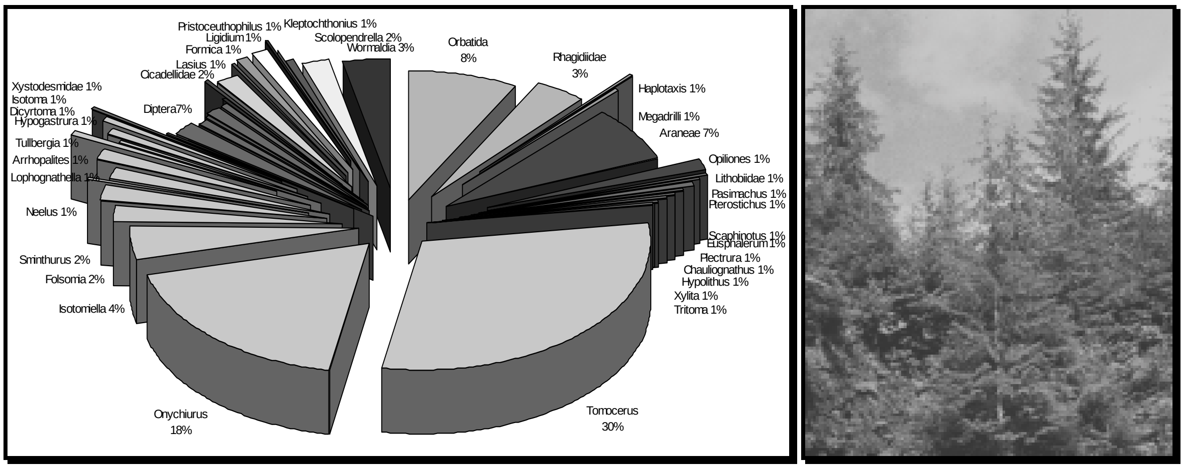


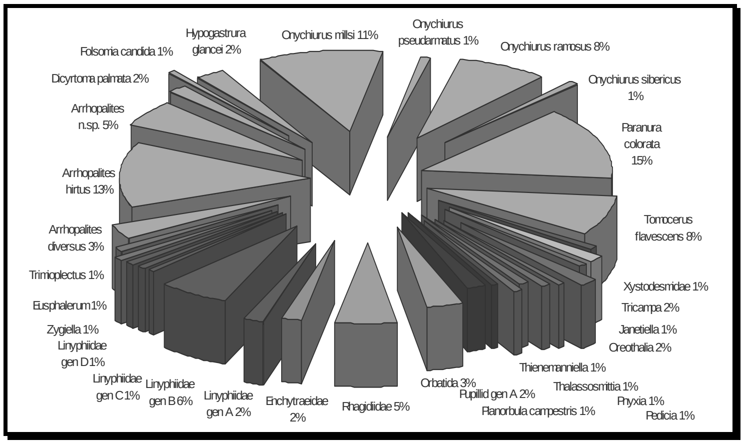
Figure 7. Invertebrate Composition Chart and Photograph of the Terrestrial Epigean Habitat

Terrestrial Entrance Habitat

Terrestrial entrance habitats typically have environmental parameters that are a little less harsh or abrupt than epigean ones. Entrance habitats represent a transitional gradient between epigean and hypogean (cave) environments. They are dependent on features present in both of these environments for development of their own character. Epigean invertebrates moderately adapted for cave life and hypogean invertebrates moderately adapted for surface life mingle in entrance areas and create an entrance-unique community structure.

Entrance environments also have features specific to themselves. Since they function as a funnel for water into the karst environment, they can be affected to a greater extent during periods of flood. In some circumstances they also have been known to possess their own entrance specific invertebrate species.

The invertebrates present in the entrance of Starlight Cave are primarily a subset of epigean species (see Figure 8). Many of the epigean species of primary abundance such as *Tomocerus*, *Onychiurus*, *Rhagidiidae*, and *Orbatidae* are represented in the entrance as well, although their percent compositions are different. The percent of species in entrance trophic levels are also similar to those in epigean habitats. Detritovores and other primary prey species represent approximately 82% of the total community abundance. This is very close to the epigean communities primary prey composition of 85% of the total community abundance. It appears that the trophic "game" is staying the same as epigean environments, but the "players" are changing.



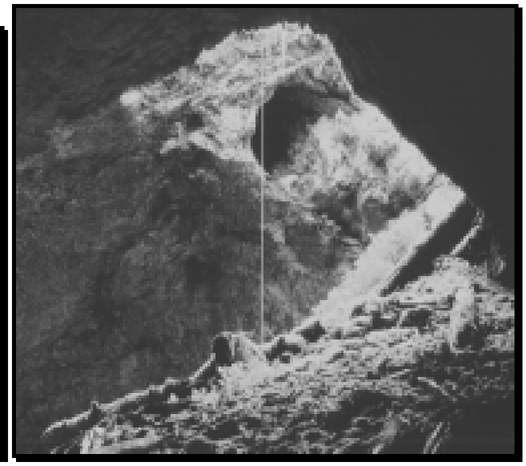


Figure 8. Invertebrate Composition Chart and Photograph of the Terrestrial Entrance Habitat

Terrestrial Cave Habitat

The terrestrial cave habitat is the most resource restrictive environment in the Starlight cave system. This cave habitats has perennial darkness, cold temperatures (40-45°F), patchy food resources dependent on depositional mechanisms, and varied substrates. Biotic diversity is also very low in deep cave habitats and is usually centered around food resource rich areas (see Figure 9).

Collembolans (*Arrhopalites*, *Hypogastrura*, and *Paranura*) are the most populous family in these deep cave environments. Collembolans and Orbatid mites are prey items for the predatory Rhagidiid mites, which seem to have the same percent composition in all habitat types. All species found in the cave environment are also found in the entrance areas, but at different percent compositions. This indicates that the trophic structure has changed when going from entrance to cave habitats.

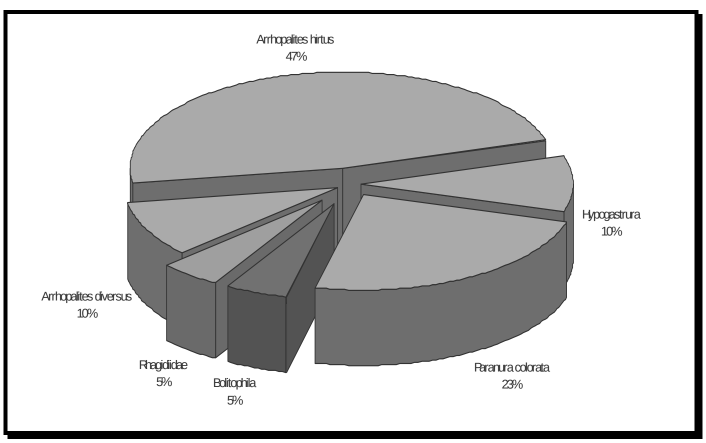


Figure 9. Invertebrate Composition Chart and Photograph of the Terrestrial Cave Habitat

Appendix A. Specimen List for Aquatic (Insurgence, Cave, and Resurgence) and Terrestrial (Entrance and Cave) Environments

Acari	
	Orbatida
	Rhagidiidae
Amphipoda	
	Crangonyx richmondensis
	Gammarus lacustris
	Hyalella azteca
	Stygobromus n.sp. A
Annelida	
	Enchytraeidae
	Glossiphonia complanata
	Megadrili
	Polycelis borealis
	Rhynchelmis
Araneae	
	Linyphiidae gen A
	Linyphiidae gen B
	Linyphiidae gen C
	Linyphiidae gen D
	Zygiella
Bivalvia	
	Musculium
Coleoptera	
	Eusphalerum
	Hydaticus
	Trimioplectus
Collembola	
	Arrhopalites diversus
	Arrhopalites hirtus
	Arrhopalites n.sp.
	Dicytoma palmata
	Folsomia candida
	Hypogastrura
	Hypogastrura glancei
	Onychiurus millsi
	Onychiurus pseudarmatus
	Onychiurus ramosus
	Onychiurus sibericus
	Paranura colorata
	Tomocerus flavescens

Copepoda	
	Acanthocyclops capillatus
	Diacyclops
Diplopoda	
	Xystodesmidae
Diplura	
	Tricampa
Diptera	
	Bolitophila
	Chironomidae
	Eukiefferiella
	Janetiella
	Krenopelopia
	Oreothalia
	Parametriocnemus
	Pedicia
	Pnyxia
	Tanytarsini
	Tanytarsus
	Thalassosmittia
	Thienemanniella
	Trissopelopia
	Simulium
Ephemeroptera	
	Baetis
Gastropoda	
	Planorbula campestris
	Promenetus umbilicatellus
	Pupillid gen A
Odonata	
	Zoniagrion
Ostracoda	
	Candona
Plecoptera	
	Paraleptophlebia
	Zapada
Trichoptera	
	Rhyacophila
	Wormaldia

Acknowledgments

I would like to thank Kevin and Carlene Allred for their help in collecting invertebrates and Dr. Kenneth A. Christiansen, Dr. Robert Hershler, Dr. Richard Hoffman, Dr. John R. Holsinger, Dr. Masaharu Kawakatsu, Dr. Ken Stewart, and Dr. Miloslav Zacharda for their help in identifying select specimens from the collections. Finally, I would like to thank Dr. Lorraine Landis and Dr. Richard Carlson for reviewing the manuscript.

References

Aley, T., Aley, C., Elliott, W.R., and P.W. Huntoon. 1993. Karst and Cave Resource Significance Assessment: Ketchikan Area, Tongass National Forest, Alaska. Ozark Underground Laboratory. Protem, Mo. pp.1-79.

Allred, C. 1988. Starlight Cave and El Capitan Cave Trip Report. The Alaskan Caver. 8(6):3-6.

Allred, C. 1992. Thunder Falls Cave and Whispering Canyon Cave. The Alaskan Caver. 13(5):16-18.

Allred, K. 1988. Starlight Cave: Technical Preliminary Report #5. U.S. Forest Service in-house report.

Craig, Alaska. pp.1-3.

Allred, K. 1992. Starlight Cave: Preliminary Report #110: Addendum to Report #5. U.S. Forest Service in-house report. Craig, Alaska. pp.1.

Baichtal, J.F. 1991. Management of the Karst Areas Within the Ketchikan Area of the Tongass National Forest, Southeastern Alaska. The Alaskan Caver. 11(6):10-21.

Carlson, K. 1991. The Effects of Cave Visitation on Terrestrial Cave Arthropods. Proceedings of the National Cave Management Symposium, Bowling Green, Kentucky. American Cave Conservation Association, Inc., Horse Cave, Kentucky. pp.338-345.

Cole, G.A. 1983. Textbook of Limnology: Third Edition. The C.V. Mosby Company, St. Louis, Mo. pp. 258-272.

Holsinger, J.R., Carlson, K.R., and D.P. Shaw. 1997. Biogeographic Significance of Recently Discovered Amphipod Crustaceans (*Stygobromus*) in Caves of Southeastern Alaska and Vancouver Island. 12th International Congress of Speleology, La Chaux-de Fonds, Switzerland. 3:347-349.

Palmer, A.N. 1991. Origin and Morphology of Limestone Caves. Geological Society of America Bulletin. 103:1-21.

Rand, G.M. (ed.) 1995. Fundamentals of Aquatic Toxicology: Effects, Environmental Fate, and Risk Assessment: Second Edition. Taylor and Francis, Washington, D.C. pp.71-98.

Impacts on invertebrate cave fauna in forested karst ecosystems and recommended protection measures in forested karst areas of Tasmania

Arthur Clarke
Department of Zoology, University of Tasmania, Sandy Bay, Tasmania 7005, AUSTRALIA

ABSTRACT

The living area for invertebrate fauna in the aquatic and terrestrial habitats of karst can be described as "karst bio-space" which can be considered in areal terms as micro-caverns (<1mm), meso-caverns (1mm to 15-20mm) and macro-caverns, including caves (>1.5-2.0cm). In many karsts, including the solutional karst of carbonate rocks, the meso-caverns probably represent the major habitat space component for invertebrate cavernicoles in the karst bio-space. There are about 300 carbonate rock areas in Tasmania (Australia), but the total karst area is probably only around 5% (3,150 sq. kilometres) of total land area, of which probably less than 60% is forested. Several other karst areas of Tasmania lie downstream from actively logged karst catchments. In many of these forested karst areas, ground-breaking activity associated with timber plantations and timber harvesting has had a significant impact on karst processes impacting on cavernicolous invertebrates, particular aquatic species which live in the meso-caverns and macro-caverns of the saturated epikarst and endokarst and flooded (phreatic) regions. Protection measures for the invertebrate fauna of forested karst ecosystems in Tasmania generally fall into one of seven categories: cave invertebrate species protection, habitat protection (including caves, karst surface environments, adjoining lands and catchments), recommended amendments to the Forest Practices Code of Tasmania, changes in land tenure in some forested karst areas (including recommendations for reservation of some karst areas in government owned land and landcare programmes on private land), habitat restoration and enhanced breeding programmes, mechanisms to increase public awareness of the uniqueness and fragility of cave ecosystems and recommendations for further research and study to assist in broadening the knowledge base of cavernicolous faunas in Tasmania and in particular to promote the conservation and management of cave fauna.

Foreword

The following paper represents a summary of recent findings in relation to the invertebrate cave fauna of forested karst in 50 carbonate rock areas of Tasmania (see Figure 1). The findings are based on a recent report (Clarke 1997a) detailing the impacts to invertebrate cave fauna and management prescriptions for the protection of cave fauna in specific karst areas in Tasmanian forest (Figure 1).

Introduction

Centered around a latitude of approximately 43 degrees South, Tasmania is the island state of Australia, approximately 150km south of the Australian mainland. It is well endowed with karst and there are reportedly over 4,000 caves (pers. comm., I. Houshold, 1996) in over 300 separate areas of carbonate rock (Kiernan 1995), some of which are not karstified. Although many of these karst areas are quite small, the total karst area in Tasmania probably represents approximately 5% of the land surface of 68,332 sq. kilometres. In northern and northwestern Tasmania, some karst lies beneath improved pastureland; in western and southwestern Tasmania there is a considerable area of karst underneath buttongrass sedgeland. The area of forested karst in Tasmania is probably about 1800 square kilometres, representing less than 60 percent of the total karst area. A rough calculation would suggest that only about 25-30% of this forested karst lies in reserved areas such as National Parks and World Heritage Areas.

This paper includes a synopsis of the major impacts of forestry activity on karst surfaces and karst catchments and the impacts to caves from cave visitors, together with some of the consequential effects on cave fauna from both surface (forestry) and underground (caving) activities. Included are some of the recommendations from Clarke (1997a) and Eberhard and Hamilton-Smith (1995) for protection of cavernicolous invertebrates, with particular emphasis on protection requirements in the significantly karstified areas of carbonate rock in Tasmania: in areas with recorded karst bio-space (Clarke 1997b; 1997c).

Karst bio-space is represented as the sum-total of the actual or potential habitats and micro-habitats of all living species in karst (Clarke 1997a; 1997b; 1997c). This bio-space can be described in dimensional terms as micro-caverns (<1mm), meso-caverns (1 to 15-20mm) and macro-caverns (>1.5-2.0cm) (Clarke, 1997b; 1997c; pers. comm., Hamilton-Smith, 1997). In many karsts including the solutional karst of carbonate rocks, the meso-caverns probably represent the major habitat space component for invertebrate cavernicoles in the karst bio-space. Most of the carbonate rock karsts of Tasmania occur in forested karst areas or lie downstream from karst catchments, many of which are being actively logged. In logging areas, ground-breaking activity associated with timber plantations and timber harvesting has had a significant impact on karst processes impacting on cavernicolous invertebrates, particular aquatic species which live in the meso-caverns and macro-caverns of the saturated epikarst and endokarst and flooded (phreatic) regions.

The ground breaking impacts of forestry activity on karst and cave fauna

Forest practices commonly include road making and snigging tracks; quarrying of stone for road emplacement, fill for low-lying areas or as road gravels; timber harvesting, clearing, windrowing and burning plus the development and maintenance of plantations. Most of these forestry practices will lead to significant impacts on cavernicolous faunas, particularly direct effects on aquatic invertebrates and indirect effects on terrestrial species either in karst areas underneath forest activity or karst downstream from catchments that are being worked. The cave fauna of karst bio-space will be directly impacted by surfaces disturbances in karst (Clarke 1997b; 1997c), particularly ground breaking activity and the destruction of surface litter or mulch by forestry practices including fire (Holland 1994).

Soil mantles on carbonate rock are generally thin, clayey residual soils (Gillieson 1996; Jennings 1985; Kiernan 1988; 1990) with even thinner mantles where limestone purity is higher (Lewis 1996). The soils over carbonate rock in karst areas have been likened to being on a sieve, because surface waters that drain into the immediate underlying epikarst (see below) can carry soil particles and grits directly into the karst hydrologic system (Lewis 1996). Solutional karst processes may also be impeded by blockages in solution-widened cracks or fissures in the bedrock due to mobilisation of clays and grits from disturbed soil profiles. In instances where karst slopes have been reduced to bare rock surfaces due to soil loss from logging and burning, trees are not likely to grow again until the litter and moss base has become re-established, a process which could take several centuries to occur. In areas previously covered by glacial tills, e.g. on the now steep bare rock slopes of logged and burnt limestone surfaces on Vancouver Island in Canada, the forest may not return until "….the next glaciers have deposited a new layer of till..." (Harding & Ford 1993).

Ground breaking activity in karst catchments usually leads to an increase of sediment influx into streams and forest removal or changed vegetation regimes in the catchment which lead to altered stream flow conditions. Flooding in stream caves often occurs as a result of the increased water yield following forest removal.

Aquatic cavernicoles in hypogean (underground) habitats of karst areas will be threatened by the same impacts that affect aquatic species in epigean (surface) habitats. The effects on cave faunas will be more marked because of the limited mobility of some species to avoid impacts (e.g. the minute hydrobiid gastropods) or the narrow habitat range due to restricted hydrological system limits imposed by the individual subterranean karst, together with the naturally low nutrient input levels.

Terrestrial cavernicoles in hypogean habitats of karst areas will be directly and indirectly impacted by effects on aquatic species and alterations to stream hydrology which promote sediment deposition, affect moisture input levels or interfere with natural air current movements. Terrestrial cave faunas will also be directly impacted by disturbances to the epigean karst surface which will modify bio-space humidities due to reduced percolation flow or introduce toxic pollutants (including sedimentation) and similarly modify other natural meteorological conditions related to air volumes and air flow (Clarke 1997a; 1997b).

A number of caves and karst areas in Tasmania have been degraded by land surface disturbance in upstream catchments. Turbid floodwaters have been observed emerging from cave effluxes in the Gunns Plains karst in northern Tasmania and in the Weld River karst of southern Tasmania. Both these karsts are situated downstream from logging operations in forested catchments. Some of the stream caves in the Gunns Plains karst area contain very few aquatic species and during a recent visit in late December 1996, the writer noted that the terrestrial species component of cave communities in these sites at Gunns Plains appear to be mainly limited to epigean accidental species and trogloxenes. Similar impacts have been reported in sections of the Mole Creek karst as a result of poor management in forested areas, particularly on private landholdings (Kiernan 1984; 1989). In the Ida Bay karst of southern Tasmania, limestone quarrying has impacted on two cave systems which have related hydrological drainage during periods of high recharge: Exit Cave and Bradley-Chesterman Cave (Clarke 1989b; 1991b; Houshold 1995; Kiernan 1993).

Protection measures for invertebrate cave fauna in Tasmania

The following recommendations are based on the recent papers and findings of bio-speleologists in Australia (Clarke 1989b; 1997a; Eberhard and Hamilton-Smith 1995; Hamilton-Smith and Eberhard, in press, 1997). The recommended protection measures (and their sub-sections) listed in this paper, generally fall into one of seven categories: cave invertebrate species protection, habitat protection (including caves, karst surface environments, adjoining lands and catchments), recommended amendments to the Forest Practices Code (FPC) of Tasmania (Forestry Commission 1993), changes in land tenure in some forested karst areas (including recommendations for reservation of some karst areas in Crown land and landcare programmes on private land), habitat restoration and enhanced breeding programmes, mechanisms to increase public awareness of the uniqueness and fragility of cave ecosystems and recommendations for further research and study to assist in broadening the knowledge base of cavernicolous faunas in Tasmania and in particular to promote the conservation and management of cave fauna.

Eberhard and Hamilton-Smith (1995) suggest that cave invertebrate species may be protected by consideration for listing as endangered ecological communities under the auspices of the Commonwealth's Endangered Species Protection Act 1992 or by legislative protection of cave species by adding additional cave invertebrates to the list of rare and threatened species (following IUCN Red Data Book Codes applied at a State Level) under the Threatened Species Protection Act, 1995 (Eberhard and Spate 1995). In Tasmania, further cave invertebrates should be included in the "Threatened Fauna Manual for Production Forests in Tasmania" (Jackson and Taylor 1995). Collection of described cave species should be discouraged by promoting the publication of cave fauna collection records and new species descriptions in speleological journals or elsewhere in the public domain (Clarke 1997a).

Habitat protection of caves with known fauna: (a) A register of all known caves with cave fauna should be prepared to assist in planning purposes forest-based activity or other permitted activities in forested karst areas. (b) Specific within-cave micro-habitats and exclusion zones should be defined to protect fauna in some caves of forested karst areas, perhaps by gating or limiting access. All such protective measures should be undertaken in consultation with biospeleologists or relevant local speleological organisations.

Habitat protection of karst areas: No forestry activity (roading, quarrying, plantation development or logging) or other surface disturbance (especially ground breaking activity) should be permitted in forests which contain the significantly karstified areas, e.g. those karst areas in Tasmania defined by Kiernan (1995) as "Category A" karsts, known or believed to contain a significant karst bio-space. Influencing the activity of land managers in private forest lands remain a particular problem. Pollutants such as petroleum products (oils and lubricants), herbicides (or pesticides) and fertilisers should be absolutely avoided on the surface of karst area in Tasmanian forests. The use of fire is not an acceptable management tool in (forested) karst areas. All fires, whether as cool fires or hot fires during regeneration burns, ground fuel reduction burns or perimeter hazard burns will affect cavernicolous invertebrates which are reliant on natural karst process and input of natural organic material from surface systems.

Habitat protection of karst catchments: Roading in karst catchments of Crown lands and private lands should strictly follow strict guideline, such as those in the Tasmanian FPC (Forestry Commission 1993) and be constructed in such a manner that avoids sediment input to streamways. Where possible roads in karst catchments should follow ridgelines; if not on ridgelines, roads should run parallel to and at least 100 metres distant from major watercourses and incorporate sufficient sized drainage channels and sediment traps or settling pits to prevent sediment-laden waters reaching watercourses. If sediment overload is likely to be a problem, filtering mechanisms (such as tea-tree brush or pea-straw bales) should be deployed. Karst catchments should only be partially logged in any given season and logging coupe sizes should be minimal to minimise runoff and altered flow regimes in streams draining into karst areas which are known or likely to contain cave fauna communities.

A detailed submission has been presented to the Regional Forest Agreement process in Tasmania by Clarke (1997a) which includes a substantial number of recommended amendments to the Forest Practices Code (FPC), particularly in relation to management of karst catchments. These include the revision of the FPC to prevent further forestry activity in karsts known or likely to contain cave faunas, recognition of dolines and sinkholes as potential water catchment sources (for subterranean drainage) and their inclusion in the FPC as catchment draining watercourses. (Following the completion of logging operations which involve deforestation, many intermittent surface watercourses or otherwise dry channels become active watercourses during rainfall periods and similarly, some dolines become sinkholes and some sinkholes become significant swallets.) Other recommended amendments to the Tasmanian FPC include changing management and work practices in karst catchments, such as widening the forestry activity and logging buffers in riparian zones of karst catchment streams, altering logging methods to suit the slope angle, surface geology and vegetation type and restricting use of fertilisers or herbicides etc. in plantation forests. Specific recommendations are also made in relation to plantation forests including preferred planting of native species and avoidance of fast-growing introduced or exotic species with higher evapo-transpiration rates, such as *Pinus radiata* or *Eucalyptus nitens*, both of which effectively alter surface ecology and stream flow levels (Clarke 1997a).

Protection of cave fauna by changes in land tenure, including reservation of karst areas by reservation of government owned (Crown) land to protect karst bio-space and its cave communities. Applicable Tasmanian karst areas with high conservation significance include the "High Sensitivity Zones" in the Junee-Florentine karst of southern Tasmania (Eberhard, 1994; 1996) which could be protected by an extension of the Mt. Field National Park boundary; cave fauna communities in the Mount Cripps karst area in central-northwestern Tasmania (Clarke 1997a); cave fauna communities in the Mole Creek karst area of northern Tasmania, outside the present Mole Creek Karst National Park (Kiernan 1984; 1989); fauna in the caves of karst outliers beyond the Hastings Caves State Reserve (Clarke 1997a) and cave fauna communities in the unprotected North Lune karst of southern Tasmania (Clarke 1990).

Conservation management of cave communities in private forest presents a more difficult proposition, but can be achieved to some extent by the adoption of regional planning schemes, Landcare programmes and conservation covenants (Dyring 1995). Some of these proposals may be practical to assist in the conservation of cave communities occurring in forested karst areas in Permian limestone karst of the Gray and Mount Elephant areas on the east coast of Tasmania (which includes some areas in State Forest). Cave fauna communities in Ordovician limestone karsts at Gunns Plains and Loongana in northwestern Tasmania should be recognised and protected as far as possible. Most of these areas are either in privately owned agricultural or forestry land (including additional areas at Mole Creek) or under threat due to unfortunate forest practices that are occurring in their catchments. Smaller areas which support threatened cave species, are often in pseudokarst sites located on private land. Some of these sites are only known by one or two species, sometimes equally rare and threatened as karst area species and the pseudokarst species should be recognised and protected as far as possible. Public awareness and education is probably the only means of protecting these sites, including advice to the landowner.

Preparing detailed studies of the habitats of rare and threatened species as an adjunct to cave management plans including a detailed study of the currently vulnerable or endangered species, such as the blind cave beetle *Goedetrechus mendumae* to ascertain population numbers, habitat requirements and true conservation status as part of the Exit Cave Management Plan. Additional specific studies of other rare and threatened species, including a study to search for recorded species not sighted since 1910 (Clarke 1997a; 1997c) or similar studies of specific cave communities to determine appropriate management of caves or karst areas in other parts of Tasmania, particularly in the forested karst areas.

Other recommendations for protection of cave fauna include: (a) rehabilitation or restoration of cave or karst catchments; (b) habitat restoration in caves and micro-habitat protection as an aid to enhanced breeding; (c) increasing public awareness and promoting more education on the uniqueness and fragility of cave ecosystems (Clarke 1997c).

Rehabilitation and habitat restoration in karst areas and karst catchments

Gillieson (1996) suggests that the rehabilitation and restoration of caves is best achieved by remedial activities related to the karst surface. Fundamental to the process is the restoration of the normal hydrological system. Amongst the other key elements recommended by Gillieson are control of any active erosion, ensuring there is a stable vegetation cover and getting the soil biology working, then establishing a monitoring programme above ground and below in the cave itself (Gillieson 1996).

Cave communities, species diversity and population densities have been impacted in both Exit Cave and Bradley-Chesterman Cave as a result of flocculent clays mobilised from the disturbed terra rossa surface soils and exposure of palaeokarst deposits (Clarke 1989a; 1989b; 1991a; 1991b; 1997c; Eberhard 1990a; 1992a; 1992b; 1993; Gillieson 1996; Houshold 1992; Houshold & Spate 1990). The severity of impact is more marked in Bradley-Chesterman Cave where other accidental contaminants including petroleum products have entered the stream system. Following closure of the limestone quarry, a restorative programme has been underway to rehabilitate the quarry site and ensure that all drainage points only permit the input or recharge of flocculent free waters into the karst aquifer (Clarke 1991b; Gillieson 1996; Houshold 1995). This has been achieved by using a number of natural organic filtering devices including fibrous bark of the Brown-topped Stringybark (*Eucalyptus obliqua*), Leptospermum and Melaleuca tea-tree brush with seed capsules plus hay bales or pea-straw. There has been a marked improvement in the water quality of Eastern Passage of Exit Cave and some improvement in Bradley-Chesterman Cave (Eberhard 1995), though the depth of silt still remains a problem and may take hundreds of years to be flushed out. However, during recent inspections in 1995 and 1996, it was noted that epigean (surface) species are beginning to re-colonise Bradley-Chesterman Cave (Clarke, in press 1997) and their presence may assist the return of surviving cave fauna species forced to migrate into karst biospace beyond the cave space during original impact from quarry runoff.

Another example of cave fauna protection by restoration of cave and karst catchments is demonstrated by the sustainable landcare management initiatives adopted by the Waitomo Catchment Trust Board to protect Waitomo Glowworm Cave and other stream caves of the Waitomo Catchment in New Zealand (Martin 1996). In 1992, the Waikato Regional Council embarked on a comprehensive conservation policy designed to protect the soil and water resources in the Waitomo River catchment. This included protection schemes for existing native forest, gradual retirement or afforestation of steep slopes, particularly where erosion was already apparent, establishment of temporary sediment dams, pole planting on active eroding slopes to prevent further downward slide of sediment and retirement of riparian stream margins with establishment of suitably wide buffer zones where no ground-breaking surface disturbance occurs (Martin 1996).

Rehabilitation methods such as those described in previous paragraphs may be able to be applied to other forested areas to prevent runoff from unmade roads or snigging tracks entering catchment streams that drain into karst areas or caves. Similarly, these techniques or similar methods could be used to assist all forest land managers including private landowners ensure that exposed or disturbed sediment is not washed into dolines. Forest land managers should be encouraged to strictly follow the Forest Practices Code in relation to karst catchments and re-vegetate exposed land surfaces to ensure that future forestry or other forest-based activities do not permit sediment influx into streams that drain into karst.

Habitat restoration in caves

Habitat restoration in caves is described by Gillieson (1996) as requiring a long time scale to achieve satisfactory results. Habitat restoration is already occurring in some caves in forested areas of Tasmania where “no-go” areas have been defined by taping off areas in so-called “substrate protection zones” e.g. in caves of the Mole Creek karst: Kubla Khan (MC-001), Little Trimmer (MC-039) (Eberhard & Hamilton-Smith in press 1997) and in My Cave (MC-141). This course of habitat restoration is only useful if all the cave visitors have good intentions and don’t overstep the line to get their good photo shots! Management plans for caves can assist the process, but once again unless the cave fauna are locked in (or the cave visitors are locked out), the process is reliant on voluntary compliance by the cave visitors (Hamilton-Smith & Eberhard, in press 1997) being prepared to do the right thing. Habitat restoration is also being conducted at Exit Cave in southern Tasmania, following closure and rehabilitation of Benders (limestone) Quarry which was generating sediment input and probably dilute concentrations of sulphuric acid into cave waters (Houshold 1995).

The impact on cave fauna by cave visitors

Cave visitors can impact on the biological attributes of caves in various ways: by both deliberate or accidental means. In late December 1996, the writer found a deliberately baited “fishing line” in Gunns Plains Tourist Cave; a piece of hay-bale twine tied around a piece of meat had been placed in the cave stream where the large Tasmanian freshwater crayfish: *Astacopsis gouldi* was known to frequent. Cave visitors have also been known to light fires in caves for warmth, apart from the more inadvertent acts of littering with food scraps, confectionery (“lollie”) wrappers including small pieces of sharp-edged foil and “accidental” leaving behind of clothing lint, plus the more deliberate discard of plastic wrappers or food containers, used torch batteries, spent carbide or human wastes.

Cave visitors need to be more informed about the environment they are passing through and be aware that the habitat niches for terrestrial or aquatic species in caves are numerous and variable, as well as often being fragile and easily destroyed. It is highly probable that many cave invertebrates have perished as a result of cavers inadvertently walking on a species or compacting the loose and friable sediment in which the species once lived (Gillieson 1996). Faunal habitats may include the substrate that cavers walk over with boots, the muddy-floored passages they crawl through on their hands and knees, the cave walls they brush against with overalls or the streamways they wade through with gumboots. Even the small impact of a boot-sized imprint on a moist sandy slope or gravelly streambank could be impacting on a habitat that supports a small range of species, possibly impacting on part of a food chain within the wider cave ecosystem. Repetition of foot traffic in certain areas, such as over-use of soft sediment banks or clay-banks as pathways, can lead to collapse of these features or development of erosion gullies, both of which potentially affect cave species habitats. Cave visitors may be requested to walk in cave streams to avoid these unconsolidated or fragile sediment banks and potential erosion gullies; but in fact the stream beds may be equally or more important as habitat niches for aquatic species such as hydrobiid gastropods, anaspidean syncarids, crangonyctoid amphipods or even the aquatic larvae of adult insects.

Some cave communities in forested karst areas of Tasmania maybe under threat due to visitor access by cavers which has been inadvertently assisted by virtue of the roading emplaced by Forestry Tasmania or its predecessor. Hence, it may be appropriate that some means for dialogue be established between the Tasmanian Forest Practices Unit and the Tasmanian Parks and Wildlife Service with the speleological fraternity to discuss the possible installation of road barriers or gates on cave entrances to limit access to sensitive sites. Similarly, further management plans may need to be addressed by Forestry Tasmania for caves in State Forest or other forested areas.

Micro-habitat protection as an aid to enhanced breeding

Many of the macroinvertebrates in caves, especially the troglobites, are likely to be “low-breeding species” easily affected by environmental change (P. Greenslade, pers. comm.). Disturbances to karst surface environments such as mechanical ground-breaking activity, vegetation modification and other ecological interference above caves can lead to a drying out of the normally humid bio-space (Clarke 1997b) which may unnaturally stress or desiccate cave invertebrates. Similarly, surface activity in the karst catchment can affect both the water quality of streams and stream ecology which are fundamental to cave ecosystems, particularly to aquatic populations. In caves where typically low-breeding cave invertebrates are only known from small populations or where species numbers are less abundant than would be expected, these individual species may be already vulnerable and at further risk of becoming endangered, possibly to the point of extinction, hence some micro-habitat protection maybe required as an aid to species survival.

Breeding enhancement is unlikely to be successful unless the micro-habitats of threatened species are accurately defined and the source of threat is nullified or curtailed altogether. Ideally, these particular micro-habitats within caves should be closed off to access by cave users, unless artificial breeding colonies or underground laboratories are established, such as those in France. In Slovenia, over-collecting of the rare aquatic vertebrate: the salamander Proteus (the first troglobite ever described) lead to it becoming an endangered species; its continued existence is now only guaranteed because of protection in artificial breeding colonies outside of Slovenia (Humphries 1993; pers. comm., A. Mangin, 1997). Underground (cave) laboratories have the ability to ensure species survival because they can environmentally enhance the habitat niche of rare and threatened species and monitor that immediate environment without the impacts of regular cave visitors to an unprotected site. In late August this year, the writer was able to observe some of the 600 captive specimens of Proteus in the specially designed glass and concrete tanks (under black polythene sheeting) in the naturally cool and moist cave environment of the C.N.R.S. Laboratoire Souterrain at Moulis, in the Saint-Girons district of southern France.

In Tasmanian caves, micro-habitat protection is virtually the only means to promote survival of threatened species, providing a more stable environment to enhance breeding and hopefully maintain or increase population numbers. In order to define these particular micro-habitats or the broader habitat range of any endangered species, cave biologists (and possibly cave managers) should carefully study the known or likely habitats for these species and select appropriate within-cave protection zones or "no-go" areas to exclude visitors from this section of the cave. It should be possible to determine or define these protection sites during the course of cave management plans. In addition to creating zones of "in-cave" isolation or closure of known species micro-habitats with appropriate signage or physical barriers, the best additional assistance is an assurance that the karst surface and catchments will remain undisturbed.

Public awareness and education on the uniqueness and fragility of cave ecosystems

Means to assist in conservation and protection of cave ecosystems and their fauna include: increasing the awareness of other karst land users; inclusion of appropriate cave ecology coursework in school or tertiary curricula, or where ever biology is taught; preparation of media articles in newspapers or television, publication of articles in speleological magazines (including records of cave fauna collections) and signage or information leaflets at popularly visited cave entrances.

Cave visitors themselves need to be educated, to be more aware of their subterranean environment and its ecosystem, and encouraged to adopt a cavers' equivalent of the bushwalkers' Minimal Impact Bushwalking code: look around you, tread lightly and take nothing but photographs! The majority of speleologists that visit Tasmanian caves would belong to affiliated or member clubs of the national caving body: the Australian Speleological Federation (ASF). This national body already has its own established Code Of Ethics in relation to cave use and most ASF clubs should have access to copies of these for distribution to new members. However, caving is becoming increasingly popular as an outdoor adventure sport or recreational activity for young people, but unfortunately, many are not involved with caving clubs and do not necessarily know about the ASF cavers' Code of Ethics or other conservation requirements for caves, cave fauna and cave ecosystems.

It has been recently suggested that repeated cave visits may have a greater biological impact than the physical effects of sediment compaction and erosion (Gillieson 1996). Although the Tasmanian Parks and Wildlife Service and Forestry Tasmania are introducing cave management plans for frequently visited caves, these plans are often more directed at conserving physical features such as speleothems or sediment deposits, rather than the biological attributes of a cave. Therefore, all Government departments and speleological organisations or other cave management structures, need to include provision for conservation of cave fauna in their management plans as well as being involved in public awareness and education campaigns aimed at the persons who visit caves. If cavers are careful to avoid known or likely faunal habitats and otherwise mindful of their caving activity in this subterranean environment, e.g. remaining on established or marked passage routes in caves, the impacts to cave fauna will be less severe.

REFERENCES

Clarke, A. (1989a) Invertebrate species from Arthurs Folly (IB-110). From unpublished submission: "Caves north of the South Lune Road and proposed W.H.A. boundary" to Secretary, Lands, Parks & Wildlife (10-4-1989). 7pp.

Clarke, A. (1989b) Some environmental aspects of karst: the sensitivity of karst hydrologies to human impacts. Report submitted to Tasmanian Dept. of Environment & Planning, May 1989. 13pp.

Clarke, A. (1990) North Lune - a new limestone karst area in southern Tasmania. Jnl. Tas. Cave & Karst Res. Group, No. 4: 27-37.

Clarke, A. (1991a) Quarrying, karst research and land tenure at Ida Bay. Australian Caver, 128: 7-11.

Clarke, A. (1991b) Karst research and limestone quarrying in the WHA at Ida Bay, southern Tasmania. Jnl. Tas. Cave & Karst Res. Group, No. 5: 7-19.

Clarke, A. (1997a) Management prescriptions for Tasmania's cave fauna. report to Tasmanian RFA Environment and Heritage Technical Committee, Tasmanian Parks and Wildlife Service. March 1997. 186 pp.

Clarke, A. (1997b Karst bio-space. In Proc. 21st Biennial Conf. Aust. Speleo. Fed., March 29th-April 3rd 1997, Quorn, South Australia. 18pp.

Clarke, A. (1997c) Karst Bio-space: An introduction and description of some of the disturbance impacts to invertebrate cavernicoles in Tasmania (Australia). In Proc. 12th International Congress of Speleology, Vol. 6; La Chaux-de-Fonds, Switzerland, August 10-17, 1997; (in press Int. Union Speleology/ Swiss Speleological Society). 8pp

Clarke, A. (In press, 1997) The re-colonisation of fauna in Bradley-Chesterman Cave - an ACKMA conference sequel. In Press to "Aust. Cave & Karst Management Jnl."

Dyring, J. (1995) Reservations about Tasmanian karst. In Press for Proc. 11th ACKMA Conf., Tasmania, 1995.

Eberhard, R. (1994) Inventory and Management of the Junee River Karst System, Tasmania. (Report to Forestry Tasmania) 125pp.

Eberhard, R. (1996) Inventory and Management of Karst in the Florentine Valley, Tasmania. (Report to Forestry Tasmania) 139pp.

Eberhard, S.M. (1990) Ida Bay Karst Study: The cave fauna at Ida Bay in Tasmania and the effect of quarry operations. Unpubl. Report to Dept. of Parks, Wildlife and Heritage, Tasmania, May 1990. 25pp.

Eberhard, S. (1992a) Investigation of the potential for hydrobiid snails to be used as environmental indicators in cave streams. Preliminary Draft Report, to P.W.H., February, 1992. 18pp.

Eberhard, S. (1992b) The effect of stream sedimentation on population densities of hydrobiid molluscs in caves. Unpubl. Report to Dept. Parks, Wildlife & Heritage, May 1992. 11pp.

Eberhard, S. (1993) The conservation status of rare and threatened cave species in Tasmania. Report to TASPAWS, July 1993. 12pp.

Eberhard, S. (1995) Impact of a limestone quarry on aquatic cave fauna at Ida Bay in Tasmania. In Press for Proc. 11th ACKMA Conf., Tasmania, 1995.

Eberhard, S. and Hamilton-Smith, E. (1996) Conservation of cave fauna in Australia. Australasian Cave & Karst Mangt. Assoc. Jnl. 23: 4-14.

Eberhard, S. and Spate, A. (1995) Cave communities. Submission to the Endangered Species Unit, Aust. Nature Conservation Agency, Canberra. 15pp.

Forestry Commission Tasmania. (1993) Forest Practices Code. Forestry Commission, Hobart, Tasmania. 98pp.

Gillieson, D.S. (1996) Caves: processes, development and management. Blackwell Publishers Ltd., Oxford, UK. 324pp.

Hamilton-Smith, E. and Eberhard, S. (In press, 1997) Conservation of cave communities in Australia. "Draft chapter" in Press to Wilkens, Culver and Humphreys (eds.) Subterranean Ecosystems. Elsevier.

Harding, K.A. and Ford, D.C. (1993) Impacts of primary deforestation upon limestone slopes in northern Vancouver Island, British Columbia. Environmental Geology: environmental changes in karst areas. 21: 137-143.

Holland, E. (1994) The effects of fire on soluble rock landscapes. Helictite, 32 (1): 3-10.

Houshold, I. (1992) Geomorphology, water quality and cave sediments in the Eastern Passage of Exit Cave and its tributaries. Report to Parks, Wildlife & Heritage, March, 1992. 18 pp.

Houshold, I. (1995) Rehabilitation of the Lune River limestone quarry. In Press for Proc. 11th ACKMA Conf., Tasmania, 1995.

Houshold, I. and Spate, A. (1990) The Ida Bay karst study - geomorphology and hydrology of the Ida Bay karst area. Report to World Heritage Area planning team, Tasmanian Dept. Parks, Wildlife & Heritage. Vol. 1. 63 pp. (& 11pp. appendix)

Humphreys, W. (1993) To collect or not to collect? - that is the question. Western Caver, 33: 5-7.

Jackson, J. and Taylor, R. (1995) Threatened Fauna manual for production forests in Tasmania. Forest Practices Board, Forestry Tasmania. 172pp.

Jennings, J.N. (1985) Karst Geomorphology Basil Blackwell, Oxford. 293pp.

Kiernan, K. (1984) Land use in karst areas - Forestry operations and the Mole Creek Caves. Report to Forestry Commission of Tasmania, National Parks and Wildlife Service of Tasmania and Australian Heritage Commission. 320pp.

Kiernan, K. (1988) The management of soluble rock landscapes: an Australian perspective. Speleological Research Council Ltd., Sydney, Australia. 61pp.

Kiernan, K. (1989) Karst, caves and management at Mole Creek, Tasmania. Dept. of Parks, Wildlife & Heritage, Occasional Paper, No. 22. 130pp.

Kiernan, K. (1990) Soil and water degradation in carbonate rock terranes. Aust. Jnl. Soil & Water Conservation, 3 (4): 26-33.

Kiernan, K. (1993) The Exit Cave Quarry: tracing waterflows and resource policy evolution. Helictite, 31 (2): 27-42.

Kiernan, K. (1995) An atlas of Tasmanian karst. Tasmanian Forest Research Council, Inc., Research Report No. 10. Vol. 1 (255 pp.) & Vol. 2 (351 pp.)

Lewis, S. (1996) Clearcutting on karst: soil erodes into limestone caves. Watershed Sentinel, 5 (4):

Martin, G. (1996) Karst management in New Zealand with a focus on Waitomo (Part Two). Aust. Cave & Karst Managt. Assoc. Jnl., 25: 9-12.

Entranceless and Nonproper Cave Management

Rane Curl, Ph.D.

It is possible to estimate the number and lengths of both entranceless and nonproper caves in a region based on data from known caves. The procedures are statistical and can be implemented with a computer. It turns out that there are typically on the order of ten times as many entranceless proper caves as have natural entrances, although they are on the average shorter. There are vastly more nonproper caves. Management plans for a cave region should include both entranceless and nonproper caves, considering their importance as parts of karst hydrological systems, as habitats for cave biota, and as reservoirs of information about regional speleogenesis, paleoclimates and paleobiology, and all other issues of interest in known and proper caves. At the same time, it may be desirable to maintain the state of entranceless caves in order to maintain the associated environments.

The Karst Waters Institute - Karst Science Serving Groundwater and Biological Resources

Rane Curl, Ph.D. and Ira Sasowsky, Ph.D.

Abstract

The Karst Waters Institute (KWI) was formed in 1991 to improve scientific understanding of karst water systems as interacting geological and biological environments, through research and educational programs. Major accomplishments to date have been the instigation of four interdisciplinary conferences on Karst Geomicrobiology and Redox Geochemistry (1994), Bahama Paleokarst (1995), Climate Change - the Karst Record (1996), and Conservation and Protection of the Biota of Karst (1997). KWI has also cosponsored other conferences, published extended conference abstracts, and conducted field courses in biospeleology. In the future, in addition to continuing scientific conference and educational programs, KWI expects to grow as a resource to develop specialized karst science workshops for resource managers, as a central agency to provide contacts with the interdisciplinary karst science community, to undertake specific research projects directly or cooperatively, and to be a scientific partner in cave and karst management projects.

Protecting Stanton's Cave

Robert R. Currie and Jim Petterson

Stanton's Cave is a significant biological, archeological, and paleontological resource located in Marble Canyon, Grand Canyon National Park, Arizona. It once supported the largest known maternity colony of *Corynorhinus townsendii* (western big-eared bat) in Arizona. The largest number of split-twig figurines ever recovered from a single site was found there, and important paleontological deposits have been excavated from the site. In the 1970s a chain-link fence was installed at the entrance in an attempt to protect the cave and its archeological resources. The fence completely covered the cave entrance, and no provision was made for the bats to continue to use the cave. Several years later a small hole was cut in the upper part of the fence to permit bats to enter the cave. This effort was not successful. In the summer of 1996, less than 20 individuals were observed exiting the cave. Additionally, the fence was not secure, and unauthorized visitors regularly entered the cave. This further disturbed the bats and put the cave's other resources at risk. In April 1997 the fence was removed, and an angle-iron bat gate was installed. Less than one month later, 120 bats were observed exiting the cave. This project was a cooperative effort with the National Park Service, U.S. Fish and Wildlife Service, and Bat Conservation International and is an example of how to combine the resources of the Federal and private sectors effectively to accomplish essential cave protection tasks more efficiently.

Bat Usage Of The Weymer Creek Cave Systems On Northern Vancouver Island, Canada

Trudy A. Chatwin, Martin Davis, and David Nagorsen

Trudy A. Chatwin
Ministry of Environment
Lands and Parks
2080 Labieux Road
Nanaimo, B.C. V9T 6J9

Martin Davis
Island Karst Research
3974 Blenkinsop Road
Victoria, B.C. V8P 3P9

David Nagorsen
Royal British Columbia Museum
675 Belleville St., Victoria
B.C. V8W 9W2

INTRODUCTION

Nine species of *Myotis* bats inhabit British Columbia in summer, yet up until 1993, no winter aggregation sites were known for any *Myotis* in British Columbia (Nagorsen, 1993). Therefore any new information regarding critical hibernacula sites and characteristics of these sites is vital to bat management and conservation. The Province of British Columbia is initiating legislation and guidelines to regulate forest practices and ensure protection of forest-dependent endangered species at this time, yet due to the paucity of information for forest-using bats, recommendations are based on information from other jurisdictions. Thus, in 1993 when cavers discovered hibernating *Myotis lucifugus*, *Myotis volans* and the endangered *Myotis keenii* in Labyrinth Cave in a Vancouver Island coastal montane forest slated for logging, measures were taken to protect and study the Weymer Creek cave system.

Since the Labyrinth hibernacula had its main entrance at around 900 metres above sea-level, we theorised that bat hibernation in coastal areas may be related to the constant cool temperature over the hibernation period in the higher elevation caves. If this theory proved true, then efforts to locate and conserve bat hibernacula in coastal karst areas might be focused on higher elevation sites. The goal of our study was to determine critical habitat characteristics for bats in this coastal forest area in order to make recommendations for conserving bats and bat habitat in temperate forest karst environments.

OBJECTIVES OF THE STUDY

1. To document cave usage by bats in the Weymer karst area through discreet visitation, electronic monitoring, guano collection and skeleton collection;

2. To determine the physical characteristics of bat hibernacula through year-round monitoring of temperature and humidity patterns in caves of different elevation ranges;

3. To document summer habitat use patterns of bats in caves and surrounding montane forest;

4. To determine the impact of clear-cut logging on cave physical characteristics and bat use patterns.

WEYMER CREEK STUDY AREA

The study area (Figure 1) comprises approximately 600 hectares in the Weymer and Green Creek drainages at the northwest end of Tahsis Inlet, Vancouver Island (Latitude 49°51-53' N and Longitude 127°37-39.5' W). This relatively remote area is accessible by a steep trail and ranges in elevation from sea level to 1126 metres. The area is underlain by limestone with several well developed cave systems at various elevations. Weymer and Green Creeks are primarily in the Coastal Western Hemlock Biogeoclimatic Zone, with coniferous forests of sizeable Western Red Cedar, Western Hemlock, and Amabilis Fir. Part of the study area has been clear-cut logged up to 20 years ago and has young forest regrowth. A significant portion of the cave area was set aside as Provincial park, while the remainder is Tree Farm Licence #19 held by Pacific Forest Products.

INVESTIGATION TECHNIQUES

CAVE USE BY BATS

To document cave use by bats we used both direct inspection methods and indirect methods:

- Hibernation could only be confirmed by cave visits and exploration by cavers
- Skeletal remains are used to confirm past use
- "Guano mats" and finding guano was used to confirm use
- Remote ultra-sonic detectors were deployed to monitor bat passes near entrances

CAVE TEMPERATURE MONITORING

To characterize the physical habitats suitable for bat hibernation we deployed 'Onset' Temperature and humidity data loggers in caves and surface control sites at sea level, mid-elevation (around 500 metres), and high elevation (850-950 metres) (Figure 2). For low-elevation, finding replicate caves of sufficient length was not possible, so shorter caves were used. The loggers were also placed in comparable caves with similar elevations in clear-cuts. The pair of temperature and humidity loggers were placed 10 metres within the cave entrance, deep within the cave (where possible > 100 metres from entrance) and outside cave entrance. Data was taken at half-hour intervals.

Weymer Creek Cave Temperature and Humidity Sensor/Data Logger Experimental Design Set-up

Variables	**Treatment type logged**	**Treatment typed unlogged**
Low-elevation- near entrance	1	1
Mid-elevation- near entrance	2	2
High-elevation- near entrance	2	2
Low-elevation deep in cave	2	2
Mid-elevation deep in cave	2	2
High-elevation deep in cave	2	2
Low-elevation ambient	1	1
Mid-elevation ambient	1	1
High-elevation ambient	1	1
Total logger sites	**14**	**14**

CAVE TEMPERATURE DATA ANALYSIS FOR WINTER 1996/97

At each data logger site, temperature data was down-loaded and daily means were calculated for the period of October 30, 1996 to March 6, 1997. These dates were chosen as it was considered to be the hibernation period and it was the time period when all data logger sites were monitored. The mean temperature for this period was calculated for each site. To examine temperature fluctuation over the hibernation period, the range was calculated by subtracting the lowest daily mean from the highest daily mean. T- tests or ANOVA was used to make comparisons for temperature at the logger sites. Humidity data has not been analysed as yet.

SUMMER CAVE AND FOREST HABITAT USE

To document bat species and use of caves and surrounding forest in the non-hibernation period we:

- Mist-netted at forest edges, ponds and outside cave entrances;
- Noted presence of bats in caves;

- Collected remains of bats in caves;
- Used remote and hand-held bat detectors to record echo-location calls.

CAVE TEMPERATURE DATA FOR WINTER HIBERNATION OCTOBER 1996 - MARCH 1997

The results for one hibernation period indicate several interesting trends:

1. When all caves were considered, There is a significant difference for both the temperature range ($p = 0.0000$) and mean temperature ($p = 0.01$) between the outside, near entrance and deep within the cave sites. Deep within all caves are therefore cool stable environments.

2. For all caves there is no significant difference between forested and clearcut temperature range or mean daily temperatures. During winter, clearcut and forested cave conditions may not vary significantly. Summer temperature variations between clearcut and natural caves would be expected to be greater.

3. For all caves, there is no significant difference for temperature range between caves at low, medium, and high altitudes. However, the mean temperature of caves at high elevation was significantly lower ($p = .004$) than caves of medium or low elevation.

The temperature data was analysed for only logger sites deep within caves as these areas would provide suitable security for hibernating bats. Deep within caves there is a trend towards difference between mean temperatures at low, medium and high elevations ($p = 0.002$) with high elevations having significantly lower temperatures, however there was no significant difference between caves of medium and high elevations.

Deep within caves there was no significant difference between the temperature range of high, medium, and low elevation caves, although medium elevation caves had a very high range of temperatures.

1. There was no significant difference between forested or clear-cut deep-cave temperature ranges or mean temperatures. This indicates that bats theoretically could hibernate deep within caves surrounded by clearcut forests, as they do in Wormhole Cave. The clearcut mean temperature appears to be higher than the mean where bats were hibernating.

2. Deep within caves there is a significant difference between mean temperatures, where bats were hibernating and deep within those cave were bats were not hibernating ($p = 0.03$). Although not significant, there is a trend towards smaller temperature ranges in cave locations where bats were hibernating. The data suggests that bats are choosing caves with winter mean temperatures near 3oC with very little fluctuation in temperature. These cool stable environments appear to be located deep within caves at medium or higher elevations. Further cave exploration will confirm these results.

WEYMER BAT CAVE USE AND DATA LOGGER SITES

CAVE	BAT PRESENCE	DEPTH	TREATMENT	ELEVATION
Boneyard sump		Deep	Old-growth	Low
Boneyard mousedig		Deep	Old-growth	Low
Boneyard		Outside	Old-growth	Low
Cave 176A		Near entrance	Old-growth	Low
Deer Drop	**Hibernating**	Deep	Old-growth	High
Deer Drop	**Roosting**	Entrance	Old-growth	High
Headwall Cavern	**Summer bats (suspect hib.)**	Entrance	Old-growth	Medium
Headwall Cavern	**Summer bats (suspect hib.)**	Deep	Old-growth	Medium
Labyrinth	**Roosting**	Entrance	Old-growth	High
Labyrinth	**Hibernating**	Deep	Old-growth	High
Labyrinth Keen's	**Hibernating**	Deep	Old-growth	High
CAVE	**BAT PRESENCE**	**DEPTH**	**TREATMENT**	**ELEVATION**
Labyrinth		**Outside**	**Old-growth**	**High**

Marmot maus.		**Entrance**	**Clearcut**	**High**
Marmot maus.	**Skeleton remains (suspect hib.)**	**Deep**	**Clearcut**	**High**
Marmot maus.		**Outside**	**Clearcut**	**High**
Slot Canyon McLeod		**Entrance**	**Old-growth**	**Medium**
Slot Canyon Rocking	**Summer bats (suspect hib.)**	**Deep**	**Old-growth**	**Medium**
Slot Canyon		**Outside**	**Old-growth**	**Medium**
Whistling Cave Between ent.		**Deep**	**Clearcut**	**Medium**
Whistling Cave Canal/ sump		**Deep**	**Clearcut**	**Medium**
Whistling Cave Clearcut		**Outside**	**Clearcut**	**Medium**
Whistling Cave		**Entrance**	**Clearcut**	**Medium**
Whistling Cave		**Entrance**	**Clearcut**	**Medium**
Wormhole	**Roosting**	**Entrance**	**Clearcut**	**High**
Wormhole	**Hibernating**	**Deep**	**Clearcut**	**High**

WHERE TO NOW??

The research thus far has confirmed the importance of the Weymer Cave Systems to *Myotis* bats at all times of the year. Cave exploration, the placement of data loggers and bat work has set the stage to collect some exciting new information and make a significant contribution to bat research and conservation. This study was funded by Forest Renewal British Columbia - Research Program from May 1996 through March 1997. Work since that time has been primarily done on a voluntary basis. In order to continue, funding must be acquired.

Next year's work :

- Maintenance and down-loading of temperature loggers to maintain a two year temperature profile of all sites;
- Conduct systematic bat detection and capture/marking sessions at all cave entrances to determine chronology of bat use and swarming in this location;
- Locate summer roosts and critical feeding locations for bats using the caves by conducting radio-telemetry studies;
- Continue cave exploration, guano monitoring, and bone collection in caves in order to understand past and present bat use.

MIST-NETTING AND SWARMING

Mist-netting over 15 "net-nights" in July and August 1996 and 14 "net-nights" in August and September 1997 confirmed the presence of 5 species of *Myotis* using the caves and surrounding forest: *Myotis lucifugus*, *Myotis yumanensis*, *Myotis volans*, *Myotis keenii*, and *Myotis californicus*. Forest capture rate was typically low (.1 bat per "net-night", but did confirm the presence of *Myotis californicus* which was not captured or found using caves. Netting outside high and medium elevation cave entrances during warm nights in August was highly productive with capture rates up to 22 per "net-night" outside Labyrinth Cave. The capture total over both years was 92 bats; 46 *Myotis volans*, 30 *Myotis lucifugus*, 6 *Myotis keenii*, 3 *Myotis yumanensis*, 6 *Myotis lucifugus*/*yumanensis*, and 1 *Myotis californicus*. With the exception of 2 female *Myotis volans* and 1 female *Myotis lucifugus* (both non-reproductive) all bats were males. Most of the male bats had swollen penes and testes, indicative of readiness for mating behaviour. All bats handled were adult as determined by ossification of metacarpal-phalanges joint.

SWARMING

We believe the summer captures of bats was typical of "swarming" as reported by Fenton (1969) and in Alberta mountain caves by Schowalter in 1980. Swarming was first observed at Labyrinth Cave (950 m) on August 14, 1996. On this evening bats were first observed flying near the cave entrance at 2230 hrs. We captured 22 bats outside the cave, but estimated that over 100 bats were flying in and out of the cave. Flying behaviour lasted until 0330 hours the next morning. On August 8 and 9, 997 we netted outside Labyrinth, Cathedral, Keyhole, Fracture, Deer Drop and Cool Down caves (all high elevation caves). On August 10, 1997 we netted at Slot Canyon and Fallen Giant caves at 520 metres elevation. We captured 19 bats at Slot Canyon and only 1 bat at Fallen Giant. In August 1997 swarming behaviour commenced at 2330 hours and groups of bats were captured until after 0420 hours. Captured bats had distended bellies and were not present at the caves until 1 hour after dark, indicating that they had fed before coming to the caves. Bats were flying in and out of caves.

In hopes of following swarming chronology, and anticipation of capturing females we conducted a netting session outside Labyrinth, Cathedral, Deer Drop and Fracture Caves on September 5 and 6, 1997. Unfortunately, the weather was cool and wet and only 2 male bats were captured outside Cathedral Cave on September 6. However many bats were observed flying about inside Labyrinth Cave this same evening. Additional funding, will permit use to follow the swarming chronology on a more systematic basis in the next year. Banding bats will help to define the relationship between the swarming and cave hibernation.

REFERENCES

Fenton, M.B. 1969. Summer activity of *Myotis lucifugus* (Chiroptera: Vespertillionidae) at hibernacula in Ontario and Quebec. Canadian Journal of Zoology **47**:597-602.

Nagorsen, D.W., A.A. Bryant, D. Kerridge, G. Roberts, A. Roberts, and M.J. Sarell. 1993. Winter Bat Records for British Columbia. Northwest Naturalist **74**:61-66.

Schowalter, D.B. 1980. Swarming, Reproduction, and Early Hibernation of *Myotis lucifugus* and M. volans in Alberta, Canada. Journal of Mammalogy 61(2): 350-354.

BRITISH COLUMBIA

Ministry of Environment, Lands and Parks

EPIK: Cartographic Method for Assessing the Vulnerability of Karst Aquifers for the purpose of Delineating Protection Zones

Nathalie Doerfliger and Francois Zwhalen
Hydrogeology Centre, University of Neuchâtel, 11 rue E-Argand, 2007 Neuchâtel, Switzerland
Original paper was published in French in the Proceedings of the 12th International Congress of Speleology, 1997, Switzerland - Volume 2

Abstract

The EPIK method is a general multi-attribute method used for karst aquifer vulnerability mapping, providing a basis for assessing the groundwater protection zones in the karst environment. Developed with the support of the Federal Office for Environment, Forest and Landscape the goal of this method is to produce vulnerability maps for karst spring water catchments. According to the selected attributes, the assigned vulnerability zones can be the basis for delineating groundwater protection zones. After having determined the spring water borderlines, we proceed in four steps: 1) mapping of the epikarst (geomorphological approach), 2) protective cover mapping, 3) infiltration conditions mapping, and 4) characterization of karst network development. Each of these attributes is subdivided into classes that are weighted by a theoretical coefficient. The four attribute maps are then overlaid using a GIS and degree of vulnerability is calculated for each zone; the result is the vulnerability map. Some of the results obtained from field testing this method in Switzerland are presented here.

1. Introduction

Water resources in karstic environments are important for water supplies in most countries, but being sensitive to anthropogenic impacts, they are considered vulnerable.

This vulnerability is explained notably by the strongly heterogeneous structure of karst aquifers, with on the one hand very high permeabilities in underground conduits surrounded by low permeability blocks, and on the other hand of very concentrated localized surface recharges.

Vulnerability of aquifers

Vulnerability is an intrinsic property of the aquifer that is dependent on its sensitivity to natural and anthropogenic impacts (Foster, S.S.D. 1987). It is used to characterize, with the help of geological and hydrological information, the sensitivity of the aquifer to anthropogenic contamination, whether it is of a discrete (i.e., concentrated) or diffuse nature.

Special protection

Due to their specific functioning and their vulnerability, karstic aquifers call for special protection. The federal water protection law of 1993, requires the delineation of protection zones “S” for all potable water catchments: in karst environments their delineation relies principally on morphological criteria and transit velocities established by dye tracing (Practical methods for the delineation of protection zones, 1997). The designation of protection zones for all Swiss water supplies is essentially complete. Despite this considerable effort, the protection of supplies in karst environments is still often imperfect.

In view of this situation, it became necessary to propose and to develop a vulnerability mapping method for karst aquifers based on different specific criteria for the hydrodynamic behaviour of the karst system. This method aims to be objective; it is based on geological and hydrogeological criteria and is independent of land use and economic considerations.

2. Multi-criteria approach: the EPIK

method

The approach proposed here to evaluate the vulnerability of contributory basins for karst spring catchments is an indexed multi-criteria approach, termed EPIK; it takes into account four criteria, corresponding to four specific characteristics of the functioning of a karst aquifer such as the one described below.

After having determined the limits of the spring catchment, one proceeds in four steps:

1) mapping of the epikarst,

2) mapping of the protective cover,

3) mapping of infiltration conditions and

4) characterization of karst system development and assignment of a global factor to the catchment.

The mapping of the criteria subdivided into indices is performed with the help of direct or indirect methods, local or global methods as in the case of geomorphological study, the use of a numerical elevation model, auger probes, air photo interpretation, geophysics, and dye tracings.

Functioning of a karst aquifer

Karst aquifers are characterized by geomorphological peculiarities, hydraulic phenomena such as the existence of major springs, swallets, the absence of surface drainage, the presence of karstic networks and hydrographs typical of springs. From these characteristics, one can propose the following image of a karst aquifer, such as the one illustrated in figure 1:

“A network of connected conduits (karst network) ending at outlets draining or feeding supplying fissured and fractured rock masses of weak permeability”.

Figure 1: Schematic representation of the functioning of a karst aquifer (Doerfliger et al., 1995)

The criteria of the EPIK method

From this diagram, four of the most relevant criteria are differentiated as follows:

Criterion E: Epikarst (karstic morphology)

E1 - Caves and depressions capturing a watercourse

- sinkholes
- lapiaz (karrenfields)
- cuestas
- outcrops with intense fracturing (road edges/artificial outcrops)

E2 - Intermediate zones between sinkhole alignments - dry valleys

E3 - the balance of the catchment

Criterion P: Protective cover

A. Soil resting directly on carbonate formation aquifers or on very permeable coarse detrital formations (e.g., colluvium, lateral moraines...)

P1 0 - 20 cm of soil

P2 20 - 100 cm of soil

P3 >100 cm of soil

B. Low permeability geological formations with or without soil (e.g., lacustrine muds, clays...)

P3 >100 cm total soil and low permeability geological formations

P4 >soil with thick (8 m) geological formations of very low permeability [muds-clayey-silty] to be verified in a punctual manner

Criterion I: Infiltration conditions

I1 - perennial and intermittent swallets

- stream beds and banks
- perennial and intermittent streams feeding a swallet or a sinkhole
- infiltrating streams

A/ Inside a sinking stream catchments feeding swallets

I1 - Portion of the catchment that is artificially drained

I2 - Portion of the catchment that is not artificially drained and whose slope is greater than 10% for cultivated zones, 25% for meadows and fields

I3 - Portion of catchment that is not artificially drained and whose slope is less that 10% for cultivated zones, 25% for meadows ad fields

B/ Outside sinking stream catchments feeding swallets

I3 - Surfaces at the toe of a slope serving as runoff collectors and slopes feeding these low points (slopes greater than 10% for cultivated zones, 25% for meadows and fields)

I4 - the balance of the catchment

Criterion K: Karst Network

K1 - Well-developed karstic network, with non-obstructed, well-connected decimetric to metric conduits

K2 - Poorly-developed karstic network, with poorly connected or plugged (obstructed) conduits, or decimetric dimensions or less

K3 - Outlet in a porous medium providing protection (with protective effect) (to be confirmed)

- Non-karstified fissured aquifer

Vulnerability assessment

For each criteria E-P-I and K, one establishes a spatial distribution map of their indices. These four maps are digitized and converted into a graphic format (raster); this format allows, with the help of a Geographical Information System (GIS), the assignment of class values to all cells (polygons) in the catchment. The latter is divided according to grid squares of 20 metres per side. Then the maps are superimposed: the values of the class indices are added and multiplied by the relative weight, so as to obtain a synthetic map of vulnerability (Doerfliger, 1996), according to the weighting equation below:

$$F = \alpha E_i + \beta P_j + \gamma I_k + \delta K_l \quad (1)$$

with F: protection factor E_i, P_j, I_k and K_l: values of indices of each criteria class/α, β, γ, δ: relative weighting coefficient

To assign values to the weighting coefficients, we have carried out different sensitivity tests and made a particular note of the following factors:

- A sinkhole covered with thick soil (E1-P3) is more vulnerable than a compact limestone slab overlain by a thin soil cover (E3-P1)
- A sinking stream (I1) is very vulnerable, independent of the protective cover
- A dry valley (E2) is as vulnerable as a low topographical location that collects run-off.

By taking into account these factors and the different weighting tests performed, the following values have been used for the calculation of the protection factor:

1. The indices of criteria E,P, I and K are weighted as follows:

E_1	E_2	E_3	P_1	P_2	P_3	P_4
1	3	4	1	2	3	4
I_1	I_2	I_3	I_4	K_1	K_2	K_3
1	2	3	4	1	2	3
Reminder: The lowest weighting value corresponds to the most vulnerable situation						

Table 1 Weighting of criteria indices E, P, and I

2. Since criteria E and I play a less important role for karst protection than criterion P, we have assigned to them a greater relative weighting. The weighting attributed to criterion E relative to criterion I is the same. K has a relative weighting that lies between that of E and P.

α	β	γ	δ
3	1	3	2

Table 2 Relative weighting attributed to criteria E, P and I 3.

During the calculation of the protection factor F for the different possible combinations, one obtains values ranging from

19 to 34. The following combinations of given criteria are incompatible: K_1 with E_1, I_1 and P_3 or P_4,

Determination of protection zones

The combination of the different weighting factors specific to each criterion according to the above-described equation allows us to assign to every point in the catchment one of three "S" protection zones.

less than or equal to 19	Zone S1
between 20 and 25	Zone S2
F > 25	Zone S3

Table 3 Vulnerability Equivalence and protection zones

3. Application examples

Two application examples are presented. They involve the mapping of vulnerability of the catchment of springs (Clarive and Tine) of the commune town of St-Gingolph (VS) in the median plastic Prealps and the mapping of the vulnerability of a part of the catchment feeding the springs of the Saivu, of the Font and the Bâme in Bure in the Tabular Jura (northwestern Switzerland)

St- Gingolph - Valaisian Prealps

In this case frequent pollution of agricultural origin (dung and liquid manure) affects the quality of the Clarive and Tine springs. The use of the EPIK method on this criterion has managed to highlight the relatively high vulnerability of this catchment - a considerable area of moderate to high vulnerability zones (Figure 2). The catchment is characterized by the predominant protection zone S2 (Figure 3).

Tabular Bure-Jura

Within the framework of the impact study of the future national highway N16, the karstic catchment of the La Font, Saivu and Bame springs has been the subject of important studies, notably hydrogeological ones. This catchment (some 15 square kilometres) is located in Ajoie, in the Tabular Jura (an aquifer developed in the carbonates of the lower Sequanien). The waters of this site are drained via an underground karstic network, the Milandrine.

The three criteria E, P, and I were characterized with the help of existing available data (geophysical, drillings records, air photos,...) and field work (mapping, probes with a hand auger...). Complementary studies (geophysical, drillings, dye tracings...) were also carried out with the aim of thoroughly testing the EPIK method. The results obtained following these different types of field work have allowed us to appreciate the advantages of the new method (Doerfliger et al., 1996).

4. Conclusions and perspectives

The EPIK method is a tool entirely adapted to the management of water resources in a karstic environment. It allows the derivation of specific vulnerability maps; these maps constitute a new basis for the establishment of protection zones in karstic terrain. Protection zones are thus better targeted, especially the most restrictive zones (S1).

Combined with a map of potential risks, the EPIK maps should in the future facilitate the establishment of an appropriate regulations relative to protection zones in a karstic environment. The test applications of this method on several test sites, have demonstrated the feasibility of this new approach in karstic terrain.

So far, the concept of establishment of these new maps is relatively clear and the current research is focussed on the characterization of epikarst (cf. Puech, 1997, in ce colloque) and the transfer of contaminants introduced into the protective cover.

The contamination of karstic aquifers is not inevitable. The delineation of protection zones matching the hydrogeological functioning of the karst, significantly contributes to the protection of springs and karstic groundwater resources.

Acknowledgments

The authors of this paper wish to thank the federal office of Environment, Forests and Landscape as well as the National Hydrological and Geological Service for the support provided during the development of this EPIK method, as well as the members of the karst group of the Swiss Hydrogeological Society. Our thanks are also extended to the Canton of Berne, Hydraulic and Energy Economy Office of the Canton of Berne.

(no figure)

Figure 2: Vulnerability map for the catchment of St-Gingolph springs

(no figure)

Figure 3: Protection zones map for the catchment of St-Gingolph springs

Bibliographic references

DOERFLIGER N. and ZWAHLEN F. 1995. EPIK: a new method for outlining of protection areas in karstic environment. International Symposium on Karst Waters and Environmental impacts, Antalya, 10-20 September 1995. Sous presse chez Baikema.

DOERFLIGER N., Tâche E. and ZWAHLEN F. 1996. EPIK, une méthode pour cartographier la vulnérabilité des aquifères karstiques: appiication à deux sites dans le Jura suisse. ESRA '96, L'eau souterraine en région agricole, colloque, Poitiers, 9-12 septembre 1996, S7-17-20.

DOERFLIGER N. 1996. Advances in karst groundwater protection strategy using artificial tracer test analysis and multi-attribute vulnerability mapping (EPIK method). Thesis, University of Neuchâtel, Switzerland, 225 pp.

FOSTER S.S.D. 1987. Fundamental concepts in aquifer vulnerability, pollution risk and protection strategy. In Vulnerability of soil and groundwater to pollutants (W. van Duijvenbooden and H.G. van Waegeningh, eds). TNO Committee on Hydrological Research, The Hague, Proceedings and Information, No 38, pp. 69-86.

