

Chapter 14

National Karst Research Institutes: Their Roles in Cave and Karst Management

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Abstract This chapter defines “national cave and karst research institute” as “an organization created to conduct, facilitate, and promote state-of-the-art cave and karst research, education, and management, and recognized nationally as a leading authority on such matters.” Twelve institutes from nine countries were identified; one institute is inactive. Most were created as governmental programs, often affiliated with a university, while the rest are non-profit, for-profit, or hybrid (combining at least two of the other three organizational structures). Each structure inherently lends itself to different levels of authority and engagement in cave and karst management issues.

The role of national institutes in cave and karst management is a subset within each of the institutes’ basic purposes: Research, education and publication, independent advice and arbitration, data archiving, funding generation and granting, and collaboration facilitation. To date, most institutes have focused their efforts on theoretical research, archiving of data, and production of publications, and not on applied management issues. While activity in karst management is generally increasing, it is conducted mostly by the younger institutes and includes greater education efforts, funding, and advisory service. Because of widely different circumstances in each institute’s origin, administration, age, and national laws and culture, generalizations are difficult but some trends are proposed for the next few decades:

- Karst institutes will increasingly develop hybrid organizational structures.
- Karst institutes will predominantly focus on karst management issues.
- Technical and public education will become prominent karst institute programs.
- Karst institutes will increase their support of digital open access karst libraries and the creation of virtual karst research tools.

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- Karst institute funding will increase through diversification of services and perceived increase in value.
- Karst institutes will formally link for greater effectiveness and better use of limited resources.

14.1 Introduction

Until the middle to late twentieth century, relatively little research occurred in caves and karst areas, even though about 20–25% of the world's land area is underlain by soluble rock (Ford and Williams 2007). In many areas, caves were considered curiosities rather than sites of serious scientific inquiry that could yield valuable information beyond archeological or paleontological data. This attitude changed as cities expanded into surrounding karst areas, and people discovered their understanding of these complex natural resources was inadequate for effective management.

Cave and karst research institutes grew from the desire to better understand these areas and their contents. Some early institutes grew from the research interests of a motivated individual (e.g., Emil Racovita's fascination with cave biology leading to the Romanian institute) or from the discovery of an important research site (e.g., development of the Karst Research Institute in Slovenia within the karst type area). Although most did not emerge in response to the needs of natural resource management, all were developed with the common purpose of consolidating knowledge, information, talents, and funds to facilitate research.

The purpose of this chapter is to describe the types of national cave and karst research institutes, the advantages and limitations of their structures, the roles they play in cave and karst management, and what changes they are likely to see in the future. While regional institutes and related organizations exist, they will not be addressed in this chapter except to distinguish them from national institutes. Much of the information on national institutes applies to them when scaled to their local level or specific function.

This chapter is the first report to comprehensively discuss national karst research institutes. Little information is directly available on this subject. Much of this information was gathered through personal experience with most of the institutes. Many aspects of the institutes' histories, programs, and administrative details have not been published, except through ephemeral brochures, leaflets, and Web site postings.

14.2 Types of Institutes

Cave exploration and research is a passion for certain people. Caves' high vulnerability to environmental impacts often directs their passion into education and management. Caves and karst also serve as the focus for many businesses, most notably

tourism, but also, especially in the past 30 years, for environmental management consulting. Cavers (cave explorers) serve as the foundation for research, education, management, and commercial efforts. Their discoveries and maps lead the way for others to follow, and most cave and karst professionals build their careers on the inspirational foundation of their own caving experiences.

This wide range of interests, purposes, and specialization makes cave-focused organizations among the most diverse types in the world. The Union Internationale de Spéléologie (UIS) is typical of many such organizations down to the local level. It has the dual purpose of representing those who are interested in exploration and the recreational aspects of caves, as well as those fixed on the sciences and non-recreational issues. Its commissions include groups focused on “Archeology and Paleontology,” “Atlas of Karst Regions,” “Cave Mineralogy,” “Cave Rescue,” “Education,” “Glacial, Firm, and Ice Caves,” “Karst Hydrogeology and Speleogenesis,” “Microbiology and Geomicrobiology,” and “Speleothem Protection and Conservation,” among numerous other topics (UIS 2010). Many cave-interest organizations function separately from the UIS and focus exclusively on these or other specific subjects. Are they cave and karst research institutes?