Instructions pratiques pour la détermination des secteurs de protection des eauxdes zones et des périmètres de protection des eaux souterraines. 1977. Révision partielle en 1982. Office fédéral de la protection de l'environnement.

Heceta Island: An Example of Karst Management in the Tongass National Forest, Alaska

Kris Esterson

Abstract

Heceta Island is located in the Tongass National Forest, Alaska and contains some of the most extensive and well-developed karst in the Tongass National Forest. Timber harvest has been active on the karst of the island since the 1950's and continues today. The most recent timber sale, the Heceta Sawfly Salvage Sale, will extract approximately 18 million board feet out of 19 units. The Tongass Cave Project examined the units in August 1997 and found that 16 of the 19 units contain significant caves and karst features, many previously unknown. The TCP discovered 23 new caves in units cleared and sold by the USFS. Hydrologic traces confirm connections between karst features inside the new units and a class one stream and the 2 km long Arabica Cave System. The protection of caves and karst features in units already sold in the Heceta Sawfly Salvage Sale remains uncertain as does the actual protection of karst on the rest of Heceta Island and elsewhere in the region.

Northern Vancouver Island Karst and Cave Tourism, Past and Present

Karen Griffiths

Abstract

Karst and cave tourism has been developing on northern Vancouver Island over the past 25 years. Beginning in the early seventies, sites with engaging names such as the Devil's Bath, Vanishing River, Eternal Fountain, and the River-to-Nowhere were improved with footpaths, signs, and viewpoints, and "designated" for self-guided public recreation and tourism. The Little Hustan Lake Caves and the Upana Caves were similarly developed for the public in the eighties. The roles of these karst sites has evolved over the years. Today, they increasingly interpret the ecological values of karst resources for a "greener" public. This development, as well as contemporary issues surrounding sustainable management, will be discussed.

Analogous midsummer maximum daily air temperature and relative humidity profiles from sideslopes of a northern Vancouver Island sinkhole before and after clearcutting.

Paul Griffiths

Abstract

Relative humidity (RH) and temperature profiles were obtained from the undisturbed Sinkhole Cave doline entrance (Cross River, northern Vancouver Island) at mid-day on August 25, 1982. The 15-m deep, 30-m wide doline, which was once made more impressive by the towering old-growth forest canopy, was harvested sometime after 1983. The logging residue was lightly burned to prepare the ground for tree planting. In order to assess the effects of clearcutting on the summer climatic regime, measurements were repeated at mid-day on August 8, 1987. The analogous "before" and "after" RH and temperature profiles are presented for comparison.

Searching For Cave Entrances In Old-Growth Forests: An Overview Of Ground-Based Methods Employed In North And Central Vancouver Island, British Columbia

Paul Griffiths
544 Springbok Road, Campbell River, British Columbia, Canada V9W 8A2 email: pgriff@island.net

ABSTRACT

Ground-based methods have been used since 1982 by forest licensees and inventory contractors to search for cave entrances in the remnant old-growth forests of North and Central Vancouver Island. Methods have ranged from a low intensity preliminary reconnaissance to a high intensity saturation search. Moderately intensive sampling methods, such as the grid pattern (i.e., strip) search and judgmental search, will be evaluated for effectiveness and cost efficiency.

INTRODUCTION

The remnant primary old-growth forests of Canada's West Coast are globally rare temperate rainforests (ref.).

The forests atop North and Central Vancouver Island's karst are complex ecosystems. Very old and large coniferous trees form a dense canopy, which, combined with frequent fog and precipitation, make aerial detection of all but the largest cave entrances difficult. Consequently, resource managers most commonly employ ground-based search methods to inventory cave entrances in old-growth forest stands.

Methods that have been successfully used by the BC Ministry of Forests and coastal timber licensees include:

a) Reconnaissance (or walkabout)

b) Strip (or transect)

c) Judgmental (or feature-oriented)

d) Total (or saturation)

The search strategies have occasionally been combined and stratified, or at least modified to better suit field conditions. The most appropriate field method depends on the specific objectives of the cave entrance inventory and the nature of the forest environment.

The reconnaissance is normally the least intensive ground search method, while the strip and judgmental, based on systematic sub-sampling, are moderately intensive. Searching can also be very intensive, such as with total surveys (i.e., as would occur in a tight grid network).

All surface inventories usually begin with a desktop review of aerial photography, geological mapping and records of known feature occurrences. These front-end tasks, or "filters", constitute important elements of the stratified inventory.[1]

Background to specific requirement

The specific requirement to locate cave entrances was introduced in the Cave/Karst Management Handbook for the Vancouver Forest Region[2] (June 1994) hereinafter

[1] Photogrammetry can identify certain biophysical indicators (e.g., large tree canopy gaps and surface lineaments that are sometimes associated with cave entrances). Aerial photography can also reveal karst features in adjoining and analogous cutover areas, from which inferences can sometimes be drawn about the closed canopy inventory area.

[2] The Handbook guidelines are optional or voluntary

referred to as the "Handbook"). Retained in the July 1994 version, the current guideline[1] reads as follows:

"When a proposed development boundary lies within a karst formation, as identified by the L5 feature in the recreation inventory, a systematic surface inventory to locate cave entrances must be undertaken within this area as well as for the karst formation surrounding the development boundary."

Accordingly, the primary objective of all ground searches is to locate cave entrances to meet this administrative requirement. The information collected as a result is used for updating recreation inventories, the completion of which is required under section 28(d)(i) of the Forest Act.

Surface surveys can also lead into a complete multidisciplinary cave/karst inventory and assessment project, which necessitates the subsurface inspection of found caves. Locating "hydrological" features, such as active insurgences and exsurgences, is also an important precursor to the design of dye tracing studies. Found swallets can be used for the introduction of dye, while springs serve to monitor dye travel.[2] The surface inventory information is also used to enable concurrent or subsequent subsurface inspection of caves. In practice, a secondary objective may be to establish other important biophysical site characteristics (e.g., soils, wildlife, etc.) (This phase of inventorying is beyond the scope of this paper.)

practices not currently in the Forest Practices Code (FPC), but the implication is that they are to be used to meet resource management objectives. The handbook was to have been replaced by the FPC Cave Management Guidebook in preparation (ref). Nonetheless, handbook guidelines can be made legally enforceable when they are inserted in plans, prescriptions and contracts. (ref) The MOF Regional Manager requires the interim implementation of the Handbook procedures, including systematic surface inventories, under the authority of a written directive to MOF Districts and licensees.

[1] Previously, MOF management guideline and policy statements prescribed only general cave inventories. The current Handbook also states that the "extent and intensity" of the surface inventories must be approved by the MOF District Resource Officer Recreation.

[2] Dye studies are being used with increased frequency by BC resource managers and recreational cavers to enrich the understanding of the hydrogeology of the more sensitive karst units.

METHODS

Sampling surveys:

The objective of the systematic surface inventory is to gather information about the occurrence of cave entrances over the ground sampled, and to occasionally make inferences about adjacent unsampled terrain. Of the three sampling survey methods described below, only the reconnaissance search is not, strictly speaking, a systematic search (i.e., a search type that is not characterized by a system or method).

Reconnaissance

The reconnaissance is most often used in combination with the judgmental search. The search route usually consists of a transverse line (i.e., a line that crosses from side to side between the boundaries of the inventory area). In addition, it can be used to search along projected road right-of-ways.[3]

This reconnaissance is a type of sampling survey often used as the first field phase of a stratified inventory.

[3] It is generally accepted that the roadbuilding phase of forest development can produce the greatest impacts.

Figure 1a: Reconnaissance search - rectilinear layout

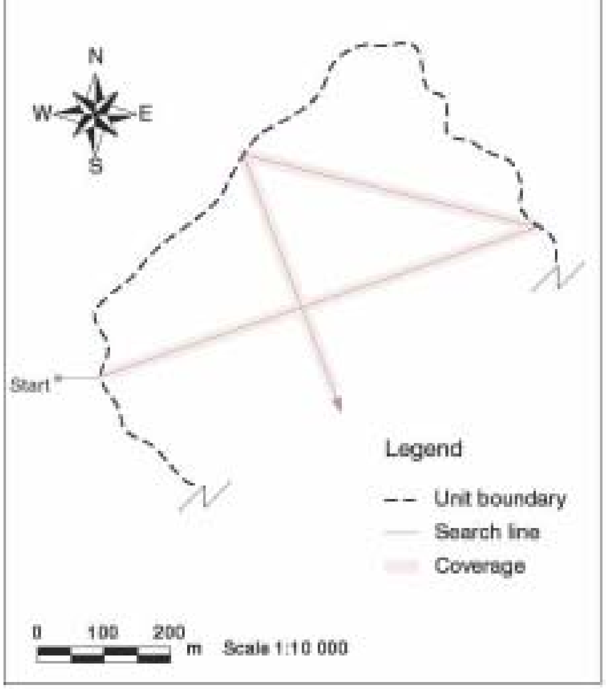


Figure 1b: Reconnaissance search - along projected road right-of-ways

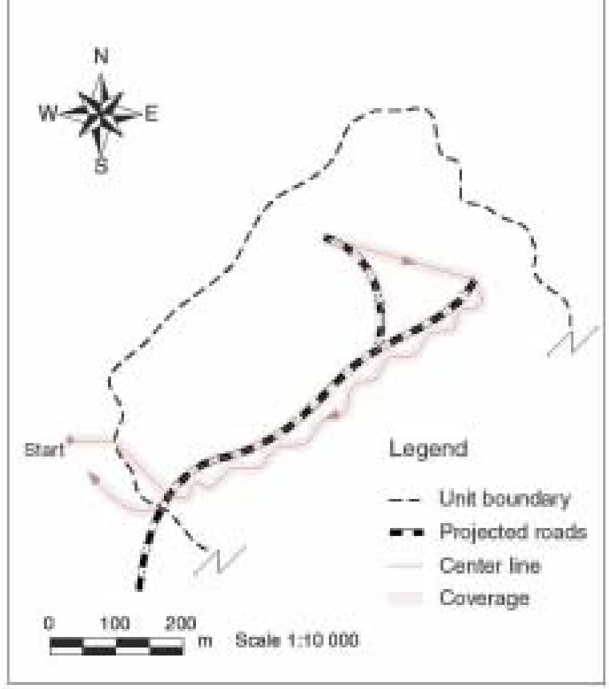


Figure 2: Strip search - 90-m center lines with lateral rovers

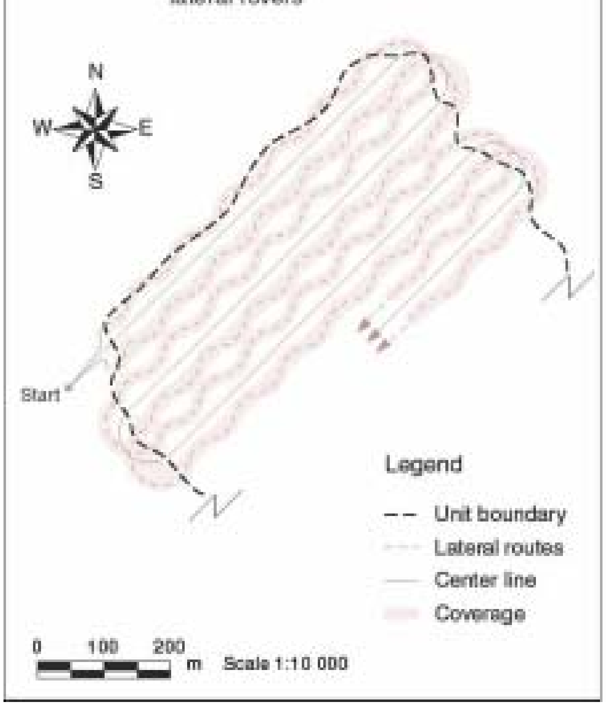
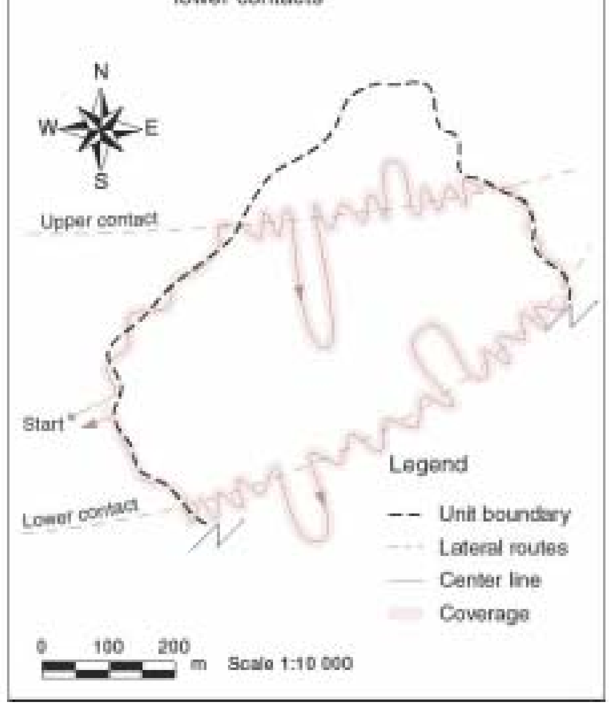


Figure 3: Judgmental search - along upper and lower contacts



Strip

With the strip search method[1], the general grid layout and orientation of search lines are selected based on practical considerations. Thereafter, the individual search lines are mechanically and uniformly spaced at fixed intervals.

Typically, a single person establishes a search center line with a handheld compass, clinometer and hip chain, while making the necessary observations within the field of view. Two lateral searchers rove over the ground in a “zigzag” fashion on opposite sides of the center line. At a minimum, the azimuth and chained distances are recorded for the center line. Clinometer readings may be taken when traversing sloped terrain. [2]

Depending on the type of karst terrain to be searched, the center line interval (and the width of the strips) is sometimes varied. Inventories have been conducted at 100-m, 50-m and 30-m center line intervals. The visibility and ease of cave entrance recognition under different forest stand conditions may set the optimal balance between these limits. The 90-m width is the most commonly used center line interval and assumes a mean visible range of 10-15 m. At this interval, the three members of the crew start the search spaced 30-m apart.

The strip method is a technique that is particularly useful when making comparisons between karst zones.

Judgmental

The judgmental search is the second type of systematic sampling survey. The method is based on the recognition that surface karst features do not occur in random order.[3] By analyzing inventory data, it has been possible to identify the association between surface karst features and one or more terrain variables. These correlations have been verified by regression analysis and established for Vancouver Island forest karst ecosystems. For example, there is shown to be a strong positive or direct correlation between the topographic position of swallets and upper limestone contacts. Conversely, a negative (i.e., inverse) correlation exists between steep hillslopes and dolines. There are many such correlations, learned principally through experience.

Total

Total searches are usually conducted on a regular grid system, with quadrants as small as 20 m by 20 m.4 They are occasionally employed for small development units, and generally yield the most accurate results.

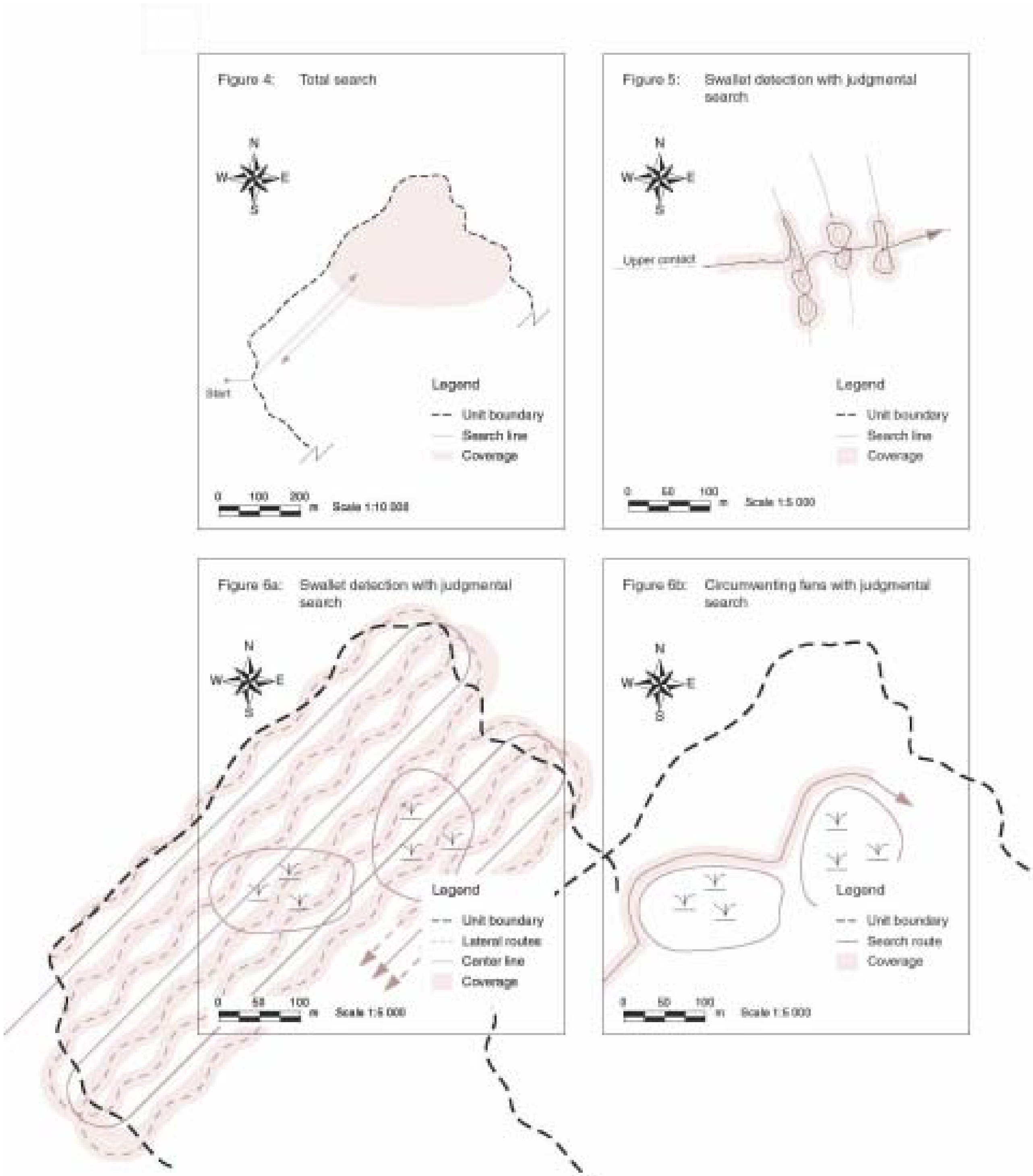
---

[1] The strip search was first used in 1982 to inventory selected timber harvest units in the Tahsish River drainage of northwestern Vancouver Island.

[2] More accurate center line surveying can be specified however. To maintain 1:100 horizontal accuracy, for example, the instruments must be capable of readings in one-degree increments. Distance measurements to the nearest 0.1 metre are periodically required by the sponsoring agency or client. Shots average 10-12 m depending on conditions. The survey stations are established in the field and marked. If the search center lines are accurately surveyed, they can be used to tie in features found.

[3] It was first used to survey selected timber cutblocks in the Holberg area of Northern Vancouver Island, where inventory areas were interspersed with poorly drained transitional fen-bogs and hydrophilic vegetation. The initially mandated ground search of these areas entailed time-consuming and exhaustive fieldwork. (The poorly drained areas did not show many features!)

[4] Strip searching with narrow transects can also lead to complete ground coverage under certain conditions.



As with all search methods, the nature and location of notable karst surface features, other than cave entrances, must also be described in field notes, to both characterize the karst terrain and to aid in locating the feature again later.

DISCUSSION

This following discussion is a comparative evaluation of the two most commonly employed methods of systematic surface inventorying—strip and judgmental sampling surveys.

Compliance with applicable guidelines

Both search methods generally satisfy the legislative requirement to perform an orderly and methodical surface inventory, as established in the Handbook.

Human Resources:

Number of persons required

The minimum crew size for the transect search is three persons, assuming that the center line surveyor uses a hip chain as a distance measurement device. A chained traverse requires a second person on the center line.

The judgmental search method generally requires fewer persons over shorter periods. In theory, one person can perform this type of surface survey, provided that provincial safety and client policy requirements are met.[1]

Required skills

The relatively higher cost of the strip search (See “Estimated Costs”), and higher crew complement, can lead to the use of less skilled and inexperienced labour. Although most persons can readily recognize classic cave entrances, difficulties in interpreting the full range of certain karst characteristics associated with unusual or uncommon atmospheric openings can bias the search. These are not inconsequential problems if systematically repeated throughout the inventory unit.

The judgmental search generally requires a higher skill level than that called for in grid or transects searching and this can add to the cost. This eventuates in higher quality documentary output however.

Lower turnover can help to ensure consistency between searchers.

Duplication of effort

This strip method does not efficiently take into account for the field knowledge acquired by forest workers who may have already traversed the inventory area, many of whom can reliably recognize cave entrances. The reliability of karst-specific observations made by these workers has steadily improved over recent years. Indeed their capability can exceed that of sport cavers, who, perhaps because of their location and/or interests, may have been minimally involved in searching for caves in old-growth forest.

Timing and scheduling

The longer duration of the strip search, unless multiple crews are deployed, means that it is potentially subject to more frequent weather-related interruptions and delays (e.g., hazardous windstorms, snowfalls, etc.). This becomes an important limiting factor in remote locations where access is by air transport or watercraft.

Efficiency

One of the drawbacks of the strip search arises from the fact that karst surface features (e.g., cave entrances) are not evenly spaced over the entire inventory unit, but are determined by topography and clustered. This can sometimes mean that broad tracts of land are sampled where no significant features are found. Such is particularly the case when the nature and/or depth of the regolith may have masked, or almost completely obscured, the surface expressions of the karst formation.

Cave entrances are frequently controlled or at least influenced by topography. For example, in hillslope areas, swallet-type cave entrances are most likely found where surface streams intersect the upper limestone contact. As ellipsoid features, with a tendency toward downslope orientation, these swallets are not as quickly located if the multiple strips are run across the hillslope, and below the contact zone.

(See Figure 5)

With the judgmental search, the field personnel can usually be deployed more efficiently. For example, each person can follow separate pre-designated search routes. As well, persons can handle separate field tasks in the same zone concurrently.

[1] It is permissible for one person to work alone) if a means of periodically checking the well being of this individual is instituted pursuant to Section 8.32 ("Men Working Alone") of the BC Industrial Health and Safety Regulation. (ref) This procedure entails a scheduled check-in by portable VHF radio. In practice, however, a minimum two-person crew is deployed in during periods of inclement weather and/or in remote forest development areas. Transceivers are also used in cases where voice communication between workers is not possible.

Rate of progression

A limiting factor for the strip search can be the sponsoring agency's or client's requirement to accurately survey the center line.[1] As the center line surveyor is generally the slowest person in the three-person crew, lateral searchers must accommodate this to maintain their position relative to the center line. One of the advantages of the strip search is that the surveyed center lines are available for accurate entrance tie-ins.

In addition, the field tasks are generally more onerous for one lateral searcher than for the other. This is particularly true when multiple karst surface features are found. Hence one lateral searcher must periodically wait for the other. Although pacing distances is much quicker and easier, especially for independent searchers or in shrubby or dense forests, it is less accurate than chaining. Transect distances and cave entrances along transects are measured by using metric hip chains.

Obstacle areas:

Problems can arise when a strip is constrained to a straight-line course over obstacles (e.g., short steep bluffs, perched bogs, windfall areas, etc.). The rate of progression is negatively impacted when such difficult zones are traversed and the lateral searchers are deflected off of their search route axes. Furthermore, these areas frequently exhibit lower karst cave entrance potential except at the periphery.

Of the two sampling survey methods, the judgmental search better lends itself to where there are extensive patches of dense undergrowth or windthrow on uniform terrain. These occurrences are rarely associated with cave entrances. While the strip search center line must generally follow a compass course through these patches, the judgmental searcher is not bound to a straight-line compass traverse. The latter searcher can circumvent these obstacles whenever necessary.

(See Figure 6a and 6b)

Sampling bias

The probability of finding a cave entrance using the strip method largely depends on its size (assuming symmetry in all other respects). Entrances must be large enough to see at a reasonable viewing distance. (Note: A dry (i.e., noiseless) pit measuring 0.25 metre across can easily be missed at a distance of 10 m with moderate understory.) Thus, large entrances are more likely to be found than small ones.

Similarly, sampling biases can occur when an inexperienced observer underestimates the potential of karst land units with few surface karst expressions. How thoroughly the ground is searched will also depend on the care exhibited by individuals—the less perceptive searchers will tend to miss features.

Failure to locate a cave entrance could result from this bias. In addition, individual bias can be introduced by the differing physical stamina of lateral searchers. For example, more enthusiastic and energetic lateral searchers will tend to cover more ground (i.e., the overall amplitude of the "zigzags" tend to be greater). If lateral searchers are imperfectly matched, then the overall rate of progression is reduced to that of the slowest person.

(See Figure 7)

The judgmental method is not as biased toward large cave entrances, as all features along the access route and the target zone are more likely to be inspected. Size distributions of entrances obtained by this method cannot be compared directly to results provided by the other methods.

Cave entrances of all types may be more easily missed when wide center line intervals and strips are used. Ten-metre wide strips can increase the number of small entrances found. However, if larger entrances are the primary object of the surface survey (e.g., because they are more likely to be penetrable), then narrower grids may not be advantageous.

A particular potential bias toward finding large cave entrances exists because the center line searcher more readily sees them. Entrances at the limit of his visibility range, but still within the middle strip, will be missed more often than in the lateral strips. this is due to the fact that the center line person does not normally break the chain to inspect collateral features or to "zigzag".

(See Figure 8)

Another potential bias arises between the lateral searchers themselves. The probability of finding an entrance in a homogeneous land unit is roughly proportional to the amplitude and length of the search path wave or "zigzag" (i.e., the distance traveled). Assuming the same visibility

[1] Resource managers have occasionally required surveying search routes to 1:100 accuracy. This involves the use of a hand-held compass and clinometer.

range, the probability is greater if the searcher increases the amplitude of the "zigzag". Statistically, a more energetic lateral searcher can be expected to find more entrances if he covers a greater distance.

Table 1 shows increases in the probabilities of finding analogous cave entrances of different sizes for transects of different widths. As expected, wider strips find more entrances than narrow or line transects, and the effect is greatest for small entrances.

Table 1: (to be placed here)

Coverage

If a 90-m interval search line is selected and a 15-m lateral visibility range is assumed for equidistant searchers, then a 100% sample is theoretically possible with the strip method. In practice, however, the actual sample size is highly variable when the terrain is broken and where poor visibility conditions prevail. Inventory contractors have reported that a 50-80 percent sample is possible under optimal conditions.

Right-of-ways

Unless the projected right-of-ways can be used as reference or base lines, the non-rectilinear layout means they can be searched only by the intersecting fixed searchlines, and the random intersections of lateral search routes. These intersections can occur at perpendicular and oblique angles on hillslopes.

This judgmental method can be efficiently employed to search along projected road right-of-ways. The method allows for efficient linear searching of projected right-of-ways, particularly those that traverse across hill slopes. One person can usually search the standard road width (ref.) from the center line assuming a visibility range of 15 m.

Concurrent tasks

For strip searches, concurrent subsurface inspection of complex and/or technically difficult caves necessitates lengthier surface carries. The requisite heavy loads of harnesses, rope, and hardware are transported over search paths or cached at intervals. This reduces the overall rate of progression. Judgmental searchers tend to carry the gear for preliminary subsurface inspections of caves at all times.

Other karst surface features and terrain characteristics

Strip searching for more common karst surface features (e.g., dolines) allows the searcher to make more precise determinations about karstification (e.g., index of subsurface karstification1). However, in the case of narrow transects there is no guarantee that the unsampled features that lie outside the transect are as numerous as inside the transect.

In the judgmental search, the knowledgeable searcher can design traverse routes to make some inference about the karstification of the unsampled portion of the inventory area. The level of experience required is higher though.

Estimated cost

The average cost of strip searching varies according to center line interval—for lines established at 90-m intervals, and to 1:100 survey accuracy, it ranges $200-250 per hectare. This cost estimate includes the associated field tasks (e.g., entrance identification).

The cost range for judgmental searching is $50-80 per hectare. In judgmental sampling, a search area is divided into zones of known higher probability, and traverses are selected by an experienced contractor for the purpose of sampling these zones. This approach has several advantages. If search routes are carefully selected, the results will be obtained in less time than required for a systematic grid or transect search. Aside from the temporal efficiency, the overall cost of the search will be much more favorable.

Conclusions

For most inventories in large forest tracts, it has not been economically feasible to search 100 percent of an inventory area. The number of field workers required and the manner in which they can be deployed greatly influence the cost of a survey. Aside from cost, the time required to complete more intensive searches is also a major consideration.

Larger units may require many repeat visits and take

[1] The karstification index is the number, expressed in square kilometres of apertures of karstic conduits (e.g., swallets, dolines, exsurgences, etc.) which can be detected on the surface of the karst. The index of subsurface karstification is the sum of discrete karst surface features sampled divided by the total area of the strip transects.

several years to complete. Administrative timelines and ground access problems (e.g., inclement weather) are often important constraining factors.

The prevailing compromise is to use a moderately intensive method and to randomly exclude many of the smaller features from more detailed fieldwork. Field time is thereby most profitably employed on the cave entrances of primary interest and importance.

Carefully designed sampling surveys have become an accepted method of inventorying for cave entrances in forest development units that cannot be completely searched due to time and cost constraints.

Though the statistics for finding entrances and of projecting the number of unsampled entrances have not been developed for the two systematic sampling methods, strip and judgmental, it is believed that for a given land unit they produce similar results.

The strip search appears to be most useful where cave/karst features (i.e., possible cave entrances) are spread more diffusely or homogeneously through the understory, instead of being concentrated in discrete locations. The judgmental search is better for finding small features and is less costly if the experienced searcher can predict where features are more likely to be found or not found—search routes are designed and optimized accordingly.

The risk of not finding the features that may occur in unselected routes or adjacent zones is minimized by carefully designing search routes, adjusting the search intensity (i.e., stratified sampling), and by utilizing knowledgeable and experienced field workers.

Note:

In the course of preparing this review we have discovered a possible application to future searches for persons reported missing from caves unknown to the BC Cave Rescue organization.

GLOSSARY

Azimuth - the true bearing of a survey line, determined by measurement with a compass

Cave - cavity in the earth, which connects with the surface, contains a zone of total darkness and is large enough to admit a human being

Canopy gap - refers to an area within the forest where the canopy (leaf height of tallest stems) is noticeably lower than in adjacent areas.

Clinometer - a handheld instrument used to measure slope

Doline - synonymous with sinkhole, usually a large sinkhole. (see also sinkhole)

Ellipsoid - oval-shaped

Ground search -

Hydrophilic - describes an entity that is attracted to water

Karst - region underlain by compact and soluble carbonate rocks in which appear distinctive surface and subterranean features, caused by solutional erosion.

Karst formation - a distinctive mappable body of karst

Karstification - all genetic and evolutionary processes resulting in surficial and subsurface forms in a karst region

Photogrammetry - the technique of making surveys and maps by aerial photographs

Quadrat - a square

Recreation inventory - the identification, classification and recording of recreation features, visual landscapes, recreation opportunity spectrum (ROS), recreation features of rivers and specific point locations of recreation sites, trails, caves etc. ROS is the mix of outdoor settings based on remoteness, area size, and evidence of humans, which allows for a variety of recreation activities.

Regolith - the unconsolidated mantle of weathered rock and soil material on the earth’s surface; loose material above solid rock (approximately equivalent to the term “soil” as used by many engineers.)

Search - the act of seeking or looking diligently for features

Sinking stream - a stream that disappears underground

Sinkhole - an elementary form of karstic depression, simple and closed, frequently circular or elliptical, wider than the depth, with a flat or funnel-shaped bottom. A general term for a closed depression. It may be a basin, funnel or cylindrical shape. (see also doline)

Stratified search - a search applied in layers and conducted sequentially

Surface inventory - the process of making a list of features found on the surface

Surface survey - the process of finding features on the surface

Swallet - the place where a stream disappears in a closed depression or a blind valley

Systematic surface inventory - an inventory characterized by a system or method

Transect - a transverse line (i.e., A line that crosses from side to side)

Understory - any plants growing under the canopy formed by others, particularly herbaceous and shrub vegetation under a tree canopy

Windthrow - also known as blowdown and windfall; uprooting by the wind. Also refers to a tree or trees so uprooted.

REFERENCES CITED

Paloc, H. Glossary of Karst Hydrogeology: A Selection of 49 Specific Terms. Bureau de Recherches Geologiques et Minieres. Orleans, France. (Géologiques et Minières)

Plants of Coastal British Columbia including Washington, Oregon and Alaska. Compiled and edited by Pojar, J. and MacKinnon, A. BC Forest Service, Research Program. Lone Pine Publishing. Vancouver, Canada. 1994

British Columbia Industrial Health and Safety Regulations. Workers' Compensation Board of British Columbia.

A Statement of Crown Land Cave Policy and Administration. Province of British Columbia. Ministry of Lands, Parks and Housing. Parks and Outdoor Recreation Division. January 1981.

First Draft of Cave/Karst Management Guidelines for Vancouver Forest Region. Province of British Columbia. Ministry of Forests. Vancouver Forest Region. Recreation Section. March 1981

A Method to Manage the Cave/Karst Resource within BC's Provincial Forests. Province of British Columbia. Ministry of Forests. Vancouver Forest Region. Recreation Section. August 1983.

Cave Management Handbook (Including Cave/Forestry Guidelines for the Vancouver Forest Region). Province of British Columbia. Ministry of Forests. Vancouver Forest Region. August 1990.

Stewardship of Cave and Karst Resources in BC: A Review of Legislation, Policy and Management. Prepared by G. G. Runka for the Recreation Branch, Ministry of Forests. G. G. Runka Land sense Ltd. July 1992.

Cave/Karst Management Handbook for the Vancouver Forest Region. Province of British Columbia. Ministry of Forests. Vancouver Forest Region. March 1994.

Cave/Karst Management Handbook for the Vancouver Forest Region. Province of British Columbia. Ministry of Forests. Vancouver Forest Region. May 1994.

Cave/Karst Management Handbook for the Vancouver Forest Region. Province of British Columbia. Ministry of Forests. Vancouver Forest Region. July 1994.

Outdoor Recreation and the Forest Practices Code of British Columbia: How outdoor recreation is managed under the Forest Practices Code. Ministry of Forests. Recreation Section. Range, Recreation and Forest Practices Branch. Province of British Columbia. February 1996.

Tahsish Cave/Karst Inventory Project. Conducted by Cave Management Services for BC Ministry of Forests. Report date: November 1982.

Draft Karst and Cave Resource Management: Forest-Wide Direction, Standards and Guidelines. United States Department of Agriculture, Forest Service, Tongass National Forest. June 1994.

Timber Tenure System in British Columbia. Government of British Columbia. Ministry of Forests. Resources, Tenures and Engineering Branch. (Unpublished brochure) March 1996.

R.J. Stathers et al. Windthrow Handbook for British Columbia Forests. Research Program Working Paper 9401. Ministry of Forests Research Program. 1994.

A Glossary of Karst Terminology. Geological Survey

Water-Supply Paper 1899-K. Complied by Monroe, W.H. United States Government Printing Office. Washington. Second printing. 1972

Industrial Health and Safety Regulation. Workers Compensation Act. Province of British Columbia. Consolidated January 14, 1994.

Syrotuk, William G. An Introduction to Land Search Probabilities and Calculations, Arner Publications, Westmoreland, New York. 1975.

Addendum:

Transcription from the October 1997 Karst And Cave Management Symposium Panel Discussion Regarding the Search Methods

Phil Whitfield:

Between grid searching and other techniques for karst inventory; Part 1, which is the ideal technique, and Part 2, which gives you the most bang for your buck?

Tom Aley:

I would argue that first you need to focus the inventory on what system you are dealing with on that site. If you're going through the woods on straight lines at whatever the separation between them is, what that is...is a search for random features. These are not random features - they are part of a system. Characterize the system, the processes that protect it and then do whatever appears to be the appropriate search for that system.

Jim Baichtal:

I think ideally the best thing to start with is to figure out the hydrology of the area. Then what Tom was saying that they're not random on the landscape? If you have a more experienced group of individuals out there they don't necessarily have to cover all the ground to probably get at least 90% of what's out there.

Tom Aley:

I think as you tend to have areas that appear to be more sensitive you might want to focus more attention on those areas. Or maybe put more focus on the areas that are marginal, should we stay out of them all together, can we perhaps do something. You can do a lot of tailoring of effort.

APPENDICES

Legislative Background

The Government of BC recognizes that caves are a unique non-renewable resource with geological, scenic, educational, cultural, biological, hydrological, paleontological and recreational values (ref). The protection and management of caves on Crown forest land in BC are considered to form an essential part of integrated resource management mandated under the BC Ministry of Forests. (ref)

In BC, where the public owns 94 percent of the land, the timber tenure system, and more specifically, tenure system and, more specifically tenure agreements, play a significant role in determining who is responsible for resource inventories. The current tenure system was established as a result of the 1979 Forest Act. The most common type of tenures containing karst resources in BC are the Tree Farm Licences (TFLs), Timber Licences (TLs) Forest Licences (FLs), and Timber Sale Licences (TSLs).

The Ministry of Forests is responsible for inventories on FLs and TSLs awarded under the Small Business Forest Enterprise Program. These two types or tenure make up 71% of the total annual allowable cut that is attributed to the various licences in BC. The licencees, typically large forest companies, are responsible for resource inventories on TFLs and TLs (about 29%).

Although many other statutes affect the tenure system, the Forest Practices Code (FPC) of British Columbia Act, introduced in 1995, and its associated regulations, are the most significant.

The Ministry of Forests Act requires the Ministry of Forests (MOF) to manage, protect, and conserve forest resources including recreational resources. The Forest Practices Code (FPC) of British Columbia Act - in Part 1 - Definitions of the Forest Practices Code Act - defines a "recreation resource" as (a) a recreation feature, (b) a scenic or wilderness feature or setting that has recreational significance or value, or (c) a recreation facility. The FPC Act further defines a "recreation feature" as "a biological, physical, cultural or historic feature that has recreational significance or value".

While caves and their entrances are not defined under the FPC Act, they are recognized as a subset of "recreation features" (ref). The FPC Forest Development Plan Guidebook (December 1995) on page 15 recognizes caves as "resource features". The FPC Logging Plan Guidebook (December 1995) on page 21 uses cave and karst features as an illustration of how to plan for a known “recreation feature”. As well, there are numerous cross-references to the FPC Cave Management Guidebook in preparation

The Forest Act and the FPC Act oblige licensees to establish where recreation features are found. Furthermore, these features must be identified on forest development plans and logging plans, pursuant to Part 3, Section 15 and Part 4, Section 33 of the FPC Operational Planning Regulation.

The IUCN Guidelines for Cave and Karst Protection

Elery Hamilton-Smith
Rethink Consulting P/L
P.O. Box 36, Carlton South, Victoria 3053, Australia

Abstract

In 1992 at the Caracas Convention, it was decided that work would commence on a series of guidelines for cave and karst protection. A small group headed by Dr. John Watson of Western Australia began preparing a draft which was circulated to cavers and cave managers throughout the world. Over 600 comments were received for preparation of the final manuscript which was produced in Australia during 1997. The guidelines centre upon the management of protected areas, but give due recognition to the fact that much of the world's karst is not in such areas. They place the focus on karst as a whole, not just on the caves. This is partly because many of the other features of karst are as important as the caves, and partly because effective protection of the caves is dependent upon protection of their context. There is clearly more work to be done on guideline development. In particular, we plan to look at karst-dependent biota, including not merely troglobitic fauna, but also the microflora of caves and the surface flora and fauna, with particular attention to those species found only on karst. Other special issues include the development of caves for tourism purposes and the protection of lava tunnels.

Introduction

The International Union for Conservation of Nature, first established in 1948, is the major world body working for nature conservation. It is an inter-governmental agency which also provides for membership by key voluntary national conservation bodies and for the participation of individuals in the various working groups within its structure. The major agencies through which it works are the commissions, such as the World Commission on Protected Areas (WCPA), the Species Survival Commission (SSC) and the Commission on International Trade in Endangered Species (CITES).

Within the WCPA, which is a network of over 1,000 individuals, a working group was formed and published in 1992 the booklet, *Guidelines for Mountain Protected Areas.* At the conference in Caracas in that year, Dr. John Watson of Western Australia undertook to prepare a comparable booklet on Caves and Karst. Other members of the network volunteered at least interest, and John recruited a small group in Australia to commence drafting a first manuscript. We commenced work using conventional mail for communication, but fortunately this coincided with the boom of development in the Internet, so that by the time the first draft was ready, it was made available through the World Wide Web. This meant that many thousands of people throughout the world read that draft and many hundreds made comments on it. Some regional editing means that we have little idea of exactly how many individuals contributed - but in all, over 600 changes were made to the draft as a result of their input.

The result is now published and available (Watson et al., 1997).

Some Constraints

We were aware right from the beginnings that we could not do justice to some issues that at least some people associated with caves would have liked to have seen dealt with.

The first of these was artificial cavities. While acknowledging the importance of many of these from a cultural heritage perspective, e.g., Tun Huang Grottoes of China or the Hypogeum of Malta, we felt that our working group was not the appropriate one to deal with such a matter. The only things genuinely shared with natural caves are the fact that they are underground and that their exploration may involve very similar techniques.

The second was much more problematic and comprised lava caves and other forms of pseudokarst. We noted in our document the importance of these, and that many of the principles and guidelines might well be applicable. But in a publication which was primarily focused upon the broader context of karst, even though giving a secondary focus to the caves in that context, lava tubes did not sit easily. We came to the viewpoint that to treat lava caves properly, they should be located within their own context of volcanic landforms. Bill Halliday has rightly responded that most vulcanologists see caves as relatively unimportant, and so even if a volcanic landforms group were formed, the caves might not get due recognition. We are, nevertheless, exploring the possibility of establishing such a working group. If it is not established, or if it is established but ignores caves, we will re-examine our position. Certainly, the next step in our program, discussed further below, is to examine issues relating to biota and here we must obviously pay attention to lava tubes as much of our contemporary understanding of the evolution of cavernicoles has profited greatly from studies in Hawaiian and Australian lava caves.

Then for reasons of space and time, we have not done justice to cave contents, including sediments, minerals, biota, and/or the palaentological / archaeological / cultural heritage within caves. We will be commencing with the biota, but will cast this widely, endeavouring to include karst-specific surface vegetation or fauna and cave microflora, both of which are so often omitted or under-valued in biological studies of caves and karst.

I think, in retrospect, we have also paid inadequate attention to karst islands, which is reprehensible when one considers just how many of the world's small islands are comprised of karst. Interestingly, my awareness of this as an omission resulted from work at Cape Range, Western Australia which is a peninsula rather than a true island, but where the karst is effectively an island and behaves as such.

Basic Principles

As noted above, we have assumed that we should focus first upon karst rather than caves, so that caves are treated within their broader context. At the same time, we recognise that the cultural importance of caves means that they, rather than the enclosing karst, often provide the perceptual focus of interest, even by land management professionals.

Secondly, we emphasised that karst system boundaries must be delineated in terms of watershed boundaries, and even further that subterranean watershed divides often do not coincide with surface divides. This means that protected area boundaries, for reasons of either history or economics, often fail to adequately protect the karst resource. Managers of karst protected areas thus often find themselves forced to try and influence the management of adjoining lands. Declaration of protected areas alone does not provide an adequate policy basis for karst protection - but it is often an absolutely important opening gambit.

Thirdly, we argued that the integrity of karst is essentially dependent upon maintaining the integrity of the hydrological system. Along with this, there are a number of other threats which must be considered in relation to the very distinctive vulnerabilities of karst landscapes.

Although perhaps not a major principle, this is a good place to note that throughout the guidelines we not only argue for protection, but to emphasise the potential importance of restoration of both karst areas and caves.

Some Guidelines

There is not enough space here to list all the 31 guidelines which have been proposed, nor indeed, would that be of interest. I have chosen to simply select some of those which can serve to demonstrate the approach taken, emphasising that we have endeavoured to constantly reflect the basic principles above. So, to some examples :

- Integrity of any karst system depends upon the relationship between land, water and air.
- Monitoring for groundwater pollution should be both event-based and at regular intervals.
- New caves should only be opened for tourism if sustainability can be demonstrated ; restoration of the old may be a better option.
- Protected areas are an important strategy but may need to be supplemented by catchment management agreements in one form or another.
- Karst not within protected areas may still be effectively protected through public education, planning controls, or heritage agreements
- Karst landscapes are complex in being three-dimensional and comprising rock, soil, water,

vegetation and atmosphere.

- Even apparently minor changes to the surface may have drastic impacts on karst, e.g., mining of karren for decorative purposes or inappropriate fire regimes.

- Observation of minimum impact codes by cave visitors : note in particular examples from Switzerland and Australia.

Finally in this brief description, much of what is contained in the publication will be familiar to experienced karst managers. However, every attempt has been made to ensure that the presentation is internationally relevant and acceptable and so provides a baseline for world utilisation. This does not mean that it is a lowest common denominator ; it focuses upon the attainment of what is fashionably termed 'best practice'. Most importantly, in representing a world standard, it will support and assist the efforts of even the most experienced karst managers to convince their political masters of the importance of good conservation practice.

Future Directions

Having now succeeded John as convenor of the working group, I must say a little about my own thinking on future directions.

One of these is to foster co-operative arrangements and sharing with other international bodies. There is no point in our own working group undertaking a task which is also being done, and indeed may be better done, by some other agency. We are already in touch with and planning arrangements for both co-operation and what might be termed 'job-sharing' with the International Geographical Union (IGU) and the International Speleological Heritage Association (ISHA). Indeed I must acknowledge the great contribution already made by ISHA in ensuring a much richer response to our initial draft by European countries then would otherwise have been possible.

Then I have already had a discussion with the newly elected chair of the Commission on Cave Tourism of the International Union of Speleology (IUS). It is anticipated that a project on establishment of standards for cave development for tourism purposes will be developed and implemented by this commission. Hopefully, this will also enlist the interest of the International Show Caves Association (ISCA).

Most immediately, we plan to commence work on a supplementary series of guidelines on the protection of karst biota. This in turn demands co-operation with those responsible for the Council of Europe policies in this area and with the Karst Waters Institute program here in the United States. We are also awaiting publication of a major work on karst communities which is currently in press with Elsevier and which will provide an even stronger data base than is yet readily available.

So, I see the future as an active and busy one. The special opportunities provided by working within an inter-governmental organisation are immensely valuable and if we are able to use them well, will help to strengthen karst protection throughout the world.

References

Watson, John, Hamilton-Smith, Elery, Gillieson, David and Kiernan, Kevin (Eds.) 1997. *Guidelines for Cave and Karst Protection.* IUCN, Gland, Switzerland and Cambridge, UK, 63pp.

Bat Interpretation by Infra-red Imaging at Naracoorte World Heritage Area, South Australia

Elery Hamilton-Smith and Brian Clark

Elery Hamilton-Smith
Rethink Consulting P/L
P.O. Box 36, Carlton South, Victoria 3053, Australia.

Brian Clark
Manager, Naracoorte Caves Conservation Park
P.O. Box 134, Naracoorte, S. Aust. 5271, Australia.

Abstract

Amongst a range of other remarkable features, including the massive deposits of sub-fossil vertebrates which led to its recognition as a World Heritage Area, the caves at Naracoorte house the largest known (and most Southerly) maternity site of the Bent-winged Bat, *Miniopterus schreibersii*.

It is just not feasible to make this site directly accessible to visitors. In order to provide an experience of the cave and its residents, four video-cameras with active infra-red LCD lighting have been installed. These can be 'driven' around the cave using controls in the visitor centre above, and also have a sufficient zoom capacity to home in a single bat, or even a single cockroach.

The images are transmitted to a series of television monitor screens in the visitor centre above. There is also excellent recording capacity for both education and research purposes Examples of the recordings will be shown.

Introduction

The Naracoorte Caves were discovered in about 1845, and became widely known by the 1860s. This was due in part to the presence of a "petrified aboriginal", taken by a wandering showman and placed on display in Sydney and then in Europe. But more significantly, it was the site of pioneering speleological research by the Rev. Julian Tenison-Woods, a remarkable priest recognised as one of the greatest Australian naturalists of the 19th century. Although his interpretations of the caves were probably seen as idiosyncratic at the time, in the light of current understandings he was much closer to truth than any of his contemporaries.

On his departure, interest in the caves focussed upon guano mining and then tourism, and their research values were overlooked or forgotten until the 1960s. It was then recognised that one of the caves housed the most southerly nursery colony of the Bent-winged Bat, *Miniopterus schreibersii*, usually housing some 250,00 individuals. The research which followed made a significant contribution to understanding the bionomics of this remarkable species, and led to the discovery of a number of new species of guanophilic invertebrates (Hamilton-Smith 1972).

Then in 1969, Rod Wells and Grant Gartrell dug their way into a previously un-entered section of the Victoria Cave and saw what proved to be an immense and truly diverse deposit of mammalian and other sub-fossils from the Pleistocene era (18,000-200,000 years BP). Further such deposits have since been discovered, including one of 400 m^2 in extent, and others which extend the age sequence back to 350,000 years. As a result, in 1994 the park was granted World Heritage Status together with Riversleigh in Queensland as the *Australian Fossil*

Mammal Sites. The fossil chamber in Victoria Cave has been open and interpreted to the public virtually since its first discovery. An above ground interpretation centre was also developed, and will shortly be replaced with an expanded and improved centre.

However, for purposes of this paper, we will focus upon the Bat Cave and the interpretive system which provides visitors with a close-up view of the cave interior and the bats at home.

The Bent-winged Bat

The *Miniopterinae* have long been recognised as a particularly distinctive sub-family of bats. Their most obvious feature is the long and relatively narrow wing, which is so long that it has to be doubled back when the animal is at rest. They fly high and fast, and feed largely on moths and beetles.

A key characteristic of the subfamily is that young are reared in caves which enable the population to build a warm microclimate which will enable survival of the young until they are able to regulate their own body temperature. In tropical areas, this is easy, and populations are often small, utilising a number of small maternity sites. However, in dispersing to the cool temperate zone, it becomes necessary to find caves with sizeable domes where a large population can generate the temperatures required. At Naracoorte, this means a dome of some 100 feet in diameter and 100 feet in height (Dwyer and Hamilton-Smith, 1965).

During late spring and early summer, the regional population which has dispersed over an area of some 100 miles radius commences a movement back to the maternity site, and the pregnant females gather at specific cave sites, again with a domed roof, but often relatively small, and now recognised as 'acclimatisation' sites. Others return to the maternity site, and the warming of that cave commences. Many, perhaps most, of the juveniles are born in the acclimatisation site and then transferred to the creche site.

The juveniles are placed in selected small domes within the large chamber, with the youngest located at the highest point where the temperature may reach as much as 37°C. As further new arrivals occur, so the growing bats are gradually pushed to the cooler outer edges of the cluster. As they become capable of independent flight, they will fly about within the cave for a short period, perhaps only several days, before going out to feed. At this stage, the total population may be as many as 200,000 bats.

By the age of about 15 weeks, they are weaned and disperse outwards to caves across the population range. Mating takes place during autumn (in the second year), but implantation is delayed during the winter torpidity, and finally takes place in spring, when the whole cycle repeats itself.

Until recently, the public were only able to see the exit flight. Entry to the cave itself would have disturbed the bats, been an unpleasant and somewhat frightening experience for most people, and exposed visitors to the possible (but unconfirmed) risk of histoplasmosis.

Using Infra-red Imagery

It was recognised that there was an excellent opportunity to provide an opportunity to help members of the public understand bats, and develop a recognition of the importance of habitat conservation. Bat flight viewing coupled with educational audio-visuals and talks were used for a period, but this was at the one time exciting and frustrating. Preliminary work on testing the feasibility of using active infra-red photography to display the bat cave to visitors commenced in 1994. Investigation showed that systems already developed for security surveillance purposes could be utilised, so installation and construction commenced in early 1995, with the new Bat Observatory being opened to the public in October 1995.

The installation currently involves four video cameras, each mounted on a track system with their actual location being able to be controlled from above ground. All have zoom lenses, again subject to remote control. Each camera has a hood to eliminate fouling of the lens, and each is fitted with an infra-red LED panel comprising some 30 diodes.

Real time images are transmitted by cable to the bat observatory above ground. Here they are displayed on a series of television monitors, and can also be recorded on or re-played from videotape. A staff member controls the cameras, and seeks out events and behaviour of special interest.

Although the objective is the enhancement of public understanding, the system clearly has great potential to facilitate research on the population. It has already demonstrated that the bats are much more active during daylight hours than had been expected, that they frequently drink from drip sites throughout the cave and they have complex patterns of movement from one roosting site to another, both over the course of a day and from day to day. The first of what is hoped to be a series of specific research projects is currently nearing completion.

The major problem is one of how we might best inform the public of the opportunity.

It is difficult to both capture the nature of the somewhat complex character of the experience and to overcome the initial aversion to bats which so many people have. Thus, in the first year of operation, only 2,400 visitors (out of a total of some 40,000 visiting the park as a whole) visited the centre. Part of the problem is that the centre competes with four other caves, each offering a totally different experience, and one having access to the remarkable fossil deposit. One could say that the problem is one of the embarrassment of having too much to offer. However, those who have visited the centre and watched the bats in their home setting express considerable enthusiasm and delight, and many have talked of the way in which it has helped them to perceive bats in a totally different way.

There has been only one disappointed customer who asked for her money back. She had brought her children to the park in order to show them Batman, Robin and the Batmobile!

Further experiment and development is under way, along with a multi-million dollar re-development and enhancement of the park as a whole. This includes a considerable extension of the park area, new picnic and camping areas, a new entrance to the Fossil Cave, a refit of another cave, and a new state-of-art visitor centre. This will make it possible to encourage visitors to stay long enough to see more of the park, and will doubtless assist considerably in marketing of the bat centre.

References

Dwyer, P. & Hamilton-Smith, E., 1965. Breeding Caves and Maternity Colonies of the Bent-winged bat in South-eastern Australia. *Helictite,* 4(1) : 3-21.

Hamilton-Smith, E., 1972. The Bat Population of the Naracoorte Caves Area. *Proceedings 8th. National Conference, Australian Speleological Federation,* pp. 66-75.

Monitoring visitor experience and environmental conditions at Jenolan Caves, New South Wales, Australia.

Elery Hamilton-Smith
Chairman, Social and Environmental Monitoring Committee
Jenolan Caves Trust.
P.O. Box 36, Carlton South, Victoria 3053, Australia.

Abstract

The Jenolan Caves are one of the most extensive and diverse cave systems in Australia. They were the leading tourist resort of Australian in the 19th. century, and remain popular to this day, currently attracting some 300,000 visitors per year. Although perhaps not a high number by world standards, the location of the caves in the bottom of a deep valley with precipitous hills on all sides leads to a range of environmental problems and constrains the quality of the visitor experience.

The Jenolan Caves Trust, responsible for managing this and three other cave systems, commenced examining options for further development. It became clear that the costs involved in providing improved access would be huge, and that this would only be financially viable if visitor numbers increased. In turn questions were then raised about the environmental impacts of a larger visitor population.

A think-tank session led to the establishment of a comprehensive program (based upon the VIM model) of monitoring the quality of both the environment and the visitor experience. Issues of visitor experience were included because it was felt that a full understanding of the values placed upon the site by visitors and the quality of their experience was central to any change strategies which may prove necessary.

This paper reports both progress and problems.

Introduction

Jenolan Caves are reputed to have been discovered in approximately 1838, although the details of that discovery are hidden in a mass of mythology. By 1866, they had become so well known as a site for excursionists that the government of the day placed a relatively extensive protective reservation over them and appointed a resident ‘keeper’ in the person of Jeremiah Wilson.

Wilson was an innovator. He established the use of magnesium ribbon photographer’s lamps for illumination, later replaced by probably the first electric illumination in caves by 1880 and then the installation of Australia’s first hydro-electric generator, and with his brother, also developed remarkably effective means of screening the caves against vandalism.

It soon became the leading tourist resort of the day, despite the distance and extremely difficult terrain between Sydney and the caves. People came by horse, coach, bicycle and even walking the 27 miles from Katoomba. Then in 1903, the first car made the journey, and the traffic has increased steadily ever since!

The Resource

The most spectacular surface karst feature is a wall of limestone 90 m high and 150m wide at the confluence of the Jenolan River, Surveyors Creek and Camp Creek. The three spectacular karst bridges - the Grand Archway and Devil’s Coachhouse at present stream level and Carlotta Arch at a higher level - are world famous. Small karst gorges occur in both the Jenolan River Valley upstream of the Devils Coach House and in the valley of Surveyors Creek.

Dolines are not plentiful but a number of small alluvial flats, apparently filled dolines, are significant features of the valley. Rillenkarren is the most common form of surface solution sculpture and is particularly well developed on Lucas Rocks.

The extent of cave development in a relatively thin (outcrop width of 300 m) body of steeply-dipping limestone is remarkable. The main Jenolan Cave System contains over 30 km of passage developed in a 1km length of the limestone body. Caves north of the Grand Arch are essentially horizontal stream passages developed at a variety of levels and joined at intervals by vertical shafts which may extend to the surface. Those south of the Grand Arch have prominent phreatic loops and appear to have formed under a higher hydraulic gradient than those to the north. In addition to streamways and phreatic conduit passages, Jenolan Caves contain a number of chambers resulting from both solution and breakdown, the largest of which is the Exhibition Chamber in Lucas Cave with a floor area of some 3,300 m^2. There are a multitude of tour routes through the cave system.

Jenolan is renowned for its range and profusion of calcite speleothems, including superb examples of less common forms such as helictites, ribbon helictites, shields, monocrystalline stalagmites and subaerial stromatolites. Aragonite speleothems, often with spectacular morphology, are found in restricted localities and result from a relationship with the weathering of dolomitic palaeokarst deposits. The gypsum speleothems, resulting from the weather of pyrite deposits within and adjacent to the limestone, are also significant and include forms not reported elsewhere, but are less well known than the calcite and aragonite speleothems.

The Beginning of Concern

The caves had long been managed by a diversity of government departments, and very little attention had been paid to environmental issues. Then the first plan of management was published in 1989, and in the same year, the Jenolan Caves Trust was established by the government with a charter to not only operate the caves as a tourist attraction, but to ensure protection of the natural and cultural resource values of the site.

Visitor numbers continued to increase, and concern about this mounted, partly because of the difficult access road and the constrained area at the caves led to an unacceptable degree of crowding, but also a genuine concern about impacts upon the karst resource. A study was commissioned in 1992 to examine options for future development and this focussed upon the problem of road access. However, this in turn led to a new concern about the problem of visitor numbers. It became clear that not only were numbers continuing to increase, but that a new means of access would both create and demand (for reasons of financial viability) a further increase in numbers.

Accordingly, still another study was commissioned to advise on the ‘carrying capacity’ of the reserve. This study operated on a ‘think-tank’ basis and in reporting (Manidis Roberts 1995), argued that the concept of carrying capacity was no longer a useful one, and recommended the establishment of a system of research and monitoring to identify the key problems and develop corrective management. This plan was based upon the Visitor Impact Management (VIM) system as developed by Prof. Alan Graefe of Pennsylvania State University (Graefe et al., 1990).

The Monitoring Program

VIM depends upon distinguishing the key environmental units within the overall resources, and at Jenolan, four have been defined - developed underground, developed above ground, undeveloped underground and undeveloped above ground. These four each consist of a range of sub-units, but within each unit, there is a relatively uniform set of values, vulnerability and problems. For example, all caves in the developed underground category suffer the same problems, all arising out of having too many people passing through, while the undeveloped caves have low visitor numbers but share the problems of trampling on unprotected floors and other physical damage.

The nest step involves defining objectives for each unit (or sometimes sub-units), and at Jenolan, this presents the first of our implementation problems. Although it is relatively easy to define a series of environmental objectives, there is no visitor services plan in place, and determination of objectives for either direction or quality of visitor service remains extremely vague and ambiguous. Once having established objectives in measurable terms, one seeks simple indicators which will demonstrate the extent to which objectives are or are not being achieved, which can readily be monitored and which will help to determine the cause of shortfalls in achievement. Where the need for action is identified, then management can respond, and hopefully, solve the problems.

This VIM approach was implemented in 1996, with a staff of two and a cross-disciplinary overseeing committee, known as the Social and Environmental Monitoring (SEM) Committee appointed in 1996. Some aspects of the program are implemented by the staff, often with the support of the SEM committee members, while other specific aspects which demand a better research base have been undertaken by graduate students, often under the supervision of one or more members of the committee.

As the program has developed, we have come to find some of the assumptions made by virtually everybody were wrong, and some indicators have taught us little, while others have emerged as a result of our experience. Thus, another of the implementation problems is the need to determine the most useful and practical directions, defined in terms of their outcomes for policy and decision-making.

The final problem worthy of discussion at this point is that the program is a relatively sophisticated and complex one, and for this and other reasons, we have not yet managed to communicate it adequately to tour guides and other staff, and hence not at all to the general public. But there is no question that to achieve the full potential of the program, it must be communicated to others. A newsletter is about to be published as a step in this direction.

The role of the committee is basically a two-fold one - the oversight of the program as discussed already, and advice to the Trust on our findings and their implications. In the first two years of operation, we have made a few minor recommendations, compiled a major report on traffic problems, and have just submitted our first 'State of the Environment Report' (Jenolan Caves Reserve Trust 1997: 20-23). This is essentially a social and environmental audit, and from now on will be submitted annually and included in the annual report of the Trust.

Some Illustrative Results

Given the complexity of the program, a few examples must now bring some life into this account and demonstrate some of the outcomes to date.

Motor Vehicle Emissions

At the time the SEM committee was established, it was assumed by both the trust and members of the committee that motor vehicle emissions, both gaseous and particulate, were a major problem. This was based in part on the extent to which exhaust emissions were often noted in the Grand Arch and at times could be detected by their odour penetrating into the caves. It was feared that these emissions may lead to serious damage to speleothems and to the cave environment generally. Accordingly, one of the first research programs developed set out to establish the extent of their impact. Somewhat to our surprise, we found that although both gases and dusts penetrated some 100 metres into the caves, they then ceased penetration quite abruptly and did not reach the well-decorated passages. It has since been established that this 100 metre point is the location of a thermocline, and that in a way which we do not yet fully understand, this thermocline acts as an effective barrier. Although there is still some concern about the accumulation of solid residues including zinc and cadmium from the tires of motor vehicles, the outer 100 metre zone is degraded in various other ways, some of long standing, and in general, we now see the emissions problem as less serious than many others.

As a side effect, I note that the testing for solid residues revealed “hot spots” in the caves with extremely high levels of lead, zinc, cadmium and copper. These all resulted from such practices as in-cave fabrication of metal steps or walkways and carelessness in waste disposal by electricians. Neither happens any longer.

The Access Road

In particular, I was asked at this stage to review the evidence relating to the need to replace the present access road. With the support of staff, other SEM committee members and various other scientists, I did this. The report argued that although the exhaust emissions could no longer be seen as a major threat, there were two other issues of very serious concern indeed.

The first of these was the discovery that not only was the road of antiquated and somewhat dubious construction, but it was constructed on a hillside which was at serious risk of landslides. This was borne out by the fact that there had been three such landslides in the previous thirty years, each of which had resulted in total road closure for a period of at least two weeks. Although the Department of Tourism had noted that this caused a serious drop in income, the frailty of corporate memory meant that nobody seemed to appreciate that this is a totally unacceptable level of risk.

The second was that the traffic congestion and confusion in the public area at the caves detracted greatly from the quality of the visitor experience ; the general concourse area, which should have been a pedestrian area, often resembled a peak period traffic jam, and was just not worthy of a world-class tourism destination.

The trust has been able to use this report in its efforts to expedite a decision by the relevant minister of government to allow them to investigate the construction of an alternative, perhaps by cableway.

Cave Temperature and Carbon Dioxide levels

Another concern about the cave environment was the impact of visitor numbers upon cave temperature and carbon dioxide levels. There certainly is such an impact, but temperature levels are less of a concern than anticipated. Because the highest peaks of visitor numbers are not at the times of highest surface temperature, the increase in temperature fails to reach the level of the maximum natural temperature. Certainly, if we used temperatures as measured at hourly intervals, we would could demonstrate an increase in average annual temperature, so our next question is to assess the impact of this increase in the average.

Somewhat similarly, the rise in carbon dioxide levels only rarely reaches the point where any threat is presented to human comfort or speleothem integrity. But the data accumulated will enable us to more adequately prescribe appropriate tour party sizes and timing for specific sectors of the cave.

The discovery recognition of the importance of the thermocline in all entrance tunnels now provides a new focus for research and possible monitoring. We may find that its behaviour is the simple indicator of in-cave environmental conditions which we need.

Dust in the Caves

One of the most difficult problems is that of dust deposition in the caves. Some of this dust is the natural result of roof fretting or other breakdown processes. However, far too much consists of lint from clothing, flakes of skin and other human-introduced debris. This was noticed many years ago, and led to the development of a washing program, initially with a steam generator, and later with a high pressure spray of cold (cave) water. Although relatively effective, scanning electron microscopy indicates that there is a slight impact upon the speleothem surface and obviously, this will be cumulative over a long period.

It is clearly desirable that we find an alternative response which will prevent or at least reduce accumulation. One useful way of reducing such inputs proved to be the removal of the excessive protective wire screening in the caves which had served to extract lint from clothing as visitors brushed past it. This was actually undertaken for aesthetic reasons, but reduction in lint levels was a valuable side-effect. Consideration is now being given to a test program of issuing suitable overalls to visitors. Further comments or suggestions will be welcome.

Quality of Visitor Experience

I have already noted that the objectives for visitor experience are not formally articulated, and by extrapolation from practice, are vague and ambiguous. Little attention is given to meeting the specific needs of specific kinds of visitors. So, we cannot yet proceed by measuring the extent to which objectives are achieved.

Immediately prior to the appointment of the SEM committee, a market research consultancy were commissioned to undertake a study of ‘visitor satisfaction’. Apart from some technical problems with the execution of this study which made the results of very low reliability, one can only have very serious doubts about the simplism of the visitor satisfaction concept when examining a phenomenon as complex and interactive as the tourism experience.

So currently, we are developing a number of exploratory studies to examine such dimensions as the values, perceptions and expectations of visitors. The first of these examined, largely through systematic participant observation coupled with informal interviewing, the expectations and experiences of those travelling to the caves on tour buses. The purpose of these studies is to inform the development of a visitor services plan.

Conclusion

Our experience does not necessarily serve as a model for other areas. It grows out of the very special characteristics of Jenolan Caves as a resource and the Trust as a managerial environment. It is dependent upon a high level of funding and ready availability of expertise from the SEM Committee members and their colleagues. However, I would argue that the underlying principles, adapted as they are from the experience of Graefe and others in the US National Park system, are of very wide application.

As one contrasting example, I have been commissioned to develop a parallel program for the Australian Alpine Parks - a complex of extremely diverse parks under the administration of park agencies from three different governments - with the specific brief that whatever we do must demand minimal finance and manpower ! There is no question that if adopted, the VIM can achieve what they need, even though it will not be at the level which we should be able to achieve at Jenolan.

Examining the potential application of the VIM process to other areas has led us to look critically at the underlying assumptions of the process. As a result, we are shifting from a visitor impacts focus to quality maintenance focus. This arises out the extent to which other human activities, (e.g., soil disturbance off the reserve area, feral animals, etc.) also have a potential impact upon natural environmental processes.

The other point that the Jenolan experience, coming as it does after a lifetime of involvement in issues relating to cave management, convinces me that every significant cave or karst area that wishes to maintain environmental quality and/or quality of visitor experience, should develop a deliberative program of this type.

References

Graefe, AR, Kuss, FR, & Vaske, JJ, 1990. *Visitor Impact Framework.* Washington, DC, National Parks and Conservation Association.

Jenolan Caves Reserve Trust, 1997. *Annual Report 1996-97.*

Manidis Roberts Consultants, 1995. Determining an Environmental and Social Carrying Capacity for the Jenolan Caves Reserve. Bathurst, NSW, Jenolan Caves Reserve Trust

Cave Softly . . . and Leave No Trace - Poster Presentation

Val Hildreth-Werker and Jim C. Werker

Abstract

Visitor impacts and restoration efforts in undeveloped caves are illustrated through this educational poster display. The exhibit, coordinated by Val Hildreth-Werker, is a joint project between the USDA Forest Service and the National Speleological Society. The five museum-quality display boards were designed as add-on pieces for a Forest promotion of the caves on the Guadalupe Ranger District of Lincoln National Forest. Emphasizing the ethic of cave softly . . . and leave no trace, the caption on each photographic board describes an aspect of destruction along with the restoration efforts required to repair or remediate the damage.

A Synthesis of New Cave Lighting Design Concepts Using Low Voltage Lighting Systems to Light Developed Caves

Rodney D. Horrocks

Abstract

A new low voltage cave lighting design concept was developed by Neil Kell after visiting many of the show caves in the U.S., Caribbean, Australia, and New Zealand in 1993. This new concept establishes two separate lighting systems, an access (trail) system that addresses safety concerns and a feature-based system that reduces resource damage and facilitates interpretation. The primary purpose of the access lighting system is to assure safe travel for visitors during a normal tour and during an emergency evacuation of the cave in case of a power outage. The feature lighting system is designed to protect cave resources and highlight features both as an aid in interpretation and to provide visually appealing scenes for the public. The system essentially eliminates algae and disability glare and reduces vandalism. It also limits impact on the cave from routine maintenance of lights, by careful wattage selections and by using specially-designed shrouds and light placement techniques. Since its design is not restricted by an attempt to use the same lights for access, creativity is used to design a system that addresses visual effect and atmosphere. This concept incorporates the intrinsic nature of caves into the design, and it combines contrast, texture, and color into visually eye-catching scenes. The system allows for interaction between the interpreter, public and the cave environment, providing maximum flexibility in accommodating varying visitor interests. This system tells an interpretive story, lighting aspects of history, cave origin, speleogens, and speleothems. This lighting concept, which has been applied at Timpanogos Cave, Utah, and Mitchell Caverns, California, can better protect our caves, save energy, and give our interpreters a valuable tool to better interpret the underground world.

Mountain Ladyslippers on White Ridge, Vancouver Island

by Frank Hovenden and Betty Brooks

White Ridge is a new (1995) Class A Provincial Park which abuts the western edge of Strathcona Park on Vancouver Island. It is 1315 hectares in size and is known not only for its well developed karst geology, but also its rare plants.

Last summer the caving community held a "speleofest" there. Experienced cavers from throughout North America gathered to explore and map some of the extensive cave systems which are found in the White Ridge area. While hiking with some of the cavers one of the authors discovered a small patch of Mountain Ladyslipper (*Cypripedium montanum* Dougl. ex Lindl.) growing on the face of White Ridge (August 8,1996). Although we have worked and recreated in this region for many years neither of us had ever seen this magnificent orchid before.

A review of the literature (Szczawinski, 1975) showed that there have only been scattered reports of its presence on Vancouver Island (in the southern portion) and that it was believed to be extinct on the Island at the present time. The last previous record was from Spectacle Lake in 1958.

The species ranges from Alaska south to California and east to Saskatchewan. It is found in a number of scattered locations in B.C. mainly east of the Coast-Cascades Mountains. The only coastal mainland record is from Bella Coola (1966). It is represented in 8 of the 12 B.C. biogeoclimatic zones, with White Ridge being the only record in the Mountain Hemlock (MHmm1) zone.

In conjunction with the Strathcona Wilderness Institute we revisited the area this year to relocate the patch of orchids, accurately describe the site, and collect a specimen for the Provincial Museum. The orchids were found growing on a unique microsite on the exposed limestone face of White Ridge. There are approximately 150 to 200 plants growing in an area measuring 4m by 1m. They are growing in a small pocket of organic soil mixed with pulverized limestone. When visited on July 28,1997 the flowers were in full bloom. The site is located on a small bench which runs across the bare limestone face with slopes in excess of 120%. It has a westerly aspect and an elevation of 1100m above sea level. This area is constantly being disturbed by snow slides during the winter months. Although the particular site is somewhat protected by a band of scrub timber some 50 m above, it is in an extremely vulnerable situation. There are epikarst features directly associated with the site. There is a .3m tube in the limestone 5m west of the site while a small cavern is found behind it at the base of the slope.