Merriam-Webster (2010) defines “institute” as “an elementary principle recognized as authoritative; an organization for the promotion of a cause; an educational institution and especially one devoted to technical fields.” Probably, all of the UIS commissions and similar-interest organizations qualify as promoting a cause. All are devoted to the technical field of cave and karst science, often specializing in a sub-discipline, but few offer educational programs. The definition of “institute” also requires recognition of authority, which is difficult to quantify; all organizations are seen as authoritative at some level and by certain groups. This is complicated by the fact that, while the situation is improving, outside of the cave and karst community, relatively few cave and karst organizations are known to the general public, mainstream science, education, and management groups, or governmental agencies. Fewer still are accepted as authoritative.

This chapter defines “national cave and karst research institute” as “an organization created to conduct, facilitate, and promote state-of-the art cave and karst research, education, and management, and recognized nationally as a leading authority on such matters.” Institutes which have not fully met those requirements are included in this chapter if they are working to fulfill them. Organizations that use “institute” as part of their name but do not fit the definition are not.

Table 14.1 summarizes basic information about all known national cave and karst research institutes as defined above. Table 14.2 summarizes their goals and programs. The information, including discussion in the following sections, was collected through a questionnaire, and supplemented by the institutes’ Web sites and publications, and interviews with their staffs. Web site addresses are included in the list of references at the end of this chapter (except for the Cuban Speleological Society which does not currently have a Web site). The sections that immediately follow examine the different types of institutes and their functions in greater detail, with an emphasis on karst management.

Table 14.1 Leading international karst institutes. [Center for Cave and Karst Studies (2010); Emil Racovita Institute of Speleology (2010); Hoffman Environmental Research Institute (2010); Institute of Karst Geology (2010); Instituto do Carste (2010); Karst Research Institute (2010); Karst Waters Institute (2010); National Cave and Karst Research Institute (2010a); Swiss Institute of Speleology and Karstology (2010); Ukrainian Institute of Speleology and Karstology (2010); Veni G (1985)]

Institute	Year created	Country	Type	Staff	Funding source(s)
Cuban Speleological Society (CSS)	1940	Cuba	Governmental	n/a	Government
Emil Racovita Institute of Speleology (ERIS)	1920	Romania	Governmental	40 fulltime, variable part-time, and students	Government, grants, contracts
Hoffman Environmental Research Institute/Center for Cave and Karst Studies	1999/1979	USA	Hybrid	7 fulltime, 3–8 part-time, 6 students	University, grants, contracts
Institute of Karst Geology (IKG)	1976	China	Governmental	153	Government
Instituto do Carste (IC)	2007	Brazil	For-Profit	1 fulltime, 18 variable	Private donations, event fees
International Research Center on Karst (IRCK)	2008	China	Governmental	n/a	Government
Italian Institute of Speleology (IIS)	1926	Italy	Governmental	3	Government
Karst Research Institute (KRI)	1947	Slovenia	Governmental	25	Government
Karst Waters Institute (KWI)	1991	USA	Non-Profit	15 (all volunteers)	Grants, contracts, event fees, private donations
National Cave and Karst Research Institute (NCKRI)	1998	USA	Hybrid	6 fulltime, 2 part-time, variable students and volunteers	Government, grants, contracts, event fees, private donations
Swiss Institute of Speleology and Karstology (SISK)	2000	Switzerland	For-Profit	11 fulltime, variable students and volunteers	Contracts, grants, membership fees
Ukrainian Institute of Speleology and Karstology (UIJK)	2006	Ukraine	Governmental	4 fulltime, 7 part-time	Government grants, university

Table 14.2 The purposes and programs of the international karst research institutes. [Center for Cave and Karst Studies (2010); Emil Racovita Institute of Speleology (2010); Hoffman Environmental Research Institute (2010); Instituto de Karst Geology (2010); Instituto do Carste (2010); Karst Research Institute (2010); Karst Waters Institute (2010); National Cave and Karst Research Institute (2010a); National Cave and Karst Research Institute (2010b); Swiss Institute of Speleology and Karstology (2010); Ukrainian Institute of Speleology and Karstology (2010); Veni G (1985)]

Institute	Purpose	Programs
Cuban Speleological Society	Initially, to conduct cave and karst research in Cuba	Research programs were absorbed into other governmental departments. Now it serves primarily to train and organize cavers and host related conferences
Emil Racovita Institute of Speleology	Conduct interdisciplinary research on physical and biological components of the karst environment and related fields to provide a better understanding of karst processes to assess best practices for their preservation and conservation; provide scientific consulting for cave and karst management; coordinate the national cave inventory; publish karst books and journals; promote educational activities	Romanian karst science: geology, mineralogy, hydrogeology, and karst hydrochemistry; taxonomy, morphology, ecology and zoogeography of edaphic and subterranean fauna; use relative and absolute dating to reconstruct paleoclimate and paleoenvironmental conditions based on a variety of cave and karst deposits; karst water properties, establishing mechanisms for transfer of chemical contaminants using geochemical and radio-nuclear methods; conferences; scientific advisors to caving organizations and for cave management; and publications; formal education through coursework at undergraduate and graduate levels
Hoffman Environmental Research Institute/Center for Cave and Karst Studies	To be a leader in basic and applied research that aims to better understand landscape/atmosphere/water/human interactions, primarily through post-doctoral, graduate, and undergraduate study programs and associated research in the environmental discipline	Research in hydrogeology, geomorphology, geochemistry, climate change, and water resource issues; formal education through coursework and field studies programs; karst resource inventory, management, and training; water resource development through training; training in air quality monitoring and research in carbon sequestration technologies; support of international communication and efforts in karst science and conservation through leadership and active participation
Institute of Karst Geology	Undertake basic and applied karst geological research to establish foundational, strategic, and forward-looking karst theory and work	Major research subjects include basic karst studies, rehabilitation of desertification, development of karst water resources, geological hazards prevention, construction of a national Chinese karst geology database, development of a karst geology information service, and international exchange and cooperation

(continued)

Table 14.2 (continued)

Institute	Purpose	Programs
Instituto do Carste	To conduct and support karst research and sustainable usage of karst resources	Groundwater and biological research; management and restoration of karst environments; support for young cave scientists; annual invited distinguished scholar-led workshops; public education presentations; organize speleological events; publications
International Research Center on Karst	Understand karst systems at a world scale, and develop science and technology for sustainable development in karst regions	Research on environmental problems of karst, such as water, soil, mineral, and tourism resources, especially those related to world heritage qualities, as well as rock desertification, water quality, surface collapse, and flood disasters. Cooperative karst research; international karst technical consultation; karst scientific exchange; training in karst
Italian Institute of Speleology	Organize national register of Italian caves and speleological library, and support cave and karst research	Publications; research in speleogenesis, karst mineralogy and hydrogeology; data collection and archiving; formal education
Karst Research Institute	Develop interdisciplinary basic research covering the majority of the most important topics (karst geomorphology, groundwater, speleogenesis, biology, ecology, and history of karst science); planning for landscape protection; post-graduate study program; organize annual international karst seminar; administrative location for IJIS; publish karst books and journal; develop a leading karst library	Postgraduate program in karst; publish a cave and karst journal and numerous books; library development; water resources and protection (road and rail construction, cave and karst data collection, consultation and management for tourism); multidisciplinary research on karst hydrology and ecology; laboratory analysis; computer modeling; international collaborations
Karst Waters Institute	Improve the fundamental understanding of karst water systems through sound scientific research and the education of professionals and the public	Specialty conferences, usually focused on a specific topic and multidisciplinary in nature; publication of karst research; support graduate level research in hydrogeology, geology, geochemistry, biology, and microbiology; workshops to provide training for professionals working in karst areas; inventories of cave and karst resources; introducing the general public to the importance of karst research; award to recognize major researchers