The plants directly associated with the Orchids are the following: Yellow Cedar, (*Chamaecyparis nootkatensis*), Falsebox (*Pachistima myrsinites*), Red Columbine (*Aquilegia formosa*), Indian Paintbrush (*Castilleja sp.*), Western Mountainbells (*Stenanthium occidentale*), Early Blue Violet (*Viola adunca*), and Western Sweetvetch (*Hedysarum occidentale*)

Other plants growing within a 5m radius but not associated directly were: Spreading Phlox (*Phlox diffusa*), Martindale's Lomatium (*Lomatium martindalei*), and Silverleaf Phacelia (*Phacelia hastata*).

Time and safety did not permit an extensive search for other patches of Orchids. However, similar microsites nearby showed no sign of the plant. Rock climbing gear will be necessary to undertake a proper search for other specimens at this location. At this time access to White Ridge Park is difficult. The bridge over the Heber River has been removed and the roads used by the former Elk River Timber Company have been abandoned. The trails that exist are primitive. While we oppose any development in this unique Park we would like to see improved access to aid both cavers and naturalists.

The discovery of the Mountain Ladyslipper growing on Vancouver Island is interesting, however the fact that it is growing so far from its previously reported range on the Island is significant. To the best of our knowledge this is the only report of it growing in the Mountain Hemlock (MHmm1) zone.

REFERENCES:

Douglas, G.W., G. B. Straley & D. Meidinger. 1989-1994.(4vol.) The Vascular Plants of British Columbia. Ministry of Forests, Research Branch, Victoria, B.C.

Green, R.N., & Klinka, K. 1994. A field guide to site identification and interpretation for the Vancouver Forest Region. B.C. Ministry of Forests, Victoria, B.C. Land Management Handbook No.28

Straley, G.B., R.L. Taylor & G.W. Douglas. 1985. The

Rare Vascular Plants of B.C. Syllogeus No 59. National Museums of Canada, Ottawa.

Szczawinski A.F. The Orchids of British Columbia British Columbia. Provincial Museum Handbook 16, Victoria, B.C.

Photo Captions:

1) Steve Smith of the Strathcona Wilderness Institute admires the Ladyslippers. (photo credit Hovenden)

2) Mountain Ladyslipper *Cypripedium montanum* Dougl. ex Lindl. (photo slide credit Brooks)

3) Map of the area

4) photo showing orchids and site (photo credit Hovenden)

5) photo Mountain Ladyslipper (photo credit Hovenden)

6) view of site (photo credit Steve Smith)

Biography of Authors

Betty Brooks is a naturalist/biologist from Black Creek, Vancouver Island. She has a special interest in the rare flora of Vancouver Island.

Frank Hovenden is a forester who has worked on the west coast of Vancouver Island for 18 years. He is a member of the Comox Valley Naturalists Society and writes a column called “For the Forest” which appears in the “Record” published in Nootka Sound.

The Great Leap Forward - Deforestation Ecological Disaster in the South China Karst Belt

Peter Huntoon, Ph.D.

The Sublime south China karst belt, host to some of the most exotic landscapes found on earth and a population well in excess of 100 million people, has been profoundly and detrimentally impacted by massive post-1958 deforestation. Although south china occupies a subtropical monsoon climatic zone, it endures an annual flood-drought cycle. This cycle has been sufficiently exacerbated by the loss of the “green reservoir” that desertification has occurred over large areas. A primary impact of deforestation has been lost retention of water in the uplands. Surface runoff has become more flashy, and stream discharge recessions brief. The consequence has been increased flooding during the rainy season followed by parched conditions during the dry season. Existing ground water supplies have become unreliable. Upland springs and seeps have dried up. Lowland springs, wells, and blue holes now experience accelerated and more severe dry season water level declines. Wildlife populations were decimated. Risks of crop failures have risen. The situation has grown precarious for a regional population that is as little as two crop failures away from starvation. Two trends thwart recovery: (1) heavy dependence of the local population on wood for fuel and (2) a population explosion. Reforestation efforts are underway, but they are gradually losing to human encroachment. Development of ground water offers a degree of mitigation. However, the thin, shallow karst aquifers present are characterized by an unusually great ability to transmit large volumes of water rapidly out of the region. They also possess minimal reservoir storage. Remarkable ground water developments, driven by desperation, are proceeding, but they are fraught with frustration.

State Endangered Species Associated with the Spelean Environment_Poster Presentation

George N. Huppert, Ph.D. and Betty J. Wheeler

Abstract

The passage of the Federal Endangered Species Act in 1973 prompted a number of states to draft and pass their own acts to protect state endangered species. Generally, these are species that are not endangered at a national scale but may be endangered in a given state. These species usually do not meet national standards for listing. A few states merely duplicate the federal list. A number of states have no law, however, some of these states may list species needing protection and regulate them through other laws and regulations. In most cases, the federal law requires protection of the habitat of endangered species, but state laws vary in this requirement. Some state laws are enforced only on state and federal land but not on private land. A preliminary listing of state laws and species is presented for informational purposes. As with all laws, they are only as effective as the enforcement given them. This enforcement varies greatly among the states, and because of the difficulty in documentation, it is beyond the scope of this paper.

BCI's North American Bat Conservation Partnership: Cooperative Aid for Bat Cave Management

Jim Kennedy
Assistant Director NABCP
Bat Conservation International
Post Office Box 162603
Austin, TX 78716-2603

Abstract

Early in 1997 Bat Conservation International formalized a cooperative effort to promote bat conservation, education, and research. The North American Bat Conservation Partnership, as the new program is named, helps bring people and funds together for bats. Many important federal agencies and nationwide conservation organizations have already committed themselves as partners. An expanded Web site, several publications and workshops, research support, and direct action at site level have all increased the discussion and subsequent solutions for regional bat problems. Applications are available for matching-grant funds.

Introduction

I am here today to tell you about the newest program at Bat Conservation International, and how it can help you achieve cave management goals. I am the Assistant Director of the North American Bat Conservation Partnership. Why does the CMS get the Assistant Director and not the Director? There are two reasons actually. I'm the caver in the group, so it is logical for me to represent BCI at this Symposium. Also the NABCP Director, Steve Schmauch, is giving a similar talk this week at the Bat Research Symposium in Tucson, which was unfortunately scheduled at the same time as this meeting. So what is the NABCP and how can it help us as cave managers? Simply put, the NABCP is a continent-wide effort to join people, projects, and money together to further progress in bat conservation efforts.

Background and Organization

NABCP is a core program at BCI, involving our existing National Bats and Bridges program, the North American Bat House Research Project, the well-known Bats and Mines program, and the Student Scholarship program. Some of the educational workshops that BCI conducts are part of the educational program of the NABCP. In addition to guiding these programs, the primary focus of the NABCP is to develop a continent-wide communication network involving everybody interested in bat conservation, and work with funding sources to provide real solutions for achieving efficient and effective bat conservation initiatives. This concept, where key partnerships work in conjunction through the NABCP with local or regional partners, magnifies the ability of scarce conservation dollars to accomplish goals that would not otherwise be possible.

Since initiating the Partnership at the beginning of the year, we have busy setting the framework of the NABCP program in place. Some of the most knowledgeable and leading bat authorities have agreed to be part of an Advisory Council that has helped us establish the framework documents for NABCP. We want to thank Drs. Dixie Pearson, Gary McCracken, and Tom Kunz from the U.S., Brock Fenton and Robert Barclay from Canada, and Rodrigo Medellín and Arnulfo Moreno from Mexico for volunteering, and for the valuable input we have received from them.

We have also established three regional working groups of leading bat biologists who represent the widest possible range of local and species-specific knowledge. Members who have agreed to be a part of these working groups include: Scott Altenbach, Patricia Brown-Berry, Jim Nieland, Mark Perkins, Mary Kay Clark, Rick Clawson, John MacGregor, and David Saugey. Others can be added as it becomes relevant or necessary. The key roles of these working groups are to set regional conservation priorities and to evaluate project proposals for funding.

BCI plays a lead role in raising NABCP funds from well-known sources and from sources that are typically unavailable for financing bat conservation projects. The program recruits federal and state agencies, philanthropic foundations (such as the National Fish and Wildlife Foundation), corporations, and a wide variety of private conservation organizations, groups, or individuals in a broad, voluntary collaboration to help conserve bats and bat habitat. NABCP's Federal founding partners include the BLM, EPA, FHA, USFWS, USFS, USGS, NPS, and NRCS in the United States. In Mexico, founding partners include the Asociación Mexicana de Mastozoología, Fondo Mexicano para la Conservacion de la Naturaleza, and the Instituto de Ecología, UNAM. We are actively seeking similar partners in Canada.

Each year funds are set aside in a "matching pool fund" to encourage collaboration with partners in addressing NABCP priorities in conservation, education, and research. Potential collaborators are informed of available funds and are provided with applications and guidelines which explain NABCP priorities most likely to be funded by BCI. (see appendix 2) BCI plays the lead role in raising NABCP funds that are set aside annually to encourage peer-reviewed, matching-fund collaboration between partners and others who share NABCP goals.

NABCP Programs

The main goals of the NABCP are in the areas of research, conservation, and education. We want to support projects that have the broadest impact on ecosystems, provide long term solutions, are most logistically and economically feasible, and have the most positive impact in gaining broad cooperation. Specifically, we want to: 1) establish cohesive regional conservation strategies, 2) acquire knowledge of bat status and needs, 3) identify and implement the protection of key habitats, 4) and educate the public and enlist their support, by providing training and materials that empower independent action.

We have had much progress towards fulfilling our goals, but there is still much to do. We have created a Web page (http://www.batcon.org). Many of you are probably already familiar with our Web site, but may not be aware of the most recent additions. For example, we now have inventoried and listed the 6,000 + bat papers in our library, and you can use a local search engine to easily find your particular subject matter without leaving your desk! You can also find an electronic "Rolodex®" listing major bat contacts from across the continent. We have also compiled a listing of bat cave closures across the U.S., but are still missing information from several important states. The next step for our Web site is to provide information from our joint collaborative project with the USGS - Biological Resource Division (formerly the National Biological Service): the *Species of Concern Handbook*. This information will be of tremendous value for land management issues, and will contain complete, up-to-date USA species range maps, developed in a GIS format. We have also been approached about using the Web site as a clearing house for other information, such as a continent-wide repository for bat banding data.

Educational projects are also an integral part of the NABCP. We have recently worked in conjunction with our Mexican partners to produce this easy-to-use field key to Mexican Bats, *Identificación de los Murciélagos de México, Clave de Campo*. It is a wonderful visual product complete with range maps that allows rapid, easy identification of the 137 species of Mexican bats by biologists and cavers with a knowledge of Spanish. We are also working on an new, expanded gating manual. Tentatively titled *Gating Caves and Mines*, the book will cover the different types of cave protection, pre-planning for gate building, timing, environmental issues, volunteer cooperation, and gate building techniques. It will feature the most modern minimum airflow disturbance bat-friendly gate designs. *Gating Caves and Mines* is a collaborative effort of BCI, the American Cave Conservation Association, the National Speleological Society, and the US Fish and Wildlife Service. It is scheduled for distribution by late next year. Other publications soon to be issued are the second edition of *Bats and Mines* and the aforementioned *Species of Concern Handbook*.

I won't go into great detail on the important bat research we sponsor, since most of you here are not bat specialists. I just want to mention one of our most exciting projects, the "Bats Aloft" program. Dr. Gary McCracken is discovering some very exciting information about how bats intercept and feed on high flying, northward-migrating populations of crop-destroying insects. Drs. John Whitaker and Tom Kunz have also reinforced this new data through their dietary research studies on Mexican freetailed bats. Also as part of our NABCP activities, we fund graduate scholarships to support similar good scientific bat studies that help to provide key conservation information where gaps currently exist.

Now let's talk about cave conservation. One of our more publicized recent projects involved the protection of Stanton Cave in Grand Canyon National Park, Arizona. Stanton Cave is an example of how BCI and five other cooperators worked together, each providing $3000, manpower, and material resources to replace a bat un-friendly gate (actually, a chain-link fence) with a secure, bat-compatible gate. This cave once housed one of the largest maternity colonies of Townsend's big-eared bats *(Corynorhinus townsendii)* known in Arizona. Archeological excavations and other disturbances from the 1970s lead to population decline, until 1986 when there were no bats left. In 1997 the cooperators lugged several tons of steel up very steep slopes and erected a proper gate. Recent monitoring indicates that more than 160 bats, including the Townsend's, are once again starting to re-occupy this former maternity site. This is quite a success story, showing how by working together, we can effectively accomplish much towards our common goals of protecting cave resources, including bats. The story is featured in detail in the Fall 1997 issue of our magazine, *BATS*.

There are a few other recent cave projects that I can talk about . Boulder Cave in Washington was the site of the first-ever Cave Gating Workshop last month. Sponsored by the Northwest Chapter of the ACCA, the US Fish and Wildlife Service, the Wenatchee National Forest, and BCI, the two week-long sessions attracted 20 students who built two gates to protect part of the cave for Washington's largest historic roost of Townsend's big-eared bats. This past winter I led a team of caver/biologists to inventory two caves in the Monongahela National Forest in West Virginia. No sensitive species were found in Bradshaw Run Cave and Left Tit Pit, and the data gathered on that trip will greatly aid the Forest in managing those cave resources. Far from frozen West Virginia is El Infierno de la Camotera in Nuevo León, México. I worked with Arnulfo Moreno, a Mexican bat biologist studying the endangered Mexican long-nosed bat *(Leptonycteris nivalis)*. With other cavers, I trained Arnulfo in vertical techniques and accompanied him on trips into the 55m deep pit. We found that El Infierno is an extremely important roost for that species, harboring a maternity colony of several thousand as they make their way northward following the agave bloom, their food source.

The next big step for the NABCP program is our newest conservation initiative, "Bats in American Forests". All 250 million acres of our national forests are coming up for land planning revisions. Most, if not all, of these plans have been silent with respect to management standards for bats. The USFS is now being challenged project by project through appeals and litigation. They need our help. If we, the conservation community, academic institutions, federal and state agencies, and BCI work together to clarify the issues and gaps in our knowledge, and allocate our shared resources to these needs, we can do a huge service to the USFS and indeed, the bats and the public lands that depend on them.

The NABCP is about working together for America's bats. We are even now compiling regional bat priorities. We will share them widely with bat working groups and others with the goal of gaining consensus for the highest priority actions, and allocate limited resources accordingly. We are also gearing up for our first round of matching grants. The money we have is not a lot yet, but with your help, and others in the field, we know these dollars will be spent on the highest conservation priorities.

I have with me applications and guidelines for anyone interested in submitting project proposals for funding. These will give you all of the details necessary. These proposals need to be in by the end of this year. Successful projects will receive funding next April. I will be available during the rest of this Symposium for more details.

Conservation efforts do not have to exist in a vacuum. Our North American Bat Conservation Partnership is one very powerful tool to use for cave management and protection. The successes achieved through cooperation allow us to a accomplish far more than we can as individuals. That's what we are all about: successful conservation for our threatened resources.

APPENDIX 1:

North American Bat Conservation Partnership

POLICIES AND PROCEDURES

Leadership and Peer Review—The North American Bat Conservation Partnership (NABCP) is administered through Bat Conservation International (BCI) from its headquarters in Austin, Texas. It employs a full-time staff of two, an NABCP Director and Assistant Director, assisted by additional part-time staff biologists at BCI. The Director plays a lead role in communicating and setting time lines with the Advisory Council, Working Groups, and project partners. NABCP relies upon the Advisory Council for peer review of policies, procedures and strategic planning documents, which are revised and resubmitted for final approval by at least a two-third majority, prior to implementation. The Advisory Council consists of a minimum of six nationally recognized leaders in bat biology, representing Canada, Mexico, and the United States.

Each regional Working Group consists of at least four members who are experts in bat research and/or conservation, representing the widest possible range of regional and species-specific knowledge from each of the following faunal areas: 1) Mexico, 2) western North America, and 3) eastern North America. Within each group, at least one Regional Coordinator is appointed who is responsible for intra-group communication, solicitation of suggestions from appropriate government agencies and conservation groups, and timely submission of agreed-upon priority recommendations to the NABCP Director. The Working Groups assist in setting local and species-level priorities and may serve as reviewers for project funding proposals. The Director coordinates with the Advisory Council for the timely approval of those priorities. This information is distributed to all participants and to any other potential collaborators on request. Suggestions are welcome. Periodic revisions are anticipated and follow the original procedure, relying on the Advisory Council for final approval.

Strategic Planning and Priorities—The North American Bat Conservation Strategic Plan is developed as follows: 1) Working Groups recommend conservation, education, and research priorities, 2) the NABCP Director and BCI staff facilitate communication, collate these Working Group priorities, present them for Advisory Council review, make needed revisions, submit copies to appropriate partners for comment and suggestions, and make needed revisions within established time lines, 3) the Advisory Council conducts final peer review and approval, and 4) the plans are implemented.

The North American Bat Conservation Strategic Plan guides partner activities on behalf of bats, provides opportunities for collaboration, serves as the basis for review of matching-fund proposals and opens new funding opportunities. This document is not meant to dictate partner activities, but rather to serve as a convenient coordination tool for North American bat conservation.

The first priorities will be actions that: 1) have the broadest impact on ecosystems, 2) cannot be delayed without serious consequences, 3) provide long-term solutions, 4) are most logistically and economically feasible, 5) and have the most positive impact in gaining broad cooperation.

Protection of roosts which include a large proportion of a region's bats, exceptional species diversity, or the largest remaining groups of species that are endangered or in rapid decline is a high priority. Habitats adjacent to key bat roosts warrant priority consideration, especially when they are in rapid decline or already "rare." When the loss of key roosts is unavoidable, artificial roosts may also become important.

Education initiatives which emphasize specific needs and are most cost effective in reaching the most people in target audiences are high priorities. These actions offer opportunities for broad collaboration among partners. Educational materials may emphasize such issues as the roles of bats in maintaining the balance of nature and human economies, conservation and management needs of bats, or resolution of public health or nuisance concerns.

Research priorities are those that most benefit conservation and education initiatives, such as studies that document habitat needs, ecological or economic roles, or population trends. Also important is the development of improved techniques for studying these issues or for resolving public health or nuisance problems. In some areas, field surveys are needed to document locations of key roosts and habitat. Additional suggestions for prioritizing bat conservation, education and research needs are found in the NABCP Strategic Plan.

Fund Raising and Matching Grants—BCI plays a leadership role in raising NABCP funds through private donors, federal and state agencies, corporations, and foundations such as the National Fish and Wildlife Foundation. Each year funds are set aside in a "matching pool fund" to encourage collaboration with partners in addressing NABCP priorities in conservation, education, and research. Collaborators are informed in October of available funds, and are provided with applications and guidelines which explain NABCP priorities most likely to be funded. The deadline for receiving project proposals is December 31. The Assistant Director ensures that all applications address an approved priority, and are complete before sending them for review by at least three regional or national experts whose knowledge is most relevant to the proposed project. The review process will be completed during the first three months of each year, and successful proposals will be awarded funds in April. After signing, recipients receive 75% of awarded funds, the remainder upon receipt of a final report.

Project proposals will be numerically ranked by reviewers who will score them in each of 11 areas as follows: 1) unacceptable; 2) average; 3) above average; or 4) outstanding.

1. Accordance with established local and species-level conservation priorities.

2. Feasibility of a project, based on stated budget, personnel, and completion schedule.

3. Appropriateness of approach to solving the stated problem.

4. Proportion of costs to be matched locally or defrayed through volunteers.

5. Impact in protecting large numbers of bats or populations especially important to and endangered or rapidly declining species.

6. Probability that this action will benefit additional fauna or flora beyond bats.

7. Extent to which this action solves a problem without requiring an ongoing commitment of resources.

8. Urgency of threats to be addressed.

9. Likelihood of this being the last opportunity to address the issue.

10. Impact in generating additional cooperation from key allies or the public.

11. Probability of project promptly providing measurable results leading to population recovery, improved management policies, or public protection.

Projects receiving the highest cumulative scores will be considered by the NABCP Director for full or partial funding. Since worthy needs are anticipated to always exceed available funds, the amount of matching funds and/or local volunteer contributions of time and resources will be an additionally key consideration. Finally, to the extent possible, funds for top-ranked proposals will be distributed equitably among the NABCP's geographic regions.

Time Line Management—In order to minimize time stresses on professionals committing time to Working Groups or the Advisory Council, procedures allow for individuals to be temporarily unavailable without jeopardizing overall NABCP time lines and review. Review and approval of policies, procedures, or priorities will require a majority consensus. The NABCP Director may suggest new member appointments if delays become a problem since timely completion of plans and projects is essential to partnership credibility.

Information Resources—The NABCP provides access to field consultation and website databases. The following information will be available on the BCI website: 1) contact information on leading bat biologists, conservationists, rehabilitators, excluders, and public health officials available for consultation; 2) bibliographies of more than 6,000 publications about bats and related topics; 3) text and photos from the first 14 years of *BATS* magazine. Additional website information, field consultation, and other services will be shared through project collaborators and BCI staff as it becomes available.

APPENDIX 2:

North American Bat Conservation Partnership

CONSERVATION FUND APPLICATION PROCEDURE

Introduction

The Conservation Fund is available to support projects that most effectively help bats. Annual applications for assistance must be submitted prior to December 31st, though conservation emergencies will be addressed as necessary. All applicants must fully complete and submit a Conservation Fund Application Form to the Project Assistant Director, Jim Kennedy at Bat Conservation International. E-mail submission is preferred; electronic information and applications are available from our web site at http://www.batcon.org. Otherwise, four copies are required.

The Assistant Director ensures that proposals are complete and appropriate to NABCP Conservation Fund goals before forwarding them for review by at least three regional or national experts who's knowledge is most relevant to the proposed projects.

Award Criteria

Project proposals will be numerically ranked by reviewers who will score them in each of 11 areas as follows: 1) unacceptable; 2) average; 3) above average; or 4) outstanding.

1. Accordance with established local and species-level conservation priorities.
2. Feasibility of a project, based on stated budget, personnel, and completion schedule.
3. Appropriateness of approach to solving the stated problem.
4. Proportion of costs to be matched locally or defrayed through volunteers.
5. Impact in protecting large numbers of bats or populations especially important to and endangered or rapidly declining species.
6. Probability that this action will benefit additional fauna or flora beyond bats.
7. Extent to which this action solves a problem without requiring an ongoing commitment of resources.
8. Urgency of threats to be addressed.
9. Likelihood of this being the last opportunity to address the issue.
10. Impact in generating additional cooperation from key allies or the public.
11. Probability of project promptly providing measurable results leading to population recovery, improved management policies, or public protection.

Projects receiving the highest cumulative scores receive priority consideration for assistance by the NABCP Director.

All applicants will be notified in April of proposal status. Submitted materials will not be returned. Funding may be full or partial. Grant recipients must sign a standard completion and reporting agreement and liability waiver. Upon signing, the recipient will receive a check for 75% of committed funds. The remaining 25% will be retained by BCI until the project is completed and a final report and professional quality slides of project activities are received. Grant recipients must notify the NABCP Director immediately if their project falls behind its approved schedule for completion. Only projects planned to be started in calendar year 1998 will be selected. NABCP funding is for one year only. Multiple-year projects that are selected for first year funding must reapply each year.

For More Information

For more information contact Assistant Director Jim Kennedy via e-mail (jkennedy@batcon.org) or phone (512-327-9721) or write to:

Bat Conservation International
North American Bat Conservation Partnership
P.O. Box 162603
Austin, Texas 78716-2603

Additional funding is available for student research on conservation-relevant issues. Contact Bat Conservation International's Student Scholarship Program Director, Angela England, for details at (512) 327-9721, or aengland@batcon.org.

Bat Conservation International

NORTH AMERICAN BAT CONSERVATION PARTNERSHIP

Application for Project Funding

Applicant Information

Name: ____

Title or Job Description: ____

Organization: ____

Address: ____

Phone #: __________________ FAX #: _________________ E-mail: ________________________

Reference and Phone #: ____

Project Information

General category of project (circle one): *Conservation* *Education* *Research*

Title of project: ____

Location of project: ____

Expected beginning and end dates of project:____

Results to be published? (circle one): *Yes* *No*

Total budget:

Amount obtained from other sources:

Amount requested from BCI:

Previous BCI Grants:

Payment Information (If different from Applicant Information):

Project Abstract

Detailed project narrative and itemized budget MUST be attached!

Certification

I certify that I am the primary author of the proposal, and that it was researched and developed primarily by me. I certify that the information contained in this application and the attached proposal and budget are complete and correct to the best of my knowledge. I agree to accept responsibility for the scientific conduct of this project and to provide the required mid-term progress and final reports if an award is made as a result of this application.

Signature:____ Date:__________________________

Name (printed or typed):____

APPENDIX 3:

North American Bat Conservation Partnership

CONSERVATION FUND PRIORITIES

Habitat Assessment and Protection

1. **Roosts**—Roosts are critical resources for all bats. Those sheltering thousands or millions in caves or mines are the most often noticed and can be extremely important to a large proportion of a species population. Nevertheless, other natural roosts, such as in the cavities of old growth trees or snags or in cliff faces, are also of vital importance to species who use them. In many cases, bats now survive only by roosting in manmade structures, such as buildings, bridges, and bat houses. Project efforts will emphasize discovery and protection of existing natural roosts, while strongly supporting research and education on appropriate forest management practices and on enhancement of artificial roosts. The following specific roost concerns will be addressed.

   a. **Caves and Mines**—More than half of the American bat species rely on caves or mines as critical roost resources, and loss of key sites is a serious concern. Only about three dozen caves and mines in the North American continent are known to shelter nursery colonies of hundreds of thousands to millions of bats each. Additionally, at least a dozen or more sites that formerly sheltered hundreds of thousands to millions of bats each are currently unoccupied due to intense human disturbance. Such sites are critically important resources, especially in the case of caves and mines where bats hibernate, and may impact the survival of several species over areas of many thousands of square miles. These will receive priority consideration, though regional guidelines will be developed to assist species of special concern that do not form large aggregations. For such species, an initial priority might be to protect 90% of sites known to shelter hibernating populations or maternity colonies that rank within the largest 5% for that species (as determined by local experts). These key sites could then serve as reproductive centers that greatly enhance species survival while additional measures are pursued.

   Cave and mine roosts will be categorized according to: 1) total numbers of bats accommodated (either past or present); 2) number of species sheltered; 3) apparent value to bats based on current knowledge of roosting and associated habitat needs; 4) long-term safety of the site if protected; 5) known threats if not protected; and 6) conservation status of the species involved. Careful consideration will be devoted to protection of key habitat sites over those where remnant populations may simply have taken refuge as a last resort. Such locations either cannot support long-term recovery or become death traps during floods. Marginal roosts for an endangered species will seldom take precedence over roosts that are exceptionally important for large populations or multiple species. Regional guidelines will be developed that emphasize resources used by the largest, most diverse, and threatened or endangered populations.

   Protection of ideal locations that are no longer used by bats, due to disturbance and vandalism, can be far more important than protection of marginal sites that shelter displaced bats. Thus, collection and sharing of data on roost temperature and habitat requirements, combined with knowledge of how to evaluate evidence of past use, is vital to setting protection priorities for each species.

   b. **Old Growth Forests and Snags**—Many North American bat species are heavily dependent upon old growth stands of forest where they roost beneath loose bark, in cavities resulting from lightning strikes or decay, and in woodpecker holes, all of which are most often found in very old, dead, or dying trees. Many bats are especially dependent upon spaces beneath exfoliating bark and require high snag densities, since loose bark soon falls off.

   Bats traditionally have not been considered in forest management planning, and this constitutes a major threat to their survival. One recent study indicates most Ponderosa pine snags used by bats are 150-350 years old and that their usefulness to species requiring exfoliating bark may last for only one or a few years. Collaboration in forest planning to ensure the multi age stands essential to continuous availability of snag roosts will be a high priority in areas of extensive logging. Experimentation with artificial bark for bats is in progress and may prove helpful in areas which are already snag deficient.

c. **Cliff-face Crevices**—Numerous cliff-face crevices, ideally located adjacent to a riparian habitat used by bats, likely have been lost during road construction, especially in the western United States and Mexico. It has been traditionally assumed that useable crevices were available in unlimited abundance, but we now know that many bats have very specific requirements for crevice size, inaccessibility to predators, and exposure to solar heating. Often, only a few out of thousands are suitable for bat use. An early priority will be to incorporate information on bat needs into impact assessment and planning for highway projects (see Artificial Roosts).

d. **Artificial Roosts—**As growing numbers of bats have been forced to abandon traditional roosts in caves and have lost ancient tree cavities, snags, and cliff-face crevices, they have, when possible, moved into man-made structures, ranging from mines and cavities in hydroelectric dams to buildings and bridges. Additional roosting habitats can be incorporated into new construction, especially in highway structures (bridges and culverts) with minimal or no extra cost to taxpayers, though the usefulness of such assistance varies geographically, requiring development of regional priorities. An early project priority will be to publish a handbook on how to minimize the impact of highway construction on bats while incorporating a roosting habitat into new structures.

Artificial bark may prove helpful to a variety of bat species throughout North American forests where logging has deprived bats of roosts in old trees and snags. It is currently being tested, is inexpensive to produce, long lasting, and virtually invisible to potential vandals. Artificial bark is not intended as a substitute for good forest management.

Bat houses are gaining popularity as a means of providing artificial roost sites. They already are used as important education and conservation tools and have proven especially useful in accommodating bats displaced from buildings where they are not wanted. Artificial roosts for evicted bats are already sheltering hundreds of bats each. In one case, a single large bat house has between 25,000 and 50,000 bats.

Project efforts will emphasize discovery and protection of existing natural roosts, but in many areas, the only remaining roosts are in artificial structures which are now too important to be ignored. Because natural roosts are no longer available for a large proportion of American bats, it is essential that research and education efforts be directed to improvement of artificial roosts, especially: 1) to accommodate bats evicted from buildings; 2) to enhance educational efforts as interpretive tools; and 3) to test their usefulness in integrated pest management.

2. **Habitat—**Feeding and drinking requirements need further study, but are already known sufficiently to begin incorporating knowledge of bat needs into broader wildlife habitat management plans. Available information is scattered widely in scientific papers that are largely unavailable to land managers. An early priority of this project will be to review and summarize such information for decision makers, so that bat habitat needs can be addressed in routine wildlife planning.

Many opportunities exist for collaboration to ensure that bat drinking and feeding needs are incorporated into soil, watershed, and grazing allotment planning and maintenance. Small modifications to provide suitable open water, riparian habitat, and multi age forest stands can be of vital importance to bats.

a. **Foraging—**Bat foraging habitat is typically less well defined than roosting habitat. Many species feed primarily over water or in riparian areas, especially when rearing young. Others hunt along forest edges, high above forest canopy, in the under story of mature forests, and along ridge tops. Often only slight modification of existing management procedures can greatly assist bats.

It is especially important to understand the habitat requirements of pregnant and lactating bats, since their energy needs are substantially higher than those of non reproductive individuals, which often feed in less productive habitat at greater distances from roosts. Where required management information is lacking, initiatives to assess the needs of reproductively active bats will be emphasized. Forest areas providing the greatest age, vegetational, roost, and water diversities are often of special importance in management planning for bats.

b. **Drinking**—A shortage of open-water drinking sites that are acceptable to bats is a serious problem in western North America. Many bats drink in flight as they swoop low over pond surfaces, and the amount of space required varies greatly among species. Data is currently being collected on swoop zone requirements of bats in the western United States, and will be made available to project participants so that bat needs can be incorporated into land management and wildlife conservation plans. In arid areas, acceptable drinking ponds can be more important than any other factor. Thus, maintenance or reestablishment of such sites will be a top priority in some areas. Pond dimensions and nearness to forested areas will be important considerations.

Education

1. Development and Distribution of Shared Materials

a. **Environmental and Other Educators**—Project participants will collaborate, not only on North American, but also on more specialized regionally targeted materials that empower educators to help. Such materials will include a variety of posters, teacher's aids, and activity books in any language.

b. **Land Managers**—Cooperating land managers will collaborate in the production of handbooks and videos, such as the *Bats and Mines Resource Publication*. These will provide the detailed specifications required by land management planners.

c. **Animal Control and Public Health Officials**—Education to discriminate between the common vampire and the vast majority of beneficial bats, especially cave-dwelling migrants, such as free-tailed and long-nosed bats, is a high priority in Mexico. Educational materials and initiatives must especially be emphasized in the communities closest to the most important known bat caves.

Throughout North America, the kind of exaggerated fear created by sensational media coverage of public health issues involving bats' ranks among the most serious threats to bat survival. Educational materials for animal control and public health agents are much needed, especially those produced in collaboration with leading veterinarians and other experts on public health. In Mexico, vampire control issues are also critically important.

d. **Public—**As in the case of the brochure, *Bats, Masters of the Night Skies,* which was jointly published by the Bureau of Land Management, the Forest Service, and BCI, substantial cost savings can be realized through collaboration. One of our early projects will be to design protective signs for use at gated caves and mines. Signs will be produced in a manner that permits each agency to imprint its own logo to a prefabricated sign, saving substantial cost.

2. Information Exchange

a. **Internet Web Site**—An Internet web site will enable participating biologists and educators to reduce costly duplication of efforts by sharing and accessing the latest information on: 1) bat habitat assessment and management; 2) status trends; 3) educational materials and procedures; and 4) bat experts available for specialized consultation.

b. **Scientific and Educational Publications and Materials**—BCI already maintains the world's largest literature and audiovisual library on bats. Additionally, development of handbooks, such as the *Bats and Mines* Resource Publication, and training videos, backed by multiple agency and private fenders, will rank high among project priorities. A wide range of educational materials for the public also can be jointly developed at reduced cost, and in needed languages.

Research

1. **Population Monitoring—**Very few bat populations have been monitored over time, making status determination difficult. Research on ultrasonic detection and identification, monitoring of bat numbers and species entering and exiting roosts, and estimating numbers in roosts is important. Monitoring of key roosts will be essential to tracking bat conservation needs and progress.

2. **Roost Surveys**—Many caves and mines have not been surveyed to evaluate their importance to bats. Such information is prerequisite to protection.

3. **Plant/Animal Relationships—**The impact of bats in pollination and seed dispersal remains largely unstudied, though we know that many ecologically and economically important plants of the southwestern United States and Mexico rely on them to varying degrees. In the Sonoran Desert alone, bats appear to serve as primary pollinators or seed dispersers for dozens of species of agaves and columnar cacti.

4. **Ecological and Economic Impacts**—Research on the economic impact of bats in reducing crop and forest pests will be a high priority, since such knowledge can greatly influence conservation support. Data from Indiana and Texas indicate bat impact far beyond any previously understood. For example, Texas free-tailed bats apparently are intercepting and consuming millions of pounds of some of America's most costly crop pests during their spring migration northward from Mexico. Ecological roles remain largely un-investigated, though important. They are not as immediately valuable as arguments for protecting bats, but are very important to ecosystem balance.

5. Environmental Contaminants

   a. **Agricultural Pesticides**—The effects of pesticide applications at specific times and places remain un-investigated, though available studies implicate them as a possible cause of substantial mortality. The kinds used and the timing of application could make a big difference for bats. Also, monitoring of toxicant levels in bat guano deposits in caves can serve as an excellent environmental indicator. Information sharing and research collaboration between government agencies and private groups will greatly enhance detection and monitoring of problems.

   b. **Xerobiotics—**Industrial wastes produced during the manufacture of plastics, extraction of precious metals, and compounds used in the electronics industry often mimic naturally occurring hormones such as estrogen, which are antagonistic compounds. Sometimes these compounds, or their breakdown products disrupt or interfere with natural levels of endocrine secretions. When bats are exposed to these compounds during critical life history stages, reproductive failure can be expected. Research is needed to evaluate these effects in natural populations.

   c. **Aquatic Pollution—**Many bats feed heavily over water, especially when rearing young. Research comparing bat foraging activity over areas of differing water quality could substantially enhance knowledge of threats to bat feeding habitats, especially when biologists and chemists collaborate.

Management Concerns in the Development of Rock Climbing Recreation Areas in Caves

Larry King

In the late 1980's changes in the practices, technology and ethics of recreational rock climbing coincided with a dramatic increase in the sport's popularity. Aggressive marketing, a competitive sports culture rewarding first ascents, and a tradition of climbing area user self-development helped create a situation where climbing recreation areas typically bypassed the land use planning and impact assessment process. Technological changes, primarily the use of battery powered hammer drills, greatly accelerated the development process. In 1992 rock climbers in Central Oregon began developing permanent bolted climbing routes in several lava tube entrances near the city of Bend. By 1993, approximately 250 bolted climbing anchors had been placed in five area caves. In the fall of 1993, members of several Oregon NSS Grottos initiated a program of impact documentation. Interim management policies were developed by the USFS and BLM in 1994, and the caves in question were listed in the FCRPA's Significant Cave Inventory later that year. Three of the so-called "climbing caves" contain prehistoric rock art. In some cases the pictographs have been heavily impacted by climbing activity. Use of magnesium carbonate and magnesium sulfate gymnastic chalk, in addition to "grooming" of loose rock, creation of artificial holds, removal of vegetation, permanent installation of bolted protection anchors, wildlife disturbance and graffiti are impacts that may require management in cave climbing areas. Attempts to regulate climbing activity with signs, road restrictions, seasonal closures and public meetings have met with varying degrees of success. For management purposes, the installation of permanent bolted climbing routes should be considered a form of "development" similar to trail building, rather than a simple recreational activity. The cumulative impacts of route development may be considerable, and typically result in an increase in site visitation as documented in a 1997 user survey. Management and impact assessment issues should be taken into consideration, particularly in areas of cultural significance.

Development of a Conservation Agreement to Protect Cave Invertebrates and Obviate Listing as Endangered Species in Bexar County, Texas

Kenneth J. Kingsley

SWCA, Inc. Environmental Consultants
343 S. Scott Avenue
Tucson, AZ 85701

Abstract

The Edwards karst region of central Texas contains hundreds of shallow limestone caves. Some of these include habitats for several species of invertebrates that are extremely rare and endemic to very small areas. In the Austin area, seven endemic species are listed as Endangered Species by the U.S. Fish and Wildlife Service (USFWS). This status has led to increased costs and plan changes for land owners, and enforcement challenges for the USFWS. In the San Antonio area (Bexar County), local conservationists petitioned the USFWS to list nine species of karst invertebrates as Endangered. The primary threats to the species are alleged to be land development and predation/competition by introduced fire ants. A group of local landowners (Cave Conservation Coalition), together with the USFWS, the Texas Parks and Wildlife Department, and the Texas Natural Resource Conservation Commission are creating a Conservation Agreement to obviate listing these species as Endangered. The strategy of the Agreement is to assure the conservation of the species by creating preserves and management plans for some of the known locations of the species. The existing recovery plan for the listed species in the Austin area serves as a model for the strategy. A commitment to the idea, and for cooperation in acquisition and management of sites has been made, and site specific plans are being developed. This presentation reviews the concept of the Conservation Agreement as an acceptable alternative to listing as Endangered, and describes the process of developing this Agreement.

Introduction

The Endangered Species Act is often said to be the most powerful environmental law in this country, if not the world. It is sometimes also the most hated, when Endangered Species are perceived to get in the way of economic interests. The Endangered Species that is perceived to impede human welfare is often mocked or despised, even when it is as warm and cuddly as a spotted owl or a Tipton kangaroo rat. When the species is a pale, blind troglobitic spider that has only been seen once in 30 years, human feelings tend to run strongly against it if it gets in the way of progress.

This paper describes a process by which the regulated community, a coalition of land owners, proposed a means of protecting troglobitic invertebrates to obviate their being listed as Endangered. Preventing the need to list the species benefits the species, of course, but also benefits the regulated community and the regulators. The regulated community benefits by not having regulations thrust upon it. The regulators benefit by not having to direct severely limited personnel and financial resources to a monitoring and enforcement effort, especially one that is unpopular or controversial.

Biological Background

The Edwards Limestone area of central Texas is home to more than 1,000 species of cave and karst dwelling organisms (Reddell, 1994). New species are described almost every year, and many unidentified species await formal taxonomic description. Many of these are known from only one or a few caves, but it is unclear whether this is a limitation of distribution or of knowledge.

Five species known only from caves in the Austin area were listed as Endangered Species in 1988, amid much controversy. Some proponents of listing the species undoubtedly were sincerely concerned about protecting these rare and little known creatures. Other proponents, however, have been accused of using the Endangered Species Act to further their own agendas, which included impeding economic development. In the years since the Texas cave bugs have been listed, several consultants (including this author) have profited, developers have had to pay for cave and karst surveys of their lands, create preserves, and support research, and the U.S. Fish and Wildlife Service (USFWS) has been embroiled in controversy. The list of species has increased from five to seven because of taxonomic refinements. And the known locations of some species have increased from one or two to more than fifty. Direct and opportunity costs resulting from the listing of these species have not been calculated, but undoubtedly amount to millions of dollars. A Recovery Plan for the Endangered Karst Invertebrates has been prepared, and directs continuing actions of the regulators and regulated (U.S. Fish and Wildlife Service, 1994).

Table 1. Petitioned Species from Bexar County, Texas
Animals
Texas Cave Invertebrates
Arkansas River Shiner
Topeka Shiner
Coral Pink Sand Dunes Tiger Beetle
Barton Springs Salamander
Ramsey Canyon Leopard Frog
Boreal Toad
Amargosa Toad
Copperbelly Water Snake
Flat-tailed horned lizard
Northern Idaho Ground Squirrel
Jaguar
Plants
Arizona Willow
Grimes vetchling
Parish’s Meadowfoam
Cuyamaca Lake Downingia
Wonderland Alice-flower

Table 2. Species Currently Involved in Conservation Agreements
Wet Canyon Talus Snail
Virgin Spinedace
Colorado River Cutthroat Trout
Bonneville Cutthroat Trout

In the San Antonio area, local conservationists petitioned the USFWS to list nine species of invertebrates as Endangered Species. Table 1 lists the species and some information about them.

The petition was submitted on January 9, 1992. At the time of the petition, the species were known from a total of only 16 caves, with some species only known from one cave each, and some not observed in many years. In December 1993, the USFWS published a “90-day finding” that listing the species as Endangered may be warranted. The final stages of the listing process were delayed, in part by the moratorium on listing new Endangered Species ordered by Congress in 1995, and in part by the combination of workload and lack of funding for the USFWS personnel involved in the process. As yet, no proposed rule listing the species as Endangered has been published. Officially, the determination whether there is or is not sufficient information to support a rule listing the species as Endangered has not been made.

The USFWS commissioned consultants to do a Status Report (Reddell, 1993). That resulted in an increase in the number of sites from which some species were known, but failed to find some of the species. Research on the distribution of the species continues to be done, and additional locations have been found for some of the species. Six species appear to be limited to only one or two caves (*Cicurina baronia, C. vespera, C. venii, Neoleptoneta microps, Texella cokendolpheri, Batrisodes venyivi*). Three species are much more widely distributed than had been previously known (*C. madla, Rhadine exilis, R. infernalis*).

Conservation Agreements

The USFWS has a nationwide policy of encouraging Conservation Agreements with local governments and private organizations to obviate listing candidate species as Endangered. Although this policy was rooted in policies developed in the 1970s and early 80s, it had been neglected for many years. In the past two years, conservation agreements have been developed, or at least begun, for more species than had conservation agreements developed in the past twenty years. The Service published a new "Draft Policy for Candidate Conservation Agreements" on June 12, 1997 (U.S. Fish and Wildlife Service, 1997). This policy has the potential to become an important, dynamic tool in the formulation of agreements that protect both species at risk and the interests of the regulated community. Table 2 is a list of some species for which Conservation Agreements are in effect or in preparation. The government describes the policy as follows:

> "The policy would provide incentives for private and other non-federal property owners, and state and local land managing agencies, to restore, enhance, or maintain habitats for proposed, candidate, and certain other unlisted species. Candidate Conservation Agreements would be developed by participating property owners or State or local land managing agencies to remove the need to list the covered species as Threatened or Endangered under the Endangered Species Act."

> "Under this policy [USFWS] would provide participating property owners and State and local land managing agencies with technical assistance in the development of Candidate Conservation Agreements and would provide assurances that, if covered species are eventually listed, the property owners or agencies would not be required to do more than those actions agreed to in the Candidate Conservation Agreement. If a species is listed, incidental take authorization would be provided to allow the property owner or agency to implement management activities that may result in take of individuals or modification of habitat consistent with those levels agreed upon and specified in the Agreement." (USFWS, 1997.p. 32183)

The essence of a Conservation Agreement is that the USFWS and one or more other public or private agencies agree to carry out some specific strategy for the protection of a species that is a candidate (or a potential candidate) for listing as a Threatened or Endangered Species. Because of the Agreement, the threats to the species are reduced, thus averting the need to list the species as Threatened or Endangered. Because the species is not listed, economic development of known or potential habitat of the species can be free of the potential for prosecution for illegal "take" of an Endangered Species.

(Distribution at the time of Petition)

Cicurina baronia - a small, blind troglobitic spider, known from one cave

Cicurina madla - a small, blind troglobitic spider, known from one cave

Cicurina venii - a small, blind troglobitic spider, known from one cave

Cicurina vespera - a small, blind troglobitic spider, known from one cave

Neoleptoneta microps - a small, essentially eyeless troglobitic spider, known from one cave

Texella cokendolpheri - a small, eyeless harvestman, known from one cave

Batrisodes venyivi - a small, eyeless mold beetle, known from one cave

Rhadine exilis - a small, essentially eyeless ground beetle, known from four caves

Rhadine infernalis - a small, essentially eyeless ground beetle, known from eleven caves

Conservation Agreements are not without controversy. Two (Barton Springs salamander and jaguar) have been overturned by the orders of federal judges because of lawsuits filed by groups who felt that the agreements were not strong enough. Nevertheless, it is likely that the Conservation Agreement will become an important tool in protecting wildlife.

The Bexar County Karst Invertebrates Conservation Agreement

A group of local landowners (Cave Conservation

Coalition) was concerned about the effects of having additional Endangered Species in their area. They already had the experience of having to consider the Golden-cheeked Warbler, Black-capped Vireo, and several aquifer-dwelling species in planning for their businesses and property uses. Because the USFWS was constrained from quick, decisive action on the petition to list the nine species, the implications to property owners were unclear. The Coalition was formed to create a situation with which all could live. It would provide certainty for the landowners, control expenses and prevent wasted efforts, and it would protect the species. The Coalition drew up a discussion draft Conservation Agreement. Then, with the USFWS, the Texas Parks and Wildlife Department (TPWD), and the Texas Natural Resource Conservation Commission (TNRCC), they began hammering that draft into a form that all could agree would work. Much of the remainder of this paper includes language from the current working draft of the Conservation Agreement, which may be subject to change as the agreement evolves into its final form. Remaining ahead, at this time, are public involvement processes. Also, the cooperation and participation of city and county agencies will be invited, and may result in some changes in the specifics of the Agreement.

The strategy of the Agreement is to assure the conservation of the species by creating preserves and management plans for known locations of the species. The existing recovery plan for the listed species in the Austin area serves as a model for the strategy. A commitment to the idea, and for cooperation in acquisition and management of sites has been made, and site specific plans are being developed.

The specific threats alleged to be endangering the species are losses of caves due to development, pollution, alteration of nutrient input, and predation and/or competition from the introduced fire ant (*Solenopsis invicta*). Specific management measures being developed as parts of the Conservation Agreement include:

- Establish karst preserves containing a significant number of the known populations of the species; the goal, where possible, is to have three preserved Karst Fauna Areas for each species in each Karst Fauna Region[1]
- determine and delineate the management area that needs to be included to protect the karst ecosystem associated with each cave
- obtain a written conservation agreement and management plan that includes all appropriate landowners, including those adjacent to the cave site if necessary
- control fire ants at these preserves, using a site-specific plan that includes monitoring and a treatment strategy that is consistent with the conservation of indigenous species
- develop and start a monitoring plan for each preserve that will monitor for:
    - covered and other species
    - specific threats
    - opportunities to increase habitat values

In addition, four general administrative actions, as outlined below, will be carried out:

- coordinate conservation activities
- Set up the conservation schedule
- fund conservation actions
- assess conservation progress

Administration of the conservation agreement will be conducted by the Karst Region Invertebrate Conservation Implementation Team (KRICIT). The KRICIT will consist of a designated representative from each signatory to the Agreement and may include non-voting technical and legal advisors and other support personnel as deemed necessary by the signatories. Authority of the KRICIT will be limited to developing and making recommendations for the conservation of the species to the Agreement signatories. The KRICIT will meet annually to develop recommended yearly conservation schedules, review the Strategy, and make recommendations to modify the Strategy as necessary.

[1] The Recovery Plan defines "karst fauna regions" as regions delineated based on geologic continuity, hydrology, and the distribution of troglobitic species and "karst fauna area" as an area known to support one or more locations of a listed species and distinct in that it acts as a system that is separated from other karst fauna areas by geologic and hydrologic features and/or processes that create barriers to the movement of water, contaminants, and troglobitic fauna. Karst fauna regions were defined by Veni (1994) for Bexar County. In Bexar County, because most cave structure is vertical and caves are widely spaced, a "karst fauna area" is generally just one cave.

The KRICIT will meet at least semiannually or as often as necessary to report on the progress of carrying out the Strategy.

A total of five years is anticipated for full implementation of actions identified and specified in the Strategy. Nevertheless, the parties agree that significant actions to benefit the species will be started within the first two (2) years. For karst preserves, the goal is to establish and maintain perpetual protection and management.

Funding for the Conservation Agreement will be provided by a variety of sources, including but not limited to:

- Federal sources, including but not limited to, the USFWS through Section 5 and 6 Funds under the Endangered Species Act.
- State funding sources, including but not limited to, TPWD, TNRCC, and the University of Texas.
- Private funding sources, private nonprofit conservation entities, and other participating land owners.
- Cooperating local governmental entities.

In-kind contributions in the form of personnel, field equipment, supplies, etc., will be provided by participating entities as necessary. In addition, each agency will have specific task responsibilities and proposed actions and commitments related to its in-kind contributions.

A semiannual assessment of progress toward carrying out actions identified in this Agreement will be provided to the signatories of the Agreement by the KRICIT. This assessment will be based on updates and evaluations by KRICIT members. An annual assessment of conservation accomplishments identified in the yearly schedules will be made by the KRICIT. This assessment will determine the effectiveness of the Agreement and whether revisions are warranted. It will be provided to the signatories of the Agreement by the KRICIT.

If threats to the survival of the species become known that are not or cannot be resolved through this or any Conservation Agreement, the KRICIT will promptly notify all signatories.

It is expected that, if the Agreement is successful and the management actions are carried out, the species' habitats will be preserved. That will remove the threats to the species and eliminate the need to list them as Endangered. It is possible that the activities of the parties to this Conservation Agreement alone will not be sufficient to eliminate the need to list the species as Endangered. However, the USFWS intends to enter this Conservation Agreement with the other parties because they have determined that the proposed management activities, if conducted by other property owners or agencies throughout the range of the affected species, would be expected to remove threats to the species adequately and eliminate the need to list.

The USFWS agrees that if any of the species is listed, and if at such time the Conservation Agreement has been and is being carried out in good faith by the participating property owners, then the Service will not assert additional restrictions or require additional actions above those the property owners voluntarily committed to conduct, incur, or maintain under the terms of the Conservation Agreement. To provide such assurances, the Service, simultaneous with the entering of the Conservation Agreement, will issue to the other parties a Section 10 (a)(1)(A) "Enhancement of Survival" permit. This will allow the property owners to carry out management activities on lands outside the designated preserves that may result in a take of individuals of the covered species or modification of their habitat consistent with levels agreed upon and specified in the Conservation Agreement. The probable direct and indirect effects of any such authorized take will not appreciably reduce the likelihood of survival and recovery in the wild of any species, will not conflict with any ongoing conservation program for any species, and is consistent with all applicable State laws and regulations.

In addition, if USFWS receives a future petition alleging that any cave or karst dwelling species in Bexar County should be listed as Endangered or Threatened under the ESA, then USFWS agrees to consult with the parties to decide whether to amend the Conservation Agreement to include such species and thereby obviate the need for listing of those species.

Monitoring necessary to determine how the species are responding to the prescribed management activities is built into the Agreement as a Management Action. However, it is acknowledged that meaningful methods and criteria for monitoring the species remain to be developed. The other parties to the Agreement, specifically the land owners, will grant permission to the USFWS to conduct monitoring studies within the designated Karst Preserves. They also agree that where appropriate and feasible, they will give the USFWS a reasonable opportunity to rescue individual specimens of a covered species before any authorized incidental taking occurs on their property outside the Preserves.

The initial term of the Conservation Agreement will be twenty years. It will be automatically renewed for successive five year periods unless a party elects not to renew and gives notice within twelve months of expiration date. Changes to the Agreement may be made upon agreement in writing of all the signatories.

Conclusion

The basic idea of the Conservation Agreement offers a potentially valuable tool in the protection of rare species. This approach may be especially useful for species with very limited and discrete ranges and highly specialized habitats, such as cave and karst invertebrates. The Bexar County example is unique in that the idea was propounded and developed largely by the private sector. It represents a cooperative effort between a coalition of members of the regulated community and regulatory agencies, and it is based on the best available science.

References

Reddell, J.R. (1994) "The Cave Fauna of Texas with special reference to the Western Edwards Plateau," In: Elliott, W.R. and G. Veni, editors. *The Caves and Karst of Texas. A Guidebook for the 1994 Convention of the National Speleological Society with Emphasis on the Southwestern Edwards Plateau.* National Speleological Society, Huntsville, Alabama. pp. 31-49.

Reddell, J.R. (1993). *The Status and Range of Endemic Arthropods from Caves in Bexar County, Texas.* Draft report to U.S. Fish and Wildlife Service and Texas Parks and Wildlife Department. 90 pp.

U.S. Fish and Wildlife Service. (1997). "Announcement of Draft Policy for Candidate Conservation Agreements" *Federal Register 62:* 32183-32188.

U.S. Fish and Wildlife Service. (1994). Recovery Plan for Endangered Karst Invertebrates in Travis and Williamson Counties, Texas. Albuquerque, New Mexico. 154 pp.

U.S. Fish and Wildlife Service. 1993. Endangered and Threatened Wildlife and Plants; 90-day finding on a petition to list nine Bexar County, TX, invertebrates. *Federal Register 58:* 63328-63329.

Veni, G., and Associates. 1994. *Geologic controls on cave development and the distribution of endemic cave fauna in the San Antonio, Texas, region.* Report for Texas Parks and Wildlife Department and U.S. Fish and Wildlife Service, Austin, Texas, 99 pp. + 14 plates.

Cave Maps As Geographical Information Systems: An Example From Oregon Caves National Monument

Steve Knutson
NPS Resource Tech

Land is managed using computer-run Geographical Information Systems (GIS). In such a system information is cataloged by location and type. This can then be applied to a display or tabular report on request. Cave management can be based on such a system. The following is a brief report on the development of a GIS for Oregon Caves, a medium-sized (3.5 miles) cave in southern Oregon.

Early in 1993 John Roth, Resource Specialist at Oregon Caves National Monument decided to commit resources to creation of a GIS for Oregon Caves. Crews of Earth Watch volunteers proceeded to do an inventory of 99 selected features in the cave. This information was dutifully fed into **DBASE 3**. These database files can then be utilized by **SMAPS 5.2** to create displays of the inventoried features on a line plot of the cave.

On the line plot the occurrence of a feature at a given location is indicated by a symbol, such as a circle, on the survey station near which the feature is located. The symbol can be made larger or smaller to reflect the feature quantitatively. Two or more features can be included in a display to indicate relationships. Thus we have achieved a GIS giving feature distributions, but only as stations on a line plot.

Such a GIS is very useful but after the inventory season we gained the capability of putting the line-plot from SMAPS into Garry Petrie's **KARST** program from which it could be exported via DXF format into **AutoCAD**. It was decided to continue with the Earth Watch program and set the volunteers to work resketching the cave in great detail, placing the physical features of the cave at their correct locations in the sketch. The cave would then be drawn on **AutoCAD** with a layer for each feature. After three summer work seasons, this GIS is nearly complete.

The cave was drawn on **AutoCAD 12** and is at this point (nearly finished) almost 8 megabytes in file size with 96 different layers. On a 166 megahertz computer with 32 meg of ram and a 2 meg vram video card, such a file loads in about 50 seconds with regen time a little less. With appropriate video drivers the zooms and pans are essentially instantaneous. It must be emphasized that this is NOT a "map" of the cave but a GIS, with the ability of displaying selected information or relationships by the on/off manipulation of layers, and in/out zoom. Because of the ease of adding information it of course will be the instrument for recording newly found cave information, physical extensions to the cave, or any information related to sites in the cave.

The only advice I would pass on directly is that one should do all things possible to keep the file size down and the regeneration/loading time as short as possible. AutoCAD has many such. The only technique I didn't find in a manual was using what I call an "array" to easily add information to different layers when I'm working on a particular area of the cave without going through the laborious business of changing layers. First, you create the "array" by bringing together the symbols for what is on the different layers with each symbol still on its layer. Then you make a "block" of this collection. When you want to want to place a symbol for one of these items somewhere in the cave but don't want to change layers (for instance if you are adding a lot of symbols to a particular area), just insert the array, explode it and then copy the symbol of your choice to the appropriate spot in the cave passage. The copy will be on the correct layer. When you are done, erase the array.

This project was started on a 486/33 and is now on a Pentium 166. The load/regen times are quite workable yet processor speeds will increase. In the future, even large caves can be done with a workable result.

The next step in our project will be the integration of this .DWG file into true GIS software. **ARCVIEW** now imports DWG but it remains to be seen if the imported entities are treated the same as entities in ARCVIEW. If they are, this will take the drawing into true, current GIS, since entities in ARCVIEW can be queried with reports in graphic and/or tabular form.

Address inquiries to: Steve Knutson, ORCA, 19000 Caves Hwy, Cave Junction, OR 97523; 541-592-2100; SSSKNUTSON@AOL.COM

The Nature Conservancy at work in the Indiana karst: The bioinventory of the subterranean fauna of the Blue River Bioreserve

Julian J. Lewis and F. Allen Pursell

Introduction

The Blue River of southern Indiana flows through one of the premier karst regions of the United States. The upper part of the river winds its way through a sinkhole plain dotted with literally thousands of sinkholes. In this area the dendritic pattern of surface streams common to the rest of Indiana is almost entirely absent. About halfway through its course the Blue River penetrates the Chester Escarpment and flows through a rugged hill country until its confluence with the Ohio River. In 1994 The Nature Conservancy created the Blue River Project for the purpose of more fully understanding and conserving the natural habitats and communities still present in the Blue River basin.

As part of this larger project the Blue River bioinventory of caves, springs and other hypogean habitats commenced in 1996 for the purpose of evaluating the diversity and rarity of the subterranean fauna of the area. In 1997 funding from the U.S. Geological Survey Species at Risk Program allowed the geographic scope of the bioinventory to be expanded to include all of Crawford, Harrison, Washington, and Orange counties. To date a total of 53 troglobitic or phreatobitic animals has been found in the project area (summarized by Lewis, 1993; Lewis, 1994; Lewis, Pursell, and Huffman, 1997). The purpose of this presentation is to shed some light on some of the things that have been learned about the inventory process that are of value in the management of cave and karst resources.

Rarity as a relict of collecting

The Nature Conservancy and other organizations employ a system known as "G-ranks" to categorize the global rarity of species (needless to say, it is essential that the organisms collected be identified to the species level):

G1 known from five or fewer localities globally (critically imperiled)

G2 known from 6-20 localities globally (imperiled)

G3 known from 21-100 localities globally (vulnerable)

G4 known from >100 localities globally (apparently secure)

G5 widespread and common from many localities (secure)

For example, the troglobitic Packard's cave pseudoscorpion *Kleptochthonius packardi*, previously known only from Wyandotte Cave (Muchmore, 1963), would be assigned the rank of G1. However, we have learned from experience to beware of rarity, as it may be merely a relict of collecting (or lack thereof). Discovered in the 19th century, the Packard's cave pseudoscorpion is a small, inconspicuous animal that no one has really looked for during the century since its description. About 140 caves have now been examined in the Blue River basin and *Kleptochthonius packardi* has been found in a total of six localities. Populations are apparently quite small, as the largest collection has consisted of two specimens from Saltpeter Cave, Orange County, with the other caves (Mauck's, Coon, Route 66 and Binkley) yielding only single specimens of this pseudoscorpion. *Kleptochthonius packardi* is now assigned the rank of G2, which carries with it different management connotations than a G1 species.

A second example is that of the Blue River cave millipede *Pseudotremia indianae*. At the beginning of the inventory this species was ranked G1, as it was known from only 5 localities (Shear 1972). In the course of the inventory we have found that this millipede comes readily to pitfall traps baited with limburger cheese, yielding dozens of new populations that have been discovered. The collection sites for this species now number above 50, yielding a G-rank of G3. Although fairly common in cave communities within the Blue River basin in which it is endemic, it is important to remember that from a global perspective this species has an extremely narrow range.

As some of the former G1 species have decreased in G-rank (with the discovery of additional populations, the presence of new G1 species has been revealed. Among the millipedes three species new to science have been discovered. Two of these new species have been assigned to the genus *Pseudotremia*. *Pseudotremia conservata*, recently described by Hoffman and Lewis (1997), has been found in only two caves in the southeastern part of Harrison County. A second undescribed *Pseudotremia* has been found in caves at the Mesmore Cliffs area of the Hoosier National Forest (HNF), in western Crawford County. The first population of the troglobitic genus *Scoterpes* to be found in Indiana was discovered in the Binkley Cave system of Harrison County.

Other species presently ranked G1 include two new species of *Kleptochthonius*, one in Indian Cave (Mesmore Cliffs, HNF), the other in Baelz Cave (Binkley Cave System, Harrison County). Three new species of the collembolan genus *Arrhopalites* have been found, all endemic to the Blue River area, as well as one specimen of a unique undescribed troglomorphic species of

Isotoma. A second undescribed species of the dipluran *Eumesocampa* is known from a single specimen taken in Potato Run Cave in Harrison County.

Bigger is not necessarily better!

The first caves to be inventoried in an area are typically the ones that are the most prominent, either because they have been commercialized or explored to great lengths. The Blue River area was certainly no exception to this, with most of what was previously known about the cave fauna being confined to Wyandotte or Marengo caves. It frequently comes as a surprise to the non-biologist that long caves may be the worst sites in which to search for animals. For example, Kentucky's Mammoth Cave, obviously one of the focal points of biodiversity among troglobitic faunas in North America, was cited by Barr (1967) as being inhabited by 41 species of troglobites. It might come as a surprise then to hear Dr. Thomas Poulson call parts of Mammoth Cave the "Great Kentucky Desert". This is because the cave has mile after mile of dry, food poor, low humidity, sparsely populated upper level passages. A number of species included in Barr's list of Mammoth Cave inhabitants were actually collected from smaller caves in the national park. For example the pseudoscorpions *Hesperochernes mirabilis, Kleptochthonius cerberus,* the carabid beetle *Pseudanopthalmus audax,* and the terrestrial snail *Helicodiscus punctatellus* were found in White's Cave. This is a small cave, featuring a diverse fauna, with nutrient input from the guano of the cave cricket *Hadenoecus subterraneus* and the rotting nest materials of the woodrat *Neotoma*.

The case in the Blue River area is identical to that in Mammoth Cave National Park. The best known cave in Indiana is Wyandotte Cave, occurring in identical geologic conditions to Mammoth Cave, with miles of dusty dry upper level passages lying beneath a water impervious sandstone caprock. Some species attributed (Cope, 1872) to the waterless Wyandotte Cave, like the Northern cavefish *Amblyopsis spelaea,* were actually taken from Sibert's Well Cave, a short stream cave found on the valley floor. Others, e.g. the Packard's cave pseudoscorpion or the undescribed dipluran *Litocampa* (called *Campodea cooki* by Packard, 1873, 1888), may be present in Wyandotte Cave, but are certainly much easier to find in smaller caves like Sibert's Well or nearby Saltpeter Cave.

This phenomenon is probably attributable to more than one factor. From a logistical standpoint, it is much faster to look for animals in a 200 foot long cave than one that is 10 miles long. In Wyandotte Cave there are relatively small "islands" of habitat suitable for invertebrate communities due to the input of water, separated by long stretches of the aforementioned "deserts" of passage that have few if any invertebrates living in them. This means that from an inventory standpoint the cave biologist is likely to spend more time hiking to the areas of suitable habitat than working. Small caves are more likely to have greater food input relative to their passage length since they are readily accessible to trogloxenes such as caves crickets, as well as receiving nutrients from a sinking stream or leaf litter input. Troglobites are renowned for their life history strategies entailing low metabolic rates, low fecundity, etc. Be that as it may, however, they do still have to eat. Thus, long caves may have long lists of troglobitic inhabitants, but finding these creatures may be easier in nearby short, food-rich caves.

Karst presents a wide variety of subterranean habitats

It goes without saying that any inventory of a karst region needs to include the sampling of caves. Some cave bioinventories are limited to making a single visit to each cave, with the sampling done primarily by hand collections. This is certainly an important facet of evaluating the fauna present in a cave, but we would emphatically state that more often than not this method finds only a fraction of the community present. In conducting the Blue River bioinventory we have embraced placing baited pitfall traps to sample animals that are reclusive, have small populations, or which we were just not lucky enough to find through hand sampling. An obvious criticism of this method is the non-selective capture of both target (pseudoscorpions, diplurans, etc.) and non-target (flies) organisms, as well as the concept of catching and killing extremely rare animals. This criticism is perhaps addressed best by a statement by cave biologist Dr. John Holsinger: "the rarest troglobites are the ones we need to know about most, and we can't know anything about them if we can't find them". For example, the Iceland cave sheet-web spider *Islandiana cavealis* is known in the Blue River area from one specimen (the fourth ever found, according to Ivie, 1965) taken from a pitfall trap in Stygian River Cave, Harrison County.

Besides the presence of troglobites, caves sometimes serve as windows into the non-cave subterranean habitats in phreatobites occur. Phreatobites are animals which frequently inhabit the saturated interstices of unconsolidated deposits. On the eastern fringe of the Blue River project area, in Floyd County, occur the phreatobitic isopod *Caecidotea teresae* and the amphipod *Stygobromus sp. #1.* These animals inhabit glacial till that lies on top of the New Albany Shale, a totally non-cavernous rock layer. An unexpected find was the presence of Jeannel's cave copepod *Diacyclops jeanneli* in a Floyd County well with *Caecidotea teresae*. This copepod was previously known only from a pool in Marengo Cave. It is apparently not a troglobite, as previously thought, but a phreatobite that perhaps occurs in Marengo Cave more by accident than by choice? Similarly, *Stygobromus sp. #2*, another species new to science discovered in Devil's Graveyard Cave (Harrison County), is known only from a drip pool in this streamless cave. This amphipod (only one specimen has ever been found) most likely fell into the cave from the soil/limestone epikarstic zone above the cave, where it was found as an accidental inhabitant.

Many descriptions and other records of species that are probably phreatobitic rather than troglobitic have been from caves, as they are relatively easy to enter. The saturated soil interstices inhabited by phreatobites are by their nature, more or less impossible to enter by humans. We are therefore limited to collecting them in "windows" into these habitats. Situations that present themselves for making collections occur in caves, wells, drain tiles, seepage areas and springs.

In terrestrial habitats, Vandel (1965) described soil inhabiting species as endogeans. Juberthei and Delay (1981) called the spaces that occur between the last layer of soil and bedrock a "superficial underground compartment". In the Blue River area the campodeid diplurans *Litocampa sp.* and *Eumesocampa sp.* (both new to science and endemic to the area) are likely to be edaphobites rather than troglobites. Similarly, the staphylinid beetle *Aleochara lucifuga*, apparently known only from caves and animal burrows (Klimaszewski & Peck, 1986), may be a non-troglobitic, but obligate subterranean species of some sort. Much remains to be learned about the ecological classification of subterranean organisms.

Acknowledgments

Although many people have assisted in conducting the field work for the Blue River cave bioinventory project, special thanks go to Hank Huffman, David Black, Ronnie Burns, Salisa Rafail, and Tom Sollman.

Funding for this project was initially obtained through a two year Rodney Johnson/Katherine Ordway Stewardship Endowment Grant from The Nature Conservancy, with matching funds from the Indiana Chapter of The Nature Conservancy, the Non-game and Endangered Wildlife Program (IDNR), and the Indiana Natural Heritage Program, Division of Nature Preserves (IDNR). Additional funding for the second and third years of the inventory came from the Species at Risk Program, U.S. Geological Survey, Department of the Interior.

Literature Cited

Barr, Thomas C. 1967. Ecological studies in the Mammoth Cave System of Kentucky. I. The biota. International Journal of Speleology, 3: 147-204.

Cope, Edward D. 1872. On the Wyandotte Cave and its fauna. American Naturalist, 6: 109-116.

Hoffman, Richard L. and Julian J. Lewis. 1997. *Pseudotremia conservata*, a new cleidogonid millipede (Diplopoda: Chordeumatida), with a synopsis of the cavernicolous millipeds of Indiana. Myriapodlogica, 4(13): 107-119.

Ivie, Wilton. 1965. The spiders of the genus *Islandiana* (Linyphiidae, Erigoninae). American Museum Novitates, 2221: 1-25.

Juberthie, C. and B. Delay. 1981. Ecological and biological implications of the existence of a "superficial underground compartment". Proceedings of the Eighth International Congress of Speleology, 1: 203-206.

Klimaszewski, Jan and Stewart B. Peck. 1986. A review of the cavernicolous staphylinidae (Coleoptera) of eastern North America: Part I. Aleocharinae. Quaestiones Entomolgiacae, 22 (2): 51-113.

Lewis, Julian J. 1993. Inventory of the potentially endangered or threatened subterranean aquatic invertebrates of Indiana, with censusing of *Antroselates spiralis* in the Sharpe Creek Valley. Final Report, Non-game and Endangered Wildlife Program, Indiana Department of Natural Resources, 131 pages.

Lewis, Julian J. 1994. Lost River cave and karst biological survey. Final Report, U.S. Army Corps of Engineers, Louisville District, Contract No. DACW27-94-M-0110, 63 pages.

Lewis, Julian J., Pursell, F. Allen, and Henry Huffman. 1997. The biological inventory of caves of the Blue River Bioreserve. Conservation and Protection of the Biota of Karst, Karst Waters Institute Special Publication 3, 37-41.

Muchmore, William B. 1963. Redescription of some cavernicolous pseudoscorpions (Arachnida, Chelonethida) in the collection of the Museum of

Comparative Zoology. Breviora, 188: 1-15.

Packard, Alpheus S. 1873. On the cave fauna of Indiana. Fifth Annual Report of the Peabody Academy of Science, July 1873, Boston, 93-97.

Packard, Alpheus.S. 1888. The cave fauna of North America, with remarks on the anatomy of the brain and origin of the blind species. Memoirs of the National Academy of Science, 4: 1-156.

Shear, William A. 1972. Studies in the millipede Order Chordeumida (Diplopoda): A revision of the Family Cleidogonidae and a reclassification of the order Chordeumida in the New World. Bulletin of the Museum of Comparative Zoology, 144: 151-352.

Vandel, A. 1965. Biospeleology. Pergamon Press, New York, 524 pages.

Addresses of the authors:

Julian J. Lewis
Biological Inventory of Blue River Area Caves
217 W. Carter Avenue
Clarksville, IN 47129

F. Allen Pursell
Manager,
Blue River Project
The Nature Conservancy
P.O. Box 5
Corydon, IN 47112

The Tongass Cave Project

An Advocate for Karst Ecosystem Protection in Southeast Alaska

Stephen W. Lewis
Tongass Cave Project and USDA, Forest Service, Thorne Bay RD.
Current address: 212 Observatory St., Sitka, AK 99835 (907) 747-7471,
ftswl@aurora.alaska.edu

ABSTRACT

The Tongass Cave Project (TCP), an official project of the National Speleological Society established in 1991, engages in the discovery, exploration, survey, conservation, and study of the karst and caves of Southeast Alaska. As advocates for karst ecosystem protection on the Tongass National Forest, cavers with TCP have volunteered well over 40,000 hours on the Ketchikan Area during the past decade. Over 500 caves have been located throughout the Tongass and over 300 caves have now been surveyed and mapped.

Karst Standards and Guidelines have been developed and implemented on the Ketchikan Area of the Tongass National Forest. Are these Standards and Guidelines effective? To test this, TCP cavers examined Sawfly Salvage Sale timber harvest units on Heceta Island during 1997. They noted serious problems with implementation of the guidelines. As currently designed, this timber sale will have deleterious effects on the unique Heceta Island karst ecosystem.

I discuss the history of the Tongass Cave Project. I describe the Heceta Sawfly Sale and outline steps necessary for the Forest Service to establish effective karst ecosystem protection and to regain the trust of TCP cavers.

INTRODUCTION

The Tongass Cave Project (TCP) is an official project of the National Speleological Society (NSS). Established in 1991, the goals of the TCP are to support and engage in the discovery, exploration, survey, conservation, and study of the karst and caves of Southeast Alaska.

Cavers have volunteered approximately 40,000 hours with the TCP (and before 1991 with the Glacier Grotto), participating in annual month-long caving expeditions as well as in many shorter expeditions since 1987. The US Forest Service has assisted many of these expeditions by providing logistic support under cooperative cost-share agreements. Over 500 caves have been located throughout the Tongass and over 300 caves have now been surveyed and mapped. Most importantly, with pressure from the TCP, Forest Service staff now consider caves and karst in management plans. Prior to 1988 caves and karst received no consideration.

A core group of Alaskan cavers has participated in these expeditions since the very beginning. Participants have also come from other parts of the United States, as well as Russia, Japan, England, Canada, Czechoslovakia, and New Zealand; some returning for several expeditions. TCP cavers have engaged in exchange trips with Russian, New Zealand, and Canadian cavers and other exchanges are in the works.

HISTORY OF THE TONGASS CAVE PROJECT

The foundation for the Tongass Cave Project was laid about 187 million years ago when the Alexander Terrane ended its journey from somewhere near present day

Australia, colliding with the coast of North America (Aley et al. 1993). Although a few cavers had noted its potential, the caves and spectacular karst topography located within this terrane were virtually unexplored and unappreciated until 1987. This was the year Kevin and Carlene Allred first visited northern Prince of Wales Island. Alternating baby-sitting duties with caving, they discovered and began mapping several spectacular caves including “El Capitan” and “Starlight”.

Kevin made contacts with the Thorne Bay Ranger District and by 1988 the recreation staff was able to offer a modicum of support for a month-long summer caving expedition. Through the Glacier Grotto of the NSS, Kevin initiated a cost-share agreement between cavers and the Ketchikan Area of the Tongass National Forest which, with modifications, has continued for ten years (Lewis, 1995).

1988 was also the year Congress enacted the Federal Cave Resources Protection Act (FCRPA). This signified a growing national interest in protection of caves and led Alaskan cavers to hope caves could be protected from some of the impacts of the intensive logging occurring on the Tongass. Timber harvest on the Tongass has been especially intense on karst, where well-drained soils often make for large trees (Aley et al. 1993, USDA, Forest Service 1997).

In 1989, Kevin Allred was the first to descend 598 foot El Capitan Pit, the deepest known limestone shaft in the United States. Survey in El Capitan Cave was pushed to the immense Alaska Room, extending the known length of the cave to nearly two miles. In addition, many other caves were discovered and mapped. It was clear to cavers that the karst and caves of this area were spectacular, important, and threatened. Over the next few years, short expeditions to neighboring islands including Heceta, Dall, Kosciusko, Coronation, Baker, and Noyes confirmed karst was well developed in many parts of the Ketchikan Area, not just on northern Prince of Wales Island or on the Thorne Bay Ranger District.

During the annual expeditions, cavers continued to check for caves in proposed timber harvest units; frequently discovering them just days before fallers were scheduled to begin work. This was frustrating to all concerned; layout crews, sale administrators, and especially to cavers who had little opportunity to protect the resource. In 1991, three years after enactment of the FCRPA, the first buffer was placed around a cave entrance. This was a 100 foot no cut zone around the entrance to “Captain Soup” a highly decorated and fragile cave. The unit around the buffer was soon harvested and within a year most of the trees in the buffer had blown down. Soil disturbance caused by roots being torn from the ground was probably even more damaging to the cave than careful clearcutting would have been. This demonstrated the necessity for windfirm buffers.

The Tongass Cave Project was established in 1991, a year that finally saw cavers focus just on caving rather than on a combination of caving and harvest unit inventory. TCP and the Forest Service both realized that this change would encourage continued volunteer participation. Long-time Alaskan cavers formed the Karst Research Group, a firm which contracted with the Forest Service to inventory karst in the Central Prince of Wales (timber harvest) Project Area.

During the early 1990’s, Kevin Allred told Dr. Tim Heaton, a paleontologist at the University of South Dakota, about bones he had discovered in El Capitan and other caves. Tim secured funding to conduct systematic excavations and radiocarbon dating. He determined the bear bones dated to over 11,000 years BP and a marmot tooth dated to over 44,000 years BP. Black and brown bears lived in sympatry less than 10,000 years ago. Only black bears now occur on Prince of Wales Island. TCP cavers have continued to locate bone deposits. Paleontological and archaeological work by Tim Heaton and Dr. Jim Dixon, an archaeologist at the Denver Museum of Natural History is continuing (Dixon et al. 1997, Heaton 1995a, 1995b, 1996, and Heaton et al. 1996). Caves are the only sites in Southeast Alaska where bones of this antiquity are well preserved. The finds at these sites have important implications for theories of glacial advance, climate change and human migration.

Kent Carlson began studies of Tongass cavernicolous invertebrates in the early 1990’s as well. Working in conjunction with TCP expeditions and with some financial support from the Forest Service, he collected invertebrates from caves throughout the Ketchikan Area. He discovered a number of new species and range extensions (Carlson 1994, 1996, this volume) during three summers of fieldwork.

1993 was important for karst and cave protection in the Tongass. In February, the Ketchikan Area, in cooperation with the American Cave Conservation Association, the NSS, and TCP organized a Karst Management Symposium. They brought in outside experts to educate Forest Service managers, timber industry personnel, cavers, environmentalists, and the public on the basics of karst hydrology, biology, and management. These experts emphasized the importance of considering the biological productivity as well as the three-dimensional nature of karst in land management planning. Karstlands tend to support bigger trees and more salmon than do non-carbonate terrains in the Tongass (USDA, Forest Service 1997). Besides providing educational opportunities, the symposium also offered a forum for all participants to interact and discuss karst. The Forest Service decided to fund a Blue Ribbon Panel of karst experts to examine karst of the Ketchikan Area to determine its overall significance and to evaluate management strategies to better protect this resource.

The Blue Ribbon Panelists found the karst of the Ketchikan Area to be significant at both national and international scales (Aley et al.1993). They suggested that karst resources would be found in other areas of the Tongass and concluded that karst was being degraded by timber harvest, by road location, operation, and construction, and by quarry construction. They noted that karst requires different management strategies than those appropriate for non-carbonate terrains. In the islands of the Tongass this means treating karst as three-dimensional islands within islands. In addition, their analysis showed karstlands to be critically important to fisheries resources.

Later in 1993, TCP appealed the Central Prince of Wales timber sale. The directors felt that it contained inadequate provisions for karst protection. Knowledge gained from the Karst Management Symposium and preliminary findings of the Blue Ribbon Panel led TCP to conclude recommendations made by the Karst Research Group in 1991 were based on inadequate information. Karst needed to be treated as a system, not as an amalgam of discrete features. The appeal was “friendly” and attempted to change minds rather than polarize positions. The Forest Service rejected this appeal. Nevertheless, the Thorne Bay Ranger District implemented most of the requests made in the appeal.

In 1993, TCP cost-share expeditions worked concurrently on northern Prince of Wales Island and far to the south, on the Craig District’s Dall Island. Major discoveries were made at both locales. In addition, without Forest Service support, TCP expeditions visited the two other Administrative Areas in the Tongass National Forest. An expedition to Etolin Island in the Stikine Area revealed small but significant pockets of karst. The Forest Service has since provided funding for several other TCP expeditions to examine newly discovered areas of karst and caves in the Stikine Area. An expedition to Chichagof Island in the Chatham Area revealed the presence of very large and spectacular areas of karst and caves. Unfortunately, the Chatham Area has not provided support for further expeditions. In fact, Area management has hardly acknowledged that some of the most significant and spectacular karst and caves in the Tongass occur in the Chatham.

In 1994 the Ketchikan Area unilaterally committed to implementing Karst Standards and Guidelines which became the basis for those adopted in TLMP. These guidelines outlined a means of assessing the vulnerability of the karst landscape. The Forest Geologist asserted that the process established in the guidelines was the minimum necessary to meet the requirements of the FCRPA. There have been problems with implementation of these guidelines and dissension within the TCP as to whether they are adequate, even when fully implemented. Nevertheless, they were an important step towards the protection of Tongass karstlands.

TCP cost-share expeditions explored Prince of Wales, Dall, and Heceta islands during the next two years. Major new cave systems were discovered on Heceta. Over 70 caves were discovered in less than six weeks during these expeditions. Many of these caves are over 300 feet deep and several exceed a mile in length. Dye traces funded by the Ketchikan Area, with TCP support, confirmed large areas of the island are hydrologically connected, sometimes unpredictably. In addition, TCP directors disillusioned with what they saw as “business as usual” with Forest Service timber harvest on karst led additional “independent” expeditions on northern Prince of Wales Island.

The 10th annual TCP cost-share expedition returned to Heceta Island in 1997. Once again more than 50 new caves were discovered, most of which were mapped. TCP caver and geologist, Kris Esterson undertook dye trace work with support from the NSS and Ozark Underground Laboratory. His traces confirmed large areas of hydrologic connectivity and provided important information about the ability of “dry” features to conduct water and materials rapidly into significant caves and the karst system (Esterson, 1997). Dye was transported from one such feature over 2.5 miles at a minimum rate of 1186 ft./day. Fluorescein from this sink was also detected one-half mile away in Arabica Cave, one of the deepest and longest of the many caves on Heceta Island.

Increasing evidence suggests Heceta Island contains some of the most highly developed and integrated karst on the Tongass. Well over 50% of its karsted lands have been harvested. Nevertheless, the Forest Service recently sold the 15.2 million board foot Heceta Sawfly Salvage Sale (USDA, Forest Service 1996). In 1996, during initial planning for this sale, the Forest Geologist assured TCP cavers that all Karst Standards and Guidelines would be rigorously implemented. Although not sure any harvest at all should be occurring on Heceta karst, cavers arrived for the 1997 expedition in optimistic frames of mind. Karst Standards and Guidelines, as explained to cavers by the Forest Geologist, should have taken care of most of the serious problems cavers envisioned for the Heceta Sawfly Sale. Sadly, this was not to be.

Several small salvage units had been harvested on Heceta in 1997, one of which was the Triangle Salvage Sale. During the 1997 expedition, TCP cavers explored a cave near this recently harvested unit. This unit had been laid out several years ago, just after the Ketchikan Area implemented the Karst Standards and Guidelines. The original plan had been modified just prior to harvest, endangering caves outside the unit. A shovel yarder had been driven between several very large sinks, many of which contained caves. By the time timber had been removed, the edges of these sinks were damaged and in one case a log had been pulled out of a sink, destabilizing its steeply sloping sides.

TCP had also been asked to map several caves in or adjacent to Sawfly Salvage units. In the first unit cavers examined, they noted buffers were improperly laid out and were of insufficient width to be windfirm.

Optimism faded rapidly.

KARST STANDARDS AND GUIDELINES AND THE HECETA SAWFLY SALE

Are the Karst Standards and Guidelines working on the Tongass National Forest? To test this, the cavers decided to examine more of the Sawfly Sale Units for compliance with Karst Standards and Guidelines.

Karst Standards and Guidelines require a four-step landscape assessment. First, karstlands are identified. Then, karst features and caves are inventoried. Third, the hydrology of the karst is delineated, and finally, karstlands are classified into one of three categories of vulnerability to disturbance. Throughout this process it is essential to view the karst as a system, not a collection of discrete surface features. It is also important to remember that most caves and caverns have no entrance accessible to humans, but are still sensitive to disturbance. Surface features are clues to the existence of these entranceless caves. In large areas of contiguous karst it is essential to complete all four of these steps prior to initiating plans for timber harvest. This is the only way to ensure a truly systematic approach to the assessment.

There are three classes of vulnerability, high, medium and low. Under current standards and guidelines, low vulnerability karst is generally treated much as non-karst landscapes. Medium vulnerability karst requires some modification of harvest techniques to reduce disturbance, but timber harvest is permitted.

Timber harvest is not permitted on high vulnerability karst. Such karst is defined by the presence of any one of a number of features. Lands over caves are by definition, high vulnerability karstlands. All karst on slopes steeper than 72% is classified as high vulnerability. Any watershed draining into high vulnerability karst, even if the watershed is not on carbonate rock, is to be considered high vulnerability and receive the same protective measures. In addition, sinks and epikarst features greater than 8 feet in depth are defined as high vulnerability. Unfortunately wording from preliminary standards and guidelines has been changed so that they now allow harvest within such features if there is no evidence of active water movement.

Karst Standards and Guidelines require windfirm buffers of no less than 100 feet wide around high vulnerability karst. However, according to Thorne Bay Ranger District foresters (personal communication), the width of a buffer must be equal to two tree heights (or over 300 feet for much of the Tongass) in order to be windfirm. No roads are to be built on high vulnerability karst unless there is "no alternative" method to reach less vulnerable areas for harvest.

The Karst Standards and Guidelines emphasize that a systematic approach is essential to adequately protect karstlands. As a rule, features are not isolated, but are parts of a much bigger system. This is especially true for large, contiguous areas of carbonate bedrock such as occur under the Heceta Sawfly Sale.

Karst Standards and Guidelines as originally proposed were stronger than those adopted in the new Tongass Land Management Plan (USDA Forest Service 1997). In most instances, "shall" and "will" have been replaced with "should be" and "may be". There are many instances where these guidelines have been further weakened with conditional wording such as "where appropriate" and "to the extent feasible". While this may give managers greater flexibility, TCP feels that such language leaves too much room for subjective interpretation. This weakens the guidelines, almost to the point of non-existence, in the hands of anyone lacking an understanding of karst and caves and the desire to protect the karst ecosystem.

Although a start had been made on all parts of the karst assessment, only two of the four steps had been completed on Heceta before the Forest Service began plans for the Sawfly Salvage Sale. Karstlands had been identified (virtually all the sale area is on karst) and a model had been developed to identify areas of higher vulnerability. However, only very preliminary inventory and hydrology work had been completed.

TCP cavers walked all the proposed harvest units and found only a handful, which met Karst Standards and Guidelines. In all cases, buffers around high vulnerability features were only 100 feet wide and, effectively less where they had been measured from the center rather than edge of features. In no case did TCP observe buffers designed to meet the two-tree height definition of windfirm.

In many Sawfly Sale Units, high densities of "dry" epikarst features and sinks greater than 8 feet deep were not treated as high vulnerability karst. Esterson's dye traces underscore the importance of "dry" features (Esterson 1997). Surface waters will be uncommon except where karstlands abut non-carbonate terrain. Therefore, in large blocks of highly developed karst, almost all features will be dry. Evidence of surface flow will be rare in the interior of extensive karstlands such as those on Heceta. Wording in the Karst Standards and Guidelines needs to be changed to require that all features >8 feet deep be treated as high vulnerability karst unless proven otherwise by dye traces.

In several cases, harvest had been planned on slopes steeper than 72%. A number of units drain into high vulnerability features outside the unit with no evident protection for the watershed. All too often features were treated as discrete entities without adequate consideration for the system of which they are a part.

A road was planned and built through high vulnerability karst adjacent to unit 14 even though helicopter logging may have been a viable alternative. The economics of helicopter logging were not applied to this unit, but rather to the sale as a whole (Lewis 1997), a very poor method of determining real viability. More roads are currently being built through high vulnerability karst on Heceta, such as those in Unit 9.

The fact that the Forest Geologist did not meet with TCP cavers at all during the caving expedition exacerbated the entire suite of problems. This was true even though cavers informed him early in the expedition that they had noted serious problems they wished to discuss.

All cavers felt the great majority of the units did not meet Karst Standards and Guidelines, with many units requiring major modifications. This, combined with the lack of communication during the expedition, led cavers to lose confidence in the Forest Service's commitment to karst and cave protection.

Are the Karst Standards and Guidelines working? No, Not Yet.

RESTORING KARST ECOSYSTEM PROTECTION AND REBUILDING TRUST

There are a number of ways that the Forest Service can rebuild the trust it once had among cavers. Time must be taken, or made, to communicate honestly and openly with TCP and other cavers. Forest Service personnel must admit problems when they exist and not make promises that can't be kept. Cavers' contributions and concerns must be acknowledged and cavers should be kept in the decision making loop. Most importantly, the Forest Service must implement the original intent of the Karst Standards and Guidelines. When there is any doubt, karst should be considered to be high vulnerability until proven otherwise. In most cases, this should maintain the unique natural processes and productivity of the karst landscape. It will require treating the landscape as a three-dimensional system and taking past mistakes and overall harvest levels into account in designing protective strategies.

The role of the cavers and the TCP, as well as Forest Service Karst Specialists, should remain that of advocates for the caves and karst. They should continue crediting the Forest Service for good management practices when deserved and continue effectively and vocally characterizing problems when necessary.

Since the end of the 1997 cost-share expedition, the Forest Service has received many letters from disappointed cavers. During the final weeks of September communication has improved and efforts are in place to reevaluate the Heceta Sawfly Sale. The Forest Geologist plans to spend several weeks on Heceta examining units in person, and plans are being made to bring cavers out to discuss the issues on the ground. Only time will tell if these plans and promises are meaningful. Unfortunately, as these discussions drag on, road construction continues. It will take serious implementation of the original intent of the Karst Standards and Guidelines, including immediate cessation of road construction through high vulnerability karst, and possible renegotiation of the Sawfly Sale contract, to begin to restore TCP's trust.

The goal for the TCP, all cavers and hopefully, for the

Forest Service is cooperative stewardship of the karst and caves of the Tongass National Forest, ensuring that these systems and the treasures and secrets they hold are protected for generations to come.

ACKNOWLEDGEMENTS

Enormous thanks are due to my fellow cavers and members of the Tongass Cave Project, without whose energy and support none of this work would have been accomplished. I also thank the numerous persons in the Thorne Bay and Craig Ranger Districts who have assisted in many ways to make the annual expeditions work. You know who you are. Thanks also to the USDA Forest Service for providing funding to support the caving expeditions and my participation at this symposium.

LITERATURE CITED

Aley, T., C. Aley, W.R. Elliott, and P.W. Huntoon. 1993. Karst and Cave Resource Significance Assessment, Ketchikan Area, Tongass National Forest, Alaska. Prepared by Ozark Underground Laboratory for the Ketchikan Area, Tongass National Forest, Federal Building, Ketchikan, AK 99901. 79pp + appendices.

Aley, T. and C. Aley. 1993. Delineation and Hazard Area Mapping of Areas Contributing Water to Significant Caves. In: D.L. Foster (ed.): Proc. Natl. Cave Mgmt. Symp., 1991. Amer. Cave Conserv. Assn. Pp. 116-122.

Allred, K., C. Allred, S. Lewis, and M. Fritzke. 1993. Caving in the Tongass. NSS News 53: 89-101.

Carlson, K.R. 1994. Inventory and Assessment of Ecological Relationships Between Cavernicolous (Cave Adapted) Invertebrate Species and Their Interactions in Representative Karst Ecosystems on Carbonate Terrain in the Ketchikan Area Tongass National Forest, Part I. Dall Island. 60 pp.

Carlson, K.R. 1996. Inventory and Assessment of Ecological Relationships Between Cavernicolous (Cave Adapted) Invertebrate Species and Their Interactions in Representative Karst Ecosystems on Carbonate Terrain in the Ketchikan Area Tongass National Forest, Part II, Coronation Island. 93pp + appendices

Carlson, R. 1993. Overview of Archaeological Resources Associated with Caves and Rockshelters in Southern Southeastern Alaska. Alaska Anthropological Assoc., 20th annual meeting. 12 pp.

Dixon, E.J., T.H. Heaton, T.E. Fifield, T.D. Hamilton, D.E. Putnam, and F. Grady. 1997. Late quaternary Regional Geoarchaeology of Southeast Alaska Karst: a Progress Report. Geoarchaeology: an International Journal 12: 689-712.

Esterson, K. 1997. 1997 Dye Tracing Results, Heceta Island, Tongass National Forest, Alaska, e-mail version. 3pp.

Heaton, T.H. 1995a. Middle Wisconsin Bear and Rodent Remains Discovered on Prince of Wales Island, AK. Current Research in the Pleistocene 12: 92-94.

Heaton, T.H. 1995b. Interpretation of 13C Values from Vertebrate Remains of the Alexander Archipelago, Southeast Alaska. Current Research in the Pleistocene 12: 95-97.

Heaton, T.H. 1996. The Late Wisconsin Vertebrate Fauna of On Your Knees Cave, Northern Prince of Wales Island, Southeast Alaska. Journal of. Vertebrate Paleontology 16: 40A-41A.

Heaton, T.H., S.L. Talbot, and G.F. Shields. 1996. An Ice Age Refugium for Large Mammals in the Alexander Archipelago, southeast Alaska. Quaternary Research 46: 186-192.

Lewis, S.W. 1995. Karst Ecosystem Protection in the Tongass National Forest. NSS News: 53, pp. 32-39.

Lewis, S.W. 1997. Summary Notes of a Trip to Heceta Island to Examine Problems with Implementation of Karst Standards and Guidelines on the Heceta Sawfly Salvage sale as Perceived by Cavers (Modified after consultation with Steve Kimball [Thorne Bay District Ranger] on September 17, 1997). 4pp.

USDA, Forest Service. 1996. Environmental Assessment: Heceta Sawfly Salvage Project. Ketchikan Area, Thorne Bay Ranger District. 38pp + appendices.

USDA, Forest Service. 1997. P.3-82 in Tongass Land Management Plan Revision, Final Environmental Impact Statement, Part 1. Forest Service R10-MB-338b. 510pp.

The author has also used numerous reports prepared by cavers of the Glacier Grotto and TCP. Many of these have been published in the *Alaska Caver*, publication of the Glacier Grotto.

Roosting And Hibernal Ecology Of Bats In Southeast Alaska's Karstlands

Stephen W. Lewis
Tongass Cave Project and USDA, Forest Service, Thorne Bay RD. Current address: 212 Observatory St., Sitka, AK 99835 (907) 747-7471, ftswl@aurora.alaska.edu

ABSTRACT

The five species of bats present in Southeast Alaska are among the state's least understood mammals. Bats may be dependent on the old growth forests and caves of the karstlands of SE Alaska. Recent work in Pacific Northwest forests suggests bats require large dead trees in old-growth stands for maternity roosts during summer. Our summer 1997 research suggests this may also be the case in the Tongass although more work is necessary to confirm this. We found evidence that during the latter part of summer male bats are using caves for roosts. Our preliminary data suggest that bats using caves for winter hibernacula may be selecting sites for something other than microclimatic stability. Further work will document winter bat activity relative to cave microclimate and outside weather patterns.

INTRODUCTION

There are 5 species of bats known to occur in Southeast Alaska. These include *Myotis lucifugus*, *M. volans, M. californicus*, *M. keenii*, and *Lasionycteris noctivagans* (Parker 1996). These are among the least understood mammals in Alaska. The impact of habitat modification such as timber harvest on the viability of these species may be significant (Parker et al., 1996: Christy and White, 1993). The karstlands of Southeast Alaska are internationally and nationally significant because they occur within a unique setting; a high-latitude temperate coniferous rainforest (Aley et al. 1993). This forest atop the karst comprises an ecological system with increased productivity for plant and animal communities and well-developed spruce and hemlock trees relative to adjacent non-carbonate terrain (Lewis and Baichtal, 1997). It is these qualities that have led to heavier timber harvest in karstlands and which may make them especially important to bats, both for the presence of caves for hibernacula and for the presence of large old-growth trees which are known to provide summer day-roosts and maternity roosts in other parts of the Pacific Northwest (Brigham et al. 1996; Vonhof and Barclay, 1996).

The karstlands of Southeast Alaska provide caves as potential roosts and hibernacula for bats. Preliminary surveys in Southeast Alaska show bat activity in many of the caves inventoried (U.S.D.A. 1996: p 1-6, and Tongass Cave Project, unpubl.). However, information on the temporal nature of this use is lacking. Preliminary monitoring suggests that bats use caves in Southeast Alaska during the coldest portions of the winter although I observed evidence of use during late summer (Lewis, unpubl. 1996, 1997). Spring and fall observations are lacking. Recreational use of caves and mines may disturb bats and cause increased mortality due to energy depletion (Speakman et al., 1991; Thomas et al., 1990), even when disturbing stimuli are non-tactile and arousal is not immediate (Thomas, 1995). Cave and mine morphologies are important in determining temperature, humidity, and airflow within hibernacula (McManus, 1974; (Brack & Twente, 1985; Twente et al., 1985; Clawson et al., 1980; Nagel & Nagel, 1991; Raesly & Gates, 1987).

SPECIES COMPOSITION AND FORAGING AND ROOSTING BEHAVIOR

Our trapping, banding, and radio tracking of bats on northern Prince of Wales Island (Figure 1) during the summer of 1997 provided a number of interesting results and raised a plethora of new questions. We captured only 6 bats during over 100 mist net and harp trap nights between 8 June and 21 September, 1997. Abundant rainfall and an untested version of harp trap used over part of the summer were certainly in part responsible for the low rates of success. We captured all bats in mist nets either along riparian corridors or at cave entrances. Previous work (Parker, 1996) suggested a preponderance of *M. lucifugus* in Southeast Alaska. We captured a male and female *M. lucifugus*, as well as 3 male M. californicus and 1 female M. keenii. Additional work is essential to determine whether or not this higher equitability of individuals of each species is better reflects the distribution of bats in Southeast Alaska than did the earlier study.

The results of limited telemetry work (the first ever with Southeast Alaskan bats) raised interesting questions. The only individual that remained telemetered long enough to obtain useful data was an adult female M. lucifugus. She was located over a one week period foraging along the lake where she had been captured. She consistently roosted in a patch of old growth approximately 5km away although the actual roost (or roosts) was not located. Much of the study area consisted of relatively young second growth. This individual followed a stream corridor from her roost through second growth to the outlet of the lake around which she foraged. Telemetry studies in other parts of the Pacific Northwest (Brigham et al., 1996; Vonhof and Barclay, 1996) have noted much shorter commuting distances of approximately 2km. Once again, further research will be crucial to determine what type of roosts are necessary for maternity colonies, and whether Southeast Alaskan bats routinely commute such long distances between roosting and foraging sites.

Caves as Roosts and Hibernacula

Maps drafted by members of the Tongass Cave Project (TCP unpubl.) of over 400 caves throughout the Tongass provide information on sites in caves used by bats. I have used this information to identify 3 caves where temperature and humidity were recorded within roosting sites and outside the cave. Cave entrances ranged from 400 to 2100 feet above sea level. I will expand sampling to more sites and monitor bat activity levels as well as microclimate as funding becomes available. Microclimatic variables were recorded from September 1996 through September 1997, with monitoring continuing. Patterns between outside and inside cave temperatures varied greatly between sites.

Eagle's Roost Cave is located on northern Prince of Wales Island. It's entrance opens on an eastern exposure at an elevation of approximately 800 feet. Temperatures in a side passage with evidence of year-round bat usage were relatively stable between September 1996 and September 1997 (Figures 2 & 3). They remained at about 3.9 °C and varied less than 2°C over the year. Outside temperatures during this time fluctuated from -15°C to 25°C. Relative humidity was only measured from September 1996 through June 1997. It remained at 100% throughout this period.

The situation was very different in nearby El Capitan Cave (Figures 4 & 5). Data loggers were located in the main passage where bats have been noted in the winter. The entrance to El Capitan Cave is situated on a southern exposure at approximately 400 feet above sea level. From April through October temperatures in the cave were quite stable, ranging from 4 to 5.5°C, while outside temperatures ranged from 0 to 24°C. Cold snaps in late November, December, and January had dramatic effects on in-cave temperatures. When outside temperatures dropped to below -9°C (minimum -11°C) temperatures in the cave plummeted within a day dropping to -1°C during the prolonged cold spell in December and to 0 to 0.8°C during shorter cold spells. A long period of temperatures just below 0°C during March was strongly correlated with a drop in cave temperature to 1.2°C. Relative humidity, which was a constant 100% during much of the year plummeted to 75% during the long December cold spell and to about 85% during the shorter November and January cold spells. The relative humidity logger failed in mid March.

A similar pattern was noted in Glaz Gorie (Mountain Eye) Cave (Figures 6 & 7), an alpine cave at approximately 2100 feet in elevation on Heceta Island. Data loggers were hung in a pit at the ceiling level of the adjoining chamber, where bat guano had been noted. Summer highs in this treeless area reached 34 °C, while winter lows dropped to about -17°F. As in El Capitan Cave, in-cave temperatures were relatively stable between April and October, this time ranging from 2.5 to 5°C. And, once again, during the winter, there were strong correlations between outside cold spells and sharp drops in temperature and humidity within the cave. In Glaz Gorie cave temperatures dropped as low as -7.5°C during outside cold snaps and rarely climbed above 1°C throughout the winter months. Relative humidity dropped as low as 80% during these cold spells.

In summary, climatic variables recorded over the past year in 3 sites used by bats ranged from very stable to quite variable during the winter but were relatively stable in all sites during summers. This suggests that bats may be choosing roosting or hibernation sites for reasons other than just the stability of the microclimate. An expanded study is essential to determine how these differences in microclimate are related to cave morphology and to determine how or whether bat activity is related to such variation. This will provide insights into other parameters that may be important in determining how bats choose winter roosts.

IMPLICATIONS FOR KARST AND CAVE MANAGEMENT

The Federal Cave Resources Management Act requires Federal land managers to "secure, protect, and preserve significant caves on Federal lands" (United States Congress 1988). In the Tongass National Forest this requires treating the karst landscape as an ecological unit (Baichtal 1996). Bats are an integral part of this ecological system. With continued funding, this study will provide information on timing of cave use by bats in Southeast Alaska, cave morphologies most useful to bats, and the importance of old growth and other habitats for foraging and reproductive bats. This information will be critical to managers in determining the need for seasonal regulation of recreational use of caves to protect bats. Knowledge of foraging and roosting needs of forest dwelling bats in Southeast Alaskan karst will also be important in maintaining a functioning ecosystem ensuring viable populations of bats.

ACKNOWLEDGEMENTS

Jennifer Griffin, Tony Fischbach, Eva Patton, Rachel Myron, Dave Love, and John Locke, provided help and companionship in the field. The US Fish and Wildlife Service provided support to Tony Fischbach. Financial and logistical support was provided through the USDA Forest Service, Thorne Bay Ranger District. Additional financial support was provided by the University of Alaska Museum through the Mammal Lab and a Geist Fund grant, and by the Alaska Department of Health and Human Services. Thanks to all!

LITERATURE CITED

Aley, T, C. Aley, W.R. Elliott, and P.W. Huntoon. 1993. Karst and cave resource significance assessment, Ketchikan Area, Tongass National Forest, Alaska. USDA Forest Service, Ketchikan Area, Tongass National Forest. 79pp + appendices.

Baichtal, 1996. Characterization of the karst landscape, basis for an ecologically-based management strategy. In Tongass Land Management Plan Revision, Revised Supplement to the Draft Environmental Impact Statement, Proposed Revised Forest Plan. R10-MB-314c. pp.I.2-I.11.

Brack, V., Jr., and J. W. Twente. 1985. The duration of the period of hibernation of three species of vespertilionid bats. I. Field studies. Can. J. Zool. 63:2952-2954.

Brigham, R. M.., M. J. Vonhof, and R. M. R. Barclay. 1996. Roosting behavior and roost-site preference of forest-dwelling California bats (*Myotis californicus*). J. Mamm.

Christy, R. E., and S. D. West. 1993. Biology of bats in Douglas-fir forests. Gen. Tech. Rep. PNW-GTR-308. Portland, OR. USDA, For. Serv., Pacific Northw. Res. Stn, 28 pp.

Clawson, R. L., R. K. Laval, M. L. Laval, and W. Caire. 1980. Clustering behavior of hibernating *Myotis sodalis* in Missouri. J. Mamm. 61: 245-253.

Lewis, S.W., and J.F. Baichtal. 1997. Protecting caves, karst, and bats in the Tongass National Forest, Southeast Alaska pp. 42-46 in Sasowsky, I.D, D.W. Fong, and E.L. White, eds., Karst Water's Institute Special Publication # 3, Conservation and protection of the biota of karst, Extended abstracts for the symposium held Feb 13-16, 1997 in Nashville, TN. 118pp.

McManus, J. J. 1974. Activity and thermal preference of the little brown bat, *Myotis lucifugus*, during hibernation. J. Mamm. 55:844-846.

Nagel, A., and R. Nagel. 1991. How do bats choose optimal temperatures for hibernation? Comp. Biochem. Physiol. 99: 323-326.

Parker, D.I. 1996. Forest ecology and distribution of bats in Alaska. MS Thesis, Univ. of Alaska, Fairbanks. 74 pp.

______., J.A. Cook, and S.W. Lewis. 1996. Effects of timber harvest on bat activity in southeastern Alaska's temperate rainforest. pp. 277-292, in, Bats and Forests Symposium, October 19-21, 1995, Victoria, British Columbia, Canada (eds. R.M.R. Barclay and R.M. Brigham), Research Branch, B.C. Ministry of Forests, Victoria, B.C., Working Paper 23/1996, 292 pp.

Raesly, R. L., and J. E. Gates. 1987. Winter habitat selection by north temperate cave bats. Am. Midl. Nat. 118:15-31.

Speakman, J. R., P. I. Webb, and P. A. Racey. 1991. Effects of disturbance on the energy expenditure of hibernating bats. J. Appl. Ecol. 28:1087-1104.

Thomas, D. W. 1995. Hibernating bats are sensitive to nontactile human disturbance. J. Mamm. 76:940-946.

______., M. Dorais, and J-M. Bergeron. 1990. Winter energy budgets and cost of arousals for hibernating little brown bats, *Myotis lucifugus*. J. Mamm. 71:475-479.

Twente, J. W., J. Twente, and V. Brack, Jr. 1985. The duration of the period of hibernation of three species of vespertilionid bats II. Laboratory studies. Can. J. Zool. 63:2955-2961.

U.S.D.A. 1996. Tongass land management plan revision, revised supplement to the draft environmental impact statement, proposed revised forest plan. R10-MB-314c. U.S.D.A. Forest Service, Juneau, AK. 561pp.

United States Congress. 1988. Federal Cave Resources Protection Act of 1988. HR 1975.

Vonhof, M. J, and R. M. R. Barclay. 1996. Roost-site selection and roosting ecology of forest-dwelling bats in southern British Columbia. Can. J. Zool.74: 1797-1805.

Conservation Of Cave Roosting Bats at a North Florida State Park

Mark Ludlow and Jeff Gore
Florida Department of Environmental Protection
Florida Caverns State Park
3345 Caverns Road
Marianna, FL 32446

Florida Game and Fresh Water Fish Commission
3911 Hwy 2321
Panama City, FL 32409

ABSTRACT

Florida Caverns State Park was established by the federal Civilian Conservation Corps during 1937 to 1942, and features the state's only developed tour cave, the Florida Cavern. The park also contains several undeveloped caves, including Old Indian Cave, which houses a colony of 10,000 southeastern bats (*Myotis austroriparius*), as well as Florida's only population of Endangered gray bats (*M. grisescens*). In 1967 the park paved a road adjacent to Old Indian Cave and public visitation was encouraged. The resulting formation damage and bat disturbance prompted cave entrance closure with grid-type gates in 1970. These obstructions unintentionally eliminated the bat roost. In 1982 the largest entrance was reopened and a perimeter fence installed. The bat colony quickly recovered. In 1993 funding was provided by the U.S. Fish and Wildlife Service to further enhance both bat protection and bat interpretation at the park. A second large entrance to Old Indian Cave was ungated and fenced. The bats responded immediately to the reopened passage, and currently the 2 fenced entrances are used on approximately a 50/50 ratio by emerging bats.

Introduction

Florida Caverns State Park is a 1300-acre preserve in the Panhandle of the state. It is 58 miles west of Tallahassee and 70 miles north of the Gulf of Mexico. Elevations on the park range from 70 to 150 feet above sea level. The park is 3 miles north of the town of Marianna. Florida Caverns park is bisected by the Chipola River, a major tributary of the Apalachicola River. Principal habitat types include floodplain hardwood swamp, and beech-magnolia dominated hardwood forest on the limestone bluffs above the river.

In the early 1930s, the presence of numerous highly decorated caves, and a natural bridge over the Chipola River prompted 2 private investors to buy the land with the intention of developing an attraction. Perhaps due to a shortage of development capital, the land was eventually donated to the state, and was developed into the 7th Florida state park by the Civilian Conservation Corps.

The park's 30-plus caves are located in a narrow band of chalky Eocene limestone belonging to the Crystal River group, which is rich in marine fossils.

Florida Caverns State Park is also home to an array of plants and animals not normally associated with "subtropical" Florida. Appalachian relics such as Bloodroot, Allegheny spurge, Columbine and many others have made the Caverns a "must see" for botanists.

For the zoologically-oriented, Florida Caverns features blind cave salamanders, cave crayfish, and 3 species of cave-roosting bats; the Eastern *pipistrelle*, Southeastern or Mississippi *myotis*, and the federally-endangered gray bat. Florida Caverns has the only gray bat hibernation cave in the state; the next nearest site is in northern Alabama. Specimens of the Long-eared bat (*Myotis septentrionalis*) and Indiana bat (*Myotis sodalis*) were recorded from the park in the 1950s, but have not been seen in recent decades.

Historical Background

In a 1955 note in the Journal of Mammalogy, Dale Rice first reported large colonies of *Myotis* roosting in the park's Old Indian Cave. Although known to locals for decades if not centuries, this cave remained relatively pristine until 1967. Until that time virtually all of the development on the park was in the tour cave area on the east side of the property. In 1967, funding was obtained for development of a boat ramp, and camping and swimming areas on the west side of Florida Caverns. A 2-lane paved road was built which ran east-west, and passed less than 200 feet from the entrance to Old Indian Cave.

A parking lot was built in front of the cave and unsupervised public visitation was permitted. In response to the graffiti and formation damage which occurred, the cave was gated in 1970 with grid-type iron gates. A primary entrance was obstructed with vertical concrete pillars. In June of 1981 only 2 determined *Myotis* bats were located in Old Indian Cave. In a 1971 publication, Lee and Tuttle estimated that the cave was used historically by 125,000 to 300,000 *Myotis*.

Recognition of a problem with the *Myotis* roost and cave gating was less than expeditious. However, 12 years after Old Indian Cave was first gated, the concrete pillars were removed, and a 7-foot perimeter chain link fence was installed at the largest southeast cave entrance. This was in 1982. The bat colony gradually began to recover, and winter counts of 500 to 1100 bats were made by Florida Game and Fresh Water Fish Commission biologists.

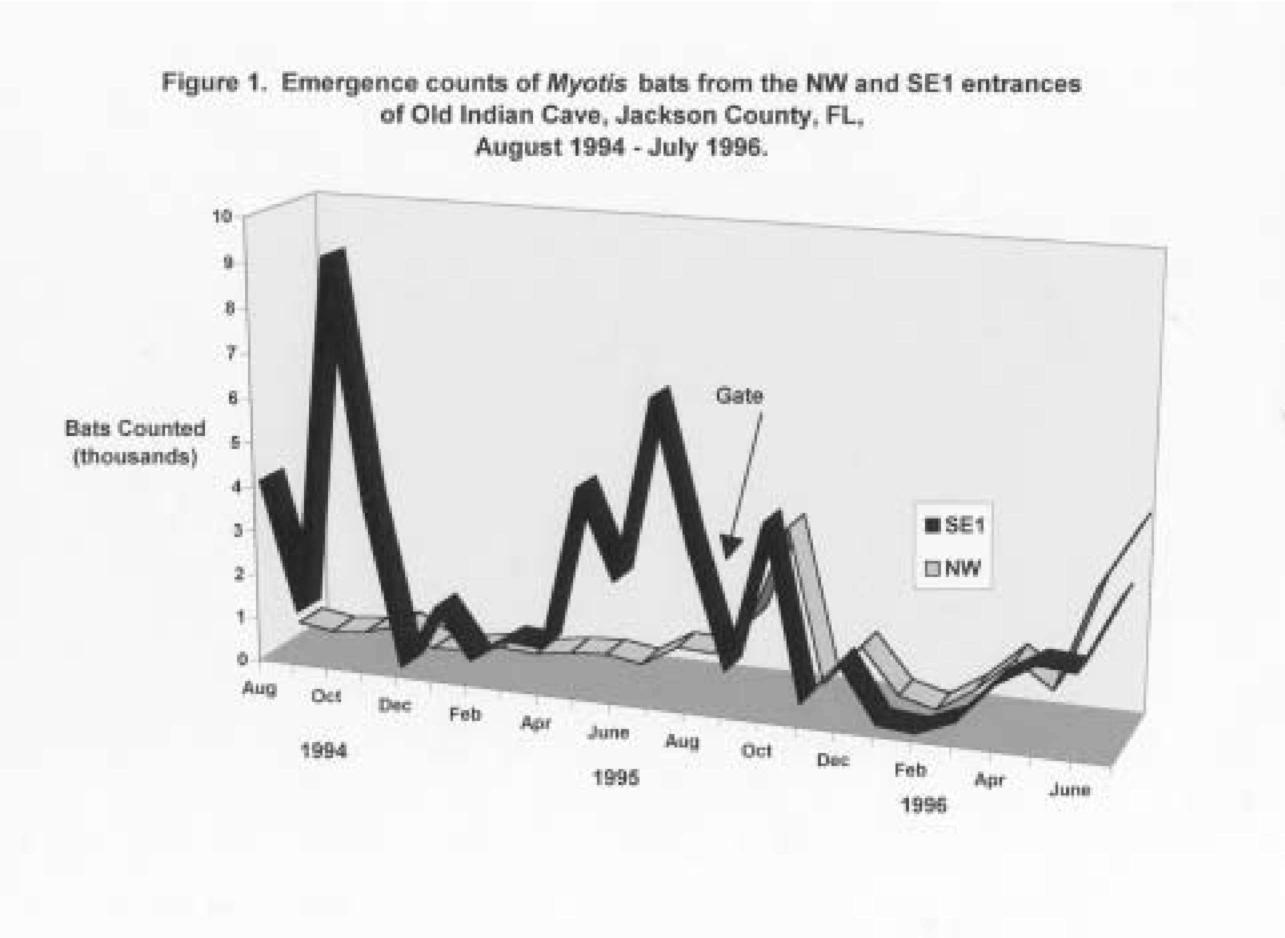
Methodology

Due to the successful re-establishment of the bat colony using perimeter fencing, the Florida Caverns Cave Management Plan placed bat roost enhancement and restoration at the top of resource management priorities. In 1994, funding was obtained from the U.S. Fish and Wildlife Service's Partners in Wildlife program to un-gate and fence 2 additional cave entrances. The first of these entrances to be restored was the northwest entrance of Old Indian Cave. This is the same bat roost which was restored via the 1982 perimeter fence. The change was simply to fence and then un-gate the northwest entrance, hopefully to benefit an extant bat colony.

A study was designed to determine the bats' out-flight response to the removal of the gate from the roof of Old Indian Cave. Simultaneous counts were conducted each month, at the open and still-gated entrances to cave. Counts were made with the aid of red-lens electric headlights and clicker-type counters. Physical measurements and reproductive condition data were also collected on a sample of the bats. Cumulative totals of bats emerged were made at 10 minute intervals. Twelve months of emergence count data were obtained.

Results

In August of 1995, the gate was cut away from the northwest entrance (abbreviated NW in graphic) and the new perimeter fence secured. An additional 12 months of simultaneous counts were made with both this and the southeast (SE1) entrance (fenced 1982) now unobstructed. The bat count results are shown in Figure 1. It is obvious that during the 1994-1995 period, with the gate in place, a very small percentage, actually 8 percent of emerging bats passed through the gated entrance. Immediately following removal of the gate, the usage of both now-open entrances was virtually the same. The overall percent using the newly-opened entrance averaged 52 percent for the 12-month post-removal monitoring.



One can speculate on several benefits to this type of bat-access restoration; more rapid access to a sunset peak in insect activity, improved avoidance of predators and humans entering the cave. In any event, the bats seem to have responded positively to the change. At present Old Indian Cave is used by approximately 150 gray bats in winter, and up to approximately 10,000 Southeastern *Myotis* bats.

Earlier, I mentioned the park restored two cave entrances. The second site was at Miller's Cave, a roost which was apparently extinguished in the 1970s, first by human disturbance and then by gating. Confirmation of a historic roost was provided by Southeastern *myotis* skulls and long bones present in layer of mud on the cave walls. In 1994, the perimeter to the largest entrance to Miller's Cave was also fenced and the grid-type gate removed. Response to our "engraved invitation" to the bats has not been dramatic. For two years groups of only 2-3 *Myotis* bats were seen to emerge from the cave at sunset. Then in August of 1997, 25 bats were observed emerging from this cave. We remain hopeful that the historic roost at Miller's Cave will eventually become re-established.
There is a third recorded bat cave on the park, on a parcel which was recently acquired by the Florida Park Service. It is in an isolated and unpatroled location and fencing does not appear practical. The park is currently considering a modern, bat-friendly gate for Ellis Cave, and we would be interested in hearing from those who have Gray and Southeastern *Myotis* colonies using gated cave entrances.

Conclusions

At Florida Caverns State Park, fencing *Myotis* roost caves has been successful in maintaining access for bats and achieving an acceptable level of security from human disturbance. Fencing was also used successfully at other bat caves in Florida such as Judge's Cave (Jackson County) and Grant's Cave (Alachua County). Elsewhere in the U.S., "bat-friendly" cave gates have been designed which successfully permit the passage of the animals while controlling human access (see Tuttle and Taylor, 1994). In evaluating fencing versus gating to protect a bat colony, one must consider such factors as cave entrance size and shape, remoteness of site, level of on-site supervision available, response of the bat species using the cave to gating, and level of human disturbance to which the cave is subjected.

The park has taken several other measures to enhance public awareness of bat conservation issues. A new interpretive exhibit on the 3 cave roosting bats found on the park was also funded by the U.S. Fish and Wildlife Service Partner's in Wildlife Program. We offer free in-house brochures on bats and cave conservation. The park has adopted a bat and cave symbol as the logo for the park. The gift shop also sells the "Bats of the Southeastern U.S." poster. We have also produced a new video interpreting the ecology of the park, which includes excellent bat footage. The administration of Florida Caverns State Park is continuing to look for new ways to enhance bat conservation and improve bat interpretation at the park, and we welcome any comments or suggestions.

Literature Cited

Lee, D.S., and M. D. Tuttle. 1970, Old Indian Cave: Florida's first bat sanctuary. Fla Nat. 44:150-152.

Rice, D. W. 1955. Status of *Myotis grisescens* in Florida. J. Mammal. 36:289-290.

Tuttle, M. D. and D. A. R. Taylor. 1994. Bats and Mines. Bat Conservation International, Inc. Resource Publication No. 3. 41 pp.

Advances in GPS Receivers for Locations in Densely Forested and Hilly Terrain — Poster Presentation

John T. M. Lyles

Abstract

The first inexpensive consumer global positioning receivers used by cavers had five to eight channel sequential scanning circuitry to allow locking in on a sufficient number of satellites to get a usable 'fix' of location. This technology was cheaper to manufacture and also used less battery power. In a heavily forested canopy, these handheld units often lost lock on the signals, or never gained the initial lock on which to establish the calculations. Recently, twelve channel parallel receivers have become available, with similar costs and ease of operation, from the same manufacturers. The advertised advantages have been faster locking and improved ability to hold enough satellite signals to continue updating the position. Better operation in heavily forested areas has been addressed, according to the manufacturers. The author will share first hand experience with two Garmin units, an older eight channel sequential architecture receiver, and a new twelve parallel channel model. Usage in locating a national forest cave in dense timberland in the mountains of southern New Mexico will be described. This will provide cavers, cave scientists, and management with a firsthand understanding of the advantages of these two GPS receiver architectures.

[This paper was not presented at the Symposium because the author was unable to attend.]

Conservation Practices for the Improvement of Water Quality of the Mammoth Cave Karst Aquifer

Joe Meiman and Chris Groves

Abstract

The aquatic ecosystem of Mammoth Cave, Kentucky, the most biologically diverse cave aquatic ecosystem known, has experienced chronic and acute contamination from an assortment of land uses within its watershed over the past 200 years. Threats have included sediment, human wastes, agricultural chemicals, runoff from livestock feeding areas, and hazardous chemical spills. Since 1900, Mammoth Cave National Park and its cooperators within the Mammoth Cave Area Biosphere Reserve have taken measures to improve the water quality of the Mammoth Cave karst aquifer. Between 1989 and 1996, a regional sewer system was constructed. Now an average of 430,000 gallons per day of sewage which one entered the aquifer is treated by this system. Ninety animal waste best management practices (BMPs) now annually collect some 2,000 tons of animal waste which once flushed into the cave following every rainfall, with the waste now replacing, or supplementing, commercial fertilizer. A continual threat to the aquifer's health is the possibility of accidental spills along 12 miles of interstate highway and 11 miles of a major railroad that cross the park's watershed. Detailed maps depicting landmarks and drainage features along these transportation corridors now allow emergency responders to locate spills precisely with respect to karst recharge features. No one agency has the resources or authority to solve all threats to the water quality of the Mammoth Cave aquifer. The Mammoth Cave Area Biosphere Reserve has provided the cooperative platform for the improvement of water quality as well as promoting an ecologically sustainable economy.

Surface Developments Above Wind Cave - Studying the Impacts

Jim Nepstad
Wind Cave National Park

Abstract

A number of surface developments lie above Wind Cave, located within Wind Cave National Park in South Dakota. Investigations have shown that contaminants found in parking lot runoff can make it into parts of the cave via drips in as little as six hours, and will persist for years. It has also been shown that some of the sewer lines in this old national park are in disrepair, and are likely leaking small amounts of sewage into the underlying cave. Finally, a thorough site assessment on a former dumping ground above the cave has revealed progressively decreasing amounts of pentachlorophenol in selected cave waters. Wind Cave National Park is attempting to mitigate these problems by securing funding for capturing and treating contaminated parking lot runoff, installing dual-contained sewer lines, and banning the disposal of wastes above the cave.

Introduction

The Act of Congress that created Wind Cave National Park was signed into law by President Theodore Roosevelt on January 9, 1903. Wind Cave is thus contained within a very old national park; the seventh in United States history, and the first national park set aside within the United States to protect a cave.

These simple facts of history are a matter of pride to many of the employees and supporters of Wind Cave National Park. They are also an indirect source of many of the cave management challenges currently confronting the park. Decisions regarding the placement and construction of major surface developments were made almost a century ago. At that time, cave/surface interactions were poorly understood.

In the 1980's, concern began to grow among park staff that some of the developments and activities taking place on the surface could potentially be impacting the underlying cave. Much of the 1990's has been spent performing research into the surface developments thought to contribute the most impacts to the cave - the parking lot, sewer lines, and a waste disposal area known as the Mixing Circle.

Parking Lot Runoff

An asphalt parking lot roughly 2.5 acres (1 hectare) in size is utilized by visitors to the cave. Runoff from precipitation events leaves the parking lot via a series of four drains. All four drains direct their flow to an adjacent dry streambed. Despite the fact that more than 60,000 gallons (227,125 liters) of runoff flows off the parking lot for each 1 inch (2.54 cm) of rainfall, runoff fails to flow much more than 50 feet (15 m) down the dry streambed before completely disappearing.

The park is concerned that petroleum hydrocarbons and other contaminants commonly found in parking lot runoff may be infiltrating into underlying cave passages. Of even greater concern is the effect that a large spill from an RV fuel tank or fuel oil delivery truck could have on the cave below. Such disasters, while not common, can and do happen given enough time. A vague report in the park's historical files describes a large fuel truck overturning in 1960, "spilling much oil." Such a spill on the parking lot would immediately send large quantities of a contaminant directly to the dry streambed, where it would disappear long before the park could react.

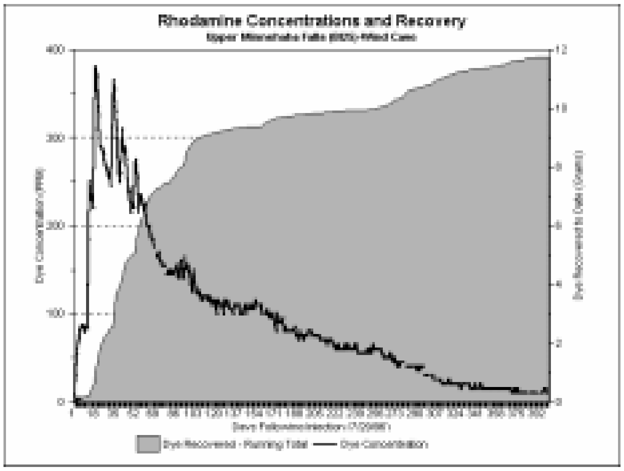


Figure 1. Dye trace data from Upper Minnehaha Falls in Wind Cave. The multiple peaks in dye concentration during the first two months corresponded with individual rain events.

Past researchers had demonstrated via dye tracing that runoff from the southern parking lot drain could enter parts of the cave in less than two days. At that time, researchers lacked detailed inventory data for this huge cave; most of this data was collected during the 1990's. Using the newly collected inventory data, park staff were able to produce detailed maps documenting where dripping, seeping, or pooled water existed in the cave. It soon became clear that several important locations had not been sampled, mainly because the researchers were unaware of the existence of these sites. Of the sites they did sample, many were sampled for only a few weeks.

In order to gain a better understanding of the extent of the cave affected by parking lot runoff, the dye traces were repeated by park staff during the summer of 1996. Nearly three times as many sites were monitored, some for well over a year. One site, Upper Minnehaha Falls, was set up with an automatic sampling device. This site was known to react very quickly to precipitation events on the surface.

Dye was injected on July 29, 1996 during a simulated 1 inch rain event. A total of three cave sites received parking lot runoff less than 24 hours following dye injection. Upper Minnehaha Falls contained measurable quantities of dye within six hours of injection. Dye concentrations at these three sites peaked after roughly three weeks, and remains in measurable concentrations as of this writing (October 1997). Figure 1 documents dye recovery for Upper Minnehaha Falls.

To date, a total of fifteen cave sites have received measurable quantities of dye from just one of the four parking lot drains. These sites are contained within an area that encompasses roughly 90,000 square feet (8,360 square meters). The length of time before a site went positive, and its peak concentration, varied from site to site. However, the persistence of the dye - the amount of time it remains in measurable concentrations once it arrives - seems to be fairly consistent. All sites that received dye during this trace remain positive after more than one year.

The information gained from this trace indicates that contaminants found in ordinary parking lot runoff could be infiltrating into the cave. Lab testing has confirmed this. In addition, we now know that a fuel spill of even a few gallons could have serious consequences. Based on the amount of dye injected and the concentrations measured in the cave, it is estimated that if even five gallons (19 liters) of gasoline were to escape from a parking lot drain, visitors to certain areas of the cave may very well be able to smell the infiltrating contaminants. It is reasonable to assume that such a spill (or a larger one) would seriously impact the cave's native biota.

Sewer Lines

More than 1,000,000 gallons (3,785,000 liters) of sewage flows each year through sewer lines overlying parts of Wind Cave. Some of these sewer lines date back to the 1930's or earlier, when many of the structures currently visible in the park were constructed. Some may be even older. Park reports indicate that many of these lines began to develop problems as early as the 1950's. Apparently the problems were judged to be severe enough by the early 1980's that the park secured funding to slipline many of the lines. During the sliplining process, lengths of plastic pipe are inserted into the old lines, and the flow is diverted into the new pipe.

Institutional memory had it that all of the 8,000 feet (2,400 m) of sewer lines in the park had been sliplined, and thus was "cave-friendly." During some spring flooding in 1991, however, park staff noticed an overflowing sewer manhole. When the clogged line below this manhole was cleared soon afterwards, it was learned that small branches and sticks had been clogging the lines. The presence of surface vegetation in the sewer lines shattered the park's confidence in the integrity of the system.

The park soon acquired a special video camera for monitoring sewer lines. Bare-bones (but perfectly functional) systems can be purchased for as little as $4,000. During a one-week period, nearly all of the 8,000 feet of sewer lines in the park were visually inspected. What was discovered was that while most of the main sewer line had been sliplined, very few of the lateral lines had been. Many of these lateral lines, which connect individual buildings with the main line, were broken and clogged with invading roots.

How much sewage is leaking into the underlying cave is difficult to measure, but given the condition of many of the lines, it is very safe to say that at least some leakage is taking place. Wind Cave is a very nutrient-poor environment, and the cave's native biota reflect this. Nutrient-rich sewage entering the cave threatens to alter this environment. It also represents a potential health risk, since many of the worst lines are located over the cave's developed tour routes.

Burning Fence Posts

A seven-foot (2.1 m) tall fence stretches for more than 44 miles (71 km) around the boundary of Wind Cave National Park. The fence, which keeps the park's bison herds from wandering onto private lands, required nearly 15,000 fence posts to construct. Most of the fence posts were treated with wood preservatives such as pentachlorophenol to increase their life in the field.

The fence requires regular maintenance. Several hundred posts are replaced in an average year. The old posts are hauled out of the backcountry, and in the past were piled up in a park storage area known as the Mixing Circle. Other combustible items were added to the pile, and each winter the pile was burned in a large open fire. Park photographs show this tradition occurring over at least a 35 year period.

The Mixing Circle burn pile was located in the middle of a dry streambed. About once every five years, heavy precipitation or rapid snow melt cause flooding in this streambed. Flood waters were seen pouring through the ashes of the burn pile at least twice during the early 1990's. In 1994, some routine water quality tests revealed the presence of pentachlorophenol in water dripping into a cave room known as the Pile Up. The Pile Up is located just down dip and about 200 feet below the burn pile in the Mixing Circle.

Water from the Pile Up was frequently consumed by explorers on long exploration trips to areas beyond. While the pentachlorophenol levels detected were below safe drinking water standards for humans, discussions with the U.S. EPA led to concerns that dioxins may also be present. A certain percentage of pentachlorophenol will convert to dioxin when consumed in an open fire. The park immediately halted the further burning of fence posts and all other sources of trash in the park. Subsequent testing by the EPA, together with a formal site assessment of the soils and groundwater in the area, revealed progressively smaller amounts of pentachlorophenol in cave waters. Cave explorers can safely consume water from the Pile Up once again.

Solutions

Defining a problem is only an initial step. Wind Cave National Park has begun the long and difficult process of solving the above problems.

The simplest solution involved the issue of burning old fence posts. The park has simply banned the practice of burning any form of human trash. While this means the park must transport more trash to a local community's landfill, it is none-the-less a solution that the park has direct control over, and which requires no outside funding. Interestingly, the park has discovered there is a market for the old fence posts. Local ranchers now bid on them as surplus government property.

Potential solutions to the parking lot and sewer line problems are not as simple, and are more varied. All of them require large sums of money, making it necessary to compete for outside funds. One obvious solution would be to simply remove the developments from above the cave and move them somewhere else. In this case, the age of the park once again returns to haunt us. The Visitor Center and many surrounding buildings are part of an Historic District listed on the National Register of Historic Places. Even if the present developments were removed, some kind of transportation system would have to be devised to bring visitors to the cave entrance. As long as visitors wish to view Wind Cave, some sort of parking and sewage facilities will always be necessary. The park's proposed solutions to these problems therefore focus on keeping things where they are.

It was quickly realized that simply replacing old sewer lines with new traditional lines was an incomplete solution. While the leaks would be fixed and the new system would last longer than the old one, a day would eventually come when it once again would begin to fail. How does one determine that sewer lines are failing? As the park has demonstrated, video systems do work. But as someone who has participated in the inspection of thousands of feet of active sewer lines, this author can state with authority that the nature of the work is decidedly unpleasant and time-consuming. It is very likely that the park would once again fall under the "out of sight, out of mind" spell that held us for so long before. The simple fact of the matter is this: leaks in traditional sewer lines are generally discovered well after the system has failed. When the public tour portion of a world-class cave is located directly under sewer lines, this is unacceptable.

The park has therefore decided to build a leak detection system directly into the new lines. Dual-contained HDPE lines - a pipe within a pipe - will completely replace all existing lines in the park. Manual inspection ports will be placed at regular intervals. If flow is discovered between the primary and secondary lines, a leak will have been detected, and the system can be repaired. Inspections will be simple enough that they are likely to be performed regularly and often. Funding for this new system has been secured, and work is scheduled to begin in 1999. Video-taped evidence of leaking sewer lines over the public tour portion of the cave proved to be an effective marketing tool.

The parking lot issue is trickier to solve and to sell. Two problems must be addressed: the day-to-day contaminated runoff, and the potential for more serious contamination resulting from large spills on the parking lot. Porous pavements, which would allow for more even infiltration and hence drastically reduced runoff, were considered because they would allow for more natural infiltration. Unfortunately, they fail to contain spills and actually make clean up more difficult.

The solution the park is presently leaning toward involves redesigning the parking lot so that all runoff is carried to a central facility. More than 30 feet (9 m) of road fill exists beneath the down-slope end of the parking lot. Large tanks will be buried in this fill which will capture the “first flush” from each rain event. Numerous studies have documented that the majority of contaminants in parking lot runoff are transported in the initial stages of a rain event. Subsequent runoff tends to be comparatively much cleaner. Once the tanks are full, subsequent runoff will be directed to daylight, much as it is now. An oil/water separator and air stripper will remove petroleum hydrocarbons from the runoff in the tanks. The treated runoff will then be released.

Should a large spill occur on the parking lot, the contents of the spill will be directed to the holding tanks. The contents can then be removed and shipped out of the park, drastically reducing the likelihood of serious contamination in the cave.

The park has attempted to secure funding for the above solution, so far without success.

Why Did These Events Occur in a National Park?

The author attributes the above problems to a poor understanding of surface/cave interactions, the use of low quality construction materials (by today’s standards), poor infrastructure design, and a failure to adequately consider the potential consequences of seemingly innocent actions.

As noted above, Wind Cave National Park was established in 1903, making it a very old national park. It was developed well before anyone began studying, or even thinking about, water movements between the surface and cave. Thus, surface developments were often inadvertently placed in sensitive locations. Had park management known of the potential problems posed by these developments, it is possible they would have acted differently. Older surface developments were constructed with the materials of the day. Clay pipe was used for sewer lines. The park’s original water lines were constructed of wood! Subsequent water lines were constructed with metal pipe, but after more than 50 years in the ground, these pipes are falling apart. Once buried, water and sewer lines are invisible and difficult to inspect. Because of this, problems generally are not discovered until well after leaks have developed. Modern utility systems overlying cave and karst areas should be designed with the best materials available, and should include a simple inspection system if possible.

The parking lot functions much like a hypodermic needle; instead of allowing even infiltration over the cave (at Wind Cave, more than 95% of precipitation is taken up in the evapo-transpiration process), the parking lot directs contaminated runoff right into the veins of the cave. We cannot change this aspect of the parking lot, but we can at least make sure the needle, and what it injects, is clean.

Finally, national parks, like the rest of society, sometimes fail to adequately consider the consequences of their actions. Burning wooden fence posts seemed like a good idea. Until the modern-day Material Safety Data Sheet (MSDS) came into existence, few people were aware of exactly what could happen if the posts were burned in an open fire. Still, careful thinking could have revealed a potential threat to the cave. That alone could have prevented the problem.

It is important to recognize that the problems described in this paper are not unique to Wind Cave. Most caves developed for public viewing have parking lots, sewer and water systems, and waste disposal issues. It is hoped that the managers of these caves will heed the lessons learned recently at Wind Cave National Park. Treat the surface as the roof of the cave, which, of course, it is.

Christmas Tree Cave Bat Gating Project, Mt. Adams Ranger District

Jim Nieland, David Anderson, and Chandra Madrona

Abstract

Three significant maternity colonies of Townsend's big-eared bats (*Corynorhinus townsendii*) are known to exist in Washington State. Christmas Tree Cave is a 1000 foot segment of lava tube with entrances at each end. It is unusual because it meets environmental criteria for both a maternity roost site and a hibernaculum for the species. The west entrance harbors a maternity colony of 125 animals. During a WDFW survey in 1995, a trail was discovered that was cut through heavy brush to the entrance. Because this species is thought to have undergone a decline throughout its range and is known to be intolerant of disturbance, the Cave Habitat Work Group organized an effort to gate the cave. The ad hoc Work Group, established in 1994 to address cave habitat issues and cave species in Washington State, consists of approximately 25 individuals from various public agencies and caving organizations. In the fall of 1996, over 46 volunteers provided 660 hours of labor to gate the cave. Seven tons of steel were carried to the two entrances, cut, and welded to fit the design for zero air flow disturbance bat gates. An exit survey will be conducted each year, and every three years hibernating bats will be counted. These surveys will monitor the effectiveness of the gating project in protecting Townsend's big-eared bats from disturbance. In February, 1997, 129 Townsend's big-eared bats were counted using the cave, an average number based on previous surveys. The hibernation survey shows acceptance of the gates by the species.

The Human Nature of Caving and Cave Conservation at Mammoth Cave National Park

Rick Olson
Ecologist, Division of Science and Resources Management
Mammoth Cave National Park
Mammoth Cave, Kentucky 42259

Introduction

In general, the optimal management of cave resources is both complex and controversial. Mammoth Cave is certainly no exception, and given the history of use by our culture over the past two centuries, it is best to start with some statements that everyone concerned can agree upon.

1. Within human lifetimes, or even that of human cultures, caves must be considered non-renewable resources. When we visit caves, we unavoidably degrade the resource base to varying degrees, particularly in passages above the flood zone that do not have developed trails, .

2. As National Park Service employees, we are charged with the conservation of cave resources such that they will remain unimpaired for future generations. Simultaneously, we are charged with the interpretation of these same cave resources to current generations.

3. In undeveloped passages, small groups (eg 3-4 people) of highly experienced individuals traveling in single file cause the least damage. In particularly vulnerable areas, even the minimum possible damage may be unacceptable. Conversely, larger groups (eg 30-40 people) can traverse passages with developed trails, and have virtually no <u>additional</u> impact upon the cave.

4. It is crucial that we put caves and people in perspective.

The smallest of enterable passages are at least equal in age with human civilization. The grand avenues of Mammoth Cave are much older than our species. Caves do not need people in order to have value; the geological and biological resources of caves are inherently valuable as part of the Earth and its biosphere. Cultural resources do add humanly relevant value to caves, but again, the value of these antiquities is not dependent upon direct visual appreciation by us now. The value rests in knowing that these resources are there, and in being able to appreciate what we have learned from them. The question "If we can't go see it, then what good is it?" has no validity.

Speleo-Sociology

Education, research, resources management, facility maintenance, and recreation constitute five major categories of subterranean activity in the park. Educational trips are conducted by (and for) park employees, by park environmental education specialists primarily for young visitors, and by university professors for course field trips. Underground research is conducted by a wide range of people with approved project proposals including professors and Cave Research Foundation personnel. Resources management is carried out by park employees and cooperating organizations such as the National Speleological Society, underground facility maintenance is done by park employees, contractors, and cooperators such as Target Stores, and recreational trips are conducted by park employees for the visiting public. All of these underground activities take place both on and off developed trails to varying degrees.

Cutting across all the different groups that work in park caves is a dichotomy based upon what attracts each person. Broadly speaking, some people are primarily drawn by an interest in caves/karst, and some people are attracted for either professional reasons or an interest in helping the Park Service. Both types of attraction are good because we need all the various types of expertise and human energy. BUT, and this is a big but, people drawn by interest in caves/karst are generally more aware of how careful we must be in caves, whereas professionals and civic-minded volunteers are generally not. Now this is just a statement of fact that we need to consider in planning, and not a criticism of these good people. Knowledge of caves and karst is not instinctual, and most people weren't lucky enough to be taught anything about it in school. So, before we send any group of people into a cave, we need to insure that they understand the basics of cave conservation relevant to their task, and the presentation of that information needs to be tailored according to their current level of understanding. The cost of ignoring this can be high. In October of 1995, people associated with a stucco contractor working near the Snowball Room in Mammoth Cave were found to be collecting gypsum.

One common aspect of the people involved with park caves is that change is unwelcome, especially regarding traditional activities. The ethics of cave use continually evolve, traditions tend not to, and tension results. In order to provoke thought about the state of cave conservation in the park, three sets of educational objectives for interested park employees were developed at successive levels. These objectives ask participants to compare/contrast insidious and catastrophic impacts, ponder current policies, and recommend ways to achieve sustainability in our use of cave resources.

Introductory cave conservation trip educational objectives:

1. Compare and contrast insidious* and catastrophic impacts to cave resources. (*operating in a slow or not easily apparent manner, more dangerous than seems evident).

2. List the two primary goals of cave entrance management, and the consequences to biotic, geologic, and cultural cave resources when these goals are not achieved.

3. Evaluate the possibilities for remediation of catastrophic damage to carbonate and sulfate speleothems.

The destinations for consideration of these objectives were Floyd Collins Crystal Cave, and Great Onyx Cave. Given the massive destruction that Crystal Cave suffered most recently in 1995, the emphasis is on catastrophic impacts. For comparison, Great Onyx Cave serves as an excellent example of sustainable show cave management. This is in stark contrast with Crystal Cave where vandals easily dug under an inadequate gate, stole carvings made by Lee Collins, and mined helictites and gypsum for months. The loot was sold to local rock shops who openly marketed cave minerals since no effort was made to enforce the 1988 law prohibiting such sale.

Intermediate cave conservation educational objectives:

1. List seven insidious anthropogenic impacts to surfaces in cave passages, and rank them in order of most to least reversible.

2. Compare virtually unimpacted cave passages with those most heavily visited, and describe the aggregate effect of all types of human impacts. Discuss how this relates to the quality of interpretation and the visitor experience.

3. Discuss the issue of carrying capacity as it relates to how we increase public knowledge, understanding, and appreciation of cave resources in light of the NPS mandate to conserve these same resources unimpaired for future generations. Can we justify managing toured routes as “sacrifice areas”?

4. Bonus question: Where in the Mammoth Cave System has spray paint vandalism occurred?

The areas selected for these objectives were New Discovery and Gothic Avenue in Mammoth Cave. Since Gothic Avenue was part of the first tours beginning in 1816, the emphasis is on insidious impacts. New Discovery was selected for comparison since this area offered the only possibility for viewing minimally impacted cave resources without causing additional damage. From this comparison, an understanding of the restoration task before us, and the types of damage we must prevent could be gained. The answer to the bonus question is surprising: When the current building over the New Discovery Entrance was being constructed, the entrance was left unsecured at night. Knowing this, members of a volunteer youth group assisting with the construction returned for an evening foray. In order to keep from losing their way, they spray painted large white arrows pointing out.

Advanced cave conservation educational objectives:

1. State the two primary differences between cave trips on developed trails, and those beyond developed trails.

2. List at least three impacts to the Wild Cave Tour Route, and rank them in order of most to least reversible.

3. Explain the essentials of “caving softly.”

4. Outline a management policy for the Wild Cave Tour Route that is most consistent with the NPS Mandate.

The passages selected for consideration of these objectives were those included in the Wild Cave Tour Route since such off-trail trips are currently the greatest source of tour-related impacts to Mammoth Cave. As an example, calcite speleothems along the tour route are frequently climbed or crawled upon. Since these speleothems appear to be soiled beyond hope after 25 years of Wild Cave Tours, the current cave conservation rule of avoiding contact with these kinds of mineral deposits has not been initiated. These objectives are intended to provoke thought about marking a minimum impact route through these decorated areas, cleaning the speleothems to restore natural appearance/processes, and establishing photographic monitoring points. These steps would be particularly timely since the number of Wild Cave Tours offered was doubled last year.

In addition to the interested park employees for which they were originally developed, the above three sets of educational objectives are relevant to all park employees, educators, researchers, maintenance staff, resource managers, plus cooperators and contractors who venture underground in the park. With modification, these objectives can also be adapted to many other sites. To date, the cave conservation education that park staff receive has been conducted on a voluntary basis for those interested enough to participate on their own time. In my opinion, this topic is so central to the NPS Mission at Mammoth Cave that it should be given equal status with other subjects such as Safety, Mission Renewal, or Hospitality Training.

Cave Trips Beyond Developed Trails

The tours we lead beyond developed trails offer visitors an experience much more intense and even qualitatively different from conventional guided cave trips. These experiences are more intense because the human risk factor is greater, and different because in undeveloped passages we routinely come in contact with the cave. This combined human and resource risk factor carries great responsibility for us as trip leaders and resource stewards. To date we have done far better at ensuring human safety than we have at conservation of cave resources. Part of this is due to slower evolution of conservation standards, relative to safety guidelines. Be that as it may, we need to increase awareness and understanding among NPS staff and visitors of the fragility of cave resources, and how cavers minimize impacts. For most participants, this is their first caving experience, and they may go on to explore caves on their own. Therefore we must instill, at a minimum, a current cave conservation ethic.