<p>National Cave and Karst Research Institute</p>	<p>Further the science of speleology; centralize and standardize speleological information; foster interdisciplinary cooperation in cave and karst research programs; promote public education; promote national and international cooperation in protecting the environment for the benefit of cave and karst landforms; and promote and develop environmentally sound and sustainable resource management practices</p>	<p>Research in cave and karst hydrogeology, geophysics, geomicrobiology, geochemistry, management and land use, and extraterrestrial speleology. Undergraduate to doctoral student programs in the above research topics. Formal, informal, and non-formal public education program through conferences, presentations, workshops, and field instruction. Two scientific book series and one children's book series</p>
<p>Swiss Institute of Speleology and Karstology</p>	<p>Develop and maintain the Swiss speleological archives; encourage and participate in karst research; educate the public to promote respect for karst environments; establish links with university departments to promote academic karst education and research; become the source for assistance, information, and guidance in Swiss cave and karst management; improve the Swiss public's view of and respect for caves and cave science</p>	<p>Research in the sustainable management of karst waters, including the development of an underground laboratory, and the effect of climate change; cave climatology, including ice caves; paleoclimatic reconstruction; speleogenesis. Applied research in the development of an underground positioning system, improving the prediction of karst occurrences for civil engineering work, and 3D underground modeling. Consulting in cleaning polluted karst sites, procedures for karst conservation, evaluating cultural value of caves and karst, and urban and natural area development of karst. Teaching programs, conferences, and excursions for schools and the public. Production of instructional materials for teachers. Publication of scientific books and literature, as well as informational books and materials for the general public</p>
<p>Ukrainian Institute of Speleology and Karstology</p>	<p>Develop, promote and coordinate scientific interdisciplinary research in caves and karst; conduct and promote fundamental, pilot and applied research on priority topics of caves and karst; develop scientific collaborations in cave and karst science; serve as a repository for cave inventory, documentation, and information relevant to caves and karst; provide scientific guidance in issues of protection and use of cave and karst resources; promote and conduct cave and karst educational programs, particularly on post-graduate and Ph.D. levels; raise public awareness of knowledge about caves and karst and their vulnerability</p>	<p>Research in karst hydrogeology, geomorphology, geospeleology, speleogenesis, high mountain karst, gypsum karst, environmental problems in karst, cave survey, cartography and visualization, and cave management, including studies at two karst field stations; Ph.D. program in karst/cave studies; database development (including on-line); cave and karst bibliography, regional karst GIS, cave registers, hydrochemistry, and cave archeology; publication series</p>

14.2.1 Governmental Karst Research Institutes

Governmental national karst research institutes are those created by national governmental decree. As such, they officially represent those nations on matters involving caves and karst. Some governmentally created institutes have varying levels of authority to manage caves and karst, or to review and approve activities in caves and karst areas. Even when the institutes have no formal management authority or review capacity, as true governmental organizations, they can access sites and information that are not available to other institutes. Additionally, their opinion and approval, if not required, carries greater influence.

More than half of the national karst research institutes described in Tables 14.1 and 14.2 are governmental: Cuban Speleological Society (CSS), Emil Racovita Institute of Speleology (ERIS), Institute of Karst Geology (IKG), International Research Center on Karst (IRCK), Italian Institute of Speleology (IIS), Karst Research Institute (KRI), and Ukrainian Institute of Speleology and Karstology (UISK). They include the oldest institutes and in general have the largest number of employees and highest levels of funding. While this sounds like a highly favorable situation, it may be limited by cultural and economic factors. For example, institutes in countries with weak economies generally have funds to hire numerous people, but little money to invest in equipment, travel, and research projects.

Governmental support can change, strengthening or weakening an institute. CSS was created as the center for cave research in Cuba. However, by the mid-1960s, its research scope was transferred to governmental agencies within the Cuban Academy of Sciences. It no longer functions as an institute as defined in this chapter but is included for its historical role; CSS now mainly serves to train cavers, conduct speleological conferences, and through them, support karst research programs (Fig. 14.1). In contrast, IKG grew and consolidated much of the national cave and karst research in China, which led to expansion and the creation of its Karst Dynamics Laboratory in 1997 (Karst Dynamics 2010), and establishing the IRCK in 2008 (IRCK 2010).

Karst protection and management was not a mandate in the creation of the older institutes, although it is a component of all of the institutes' programs. Some have updated their original mandates. Prior to the 1970s, karst management was not widely recognized as a necessity or even a topic for study or action. It is still a secondary field of research for most of these institutes, attracting the most attention in China (IKG and IRCK) and Slovenia (KRI).

14.2.2 Non-Profit Karst Research Institutes

Non-profit national karst research institutes are privately created. They may or may not have a paid staff and all funds they receive are directed into the institute to conduct programs, buy necessary supplies, and pay fair staff wages. Surplus funds do not accrue to the institute's staff or board, the body that governs most non-profit organizations, but are distributed to support the institute's goals.



Fig. 14.1 The Cuban Speleological Society’s Escuela Nacional de Espeleología offers dormitory, classroom, and research space to train cavers in safe caving, rescue, mapping, and other techniques on site and in nearby Caverna de Santo Tomas

Only one of the listed national karst research institutes is a non-profit organization: Karst Waters Institute (KWI). It has no paid staff but a dedicated group of volunteers who serve on its board and assist with its functions. KWI is best known for producing an excellent series of conferences and associated proceedings. While it has a broader scope, other activities are limited by available funding and personnel. KWI is focused on basic research, and so its experience is not directly pertinent to the karst management theme here. Still, the experience of KWI and other non-profit cave and karst organizations has much to teach about the roles of non-profits in karst management.

Non-profits lack immediate recognition as actual authorities and must earn respect through action, such as providing information, conducting research, hosting conferences, and offering grants and scholarships. The presence of one or more regionally or nationally recognized karst experts on their board or staff also builds prestige. Once these organizations become recognized authorities, their representatives might serve on committees and advisory groups created by regulatory authorities to offer consul on management issues.

Non-profit institutes, by definition as privately created, have no authority to manage caves and karst beyond those they may own. As of 2009, 25 non-profit organizations in the U.S. acquire and protect caves and karst areas; some were created for that specific purpose (Wilson and Cousineau 2009). In most of the other

countries containing karst research institutes, the ownership of caves and all underground resources is limited to the governments.

In the U.S., major non-profit cave-interest organizations date to the founding of the National Speleological Society in 1941, but it was not until the 1980s when several began to form with the primary purpose of cave and karst conservation. Most rely on volunteer staff. Some organizations are not focused on karst, and with a wider base of support, they have the means to hire employees and protect caves through both specific and broad action. For example, The Nature Conservancy is the largest private cave owner in the U.S. with 113 preserves protecting cave ecosystems in 1999 (Foster 1999; Wilson and Cousineau 2009). Fewer non-profit cave protection organizations exist outside the U.S., but those in Europe began to work together in 2008 as the European Cave Protection Commission (ECPC) in an attempt to more effectively meet their goals (Grebe et al. 2009).

The success of non-profit institutes is tied directly tied to the availability of funds and staff. The most successful raise funds aggressively and often hire experts to serve in key staff positions. Consequently, they experience smaller decreases in funding and their staffs provide their programs continuity and historical memory, which suffers when volunteers are less available. However, even under ideal circumstances, the lack of actual authority may defeat their efforts. Lacking notable funding and paid staff, the ECPC failed in its admirable initial efforts to establish a written declaration for cave protection by the Parliament of the European Union (Christiane Grebe 2010, personal communication).