In terms of actual cave conservation practice for guided trips in undeveloped cave, the Trog Tours have taken the lead. In White Cave the path has been defined with flagging tape where there is potential for confusion or where there are fragile features, just the way it’s done in Carlsbad, Lechuguilla (Werker and Werker, 1997), Jewel, Wind, and other caves. Additionally, cave restoration in the form of cleaning smeared mud from flowstone has been introduced as part of the educational experience for the youngsters on Trog Tours.

Designated trails are for all who enter undeveloped passages, not just those on guided tours. Trails have been established in fragile areas of the Flint Ridge System since the fifties, but there have been some lapses in conservation measures that are now being addressed. As an example, in the summer of 1996 a flowstone mass below the Doyel Valley Entrance was cleaned, and a path flagged. The routes leading on from the flowstone were marked with plastic pin flags and flagging tape to guide researchers travelling through.

Especially for trips beyond developed trails, consideration must be given to the type and level of activity appropriate for any underground location in the park. The NPS Cave Classification System (NPS, 1991) provides a mechanism for evaluation of resource sensitivities, safety hazards, and therefore the level of caving skill needed. The maximum party size and number of trips to any given area per year should be determined based upon resource sensitivity. Minimum party size should be based upon safety. Qualifications, responsibilities, and authority of party leaders need to be specified. Evaluation of resource vulnerabilities, safety issues, and party leader/participant qualifications should be done by a Cave Resources Specialist.

Permit caving in Ganter Cave was terminated this year after approximately a decade for three reasons: 1) staff workload concerns in the Ranger Division, 2) inadequate baseline resources inventory, and 3) lack of a resources monitoring program. Permit caving in the park should be reconsidered after the Lesser Caves Inventory (House, 1995) is complete. This database will enable us to determine if there are park caves that do not contain unique or threatened resources, and that are acceptably safe for permit caving. National Parks have many functions, and one of them is to serve as a “control group” for the great American “socio-economic experiment.” As part of this, we need to have some caves that are not subjected to the impacts of even conservation minded caving in order to detect changes over the long term. In Kentucky alone there are more caves than most cavers see in a lifetime, so “supply” is not an issue. The issue centers on to what extent the park can “provide for the enjoyment” of park resources by individuals with adequate caving skills, given it’s conservation mandate.

If caves appropriate for permit caving are identified, then the existing permit system should be compared with others (Goodbar, 1995), and modified to the extent needed. Oversight by a Cave Resources Specialist is necessary, but that workload can be reduced through the development of volunteer trustees. This approach has worked very well at Sequoia and Kings Canyon National Parks (Schmitz, 1996).

Cave Trips On Developed Trails

In order to obtain the greatest amount of learning at the least cost in resource damage, educational trips should use passages with developed trails if the educational objectives can be realized. Whereas much can be learned about cave resources on developed trails, familiarity with a cave system itself, such as Mammoth Cave, is not so easily acquired. The ability of park employees to interpret Mammoth Cave to visitors is in part related to their familiarity with the developmental history of the cave system, and the spatial distribution of resources. The challenge is to provide that field education with the minimum of damage. University field classes, park employees, CRF resource inventory teams, and other groups with a justifiable need for detailed information about park caves have benefited from educational underground field trips. Awareness and understanding of resources are required for their optimal management. Those things unknown to us are more likely to be inadvertently destroyed.

Recreational trips into park caves by employees are not currently permitted, but perhaps should be in areas with developed trails where the increment of additional impact will be undetectable, assuming the high conservation ethic that can be provided through training. Educational trips into caves will always have a recreational component to them, and it is fair to say that recreational trips inevitably have an educational aspect as well. Most park staff members cannot derive the same benefit from a guided cave tour as a visitor because tours must be geared toward a low level of familiarity with cave resources. The privilege of access to cave passages with well developed trails should be extended to properly trained park staff, their family members, and friends because both resource protection and interpretation of cave resources will be enhanced. It is through shared experiences underground that park staff learn to appreciate the central resources of the park, and build professional friendships. Deep appreciation is what motivates park staff to give the extra effort needed to protect cave resources under the high visitor density situations encountered at Mammoth Cave. Strong professional friendships translate into the high morale fundamental to quality interpretation.

Literature Cited

Goodbar, J. 1995. Cave Permits and Permitting Systems. Proceedings of the 1995 National Cave Management Symposium, p.99.

House, S. 1995. Resource Inventory of Less Extensive Caves: Mammoth Cave National Park, Kentucky. Proceedings of Mammoth Cave National Park's Fourth Science Conference, p. 207.

National Park Service 1991. NPS-77, Natural Resources Management Guideline, Cave Management. p. 147.

Schmitz, S. 1996. Lost Soldiers Cave Restoration Project. NSS News, v. 54, n. 2+3, p. 63.

Werker, V., and J. Werker 1997. Lechuguilla Restoration: Techniques Learned in the Southwest. NSS News, v. 55, n. 4, p. 110.

Rick Olson has been active in the exploration and study of the Mammoth Cave System for 24 years. Like other fossil cavers, he has pictures of caves that were once pristine, and are now severely degraded. Most of his research has been driven by the need for science-based management of cave and karst resources to stop the destruction.

Cave Entrance Management: Principles and Practice at Mammoth Cave National Park

Rick Olson, John Fry, Joe Meiman, Bob Ward, Scott Henrickson, Jeff Bradybaugh
Division of Science and Resources Management
Mammoth Cave National Park
Mammoth Cave, Kentucky 42259

The Value and Vulnerability of Cave Entrances

In terms of access and security, cave entrances are the door to the bank vault. In terms of physical, biological, and energy exchange, cave entrances and other karst features are portals between surface and underground ecosystems. Entrances are more likely to contain greater and more diverse historical, archeological, and paleontological resources than adjacent surface sites or locations deeper in the cave. Continued protection of these cave resources is far more difficult near entrances than in remote underground locations.

Within terrestrial cave communities, keystone species such as bats, crickets, and packrats regularly commute through entrances to feed on the surface and return for refuge to the cave. Their feces are the food source for many cave-adapted organisms, and a separate community depends upon cricket eggs which are laid in drier, usually more remote, passages. Wildlife, including birds such as owls and swallows, nest in entrance vestibules, and mammals such as raccoons, porcupines, and bears also venture into caves. These species are important components of surface communities as herbivores, predators, and, in the case of bats in the Southwest, primary pollinators of ecologically significant cacti (Tuttle, 1995).

Natural rates of air and water exchange through entrances are vital for cave-adapted communities (Poulson and Kane, 1977), cultural resources, and even minerals. Changes in cave temperature, humidity, and input of organic material from entrance alterations can have catastrophic consequences. The biotic and abiotic resources that either live in or are housed within cave ecosystems have arrived at a particular equilibrium over many thousands of years. It is difficult to keep in mind that speleothems, biological communities, and archeological artifacts are ancient in comparison to the time scale we as resource managers function within.

Cave entrances are often places of great beauty. In these typically cool and moist environs, ferns, mosses, and liverworts may be locally abundant. Viewed from within, cave entrances often frame the surface world, and put its biological richness in perspective.

Management Options for Cave Entrances

There are many kinds of cave entrances, but they can be differentiated into a few operational categories based upon the degree of anthropogenic alteration. These categories are natural, modified-natural, and artificial. In addition to operational category and the resources present, an optimal management prescription for a given cave entrance depends upon human use levels, degree of prominence or obscurity, proximity to people, and safety concerns. Examples will be given below in order of simple to complex.

Natural entrances

An obscure natural entrance to an undeveloped cave in a remote location is clearly the easiest to manage since periodic monitoring, especially of endangered species populations, is all that will be needed. A natural entrance in a prominent location will be noticed even if it’s not near high human activity areas, and of course any entrance near where people gather will be found. That these factors determine whether a cave is likely to be noticed was demonstrated during the Civil War with saltpeter caves in Tennessee, Alabama, and Georgia. Of the 160 Confederate saltpeter caves documented, only 11 were captured of which 9 were highly visible or near Union encampments. The other two were captured through luck or an informant (Osterlund, 1980).

A decision on whether to gate any given natural entrance should be based upon the presence of sensitive resources, safety hazards such as vertical shafts, or upon evidence of vandalism. Should a decision to gate be made, the design should be an Airflow Bat Gate of the American Cave

Conservation Association (ACCA) design unless there are indications to the contrary. These angle iron gates are very secure, and allow free movement of air (Powers, 1991).

Natural entrances to developed caves are generally secured in some fashion. Esthetics should be considered in all cases, and especially in these high-visibility situations. If an airflow bat gate is installed in a show cave, then the door may be built high enough to walk through. Lacking this or other special need though, the door should be built low to maximize open horizontal bar spaces for bats.

Modified-Natural Entrances

All of the considerations for management of natural entrances apply also to modified-natural entrances, with the additional difficulty of insuring natural rates of water and air flow, and the passage of wildlife. Many entrances to developed caves have been modified in the past for tour operations or security, and the consequences to both natural and cultural resources were often not realized. Diverted water and the organic matter it carries should be returned to the original destination wherever possible. Restoration of water flow is easier to judge since streams and their bedload, guided by gravity, are readily visible. Restoration of air exchange is much more of a challenge.

Enlarged cross-sectional areas of entrance passages can greatly increase the penetration of dry winter air into habitat for cave-limited species which are more susceptible to desiccation than their surface counterparts. Ironically, mixing of this same cold air with warmer and humid cave air can result in localized condensation of water where none existed before. Locally drier habitat crucial for cricket eggs (as an example) and conditions for minerals may be affected. If this condensate drips on wooden historical or archaeological materials, then fungal decay will set in.

The original effective cross-sectional area of an enlarged entrance can be restored through the use of baffles on the bars of an airflow bat gate. Historical research, paleontological study of pre-modification bat roosts, and estimates of past excavation can guide how large the baffles should be. Investigation of pre-disturbance bat use is especially useful for determining environmental restoration targets since bats have species-specific and rather narrow acceptable temperature ranges. Similarly, natural entrances have been framed in to provide greater security. Because bats have such specific environmental requirements for hibernation, roosting, or maternity sites, reduction of effective entrance diameter may render a cave unsuitable (Richter et. al., 1992).

In the environmental aftermath of changes to entrances for security or tour operations, bats (and other trogloxenes) may not be able to simply move to another cave. They often die, and the community of cave-adapted life dependent upon them is lost as well. When confronted with this reality, people sometimes ask "Can't they live somewhere else?", not realizing that this very type of incremental habitat destruction pushes species towards extinction. It is a great challenge to achieve simultaneous solutions that accommodate the need for entrance security, tour operations, and healthy cave ecosystems. This compatibility has been achieved at Wyandotte Caves State Park in Indiana, at Carlsbad Caverns National Park in New Mexico, and at La grotte de Reclere in Switzerland (Blant, 1994). We are fortunate to have these examples to follow.

Artificial Entrances

Access to sections of caves many hours of travel from original entrances has been provided through artificial entrances. As with other alterations to the cave environment, the consequences can be severe. In areas with growing carbonate speleothems, the deposition mechanism can be changed from carbon dioxide outgassing at saturated humidity to evaporative precipitation caused by an influx of dry winter air. The result can be serious degradation of the very resources for which an entrance was installed.

Assuming access is still desired, a solid door or an airlock is usually the appropriate treatment for an artificial entrance, depending upon the amount of airflow, and human traffic. Airlocks may contain labyrinthine openings for keystone species such as crickets and packrats. Such a "leaky airlock" is justified if that is what restores pre-disturbance function. A major exception occurs if a state or federally listed species of concern has colonized the area, and would be adversely affected by an airlock. A gate might then be installed that accommodates the species biological needs, and which could be converted to a solid door or airlock if the situation is resolved by either recovery or extinction of the species population.

A mine opening is an artificial entrance to an artificial cave, and management considerations are similar to those for caves. Historical and biological resources issues plus safety considerations are key elements of any mine management prescription. Many mines have become bat refugia (Tuttle and Taylor, 1994), and a growing number of entrances have been fitted with airflow bat gates (Stolzenburg, 1996).

Examples from Mammoth Cave National Park

The foregoing principles of cave entrance management have been applied to eighteen entrances within the park over the past four years (Fry, 1996), and a three year ecological restoration project in the Historic Entrance of Mammoth Cave was recently initiated (Olson, 1996). Selected examples are summarized below, and ongoing work in the Historic Entrance is described.

Natural Entrances

The vast majority of entrances in the park are protected by their obscurity since they are hard to find even on a good day. However, White Lightning Cave was gated in September of 1994 because it is marginally visible from the Green River where a tour boat passes by, and there were signs of illegal entry by inexperienced people to the top of a 70 foot pit.

A concrete wall with a restrictive 2X3 foot opening in the entrance of Long Cave was replaced with the first Airflow Bat Gate in the park by ACCA and MCNP staff in May of 1994. Temperature in the hibernaculum has been remotely monitored since before the wall was removed in order to document the environmental restoration. It is hoped that the former colony of 50,000 Indiana Bats, whose population has dropped to less than 1000, will recover.

Modified Natural Entrances

The entrance to Proctor Cave has evidence of minor enlargement to accommodate tours, but given the lack of vulnerable resources, evidence of extensive former use by wildlife, or apparent environmental impacts to the ecotonal area of the cave, no restoration was considered necessary for the cave microclimate. In June of 1994, the entrance was fitted with an ACCA Bat Gate whose sturdiness and double lock mechanism foiled an attempted break-in during the winter of 1996.

Given that the Historic Entrance ecotone of Mammoth Cave was likely once the largest bat hibernaculum (9-13 million) in the world (Tuttle and Kennedy, 1996), that wooden historical and archaeological artifacts were decaying due to condensation, and that the rockfall rate was greatly accelerated, an ecological restoration was considered necessary, after a few years of debate. In April of 1994, the first cave atmospheric monitoring (CAM) stations were installed, during the summer of 1995 paleontological inventory to support environmental reconstruction began (Toomey et al, 1995), in February of 1996 permission to install Plexiglas baffles on the existing grid gate was obtained, and in August of 1996 an ACCA Bat Gate was installed with baffles affixed. In February of 1997, spring-loaded Plexiglas doors were added to the ACCA Bat Gate to reduce the influx of air during cold snaps. This action was taken primarily to prevent condensation near wooden artifacts, and halt the resulting rot. Historic bat hibernation sites will be environmentally restored to the extent that protection of wooden cultural artifacts allows; a shift in the location of hibernation sites is considered a good trade for this protection. The plan to minimize human disturbance of bats has two components. First, a refuge for hibernating bats has been designated by diverting tours and other human entry from a portion of Audubon Avenue/Rafinesque Hall during hibernation months. Second, human activity in the Historic Entrance vestibule will be reduced during the hours of the day and times of the year when swarming and mating occur.

Artificial Entrances

In July of 1994, the adit into Colossal Cave was fitted with an ACCA Bat Gate because federally-listed Indiana Bats hibernate within. Fortunately, the wooden historical artifacts and other resources within the cave are not being seriously affected by the unnatural influx of winter air. Should we be lucky enough to have populations of endangered bats recover sufficiently to be delisted, then the bat gate will be converted to a solid door. Species management is conducted primarily on a population basis, but seasonal timing and the method of conversion must minimize entrapment of individual animals. This is easier said than done since bats will crawl through small holes to regain entry to “their” roost, and may not be equally able to find their way out.

During a five month period from October of 1995 to February of 1996, the Frozen Niagara Entrance adit into Mammoth Cave was fitted with a revolving door airlock. Design and construction were complicated due to high visitor use, and the need to accommodate the needs of commuting cave life. Though no cave life could have communicated with the surface via the current route, the presence of cave popcorn and the quantity of cricket guano were indications that an opening had existed somewhere nearby. Given that the local landscape has been much manipulated over the past 60 years, and that the original openings might not still exist, the block building which housed the airlock was designed to leave small openings in an existing wall unchanged. This “leaky airlock” strategy appears to have been appropriate based upon physical and biological data. Environmental monitoring at a CAM station documented the elimination of cold, dry pulses of winter air associated with tours, and biological monitoring indicated no adverse impact on invertebrate populations (Poulson et al, 1997).

Literature Cited

Blant, M. 1994. La protection des chauves-souris face a l' exploitation touristique d'une gotte (Reclere). Societe Jurassienne D' Emulation, p. 59.

Fry, J. 1996. Eighteen Cave Gates and Airlocks: Conclusion of a Three-Year Project to Restore Cave Entrance Dynamics at Mammoth Cave National Park. Proceedings of Mammoth Cave National Park's Fifth Science Conference, p. 69-83.

Olson, R. 1996. This Old Cave: The Ecological Restoration of the Historic Entrance Ecotone of Mammoth Cave, and Mitigation of Visitor Impact. Proceedings of Mammoth Cave National Park's Fifth Science Conference, p. 87-95.

Osterlund, M. 1980. The Size and Location of Saltpeter Mining Sites in Tennessee, Alabama, and Georgia. National Cave Management Symposia Proceedings, p. 108.

Poulson, T., and T. Kane 1977. Ecological Diversity and Stability: Principles and Management. Proceedings of the National Cave Management Symposium, p.

Poulson, T., K. Lavoie, and K. Helf 1997. Three Years of Census Data on Nine Entrance Communities in Caves With and Without Entrance Retrofitting. Proceedings of the Sixth Annual Mammoth Cave National Park Science Conference, p. 62.

Powers, R. 1991. Design Improvements for Gating Bat Caves. Proceedings of the National Cave Management Symposium, p. 356.

Richter, A., S. Humphrey, J. Cope, and V. Brack 1992. Modified Cave Entrances: Thermal Effect on Body Mass and Resulting decline of Endangered Indiana Bats (Myotis sodalis). Conservation Biology, v. 7, n. 2, p. 407.

Stolzenburg, W. 1996 Out of Sight, Out of Mine. Nature Conservancy, September/October, p. 18.

Toomey, R., R. Ward, R. Olson, and M. Colburn 1995. Cooperative Cave Paleontological Resource Management, Mammoth Cave National Park, Kentucky, USA. National Cave Management Symposium Proceedings, p. 291.

Tuttle, M. 1995. Saving North America's Beleaguered Bats. National Geographic, v. 188, n. 2, p. 38.

Tuttle, M., and J. Kennedy 1996. Mammoth Cave Survey For Historic Bat Use. Unpublished report to MCNP. P. 4.

Tuttle, M., and D. Taylor. Bats and Mines. Bat Conservation International, Inc. Resource Publication No. 3., p. 4-5.

SpeleoMeshing: A Technique for High Definition Cave Surveys

Greg Passmore

Abstract

A set of novel computer techniques for cave and mine mapping are collectively referred to as SpeleoMeshing. This process yields detailed volumetrics, dense meshes for structural finite element analysis and photorealistic rendering. the techniques are low cost, high in accuracy, and suitable for use on personal computers. The process is composed of three steps: collection of passageway profiles, conversion of the profiles into 3-dimensional modes and, optionally, collection and application of texturemaps on passageway walls for photorealistic rendering. The first step of the process uses a simple pocket laser to outline each passage profile along survey lines for photographic capture. The photograph is subsequently digitized and used to calculate passage profile axiometric distances. In the second step, the resulting axiometric passage profile data are extruded between profiles into a 3-dimensional wireframe mesh. These wireframe mesh data are suitable for high accuracy volumetric analysis and for structural finite element analysis. For high quality rendering, a third step, photographs of passageway walls are taken for color and texture definition. The resulting photographs are then texturemapped onto the 3-dimensional model and computer rendering techniques are used to produce near photorealistic renditions of the cave. This paper will present details of the process, a description of the tools needed, and examples of computer imagery resulting from SpeleoMeshing.

[Note: This paper was not presented at the symposium, because the author was unable to attend.]

Conservation/Restoration Efforts in the Caves of Carlsbad Caverns National Park

Dale Pate

The caves of Carlsbad Caverns National Park are extremely fragile, and tremendous damage has been done in the past. Numerous restoration projects are ongoing in Carlsbad Caverns, Lechuguilla Cave, and a few other park caves. Along with restoration efforts, ways to limit future impact are being explored with good success. Various projects will be highlighted, with illustrations of progress. Much of this work could not be done without the dedication of numerous volunteers who give their time to preserve and protect the caves of the park.

Conservation Challenges: Restoration of the Caves of Central Oregon

Garry Petrie

Abstract

Fifteen years ago, the NSS held its annual convention in Bend, Oregon. Since that time, the local population has increased threefold, and the interest in outdoor recreation has exploded. At the same time, the USFS and the BLM have seen their budgets to manage these recreational resources diminish. The caves of the Bend area, once showcased by the NSS, are now marred, vandalized, dumped on, and encroached upon. The review of the current situation and the time line that led to it is intended to spur people into action. In 1993, seven caves were bolted with sport climbing routes. In 1996, the BLM took the unprecedented action of ceding six significant caves to the State of Oregon. That same year, a book was published documenting the vanishing Native American pictographs in these caves. In 1997, the USFS and BLM finally acknowledged the caves were at risk by banning climber's chalk and initiating new seasonal closures for bat habitat. The community has begun to notice and clean up has started in Horse Cave and the Redmond Airport Caves.

In the last thirty years the population in and around Bend, Oregon, has tripled. The population has doubled since the 1982 Bend NSS Convention. Many of the people moving to Bend are young and outdoors orientated. The results for the caves have been vandalism, illicit and illegal visitation, loss of wildlife habitat, as well as an explosion of legitimate use.

Local municipal, county, state and Federal agencies manage the caves in central Oregon. Unfortunately, they have been slow or unable to preserve and protect the natural history of the caves. At every location, new management plans are being drafted to address these issues. However, the biggest problem is changing attitudes of the people visiting the caves.

The City of Redmond, twenty miles north of Bend, in October of 1997 began seeking the services of individuals or firms qualified to provide a Master Plan for the Redmond Caves. The Redmond caves are a series of five small caves located on the edge of town, actually within the city limits. An University of Oregon collection of artifacts taken from the caves during the 1940's suggests human habitation possibly 4,000 years ago. Unfortunately, the site has a history of trash dumping, spray paint, fires and illicit use.

The City plans to develop the site in cooperation with the BLM, which owns the property. The City is asking for citizen involvement in setting goals, rehabilitation, resource planning and defining appropriate uses of the caves. If city personnel make routine visits for trash collection and maintenance, then vandalism will be curtailed. The City plans to develop an interpretive and education program to attract visitors for the enjoyment of the cave's natural features.

Some caves in central Oregon are on private property. Two such caves on private property were Horse and Lewis Farm caves. To make room for a housing development, Lewis Farm's entrance was filled in and the cave destroyed. At Horse cave, the second-generation owner is interested in restoring his cave to a natural, cleaner state that might attract wildlife and enhance the property's value. Recently, a community based clean-up effort, with support from local businesses and the Stop Oregon Little and Vandalism program, worked for two weekends at the cave. They removed trash from within and around the cave, as well as cleaned spray paint from the cave's walls.

Lewis Farm and Horse caves are part of the greater Horse Lava Tube System, which runs south to north along the eastern edge of Bend. Six caves of the system are contained within a single square mile. That square mile is commonly referred to as Section 11. The two largest caves, Garbage #1 and #2, acquired their names from being within the former Bend landfill. These caves are some 350 and 150 feet long. The other caves, Williams, Vulture, Stevens Road and Hobo, are all small, single room caves.

All of the caves contain trash and fire rings. In addition, two of the caves each contain an automobile, one a couch and a console television. The surface of the entire site is littered by illegal trash dumping and off-road vehicle erosion. Section 11 is threatened by target shooting, teenage drinking, trash dumping, off-road vehicles, vandalism, urbanization, encroachment by development and outstanding history of a lack of commitment from management, the BLM.

The State of Oregon brought suit to the BLM over statehood land grants from the Federal government. It was decided in Federal court the BLM must cede some 4,000 acres to the state. As part of that decision, the BLM gave title of Section 11 to the State of Oregon. In making this land transfer, the BLM needed to ensure the protection and preservation of the Section 11 caves, as described in the Federal Cave Resource Protection Act of 1988. The BLM accomplish this goal by writing a restrictive covenant on the property title, that open space 350 feet from cave passage be maintained and the caves managed to conserve the biological, geologic, recreational and educational resource values present.

Section 11 lies outside Bend's urban growth boundary and is zoned agricultural within Deschutes County. Unfortunately, the State of Oregon has no money for cave management and the current plan of record is to pass on the cave management task to any future leaseholders of the property. The State is obligated to manage the property for the benefit of the public school system and any revenue generated from the property is given to the schools. A master land use plan was developed for the State, which defined areas of open space, agriculture lease areas and parks. It is expected that in the future the property will be a site of a junior or senior high school for the City of Bend.

Further south of Bend is the Arnold System, which is facing an entirely new challenge to conservation. In 1991 sport climbing began in the biologically sensitive twilight zone in the entrance of several caves. The difficult, inverted climbing the cave's ceiling presented attracted the climbers. At Skeleton cave, climber's chalk became a problem because of its contrast of white on black basalt and because the chalk was protected from the washing rains. In March of 1994, at a public forum, the climbers promised to minimize their impact by using colored chalk and periodically cleaning the cave's walls. Later, in May of 1996, the US Forest Service attempted to clean the chalk deposits and discovered the deposits were permanent. As a result, in June of 1997 the US Forest Service and the BLM prohibited the use of chalk in all caves in central Oregon.

During 1992 and 1993, the climbers began setting bolted routes into the walls and ceilings of several caves. In Pictograph cave, forty-nine bolts were discovered in two distinct areas of the cave. In March of 1994, at the same

public forum, the climbers agreed to a moratorium on any new bolting. Later, the US Forest Service issued new rules requiring permission for the placement of climbing bolts. Out of concern for the bat populations in the Arnold system, the US Forest Service for the first time seasonally closed seven caves of the system.

At Pictograph cave, also part of the Arnold system, the BLM began drafting a new management plan in accordance to the Federal Cave Resource Protection Act.

In June of 1996, the BLM restored the former name of the cave, Stout cave. In 1997 the BLM blocked the quarter mile access road to the cave and built a new fence enclosure. Unfortunately, off-road vehicle drivers simply drove around the road's blocking berm and illegal traffic continues.

At Hidden Forest cave, also part of the Arnold system, 137 bolts were set in sport climbing routes. In September of 1996, Greg Bettis, of the Rock Art Research Education TM published a book documenting the resource damage and counterfeit drawings in the cave. US Forest Service "No Chalk" and "No Climbing" signs have been repeatedly defaced and destroyed in Hidden Forest. To date, some thirty-four climbing violations, citations and warnings have been issued.

At Charcoal #1 cave, immediately adjacent to Hidden Forest, fifty-three climbing violations, citations and warnings have been issued. The cave has unique charcoal deposits and art dating from early Native Americans. Metering the parking lot between Charcoal and Hidden Forest counted upwards to forty vehicles per week this

summer. Fortunately, Derrick cave was saved similar high rates of visitation when all bolts were removed.

Urban encroachment and an unaware public leave the future of central Oregon's cave uncertain. Few citizens are interested in visiting the local caves because of the illicit and illegal activity that prevails. This increases the pressure on the more remote caves. In addition, sport climbing has placed new demands on cave resources.

Loosing the caves and the unique experiences they provide forever is certain, unless immediate action is taken. If their natural beauty were preserved through regular monitoring and maintenance, then vandalism and inappropriate use would be discouraged. Managers must balance the needs of the public, wildlife and preservation while developing their cave management policies. A successful plan results in a cooperative effort involving the public and government to preserve these caves.

References:

Nieland, Jim and Larson, Charlie. 1969. An Introduction to Caves of the Bend Area. Guidebook of the 1982 NSS Convention, Huntsville, Alabama.

Larson, Jo and Larson, Charlie. 1987. Central Oregon Caves. ABC Publishing, Vancouver, Washington.

Greeley, Ronald. 1971. Geology of Selected Lava Tubes in the Bend Area, Oregon. State of Oregon Department of Geology and Mineral Industries, Bulletin #71, Portland, Oregon.

Bettis, Greg. 1996. Recreational Impact to the Hidden Forest Cave Site: Abbreviated Information on Site Condition, Rock Art Research Education, Report #1996-1.

A New Map for Carlsbad Caverns

Jason M. Richards

Abstract

Through the years, Carlsbad Cavern has had an ongoing mapping project. In the 1960's and early 1970's. the Guadalupe Cave Survey (GCS) was the primary group surveying in Carlsbad Cavern. The "old timers" of the GCS were the forerunners and trailblazers to much of the cave we know today. In the early 1970's, the GCS joined ranks with the Cave Research Foundation (CRF). Along with CRF came survey procedures, however, a set of park approved standards was lacking. Up until the early 1990's, much of the survey in Carlsbad Cavern was resurvey. There were resurveys over resurveys, floor detail on sketches was omitted, and there were no running profiles and very few cross-sections. Survey designation numbers were out of control, with some designations having as many as nine characters. Foresights on the azimuths were not verified by backsights, and inaccurate loop closures were common. Although not required at that time, there was no inventory of important features tied to the survey. The impact to the cave was tremendous by repeatedly surveying the same areas. For all of the above reason, and the fact that Carlsbad Caverns was now designated a World Heritage Site, the consensus of the Cave Resource Office staff and the leaders of CRF (Guadalupe Escarpment Area) was that a high quality working map was needed. This paper will demonstrate the reasons for our decision by the use of examples and will show the progress of the new survey.

An Inventory of Caves and Related Karst Features in the Canadian Rockies, with Management Recommendations

Jonathan Rollins

Abstract

Stretching for 1,450 km from the Yukon border in the north to the US border in the south, and 150 km from the Alberta foothills in the east to the Rocky Mountain Trench in the west, the inventoried area covers 180,000 sq km, with carbonates being the predominant rock type. The inventory includes 175 caves with detailed descriptions, surveys and management recommendations. The majority of caves are alpine, with entrances located above the tree line (average altitude - 2,000 m). As you would expect with alpine caves, depth, not length is the dominant feature. Nine caves are approximately 250 m deep, and the majority of caves contain pitches. Karst areas have been heavily glaciated, with large areas of exposed pavement and felsenmeer common. Many karst areas are bordered by active glaciers and associated moraine features. The caves tend to be in isolated locations, the majority requiring at least a one day hike from a vehicle. Remarkable caves include the 20 km long Castleguard Cave ending in an ice-plugged passage beneath the Columbia Icefield, the 536 m deep Arctomys Cave, Close to the Edge Cave with a 244 m deep entrance shaft, and the 12 km long Yorkshire Pot with 200 m of entrance pitches. A simple three level management classification system has been suggested, based on access and the occurrence of special features. Recommendations have been made for specific caves.

Biotic Carrying Capacity at Oregon Caves

John Roth

Abstract

Based on microbial, macroinvertebrate, and bat surveys at Oregon Caves, efforts have been made to establish limits on the size, location, and number of public cave tours so that significant and irreversible resource damage does not occur. Macroinvertebrate biodiversity, bat roosting sites, and relatively slow growing microbial colonies near the tour route appear to be affected by human visitors. Baited traps were placed in such areas to determine whether >10 % of macroinvertebrate populations are being affected by trail traffic. Similar studies are on-going with bats. Lag effects and the impacts of organic enrichment, airflow, trail surfaces, artificial lights, trampling, bat gates, vibrations, and noise disturbance are discussed.

Methods for Monitoring Large Colonies of Mexican Free-tailed Bats - Poster Presentation

Bill Route, Tom Bemis, and David Roemer, Val Hildreth-Werker and Jim Werker

Bill Route, Tom Bemis, and David Roemer
(Carlsbad Caverns National Park)

Val Hildreth-Werker and Jim Werker
(Southwest Composites and Photography)

Abstract

Carlsbad Cavern hosts a colony of several hundred thousand Mexican free-tailed bats (*Tadarida brasiliensis mexicana*). Colony size, behavior, and roost geography have all been problematic for obtaining accurate abundance estimates. Past methods have varied from gross ocular counts to complex calculations using video and still photography. No method has provided a measure of precision nor has any method proven valuable as an index to trends. We investigated the use of reflective infrared photography (RIP) for routine monitoring of this colony. The RIP method involves taking repeated infrared still-photographs from fixed points in the roost. Colony size is then estimated from the area of cave ceiling covered by bats. Using a roost density of 2,153 bats/m^2 and the mean area of ceiling covered with bats, we estimated there were 353,000 (+/- 22,000) resident bats roosting in Carlsbad Caverns in fall 1996. We believe that immigration and emigration contributed to increasing trends in area estimates in spring 1996 and 1997, and a decreasing trend in fall 1997. Thus, only the fall 1996 estimate was representative of the resident colony. We argue that with refinements, including monitoring flight noise, developing ceiling contour maps, and carefully timing photography, this method will provide valid estimates of annual trends.

Introduction

Mexican free-tailed bats roost in colonies that can exceed several million (Altenbach et al. 1979, McCraken 1984, Wilkins 1989). These large colonies usually occupy caves, though bridges and buildings are also used (Wilkins 1989). Investigators have estimated colony size using a variety of methods ranging from gross ocular counts, to video and still photography (Altenbach et al. 1979, Thomas and LaVal 1988). However, few methods have provided a measure of statistical precision. Colony size, roost geography, repeatability of methods, and cost efficiency are all concerns when determining appropriate methods for estimating abundance. Investigators and managers need a variety of procedures to choose from so that consistent and useable data can be obtained. Herein, we present progress toward developing reflective infrared photography (RIP) as a means of estimating colony size and assessing long-term trends in large colonies of Mexican free-tailed bats.

Background

Carlsbad Caverns National Park (CCNP) hosts a colony of Mexican free-tailed bats that reportedly reached three million in the late 1920s (Bailey, pers. comm. with Allison, see Allison 1937). Another estimate of 8.7 million in June 1936 (Allison 1937) was revised down to 3.6 million by D.M. Roemer and W.T. Route (in prep.). Both Bailey and Allison (Allison 1937) made their estimates from visual approximations and rough calculations of the volume of air filled with bats during the evening exodus. The accuracy and precision of these point estimates can not be evaluated.

Investigators at CCNP have documented a series of large-scale die-offs and a population decline beginning in 1955 (Ahlstrand 1974). Similar declines were noted throughout the southwestern U.S. and Mexico. Residues of organochlorine pesticides, primarily DDT and its metabolite DDE, likely contributed to this decline (Clark 1988, Geluso et al. 1976, Geluso et al. 1981). Despite the ban on DDT in the U.S. in 1972, DDT may still be causing harmful effects to wildlife in the Pecos Valley and the Guadalupe Mountains (Clark and Krynitsky 1983).

Prompted by this decline, Constantine (1967) used ceiling counts to estimate there were 66,700 bats in the colony in June of 1957. Sixteen years later, in September 1973, Altenbach et al. (1979) employed moving and still photography to estimate there were 218,153 bats in the colony. Most recently, CCNP staff used computer counts of video footage taken during the evening exodus to estimate there were 147,418 bats on 20 September and 142,386 bats on 1 October 1987 (Roth 1987). Each of these estimates were obtained using different methods and at various times of the year. Ocular counts are highly dependent on observer experience. The use of moving and still photography was complex and not easily repeatable (K. Geluso pers. comm.). Computer counts of video footage held promise, but as much as 60% of the flight was missed because of poor camera field-of-view and darkness (Roth 1987). None of the investigators provided a measure of precision and thus statistical comparisons between years are inappropriate.

To better understand how this colony reacts to disturbance and environmental change, we attempted to develop a monitoring technique that would provide a consistent and statistically robust estimate of abundance both before young were born and again just prior to migration each year. This would provide insights into over-winter survival and emigration as well as over-summer survival and recruitment. Both are critical for developing management strategies. We also wanted a method that was user-friendly, relatively inexpensive, and that would be comparable with data collected elsewhere in the region.

Study area

CCNP is a 18,926 ha (46,766 ac) park situated in the Chihuahuan Desert of southeastern New Mexico. It was first established as a unit of the National Park Service (NPS) in 1928 to protect Carlsbad Cavern, as well as other caves and portions of the surrounding desert. Carlsbad Cavern itself has approximately 48 km (30 mi.) of cave passage and is 316 m (1,037 ft) deep. The cave was carved by water percolating through an exposed limestone reef which formed along an ancient inland sea during the Permian period some 280 to 250 million years ago. The cavern receives more than 500,000 visitors per year with the highest visitation occurring from June through August when 2,000 to 6,000 visitors walk through the cave each day (NPS 1996). The two visitor access points are through a large natural entrance or by an elevator, which goes from the surface to a depth of 229 m (750 ft).

The large natural entrance measures about 21 by 12 m and is the primary flight route of bats using the cavern. A second, smaller natural entrance (6.4 by 3.4 m) is used to a lesser degree by bats, likely because of its combined small size and steep incline. As far back as the 1950s and up to the 1980s, the roosting site of the Mexican free-tailed bat colony was centered 21 m (69 ft) west of this small natural entrance. Currently, the colony roosts about 220 m (722 ft) east of the small natural entrance. The historic and current roost area are in a portion of Carlsbad Cavern known as Bat Cave. Bat Cave extends approximately 594 m (1,950 ft) to the northeast from the large natural entrance.

In addition to Mexican free-tailed bats, 12 other species of bats are known to occur in Carlsbad Cavern, but their numbers are small compared to the free-tail colony. A population of about 3,000 cave swallows (*Hirundo fulva*) began using the cave in the mid 1960s for nesting (West 1991).

Methods

During the winter of 1996, 15 permanent photo-points were placed at strategic locations in Bat Cave (Hildreth-Werker et al. in prep.). Each photo-point consists of a stainless-steel receiving-pin drilled and fastened with epoxy to bedrock. A stainless steel monorod with camera mount and flash mount (patent pending) provided fast, and precise photographs at each point. For complete overlap of photographs, two additional photo points were installed during the winter of 1997, bringing the total to 17. In addition, an articulating monorod was developed and used in 1997, enabling angled photographs for bats roosting low on cave walls.

Photographs were taken with a Nikon™ FM2 camera and a Nikon™ 28mm fixed-focal point lens (mention of product name does not constitute endorsement). We mounted an infrared flash unit (Sunpack™ 622 with

TriPak II batteries) along side of the camera to illuminate the cave ceiling. Kodak™ HIE black-and-white infrared film was exposed by remote control with F-stop set at 5.6, focus set on the infrared setting for infinity, and the shutter left open while one to 10 flashes were fired depending on ceiling height. Negatives were processed and enlarged to 11 by 14 inch black-and-white paper prints. The negatives were scanned and the resulting digital images placed onto CD-ROM for archival, digital enhancement, and future evaluation with GIS technology.

Gridded transparencies were developed to correspond to the ceiling at each of the permanent photo-points. Grid cell size was calculated from the average ceiling height at each point. Average ceiling height was estimated when bats were not present by raising a helium-filled balloon at three arbitrarily selected locations within the area encompassed by each photograph.

Complete sets of photographs were taken each day for five consecutive days in spring and fall 1996 and 1997. Gridded transparencies were overlaid onto the 11 by 14 inch photographs and grid cells containing bats were counted independently by three observers. Counts by observers were averaged over each five day session to provide an estimate of the area of ceiling covered with bats.

Roosting density can be highly variable depending on factors such as bat physiology and cave temperature. To estimate abundance we multiplied roost area by 2,153 bats/m^2 (200 bats/ft^2), a conservative estimate of roosting density for Mexican free-tailed bats (Constantine 1967, McCraken 1984, B. Keeley unpub. data). Final estimates were rounded to the nearest 1,000 bats because we considered accuracy beyond that to be impractical. Estimates should be considered conservative. All significance levels and confidence intervals were set at the 0.05 level.

To calculate a minimum population estimate we necessarily made the following assumptions: 1) the entire resident colony, and only the resident colony, was present during the photo sessions (i.e., the population was closed to immigration and emigration); 2) all bats could be photographed during the photo sessions; 3) our methods did not disturb the colony; 4) measurements of ceiling height were accurate and provided unbiased estimates of ceiling area; 5) grid counts were accurate and the resulting estimates of roost area were unbiased; and 6) the roosting density estimate of 2,153 bats/m^2 (200 bats/ft^2) is conservative and remained constant during the photo sessions.

Results

Spring and fall photo-sessions occurred in late-May/early-June, and late-August/early-September, respectively. Photography normally began about 9:00 a.m. (time of first photograph) and ended about 11:00 a.m. (time of last photograph). Each five-day session required approximately 15 hours in the cave to set up and photograph the colony and about eight hours in the darkroom to develop and print film. An additional two hours were required for each of three observers to tally ceiling grids filled with bats. Thus a total of 29 hours were expended to complete each five day photo-session. Our methods resulted in minimal disturbance to the colony. Occasionally a bat would fly, but we noticed only minor and short-lived changes in colony noise during sessions.

During both years the colony roosted at the far end of Bat Cave about 220 m east of the small natural entrance above photo-points one through four (Fig. 1). Ceiling geography varied from vertical walls to gradually sloping ceiling domes. Most bats were found along the upper-most portions of three natural domes and a closed mine shaft where ceiling heights ranged from 24 to 30 m (78 to 95 ft) above the cave floor. Small numbers of bats were found low on the cave walls during fall sessions both years. We were unable to photograph these bats in 1996, but a new camera mount in 1997 allowed angled photography of these areas. On days one and two of the 1997 fall session we took photographs at angles between 15° and 30° to record bats occupying low positions on the cave walls. These bats comprised 11.8% of the total area calculation for the 1997 fall session.

In the spring of 1996, we estimate bats occupied 89.6 m^2 (+/- 23.6 m^2) of cave ceiling (Table 1), but by fall this nearly doubled to 163.5 m^2 (+/- 10.0 m^2) (Table 2). In 1997 bats occupied an estimated 36.5 m^2 (+/- 13.9 m^2) in spring (Table 3) and 88.7 m^2 (+/- 32.0 m^2) by fall (Table 4). Each year the area covered by bats expanded by fall, and each year this expansion was further into Bat Cave.

Within-day observer estimates were similar for all sessions as illustrated by the consistently low coefficient of variation ($CV_o \leq 11\%$, Tables 1 - 4). Estimates between days were more variable (CV_d 7 - 45%), due to increasing trends in area of ceiling covered with bats during the spring of 1996 and 1997 and the decreasing trend in the fall of 1997 (figs. 2,4 and 5). Only the fall of 1996 provided consistent daily estimates (fig. 3).

Figure 1. Mexican free-tailed bats (black patches) roosting in natural domes and near an old mine shaft (center right)on cave ceiling in Carlsbad Cavern, New Mexico. Image taken May 28, 1997 using reflective infrared photography.

Using the roosting density of 2,153 bats/m^2 (200 bats/ft^2) and the mean area of ceiling covered with bats, we estimate that in the spring of 1996 there were about 193,000 bats (+/- 51,000) in Bat Cave and by fall this nearly doubled to 353,000 (+/- 22,000). In the spring of 1997 we estimate there were 79,000 bats (+/-_30,000) increasing to 191,000 (+/- 69,000) by fall. However, we believe only the fall 1996 estimate of 350,000 bats was representative of the resident colony. This is because the increasing trends in area estimates both springs and the decreasing trend in the fall of 1997 suggests that the population was not closed to emigration and immigration.

Discussion

We conducted our spring photo-sessions at the end of May to limit disturbance to pregnant females, which give birth in mid-June to mid-July. Unfortunately, our spring sessions were probably too early. Daily area estimates for both years generally increased (figs. 2 and 4). From our data we could not determine whether this ingress was due to returning residents or merely transients moving through on their way to other caves. Constantine (1967) documented bats banded from Bat Cave in early spring being found over 400 straight-line miles distant within days. Similarly, bats banded 400 miles away in other roosts were found in Bat Cave.

The opposite occurred the fall of 1997 when daily estimates generally decreased (fig. 5) and we believe fall migration was already in progress. Personal observations (all authors), and those of park naturalists, suggested that the resident colony appeared larger in 1997 than in 1996, though our area estimates indicate otherwise.

The fall 1996 session provided consistent estimates between observers and days ($CV_o \leq 6\%$, $CV_d \leq 8\%$) with no trends evident (fig. 3). This photo-session is believed to be representative of the resident colony at that time and the data show the potential for the RIP technique. Repeated within season, the technique has the distinct advantage of providing confidence intervals and thus statistical comparisons between years. This makes it a good tool for evaluating long-term trends.

The timing of photo-sessions is critical in order to avoid migratory movements which could severely misrepresent abundance. Our data indicate that the time between arrival of the entire colony from Mexico and when females give birth is extremely short.

Shadows on some photographs may have resulted in overestimates when observers counted them as a patch of bats. In 1997 we added a second flash unit to reduce shadowing. In the future we can further decrease the potential for this error by using reference photographs of the ceiling without bats. Fortunately, the potential to overestimate is balanced somewhat by bats that roost in cracks which are not photographed and thus not counted.

Individual ceiling height measurements were accurate, however, the nonrandom selection of few measurements (n = 3 for each photo-point) may have resulted in biases. This is potentially our greatest source of error. The degree of bias would depend on ceiling geography and colony arrangement. We believe this to be minimal during 1996 and 1997 because of the similarity in colony arrangement between years, but we acknowledge this is a concern. We are currently creating contour maps of the ceiling using laser survey technology. These contour maps will be digitized to form a base map in a Geographic Information System (GIS). Photographs of the ceiling will be referenced to the base map, to calculate area estimates of bats more accurately.

There are few data on roosting densities of Mexican free-tailed bats and there are no data specific to Carlsbad Caverns. We attempted to use a telephoto lens to evaluate roosting density in Bat Cave, but the 24 to 30 m high ceilings and complete dark prevented us from obtaining usable images. The density estimate we used of 2,153 bats/m^2 is conservative, though it was probably not constant during the photo sessions. Further research is necessary to estimate roosting density specific to Bat Cave.

Accurate estimates are seldom attainable for large populations of free-ranging wildlife. For monitoring, investigators often resort to techniques which may be inaccurate, but are unbiased, repeatable, and provide a measure of statistical precision (e.g., confidence intervals) so that year to year trends can be determined. Furthermore, given that accuracy is a problem, investigators strive to underestimate rather than overestimate abundance. This reduces the chance of careless management which could lead to population declines. The RIP method is reasonably unbiased and provides a conservative estimate of abundance. We demonstrated the repeatability of the method with consistent estimates between observers. Additionally, the photographs are permanent records of the colony and if more reliable estimates of roosting density are obtained, our estimates can be adjusted.

The method is easy to apply and the camera mount system assures consistent photographs for each point. Processing photographs requires experience, but professional services are available. The method is relatively inexpensive so that it can be done every year. Similar techniques are currently being developed at other caves (i.e., Bracken Cave, B. Keeley pers. commun.) so that regional comparisons may be obtainable in the future.

Recommendations

CCNP should continue to refine the RIP technique. Specifically, we recommend the following improvements:

1. Contour maps of the cave ceiling should be completed to reduce error associated with inaccurate ceiling area measurements. These maps should be digitized and used with digitized photographs with bats for accurate coverage estimates.

2. A photo-session should be conducted from July 15th through July 30th. Possibly, this is the best time to get a single estimate of abundance for the resident colony. Pre-birth and pre-migration estimates would be ideal, however, it is likely that timing will always be a problem. Estimates in the spring and fall could always be subject to migratory individuals from other roosts and from early or late migration of the resident colony. A late July session would include all adults and young-of-the-year just as they are beginning to fly.

3. If time and money allow, the spring and fall sessions should be continued, but photo-sessions should be conducted later in the spring and earlier in the fall. During normal years, birthing begins about mid-June and ends by mid-July. Few bats flew during our photo-sessions and we are confident disturbance was not a problem, thus a photo-session from June 10th through June 15th, might provide good estimates of pre-birth abundance without adversely affecting pregnant females. A fall session could be completed in early August.

4. Reference photographs of the cave ceiling without bats should be available for observers counting grid squares. This would eliminate any potential for shadows being counted as bats.

5. Further research should be conducted to look into the roosting density of Mexican free-tails at Carlsbad Caverns during different times of the year. If differences are found from those we used, past

estimates could be recalculated.

6. CCNP has been testing the use of flight noise recording (FNR) as an index to population trends and this should be continued. A remote microphone and data logger allow continuous recording of flight noise over a 24 hour period. The data are then graphed and the area under the curve serves as an index to abundance. Over the next four years the RIP and FNR techniques should be done simultaneously to correlate the two techniques.

Acknowledgments. Major funding was provided by the National Park Service. Additional funding was provided by Adopt-A-Bat, a program funded by visitors to Carlsbad Caverns National Park. We would like to express our gratitude to D. Pate, J. Richards, and H. Burgess for their expertise and insights in the cave environment. T. Best, K. Geluso, K. Kozie, and D. Dobos-Bubno provided critical review and helpful comments to drafts of this manuscript, and J. Lin provided help in data collection.

Table 1. 1996 spring estimates of ceiling area (m^2) covered with Mexican free-tailed bats in Bat Cave, Carlsbad Caverns National Park, New Mexico.

	Daily area estimates (m^2)					**Observer summary**[a]		
Observer	**5/29/96**	**5/30/96**	**5/31/96**	**6/1/96**	**6/2/96**	**Avg.**	**Std.**	**CV_d**
JW	71.35	84.17	77.76	70.61	121.61	85.10	21.14	25
BR	72.37	86.77	78.50	73.11	147.16	91.58	31.59	34
JL	74.88	86.77	79.99	77.11	142.05	92.16	28.24	31
Daily summary[b]								
Avg.	72.87	85.90	78.75	73.61	136.94			
Std.	1.82	1.50	1.14	3.28	13.52			
CV_o	2	2	1	4	10			
Final estimated area calculation =						**89.61**	**26.96**	**30**

a = Observer summary provides a measure of daily variability.
b = Daily summary provides a measure of observer variability.

Table 2. 1996 fall estimates of ceiling area (m^2) covered with Mexican free-tailed bats in Bat Cave, Carlsbad Caverns National Park, New Mexico.

	Daily area estimates (m^2)					**Observer summary**[a]		
Observer	**8/30/96**	**8/31/96**	**9/1/96**	**9/2/96**	**9/3/96**	**Avg.**	**Std.**	**CV_d**
JW	163.42	155.43	180.04	182.74	157.00	167.73	12.86	8
BR	173.17	156.82	171.03	171.03	145.67	163.55	11.93	7
J	158.68	157.28	170.20	170.01	140.75	159.38	12.06	8
Daily summary[b]								
Avg.	165.09	156.51	173.76	174.59	147.81			
Std.	7.39	0.97	5.46	7.07	8.34			
CV_o	4	1	3	4	6			
Final estimated area calculation =						**163.55**	**11.47**	**7**

a = Observer summary provides a measure of daily variability.
b = Daily summary provides a measure of observer variability.

Table 3. 1997 spring estimates of ceiling area (m^2) covered with Mexican free-tailed bats in Bat Cave, Carlsbad Caverns National Park, New Mexico.

	Daily area estimates (m^2)					**Observer summary**		
Observer	**5/27/97**	**5/28/97**	**5/29/97**	**5/30/97**	**5/31/97**	**Avg.**	**Std.**	**CV_d**
BR	14.96	38.74	44.41	28.06	58.44	36.92	16.46	45

DR	14.21	37.72	40.97	27.31	56.76	35.40	15.87	45
JW	17.56	39.67	43.11	28.06	57.32	37.14	15.13	41
Daily summary:								
Avg.	15.58	38.71	42.83	27.81	57.51			
Std.	1.76	0.98	1.74	0.43	0.85			
CV_o	11	3	4	2	1			
Final estimated area calculation =						**36.49**	**15.81**	**43**

Table 4. 1997 fall estimates of ceiling area (m^2) covered with Mexican free-tailed bats in Bat Cave, Carlsbad Caverns National Park, New Mexico.

	Daily area estimates (m^2)					Observer summary		
Observer	**8/29/97**	**8/30/97**	**8/31/97**	**9/1/97**	**9/2/97**	**Avg.**	**Std.**	**CV_d**
BR	134.24	99.96	101.64	61.59	42.46	87.98	36.19	41
DR	136.57	94.11	106.65	62.24	47.66	89.45	35.44	40
JW	135.92	101.36	105.17	61.69	39.58	88.74	38.09	43
Daily summary:								
Avg.	135.58	98.48	104.48	61.84	43.23			
Std.	1.20	3.85	2.58	0.35	4.10			
CV_o	1	4	2	1	9			
Final estimated area calculation =						**88.72**	**36.51**	**41**

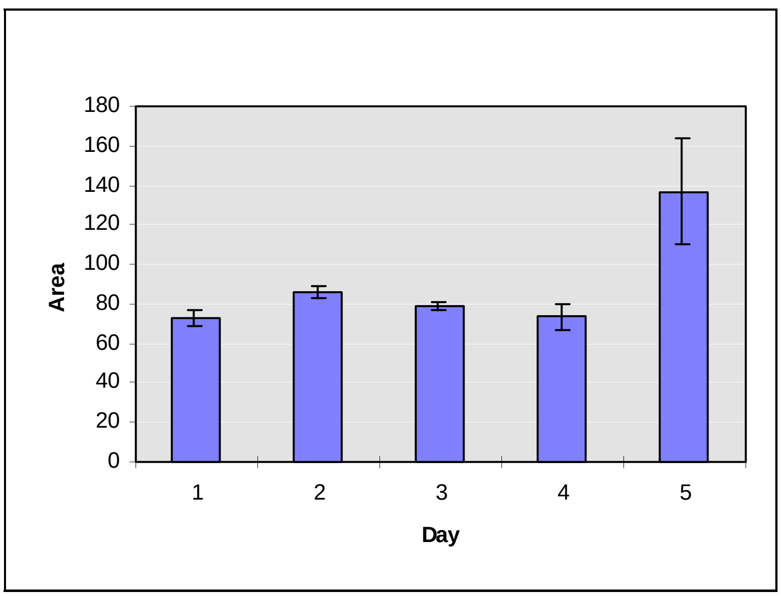


Fig. 2. 1996 spring estimates of roost area. Error bars depict two standard deviations from the mean.

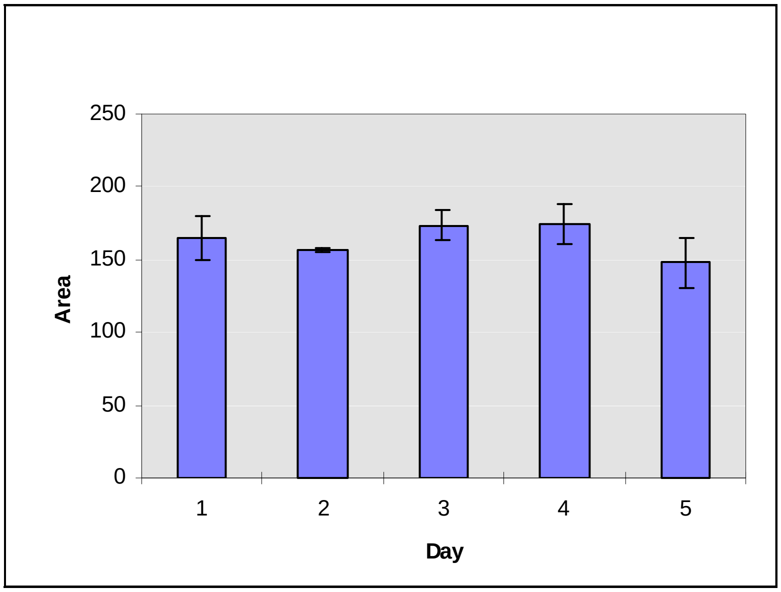


Fig. 3. 1996 fall estimates of roost area. Error bars depict two standard deviations from the mean.

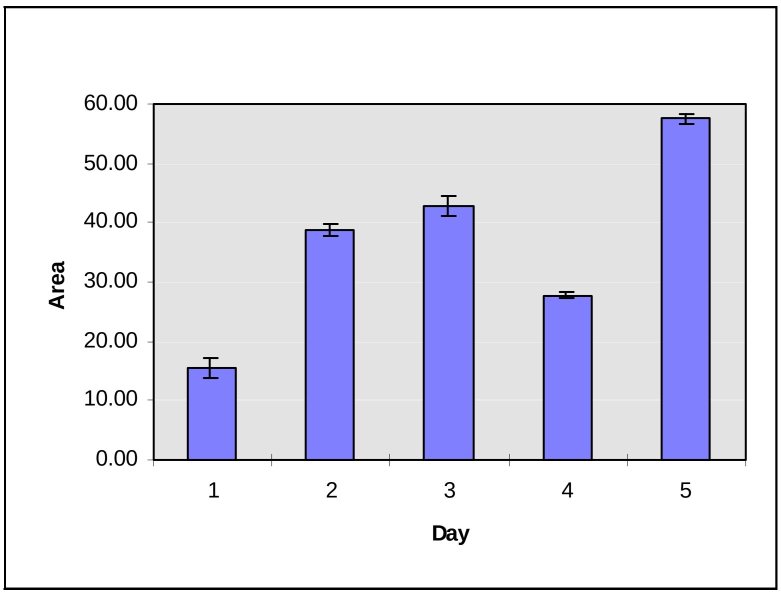


Fig. 4. 1997 spring estimates of roost area. Error bars depict two standard deviations from the mean.

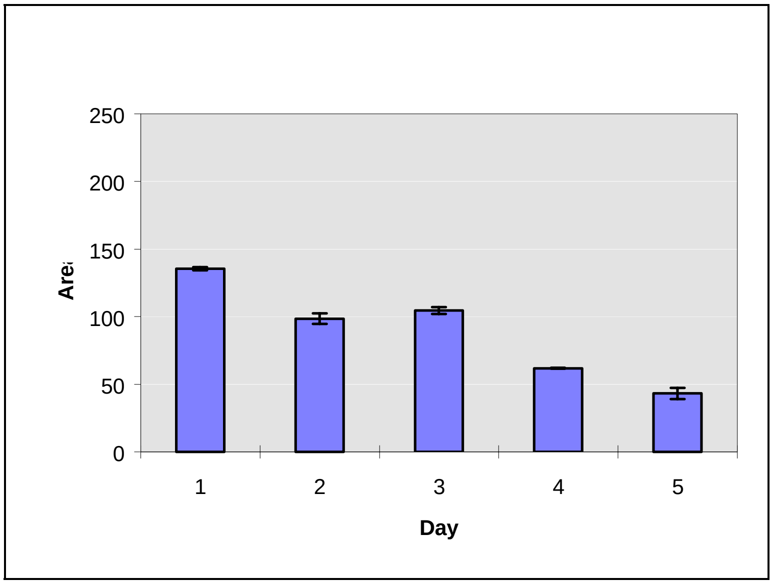


Fig. 5. 1997 fall estimates of roost area. Error bars depict two standard deviations from the mean

LITERATURE CITED

Ahlstrand, G.M. 1974. Decline of the Mexican free-tailed bat (*Tadarida brasiliensis mexicana*) population at Carlsbad Caverns National Park, New Mexico. Carlsbad Caverns and Guadalupe Mountains National Parks Research and Resource Management Report. 16 July, 1974. 15pp.

Allison, V.C. 1937. Evening bat flight from Carlsbad Caverns. J. Mammal. 18:80-82.

Altenbach, J.S., K.N. Geluso, and D.E. Wilson. 1979. Population size of *Tadarida brasiliensis* at Carlsbad Caverns in 1973. Pages 341-348 In Biological Investigations in the Guadalupe Mountains National Park, Texas. H.H. Genoways and R.J. Baker, eds. Proc. Trans. Series No. 4., Nat. Park Service, 442pp.

Bailey, V. 1928. Animal life of the Carlsbad Cavern. Am. Soc. Mammal. Monogr. (3) 195pp.

Clark, D.R., Jr. 1988. Environmental contaminants and the management of bat populations in the United States. USDA Forest Service General Technical Report RM-GTR-166: 409-413.

Clark, D.R, and A.J. Krynitsky. 1983. DDT: recent contamination in New Mexico and Arizona? Environment 25(5): 27-31.

Constantine, D.G. 1967. Activity patterns of the Mexican free-tailed bat. Univ. N.M. Bull. Biol. Ser. 7:1-79.

Geluso, K.N., J.S. Altenbach, and D.E. Wilson. 1976. Bat mortality: pesticide poisoning and migratory stress. Science 194: 184-186.

Geluso, K.N. 1981. Organochlorine residues in young Mexican free-tailed bats from several roosts. Amer. Midland Nat. 105:249-257.

McCraken, G.F. 1984. Communal nursing in Mexican free-tailed bat maternity colonies. Science Vol. 223:1090-1091.

NPS (National Park Service). 1996. Final General Management Plan/Environmental Impact Statement: Carlsbad Caverns National Park, New Mexico. U.S. Dept. of the Interior, NPS.

Roth, J. 1987. Bat counting videos. NPS Memorandum dated 4/30/87. Carlsbad Caverns National Park files. 17pp.

Thomas, D.W. and R.K. LaVal. 1988. Survey and census methods. In Ecological and Behavioral Methods for the Study of Bats. T. Kunz, ed. Smithsonian Inst. Press, Washington, D.C. 533pp.

West, S. 1991. Behavior, status and ecology of the cave swallow (*Hirundo fulva*). M.S. Thesis, New Mexico Institute of Mining and Technology, Socorro, NM. 129pp.

Wilkins, K.T. 1989. *Tadarida brasiliensis*. Mammalian species no. 331. American Society of Mammalogists. 10pp.

APPENDIX A.

Information supporting the use of 2,153 bats/m^2 (200 bats/ft^2) as a conservative estimate of roosting density:

McCraken (1984) reported 40 pups/100 cm^2 which equals 371 pups/ft^2. He did not mention adults, but if additive this becomes even larger.

A) McCraken (unpub. data) reported in a draft of his Science article that adult females were found at densities of 33-41 bats/1200 cm^2 (25.5-31.7/ft^2) and that pups were found at densities of 25 pups/50 cm^2 (464.5/ft^2). The combined average would be ~ 500 bats/ft^2.

B) Keeley (unpub. data): In a phone conversation with the lead author, Brian stated that he took a photograph of the Mexican free-tailed bat colony at Braken Cave and was able to count 315 bats/ft^2. This was in early spring before pups were born.

Cave Conservation and Management on the World Wide Web: Part II

Robert R. Stitt

Abstract

Since the last National Cave Management Symposium, where a paper was given describing cave conservation on the Internet, the use of the Internet and the World Wide Web has grown until millions of Americans are regular users, and there are over 65 million pages indexed on the World Wide Web. Sites providing cave conservation and management information on the Web have proliferated. Most NSS grottos now have home pages and thousands of cavers regularly communicate by e-mail. This paper provides information on where to find information on the Internet and what some of the trends have been over the last two years. A starting point for entry is the Cave Conservation and Management Section's Home Page which can be reached through the NSS home page http://www.caves.org/section/ccms

Digital Cave/Karst Potential Mapping In Northern Vancouver Island: A Strategic Forestry Planning Tool

Tim Stokes, Nick Massey, and Paul Griffiths

Tim Stokes
Terra Firma Geoscience Services, 246 Pine St., Nanaimo, BC, V9R 2B6.

Nick Massey
Geological Survey Branch, Ministry of Employment and Investment, PO Box 9320, Stn Prov Govt, Victoria, B.C., V8W 9N3

Paul Griffiths
Cave Management Services, 544 Springbok Road, Campbell River, B.C. V9W 8A2.

ABSTRACT

Management of forest resources on karst terrain is difficult without careful planning. A first and crucial step in this planning is the identification of karst areas. A digital, 1:250,000 scale, bedrock map for Northern Vancouver Island (NTS maps 92L and 102I) was adapted by GIS techniques to provide a strategic cave/karst potential map. The project utilized data from previous cave/karst potential maps for the Vancouver Forest Region that were manually compiled in 1994. This data set included information on: the known number of caves, karst presence or absence and the level of inspection. The first step of the digital mapping procedure was to identify all limestone-bearing units within the region and develop a set of polygon data. The limestone bearing units included the Quatsino, Parson Bay and Harbledown formations, and the Buttle Lake Group. A selective process was then used to group or divide polygons to assist in the designation of attribute information. Attribute information was developed from the previous data set and was appropriately assigned to each polygon (or polygon group). A numerical rating scheme/table was developed from these attribute data to provide low, moderate or high ratings for cave/karst potential. Bedrock character was used as the primary factor controlling the potential for cave/karst development. Massive (or thick bedded) limestone-bearing units with numerous reports of cave/karst features, such as the Quatsino Formation or Buttle Lake Group, were generally rated as high. Interbedded limestone-argillite units with no known cave/karst features, such as the Parson Bay Formation, rated as low. Other attributes that could be included in future revisions of the mapping system include: limestone purity, unit thickness, regional structure, biogeoclimatic zonation, topographic elevations, and surficial material cover. The principal benefit of this digital mapping method is its flexibility, easily providing maps of individual parameters (e.g., cave density, level of cave inspection), as well as an overall cave/karst potential rating. In addition, it is a valuable tool for information storage and would be suitable for data distribution to users via the Internet.

INTRODUCTION, BACKGROUND AND OBJECTIVES

Limestone and dolomite, the principal karst bearing rocks, make up a considerable proportion of the exposed bedrock surface of British Columbia, and occur mainly on Vancouver Island, and near the Prince George and Nelson areas. Many of these calcareous rock types occur within active timber supply areas (e.g., Northern Vancouver Island, see **Figure 1**). It has been well documented that areas underlain by karst terrain differ significantly in their geomorphological characteristics and hydrological responses from those areas underlain by non-karst terrain (Kiernan, 1990; Aley et al, 1993; Baichtal et al, 1995). The soils developed in limestone areas are typically more productive for tree growth (Pojar and MacKinnon, 1994). However, harvesting of some limestone areas (e.g., steep slopes with thin overburden cover) can lead to increased soil erosion and hence poor tree regeneration (Harding and Ford, 1993). It is therefore critical that these karst areas are recognized early during forest resource planning, so that appropriate land management strategies of harvesting, road construction, and tree regeneration are utilized.

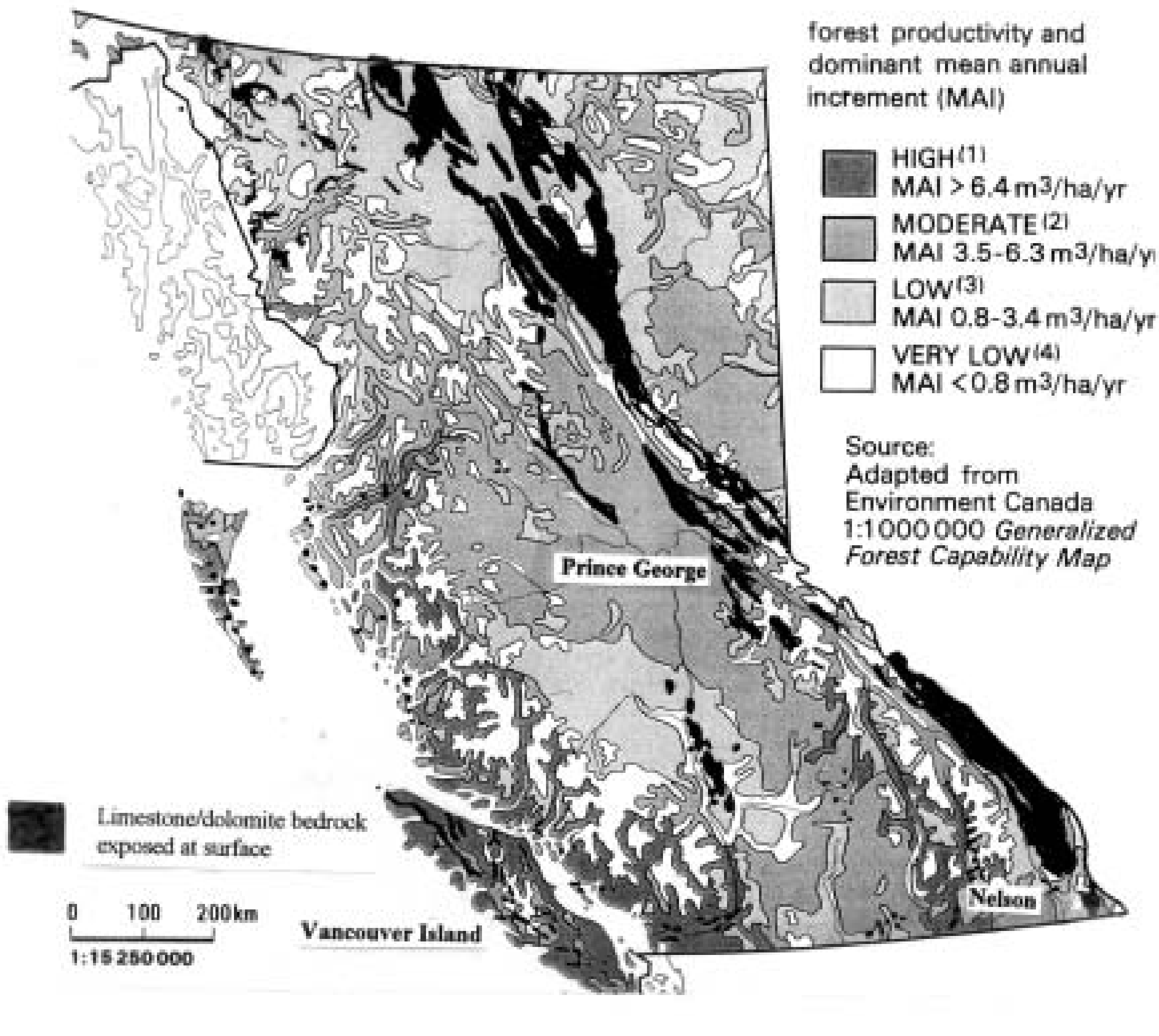


Figure 1: Karst and forested areas of British Columbia. Limestone and dolomite data (shaded black) is taken from Fischel (1992); "Limestone and dolomite resources of British Columbia". Forest productivity map from "Bigeoclimatic zones of British Columbia, 1992", BC Ministry of Forests.

This digital mapping project developed from a research proposal that was submitted to Forest Renewal BC in December 1996. The proposal was not successful, but it was still decided to try and complete a trial digital cave/karst mapping exercise for Northern Vancouver Island, including the Alert Bay and Cape Scott maps sheets (NTS 92L and 102I, respectively). Previous strategic cave/karst potential mapping had been completed manually at a scale of 1:250,000 for both the Vancouver Forest Region (covering Vancouver Island, Queen Charlotte Islands and the South-western Mainland of BC) and the Prince Rupert Forest Region of North-western BC (Stokes, 1994; Stokes 1995a; Stokes 1995b). Standard 1:250,000 scale NTS topographic sheets were used as base maps, while bedrock geology maps of various scales (approximately 1:50,000 to 1:250,000) and ages were used to determine the presence of limestone-bearing units. The locations of these units were transferred as polygons onto the 1:250,000 base maps. The polygons were then split or grouped to assist in assigning cave/karst attribute data that included: the character of the limestone unit, the number of known caves, the known presence of major surface karst features, and the level of inspection. Input for the attribute data was provided by: the BC Ministry of Forests Districts and Regions, the Geological Survey of Canada (GSC), the BC Geological Survey (BCGS), the BC Speleological Federation, and local forestry companies and consultants. This information was tabulated for each map sheet and a judgmental estimate from low to high cave/karst potential was provided for each of the polygons. The 1:250,000 scale maps for Vancouver Island and the Queen Charlotte Islands were digitized by the BC Ministry of Forests to develop 1:600,000 scale maps. (**Figure 2** shows part of this map for Northern Vancouver Island).

From an examination of the karst literature and discussions with other karst specialists, mapping of cave/karst potential at a regional scale of 1:250,000 is not common. Most other karst mapping studies have focussed on more detailed scales, e.g., the forest/karst vulnerability studies in Southeast Alaska (US Forest Service, 1995)), and subsidence hazard maps in chalk lands of Southern England (Edmonds, 1983). However, mineral potential maps, have been completed by the BCGS at a 1:250,000 scale for most of British Columbia and are used to highlight areas favorable for metalliferous mineral exploration and mining (Grunsky et al., 1994). Mineral potential and cave/karst potential maps are similar in that the goals of both are to highlight areas of interest/importance for management decisions.