14.2.3 For-Profit Karst Research Institutes

For-profit national karst research institutes are privately created. They have a paid full- or part-time staff and may hire part-time contractors. All funds are directed to conduct programs, buy necessary supplies, and pay wages, but they function as businesses where surplus funds may wholly or partially accrue to the institute's staff, board, or owners in addition to supporting the institute's goals. Theoretically, ownership can take any form, from sole proprietorship, to partnerships, to incorporated boards, or stockholders.

Two of the listed national karst research institutes are for-profit organizations: Instituto do Carste (IC) and the Swiss Institute of Speleology and Karstology (SISK). IC chose the for-profit status by design, while SISK chose it from necessity. IC is the second youngest karst research institute. It was formed in response to bureaucratic conditions that stymied efforts to create an institute within a university, along with a concurrent increase in the availability of grants and public funds for the creation of an independent research organization. SISK began with broad goals and attempted to gain public funding through government programs, but as those funds proved inadequate, it diversified its sources of income through consulting work, sales, and other for-profit activities.

IC has one staff member and several people who work and assist as needed. SISK is an older organization and employs 11 people full-time and several part-time.

Although IC and SISK operate for profit, their broader vision and purpose, which qualifies them as true karst research institutes, attracts students, professionals, and cavers to volunteer their services to support the institutes' overall goals.

From around 1980, the need for cave and karst expertise for environmental management has steadily increased, as demonstrated by the proliferation of cave and karst management, conferences and consultants. The field is lucrative, especially in areas with few cave and karst experts and where regulators and land developers recognize and appreciate such expertise. This creates opportunities for karst research institutes to conduct necessary investigations while generating funds to support their broader and more-difficult-to fund programs.

As with non-profit organizations, for-profits may lack immediate recognition as actual authorities and must earn respect through their research, unless at least one of the principle investigators is a regionally or nationally recognized cave and karst expert. However, for-profit institutes must also overcome the perception that their actions and views are biased toward making a profit. For-profit institutes may interact more frequently with regulators than other institute types. Assuming no conflicts of interest, their representatives could be more quickly recognized as authorities to serve sooner and on more karst management committees and advisory groups created by regulatory authorities.

Measuring the success of for-profit institutes is partly a matter of which standard is used. If success is determined by profit alone, an institute could potentially make enough money to pay employees and grow the institute. However, they may not have enough money to support their broader programs, which may not be financially self-sustainable through their own activities but are important to understanding and managing karst. The rich scientific publication record of the SISK and the developing programs of IC demonstrate that both organizations are channeling profits into their broader mandates.

14.2.4 Hybrid Karst Research Institutes

Hybrid national karst research institutes are created and/or sustained through means that define at least two of the above three institute types. They usually begin as one type of institute, but then change to encompass major traits of a different type of organization. Two of the listed national karst research institutes are hybrid organizations: Hoffman Environment Research Institute (HERI) and the National Cave and Karst Research Institute (NCKRI) of the U.S.A.

HERI was created in 1999 and includes the Center for Cave and Karst Studies (CCKS), which originated 20 years earlier. Both are research institutes at Western Kentucky University, U.S.A. CCKS began as a government institute, funded through a state university. Many university institutes apply for grants and external funds, and could in themselves qualify as yet another institute category, but the CCKS soon expanded beyond such grants and functioned effectively as a non-profit business. It established numerous consulting contracts for environmental management research and established a commercial dye tracing laboratory. Funds from these projects paid

non-student staff and numerous students who worked part-time and occasionally used project results in undergraduate and graduate theses. Since HERI's acquisition of CCKS and some shifts in the institute's goals, the number of consulting projects has deliberately declined while the laboratory and student assistants are still active.

NCKRI was created in 1998 by the U.S. Congress as an institute within the U.S. National Park Service (NPS). Its mandates were defined by Congress, and it was funded by a partnership between the federal government, represented by NPS, the State of New Mexico, represented by the New Mexico Institute of Mining and Technology (New Mexico Tech or NMT), and the City of Carlsbad, which constructed NCKRI's headquarters. In 2006, the partners decided to reorganize NCKRI into a non-profit for greater flexibility in achieving its mandates than was possible through the NPS. NCKRI currently maintains its governmental obligations and funding, with the funds administered by NMT, yet is a federally registered non-profit corporation.