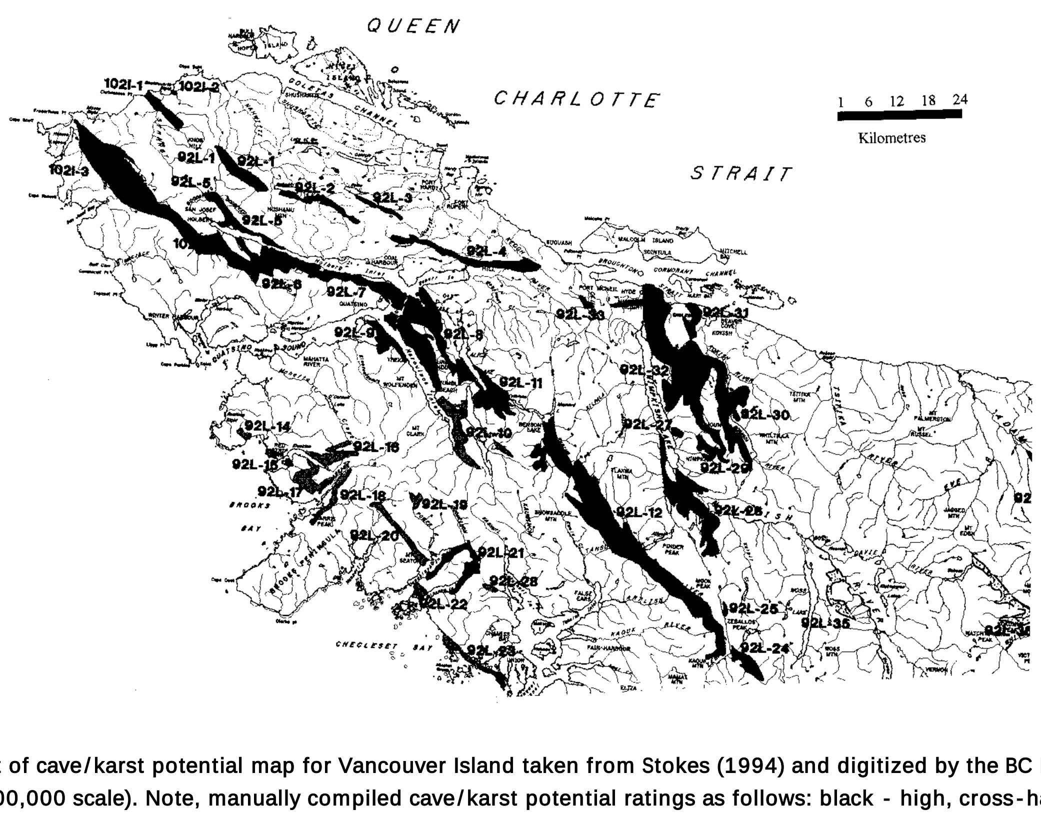


Figure 2 Part of cave/karst potential map for Vancouver Island taken from Stokes (1994) and digitized by the BC Ministry of Forests (1:600,000 scale). Note, manually compiled cave/karst potential ratings as follows: black - high, cross-hatched - moderate to high, and dotted - moderate.

The principal objective of the strategic cave/karst potential maps is to predict the likelihood and level of cave/karst development within various areas underlain by limestone-bearing formations. It is not the intention of these maps to delineate specific cave/karst sites or features, but rather to qualitatively rate or flag areas where the potential for cave/karst development exists. These maps should not be used directly for detailed karst assessments as their large scale (1:250,000) is unlikely to provide accurate polygon boundaries at smaller scales (e.g., 1:20,000). Typically, detailed karst assessments/inventories require significant field work and/or detailed mapping to verify the level of cave/karst development.

Karst potential mapping at the 1:250,000 scale can be used to evaluate two principal criteria:

- the likelihood for limestone (or other karst-forming) rocks to occur within a specific geological unit (or polygon)
- the intensity of karst development within a particular limestone (or other karst forming) rock type

These criteria can be mapped separately or can be combined into an overall karst potential rating, as was done for this trial project. In some cases, distinguishing between these two criteria might be useful for the purposes of forest development planning. For example, a polygon with a moderate cave/karst potential rating, obtained from a geological unit with a small well-karstified limestone component, may require different management/planning strategies from a similarly rated polygon that has a large, but poorly-karstified limestone component within a geological unit.

One distinct advantage of this digital mapping system is that it can analyze a combination of qualitative and quantitative attributes using an objective rating system, as opposed to the more subjective methods of the previous manually-compiled maps. Another major advantage of digital mapping is its flexibility, in that a variety of cave/karst information can be entered, analyzed and stored. In addition, once the digital map and data is completed it can be made readily available to a variety of users (e.g., Ministry of Forests, Forest Licensees, Recreational) who can then adapt the digital format for their own specific purposes.

METHODOLOGY

The digital mapping procedure starts with the initial digital bedrock data and finishes with the final cave/karst potential maps (**Figure 3**).

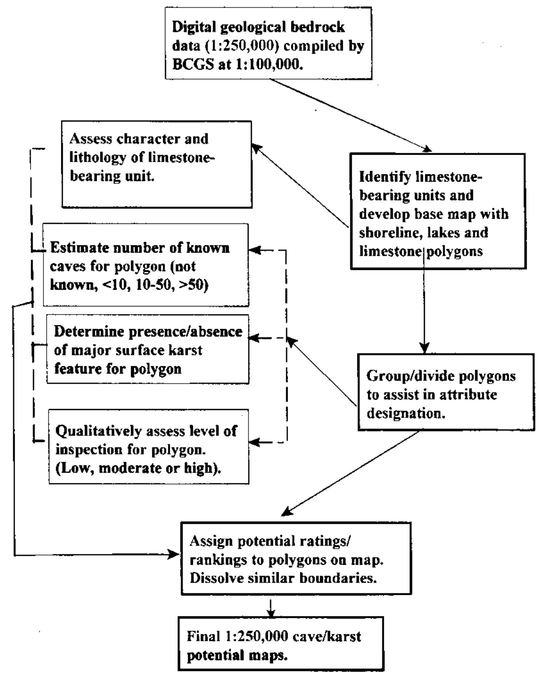


Figure 3: Flow chart for digital cave/karst mapping methodology

Digital bedrock data for the Northern Vancouver Island map sheets was obtained from Massey et al., 1994. The geology for this data was compiled at a scale of 1:100,000 for use at 1:250,000 scale. Information for this digital data was obtained from previous published maps (e.g., Geological Survey of Canada, scientific journals, and unpublished theses and mineral assessment reports). This digital bedrock data was first downloaded into ArcView R 3.0 from a series of .E00 files. A standard Pentium, 32 Mg RAM desk top computer was used for running the software. Various layers were selected from the geological information available. These layers included the coastline, lakes, islands and boundaries of the geological units. The limestone-bearing units were highlighted and all other geological units/boundaries deleted. The resultant polygons were grouped or divided. Larger polygons were separated into manageable sizes using natural breaks in their shape (e.g., at neck points, major offset faults). Smaller closely spaced polygons were collected into natural groupings. A total of approximately 39 polygons were delineated. Each was numbered and given a geographic descriptor for ease of recognition **(Figures 4 and 2)**. In some cases a combination of geological units are present in one polygon. This process of polygon separation and grouping assisted in the designation of the various attributes.

LOCATION	REGION	HOST UNIT	Bedrock Rating	NUMBER OF CAVES	Cave Rating	SURFACE KARST	Surface Rating	INSPECTION LEVEL	Inspection Rating	Total Rating	FINAL RATING
102I-2	Shuttleworth Bight	Q	5	Not known	0	Not known	0	None	0	50	moderate
92L-3	Dick Booth Creek	Q	5	Yes, <10	1	Yes	2	Low-Moderate	2	79	high
92L-33	Cluxewe Mountain	Q	5	Yes, <10	1	Yes	2	Low	1	77	high
92L-27	Kinman Creek	Q	5	Yes, <10	1	Yes	2	Moderate	3	81	high
92L-14	Side Bay	PB	3	Not Known	0	Not known	0	Low	1	32	low
92L-18	Klaskish River	PB	3	Not Known	0	Not known	0	None	0	30	low
92L-19	Mt. Seaton	PB	3	Not Known	0	Not known	0	None	0	30	low
92L-20	Schoen Lake	BL	5	Not known	0	Not known	0	Low	1	52	moderate
92L-36	Woss Lake	BL	5	Not known	0	Not known	0	None	0	50	moderate
92L-35	Kayouk	PB	3	Not Known	0	Not known	0	None	0	30	low
92L-28	Zeballos Peak	Q	5	Yes, <10	1	Yes	2	Low-Moderate	2	79	high
92L-25	Sebalhall Creek	BL	5	Yes, <10	1	Yes	2	Low	1	77	high
92E-18	Christensen Pt.	PB/Q	4	Yes, <10	1	Yes	2	Moderate	4	73	high
102I-1	San Josef River	Q/PB	4	Yes, >50	4	Yes	2	High	5	90	high
102I-3	Nawitti River	PB/Q	4	Yes, >10	2	Yes	2	Moderate	3	76	high
92L-1	Holberg	PB/Q	4	Yes, <10	1	Yes	2	Low	1	67	moderate
92L-5	Nawitti Lake	Q/PB	4	Not Known	0	Not Known	0	Low	1	42	moderate
92L-2	Washlawlis Hill	Q/PB	4	Yes, <10	1	Yes	2	Low	1	67	moderate
92L-4	Michelsen Point	PB/Q	4	Yes, <10	1	Yes	2	Low	1	67	moderate
92L-7	Victoria Lake	PB	3	Not known	0	Not Known	0	Low	1	32	low
92L-10	Benson Creek	Q/PB	4	Yes, 10-50	3	Yes	2	Moderate	3	81	high
92L-11	Atluck Camp	Q/PB	4	Yes, >50	4	Yes	2	High	5	90	high
92L-12	Nomash River	Q/PB	4	Yes, <10	1	Yes	2	Low	1	67	moderate
92L-24	Scouler Entrance	PB	3	Not known	0	Not Known	0	None	0	30	low
92L-15	Yaky Cop Cone	PB	3	Not Known	0	Not known	0	Low	1	32	low
92L-17	Mount Kotzebu	PB	3	Not known	0	Not Known	0	Low	1	32	low
92L-16	Upsowis	PB	3	Not Known	0	Not known	0	None	0	30	low
92L-22	Ououkinish	PB/Q	4	Yes, <10	1	Yes	2	Low	1	67	moderate
92L-21	Kuyquot	PB	3	Not Known	0	Not known	0	None	0	30	low
92L-23	Atluck Creek	Q	5	Yes, 10-50	3	Yes	2	Moderate	3	91	high
92L-26	Eaglewood	Q/PB	4	Not known	0	Not known	0	Low	1	42	moderate
92L-31	Mount Hoy	Q/PB	4	Yes, 10-50	3	Yes	2	Moderate-High	4	83	high
92L-29	Harbledown Islan	HA/PB	2	Not known	0	Not known	0	None	0	20	low
92L-34	Hathaway Creek	Q/PB	4	Yes, <10	1	Yes	2	Low	1	67	moderate
92L-6	Buchholtz Channel	PB/Q	4	Not known	0	Not Known	0	Low	1	42	moderate
92L-9	Marble Creek	Q/PB	4	Yes, 10-50	3	Yes	2	Moderate	3	81	high
92L-8	Nimpkish Lake	PB/Q	4	Yes, 10-50	3	Yes	2	Moderate	3	81	high
92L-32	Bonanza Lake	Q/PB	4	Yes, 10-50	3	Yes	2	High	5	85	high
92L-30	White River	Q/PB	4	Yes, <10	1	Yes	2	Low	1	67	moderate

Figure 4: Data table used for numerical rating and analysis of the four attributes: character of limestone unit (LC), number of known caves (CANADA), presence/absence of major surface karst features (SK), and level of inspection (IL). Weightings were assigned to the attributes as follows so as to allow for the greater influence of bedrock geology in determining the cave karst potential: LC - 50%, CANADA - 20%, SK - 20% and IL - 10%.

The four attributes used to rate the cave/karst potential included:

- the character of limestone-bearing unit (e.g., whether massive, thick-bedded, inter-bedded, or minor component),
- the approximate number of known caves (<10, 10-50, >50, or not known),
- the presence of major surface karst features; e.g., disappearing creeks, rock bridges, extensive sink hole areas, karst pavements (present, absent, not known), and
- the level of inspection (e.g., degree to which polygon had been assessed for caves/karst).
-

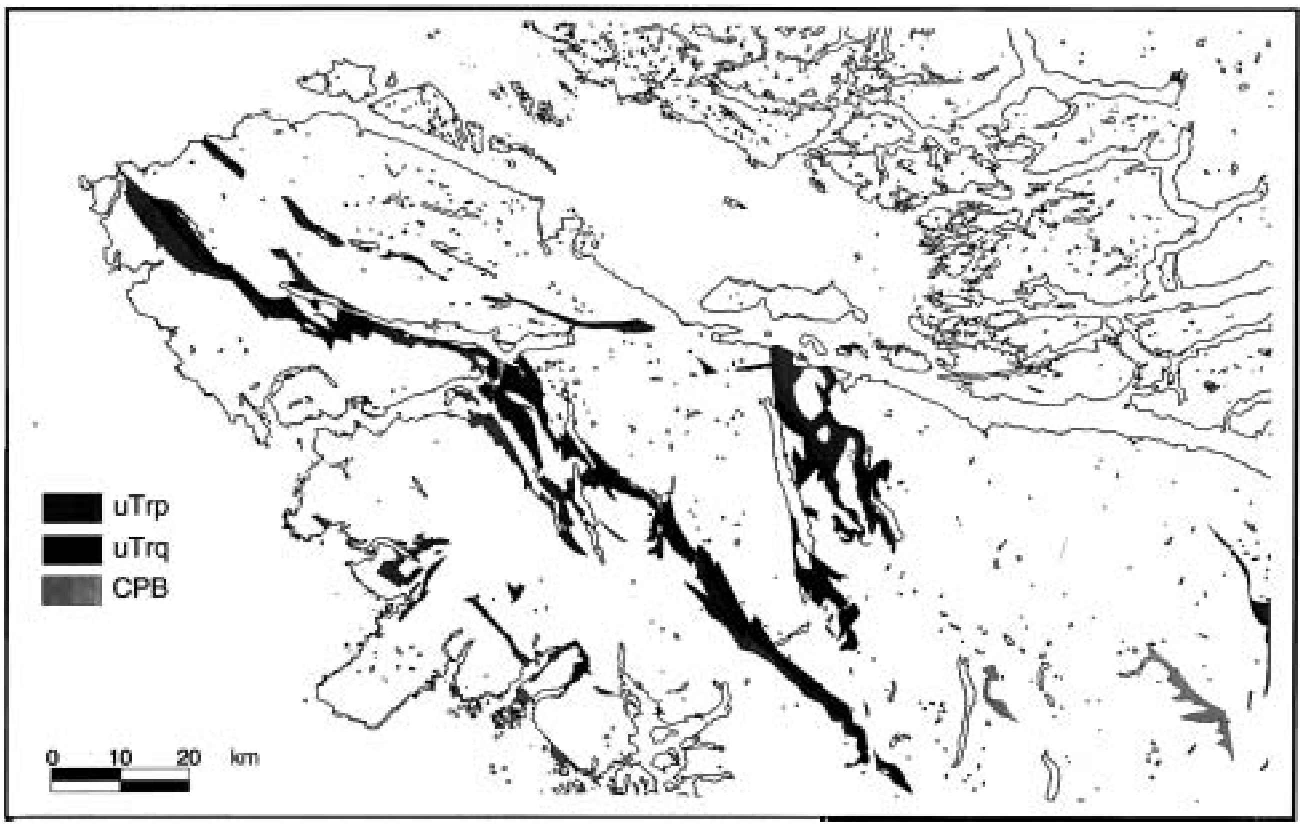


Figure 5 Limestone-bearing units within the Alert Bay (NTS 92L) and Cape Scott (NTS 102I) maps sheets. uTrp - Parson Bay Formation, uTrq - Quatsino Formation, and CPB - Buttle Lake Group. Harbledown Formation (lJh) to small to be shown at scale of map.

Limestone-bearing Units

Information gathered for the rating of the limestone-bearing areas/polygons was obtained from a variety of sources. The prime factor used was the geological character of the limestone-bearing units. Four limestone-bearing formations were identified in the Alert Bay/Caps Scott map sheets including the Buttle Lake Group, and the Harbledown, Parson Bay, and Quatsino formations **(Figure 5)**. Descriptions of the limestone-bearing units are as follows from the stratigraphic youngest to oldest:

Harbledown Formation (lJh) - Part of the lower Jurassic_Bonanza Group. Comprised of argillite, greywacke-argillite turbidity, chert, silty limestone, calcareous siltstone and feldspathic sandstone.

Parson Bay Formation (uTrp) - Part of the middle to upper Triassic Vancouver Group. Comprised of thinly bedded black argillite, siltstone and shale, calcareous argillite, grey and black limestone and shaly limestone, minor tuffaceous sandstone, grit and breccia. Includes coralline limestone.

Quatsino Formation (uTrq) - Part of the middle to upper Triassic Vancouver Group. Comprised of thick-bedded, grey to black, micritic and styolitic limestone, medium to thin bedded limestone and calcareous siltstone, minor oolitic and bioclastic limestone, garnet-epidote-diopsite skarn. May include **uTrkq**: Intermixed micritic limestone and basaltic flows, transitional between the Karmutsen and Quatsino formations.

Buttle Lake Group (CPB) - Carboniferous/Permian. Undifferentiated Buttle Lake Group. Comprised of limestone, graywacke, argillite, and chert. May include significant sills of Mount Hall Gabbro (**CPB+lTri**)

The limestone-bearing units were then qualitatively assessed for their likelihood/intensity of karst development and given a numerical value from 1 to 5. The thick bedded Quatsino Formation was rated as 5. The Buttle Lake Group limestones were also rated as 5. The Parson Bay Formation, that is commonly in stratigraphic contact with the Quatsino, and comprised of interbedded limestone with black argillite was rated as 3. Polygons with both Quatsino and Parson Bay Formations were rated as 4. The Harbledown Formation which has minor sequences of silty limestone was rated as 2.

Other Attributes

Numerical estimates of known caves within each of the polygons was obtained from local information supplied by Paul Griffiths. This attribute confirms that caves are present in a polygon and that the limestone-bearing unit has a well developed subsurface karst. However, it does not detract from the possibility that caves are still present in some polygons, but have yet to be discovered. The absence of caves could be confirmed if the area had a high level of inspection, but this is generally not the case. For simplicity four categories for the number of known caves were chosen and numbered accordingly - >50 caves (4), 10-50 caves (3), >10 caves (2), and not known (1). This method of assessment has some obvious biases. For example, larger polygons of the same limestone-bearing unit will likely have more caves than smaller.

The presence of known major surface karst features within the polygons was obtained in a similar manner to number of caves data. This information only confirms the presence of well developed surface karst, but again does not detract from the possibility that major surface karst features are yet to be found. Typically, the types of major surface karst features considered included: disappearing creeks, significant sinkhole/grike areas, rock bridges and extensive epikarst pavements. The presence of a major karst feature was given a numerical value 2, while not known was given a 0.

A qualitative rating based on the amount of cave/karst inspections for the polygons was also determined and provides an indication of the amount of local knowledge of caves or karst features within the area. Typically, this knowledge is gained from: recreational cave visits/exploration of areas, cave/karst inventories completed for the Forest Districts or forest industry, and from other research studies. Polygons were rated as follows: no known inspection were rated as none (or 0); at least one recreational caving visit, but no detailed surface examination were rated as low (or 1); repeated visits and or minor surface examinations by forest companies or districts were rated as moderate (or 3); and repeated visits by cavers and with considerable surface inspection were rated as high (or 5). Values of 2 and 4 were also provided for low-moderate and moderate-high ratings, respectively.

Weighting and Analysis

In order to determine a total numerical rating for cave/karst potential a weighting system was used to emphasize the more important influence of the bedrock (limestone) character (LC). The three attributes of cave number (CANADA), major surface karst features (SK) and inspection level (IL), provide confirmation of cave/karst development within a polygon. A weighting system was developed as follows to determine a total numerical rating value:

Total Cave/Karst Numerical Rating = 50% LC + 20% CANADA + 20% SK + 10% IL

Three ranges of values were required from the resultant data to provide the qualitative ratings of low, moderate or high cave/karst potential. These ratings imply an increasing likelihood for surface and subsurface karst development. A bar graph was completed for the numerical data (**Figure 6**). Without applying any detailed statistical analysis, it is apparent that three natural breaks are present dividing the data into three even groups: 0 to 33, 34 to 66, and 67 to 100. These ranges were used for the qualitative ratings of low, moderate and high, respectively.

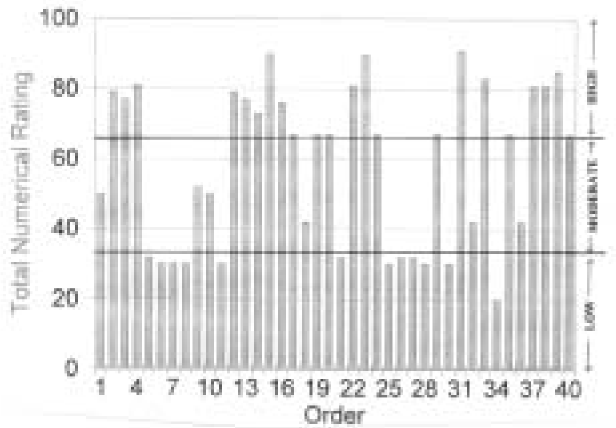


Figure 6: Bar graph of total numerical ratings for cave/karst potential. Two natural breaks were observed in data at approximately 33 and 66. These breaks were used to separate data into three fields, which were qualitatively rated as low (0-33), moder moderate (34-66) and high (67-100) for cave/karst potential.

CONCLUSIONS

This trail digital mapping project of regional cave/karst potential for Northern Vancouver Island has been successful in delineating a varied range of numerical and qualitative ratings for cave/karst development **(Figure 7)**. Polygons that included only Quatsino Formation were generally rated as having a high cave/karst potential, particularly where a significant number of caves were present and where considerable inspection had been carried out. One area of Quatsino Formation was rated as moderate where no other attribute data was available (see #102I-2 on Figure 4). High ratings were also obtained for some polygons containing a combination of the Quatsino and Parson Bay formations, and where a significant number of caves were present. Similar polygons with low or no caves rated as moderate The Buttle Lake Group rated as high where caves were known (#92L-25 on Figure 4) and moderate where cave were not known (e.g., ##92L-20, Figure 4). Polygons containing only Parson Bay Formation rated as low (e.g., #92L-35, Figure 4). No caves were known in these areas. The one polygon with part Parson Bay and Harbledown formations also rated as low.

In general, the low cave/karst potential areas would infer limited surface and subsurface karst features or where karst might only occur in a small portion of a geological unit/polygon. High cave/karst potential areas are where significant surface and subsurface karst features are likely to occur throughout a specific geological unit. Moderate cave/karst potential areas are where some surface and subsurface karst features occur within parts of the geological unit, but to a lesser extent than the higher rating. It should be understood that these qualitative ratings are not fixed and they could change as more cave/karst areas are discovered, or as more detailed geological information is available.

REFINEMENTS AND FURTHER WORK

The methodology, though simplistic, shows what can be achieved from a relatively limited data source. In comparison to the previous manually compiled potential maps, that were rather subjective and relied heavily on the judgement of the mapper, the digitally compiled maps can more objectively analyze the attribute data. Not only can this mapping technique develop cave/karst potential maps, but it can also produce maps for the various individual attributes **(e.g., Figures 8 and 9**).

Significant refinements to the digital methodology could be carried out. For example, other attributes could be added into the analysis including data on:

- limestone composition/purity,
- regional variation in formation thickness/facies (e.g., the Quatsino Formation is thicker in the north of Vancouver Island as compared with the south),
- regional structural trends (e.g., where units are sub-horizontal dipping, vertical, or within fault zones),
- biogeoclimatic zonation/paleoclimatic variations,
- topographic elevation variations,
- thickness and type of surficial cover, and
- drainages and catchment areas.

Some testing of the relative weighting for the respective attributes could be carried out to determine the most suitable spread of total numerical values. Statistical methods could be employed for evaluating the qualitative rating ranges from the total numerical values. The grouping/dividing procedure for the polygons could be examined and a more objective method utilized (e.g., by determining minimum and maximum sizes of polygons). The area size of polygons could be used to normalise some attributes (e.g., cave number). Detailed field checking was not carried out to confirm the validity/proportionality of these ratings, but could be incorporated at reconnaissance level to further refine the mapping methodology. This might be particularly important for areas where little or no cave/karst information is available.

An improvement to the methodology might be to develop a more integrated GIS approach whereby various overlays of polygon and point data are analyzed (e.g., polygons for geological units, biogeoclimatic zones and elevation ranges, and points for known cave and surface features). It might also possible to separate the two criteria included in the karst potential rating (e.g., the likelihood for limestone rocks to occur within a specific geological unit and the intensity of karst development within a particular limestone rock type) and to presented this information as two individual symbols on a map.

One other approach that should be also given consideration is to use only the characteristics of the bedrock material (purity, thickness and structure) and its physiographic location (e.g., elevation, biogeoclimatic setting) to derive the cave/karst potential rating. The other cave/karst attribute data could then be used solely for the confirmation of cave/karst features and not influence the cave/karst potential rating. This type of approach would address the problem whereby two similar geological units have different cave/karst ratings solely because only one area has been examined and the other has not.

The use of the terms primary, secondary and tertiary might also be considered for cave/karst potential instead the slightly misleading terms of low, moderate and high. This might help clarify the misconception that the various ratings (of low, moderate and high) require different level of management/inventory at more detailed scales. By using the terms of primary, secondary and tertiary cave/karst potential the intention is to stratify the relative importance of the polygons rather than to imply a particular prescription or practice.

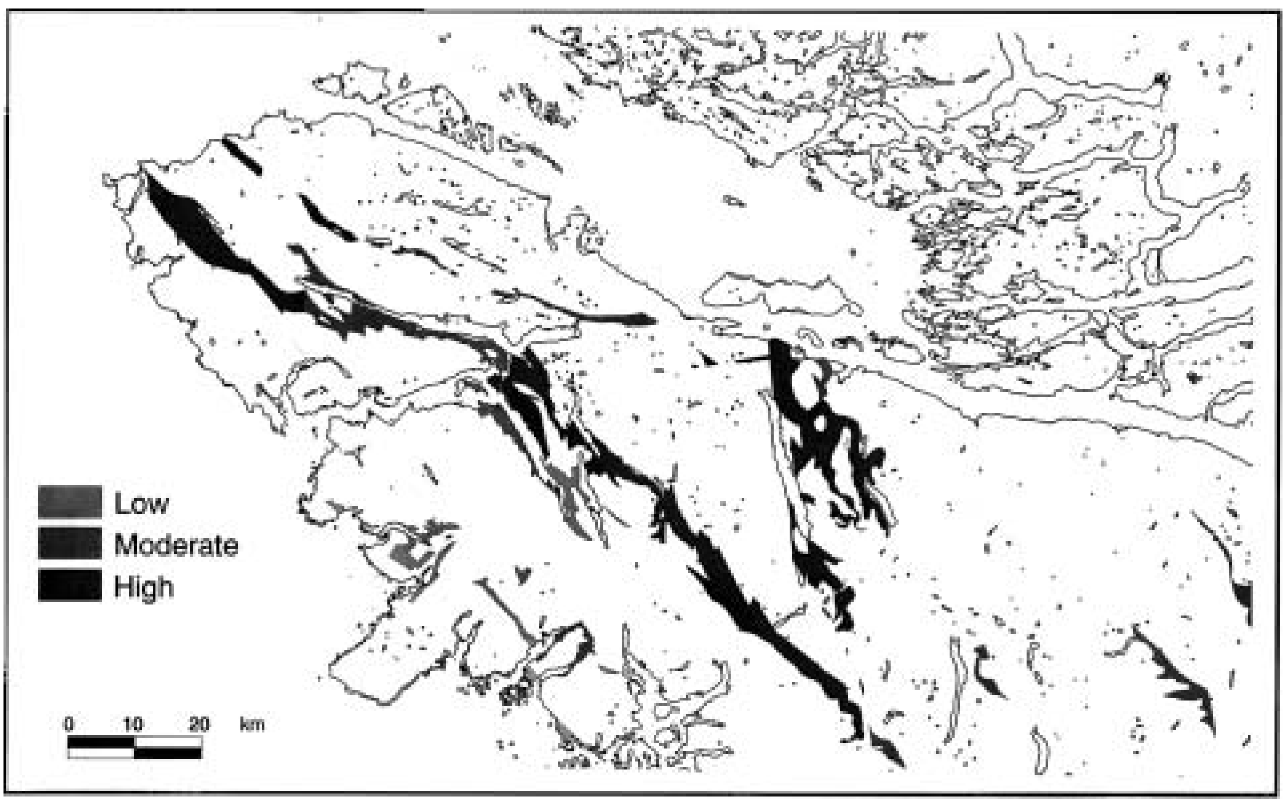


Figure 7: Digital cave/karst potential map for Northern Vancouver Island derived from data table in Figure 4. Legend with low, moderate and high cave/karst potential.

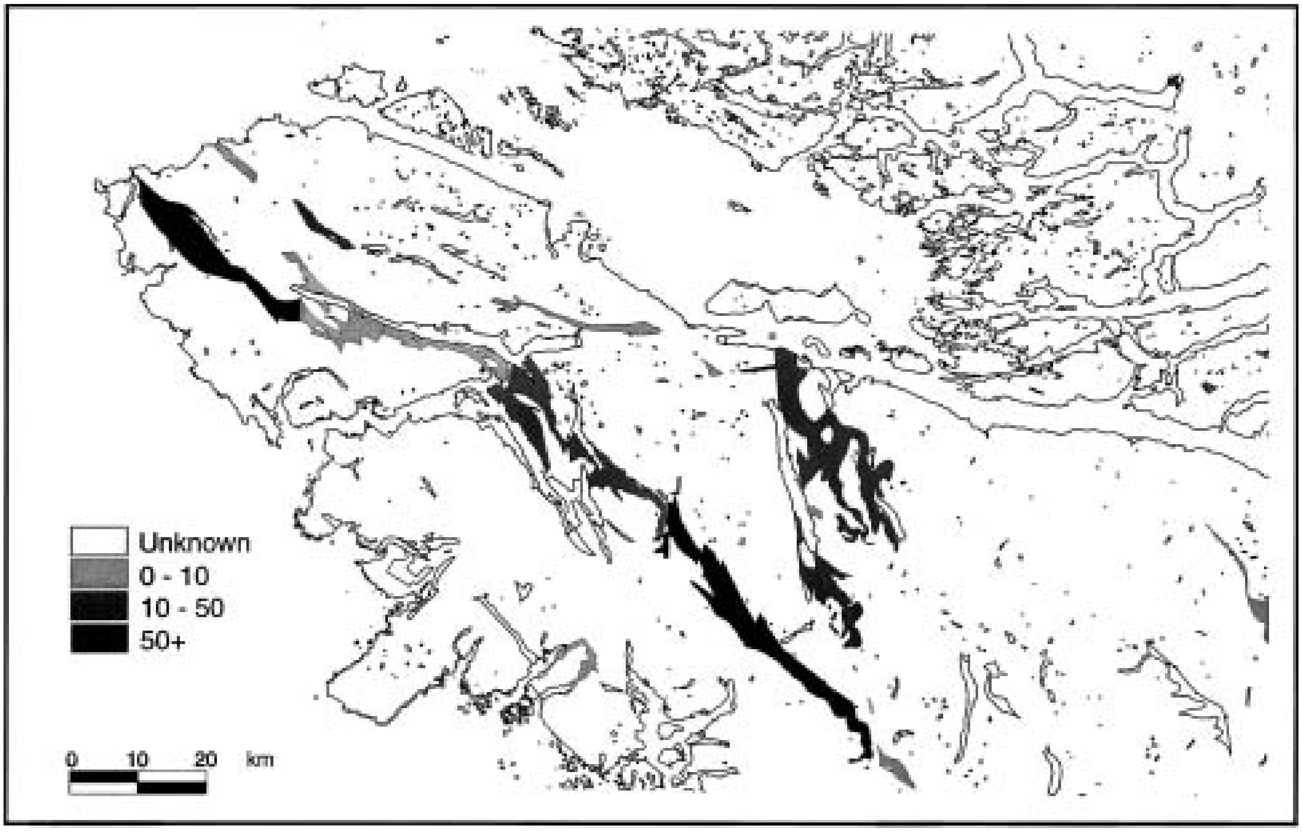


Figure 8: Digital map with the number of known cave digital maps derived from data table in Figure 4. Legend with estimate of known number of caves.

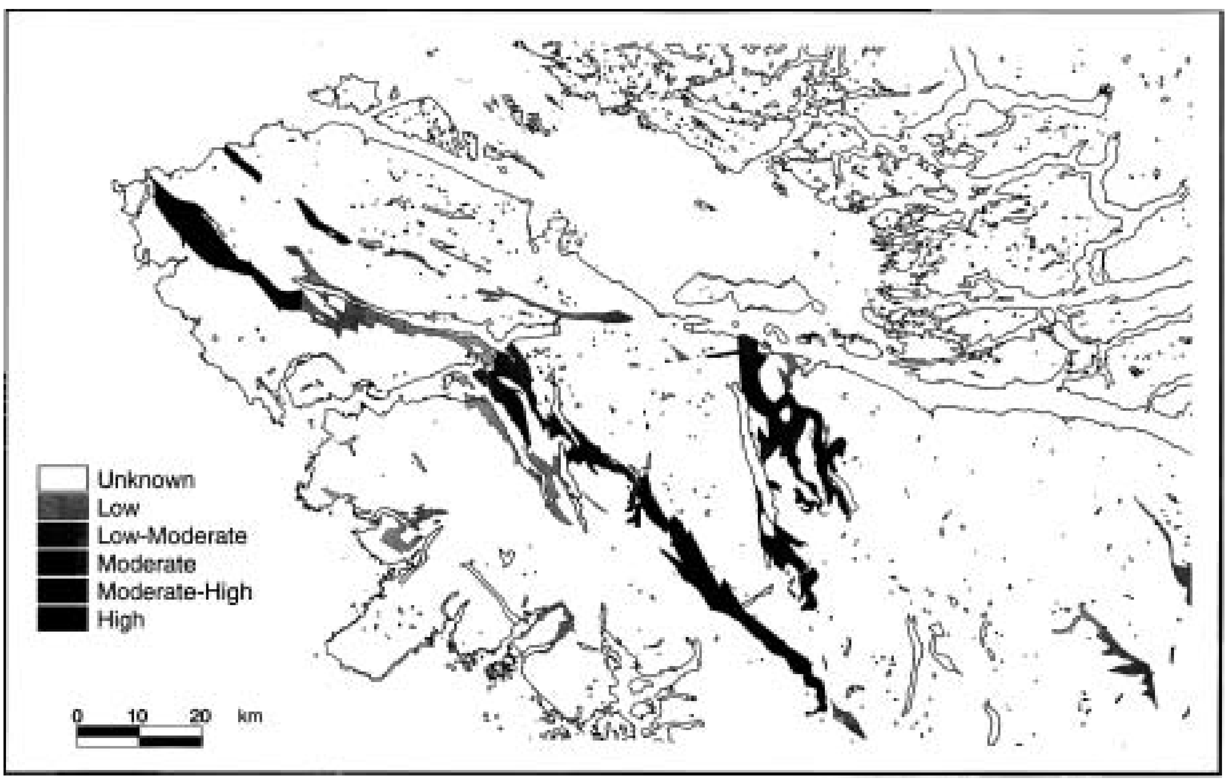


Figure 9: Digital map cave with level of inspection. Derived from data table in Figure 4. Legend with qualitative estimate

for level of inspection.

REFERENCES

Aley, T., C. Aley, W.R. Elliott and P. Huntoon. 1993. Karst and Cave Resource Significance Assessment Ketchikan area, Tongass National Forest, Alaska. Final Report, prepared for Ketchikan Area of the Tongass National Forest. 79 p.

Baichtal, J.F., Swanson, D.N., and Archie, A.F. 1995. An ecologically-based approach to karst and cave resource management. National Cave Management Symposium XII, October 25-28, 1995, Spring Mill State Park, Mitchell, Indiana.

Edmunds, C.N. 1983. Towards the prediction of subsidence risk upon chalk outcrop, Q.J.Eng. Geol, Vol. 16, p. 261-22.

Fischel, P.S. 1992. Limestone and dolomite resources in British Columbia. BC Ministry of Energy, Mines and Petroleum Resources, Openfile 1992-18. 152 p.

Grunsky, E.C., Kilby, W.E. and Massey, N.W.D. 1994. Mineral Potential Assessment in British Columbia; Non-Renewable Resources, Vol 3, p. 271-283.

Harding, K.A. and D.C. Ford. 1993. Impacts of primary deforestation upon limestone slopes in northern Vancouver Island, British Columbia. Environ. Geol. Vol 21, p. 137-143.

Kiernan, K. 1990. Soil and Water Degradation in Carbonate Rock Terranes. Australian Journal of Soil and Water Conservation 3(4):26-33

Massey, N.W.D., Grunsky, E.C. and Desjardins, P.J. 1994. Geological Compilation of Vancouver Island (NTS Map Sheets 92B, C,E,F,G,K & L) 1:250,000 scale, Ministry of Energy, Mines and Petroleum, Open File 1994-6.

Pojar, J. and MacKinnon, A. 1994. Plants of Coastal British Columbia. BC Ministry of Forests and Lone Pine Publishing. 527 p.

Stokes, T.R. 1994. 1:250,000 cave/karst potential maps of the Vancouver Forest Region. Contract completed for the MOF Vancouver Forest Region. Set of 10 maps.

Stokes, T.R. 1995a. 1:250,000 cave/karst potential maps of the Prince Rupert Forest Region. Contract completed for the Prince Rupert Forest Region. Set of 22 maps and report.

Stokes, T.R. 1995b. Evaluation of Coastal British Columbia for potential cave and karst terrain: A regional rating system. GAC-MAC Annual Meeting, final Program and Abstracts, Vol 20, p A101.

U.S. Forest Service, 1995. Final Karst Vulnerability Assessment Report: Phase II Site-Specific Verification Study, Lab Bay Environmental Impact Statement, Prince of Wales Island. Prepared by Harza Northwest Inc. and Ozark Underground Laboratories for the USDA, Tongass National Forest, Ketchikan Area, Thorne Bay Ranger District. Unpublished Report. 23 p. Maps and Appendices.

.

Restoration, Trail Designation, and Microbial Preservation in Lechuguilla Cave

Jim Werker and Val Hildreth-Werker
NSS Resource Protection & Preservation
PO Box 1018, Tijeras, NM 87059
phone 505.286.0148 werks@worldnet.att.net

ABSTRACT

A decade of travel in Lechuguilla Cave has resulted in visitation impacts and management goals that may be applicable to the conservation of other caves. Located on Carlsbad Caverns National Park, the pristine passages of Lechuguilla were first entered during 1986. Surveyed passage has exceeded ninety miles and virgin areas are still being discovered. Significant microbial communities are being investigated in Lechuguilla even though main trails through the cave have become well-worn paths displaying human impact. Misplaced footsteps and handprints mar pristine rooms. Thus, the National Park Service is actively identifying ways to lessen caver impact and methods to avoid contamination. Efforts in Lechuguilla focus on preservation of pristine areas, definition of trails, and development of techniques to minimize disturbance of the microbiota. In Lechuguilla Cave, standards are being implemented to preserve natural features and precautions are being encouraged to decrease human impact on biota.

INVESTIGATING CAVE MICROBES

From the lessons learned about impact in Lechuguilla, cavers are discovering better ways to cave softly and leave no trace. Because microbial studies in Lechuguilla are yielding positive and important results, we are developing precautions to minimize impact on microbial communities. Interest in the microbes of Lechuguilla was originally sparked by Cunningham's early investigations of folia and corrosion residue in which he noted the presence of fungal and bacterial structures (Cunningham 1991). By studying microbial communities in sub-surface environments on earth, such as Lechuguilla, Boston and NASA scientists are working to develop models for what life might be like on Mars (Boston *et al*. 1992).

The weight of the responsibility to approach restoration with respect for the microbiota is magnified by the fact that strongly positive results are coming from Mallory's investigation of bacterial agents in Lechuguilla. He is identifying cave bacteria which produce chemical substances that are effective in fighting various forms of cancer (Mallory *et al*. 1995). The impact of humans on the microbial community has been investigated by Northup and Lavoie. In separate studies, they have each tested heavily traveled routes, camps, bivy sites, and urine dumps throughout the cave (Lavoie 1995, Northup *et al.* 1997). To help cavers understand the importance of microbial preserves in caves, Northup, Lavoie, and Mallory (1997) have composed a pamphlet describing ways we can avoid impacting microbial communities (Figure 1). Suggested guidelines in the draft are designed for Lechuguilla and may not be applicable to other types of caves.

IDENTIFYING AND AVOIDING MICROBIAL IMPACTS

Unique microbes that require low-nutrient environments are sheltered by Lechuguilla. Because it is a deep cave harboring isolated pools and passages, specialized microbial communities inside Lechuguilla survive in the absence of surface nutrients. Many other caves receive major inputs of surface nutrients from streams and rivers. Unlike Lechuguilla, food is simply more plentiful where streams flow into caves and bring an abundance of carbon-loaded, nutrient-rich debris. In caves like Lechuguilla, where the carbon load is very low, microorganisms are adapted to living in low-nutrient environments. When cavers introduce skin, hair, food, mud, and other carbon-rich materials from the surface, the amount of nutrients in the cave environment may change.

With all the organic matter we bring into caves, it is easy to understand that human presence might build up the nutrient base. Surface microbes have a better chance of surviving in caves when we introduce carbon-rich nutrients. When the food supply changes, the microbial community is likely to change. The surface organisms, enabled by the introduced food supply, may take over the environment. Native organisms may not be able to survive. Adding to or changing the nutrient base may favor the survival of surface microbes over the survival of native microbes. Microbial communities requiring low-nutrient environments could easily be destroyed by human impact.

Cavers doing restoration now have to be acutely aware of contamination issues. How do we work in areas and minimize our human impact? Preserving the microbiota is the major concern for restoration projects in Lechuguilla. How do we adapt common restoration practices for use in a giant microbial preserve? Following are descriptions of techniques used in Lechuguilla and examples of how we approach restoration with respect to the amazing diversity of sub-surface microbes.

RESPECTING MICROBIAL COMMUNITIES

First, we are using surgical gloves for nearly every restoration task, especially in pristine or little traveled areas. Powder-free, non-latex, vinyl, or rubber gloves are worn. Holes and tears can be a problem. Some cavers rarely rip their gloves while others go through several pairs a day. Surgical gloves are reasonably comfortable, work well, and last longer than other choices.

Avoid latex gloves. Reported allergic reactions to latex have been increasing—from mild rashes on the hands to life-threatening episodes have been documented. Use only non-latex gloves for cave projects.

Many restoration projects require water. In Lechuguilla, water is not carried into the cave for restoration tasks—it is carefully and conservatively taken from designated pools. Striving to not cross-contaminate pools, water is used only in the area near the pool from which it came. Turkey basters or syringes are used to put pool water into spray bottles. Bottles, sprayers, basters, syringes, sponges, buckets, brushes, etc. are sterile, new, or disinfected for each area of the cave, depending on previous human impact. Because scientists have found differing microbial communities in pools only a few feet apart, we try to always identify and avoid possibilities for contamination.

To conserve water, simple filters are put to work. Restoration water and debris collected in sponges is squeezed into buckets and allowed time for the larger particles to settle. If the water does not clear, it is strained through a sponge filter. Foam or sponge material is compressed into a clean water bottle that is made into a funnel by cutting off the bottom. Debris collects around the edges of the sponge. Treated foam products are avoided since we do not know what chemicals they may add to the cave. Restoration water is filtered through this makeshift funnel and recycled for another dose of restoration work in the same area.

As a result of foot travel, mud sometimes collects on the bottoms of pools located near trails. Hand pumps are used to collect silt while the water is filtered directly back into the pool. The makeshift funnel described above is held at the water outflow of the pump, allowing debris to be caught in the filter. For some pools, a rubber hose can be attached to the pump. Two cavers can operate the device, one pumping and filtering, and one directing the hose. The pump is disinfected before using it in a different pool.

Currently, the recommended disinfectants for cave restoration tools are chlorine bleach or hydrogen peroxide (Cokendolpher, Boston, and Northup, personal communication 1997). Both compounds need a contact time of about ten minutes—do not just wipe on and off and expect to kill much. Hydrogen peroxide rapidly breaks down into water and oxygen. There are two types of chlorine bleach—calcium hypochlorite or sodium hypochlorite. These bleaches break down into sodium chloride (table salt) or calcium chloride and water. Both products are highly corrosive and special care should be taken to keep them away from caving gear. Because of the toxicity of these compounds to microbes, they should be carried and stored in the cave in small containers. In that way, any spills will not kill large numbers of desirable microbes. One tablespoon of bleach per gallon of water will destroy many microbes. More investigation is needed to determine what residue is left by various disinfecting agents, what percentage is effective, what organisms should be considered, how long the agents continue to work, and how the cave is effected.

TRAIL FLAGGING IN LECHUGUILLA

Trail maintenance is an important aspect of cave restoration. When Lechuguilla trails were originally marked, flagging tape was laid in one-foot lengths to create a dotted line of trail. Often, only one side of the trail was designated. Problems persisted with lost flagging, hard to find pathways, and too many misplaced footsteps. Based on years of observation, Carlsbad Caverns National Park made the decision that double flagged trails have positive and beneficial influence on the preservation of cave resources. Trails are now being double flagged throughout Lechuguilla. Double flagging—continuous lines of surveyors tape defining both sides of the trail—helps guide footsteps to stay on impacted areas. Double flagged trails may be visually more obtrusive. However, for the National Park Service, protection of the cave comes first—experience proves that double flagged trails do help to conserve Lechuguilla's fragile, irreplaceable resources.

Laying flagging tape for trails takes a bit of skill development. There tends to be more to the process than expected. It is good to define techniques before entering the cave, then work in small groups and designate an experienced flagging person to direct the process for each team.

Flagging should be "tied down" to prevent inadvertent movement of the tape. Long lengths of surveyors tape is used—convenient stretches vary for different types of trail. Each end of the flagging is secured to a rock or natural protrusion. Pretty or unusual speleothems are avoided. Flagging is laid in the trail, not on the fragile edges, not on pretties, and not on pristine speleothems. Rocks and protrusions are used as necessary with a wrap and twist of the flagging.

Trails for heavy traffic are laid with about an 18-inch width for walking. This distance allows for easy foot placement when carrying weighty packs—however, narrowed trails often help avoid formations on the floor or encourage slow and deliberate movement through decorated areas. When a stalagmite is obviously used as a handhold, part of it can be included inside the flagged trail. Anything inside the flagging eventually is discolored, trampled, or flattened. Remember that trails tend to expand out to and sometimes beyond the flagging.

Crawl-ways are given two to four feet of trail width, depending on how low the ceiling is and how widely cavers will need to spread hands and knees to avoid scraping the ceiling with packs.

On climbs, the flagged trail should be wide enough to accommodate handholds and footholds for cavers with different climbing styles. Cavers move through passages with varying levels of skill and footwork. It helps to try out the trails laid on slopes and climbs, going both up and down before deciding where to place flagging. The goal is to keep hands and feet inside of the flagged routes.

On steep slopes where travel tends to create erosion, zigzagging the path and making switchbacks helps preserve the trail and sets the stage for easier travel as the trail becomes worn. On unavoidable steep slopes, safety requires that we remove and set aside any loose rocks that may slide.

In Lechuguilla, a system of colored flagging is used to designate specific purposes. Orange flagging tape is used to define most trails. Red and white striped tape is used to bring attention to delicate or special interest areas. Red and white tape (with white backing) is also used to define trails across flowstone because the orange tape tends to fade onto wet surfaces. Blue and white stripes indicate leads—notes can be written on flagging with indelible markers. Solid blue tape is used at survey stations. A pink and black striped flagging has been used throughout Lechuguilla to encircle bat bones.

In some caves, it may be important to wear surgical gloves when flagging trails. Bare hands or caving gloves may introduce nutrients down lengths of trail that define pristine or untouched areas of a cave. Another consideration is the flagging tape itself. Some flagging tapes are rich in carbon. Some tapes are manufactured to be biodegradable. Some tapes will be eaten by crickets and other critters, perhaps harming invertebrate populations (Jerry Trout, personal communication 1995). Some flagging materials will degrade in ultraviolet light. Other flagging varieties are designated as non-biodegradable. What are the implications for cave applications? We should not assume plastics are inert to cave bacteria. Because some bacteria live on hydrocarbons, more research is needed to better define trail-marking materials for caves.

Stray footsteps and trails leading to nowhere are being carefully fluffed. To avoid disturbing any surrounding pristine surfaces, each footstep is gently lifted, fluffed, combed, or erased. Only the impacted areas are touched during restoration. Small plastic or nylon bristled whiskbrooms work well (Hildreth-Werker and Werker 1997). For some powdery surfaces, gentle air puffs from a turkey baster will restore footprints (Vivian Loftin, personal communication 1998). Occasionally, a fresh plastic spoon is used in unusually delicate areas.

Small laminated paper signs have been used along the trails of Lechuguilla for several years. The Park Service has decided to place simple, easy-to-read, laminated signs throughout the cave. Examples of signage include: *stay inside flagged trails*; *brush off helmet and clothes before entering this area; boots off here*; *flowstone shoes only*.

TOOLS FOR RESTORING CAVES

On white gypsum surfaces, stainless steel brushes or stiff nylon tile grout brushes are carefully used with light sweeping motions to peel off layers of grime. A heavy hand will produce unsightly grooves, so special care and a light touch are both pertinent. Stainless steel bristles are necessary to avoid introducing rust and organic materials. Stray bristles that come loose are carried out of the cave. Gypsum debris is caught in plastic bags to avoid contaminating pools or speleothems.

Campsites are gently combed or fluffed with nylon or plastic bristled whisk brooms before exiting the cave. Care is taken to not stir up dust. By lightly brushing the surfaces of the impacted campsite, buried debris and trash is found and carried out. This helps reduce the spreading of campsite edges into pristine surfaces.

Restoration tools that have served the light and packable requirements of expedition caving are listed: collapsible or folding buckets with handles; industrial sprayers that come with plastic screens on the end of the sprayer tube, cut off to screw into skinny lightweight plastic water bottles; blue tight-celled car washing sponges designed to stay soft and absorbent (blue pieces are easier to pick up when the sponge begins to deteriorate and they have to be replaced for each trip); hand-sized upholstery brushes found in auto supplies; fresh toothbrushes; whisk brooms with plastic or nylon bristles; powder-free, non-latex surgical gloves; flagging tape for trails and for special areas; variety of syringes, tweezers, and hard plastic picks; fresh turkey basters; and plastic zip-closure freezer bags, especially the two- gallon size.

REDUCING CAVER IMPACTS

Simple actions can reduce human impact. We consciously work at keeping hands off the walls, ceilings, and handy leaning places. Obviously, a handhold is often needed for balance—so we try to use small points of contact, knuckles, fingertips, etc., rather than big muddy palm prints. Lots of convenient protrusions and features are along cave trails, but we do not use them as rest stations. We sit within the trails. Why continue to destroy something outside the trail just because somebody sat there first? The old caver ethic of placing our feet in someone else's footsteps has propagated unnecessary impact.

When we see a set of footprints across a cave floor, we try to remove, fluff, comb, or erase the evidence. If we are going to do more damage by trying to restore a footstep, we leave it alone, perhaps place a sign, and hope people will learn that one footprint should not invite more.

Cave softly—and leave no trace. Move gently. Spot each other through delicate areas. Make it okay to remind each other when we forget and perform some old habit. Think about eliminating the need for restoration. Realize that different types of caves deserve different attitudes. Figure out what the caves in your area need, talk among yourselves, and make it okay to change caver behavior.

With respect for the fragile, non-renewable resources of Lechuguilla, we have worked with scientists, cavers, and the National Park Service in composing a set of guidelines for travel in Lechuguilla (Figure 2). Some points may seem obvious to the seasoned expedition caver, but cavers with varying levels of experience enter Lechuguilla. The caving code would not be appropriate for all expedition caves. However, the concepts may provide ideas for developing beneficial protocol in newly discovered caves around the globe.

In summary, we all participate in learning better ways to protect fragile cave resources. Microbial studies and restoration trips have contributed to evaluating behaviors and ethics that are necessary for protecting and conserving some types of caves. When developing guidelines for specific caves, or when doing restoration in any cave, it is extremely important to consult with the scientists and managing agencies. In choosing our actions, the cave comes first.

REFERENCES

Boston, P.J., Ivanov, M.V., and McKay, C.P. 1992. On the possibility of chemosynthetic ecosystems in subsurface habitats on Mars. *Icarus* 95:300-308.

Cunningham, K.I. 1991. Organic and inorganic composition of colored corrosion residues: Lechuguilla Cave: preliminary report. *NSS News* 49(8):252,254.

Cunningham, K.I., Northup, D.E., Pollastro R.M., Wright W.G., and LaRock, E.J. 1995. Bacteria, fungi and biokarst in Lechuguilla Cave, Carlsbad Caverns National Park, New Mexico. *Environmental Geology* 25:2-8.

Hildreth-Werker, V., and Werker, J.C. 1997. Lechuguilla Restoration: Techniques Learned in the Southwest. *NSS News* 55(4):107-113.

Lavoie, K.H. 1995. The Effects of Urine Deposition on Microbes in Cave Soils, Or: To Pee or Not To Pee.

In Dale L. Pate (ed) *1993 Proceedings of the National Cave Management Symposium, held in Carlsbad, NM*. pp 302-311.

Mallory, L., Spokas, L., and Northup D.E. 1995. Numerical Taxonomic comparison of Freshwater Microbial Communities in Lechuguilla Cave, Carlsbad Caverns National Park. *Abstracts of the General Meeting of the American Society for Microbiology* 95(0):442.

National Outdoor Leadership School, *Leave No Trace Outdoor Skills and Ethics* (Boulder, CO: LNT, 1998). Leave No Trace, Inc., PO Box 997, Boulder, CO 80306. Phone 1.800.332.4100 http://www.LNT.org

Northup, D.E., Beck, K.M., and Mallory, L.M. 1997. Human Impact on the Microbial Communities of Lechuguilla Cave: Is Protection Possible During Active Exploration?

Journal of Cave and Karst Studies 59(3):166.

Northup, D.E., Lavoie, K.H., and Mallory, L.M. 1997. Microbes in Caves. *NSS News* 55(5):111.

Northup, D.E., and Welbourn, W.C. 1995. Conservation of Invertebrates and Microoganisms in the Cave Environment. In Dale L. Pate (ed) *1993 Proceedings of the National Cave Management Symposium, held in Carlsbad, NM.* pp 292-301.

Northup, D.E., Carr, D.L., Crocker, M.T., Cunningham, K.I., Hawkins, L.K., Leonard, P., and Welbourn, W.C. Biological Investigations in Lechuguilla Cave. *NSS Bulletin* 56(2):54-63.

Microbes in Caves

Diana E. Northup[1], Kathy Lavoie[2], Larry Mallory[3]

MICROBES FOUND IN CAVES

In caves, we have microbes that are resident and microbes that are transient. Transient microbes ride into caves on air currents, in water flows, on insects, on bats, and through humans. Anything or anyone entering a cave may carry transient microbes. Resident microbes, on the other hand, occur as native inhabitants of a cave. Native microbes depend solely on the resources within the cave for survival, but transient microbes tend to thrive where abundant organic materials are available.

Microbes that live by using organic carbon are called chemoheterotrophs. Guano deposits, flowing water, and decaying wood provide organic rich matter for chemoheterotrophic microbes such as fungi. Most fungi found in caves fit this picture and are most likely transients. Bacteria can also be brought in caves as transients. However, current research shows that most native microbes in caves are bacteria.

Within a typical cave, any place with sufficient moisture might contain microbes. If there is a stream running into the cave, you might expect to find algae washed in from the surface, protozoa in the sediments at the bottom of the stream, and bacteria clinging to the surface of the water and air (bacteria like to hang out at interfaces where rock meets water and water meets air). The banks along a stream, with their deposits of sediment, would be home to fungal spores. These spores, the fungal equivalent of seeds, only grow when organic matter is encountered. Bacteria are abundant in deposits of soil or sediment, but most bacteria are dormant unless suitable food is present. Fungal spores and bacteria are found in the surface water film of limestone rock and calcite speleothems. These microbes may contribute to the formation and degradation of speleothems.

Two of the few places where you are likely to see colonies made up of billions and billions of bacterial cells is on limestone or lava tube surfaces. Those reflective white dots, clustered together in moist areas on cave ceilings and walls are actinomycete bacteria. Actinomycetes are responsible for the distinctive odor that caves and soils have, unlike musty basements whose odor is due to fungi. The air we breathe (you won't like this part!) contains millions of fungal spores and floating bacteria. Deep in caves, bacteria are found living in pools and dripwater. These bacteria are specialized to grow in very low nutrient, or oligotrophic, environments.

WHY MICROORGANISMS IN CAVES ARE IMPORTANT

Bacteria and fungi that make their home in caves are important for several reasons. Because of their long isolation from the surface and because of their existence in very low nutrient environments (we're not talking about the bat guano microbes here!), some cave microbes appear to have evolved to produce specialized chemical compounds, or toxins, with which to fend off neighboring microbes (their own version of assault rifles). These microbial chemical compounds may be useful to humans in the fight against disease or pollution. Preliminary results from Mallory's studies suggest that microbes demonstrating this sort of beneficial activity were collected from pristine sites that were rarely visited by humans.

Our knowledge of the microbial world in general is really quite limited and our knowledge of cave microbial diversity is even more limited. Thus, the potential exists to find novel microbes in caves. Investigation of such organisms may provide new details about the evolutionary relationships of bacteria and fungi.

The study of microbes in caves is also important in elucidating how speleothems are formed. There is good, although limited, evidence that microbes are involved in the formation of iron and manganese oxides, sulfur compounds, saltpeter deposits, and even calcium carbonate.

Finally, scientists are finding bacteria deep within rocks of the earth and in association with deep-sea hydrothermal vents. The deep subsurface environment is difficult to sample; thus, caves provide a more accessible avenue for studying these microbes.

HUMANS IMPACT MICROBES IN CAVES

The impact of humans on microbes in caves takes two forms. We import foreign (surface) microbes as we explore caves. Secondly, we bring additional organic matter into the cave in the form of skin, hair, food, lint, urine, and possibly even feces. You are shedding tens of thousands of skin fragments per minute! This additional organic matter does the most harm. Native cave microbes often live in very low nutrient environments and may not even be able to survive in richer environments. If we add too much organic matter, the cave habitat will cease to be a good place for native bacteria to live; and will become, instead, a good place for transient, surface microbes to thrive!

CONSERVING CAVE MICROBES

To decrease the number of foreign microbes you bring into the cave:

- Clean the mud and dirt from your boots, packs, cave clothes and vertical equipment before entering the cave.
- Wash your hair before going caving.
- Set up pitchers by drinking sources so that hands and water bottles are not dipped into the pools. Better yet, set up siphon tubes with nylon spigots, diminishing the need for cavers to stand near the water source.
- Give caves, especially very pristine ones, time to rest between human visits. Give the foreign microbes a chance to die out.

To limit the amount of human-associated organic matter entering the cave (particularly in caves without streams):

- Carry out all feces, spit, and vomit. Carry a gallon plastic bag, wet wipes, and plastic wrap with you at all times for emergencies (unexpected running from either end).
- Eat over a bag large enough to catch the crumbs.
- If you're camping in a cave, use established camps to limit the impact to a small specific area.
- Don't take a full bath or shower right before caving. Such cleanliness dries out skin and makes it flakier. A reasonable compromise is to shower the night before entering a cave.
- In very pristine areas, or areas with nutrient sources that might support interesting microbes (e.g., hydrogen sulfide or sulfur), limit the number of persons that can visit the area and the time spent in the area.
- While in the cave, limit head scratching and avoid hair combing.
- Cotton clothing is less desirable than synthetics. It creates more lint and its fibers are more readily consumed by microbes.

In conserving microorganisms and the habitat in which they exist, balance is needed. Exploration teams often inform scientists of habitat that might contain microbes of interest. If the care taken by explorers of Lechuguilla Cave can serve as a model for other exploration endeavors, we can preserve microbes that may tell us much about the world in which we live. In order to preserve the more easily impacted microbes, we may wish to establish a few microbial preserves in remote areas of pristine caves and in areas with unique habitats.

If you have comments on the draft pamphlet, please contact Diana Northup at the Biology Department, University of New Mexico, Albuquerque, NM 87131.

[1] Department of Biology, University of New Mexico, Albuquerque, NM 87131

[2] Department of Biology, University of Michigan-Flint, Flint, MI 48502-2186

[3] Biomes, 170 North Valley Road, Pelham, MA 01002-9766

MINIMUM IMPACT CODE OF ETHICS
LECHUGUILLA CAVE

Hildreth-Werker(1999) ***Comments will be appreciated*** *werks@worldnet.att.net*

The overall goal of Carlsbad Caverns National Park and the Cave Resource Office is to allow limited access to Lechuguilla Cave while minimizing all impacts to the cave. Every person entering the cave is responsible for his/her own actions and for the actions of team members. Expedition Leaders and Team Leaders have tremendous responsibility for the safety and ethics of their personnel and for impacts to the cave. If problems persist, the Leader must abort the trip and the team will leave the cave.

As we learn more about the cave environment, we are in a continuing process of evaluating and redefining caver ethics. The following statement of conduct for Lechuguilla comes from the experiences and thoughtful contributions of many cavers. Think safety, take care of yourself and your team. Move with stewardship, avoid biological as well as microbial impacts, and take care of the cave.

- **Packs, vertical gear, boots, aqua socks, gloves, clothing, etc., must be freshly washed to avoid transfer of microbes from other environments. Research is being conducted to determine whether boot soles and gloves should be treated with a disinfecting solution just prior to cave entry.**
- **No external frame packs.**
- **No carbide.**
- **Drink more water than usual. Watch for signs of dehydration.**
- **Demonstrate vertical proficiency before entering the cave.**
- **Avoid entering the cave if you know you are sick or injured.**
- **Avoid entering the cave if you are not well rested.**
- **Always travel through the cave with your team. Do not get separated.**
- **No Vibram™ boot soles. Use only non-marring/non-marking soles, light or dark colored.**
- **Wear gloves. Check your gloves for mud, dirt, and holes to avoid extra impact. Rather than grabbing handholds along the trail, use a gloved knuckle for balance where possible.**
- **Watch for *gloves off* signs. Pack in clean gloves for use in gloves off areas and in pristine areas. Powder-free, non-latex, surgical gloves are recommended.**
- **Carry clean flowstone shoes. Plastic covers for boots are also needed for some areas.**
- **Move carefully through the entire cave. Move slowly and gently through delicate areas. Move slowly enough to avoid kicking up dust.**
- **No smoking and no use of tobacco in the cave.**
- **No consumption of alcohol.**
- **No illegal drugs.**
- **Clip into all safety and traverse lines.**
- **Check ropes and rigging before clipping in, when possible.**
- **Stay on flagged trails. Do not impact the cave beyond well-established trails. Sit within the trails. Be careful not to set your pack outside the trail. Always look for and use the most impacted areas when stopping.**
- **Leave all scientific instruments alone. Avoid touching any instrument cases. Avoid going near flagging in microbe research areas. Remember, tens of thousands of skin fragments and debris fall from each of our bodies every minute!**
- **Avoid touching pools with skin, water bottles, etc.**
- **Get drinking water only with siphon tube spigots or pitchers provided at designated sites. Be double certain spigots are turned off completely. Avoid touching your water bottle with the pitcher or spigot. Handle only the pitcher or spigot handle and do not wear caving gloves.**
- **Assume all pools are off limits. Never take water from pools containing sensitive speleothems or designated for microbial research.**
- **Do not enter off-limits areas unless you have specific permission from the Cave Resource Office. Be certain you know which areas are off-limits resource protection zones.**
- **Know which special attention areas require clean clothes, shoes, and gear. Do not enter special attention**

areas wearing general caving attire. Take the extra effort to keep these areas pristine.

- **Be very conservative when water from the cave is used for restoration tasks. Filter water and reuse in same area. Be very careful not to contaminate the pools.**
- **Wear powder-free, non-latex, surgical gloves when working on restoration and consider using them when laying flagging tape for trails.**
- **Remove all solid wastes from the cave. Never leave burrito bags along the trail while traveling. Adequate wrapping will make travel more pleasant for everyone. Contain and carry vomit and spit out of the cave.**
- **Stay within the flagging tape at the bathroom sites.**
- **Deposit urine ONLY in designated sites near camps. Use urine filters as they become available. Carry out all other liquid waste. Carry out all urine when feasible.**
- **Camp and cook only in designated, approved camps. Bivouac only with prior permission from the Cave Resource Office.**
- **Use only alcohol or propane fuel.**
- **Prepare food and eat over a nylon ground sheet in camp. Sit down and eat over a disposable plastic bag (the two gallon size makes a comfy target) while traveling. Do not eat on the move. Carry out all crumbs and debris.**
- **Discard toothpaste in a plastic bag and carry it out.**
- **Do not comb or brush hair in the cave. Use a nylon swim cap, hair net, or bandanna to contain hair and catch sweat.**
- **Do not use aerosol spray of any kind.**
- **Use commercial towelettes for bathing. Never use water from the cave for bathing.**
- **Leave notes. Every day, each team is required to place a note near the stove. The note should state the day, date, all names, expected destinations, and estimated time of return to camp.**

National Cave Survey Data Collection Standards

Mike Yocum and Mike Wiles

Mike Yocum
Eastern Operations Manager
Cave Research Foundation
329 East Main Street
Frankfort, KY 40601

Mike Wiles
Cave Specialist
Jewel Cave National Monument
RR1, Box 60AA
Custer SD 57730

Abstract

A proposal for a minimal set of cave survey data collection standards has been developed by representatives from agencies and organizations that work in caves on federally-owned land. This proposal defines minimal standards for the collection of cave survey data on federally-owned lands, for the purpose of facilitating legitimate exchange of survey data. Because these standards are national in scope, the aim was to allow optimum flexibility in the specific methods employed to collect the data. Individual federal land managers retain the ability to develop site-specific standards that are more detailed than the minimal base set.

Why Establish A National Standard?

The initial motivation for proposing a national cave survey data collection standard was the desire to be pro-active. It was thought prudent to provide an opportunity for people experienced in the unique challenges and limitations of cave surveying to take the lead in developing criteria that could be used effectively in caves, rather than some day be compelled to follow standards devised for another purpose and subsequently misapplied to the collection of cave survey data.

The OSHA Confined Space Regulations are an example of such misapplication. Although designed to prevent or minimize occupational hazards in the artificially confined spaces of industry, they have been interpreted to apply to management and occupational visitation in the natural spaces of caves, where they are not only impractical to implement but simply inappropriate.

Governmental policies and standards developed in other areas may also give rise to interpretations that cannot be effectively implemented in caves. Survey data is one of those areas.

In 1990, the OMB issued Circular No. A-16, which described the responsibilities of Federal agencies with respect to "coordination of surveying, mapping and related spatial data activities" (Appendix A). It established an interagency coordinating committee, the Federal Geographic Data Committee (FGDC), chaired by the Department of the Interior. The FGDC was charged with promoting the coordinated development, use, sharing, and dissemination of surveying, mapping, and related spatial data.

In 1994, Executive Order 12096 (Appendix B) established the National Spatial Data Infrastructure (NSDI). The NSDI is an umbrella of policies, standards, and procedures under which organizations and technologies interact to foster more efficient use, management, and production of geospatial data. It is moderated by the FGDC.

Entering into partnerships with state, local and tribal governments, the private sector and other nonfederal organizations, the NSDI is developing the National Digital Geospatial Data Framework and the National Geospatial Data Clearinghouse, a widely distributed network of spatial data producers, managers, and users, all linked through the Internet. It has begun standardizing documentation of data and initiated standards development activities. Appendix C lists standards currently being developed under its auspices.

Because the standards developed under the FGDC/NSDI initiative are, where applicable, and to the extent permitted by law, mandatory for federal agencies, some of them will eventually influence the collection and use of spatial data collected in caves on federally owned lands.

One of them is already making itself felt in cave resource management. Executive Order 12096 mandated that all federal agencies document spatial data collected after January 1, 1995, using the FGDC's Content Standard for Digital Geospatial Metadata.

Metadata are data about data, data that describe what data are available, their content, quality, condition, and other characteristics. "The purpose of the standard is to provide a common set of terminology and definitions for documenting digital data. The main reason to document data is to maintain an organization's investment in its geospatial data. Organizations that do not document their data often find that, over time or because of personnel changes, they no longer know the content or quality of their data. Organizations then cannot trust the results generated from the data in which they have invested their time and resources."

Cave resource managers wrestled with metadata long before there was a standard for it. Often, because of a lack of metadata, problems are discovered only when trying to use the data. Some years ago, a CRF map of the Kentucky Avenue section of Mammoth Cave by Mick Sutton won the medal for best map at the NSS Cartographic Salon. It would be very useful to that park's resource management staff if they could integrate various levels of descriptive data for that part of the cave into a GIS application that includes the prizewinning map. Unfortunately, a recent examination of the digital data for that part of the cave revealed that it was in a format accessible only on a long defunct type of computer.

It would have saved time and wasted effort if CRF had a database showing the type, content and quality of our digital survey data. We do not. While not a happy realization, this does make us aware of work that we need to do in order to provide resource managers with useful information in a timely manner.

Mammoth Cave is not the only resource facing this problem. Regarding some of the early survey data from Wind cave, Jim Nepstad reports that in the early 1970's surveyors often corrected for declination on the Bruntons that they used. He says that,

"in itself [this] isn't necessarily a problem. But what if they didn't tell you in their notes whether they we doing that or not? What if they didn't tell you what declination they were correcting for? What if they didn't even include the survey date in their notes so you could determine what the declination was in the first place. For many miles of survey data, I resorted to GUESSING many of these things. Given the huge number of loops in Wind Cave, testing the guesses was difficult if not impossible. Very often no names were recorded either. My favorite example is the survey in Wind Cave which includes Half-Mile Hall, one of Wind Cave's more impressive passages. There are no names on the survey notes, and only the word "Tuesday" serves as the survey date." (2)

Obviously, complete and accurate metadata are essential for efficient resource management. A national standard not only provides the opportunity to evaluate data quality in an organized manner, but also makes it easier for resource managers around the nation to discuss common data quality problems and share possible solutions to those problems. The same would be true of a national standard for a minimum set of consistently collected survey data, and we now have an opportunity to develop it.

Although the initial motivation for establishing a standard was self-protective, preliminary discussions made it apparent that there exists a genuine need in cave resources management for basic completeness and consistency in the survey data that are collected.

The last decade has seen increasing emphasis on the conservation, protection and management of cave resources. The number of Cave Resources Specialists dedicated to this task in federal agencies is growing, and there is now an office of National Cave Management Coordinator. As the importance of cave management gains national recognition, there will be an increasing need for studies and reports on a national scale, with a corresponding need for basic data that consistently meets certain minimum criteria at that scale.

Usefulness for resource management is a relatively new framework for planning and evaluating activity in caves. In the past, survey data was collected primarily by cavers who were exploring. They wanted to know where the cave went and, sometimes, its relationship to surface topography. The survey data collected, and the maps created, for this purpose did not have management needs in mind. As a result, resurveying efforts are underway in a number of caves on federal lands, including some of the major cave systems in this country.

A fundamental tool for all cave management is an accurate map of the cave. Without it, there can be little practical knowledge a cave or the disposition of its resources. Resources managers also need consistent and complete survey data for scientific studies and for the GIS applications that are becoming increasingly useful management tools.

Scientific studies cannot be conducted without standard terms and units. Standardization allows scientists to access and utilize data collected from many different sources, and discover facts that may not be apparent or verifiable by examining data from only a single source. If a basic set of survey data from caves in all federally owned lands were available, that could usher in a new era in speleology as well as resource management and protection.

In recent years the introduction of GIS techniques as management tools has highlighted the need to integrate digital survey data with digital resource data. If the data isn't consistent, complete and accurate, the resulting GIS information will reflect that deficit.

Most cave survey on federal lands is done by volunteers with a wide variety of styles. Even with the best intentions, they have repeatedly produced data that is not adequate for resource management needs. It may be inconsistent, incomplete or inaccurate. One reason for a minimum standard is simply quality control when working with volunteers. Appendix D shows some examples of both adequate and inadequate work.

These volunteers often have interests in caves on lands managed by other agencies. Another reason for a national standard is to make it easier for cavers who do work in different caves with different - conflicting or non-existent - standards. From the caver's viewpoint, who wants to spend hundreds of hours on a survey project, only to find that it has to be surveyed again? It would be advantageous if all volunteers nation-wide were exposed to at least a minimal national standard.

To a limited extent this is already beginning to happen. Before exploration and survey work in Lechuguilla, standards for cave surveying varied a great deal across the country. When survey work in Lechuguilla was in progress, a survey standard was initiated for all cavers who wanted to participate. Today, many of these same cavers participate in survey work in Carlsbad Cavern, using a very similar survey standard. The same standards are in use at Lilburn Cave too. This year, a number of cavers who have worked in Carlsbad, Lechuguilla and Lilburn, will be doing volunteer work in Volcano National Park, Hawaii, using that same standard. Cavers volunteering for the Prince of Wales Island Project in Alaska, conducted in cooperation with the National Forest Service there, use a very similar standard. (3)

A final, and perhaps most compelling, reason for a standard is that caves are nonrenewable resources. Any activities that may negatively impact them, including surveying, should be kept to a necessary minimum. If agreed upon basic data were collected in a consistent manner, that would reduce the need for resurveying.

In summary, there are several reasons for the establishment of a national cave survey data collection standard by those actively involved in managing and surveying caves on federal lands. It would help ensure that the standard is practical and can actually be implemented. It would enhance and contribute to cave resource management on a national scale. It would contribute to the store of nationally consistent and reliable data for the scientific study of caves and karst. It would facilitate the use of volunteers having a wide variety of surveying styles and methods. It would reduce the impact on cave resources caused by resurveying.

While each cave resource manager has data needs that are unique, they all share a certain need too. That is to have a basic set of survey data that is consistent and complete, and to be able to collect that data as efficiently as possible, with minimum impact on the cave.

There is certainly no need for all of us to do everything the same way, but it may benefit both our work and caves if all of us do a few things the same way.

CAVE SURVEY DATA COLLECTION STANDARD PROPOSED MINIMAL CONTENT

The following table, proposing a minimal content set for cave survey data along with collection methods or procedures, was compiled by discussing recurrent data problems, creating the list of items, and submitting it for email discussion among approximately 30 cave surveyors representing the National Park Service, the Bureau of Land Management, the National Forest Service, the National Speleological Society and the Cave Research Foundation.

It should be emphasized that this is a preliminary proposal for discussion, review and modification. It should also be stressed that it represents a recommendation for a MINIMUM standard. Any cave surveyor or cave resource manager could easily exceed this minimum to meet site-specific needs.

Minimal Content	Collection Methods/Procedures
1. Cave name	None.
2. Date	Full - mm/dd/yyyy.
3. Personnel	First and last name; list all personnel.
4. Duties	List what each person did.
5. Tie-in station	Tie-in must be to unambiguous and valid station.
6. Specify units of measurement of distance, direction and elevation change	None.
7. Instruments used to measure distance, direction and elevation change	Indicate manufacturer, type and model. All instruments are undamaged and fully functional
8. Identification number of instruments used	Unique identifier, such as serial number or property number.
9. Name of instrument owner	First and last name.
10. Instrument test results	None.
11. Station markers	Specify marks and markers employed.
12. Azimuths and inclinations	All measurements are uncorrected.
13. Each shot is defined by a unique combination of “From” and “To” stations	None.
14. Station designation	Standard ASCII 1-127 character set (printable characters).
15. Distance	Decimal feet and tenths; or meters and centimeters.
16. Direction	Degrees and tenths on a 360 degree scale.
17. Vertical angle	Measured vertical angle or elevation change.
18. Passage dimensions (LRUD)Data is estimated at “From” station,	perpendicular to direction of the shot, in decimal feet and tenths, or meters and centimeters.
19. North (magnetic) arrow on each page	Labeled as Magnetic
20. Labeled Scale on each page	Bar scale.
21. Survey point/station	Station symbols are placed at correct distance and direction relative to selected scale.
22. Station label in book for each station	None.
23. Passage outlines in plan view	Drawn to correct scale and orientation.
24. Graphic representation conforming to site.	Standards are defined locally, based upon site-specific management needs. Any non-standard symbols used are defined in legend

Acknowledgments

This project was performed in partial fulfillment of Cooperative Agreement 1434-HQ-96-AG-01580 between the U. S. Geological Survey and the Cave Research Foundation. We are grateful to the Foundation for its support in this effort. The project would not have gone far without the comments, suggestions and recommendations of those who responded in the e-mail discussion group and/or reviewed this paper: Chuck Bitting, Peter Basted, Bob Buecher, Paul Burger, Joel Despain, Scott House, Bob Osburn and Fred Wefer. Special thanks are due to Pat Kambesis and Mick Sutton for all of the above, plus contributions of survey notes, old and new. We are indebted to Ron Kerbo, National Cave Resource Coordinator, National Park Service, who facilitated a very productive work session on the project. The greatest thanks go to Jim Nepstad, Cave Specialist at Wind Cave, for his unstinting willingness to share insights, experience and materials.

References

1. The Mitre Corporation, “Statement of Work, Development of Metadata Tools for the National Geospatial Data Clearinghouse.” No date.

2. Nepstad, Jim. Personal communication. September 16, 1997.

3. Kambesis, Pat. Personal communication. September 23, 1997.

Project Underground - Poster Presentation

Margot Geisler and Carol Zokaites

Abstract

Project Underground is an environmental education program designed to build awareness of, and foster responsible attitudes toward, karst resources and their management needs. The Project's aim is to educate the young public about the value of conserving these valuable karst resources. Project Underground is designed for kindergarten through high school age students. The program consists of a curriculum guide and teacher training workshops. Activities in the curriculum guide consist of student games, projects, and discussions for classroom use. The people who participate in these activities will gain an understanding of how the underground environment is an integral and important part of the total environment. These students and teachers will learn that cave and karst resources are very fragile and that we should respect, conserve, and protect these resources. Project Underground is based on a Training the Teacher model. Interested educators are trained to be certified facilitators, who then lead Project Underground workshops, helping more educators to gain a better understanding of Project Underground and its karst awareness program. The Project Underground materials are available through attendance through these workshops. The workshops and materials are a source of interdisciplinary instructional activities and provide in-service programs for classroom teachers, cavern, park, museum, nature center staff, and youth oriented group leaders.

Oil And Gas Drilling in Cave and Karst Areas: A Process of Mitigating Impacts

James R. Goodbar
Bureau of Land Management
Carlsbad, New Mexico

Abstract

Karst lands pose a unique set of problems for the oil and gas industry and for the cave and karst environments. Land management agencies have been working together with the industry to develop acceptable practices for drilling casing and cementing in lost circulation zones and operation in karst lands. Their mutual goal is to minimize the potential of encountering those problems and reduce the impacts of oil and gas drilling on caves and karst lands. This paper discusses the Bureau of Land Management's basic approach and procedures to achieve this goal.

[Note: This paper was not presented at the symposium, but was submitted in place of another paper that had been withdrawn, and is included here for completeness.]

The Background

The United States Bureau of Land Management (BLM) is a part of the United States Department of the Interior. The BLM is an agency entrusted with the management of more than 270 million acres of the nation's public lands. Management is based on the principle of multiple use and sustained yield of our nation's resources within a framework of environmental responsibility and scientific technology. BLM recognizes that it must manage for future generations as well as for present needs. It's mission is to find a balance between developing public land resources and protecting natural resources. In southeast New Mexico, the Carlsbad Field Office must balance developing oil and gas resources with the protection of cave and karst lands and the water resources associated with them.

The risks to industry can include excessive loss of drilling fluids, loss of tools and equipment downhole, down-time while fishing for tools, and expense for extensive cementing programs. In extreme instances the loss of drilling rigs and equipment due to the collapse of shallow cave passages add risks to public health and safety.

The potential hazards to cave/karst resources result from contaminants that may enter into the cave/karst systems. These contaminants include such things as lost drilling fluids (which sometimes contain chemicals) and cements, and hydrocarbons from spills or leaks from well casings, storage tanks, mud pits, pipelines, and production facilities.

This contamination could result in pollution of groundwater and aquatic and atmospheric habitats of caves, causing a die-off of cave life. Additionally, cementing operations could affect portions of underground drainage systems by restricting groundwater flow and introducing pollutants into karst systems. This could alter the quality and quantity of water reaching springs and resurgences.

Other possible impacts are vented or escaped gases, such as natural gas or hydrogen sulfide, collecting in sinkholes and caves. These gases can cause a die-off of plant and animal life that use the special habitat created by the microclimate of the cave entrances or sinkhole. In the extreme, buildup of these gases has the potential to cause underground explosions and/or asphyxiation of plant, animal, and possibly human life.

During the development of the Carlsbad Office Resource Management Plan (RMP), an agency/industry work group was convened to address the problems and possible solutions of oil and gas drilling in cave and karst areas. The results of this work group were:

(1) Recognition of mutual goals to isolate cave environments from the affects of oil and gas operations

(2) Development of criteria to initiate

protection measures

(3) Development of specific mitigative measures that may be applied.

The Carlsbad RMP and Lease Notice

The Carlsbad RMP was approved in 1988 with a decision that protection requirements for caves would be applied on a case-by-case basis at the Application for Permit to Drill (APD) stage instead of blanket stipulations. Additionally, mitigations and procedures for cave protection during oil and gas drilling operations would be developed by a joint BLM/Industry Task Force, and would be implemented where determined feasible.

After the approval of the Carlsbad RMP, a Cave/Karst Lease Notice and map was issued for all leases in potential cave or karst occurrence areas. The purpose of the notice was to inform potential lessees that the BLM may implement cave protection measures by requiring conditions of approval on APDs. The lease notice informed lessees that due to the sensitive nature of cave and karst systems, special measures may be required to protect them. Those measures could include:

(1) a change in drilling operations,

(2) special casing and cementing programs, or

(3) modifications in surface activities.

The Task Force

The BML/Industry Cave and Karst Task Force was reconvened in early 1991. The Task Force was composed of members from the oil and gas industry, government agencies, academia, and the private sector. Its purpose was to develop the more technical aspects of drilling, casing, cementing, and production operations in cave and karst areas. The main emphasis of the Task Force was to provide recommendations in the development of the Dark Canyon Environmental Impact Statement (EIS) resulting from interest in drilling wells near Lechuguilla Cave.

The Task Force was responsible for developing field procedures to resolve concerns over drilling these wells. A second goal was to address the concerns of drilling in cave and karst areas throughout the region, specifically in the cave-bearing limestone and gypsum karst areas. Members of the Task Force were asked to represent their particular interest by providing technical information, while working to reach agreement and resolution of the concerns addressed by the Task Force.

Task Force Findings

The Task Force came to early consensus that a procedure was needed for dealing with drilling proposals which was applicable in all situations. A three step process was developed:

(1) Detection of Cave or Karst Features,

(2) Avoidance of those Features,

(3) Mitigation of Impacts to Cave or Karst Resources that can not be Avoided.

Detection indicates where possible avoidance measures might be needed and would make avoidance measures more effective. Detection and avoidance measures combine to reduce the chances of needing mitigation measures. However, noting is certain until the well is actually drilled.

Detection - The Task Force's Geologic Subcommittee identified basic methods of detecting subsurface voids. These methods ranged from very simple methods such as field examinations to very sophisticated geophysical methods. These methods were evaluated to determine reasonableness and cost effectiveness. Some of the methods identified were:

(1) Field examinations and cave exploration,

(2) Aerial photographs (both color and black and white),

(3) Lineament surveys,

(4) Natural potential surveys,

(5) Electro- telluric survey,

(6) High resolution seismic survey.

Avoidance - Avoidance of cave and karst features can be accomplished in two basic ways. The first is a long range approach involving BLM's planning system. Areas identified as having significant cave or karst resources can be established as "no drilling areas" through the planning process. Drilling restrictions for these areas could include no surface occupancy stipulations and no leasing.

A second method of avoidance in areas that are already leased is relocating a proposed drilling location or right-of-way to reduce the possibility of conflict with caves or karst features. The decision to move a location, with certain constraints, can be a condition of approval of an APD. This method of avoidance would be used in conjunction with site-specific detection methods, such as field examinations or lineament surveys.

Another method of avoidance may be directional drilling. Lateral moves of the original surface location greater than 100 meters may require the operator to drill a directional well in order to hit the original downhole target. The directional portion of the well is typically below any cave or karst resource.

Mitigation - There may be instances when the drilling would be in conflict with cave or karst management, even after detection and avoidance measures have been conducted. The third step in the process is mitigating the impacts to caves/karst resources that can not be avoided.

Immediate downhole impacts would first occur during the drilling process. After completion of a well, another series of impacts could potentially occur as a result of casing deterioration. These are potentially long term impacts related to the escape of hydrocarbons from the drill hole into surrounding rock formations. In porous rock the hydrocarbons could migrate, contaminating groundwater and/or the water quality in the caves. This could impact the growth of speleothems, cave microclimates, and cave biota. In a worst-case situation, human life could be endangered by gaseous hydrocarbons escaping from a well into the cave environment.

The Task Force drilling and casing subcommittee addressed impacts of drilling, casing, cementing, and the impacts of casing failure. They developed procedures which best isolated the drilling, casing, and cementing operations from cave environments. These procedures were developed for use in limestone areas near Lechuguilla Cave and were not specifically considered for use in gypsum karst areas. The recommendations of the Task Force formed the basis for drilling conditions of approval and mitigations developed in the Dark Canyon EIS. Following their submission of recommendations, the Task Force was disbanded.

The Drilling Guide, and Resource Management Plan Amendment

Based on the recommendations of the Task Force, an Interim Guide for Oil and Gas Drilling and Operations in Cave and Karst Areas was developed. Its intent was to assist the oil and gas industry in protecting sensitive cave/karst resources including karst ground water recharge areas, cave biota, recreational, and scientific uses while enjoying the development of their lease. It was meant to fully define and help resolve the potential conflicts associated with oil and gas drilling and production operations in cave/karst areas. The associated problems can have adverse effects on both industry and cave/karst resources. The guide established a set of procedures for the detection and avoidance of cave /karst features, and the mitigation of drilling and production activities in the event that karst features are encountered. The following is taken from the Guide:

Surface Mitigations

To minimize potential problems due to reserve pit spills or leakage, the BLM may require the following actions:

(1) Use of closed systems or steel tanks,

(2) Use of modified “V” pits, constructed in cut material with extra heavy pit liners that are not broken during reclamation,

(3) Relocation of pits,

(4) Berms around the pits sufficient to contain any spills.

To minimize the potential problems due to leaking tanks or pipelines, the BLM may require:

(1) Berming around storage tanks sufficient to contain spills

(2) Leak detection systems for pipelines,

(3) Permanent liners in storage tank areas,

(4) Differential pressure shut-off valves,

(5) Corrosion-inhibiting coatings and cathodic protection.

To minimize the potential problem of vented or escaping gases the BLM may require:

(1) The use of stock tank vapor recovery systems.

(2) Flaring, rather than venting of gas, to better disperse the gases and eliminate possible gas ignitions.

Subsurface Mitigation

Mitigative measures to be implemented while drilling in high potential cave zones and lost circulation zones encompass every aspect of the drilling and completion process. These include drilling methods, casing setting depths, drilling fluids and additives and cementing programs. Every effort should be made to use applicable mitigative measures in determining the most feasible technologies available for safely drilling and completing oil and/or gas wells in cave and karst areas.

Rotary Drilling Techniques

Rotary drilling techniques should employ the use of either fresh water mud or compressed air as a circulating medium. Fresh water is more commonly used due to its affordability and availability.

Compressed air is less frequently used because of its increased equipment cost and the relative unavailable equipment in some areas. Both water and air can transport cuttings to the surface, or can indicate lost circulation in varying degrees of severity when some of the cuttings do not make it back to the surface.

When drilling with fresh water, non-toxic additives such as bentonite (gel), cellophane flakes or other non-toxic non-organic constituents can be introduced into the system to combat lost circulation zones. Viscous pills, (also known as “sweeps”), which are typically composed of the same non-toxic non-organic materials as those listed above may need to be pumped down hole to build a bridge across severe lost circulation zone(s). Sweeps may also be pumped prior to running casing to condition the borehole for cementing operations.

Fresh water resources which are often found in caves will not be contaminated by fresh water mud or compressed air. Brine water- based drilling mud should not be used since it has a higher density than fresh water. This could exacerbate lost circulation problems. The saline mud would also pollute fresh water zones.

When drilling with fresh water mud, the operator should consider using larger than normal size jet nozzles in the drilling bit. This reduces the hydrodynamic force exerted by the mud on the relatively fragile rock formations or strata. In the event that a major void is encountered while drilling, a downhole camera may be used to determine the significance of the void.

Casing selection and cementing practices are two of the most fundamental elements in the drilling and completion of a well. If successful, the well will produce trouble-free for several years and be simple to plug and abandon at the end of its productive life. The casing and cement must also maintain their integrity for several decades after the well has been plugged and abandoned to continue protecting cave resources.

All casing should meet the highest standards. The cave protection string should be set at least one hundred feet below the last known cave bearing stratum as limited by the uppermost hydrocarbon bearing zone. This will give the cave zone an extra measure of protection by providing a positive cement- to-casing and cement-to-borehole bond around the shoe of the casing.

Casing and cementing programs

Casing and cementing programs for the surface and intermediate portions of a directionally drilled well are similar to casing and cementing programs in a vertical well.

The casing should be cemented in place using the following method:

If a large void or severe lost circulation zone is encountered, isolation from above and below, rather than complete cement coverage of these zones, could be employed. This can be accomplished by using stage cementing equipment, external casing packers, cement baskets, and one-inch remedial cementing techniques.

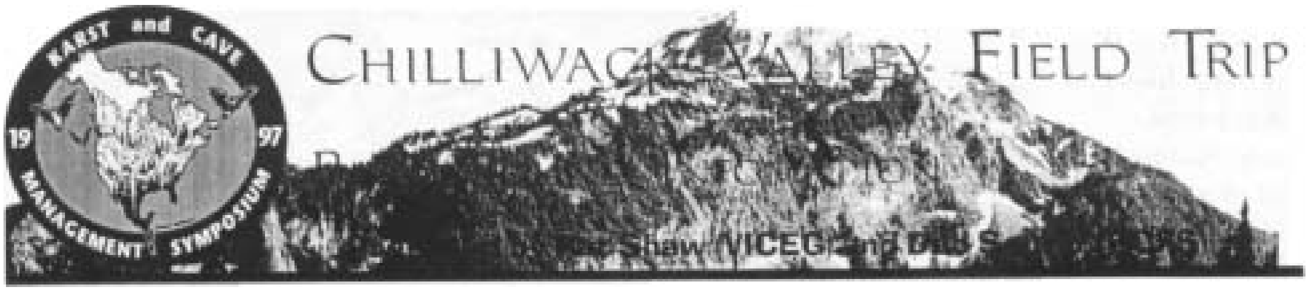
This procedure is as follows: Tie back the cement as high as possible on the primary cement job, at least to the bottom of the deepest known lost circulation zone. Strategically position flexible cement retaining devices (i.e. cement baskets) or an external casing packer/stage cementing tool arrangement immediately above the top(s) of the lost circulation zone(s). A cement evaluation tool such as a temperature survey or bond log is required to evaluate the primary cement job and to identify the gaps in the primary cement job prior to proceeding with remedial cementing techniques. Remedial cementing operations would involve running one-inch pipe with a “muleshoe” joint on the end into the annular space between the casing and the borehole. The one-inch pipe can puncture the canvas component of upper cementing basket(s) and penetrate to a depth where other cement basket(s) have been positioned. A cement slurry can then be pumped down the one-inch pipe in consecutive stages above each cementing basket at depth. If a multiple- stage cement job is chosen, the external casing packer could be actuated to provide a bridge, and the pumping of the second stage could then commence.

This technique could provide isolation of the lost circulation zone(s), but would leave substantial “gaps” in cement coverage across the zone(s). For this reason, the next casing string to be run below the cave occurrence zone should be cemented to allow the top of the cement to be tied back above all gap zones. This provides additional protection against potential fluid migration from any brine or hydrocarbon bearing formations below. (See Illustration 1)

Illustration 1 : Casing and cementing in lost circulation zones (not included here).

Chilliwack Valley Field Trip Guide

Compiled and edited by Pat Shaw



Karst areas in the Chilliwack River Valley, while far less extensive than other regions in British Columbia such as areas in the northern Rockies or Vancouver Island, have some significant and pressing management issues. A burgeoning population in the southwest BC seeking novel (and not so novel) outdoor activities will continue place increasing pressure on the limited cave resource, as has been the case with other recreational opportunities in the watershed.

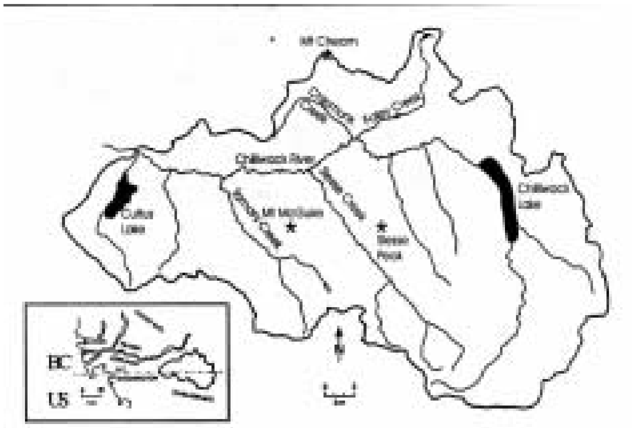
This tour will introduce participants to cave/karst issues in the Chilliwack Valley region and will present the current activities related to both conservation and preservation of the resource.

Physiographic Setting

The entire Chilliwack Valley encompasses an area of about 1230 km^2, and lays a hair's breadth north of the Canada-US Border. The Chilliwack River itself arises in Washington State, and flows about 50 km to the mouth of the valley. Most of the terrain is steep and, where not affected by timber harvesting, is heavily forested with a mixed fir and hemlock cover. Spectacular peaks rising to nearly 2500m surround the valley, some of holding permanent glaciers.

The dominant ecotype in the valley is the Coastal Western Hemlock zone (CWH), which occurs at low to middle elevations mostly west of the coastal mountains along the British Columbia coast and on into both Alaska and Washington/Oregon. The CWH is, on average, the rainiest biogeoclimatic zone in B.C. Western hemlock is usually the most common species in the forest cover. It regenerates freely under the canopy of mature stands in many sites. Douglas-fir is abundant in drier parts of the zone. Other common species are western red cedar on damp sites, ferns, and mosses. The Fraser Lowland portion of this zone, and almost all of the coastal, colony-nesting bird habitats are found in the CWH. The CWH is the most productive forest region in Canada.

Subalpine karst on the flanks of Mr. McGuire. Photo by Dick Garnick.



CHILLIWACK RIVER BASIN - GENERAL GEOGRAPHIC FEATURES

Geologic Setting

The Pacific Coast of Canada is an active subduction region, where various small tectonic plates are being thrust beneath the North American continental plate. Over the millennia, plates carrying various geologic terranes have "collided" in this region, and resulted not only in the active and massive deformation of the resident geology, but also in the accretion of the transported geology. Much of present Vancouver Island, for example, arose in the southern hemisphere and was carried north as part of the "Wrangellia" terrain. Chris Yorath, of the Geological Survey of Canada presented a very readable account of the development of plate tectonic theory, with particular emphasis on the Canadian Pacific Coast in his book "*Where Terranes Collide*".

Mississippian limestone exposure on the upper benches of Mt. McGuire. Photo by Pat Shaw.

Geologic formations in the Chilliwack River Valley are part of the Chilliwack and Harrison terranes, which are thought to have "docked" into British Columbia in the Triassic, about 150-75 m.y.b.p. Unfortunately for cavers, carbonates comprised only a minor component of the terrane, especially compared to the Wrangellia facies present on Vancouver Island! The very active subsequent tectonic history of the region has produced extensive re-organization and rearrangement—circumstances not necessarily favouring development of extensive cave systems.

Portions of the Chilliwack Formation dominate the bedrock geology of the basin (Monger 1970). Contained in the formation are two distinct limestone units, a Lower Pennsylvanian component roughly 30m thick and a Lower Permian component 60-90m thick. In places, the Lower Permian unit is rarely up to 600m thick. The Lower Pennsylvanian limestone is medium to dark-grey, argillaceous with characteristic crinoids as much as 2 ½ cm in diameter. The Permian limestone is light-grey, massive and commonly contains large chert nodules—the stunning cliffs of Mount McGuire are the most evident exposure of this unit.

Human Activities in the Chilliwack Valley

The Chihlkwayuhk people lived here about 9000 years ago. The entire Chilliwack River Valley "was criss-crossed with Indian trails" (Wilson, 1858) They lead to hunting grounds and camps, berry patches, quarry areas and other traditional resource areas utilized by the Chilliwack tribe. There has been increasing interest by archeologists and research has recovered several artifacts. There are many areas of spiritual and economic importance to the Sto:lo people of the present day.

The 1858 gold rush stimulated construction of the Whatcom Trail. Goldseekers entering the area from the United States were supposed to travel to Victoria to register. But overland access from Nooksack, Washington avoided these inconveniences. After the gold rush, settlers returned to the Chilliwack Valley to farm.

Immediately beyond the valley boundaries, the local hydrology has been anything but static. In historic times, the Chilliwack River flowed north to the Fraser River through what is now Sardis. After an extensive flood in 1894, the river changed its course to travel west to what was, at the time, Sumas Lake via what was then Vedder

Creek. Sumas Lake was drained for agriculture in 1926, in part by deepening the creek into the Vedder Canal.

Logging began in the 1920's by Campbell River Timber. By the 1940's there was logging in the side-drainages of the Chilliwack River. Roads were built to gain access to timber and their histories parallel the logging histories. Over time, these roads have also allowed access by land developers, and recreation users.

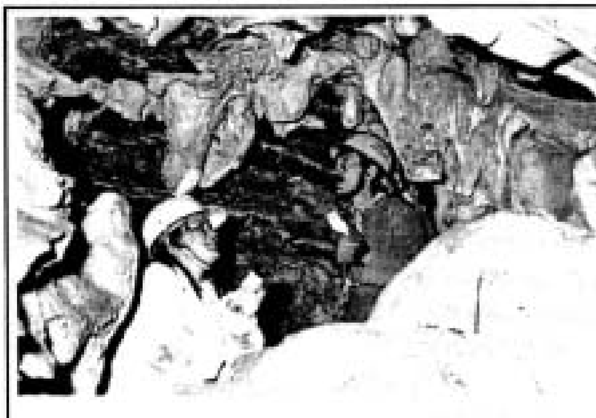
The Chilliwack Valley is Vancouver's playground. The hillsides and rivers within the valley support a range of activities as diverse as hiking/walking, white-water kayaking (notice the whitewater gates above the Chilliwack River upstream of the main bridge-crossing), river rafting, steel-head trout fishing, climbing (the NW ridge of Mt. Slesse, has been listed among the world's 50 Classic climbs), hang gliding and paraponting. The British Columbia Forest Service actively manages fourteen recreation sites and seven trails. In addition, there are numerous unmanaged trails and dispersed camping spots. In 1993, over 41,000 people visited the managed Chilliwack Valley recreation sites. A recent measurement with a trail counter revealed 1279 visitors to Mt. Cheam Trail over a single weekend. There were more than 200 visitors during one day of the 1997? Labour Day Weekend.

There are three correctional facilities operating at the eastern end of the valley, employing a total of 140 staff for 170 inmates. Mount Thurston is a forty acre, adult, minimum security facility. Inmates mill lumber and do silviculture work such as pruning. Ford Mountain is minimum security facility for 55 prisoners who routinely provide all the maintenance service for the Forest Service Recreation Sites. Centre Creek is a minimum security facility for 30 male youth with an emphasis on drug and alcohol counseling.

Cave Exploration History

Active exploration in the Chilliwack Valley by organized caving groups began in the mid-1960s. Clarence Hronek, one of the early pioneers of cave exploration and study on Vancouver Island, relocated to Vancouver and formed a group known as "**B.C. Speleo-Research**". The attention detail and obsessive documentation by this group lead to a valuable legacy of their explorations in the valley. Clarence along with regular participants Gerrit Van der Laan and Dennis Gelean concentrated efforts in the low-elevation areas of the watershed. Their work led to full exploration of the Chipmunk Caves (Symposium Stop 2) and the early digging efforts in the Well's Sink area (Symposium Stop 1).

Other caves were discovered through the 1970s - most on the north side of the Chilliwack River. Caves such as Stalo (*sic* Sto:Lo) *Cave*, *Root Cave* and *Eye Opener* were explored by both BC SpeleoResearch and members of the Vancouver Island Cave Exploration Group stranded in Vancouver.



Inside Chipmunk Cave #1, Circa 1977. Photo by Gerrit Vander Laan.

Again, an extended hiatus in exploration ensued. Members of the **Vancouver Caving Group**, a loose association of experienced cavers, and the **Cascade Grotto** from Seattle jointly re-discovered the area in the mid-1980s. A number of trips were launched from Vancouver, with particular effort being focussed on the upper benches of Mt. McGuire. Hiking was spectacular, and although some significant features were found (including a 25m phreatic shaft), caves were surprisingly absent. Cascade Grotto members, especially Dick Garnick, showed considerably more tenacity, and over the years have found a surprising number of caves.

Dick’s vigorous effort and enthusiasm has opened the area, and resulted in not only the discovery and exploration of many Chilliwack area caves, but the recognition of the resource by provincial government agencies.

The hazards of exploration in the valley come not only from the caves themselves, but also from caving technique. An accident report from the 1992 NSS American Caving Accidents documents the danger of mixing fire and caves in the Chilliwack Valley:

On Sunday, November 24 1991, a group of three (Washington)cavers visited a blowing hole near the junction of Sleese Creek and Chilliwack River in British Columbia, Canada. They were John Clardy, Tim Martin and Buff Martin. The cave was a 30 meter crawlway ending in a dig. The younger Martin brother worked at the entrance, disposing of rocks that the other two pushed out. At about 2 p.m. there was little to do at the entrance, so Buff Martin built a small fire just inside. Sparks from this fell into a deep crack packed with dry wood debris. Alarmed he tried to put it out with water from his canteen, then urine and finally soil, to no avail. Embarrassed, he said nothing to the others but despite the outward flow, the air in the crawl soon became smoky.

The other two went to the entrance to be confronted by a “jet of flame” and were trapped. Luckily, most of the heat and “lung wracking” smoke were carried out by the breeze. The three rolled and slid a wide, thin slab of rock over the crack. With flames licking up on either side the two inside quickly scrambled over this “makeshift griddle” and rolled around outside to put out their smoldering clothing. Tim Martin vomited, and all were dazed with shock. Buff Martin had suffered blistered hands. The cave continued to gush white smoke as they hiked away.

Reference: John Clardy (from American Caving Accidents, 1992)

Prussiking out of Marsh Creek Cave. Photo by Pat Shaw.

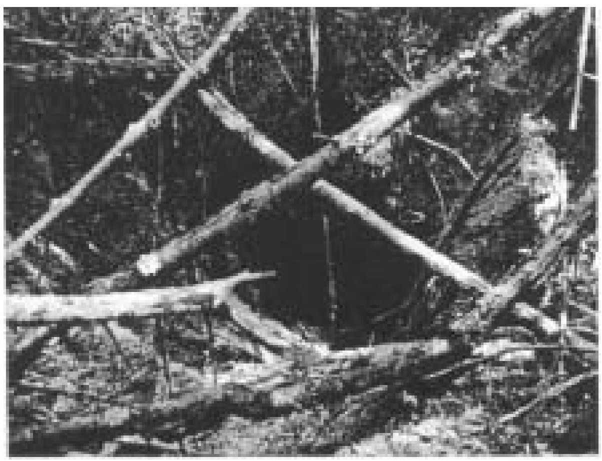
Local Chilliwack caving groups have recently organized and have already made a substantial contribution to exploration and conservation in the Valley. The Chilliwack Valley Cavers first contacted the BC Speleological Federation for support in protection of a newly discovered cave with usually abundant speleothems. Recognizing the fragility of the find, Rob Wall felt that some form of controlled access was the only way to preserve the find and sought the support of the provincial caving organization. Members of the Chilliwack group later designed and installed a gate, with funding from the BC Forest Service, and have served as stewards of the cave since.

Further significant discoveries in the Chilliwack Valley are likely. Numerous small caves have been discovered in the valley, the total surveyed length of with probably amounts to less than 5km. Future discoveries await. Probably the best finds await laborious removal of tills from the last glacial recession by enthusiastic and determined diggers!

Field Trip Stops

The field trip route will follow the Chilliwack River east (upstream) from the bridge crossing at Sardis. Branching left, we will follow the bench road, a route underlain by remnant glacial tills from an ancient outwash plain. A short diversion north from this road will take us to the first stop, which is the vicinity of Well's Sink.

Symposium Stop 1: Well's Sink Area



One doline near Stop 2 on the Symposium tour. Photo by Dick Garnick

Background:

The area around Well's Sink is typical of low-elevation karst displaying the effects of the most recent glacial recession. Most of the sedimentary deposits in the valley are remnants of outwash plains left by melting glaciers and icefields at the end of the Vashon Stade of the Wisconsin Glacial Period, which was at a maximum development in Southern BC at about 14,500-15,000 years bp. Deglaciation of the Chilliwack Valley was complete about 11,000 years bp (Saunders et al. 1987)

Well's Sink, like much of the valley, was burned in the extensive wildfire in 1938. There is no logging history in the immediate vicinity. Regrowth in the area has been slow, due to a number of compounding factors; significant blow-down, perhaps due to a thin unconsolidated soil cover; Self-thinning, and root-rot, a relative common fungal pathogen of coastal forests. The contrast of the forest condition with that at the remaining stops will be quite striking.

Sinking streams and evident dolines caught the interest first of BC Speleo Research members, and, later, Cascade Grotto members. The many days of digging have yet to reveal the hidden "Chilliwack Master Cave."

The tour route will follow a trail past a progression of filled sinks:

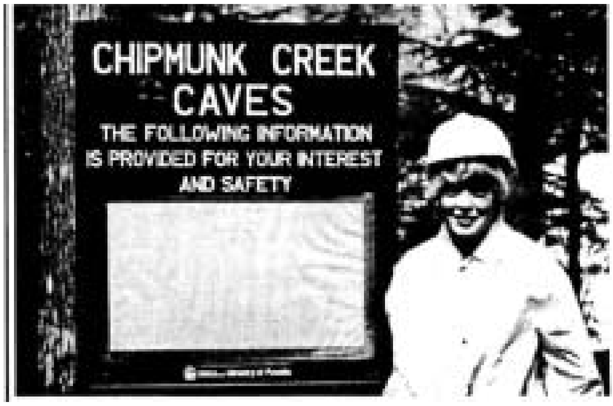
1. open with blow-down timber,
2. partially filled sink,
3. this sink took a stream 4 years ago but is presently infilled. The stream has sought a new route, and now flows on the surface.

Symposium Stop 2: Chipmunk Caves

From Stop 1, the tour will continue east along the Chilliwack River to Foley Creek, cross over by bridge then return west along the south side of the valley.

Background:

The Chipmunk Caves are perhaps the most heavily visited caves in southwestern British Columbia. Three small caves have been known for many years, originally visited by the local Sto:lo band and rediscovered by others in the 1950s and 60s. Without formal names, the caves have been referred to as "Chipmunk 1, 2 and 3". Surveys by BC Speleo Research revealed a total of 135 metres of passage, 70 of which were in the largest Chipmunk #1 Cave. When rediscovered by non-native visitors, the caves held fine displays of white flowstones, moonmilk and stalagmites. In addition, the caves were host to Townsend's Long-eared Plecotus (*Plecotus townsendi*), a bat which probably used the caves as a daily roost.



1970s vintage sign near Chipmunk Caves. Photo by Gerrit Vander Laan.

This area became a popular destination for cave tourists after publication of the cave locations on the NTS 1:50,000 topographic map. Souvenir collecting quickly decimated the easily removed speleothems. Even today, blocks of mud-encrusted flowstone are being smashed from the floors and walls by unthinking vandals.

In a report of an "International Trip to Chipmunk Caves", Clarence Hronek finished the text noting that "the knoll is like a sponge and we feel there are more caves to be found nearby". Such a find was Iron Curtain Cave, opened by Rob Wall in 1994. Exploration of the new find revealed fine speleothem displays, the significance of which (in the context of others caves in the Chilliwack Valley) led to gating and controlled access.

This area was part of an extensive burn in 1938, which affected most of the Chilliwack Valley and adjacent drainages. The present fine timber and understory are a good example of a healthy coastal hemlock forest plant community.

Issues:

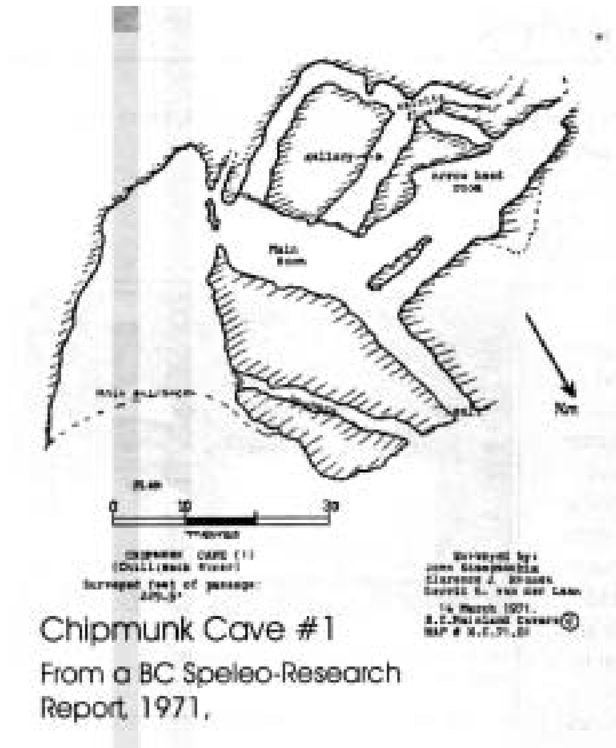
1) publicity of cave entrances in a heavily traveled recreational area. Some signage by the BC Forest Service was in place in the 1970s (See photo), but proper education of the public user is difficult.

2) education of the public to the fragility and permanence of damage to speleothem deposits.

3) Gate vs. non-gate cave management with respect to management of Chipmunk Caves versus Iron Curtain Cave.

Symposium Stop 3: Marsh Creek Cave Area

From Symposium Stop 2 at the Chipmunk Caves, we will continue west down the Chilliwack River to branch up logging roads alongside Slesse Creek on the south side of the valley. Recent work on the access road by Tamahi Logging has transformed the route from nearly impassable, as it was through the summer, to as fine as the road has ever been. Spectacular views of local mountains and important karst preservation messages await.



Background:

The upper benches of Mt. McGuire have yielded some interesting finds in the Chilliwack River Valley, and have been the focus of recent restoration efforts by the BC Forest Service in cooperation with cavers.

Logging in the valley commenced in the 1960s. Most of the area from the first crossing of Borden Creek to Marsh Creek Cave was logged from 1960 to 1967. The most recent harvesting of the McGuire benches was in 1984. In addition to the timber harvesting, both sides of Slesse Creek were burned by and extensive wildfire in 1938.

When logging roads were being pushed into the timber of upper Borden Creek, the road-builders were faced with the problem of a large open-air pit carrying a small stream which drained a nearby marsh. The solution was to 1) re-route the creek course, 2) plug the entrance with wood debris and 3) carry on building. Twenty years of wood decay led to road sloughing and re-discovery of the cave by Cascade Grotto members.

Discussions between Dick Garnick and the Chilliwack District office of the BC Forest Service led to development and implementation of a restoration plan for the entrance. In fall 1996, the creek bed course was restored and wood debris removed. It would appear from anecdotal observations, that sediment deposits and passage constrictions resulting from the road-building activities are slowly being removed and the former dimensions of the cave may eventually be restored.

The trail on this stop leads up the old abandoned logging road through the karst and through log slash filled sinks. We will then wind up through the forest into the small marsh and the big sink near the cabin. This is probably what Marsh Creek entrance looked similar to before the road building took place. From this point we will visit the big marsh that drains into Marsh Creek. From there we will move down to the Marsh Creek Cave entrance and discuss the road building and MOF cleanup work done and in progress.

References and of Interest

Monger, J.W.H. 1970. Hope map-area, west half (92H W1/2) British Columbia, Geological Survey of Canada, Paper 69-47

Monger, J.W.H. 1993. Canadian Cordilleran tectonics: from geosynclines to crustal collage. Canadian Journal of Earth Sciences 30: 209-231

Saunders, I.R., J.J. Clague and M.C. Roberts. 1987. Deglaciation of Chilliwack River valley, British Columbia. Canadian Journal of Earth Sciences 24:915-923

Acknowledgement and thanks for help in producing this pamphlet go to Dick Garnick for his usual tireless enthusiasm with the Chilliwack Valley, to him, Gerrit van der Lann and Clarence Hronek for historical photos and maps, to Graham Heslop for tracking down a key article, and to Donovan Whistler for valuable discussion on production/layout.

Northern Vancouver Island Field Tour

Compiled and Edited by Paul Griffiths

Contributors and Co-Sponsors:
Canadian Forest Products Limited, Englewood Logging Division
MacMillan Bloedel Limited, Port McNeill Division
Western Forest Products Limited, Northern Administration
Regional District of Mount Waddington
Richmond Area Speleological Society
Forest Renewal BC, Pacific Region
BC Ministry of Forests.

Thursday, October 9, 1997

1997 KARST AND CAVE MANAGEMENT SYMPOSIUM

Tuesday, October 7, 1997

Dear Symposium Participant,

This tour was conceived as one of three official same day field events of the 1997 Karst and Cave Management Symposium.

The northern Vancouver Island tour location is host along with the Queen Charlotte Islands and SE Alaska, to a majority share of the global estate of coastal temperate rainforest karst.

Port Hardy (pop. 5,000) is located on the northeastern end of Vancouver Island at the terminus of Highway 19. Without air travel, the community is accessed by ferry service from the mainland. The most direct surface route from Bellingham would have involved driving 90 minutes to the ferry terminal, followed by a two hour ferry crossing to Nanaimo on the Island, plus another six hours of driving from Nanaimo - a ten-hour trip one way!

We have tried to ensure that the selected tour stops and presentations are interesting, meaningful, and appropriate to the theme of the symposium and objectives of the tour. Enjoy yourselves!

Sincerely,

Paul Griffiths, Canadian Chair

1997 Karst and Cave Management Symposium

TABLE OF CONTENTS

Tables

Figures

Figure 14: The 1981 “Statement of Crown Land Cave Policy and Administration”

FOREWORD

An informal tour of short-listed stops was conducted with government and forest sector representatives on June 14th.

The lengthy list of proposed stops was initially screened and the feasibility of restorative work to facilitate ground access was evaluated. Before making the final selection, the degree of strenuousness was considered in relation to the expected fitness and technical competence of the participants.

A lot of energy has gone into the preparation of the designated routes and trails. The purpose is not only to provide safe access, but to allow participants to observe and study karst features with little time spent bushwhacking and watching for tripping hazards. All trails and routes were designed as easy hiking of short duration.

The occasional use of hands on bare limestone bedrock will be required at STOP 2 (“Prescribed burning on epikarst”).

No stops will involve subsurface travel. Aside from the time constraints, it was recognized that most participants would not be qualified cavers, or would not have access to caving equipment.

General Tour Information

Date

The field tour coincides with the scheduled one day break in the symposium (Thursday, October 9th), returning to Bellingham at the end of a full day. We will depart from the Lakeway Best Western Inn in Bellingham at 0600 h and return to the hotel at about 2300 h.

Fees and late registration

The fee includes all air and ground transportation, plus meals and non-alcoholic beverages. Late registration and payment will be accepted in Bellingham, if space is available, in order to give everyone the opportunity to participate.

Purpose

The purpose of the field tour is to facilitate the direct observation and study of representative surface karst environments. We have incorporated sites that have modified through forest development activities, principally roadbuilding and timber harvesting.

Objectives

One of the primary objectives of the field tour is to inform the participants, in a balanced and objective manner, of the problems, changes, challenges and opportunities related to management of coastal temperate rainforest karst on northern Vancouver Island. The tour is a first-hand opportunity to observe this type of karst—both in pristine areas as well as in areas that have been affected by industrial forestry operations.

This tour will provide an educational experience for tour participants who may not be as familiar with forest karst. The free exchange of information between specialists is encouraged, as it will help to bridge historical forest practices and new karst-specific management standards established under the BC Forest Practices Code. Thus the tour is expected to contribute significantly toward the development of a model system for forest development.

A secondary objective is to prepare the audience and approximately six volunteers for a panel discussion the following day in Bellingham. The panel members will attempt to summarize the state of the art of forest karst management in this region. Field tour observations will be openly and fairly discussed and compared. New and evolving karst management practices will also be discussed, with special emphasis on recommending ecologically based criteria for managing coastal temperate forest karst.

As both government and forest industry sectors continue to face the challenge of maintaining the timber-producing capacity of forest karsts, while ensuring an acceptable level of protection for sensitive karst resources, this discussion will be watched with interest. Questions from the floor will be welcomed and encouraged.

Concept

The organizing committee decided early that the northern Vancouver Island field tour would be one of the principal symposium tours. Particular emphasis was placed on sampling the coastal temperate rainforest karst—consistent with the symposium highlight theme. It was conceived as a looping tour offering diverse stops and minimal back-tracking.

Description of tour

We will leave the Port Hardy airport at 0905 h by motorcoach and travel south on Highway 19, taking a loop via Port Alice highway to STOP 1 (“Eternal Fountain”) and STOP 1A (“Devil’s Bath”) in the Lower Benson River drainage system. Lunch will be distributed on the motorcoach shortly after STOP 2 (“Prescribed burning on epikarst”).

A secondary loop will be followed to STOP 3 (“Cutblock AT286 D&D”) and STOP 4 (“Old-growth forest karst”) in the Upper Tahsish River drainage. From there, we will double back a short distance to rejoin the first loop, and follow the MacMillan Bloedel Limited mainline and then

Highway 19 to the Seven Hills Golf and Country Club, arriving in time for dinner.

The tour route intersects major karst units in two forest districts (Port McNeill and Campbell River), multiple forest tenures, and climbs over a representative elevation gradient.

TABLE 1: LIST OF MAIN TOUR STOPS WITH START AND FINISH TIMES

STOPS	STATUS	TIME	DESCRIPTION
START	DEP	0905	Port Hardy airport
1	ARR	0955	Eternal Fountain
	DEP	1045	
1A	ARR	1055	Devil's Bath
	DEP	1120	
2	ARR	1125	Prescribed burning on epikarst
	DEP	1235	
2A	ARR	1300	Vanishing River
	DEP	1330	
3	ARR	1340	Cutblock AT286 D&D
	DEP	1520	
4	ARR	1525	Old-growth forest karst
	DEP	1630	
DINNER	ARR	1800	Seven Hills Golf and Country Club
	DEP	1930	
FINISH	ARR	2000	Port Hardy airport

Please note: 1A and 2A will be time dependent stops (i.e., brief stops will be made only if time permits). In addition, there will be a number of "moving stops" and secondary "points of interest".

Air transportation

We will fly to Port Hardy from the Shell Aerocentre at the South Terminal of Vancouver International Airport, which is located at 4360 Agar Drive in Richmond. We have arranged to have the motorcoach from Bellingham park on the tarmac next to the aircraft. The air charter provider is Kelowna Flightcraft Air Charter Ltd. The hired aircraft is a 50 seat Convair 580 twin engine turboprop. This aircraft has a cruising speed of 520 kph (325 mph) and is reputed to be very safe. The flight will take approximately one hour. The Port Hardy airport has multiple runways up to 1,500 m (5,000 feet) long and supports instrument landing.

Table 2: Flight schedule

TIME	DESCRIPTION
0730	Motorcoach arrives with passengers from Bellingham at the Shell Aerocentre
0800	Depart Vancouver to Port Hardy
0900	Arrive Port Hardy
1945	Motorcoach returns with passengers to the Port Hardy terminal
2030	Depart Port Hardy to Vancouver
2130	Arrive in Vancouver at the Shell Aerocentre and transfer passengers to motorcoach for Bellingham

Identification for border crossing

Tour participants will be required to leave the motorcoach for customs clearance at the Canadian border crossing. Visa or proof of citizenship will be required for the Canadian and US residents. Passports, birth certificates or voter registration cards are acceptable forms of identification.

Ground transportation

We will travel in a hired motorcoach from the Lakeway Best Western Inn in Bellingham to the Vancouver International Airport. The motorcoach will leave at 0600 h from the front of the hotel. The trip to the airport will take about 90 minutes, including the customs clearance at the USA-Canada border. Ground transportation from Port Hardy on northern Vancouver Island will also consist of a hired motorcoach and forestry tour bus, to facilitate group interaction between stops.

Mean travel speeds along the tour route will be 70 km (43 mph) on the paved highways and 40 kph (25 mph) on gravel surface roads. The total travelling time excluding field stops and dinner will be about three hours.

What to bring

Clothing and footwear

Bring strong, durable fast drying clothing that will keep you warm and comfortable, as well as rain gear in case it is wet, rainy day. Remember to put the gear on before you get wet, not after! To stay warm, you will have to stay dry. Use a layered clothing approach. If possible, have a dry set of clothes ready. Sturdy boots providing ankle protection with deep-lugged soles are recommended.

Each tour participant will be required to wear a high visibility fluorescent red vest so they can be readily seen by the tour leaders and operators of moving vehicles and equipment. Each participant will also be provided with a hard hat, with an adjustable head band. The hats are to protect against potential overhead hazards. Note: hazardous trees and snags have been removed where possible to reduce the overhead exposure to visitors in the event of high winds.

Hand protection is optional. Waterproof insulated gloves will keep your hands warm and effectively prevent cuts, scrapes or irritations caused by some of the understory vegetation.

Precautions

Potential ground travel hazards

We have tried to minimize or possibly eliminate risks through trail and route selection, planning, organization, and supervision. Potential hazards such as vertical exposures, steep slopes, windfall, irritating plants, and deep mud were identified and evaluated prior to route selection. Handrails and viewing platforms and staircases have been provided at the exposed locations. In some cases, alternative routes were selected to avoid risks.

Remember to use handrails where provided!

When travelling through forest karst, it is sometimes necessary to walk on fallen trees. To avoid slipping and falling most forest workers wear caulked boots. We have provided walking trails at each tour stop to facilitate ground travel through difficult terrain. Trail surfaces will vary—short sections of the “low impact” trails may be slippery or uneven, and this problem may be aggravated by wet conditions.

The designated leaders will review the hazards of the terrain over which we plan to travel and what weather is forecasted for the tour day. Travelling through both forested and deforested karst terrain is inherently dangerous and involves a degree of risk. Even the safest looking ground can reveal a tripping hazard or worse. Walking off trail can create unnecessary risks of falling into deep karstic cavities hidden by a thin veneer of forest litter and soil.

Our goal is to prevent any mishaps. Accordingly, we would ask all participants to follow the leaders at the stops, regardless of how safe terrain conditions may appear at a distance.

Active harvesting operations

One stop will likely include first hand observation of logging operations at close range. We would ask everyone to wear the hard hat and high visibility vest provided.

Weather considerations

October is normally the beginning of the cool, rainy period on northern Vancouver Island, which lasts until spring. This is why rainwear and an extra set of clothing are highly recommended!

Minimum age

For reasons of liability the minimum age for participation in this tour will be 19 years.

Medical

Please advise the tour organizers of any potential medical problems that would prevent you from enjoying the tour

First aid and emergency response

Basic first aid coverage will be provided throughout the tour. We will have a qualified wilderness first aid person in attendance. The forest companies maintain ambulances in the field and helicopter evacuation is available according to weather. In the event the emergency requires rapid evacuation, we have identified a number of helicopter landing sites. If outside assistance is required, the organizers will make the request through the Royal Canadian Mounted Police.

Head count

You won't become lost if you stay with the group and the designated routes, but we're taking no chances! A designated person will be taking a head count before the bus departs from the Port Hardy airport and each successive stop. Remember to use the buddy system.

Environmental protection

Minimum impact

Human trampling on the sideslopes of sinkholes and other surface karst features can accelerate erosion above geological rates. Avoid these areas by staying to the trails which have been kept outside of these features. Also, we would ask visitors to avoid cutting switchbacks which could trample vegetation and lead to erosion.

This is our playground! We would ask all participants to practice minimum trace outdoor travel. These are the guidelines that we strive to uphold whenever we're caving. We try to apply the same minimum impact philosophy when travelling over the surface karst environment.

The goal of every speleologist on Vancouver Island is to preserve the natural surface karst and underground wilderness for others to enjoy. We have a very simple motto: "Leave no trace".

Smoking

We will ask all participants to refrain from smoking during the tour. If you must smoke, please do not discard cigarette butts and used matches at the parking areas or along the trails.

Food and drink

Danish fruit cup snack boxes and coffee will be served on the Vancouver to Port Hardy leg, along with complimentary juice and soft drinks. Beer and wine on the Port Hardy to Vancouver leg will be available on a cash basis.

Box lunches will be delivered to the motorcoach at the Port Hardy airport and can be eaten between STOPS 2 and 2A. The lunch will be supplied by Subway in Port Hardy - please select your sandwich from the checklist before Tuesday afternoon. Mid-morning and afternoon snacks and beverages will also be provided. You can bring additional water and food if you like, however.

Dinner

There will be a buffet style dinner at the Seven Hills Golf and Country Club. We will have a choice of roast beef and salmon, choice of salads, choice of potatoes or rice, and desert, coffee or tea. A limited quantity of red and white wine will be served with the meal—otherwise a no host bar will be available.

Restrooms

The motorcoach will come equipped with a basic restroom.

Photography

Bring your still photography and video cameras. Symposium organizers are planning to photograph and videotape highlights of the day. This record will be made available to participants at cost.

Radio transceivers

We will have portable VHF radios with us that can be programmed to the forest company channels. The radio frequencies used will be:

MacMillan Bloedel Limited, Port McNeill Division

Frequency is **168.2900** or **172.3650** MHz

Canadian Forest Products Limited,

Englewood Logging Division

Frequency is **158.1300** MHz

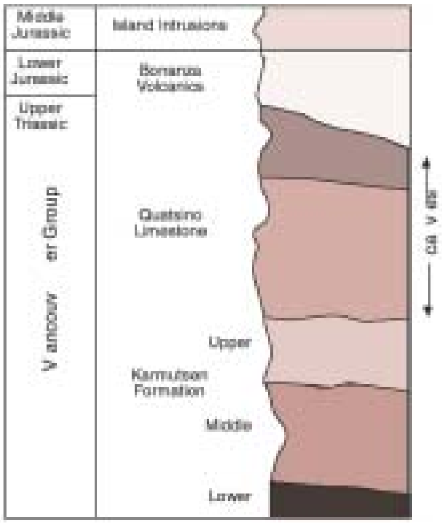
Cellular phones

Cantel AT&T and BC Tel Mobility provide overlapping cellular coverage but exact coverage is not predictable. Cellular coverage is likely to be available for the first one-half and the last one-half hour of the tour. There is confirmed cellular coverage and a pay telephone at the Seven Hills Golf and Country Club (i.e., the dinner location). The new telephone area code for this part of British Columbia is “250”.

BACKGROUND INFORMATION

Vancouver Island is the largest island on the west coast of North America. It is one of the few jurisdictions in the world fortunate enough to retain pristine examples of karst within coastal temperate rain forests. Hundreds of square kilometers of high purity limestone, combined with environmental factors unique to this forest biome, provide all the ingredients for intense karst development, with a wealth of biological and geological diversity.

Figure 1: Representative Stratigraphy With Carbonate Strata



Bedrock geology

Vancouver Island's karst is often developed in Mesozoic rocks ranging in age from Upper Triassic to Middle Jurassic. The rocks include, from the stratigraphically oldest to youngest, Karmutsen Formation, Quatsino Formation, and Bonanza Group. The primary limestone bearing unit, the Quatsino limestone, is exposed at the surface from Tahsis Inlet to Rupert Arm.

Karmutsen Formation

The Karmutsen Formation is the most extensive unit found to outcrop on northern Vancouver Island. The formation was deposited at the beginning of the Upper Triassic Karnian Stage and is mainly composed of volcanic pillow lavas and breccias that are basaltic in composition. Intercalated sedimentary rocks, including minor limestone, occur in the upper parts of the formation. The vertical development of the limestone solution caves in the overlying Quatsino Formation is often constrained by this basement volcanic unit.

Quatsino Formation

The Quatsino Formation limestone is the primary host rock for the majority of the known karst units. This formation is also Upper Triassic in age and rests conformably on the Karmutsen volcanic rocks. The stratal dip is approximately 35° to the west and the maximum thickness of beds can locally exceed 300 m. Generally, the lower part of the formation is light gray and indistinctly bedded, while the upper part is darker and more thickly bedded. Thermal metamorphism during deposition of the overlying Bonanza volcanics has transformed the limestone into marble along the contact between these units.

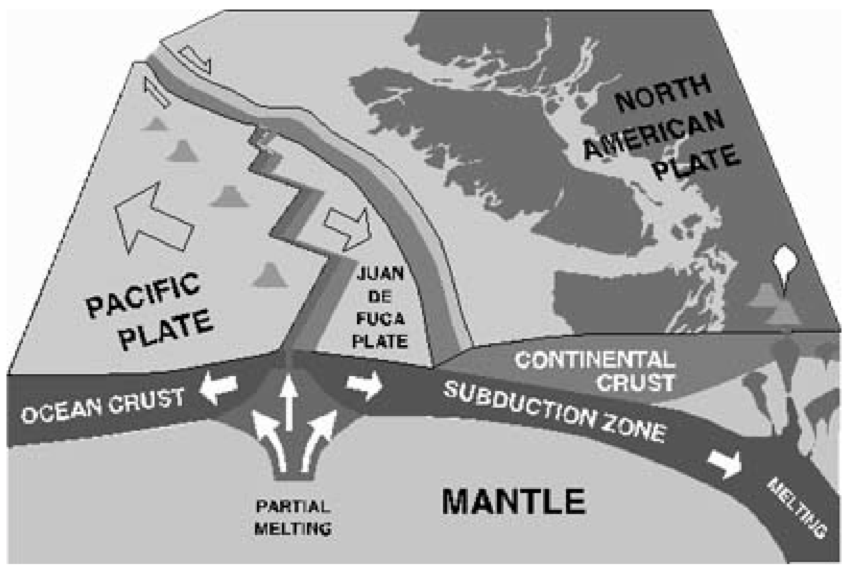


Figure 2: Plate Tectonics and Subduction Zone
West Coast of Vancouver Island

Bonanza Volcanics

Many of the surrounding mountain peaks are composed of the resistant Lower Jurassic volcanic rocks of the Bonanza Group. These rocks are mainly comprised of basaltic lavas with minor interbedded siltstones.

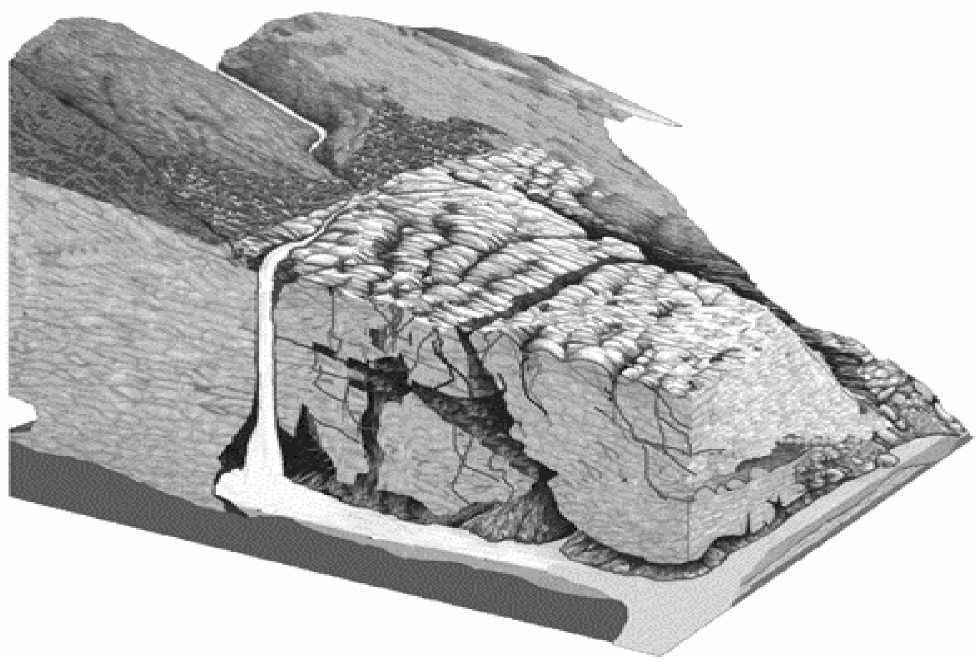
Geological structure

In general, the dip of the Quatsino limestone on northern Vancouver Island is sub-parallel to that of the Karmutsen Formation. However, the overlying limestone dips more steeply due to the influence of faults. The direction of the cave development can be significantly influenced by these faults. The stronger volcanic rocks of the Karmutsen Formation and Bonanza Group appear less faulted than those of the Quatsino.

Karstification

Vancouver Island's potential karst occurs over 4% of the landscape - some 1,200 km2. The high purity limestone, combined with other unique environmental factors, provides all the ingredients required for intense karstification.

Figure 4: Karst Network in Perspective View



Soluble rocks make up about 13% or 1,200,000 km2 of Canada's land surface. A significant amount lies well north of the permafrost line, and some of the occurrences in the Prairie provinces are salt. Vancouver Island's potential karst therefore represents just 0.1% of all soluble rocks exposed at the surface in Canada.

The karst networks on Vancouver Island are active and there are many features in different stages of development. They can be autogenically and allogenically recharged, but most are allogenically recharged.

Discrete mesoscale surface karst features include natural rock bridges, phreatic tube remnants, rock shelters, sinkholes, shafts, shakeholes, and springs. Grikes are common epikarst features, with the more pronounced ones developing up to several meters in depth. The best-developed features, including karst caves, are found above 300 m a.s.l. We commonly find them in rocky ground and they are frequently plugged with soil or humus. Solution runnels and flutes are found where the karst is only lightly covered with soil and moss.

Dry watercourses abound, and several major watercourses sink and flow underground. The Upper Benson River, for example, leaves the surface to be swallowed at the STOP 2A ("Vanishing River"). The subterranean flow is believed to rise at the "Reappearing River" in the Raging River drainage, about two kilometers away.

KARST CAVES

There are many hundreds of solution caves in Vancouver Island—most are formed in carbonate rocks such as limestone, and marble. The marble is usually associated with contact or regional metamorphism.

ABOUT OTHER TYPES OF CAVES ON VANCOUVER ISLAND

There are hundreds of non-calcareous sea caves on Vancouver Island, predominantly on the outer coast. These caves are formed by the constant action of large oceanic waves. The caves can be populated by marine mammals and many other organisms. There are a number of glacier caves that are formed by meltwater in deep snowfields, excavating drainage tunnels. In addition, there are several ice caves at higher elevations. These are commonly limestone solution caves within which ice forms and persists throughout the year. Finally, there are complex tectonic cave systems developed in sandstone and a variety of less elaborate rock fall or talus caves.

CAVE FEATURES

The most common Vancouver Island speleothems are calcite stalactites and stalagmites. Soda straws are sometimes found growing to a length of one meter or more. The largest columnar formations attain two or three meters only. Curtains and draperies are also found. Perhaps the most spectacular speleothems are the helictites found in Candlestick Cave. The vast majority of decorated caves have not been vandalized for these secondary deposits.

CAVE SEDIMENTS

Many Vancouver Island caves contain unconsolidated secondary deposits of surface origin. These range from sand and clay to stratified gravel. As previously described, cave sediments have revealed important records of the past climates and vegetation of the surrounding surface area.

BREAKDOWN

Rock material produced by the collapse of the ceiling or walls of a cave is commonplace in larger cave systems. This breakdown and may range in size from massive blocks the size of a light utility truck to a small rock. Some of the rockfall appears to have been associated with seismic activity.

LONGEST AND DEEPEST CAVES

Among Canada’s longest and deepest cave systems are found on northern Vancouver Island. Hundreds of caves have been charted since systematic exploration began in the mid-seventies, including several with multiple kilometers lengths, and depths in excess of 300 meters. Four cave systems are approaching 10 km in overall length. The deepest cave on Vancouver Island is Thanksgiving Cave, which also happens to be one of Canada’s longest and deepest.

The largest underground chambers measure up to 40 m across, and up to 100 meters in length. Deep Mother (57 m), Puits Marie-Québec (50 m), and Lee’s Leap (47 m) remain the deepest known interior technical pitches on Vancouver

Island.

TABLE 3: LIST OF THE TEN LONGEST AND DEEPEST KNOWN CAVES ON VANCOUVER ISLAND AS AT OCTOBER 7, 1997 (RANKED IN DESCENDING ORDER)

LONGEST (METERS)			DEEPEST (METERS)		
1.	Thanksgiving	7,939	1.	Thanksgiving	394 (-224, +170)
2.	Arch-Treasure	5,868	2.	Glory 'Ole	313
3.	Ursa Major	5,619	3.	Arch-Treasure	313
4.	Weymer System	5,068	4.	Q5	301
5.	Windy Link	4,353	5.	Windy Link	209 (-118, +91)
6.	Minigill Cave System	2,700*	6.	Ursa Major	190
7.	Q5	2,066	7.	Sky Pot - Slot Canyon	174
8.	Glory 'Ole	1,978	8.	Grueling	153
9.	Headwall-Fallen Giant	1,620	9.	Quatsino	152
10.	Quatsino	1,522	10.	Crackpot	148

*estimated surveyed length

Figure 5: Profile of Q5-Quatsino Master System
White Ridge Provincial Park

The master cave system consisting of Q5, Windy Link, and Quatsino caves has a combined relief of 614 meters, with a theoretical depth potential of about 900 meters. Both Q5 and Windy Link contain interior pitches that are among the deepest in Canada.

GLACIATION AND SURFICIAL GEOLOGY

Only the highest summits on northern Vancouver Island escaped glaciation at the height of the last period, which is suggested to have started before 13,000 years BP. Glacial striations have been reported at 1,500 m a.s.l. on Victoria Peak, so it is likely that most of the inland karst areas were covered by ice. Floors and walls of valleys are often mantled by glacial drift giving rise to a covered karst. Well-preserved, glacio-fluvial deposits have been found in Vancouver Island caves. Stalagmites formed on these cave sediments have been radiometrically dated by U/Th disequilibrium to 13,800 ± 1,800 years BP.

Glaciation has impacted many of Vancouver Island's karst features, occasionally completely infilling karstic cavities, or depositing a thick layer of till over the surface. Indeed, the forest cover is still equilibrating following the glacial retreat that occurred more than 10,000 years ago.

COLLUVIUM

Colluvial deposits are sometimes found in karst areas with steeper hill slopes, where snow avalanches, rock slides, and frost action processes are most prevalent. Closed depressions such as sinkholes and shafts are occasionally found to contain colluvial material.

REGOLITH

Layers of glacial, post-glacial deposits and colluvium are found atop karst on the gentler slopes and benches at lower elevations. These surficial materials mask the underlying karst topography. Forest humus and litter generally cover the lower gradient slopes of middle elevations, and bare outcrops are commonly associated with steep hill slopes and knolls. The overburden is often very thin or absent in the many sloped mid-elevation karst sites. Above 1,200 m the sub-alpine karst can be a classic lapies. Frost-shattered material and glacial till are often the only surficial deposits covering the lapies.

The soil atop mid-elevation karst is almost always present as a thin forest floor layer (i.e., a folisol). Well-drained and aerated the soil has very little mineral content, even at the lower horizons. A higher biological activity in these organic soils results partly because of the abundance of soil fauna. Low to moderate nutrient holding capacity may result because of excessive leaching (i.e., due to free drainage). As well, the soil can be slightly acidic because of high organic content and carbon dioxide in soil air. Nevertheless, the beneficial effects associated with the limestone substrate seem to override any negative soil factors.

When our Island's abundant rainfall infiltrates the soil, it picks up more CO2 where it is formed by high rates of biological activity. The concentration of CO2 in soil can attain 2 to 5% by volume, whereas the content in air is very low by comparison. The soil adds a source of organic acids which also reacts to dissolve the carbonate rocks. Soil is therefore an important contributor to the dissolution of limestone in Vancouver Island's forest karst environments.

CLIMATE

Vancouver Island's climate is the west coast marine type, largely determined by the cycling of high and low pressure systems. High levels of precipitation are due to the high relief and westerly circulation of Pacific storm systems. These westerly flows are stronger in the winter. Fall and winter storms are frequently accompanied by gales. These winds occasionally have the strength to cause some limited windthrow along old cutblock edges. Annual rainfall totals ranging over 3,800 mm have been recorded on the western side of the Island. The karst near Henderson Lake, for example, receives 6,600 mm of precipitation annually. This is the North American record for the highest mean annual precipitation.

The combination of a maritime climate and high rainfall provides ample corrosive water and snowmelt for karstification, even at higher elevations. About 80% of the mean annual precipitation falls as rain and snow during the months of October through April. Short-term intense rainfall events can also occur outside of this period.

SURFACE KARST MICROCLIMATE

Higher elevation sinkholes and other karstic depressions can create unique microclimates during the melting period, as they commonly contain perennial snow and or ice accumulations. The shape and size of these depressions influence the amount and duration of solar radiation the snow receives. Some of these features retain snow patches into the late summer, whereas other slopes are free of snow. Temperature inversions are common in these depressions, causing pockets of colder air and snow retention. The air temperature at the bottom of depressions can be up to 10oC lower than around the rim. As well, the relative humidity in the bottom is usually much higher than at the rim.

CAVE CLIMATE

The caves have characteristically stable relative humidity and temperature conditions. The degree of relative humidity exceeds 95% and occasionally exceeds complete saturation. The cave air is humidified upon contacting perennially moist interior cave walls.

HYDROLOGY

The karst networks of northern Vancouver Island can have well-developed subsurface drainage system. Allogenic rivers and streams flowing onto a subjacent geological contact will sink and circulate underground for hundreds of meters or even kilometers. The consequent subsurface streamflows are especially dependent on the meteorological conditions of the surface. Many underground rivers respond dramatically to seasonal variations, usually peaking in the fall and spring.

KARST SPRINGS

The consumption of bottled spring water continues to gain momentum in the North American beverage market, as concerns about tap water rise and sales of traditional soft drinks fall off. Interest is mounting in the karst aquifer springs of Vancouver Island, especially in those with protected recharges. The STOP 1 ("Eternal Fountain") has been the focus of interest and long-standing water license applications. Most recently an application was filed by the Eternal Fountain Spring Water Ltd. based in Victoria.

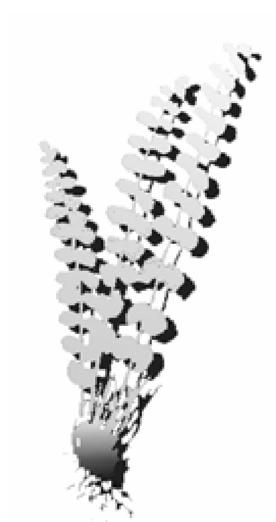
Note: The biggest selling brand of spring water in Canada remains Evian, a French flat water import of karstic origin.

BIOLOGY

TREES AND UNDERSTORY PLANTS

The dominant tree species in our rainforest karst are balsam, Pacific silver fir or amabilis fir (*Abies amabilis*) or western hemlock (*Tsuga heterophylla*). These two species are almost always associated with fresh or moist soils and poor to rich soil nutrient. There is rarely western red cedar (*Thuja plicata*) and yellow-cedar (*Chamaecyparis nootkatensis*) except in conjunction with moister discrete mesokarst features.

Western hemlock is a shade-tolerant tree species and well adapted to grow on humus and decaying wood. Western red cedar occurs mostly in moist to wet soils and is commonly found with sinkholes and swallets. Since western hemlock tends to prefer acidic, nutrient-poor soil one would therefore assume that its roots stay in the organic soil mat atop the limestone bedrock. Amabilis fir and western red cedar are more likely to penetrate with their roots down into epikarstic fissures. This type of root growth often occurs in grikes and other surface openings which become filled with soil. We have observed root systems growing into caves to a depth over ten meters.



Asplenium viride

There are relatively few understory plants due to the closed tree canopy. However, shade intolerant species can be found thriving in canopy gaps associated with treefall, cave entrances, etc. A variety of chlorophyllic plants can be found occupying entrances and twilight zones.

SHRUBS

The three dominant shrub species are commonly Alaskan blueberry (*Vaccinium alaskaense*), red huckleberry (*Vaccinium parvifolium*), and oval-leaved huckleberry (*Vaccinium ovalifolium*). Salal (*Gautheria shallon*) is present in the lower elevation karst sites.

HERBS

The dominant herb species are deer fern (*Blechnum spicant*), five-leaved bramble (*Rubus pedatus*), and bunchberry (*Cornus canadensis*). Several species of ferns, termed calciphiles, prefer but are not absolutely restricted to limestone substrates.

MOSSES

The dominant moss species are lanky moss (*Rhytidiadelphus loreus*) and step moss (*Hylocomium splendens*). Pipecleaner moss (*Rhrytidiopsis robusta*) is more prevalent at higher elevations. Flat moss (*Plagiothecium undulatum*) is more prevalent at lower elevations. Several species of mosses almost exclusively require limestone.

INDICATOR PLANTS

Ferns as a group seem particularly sensitive to bedrock and substrate control. The calciphilic green spleenwort (*Asplenium viride*) is one of the best fern group indicators on Vancouver Island. It is frequently found in moist, shaded, sheltered crevices on bare limestone outcrops.

There are not that many calciphilic flowers on Vancouver Island, but unusual combinations of fairly widespread species, or unusual vigour, may signal the presence of calcareous bedrock. If the limestone bedrock is covered by a thick layer of moist and acid humus, then most of the plants growing there will either reflect the humus, or they will indirectly reflect the limestone by visibly better growth. This is perhaps a response to better nutrient availability. Common plants found in the microhabitats of discrete surface karst features include lichens and mosses. Soil pockets enable colonization by more complex communities and higher plants such as ferns.

ABORIGINAL USE OF PLANTS

The aboriginal cultures of Vancouver Island made extensive use of the dominant tree, shrub and herb species associated with karst for food, medicine, fuel or technology. The pitch of amabilis fir, for example, was chewed and the boughs were used in the household as flooring. The knotwood of western hemlock was split, steamed, and fashioned into curved fishing hooks. Hemlock pitch was used as a protective coating for implements and other items. Western red cedar and yellow-cedar were also extensively used. Alaskan blueberries were eaten fresh or dried. Red huckleberries were eaten fresh or dried singly like raisins, mashed or dried into cakes or stored soaked in grease or oil. Their juice was consumed as a beverage, an appetite stimulant, or mouthwash. Oval-leaved blueberries were eaten fresh or dried. Deer ferns were chewed as a hunger suppressant and used as a medicine for skin sores.

ECOSYSTEM CLASSIFICATION

The predominant biogeoclimatic sub-units associated with the karst on Vancouver Island are within the Coastal Western Hemlock Zone—the CWHvm1 (Submontane Very Wet Maritime variant) and CWHvm2 (Montane Very Wet Maritime variant).

BIODIVERSITY

Sustaining biodiversity within the meaning of sustainable development is relevant to karst ecosystems on Vancouver Island. Biodiversity is conventionally defined as the full variety of life, including plants, animals, fungi, bacteria, and their habitats, and the processes that interconnect them. Past initiatives have tended to focus on the game species and the various sport and commercial fish species, (e.g., blacktailed deer, Roosevelt elk, salmon, etc.) to the exclusion of karst life forms and their biospaces (habitat). The subsurface environment within karst networks has only slowly begun to reveal cave-dwelling species.

Biodiversity is a concern in karst because forest development activities, especially roadbuilding and clearcut harvesting, are known to shift many elements of diversity. This level of disturbance can be very disruptive to the natural karst system at the site level. Karst-specific biological research and new forest practices will help to maintain biodiversity.

It has been postulated that the periods of glaciation have not significantly depleted the biodiversity of coastal temperate rainforest karst because of abundant refugia and migration corridors.

WILDLIFE

The karst of Vancouver Island provides much of the habitat for a range of wildlife found only in the BC. Mammal species typical of the biogeoclimatic unit are present and include blacktailed deer (*Odocoileus hemionis*), Roosevelt elk (*Cervus canadensis roosevelti*), wolf (*Canis lupus*), cougar (*Felix concolor*), and black bear (*Ursus americanus*). Blacktailed deer and bear are the most frequently sighted. Black bears and cougars have all been observed throughout karst environments including the twilight zones of caves.

BATS

Some of BC's wildlife are found exclusively in karst or are dependent on it for part of their habitat requirements.

Figure 6: *Myotis keenii*

There are sixteen species of bats in BC, a greater variety than in any other province. Bats have been reported in our larger cave systems, where they occasionally contribute guano or their own bodies to the food chain. Three species of bats were found hibernating in Labyrinth Cave, including Keen's long-eared myotis (Myotis keenii), a bat on the provincial "red" list of rare and endangered species. This is the only known significant bat hibernaculum on Vancouver Island and the only known hibernaculum for little brown myotis (Myotis lucifugus). In addition, this single cave supports the highest known bat species diversity of any hibernacula in BC.

Research is underway to determine if old-growth forests provide critical roosting habitat for bats native to Vancouver Island. One of the largest colonies of hibernating bats in BC is found in the large complex of tectonic caves on Thetis Island.

VANCOUVER ISLAND MARMOT

The Vancouver Island marmot (*Marmota vancouverensis*) was listed as endangered under the BC Wildlife Act in 1980. This is a globally rare species known only to inhabit Vancouver Island with a concentrated population of less than 200. In karst, they are known not so much for the extant individuals, but for the extinct members whose bones are now studied from caves. Present day colonies normally inhabit sub-alpine meadows at 1,000-1,400 meters a.s.l. Cave studies show that this animal had at one time colonized karst habitats well beyond its contemporary range. Unmarked marmot bones dated to 9,400 years BP were recently discovered in a low elevation cave on the east side of Nimpkish Lake, making them the oldest known marmot remains in BC. It remains unclear why the Vancouver Island marmot is so rare or why its range has decreased.

INVERTEBRATES

Taxonomists estimate that there are between 40,000 and 50,000 invertebrates in BC. They are therefore by far the greatest contributor to the province's biodiversity. By comparison there are only 454 species of birds and 143 species of mammals found in BC. We know the least about this biological group and even less about its role in karst ecosystems. The results of initial surveys have apparently shown that coastal temperate rain forests have a very high invertebrate diversity. It follows that rainforest karst is a healthy invertebrate habitat.

FISH

The karst "streams" of Vancouver Island's rainforests are intricately connected to discrete and diffuse hydrologic inputs. Underground systems support cutthroat and rainbow trout, and some salmon species inhabit caves and springs. Trout are occasionally washed into caves from outside and gradually lose their colour through lack of sunlight. Adult Coho salmon can be seen to migrate in a confined stream passage within the dark zone of "Bath Cave". This cave connects the "Devil's Bath" (STOP 1A) to the "Devil's Spring".

It is believed that the abundant water that circulates through Vancouver Island karst networks is likely to be beneficial to the productivity of aquatic communities including fish. This is an important consideration, given the relatively rapid, confined, and non-attenuated transport of water in karst conduits.

CAVERNICOLES

Vancouver Island's karst fauna are not confined to the surface environment. Karst caves and other karst biospaces, while they may first appear to be quite lifeless, will occasionally reveal harvestmen, cave crickets, salamanders, and frogs. Overwintering harvestmen or "daddy-long-legs" belong to a group of arthropods known as the Opiliones. The species found in many of caves is probably *Leiobunum paessleri*. Harvestmen appear to predate on small insects but will also scavenge dead animal and plant tissue. Overwintering harvestmen tend to stay away from the entrance zones during the coldest periods. Crickets or cave crickets (possibly *Tropodischia xanthostoma*) are commonly observed in groups on the walls and ceiling.

Other fauna include spiders, mites, nematodes, snails, millipedes, moths, beetles, and flies.

Dense forest cover supplies abundant decaying organic matter for cavernicoles and other karst biospace inhab ave-

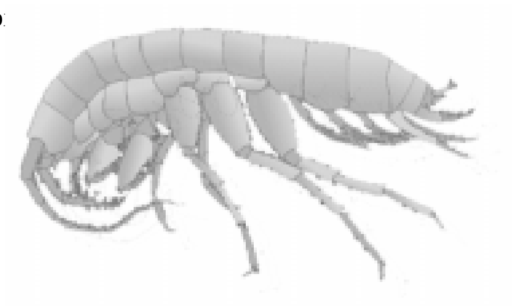


Figure 7: *Stygobromus quatsensis*

adapted *Styobromus quatsinensis*, a previously non-described white amphipod crustacean.

Compared with the karst of more southerly latitudes, the caves of Vancouver Island are believed to be relatively poor in faunal species. This is perhaps explained by the historical proximity of glaciation.

HISTORICAL AND CULTURAL VALUES

An assortment of artifacts has been found in limestone caves. Aboriginal uses of karst and caves on Vancouver Island varied according to the cultural and religious factors. Caves, springs, and underground water were often looked upon as supernatural elements, to be respected in the natural world. Caves throughout the region were used for burial and a variety of rituals. Very few of these caves have been damaged in any significant way before this century.

EARLY EUROPEAN HISTORY

Initial contact with Europeans on Vancouver at Nootka Sound occurred in the late 1700's and is extensively described in many popular accounts. The main activities were fur trading, followed by coal mining lumbering and mining. There are several late nineteenth century accounts of cave and related karst features.

MODERN ERA

Vancouver Island's surface karst phenomena, and caves in particular, have always had a value far beyond that of mere recreation. Such is the modern emphasis on caves that one Vancouver Island community, the Village of Gold River, proclaimed itself the "Caving Capital of Canada" in November 1984.

SCIENCE AND EDUCATION

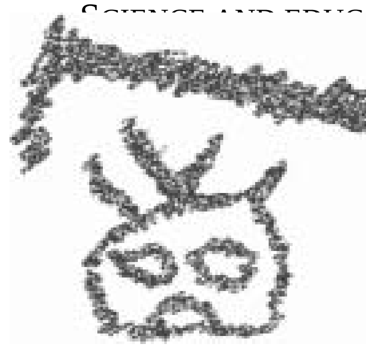


Figure 8: Cave pictograph

Vancouver Island's karst and caves have attracted a steady, albeit small number of scientists and educators. Working in cooperation with speleologists, they have recovered nearly complete skeletons of bear and deer for identification and radiocarbon dating. The sediment in which the bones are found also contain preserved pollen specimens. These provide a more complete picture of the recolonization by plant and animal life as ice began to melt, as well as information about antecedent climates.

HEAR YE! HEAR YE! HEAR YE!

Let it be known to all residents of the Dominion of Canada, that today the seventh day of November in the year of our Lord, one thousand, nine hundred and eighty four, the duly elected Council of the Municipality of Gold River in the Province of British Columbia did proudly proclaim in open session of said council that the Village of Gold river shall henceforth bear

"The Caving Capital of Canada"

And that from this day forward, any other municipality of the Dominion of Canada which attempts to claim said title as its own, shall be classed by all who witness their futile efforts as mere pretenders to the throne.

Given this day, the seventh day of November in the year of our Lord, one thousand, nine hundred and eighty four under my hand and the corporate seal of the Village of Gold River.

God Save the Queen

Mayor M. Anne Fiddick

Village of Gold River

Province of British Columbia

From page 14 of the Vancouver Province newspaper, November 29, 1984

ARCHEOLOGY

Vancouver Island continues to be inhabited by aboriginal people in multiple locations, and most of the karst is located within the traditional territory of the tribal groups. Some knowledge of aboriginal use of caves has been transmitted to speleologists by band elders.

Certain local aboriginal groups have identified mountain tops as sacred places. Butchered marmot bones found in a remote mountain top karst cave were dated to 2,900 BP.

Given its important location on the land bridge coastal migration route, the karst of coastal Vancouver Island may yet yield information about the migration of peoples along the West Coast of North America.

PALEONTOLOGY

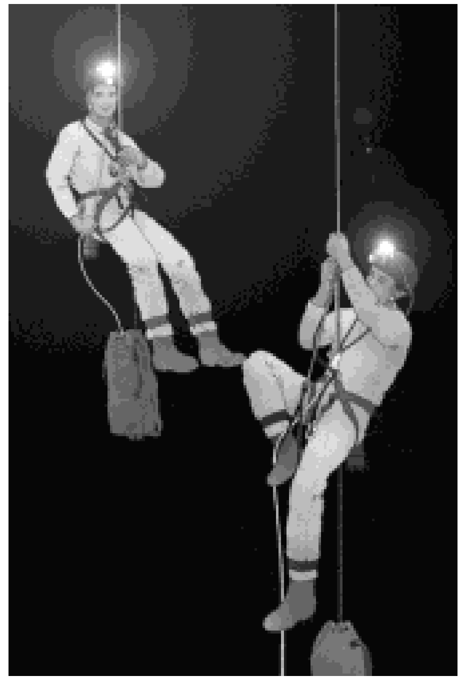
Bones removed from various caves are among the oldest known large mammal remains found on Vancouver Island since glaciation (13,000 - 16,000 years BP).

CAVE PALEOECOLOGY:

The caves of Vancouver Island have provided an exceptional opportunity for research into past flora, fauna and especially paleoenvironments. The palynology of undisturbed cave sediments has provided some unique records of the species combination in a surface environment dramatically different than the forested karst of today. For example, a pollen analysis on sediment adhering to the 9,000 year old marmot bones revealed an assemblage which suggested much more open vegetation than today. The pollen was composed of amabilis fir and western hemlock. Hemlock pollen predominated, but there were significant amounts of Douglas-fir and even some pine (*Pinus* sp.) and spruce (*Picea* sp). A large amount of charcoal was also found in some of the sediments, suggesting warm and dry conditions with higher return fire frequencies.

RECREATION

The karst of Vancouver Island is perhaps best known for its caves—Canada's finest limestone solution caves are arguably found there. Dimensionally, several caves have joined the list of Canada's ten longest and deepest caves. These caves are every bit as alluring and challenging as their worldwide counterparts.



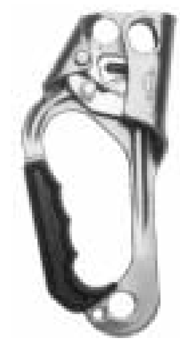
Vancouver Island was the site of some of the earliest recreational caving in Canada. The systematic exploration of karst caves began in earnest in the sixties - a scant four decades ago. This early period of exploration helped to shape the development of new equipment and techniques. Many of the originators remain engaged in exploration and scientific study.

Recreational cave exploration increased the use of the caves significantly. The early seventies saw the beginning of intense activity on the northern half of the Island, as speleologists turned their attention to the more abundant limestone deposits of the north. The caves have attracted hundreds of serious speleologists from Canada and abroad. Exploration is now increasingly shared between local caving groups and visiting speleologists speleologists from across Canada and the US, Great Britain, France, Belgium, Czechoslovakia, Germany, Spain, Italy, Indonesia, and New Zealand. Cave diving has attracted a small cadre of enthusiasts. Well-equipped teams have significantly extended the length of several northern Vancouver Island cave systems.

A first-class rescue organization known as BC Cave Rescue is recognized as the provincial cave rescue authority.

CASUAL AND COMMERCIAL USE

Until the sixties, the general Canadian public was largely unaware of karst resources in general, much less those on Vancouver Island. Interest has steadily grown since then, possibly due to the concern for health, fitness, and the environment.



Karst resources in general have had a definitive impact on the cultural, recreational, educational and economic life of Vancouver Island. Beginning in 1976 the Regional District of Mount Waddington of northern Vancouver Island sponsored public tours of the karst landmarks and caves. Horne Lake Caves Provincial Park attracts an estimated 55,000 visitors annually. More than 3,500 self-guided casual visitors experience the Upana Caves, located 17 km west of Gold River. Little Huson Caves Regional Park, another self-guided northern Island opportunity, attracts hundreds of visitors annually.

Today, it is estimated that one-third of all Vancouver Island residents have visited at least one wild cave in their lifetimes. Yet no caves have been developed as show caves for commercial purposes.

Four commercial tour operators now offer supervised surface karst viewing and visits to selected caves on a year-round basis. This tourism industry sector depends directly on the quality of the karst resources. With continuing improvements to Vancouver Island's super-highways, the demand for casual karst viewing and exploration will continue to mount. There is now a movement to apply the principles of biological carrying capacity, not just factors, to determine carrying capacity for these caves.

Northern Vancouver Island residents are quite protective of the more significant surface karst features, and are prone to decrying man-caused disturbances. The letter to the editor of the North Island Gazette reflects this stewardship ethic:

Letter to the Editor

Dear Sir:

I am writing to express my shock and disappointment in how the forest service and a logging firm treated the Benson River System and one of the natural oddities which draws tourists to the North Island.

I am referring, of course, to the Devil's Bath.

As a former North Island resident who takes pride in having lived and enjoyed the North Island, I can't believe that it was necessary to log right up to the rime of the hole.

Surely, for the number of trees involved, a 10-chain leave strip could have been implemented.

An important part of the mystique of the bath was the cedars that were growing into the hole, giving a stark contrast between the dark forest and reflected light on the water.

That is all now lost. There is now nothing but a debris-littered hole in the ground and when I took my children to see it they couldn't understand what all the fuss was about...

Brian A. Richman
Port Coquitlam

From p. 4 of the **North Island Gazette**
October 1, 1986

More About Coastal Temperate Rainforest Karst

The great majority of Vancouver Island's karst estate (about 79% or 965 km^2) occurs in the coastal temperate rainforest (CTR) biome. In North America this forest type is equivalent to the coastal western hemlock (CWH) biogeoclimatic zone. The balance of the Island's karst is found in the mountain hemlock (approximately 13% or 158 km2), alpine tundra (8% or 97 km^2), and coastal Douglas-fir zones (<1%) respectively.

CTRs are long-established forests that are exceptionally diverse and productive ecosystems in their own right. They occupy just 0.2% (or about 300,000 km^2) of the world's land surface. Pockets of CTR also occur in Chile, New Zealand, Tasmania, and Norway. Many of these pockets are predominantly hardwood and/or deciduous forests. The largest contiguous CTR area (about 150,000 km2) occurs along the west coast of North America in Oregon, Washington State, SE Alaska, and BC. Primary old growth CTR karst is restricted to Vancouver Island, Queen Charlotte Islands, and Southeast Alaska where it is commonly associated with glaciated, steeply dipping limestone.

These pristine CTR karst ecosystems are rare, and therefore globally significant for the conservation of bio- and geodiversity.

Karstification can profoundly influence the diversity and composition of biotic communities in CTR and vice versa. The forest influences the microclimate, physical structure, and energy input to karst cavities. CTR canopies and soils, for instance, moderate the patterns of runoff, snow accumulation and melt.

CTR karst ecosystems contain highly productive plant, aquatic, and wildlife communities that are vulnerable to surface disturbances. Disturbances such as wildfires, insect outbreaks, natural landslides and windthrow have influenced the natural development of CTR karst systems. The forest management practices that are used to control some of these events can also affect karst systems, changing their structures and processes.

Wildfires

Forested karst on Vancouver Island is inherently resistant to wildfire—the majority is found where the natural fire return frequency is considered to be the lowest because of its maritime exposure. Natural wildfires in primary forests tend not to be as destructive as prescribed slashburns. As well, human intervention and suppression have reduced the amount of karst affected by fire of all types.

Insect outbreaks

The high biodiversity of Vancouver Island's remaining primary old-growth forests helps to minimize the impact of insect outbreaks. Some of the outbreaks are initiated directly or indirectly by industrial forestry. Chemical and biological controls were used to minimize the area affected. The current responses emphasize salvaging damaged stands.

Natural landslides

The inherent properties of the karst on Vancouver Island mitigate against natural landslides. Mid- to high elevation epikarst is highly developed and covered with minimal overburden. The cause of natural landslides is difficult to establish in cases where proximal forest development is a contributing factor. A minimal number of landslides have been recorded in karst. A more significant number of landslides originate upslope and off the karst. Natural landslides in karst are comparatively rare because much of the bedrock is covered by a thin protective layer of organic soil and forest litter and little, if any, mineral soil. This prevents landslides and consequently surface erosion over large areas. Microsite slides can occur over short steep sections of thinly covered bedrock.

Natural windthrow

Windthrow is a random natural occurrence in karst. Hurricane strength winds are not unknown in this century. Shallow rooted tree species with large "sail" areas are especially prone to windthrow. Certain other species appear to exploit the solution cavities in thinly soiled epikarst to obtain firm anchors. These latter trees can nonetheless suffer stembreak during high winds.

EXTENT OF TIMBER HARVESTING ON KARST

Despite their sensitivity, Vancouver Island's CRT karst ecosystems are among the most developed for timber harvesting—northern Vancouver Island is one of BC's most productive timber harvesting regions. The timber volume is class 3 or greater (i.e., >410 m3/ha); usually class 4 or greater (i.e., > 691 m3/ha). The higher timber production on karst sites is due in part to the nature of the soil overlying the limestone bedrock. The age is almost always class D (i.e., 350+ years) and the height class is almost always 4 or greater (i.e., > 28.5 m)

The abundance of CRT karst in valley bottoms and mid-elevations, as well as the ability to harvest timber in these areas, has led to intensive exploitation. Estimates based on the crude analysis of 1995 satellite imagery reveals that about 84% of the CWH limestone (or about 812 km2) has been altered by historical forest development activities. By comparison, very little of the non-CWH limestone has been disturbed since commercial logging began on the Island in the 1860's.

The amount of timber harvested on karst over time shows the magnitude of this anthropogenic disturbance. About 90% of the annual harvest on karst is carried out in primary old-growth forests by clearcutting. Harvest levels in the higher elevation karst have increased relative to low elevations because the high-volume mature forests in the lower karst have already been harvested.

The replacement forests on karst, where they have been successfully established, are generally not of a merchantable age. This is especially true in Vancouver Island's northwest corner.

Figure 9: Timber Harvesting on Vancouver Island - the Early Years

TABLE 3: VANCOUVER ISLAND'S COASTAL TEMPERATE RAINFOREST KARST IN A GLOBAL CONTEXT

CATEGORY	KM^2
World's soluble rocks at surface	30,000,000
World's CTR	300,000
CTR in US and Canada	150,000
Total karst on Vancouver Island	1,200
CTR karst on Vancouver Island	965
Unlogged CTR karst on Vancouver Island	150
As % of CTR karst on Vancouver Island	16
As % of world's soluble rocks	0.0005

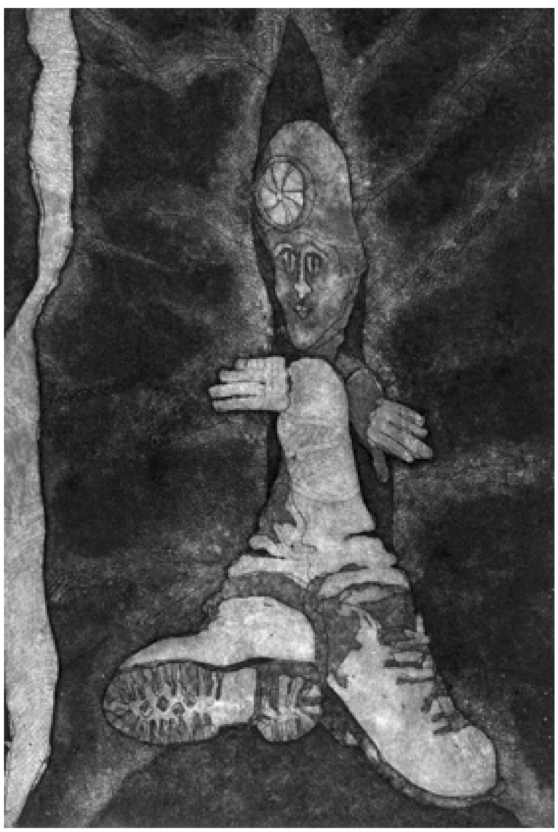


Figure 10: "Born to Cave"

SELECTED FOREST MANAGEMENT ISSUES RELATED TO KARST

Examples of karst ecosystem alterations that result from forest development activities are readily seen along the tour route. In some instances, inadequate forest practices have caused excessive soil erosion and reduced site productivity. This has been attributed in part to loss of organic matter to epikarst cavities, soil incineration, and perturbation of nutrient cycling and mycorrhizal communities. It has also been postulated that these processes may impair longer-term tree regrowth.

One of the most important determinants of karst vulnerability is the degree of epikarst development, as evaluated by the frequency and depth of the discrete surface karst features. Epikarst controls the transfer of water (and suspended or dissolved materials) to the underlying conduits and caves. Features can range in size from the macroscale (e.g., dry gullies) to dissolution runnels. The better-developed epikarst is considered to be more vulnerable to surface disturbance. The thickness and characteristics of the overlying soil are known to influence epikarst dissolution rates.

BALLAST QUARRYING

Limestone is frequently quarried in karst because it is a good road ballast. Ballast quarries can have a severe and lasting impact on karst. The number of ballast quarries developed in karst over time shows the magnitude of this disturbance. In general, the frequency of quarrying in karst is proportionally higher than in other geological settings.

ROADBUILDING

One of the major causes of soil erosion on karst is roadbuilding. The annual rate of roadbuilding has increased slightly due to the shift to higher elevation karst and new requirements for cutblock spacing. When the logging roads are cut into a slope, they change natural drainage patterns and expose soil. Knowledge of road-related problems in karst is limited. Pre-development surveys attempt to identify critical slopes and soils so that roads can be rerouted, built only under special rules, or not built at all.

Road debuilding can also have a severe impact on karst.

TIMBER HARVESTING

Harvesting by any known method inevitably results in some damage to the thin soils that generally overlie limestone. Clearcutting in karst can cause massive soil erosion and degraded quality and quantity of water (both on the surface and underground). Soil displacement and compaction are common disturbances. These disturbances can either increase or decrease the natural infiltration pattern on karst. Occasionally, displaced soil is entirely lost to karst cavities. New forest practices and harvesting equipment are aimed at reducing the amount of soil disturbance. More research and development are required to reduce and rectify any damage we do during harvesting on karst.

PRESCRIBED BURNING

The prescribed burning of logging residue can have a severe impact on karst. Slashburning after harvesting exposes more mineral soil than clearcutting alone. To minimize soil exposure and damage, guidelines based on soil conditions are used to identify where and how to burn. Foresters can pick the right time to burn to minimize exposed soil. Today only 20 percent or less of what we log, and we use lower intensity burns than in the past. The practice of intense burning was phased out in the early eighties.

SLASHFIRE ESCAPES

The escape of prescribed burns from target areas to adjacent karst is a concern. The decline in amount of area affected in recent years is reflective of the reduced number of burns, improved preventive measures, and suppression.

APPLICATION OF FOREST CHEMICALS

In normal use forest chemicals such as pesticides are applied in a manner so as to minimize adverse effects on non-target organisms. For example, the direct application to surface waters and buffer strips is avoided. These measures reduce entry and impact of the pesticides in aquatic habitats such as ponds, lakes, and streams. Karstic openings are difficult to see and may be sprayed along with the rest of the area. Contaminated detrital matter from adjoining areas can also migrate into the karst aquifer. Also, pesticides and their residues can rapidly infiltrate directly into the karst aquifer.

DEVELOPMENT-RELATED WINDTHROW

Clearcutting can expose timber stands bordering cutblocks to unnatural wind patterns and forces, with the result that less resistant trees are occasionally blown down. The inevitable consequences have dramatically altered some of the most significant karst sites. Windthrow destroys old growth-forest habitat and dislodges underlying soil and bedrock on a massive scale. It diminishes the visual appeal of surface features and renders access to some caves difficult, if not dangerous. The careful design of windfirm cutting boundaries, together with a buffer zone as an added margin of safety, is the current practice.

DEVELOPMENT-RELATED LANDSLIDES

Concern has been expressed about the occurrence of landslides that result from industrial forest development. Landslides are more common in areas that are roaded and clearcut, than in undeveloped areas. Soil mapping is conducted to identify areas prone to landslides. Landslides in steep karst subjected to timber harvesting were a more frequent occurrence before 1980. Many of the historical slope failures were linked to unstable roads and some to prescribed burning.

Despite recent efforts some landslides are inevitable, given the steep mountains, high precipitation and frequency of storms on the west coast of Vancouver Island. The statistics indicate they actually occur in only a minor fraction of all karst areas. These events can change the natural pattern of erosion and sedimentation in karst. The consequent loss of regeneration can also reduce the long-term commercial timber supply. Impacts to non-timber resources include the blockage of sinkholes, sinking streams, cave entrances, and the many inconspicuous atmospheric openings.

SOIL DISTURBANCES

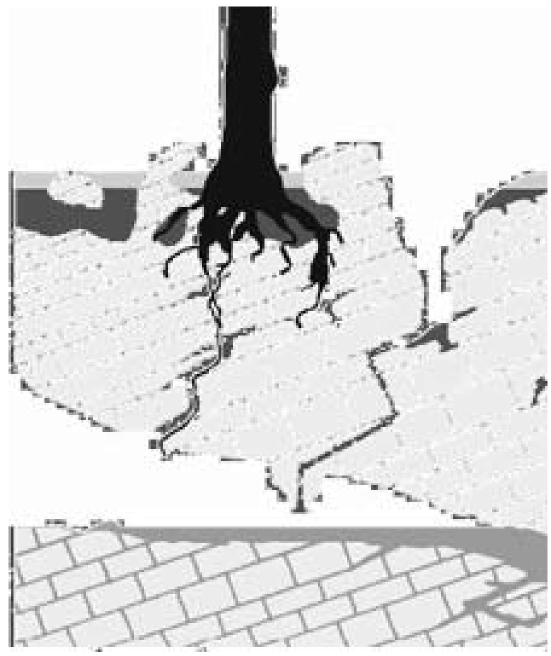


Figure 11: Cross-section of Epikarst Before Harvest

Water acting on soil exposed by anthropogenic surface disturbances can transform both surface and subsurface karst landscapes. Soil and sediment are eroded from the surface landscape, transmitted through the epikarst, then transported through karstic conduits, and eventually deposited in caves or discharged to surface watercourses at springs. Natural, or geologic erosion of this soil takes place slowly by comparison. Karst folisols can be measurably changed by clearcutting. In a 1986 study, as much as a 60% reduction in soil depth was recorded over limestone bedrock. The mean soil depth before cutting was about 25 cm. The reduction of soil depth on analogous volcanic bedrock with similar pre-harvest soil depth, gradient and aspect was insignificant by comparison.

Where the soil loss is severe, vegetation is re-established with great difficulty, and the growth of merchantable species may be inhibited.

Soil and bedrock disturbances around the rim and on the interior slopes of steep-walled depression features are another important problem. The soil covering undisturbed

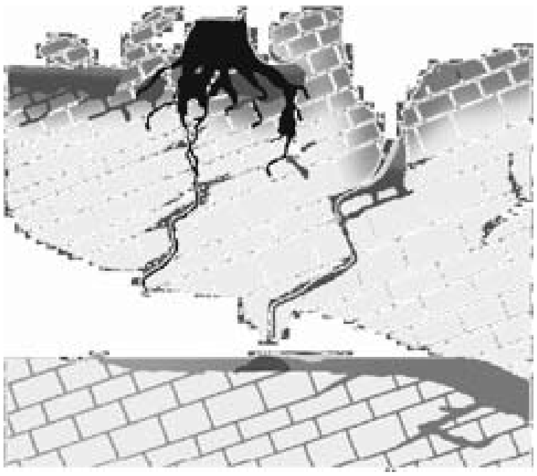


Figure 12: Cross-section of Epikarst After Harvest

slopes is already very thin. This forest vegetation is very difficult to restore.

LOGGING RESIDUE AND DEBRIS

The problem of logging residue and debris is not just one of environmental pollution and aesthetics. The accumulations can impede access to cave entrances, and pose a serious hazard to the unprotected visitor. As well, the debris can often smother the smaller vegetation and destroy wildlife habitat at the entrance. In extreme cases, entrance can be completely blocked, thereby closing the interior of the cave to the larger mammals (including speleologists). Active cave systems can trap influent debris, leading to clogging of reverse siphons by matrices of solid wood. On the surface, solid wood residue can decompose over as little as five years.

TREE REGENERATION RATES

There is public concern that the commercial timber in primary old-growth forest is not being "replaced" as rapidly as it is being cut. Where non-native commercial tree species are used for planting in the past they were not always be ecologically suited to site conditions. On Vancouver Island it can take as long as 80 years for a regenerating or "second growth" forest to grow to its optimal or peak growth stage. This peak is known as the "rotation" age. Theoretically, the sustainable yield is achieved if 1/80 of the forest is harvested and then regenerated each years. The concept looks fine in theory, but it is complicated by the fact that the primary old growth forests have existed for hundreds of years and contain a varied mosaic of species, age, size and quality.

Most of the coastal old growth is not growing at all and its volume is even declining as a result of rot and other problems. In short, after a rapid period of growth, the rate slows as trees get older. For example, annual growth on a hectare of second growth for the first 80 years might be 800 cubic meters, but over the next 150 years its rate can slow significantly so that yield will be only about 1,200 cubic meters by the time it is 160 years old. If left for 350 years the volume could decline to perhaps only 900 cubic meters as the trees begin to decay.

The primary old-growth forest karst usually contains a large volume of wood per hectare—up to 1,000 cubic meters. This is more than second or successive rotations could produce. The result is that more cubic meters per hectare are harvested in the first pass through the old growth forest than in succeeding rotations. The transition from old growth to second growth is known as the "falldown effect." It happens only on the first pass, while each subsequent generation or "rotation" achieves the even flow balance of cutting what we grow.

GROUNDWATER FLOW AND QUALITY

Certain forestry practices can have an effect on groundwater flow. Tree removal can speed runoff of snowmelt and rainfall and cause soil erosion. Besides the loss of soil, this activity can have adverse effects on the subsurface systems which receive the runoff. It can increase flooding of underground systems and cause underground streams to become turbid because of the suspended matter being carried. Also, deposition of these solids create obstructions wherever the passages narrow or change direction.

Clearcutting releases water-soluble wood extractives compounds which exhibit undesirable properties such as high biochemical oxygen demand, colour, and toxicity relative to natural run off. Normally, these extractives would be detoxified as they pass through quantities of sand or gravel in conventional aquifers. However, rapid infiltration of these substances into karst aquifers has a potential to affect limestone dissolution rates, cave ecosystems, and possibly calcite deposition. Unless the action is accompanied by visible staining of the cave surfaces, this pollution is not easily recognized.

SCENIC QUALITY

Severe visual degradation of surface karst features, including scenic cave entrances, has been major a concern. The most careful of procedures cause visual changes. Where entrance zones have successfully revegetated, the new growth can be very dense and obtrusive, completely obscuring the midground and background of a viewscape for a period of 25 years or more. In severe cases the foreground is reduced to as little as two meters. This visual degradation evokes a strong emotional impact by many members of society, with the result that public use of karst sites so affected in this manner has noticeably declined

MINING AND LIMESTONE

Vancouver Island has a greater density of known mineral showings than most other parts of BC, and many of these occurrences are clustered around limestone. The Island has excellent potential for the discovery of new mineral deposits. The centers of mineralization next to limestone deposits will continue to be areas for future exploration.

The Coast Copper Benson Lake mine was a “skarn” copper deposit. Extensive vein gold deposits were also mined alongside limestone near Zeballos and Port Alberni. The mining industry on Vancouver Island has made extensive use of the industrial forest roads for both exploration and mine development. These roads also serve to expose mineral showings that would otherwise be obscured with surficial cover.

Mining activities in BC are highly regulated. The operators must comply with the Ministry of Energy, Mines and Petroleum Resources management guidelines, Forest Practice Code, and Federal and Provincial environmental legislation. Companies are responsible for environmental damage and they must submit bonds to ensure that remedial work will take place. New mines must go through federal and provincial Environmental Assessment and public review processes. All mine sites are returned to something approximating their original state when they are closed.

BENSON LIMESTONE QUARRY

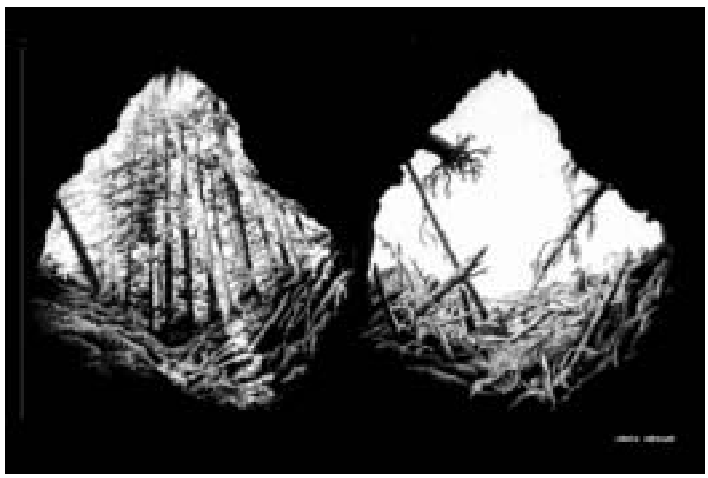


Figure 13: Glory ‘Ole as Featured on Front Cover of Canadian Caver

Artwork by Linda Heslop

After STOP 2 the motorcoach will pass within sight of the Imasco Minerals, Inc. Benson limestone quarry.

The deposit is located on the Quatsino limestone of Late Triassic age. Where the limestone has been intruded by Jurassic age Island Intrusions of diorite and gabbro it has been recrystallized to form a fine to coarsely crystalline texture and has been partially to entirely bleached to a white “marble “. The area being quarried has been bleached white by a gabbro intrusion which would have had a higher temperature than a diorite intrusion.

The quarry operates year round, weather permitting and currently employ three miner/operators and two contract haul persons. The limestone is drilled and crushed to minus six inch size, then transported thirty kilometers to Port Alice where its load on sea going barges for shipment to the company's processing plant near Vancouver.

This type of limestone is made into a number of consumer products including Acrylic Stucco, Premixed Stucco, landscape rock, White Stucco Sands, Fine flours and Fillers. The flours and fillers are used in the manufacture of drywall muds, paint products, agricultural products, plastics, paper products, etc. Although the quarry doesn't presently supply anyone directly it's products can be used as food additives.

Texada Island

The limestone quarries on Texada Island are the largest and most important in BC. In fact, Texada is the location of the only limestone deposits on the entire west coast of North America, making it the center of that industry. The three quarries on the island produce raw product for Vancouver and US markets. The majority of the limestone rock is shipped to cement plants and pulp mills along the coast of BC and Northern United States. Reserves of the rock on Texada Island are projected to be in excess of 300 million tons. At current depletion rates the reserves could provide employment for at least another century.

Limestone can reduce wood fiber requirements and prolong the life of paper

Most of the paper used in North America turns yellow and brittle within thirty years. Acid residues come from wood pulp, bleaching, or the fillers in the paper. Acid-free or alkaline papers made with fillers such as calcium carbonate (limestone) can last for two or three hundred years. They use less water, less fiber, and less bleach in the manufacturing process.

Leo d'Or marble quarry

The Leo d'Or Company began a small mine above the Bonanza Lake Caves in the eighties. The company started to extract ornamental marble (metamorphosed limestone) but eventually went into receivership and abandoned the mine. Nearby is a small underground operation .

Coast Copper tailings deposit

Acid mine drainage (AMD) can develop in underground workings, open pit mine faces, waste rock dumps, and tailings deposits. AMD can last for decades, centuries, or longer, and its impacts can travel many miles downstream. Mine tailings can be seen alongside the Benson River. The treatment of AMD can involve extensive use of limestone and lime derived from limestone.

RESPONSIBILITY FOR KARST AND CAVE MANAGEMENT IN BC

The BC Ministry of Forests is the provincial government agency responsible for minimizing the impact of industrial forest development on Crown forest lands in the province.

Cooperation between the BC Ministry of Forests and speleologists helped develop the Cave/Karst Management Guidelines for protecting caves in the Vancouver Forest Region. The procedures and principles established with the first guidelines in 1981 have changed little in the sixteen years since their introduction. The implementation and enforcement aspects, however, have improved.

Today, projected timber cutting areas are more routinely inventoried for caves and associated special karst features. After field review, surface and subsurface measures are prescribed in an attempt to protect the more sensitive features. This usually involved directional falling and yearling away from the features. Occasionally, small no-harvest zones are established around the feature. Pre-development inventories identify sensitive features so that roads can be rerouted, and harvesting modified, or no harvesting is permitted.

Figure 13: The 1983 "Method to Manage Cave/Karst Resources" for the Vancouver Forest Region

RECENT KARST MANAGEMENT INITIATIVES

It is now widely recognized that new strategies and methods of roadbuilding, harvesting, and post-harvest silviculture are needed if BC is to manage sensitive forest karst ecosystems for longer term sustainability. Several studies, including two recently commissioned by the BC Ministry of Forests, have noted that improved knowledge of forest karst resources and methods to manage them are desirable goals.

Figure14: The 1981 "Statement for Crown Land Cave Policy and Administration"

Advanced methods have occasionally been incorporated into new forest development—these will need to be validated before they are entrenched in new standards and guidelines announced under the BC Forest Practices Code.

Improved karst and cave management practices, as well as pressure from the scientific and environmental communities, are expected to continue to affect access to these sensitive forest resources and the availability of fiber throughout BC, especially on northern Vancouver Island.

HOW MUCH RAINFOREST KARST IS PROTECTED ON VANCOUVER ISLAND?

The current system of protected karst areas (i.e., established for karst protection primarily) on Vancouver Island now encompasses 4% (or about 50 km2) of the Island's total karst estate. A portion of this system is non-CTR, non-karst, or developed or modified CTR karst. Less than half of the total area protected is primary old-growth CTR karst.

Additional old-growth CTR karst is incidentally captured by pre-existing predominantly non-karst protected areas such as Strathcona Provincial Park.

Most caves on Vancouver Island are not privately owned where they occur on Crown Land. As yet, there is no specific provincial or federal law that protects caves from vandalism or obliteration. The establishment of laws to protect natural caves in BC is a longstanding goal of many speleological groups.

CAVE POLICIES

Management of caves on Vancouver Island is achieved by the combined efforts of the BC Ministry of Forests, the BC Parks, BC Environment, forest sector companies, and caving groups.

ABOUT THE TOUR PROGRAM

ON-SITE SPEAKERS AND INTERPRETERS

Designated on-site speakers, including land managers, foresters, engineers, scientists, karst specialists, and speleologists will be asked to informally present information at each of the tour stops. These individuals will be technically competent, recognized authorities on the subject of karst processes in a forest environment.

The speakers will strive to complement, and not duplicate each other. They will be accessible to answer questions, provide information, and talk to participants before and after the tour.

French and German language translation will be provided based on anticipated demand.

We have developed an extensive list of discussion themes and key messages in a checklist format. Many of the topics relate to challenges associated with all phases of past and present day forest development activities on karst (from roadbuilding through to post-harvest treatments). Road deactivation and post-harvest silviculture treatments will be covered. Examples of specific historical problems could include:

- Excessive ground disturbance caused by conventional falling and yarding
- Prescribed slashburning and wildfires
- Post-harvest induced windthrow
- Diminished tree regrowth

- Sideslope failures
- Induced subsidence
- Debris clogs, siltation, and backflooding

SAMPLE TOPIC

"Hydrocarbon spills and leaks in forest karst environments"

Gasoline contains many organic compounds that are sufficiently soluble in water to pose a threat to karst groundwater quality. Both benzene and toluene are regarded as hazardous contaminants. Even small spills of gasoline have the potential to render large portions of a karst aquifer contaminated. As an example, using the detection limit of 5 parts per billion as the criterion for contamination, one litre of gasoline has the potential to contaminate 4 x 106 litres of karstic groundwater.

SAMPLE SYNOPTIC DESCRIPTION OF A TOUR STOP

STOP 1 - ETERNAL FOUNTAIN

A low elevation karst site logged in the late sixties. Karst features include sinkholes, caves and springs. Not far from the "fountain" is the corduroy road constructed in 1912 to serve the Old Sport Mine at nearby Benson Lake. We will be passing the mine site on the way to STOP 2A. Once across the platform at the "fountain", a series of short steps climbs up the bank and to a trail circuit. A ten minute walk will bring us past small sinkholes and karstic openings in the forest floor. The trail comes out at the access road.

DESCRIPTION OF A TOUR STOP

CROSS RIVER DRAINAGE

BACKGROUND INFORMATION

The Cross River originates in Cross Lake and flows southwesterly into the Tahsish River. The area receives high annual precipitation. There are numerous sinking and dry stream beds. Streams and caves with active water flows are subject to severe seasonal flooding. During the summer months the water table drops and caves are more accessible.

Strong winter storms buffet the west coast of Vancouver Island. These warm Pacific winds are funneled up the Tahsish River valley making it prone to natural windthrow events. This is evident by the hummocky terrain, residual snags and age distribution of the forest cover.

The biogeoclimatic zone is CWH-vm1 (Coastal Western Hemlock very wet maritime influence). Major tree species include western red cedar, hemlock, and balsam. Typical undergrowth includes devils club, red huckleberry, Alaskan blueberry, sword fern, deer fern, and step mosses.

A significant portion of the watershed is underlain by Quatsino Formation limestone. Generally, the area is characterized by deep soils (60-100 cm over limestone) and zones of intense karstification. Common karst features are sinkholes, swallets, and caves. Along the rivers and streams, sculpting and karst canyons occur. Slopes are low to moderate on the valley floor. Water transport of vegetation debris and up to cobble size sediments is common.

The first cave inventory was completed in 1982. Since then, 28 more have been completed, all with the exception of three during the nineties. Draft inventory reports for all existing standing timber have just been submitted and are under review by the Ministry. Logging in proposed areas where inventories are not yet complete has been deferred until all karst inventories are complete.

UPPER TAHSISH RIVER HARVESTING HISTORY

In order to understand the present situation concerning karst management and harvesting in the Upper Tahsish River, it is important to understand the logging history of the area.

In the early 1900's the BC government sold forest companies the rights to harvest crown timber under a variety of timber tenures collectively known as timber licenses (TLs). Timber licenses grant the company exclusive rights to harvest all timber from a defined area of Crown Land, within a given time period. They are not renewable or replaceable. Once the timber is logged and the land reforested, or on the expiration date all rights and obligations under the timber license end.

During the eighties, as the expiry dates of these timber licenses drew near, there was an urgency to harvest the standing timber and logging occurred at an accelerated rate. Timber harvesting, using continuous clear cutting, started in the upper Tashish and Cross River watersheds as a result of this situation.

An amendment to the Forest Act allowed the term of a timber license to be extended, which then removed the pressure and slowed harvesting activity. New timber licenses are not issued. All harvesting is now subject to the new Forest Practices Code of British Columbia Act.

General Information

Cutblock AT286 WF (windfall) was logged in response to widespread blowdown of the forest along a block edge following the east fork of the Cross River tributary of the Tahsish. This front was aligned roughly perpendicular to the prevailing winds. The windthrow spread progressively from an unstable cutblock boundary. Many of the trees were uprooted and fell with most of their root systems intact, tearing up the soil in the process. Other trees were snapped off in the bole, with no uprooting. Salvage operations commenced in 1991/92 and concluded in 1993. A cave inventory and assessment was done prior to road construction. Results were less than satisfactory due to difficult work conditions.

Cutblock AT286 DD is an addition to this block in response to continued windthrow problems.

The current stand is 22.5 hectares (55.6 acres) in size. Approximately 30% of the volume will be removed; only dead and down trees will be taken and some hazard trees. This is a selective harvest attempting to create a feathered wind firm edge. Measures will be taken to minimize debris and soil transport into the karst system.

Approximately nine cave features have been located within the block boundary. There are a number of large sink holes, wells (flooded pits), collapse features, and stream sinks. Many of these features have been negatively affected by the large amounts of downed wood.

The Ministry of Environment (MoE) has an interest in this block due to the proximity to the proposed Forest Ecosystem Network (FEN) that is adjacent to the area. MoE is concerned with the large amount of blow down in the area and the potential for further windthrow problems creeping within the boundaries of the FEN. They have been strongly involved in the decision making process regarding the approved cutting permit.

The stand is currently being attacked by the silver fir beetle (*Pseudohylensis sericus*), a species that is known to attack windthrown trees. Company foresters and Provincial Government entomologists are closely monitoring this infestation. The principal host tree within block AT286 D&D is balsam (*Abies amabilis*), also known as Pacific silver fir. Selective cutting of the dead or dying trees and salvaging the downed timber and are expected to moderate the infestation before it spreads into the adjacent FEN. No chemical pest control agents will be used to control this insect epidemic.

Forest ecosystem network: a planned landscape zone that serves to maintain or restore the natural connectivity within a landscape unit. A forest ecosystem network (or FEN) consists of a variety of fully protected areas, sensitive areas and old-growth management areas.

Identification of Karst Features

The inventoried karst features have been flagged in the field with a combination of pink, and blue and white striped ribbon. Ribbon pieces are hung vertically at intervals around each feature. One or more pieces and/or a tree blaze are marked with the feature identifier or name. The depression features are delineated at the rim to protect the sensitive inner side slopes which are sensitive to ground breaking disturbances. The inside area is termed the "feature protection zone".

ADMINISTRATIVE MEASURES

The crew members have been briefed on the karst resources values to be protected and provided with site maps and approved prescriptions. They have taken an active interest in the implementation and refinement of prescriptions, to better protect the features or to mitigate adverse impacts. The enthusiasm of the crew has led to some innovative solutions. Workers have also been advised of the special hazards posed by the sinkholes, pits and other surface depressions.

FALLING OF STANDING TIMBER

Directional falling techniques are used to avoid dropping trees over the identified karst features. The non-merchantable trees and residuals are left as intact as possible. The leaners and safety trees are removed to comply with Industrial Health and Safety Regulation. Hazardous snags are felled away from the identified features if it is safe and practicable to do so. These snags can fall and kill or injure workers. They are sometimes knocked or pulled down by the hoe. Other snags can be retained for wildlife habitat purposes. Recovery of diseased trees will help to prevent the spread of the insect disease to the adjacent stand. Standing green trees (i.e., sound trees) are left to provide a feathered edge.

FEATURE-SPECIFIC PRESCRIPTIONS

The approved prescription is to leave any natural fallen trees in place and to remove only the windthrown tress. The buttlogs of windthrown trees are removed from inside the feature protection zone only if minimal disturbance can be assured. Small recoverable debris that is incidentally or inadvertently introduced during this operation is manually retrieved and placed outside the feature. Areas of unavoidable or unintentional ground disturbance and exposed soil are stabilized by methods such as artificial seeding.

The prescription is to fall and yard away from streams. Any introduced debris will be hand and machine cleaned concurrent with the yarding. When cleaning sinkholes and sinking streams, the overall objective is not to remove stable, natural debris that is at or below the rim or that is embedded in the sideslopes, banks, or root systems that contribute to bank or slope stability.

RECOVERY OF BLOWNDOWN TIMBER

Downed merchantable trees are limbed and bucked in place if safe to do so. Otherwise, the hoe lifts and moves the tree to a safe place. Root wads are not bucked off where they might fall into a karst feature. The hoe operator moves the buttlog away from the feature, being careful not to dislodge the mass of dirt and rocks caught up in the root system.

HARVESTING PRESCRIPTION

HOE FORWARDING OR HOECHUCKING

Neither cable yarding nor ground skidding methods are permitted. The logs are moved by a ground-based yarding method known as hoe forwarding (hoechucking). Excavators with a reach of about 15 m, multidirectional capability, and a skilled operator are particularly well-suited to this operation. The hoe is a tracked machine that travels over the ground using woven mats made of rubber tires. Use of the rubber mat reduces soil disturbance. A network of dispersed hoe trails is established on stable ground and outside of the feature protection zones. They are temporarily colddecked at intervals along the hoe trails and decked for road transportation on spur NC 3300 nearby. Logs are suspended off the ground and not dragged. A second observer is sometimes needed to guide the removal of material from within depressions. Surfaces with thin protective cover are avoided. Hoechucking can be stopped during periods of heavy rainfall. Hoechucking in very wet terrain is only permitted in dry season and only with flotation mats.

DISPOSAL OF LOGGING RESIDUE

Limbs and other residual logging wastes (mainly branches, twigs, needles, etc.) are left in place (or spread slightly over the ground to provide planting space). Slash recovery and burning are not permitted activities. Bucked windfall roots are stood up to protect the underlying ground from erosion. This also reduces the risk of a root wad unexpectedly rotating or turning back, and possibly crushing workers or recreational visitors.

POST-HARVEST TREATMENTS

Native species will be planted as soon as possible. No post-harvest pesticide treatment will be allowed, to protect the karst aquifer and cavernicoles.

CLOSURE OF BALLAST QUARRY

The limestone ballast quarry is not in use and will be closed. Old stumps and other decomposing wood residue were recently removed to other storage locations. The steep soil slope on the east side of the quarry will be restabilized and artificially seeded if necessary. A permanent closure plan will be developed that attempts to mimic the natural infiltration and groundwater circulation patterns that existed prior to development

MANAGEMENT OF FUEL

Motor-powered saws and portable fuel containers are kept in a designated area clear of the hoe access trails and away from karst features.

GLOSSARY

Adaptive management

Adaptive management rigorously combines management, research, monitoring, and means of changing practices so that credible information is gained and management activities are modified by experience.

Biogeoclimatic Ecosystem Classification System

A hierarchical classification scheme having three levels of integration - regional, local, and chronological; and combining three classifications - climatic, vegetation, and site.

Blowdown (windthrow)

Uprooting by the wind. Also refers to trees so uprooted.

Cable logging

A yarding system employing winches, blocks, and cables.

Canopy

The forest cover of branches and foliage formed by tree crowns.

Cave

A cave is defined by BC Ministry of Forests as “a cavity in the earth which connects with the surface, contains a zone darkness and is large enough to admit a human being”.

Clearcutting silvicultural system

A system in which the crop is cleared from an area at one time and an even-aged, replacement stand is established. It does not include clearcutting with reserves. Clearcutting is designed so that most of the opening has full light exposure and is not dominated by the canopy of adjacent trees (this produces an open area climate). The minimum size of a clearcut opening is generally considered to be one hectare.

Coarse woody debris

Sound and rotting logs and stumps that provide cover for plants, animals, and their predators.

Cutblock

A specific area, with defined boundaries, authorized for harvest.

Drainage structures

Includes metal and wooden culverts, open-faced culverts, bridges, and ditches.

Ecosystem

A functional unit consisting of all the living organisms (plants, animals, and microbes) in a given area, and all the non-living physical and chemical factors of their environment, linked together through nutrient cycling and energy flow. An ecosystem can be of any size - a log, pond, field, forest, or the earth’s biosphere -but it always functions as a whole unit. Ecosystems are commonly described according to the major type of vegetation, for example, forest ecosystem, old-growth ecosystem, or range ecosystem.

Edge effect

Habitat conditions (such as degree of humidity and exposure to light or wind) created at or near the more-or-less well-defined boundary between ecosystems, as, for example, between open areas and adjacent forest.

End hauling

Removal of excess materials from one section of road to another or to a designated waste area, instead of sidecasting.

Folisol

Soils consisting of decomposed vegetable litter (i.e., from foliage)

Forest Practices Code

A package of legislation, regulations, and standards that govern forest practices in British Columbia.

Ground-based systems

Logging systems that employ ground-based equipment such as feller-bunchers, hoechuckers, skidders, and forwarders.

Harvesting (Logging)

Forest harvesting activities including felling, yarding (skidding), hauling, and road building; the cutting and removal of trees from a forested area.

Large woody debris

Large tree part; conventionally a wood piece greater than 10 cm in diameter and 1 metre in length.

Old growth

Old growth is a forest that contains live and dead trees of various sizes, species, composition, and age class structure. Old-growth forests, as part of a slowly changing but dynamic ecosystem, include climax forests but not sub-climax or mid-seral forests. The age and structure of old growth varies significantly by forest type and from one biogeoclimatic zone to another.

Recreation feature

Biological, physical, cultural, or visual features that have an ability to attract and sustain recreational use.

Recreation resource

Any biological, physical, cultural, historical, scenic, or wilderness feature that has recreational significance or value, or any recreational facility.

Riparian area

The land adjacent to the normal high water line in a stream, river, lake, or pond and extending to the portion of land that is influenced by the presence of the adjacent ponded or channeled water. Riparian areas typically exemplify a rich and diverse vegetative mosaic reflecting the influence of available surface water.

Riparian management zone

The area within and adjacent to riparian and other wetlands required to meet the structural and functional attributes of riparian ecosystems.

Road deactivation

Measures taken to stabilize roads and logging trails during periods of inactivity, including the control of drainage, the removal of sidecast where necessary, and the re-establishment of vegetation for permanent deactivation.

Selection silvicultural system

A silvicultural system that removes mature timber either as single scattered individuals or in small groups at relatively short intervals, repeated indefinitely, where the continual establishment of regeneration is encouraged and an uneven-aged stand is maintained.

Sidecasting

Moving excavated material onto the downslope side during construction.

Snag

A standing dead tree or part of a dead tree from which at least the smaller branches have fallen.

Understory

Any plants growing under the canopy formed by others, particularly herbaceous and shrub vegetation under a tree canopy.

Yarding (yarding systems)

In logging, the hauling of felled timber to the landing or temporary storage site from where trucks (usually) transport them to the mill site. Yarding methods include cable yarding, ground skidding, and aerial methods such as helicopter and balloon yarding.

Mailing Address of Participants

Arnold J Albrecht
USDA - Forest Service Alaska Region
P.O. Box 21628
Juneau, AK 99802 US

Tom Aley
Ozark Underground Laboratory
Ozark Underground Laboratory
1572 Aley Lane
Protem, MO 65733 US

Stan Allison
National Parks Service Wind Cave Nat Park
RR1,Box 190
Hot Springs, SD 57747 US
stan_allison@nps.gov

David Anderson
Washington Dept of Fish & Wildlife
Olympia, WA US

Jim Baichtal, U.S.F.S Tongass National Forest
Thorne Bay Ranger District
P.O.Box 19001
Thorne Bay, AK 99919 US
/S=J.BAICHTAL/OU1=R10F05D04A@mhs-fswa.attmail.com

Bronwen Beedle
B.C. Ministry of Forests
Victoria, BC CANADA

Richard J Bielefeld
4538 Lake Washington Blvd.
Kirkland, WA 98033 US

Brian Bischoff
Canadian Underworld Tours
2120 Minto Ave.
Nanaimo, BC V9R 5X9 CANADA
bribis@island.net

Megan Bogle
Targhee National Forest
PO Box 777
Driggs, ID 83422 US

Cameron Brady
B.C. Ministry of Forests
2291 Mine Road Place
PO Box 7000
Pt McNeil, BC V0N 2R0 CANADA

Mason D Bryant
U.S.D.A. Forest Service PNW Research Station
27709 Sherwood LN 2A
Juneau, AK 99801 US
mbryant@ptialaska.net

Gabrielle K Call
The Nature Conservancy of TN
50 Vantage Way Suite 250
Nashville, TN 37228 US
gcall@tnc.org

Davis L Campbell
The Nature Conservancy of TN
50 Vantage Way, suite 250
Nashville, TN 37228 US
gcall@tnc.org

Kent Carlson
Karst Biosciences
1155 King Street
Christiansburg, VA 24073 US
kcarlson@vt.edu

Richard E Carlson
Deschutes National Forest
Deschutes National Forest
1645 Highway 20 East
Bend, OR 97701 US

Dale Chase
VICEG
7500 Central RD
Hornby, BC V0R1Z0
humpfery@mars.ark.com

Brian Clark
Naracoorte Caves Conservation Park
P.O. Box 134
Naracoorte, S. Aust 5271 AU

Mike Compton
Northwest Caving Association
PO Box 293
Yelm, WA 98597 US
ncacaver@aol.com

Lynn Cornelius
The Nature Conservancy
38609 N.E. 21st Ave
La Center, WA 98629 US

Charlie Cornfield
BC Ministry of Forests
370 South Dogwood St.
Campbell River, BC V9W 6Y7 CANADA

Sheryl Craig
2601 Grove St.
Bellingham, WA 98225 US
recraig2@telcomplus.com

Rane L Curl
Karst Waters Institute, Michigan Karst Conservancy
2805 Gladstone Ave
Ann Arbor, MI 48104 US
ranecurl@umich.edu

Robert R Currie
US Fish & Wildlife Service
160 Zillicoa St
Asheville, NC 28801 US
Robert_Currie@fws.gov

William A Curry
Conservation Association, USES, NSS
221A Highland Ave
Knoxville, TN 37916 US

Marsha Davis
National Park Service
909 First Avenue
Seattle, WA 98104 US
marsha_davis@nps.gov

Martin Davis
Island Karst Research, B.C.S F.
3974 Blenkinsop Rd.
Victoria, BC V8P 3P9 CANADA
iskar@pacificcoast.net

Scott Davis
20614 114th St. East
Sumner, WA 98390 US
sdavis@wdni.com

Joel D Despain
National Parks Service
Sequoia National Park
Three Rivers, CA 93271 US
joel_despain@nps.gov

David Ek
National Parks Service
Route 3, Box 604 - FC
Astoria, OR 97103 US
David_EK@NPS.GOV

Kris Esterson
Florida State U
446 Conradi St Apt #F205
Tallahassee, FL 32304 US
fskae1@aurora.alaska.edy

John Farr
Aegis Services Inc

Derek Ford
McMaster University, Geography
1280 Main St
Hamilton, ON L8S 4K1, CANADA
dford@mcmail.CSI.McMaster.CA

Dick Garnick
1997 KCMS, NSS/Cascade Grotto
PO Box 28310
Bellingham, WA 98228 US
rgarnick@nas.com

Margot Geisler
Project Underground
5815 W. Rois Rd.
Richmond, VA 23227 US
RICHG@chemtreat.com

James Goodbar
Bureau of Land Management
620 E. Green Street
Carlsbad, NM 88220 US
jgoodbar@nmo150wp.nmso.nm.blm.gov

Jeff Gore
Florida Game & Fresh Water Fish Commission
6938 Highway 2321
Panama City, FL 32409 US

Dale Green
Salt Lake Grotto, NSS
4230 Sovereign Way
Salt Lake City, UT 84124 US
dajgreen@burgoyne.com

Allen Griffiths
544 Springbok Road
Campbell River, BC V9W 8A2 CANADA

Karen Griffiths
Cave Treks
544 Springbok Road
Campbell River, BC V9W 8A2 CANADA
kgriff@island.net

Paul Griffiths
B. C. Speleological Federation
544 Springbok Road
Campbell River, BC V9W 8A2 CANADA
pgriff@island.net

Chris Groves Ph. D.
Center for Cave and Karst Studies
Dept of Geography & Geology
Western Kentucky University
Bowling Green, KY 42101 US

Elery Hamilton - Smith
Australasian Cave & Karst Management
P.O. Box 36
Carlton South, Victoria 3053 AU
elery@melb.alexia.net.au

Bill Heidrick
Nootka Resource Board
Box 37
Zeballos, BC V0P 2A0 CANADA

Doug Herchmer
Ministry of Forests
2100 Labieux Road
Nanaimo, B.C. V9T 6E9 CANADA
doug.herchmer@gems3.gov.bc.ca

Linda Heslop
1734 Albert Ave
Victoria, BC V8R1Z1 CANADA
linda.heslop@bcc.org

Val Hildreth-Werker
NSS
PO Box 1018
Tijeras, NM 87059 US
werks@worldnet.att.net

Greg Horne
Parks Canada - Jasper National Park
Box 10
Jasper, Alberta T0E 1E0 CANADA
greg_horne@pch.gc.ca

Rodney D Horrocks
NPS, Timpanogos Cave & Great Basin National Park
RR 3 Box 200
American Fork, UT 84003 US
Rodney_D._Horrocks@nps.gov

Bob Hounshell
Forbidden Caverns
455 Blowing Cave Rd.
Sevierville, TN 37876 US

Frank Hovenden
The Record, Box 279, Gold River, BC V0P 1G0
1420 McPhee Ave.
Courtenay, B.C. V9N 3A5 CANADA
hovenden@mars.ark.com

Peter Huntoon, Ph. D.
University of Wyoming, Dept of Geology & Geophysics
P.O. Box 3006
Laramie, WY 82071 US
Huntoon@UWYO.edu

George Huppert
ACCA /University of Wis. La Crosse
Dept of Geology & Earth Sciences
University of Wis La Crosse
La Crosse, WI 54601 US
Huppert@mail.uslax.edu

Kylie Hutchinson
Vancouver Caving Club
44-1656 Adanac St
Vancouver, BC V5L2C6 CANADA
kylieh@uniserve

Bill I'Anson
6662 Tammany Drive
Victoria, B.C. V8Z 5Y7 CANADA
bianson@islandnet.com

Jim Kennedy
Bat Conservation International
P.O. Box 162603
Austin, TX 78716 US
jkennedy@batcon.org

Ronal Kerbo
National Park Service
P.O. Box 25287
Denver, CO 80127 US

Stephen J Kimball
USDA Forest Service
Thorne Bay Rd
PO Box 19001
Thorne Bay, AK 99919 US

Steve Kimball
U.S.F.S. Tongass National Forest
Federal Building
Ketchikan, AK 99901 US

Larry King
NWACCA
PO Box 14882
Portland, OR 97293 US
lking@teleport.com

Kenneth J Kingsley
SWIC Inc. Environmental Consultants
343 S. Scott Ave
Tucson, AZ 85701 US
KjKings@azstarnet.com

Dave Klinger
Glacier Grotto
P.O. Box 537
Leavenworth, WA 98826-05 US
dklinger@rightathome

Steve Knutson
National Park Service
41811 SE Laudon RD
Corbett, OR 97019 US
sssknutson@aol.com

Jeff LaLande
Rogue River National Forest
Rogue River National Forest
P.O. Box 520
Medford, OR 97501 US
jlalande@jeffnet.org

Ken Langdale
BC Ministry of Forests - Chillwack Forest District
9850 South McGrath Road
PO Box 159
Chillwack, BC V0x x0 CANADA

Julian J Lewis
Blue River Area Cave Bioinventoring
217 West Carter Avenue
Clarksville, IN 47129 US

Steve Lewis
U.S Forest Service / U. of AK Museum
P.O. Box 19001
Thorne Bay, AK 99919 US

Mark Ludlow
Florida Dept. Environmental Protection
Florida Caverns State Park
Marianna, FL 32446 US

Chandra Madrona
US Fish & Wildlife
714 SE 15 th Ave
Olympia, WA 98501 US

John Madsen
BCSF Chilliwak Cavers
33273 Westbury Ave
Abbotsford, BC V2S-1C4 CANADA
jlmadson@msn.com

Bill Marshall
British Columbia Forest Service
Forest Practices Branch
P.O. Box 9518 Stn Prov Govt
Victoria, B.C. V8W 9C2 CANADA
WJMARSHA@MOFOR01.GOV.BC.CA

Roger E McClure
Cave Research Foundation
4700 Amberwood Drive
Dayton, OH 45424 US
rogmcclure@aol.com

Anita McMillan
Washington Depatrment of Fish & Wildlife
Pt. Angeles, WA US

Doug Medville
NSS, HI Speleo. Survey
11762 Indian Ridge Rd.
Reston, VA 20191 US
medville@patriot.net

Hazel Medville
NSS / HI Speleo. Survey
11762 Indian Ridge Rd.
Reston, VA 20191 US
medville@patriot.net

Joe Meiman
NPS, Mammoth Cave National Park
Mammoth Cave National Park
Mammoth Cave
Mammoth, KY 42259 US

Cyndi Mosch
White River National Forest
1683 Cole Village
Las Cruces, NM 88001 US
mgoar@nmsu.edu

Rachel Myron
Glacier Grotto
212 Observatory St
Sitka, AK 99835 US

Jim Nepstad
National Parks Service Wind Cave Nat Park
RR1, Box 190
Hot Springs, SD 57747 US
jim_nepstad@nps.gov

Jim Nieland
U.S. Forest Service
42218 NE Yale Bridge Rd
Amboy, WA 98601 US
jnieland@worldaccessnet.com

Marc Ohms
NPS - Jewel Cave National Monument
RR1 Box 60AA
Custer, SD 57730 US
Marc_Ohms@nps.gov

Rick Olsen
Mammoth Cave National Park
Mammoth Cave National Park
Mammoth Cave, KY 42259 US
MACA Resource_Management@nps.gov

Dale Pate
NPS
3225 National Parks Hwy
Carlsbad, NM 88220 US
dale_pate@nps.gov

Garry Petrie
Willamette Valley Grotto NSS
19880 NW Nestucca
Portland, OR 97229 US
gp@europa.com

Jim Petterson
Organ Pipe Cactus National Monument
Organ Pipe Cactus National Monument
Rt. 1, Box 100
Ajo, AZ 85312 US
Jim_Petterson@nps.gov

Mack Pitchford
2731 E 7th Ave
Vancouver, BC V5M 1T8 CANADA
Cavebear@compuserve.com

Brad Powell
U.S.F.S. Tongass National Forest
U.S.Forest Service
Federal Building
Ketchikan, AK 99901 US

Steve Rawlings
Mercer Caverns
74 River Street, Suite 209
Santa Cruz, CA 95060 US
steve@mercercaverns.com

Matt Reece
NPS - Jewel Cave National Monument
RR 1 Box 60 AA
Custer, SD 57730 US
Matt_Reece@nps.gov

Dean I Reid
MI DNR Forest Mgt. Div./MI Karst Conservancy
P.O. Box 287
Naubinway, MI 49762 US

Jason Richards
Carlsbad National Park
3225 National Parks Hwy.
Carlsbad, NM 88220 US
jason_richards@nps.parks

Reid Robinson
Box 103
Zeballos, BC V0P 2A0 CANADA
fons@island.net

Jonathan Rollins
Alberta Speleological Society
2512 - 19th St. NW
Calgary, Alberta T2M 3V4 CANADA

John Roth
Oregon Caves National Monument
Oregon Caves National Monument
19000 Caves Highway
Cave Jct., OR 97523 US
orca_resource_management@nps.gov

Scott Schulte
Missouri Dept of Natural Resources
P.O. Box 1403
Columbia, MO 65205 US
SWSchulte@aol.com

Patrick Shaw
Environment Canada / BCSF
316-230 East 16th Street
North Vancouver, BC V7L 2T1 CANADA
dps@istar.ca

Mark Sherman
KCMS / NCRI / Cascade Grotto
9417 8Th Ave NE
Seattle, WA 98115 US
mas@tc.fluke.com

Rik Simmons
BC Parks, Ministry Environment & Parks
Box 1479
Parksville, BC V9P 2H4 CANADA
rsimmons@galaxy.gov.bc.ca

Gordon Smith
National Caves Assoc. - Marengo Cave
9850 N Skyline Dr.
Floyds Knobs, IN 47119 US

Judy Smith
National Caves Assoc. - Marengo Cave
9850 N. Skyline Dr.
Floyds Knobs, IN 47119 US

Gerry Still
Ministry of Forests - Research Branch
P.O. Box 9519
Stn. Prov. Gov't
Victoria, BC V8W 9C2 CANADA
GERRY.STILL@GEMS1.GOV.BC.CA

Rob Stitt
NSS Cave Conservation & Management Section
1417 9TH Ave West
Seattle, WA 98119 US
rstitt@wingedseed.com

Tim Stokes
Terra Firma Geoscience Services
246 Pine St
Nanaimo, BC V9r 2B6 CANADA
tstokes@island.net

Tom Strong
National Speleological Society
3240 41st Avenue SW
Seattle, WA 98116 US
trstrong@zipcon.net

Janet Thorne
National Speleological Society
411 Marney Drive
Coraopolis, PA 15108 US
wesbike@aol.com

Jerry Trout
U.S. Forest Service
5990 S. Hwy 92
Hereford, AZ 85615 US

Ransom Turner
USDA Forest Service
3366 Queens Hwy
Carlsbad, NM 88220 US

Ben Van Noort
Inter Karst Consultants Ltd. - U of Northern BC
RR#6 Site 8, Comp 10
Prince George, BC V2N 2J4 CANADA
benvn@netbistro.com

Gary Vequist
Carlsbad Caverns National Park
3225 National Parks Hwy
Carlsbad, NM 88220 US

Sue Vessey
Friends of Nootka Sound
Box 103
Zeballos, BC V0P 2A0 CANADA
fons@island.net

Barry A Vilac
Golden Speleological Society
Box 1594
100 Mile House, BC V0k 2E0 CANADA

Gary Vos
USFS, Payette NF, Council RD
500 E. Whitely, P.O. Box 567
Council, ID 83612 US

Jim Werker
NSS
PO Box 1018
Tijeras, NM 87059 US
werks@worldnet.att.net

Phil Whitfield
BCSF / BCCR
2067 Valleyview Drive
Kamloops, BC V2C 4C3 CANADA
PIWHITFI@MAIL.NETSHOP.NET

Mike Wiles
NPS - Jewel Cave National Monument
RR1 Box 60AA
Custer, SD 57730 US
Mike_Wiles@nps.gov

Cat Woods
U.S. Forest Service
P.O. Box 19001
Thorne Bay, AK 99919 US
/S=C.WOODS/OU1=R10F05D04A@mhs-fswa.attmail.com

Mike Yocum
Cave Research Foundation
329 East Main St.
Frankfort, KY 40601 US
myocum@aol.com