Hybrids are the most recent type of karst research institute and may prove the most effective, based on the short periods that HERI and NCKRI have existed. Their hybrid format gives them greater administrative and financial agility in gaining funds and building effective partnerships. HERI is based on government/university funding and support, while supplementing its programs through consultations, lab fees, and grants. NCKRI is similarly situated, and soon plans to diversify its income sources through bookstore sales, workshops, rental of meeting space, and research equipment, as well as through consultations and grants. This diversification allows each institute to more easily overcome situations where a source of income may be temporarily decreased or permanently lost. Both hybrid karst institutes possess small but growing numbers of employees. HERI's staff is supplemented by students while NCKRI's is supplemented by volunteers.

The strength of a hybrid institute's organizational diversity also includes its ability to work with other organizations and be readily recognized as an authority. NCKRI's creation by the U.S. government provides nearly automatic recognition and access to government leaders, agencies, regulators, and membership on relevant committees. However, its non-profit status gives NCKRI greater administrative freedom and the ability to work with organizations and qualify for projects and funds that are restricted to non-profits and/or non-governmental organizations.

HERI's history and goals are more focused on karst management than NCKRI's, and have resulted in HERI working throughout the U.S. and several countries on multiple projects and issues. NCKRI plans to hire a director for its Applied Science Program; until then, its efforts on karst management are opportunistic. Neither organization plans to develop a cave acquisition program as part of its management efforts.

14.3 Roles in Karst Management

Table 14.2 shows that karst research institutes have similar purposes, generally to support, facilitate, and conduct cave and karst research, education, and management efforts through their own strengths and collaborations with other organizations, and

the collection, analysis, and publication of information. While specific interests differ, cave and karst management has become an increasingly important priority for the institutes, in part due to societal needs, but also because of increasing funding available for such work. The following sections review the primary functions of karst institutes relative to their efforts in the protection and management of caves and karst areas.

14.3.1 Research

The most active institutes in cave and karst management research to date are HERI, IKG, KRI, and SISK. All focus their work primarily within their own countries, except for HERI which works internationally, especially in China, in addition to the U.S.; IRCK and NCKRI's fledgling research programs are intended to be large and international. Most of an institute's research is focused locally, so the range of management issues it studies is usually based on local topics. But common trends in their research are described below as three phases in conducting environmental management investigations.

The first phase begins with issues of great urgency. An institute will typically first evaluate and/or solve a groundwater contamination, flooding, or land stability problem (Fig. 14.2). This work fell especially to the institutes before consulting hydrogeologists and engineers with karst expertise were broadly available, and it is still the case in regions which lack such consultants. Examples of such research abound: Crawford and Groves (1995) for HERI/CCKS, Yang et al. (1999) for IKG, Kogovšek and Petrič (2007) for KRI, and Wenger (2008) for SISK. Such studies may establish the authority and value of an institute, and thus be critical to assuring its long-term financial security.

The second phase of investigations involves long-term rather than immediate management problems. Water supply availability and regional land use research is common. Desertification due to soil erosion, even under humid conditions, is a major concern for karst in China (e.g., Shan 2006). Some of these studies overlap with student thesis and dissertation research, often requiring similar levels of data collection and analysis, and are conducted occasionally by students supported by the institutes (e.g., Petrič 2000). The third phase of karst management investigations involves long-range planning, with SISK and its partners making the most notable contributions in developing karst aquifer vulnerability assessment methods (e.g., Perrin et al. 2004).

Most karst research institutes do not list archeological, biological, paleontological, or tourism studies within their mandates or programs. Whether by design, recognized urgency, or availability of funding, all of the institutes have focused on geological and hydrogeological research. ERIS and KRI have the broadest research programs and include studies in other disciplines, but little has been produced specifically on the conservation and management of the rich non-geological resources often found in karst and caves. Archeological and paleontological studies have mostly been descriptive (e.g., Horáček et al. 2007) and not protective or prescriptive.



Fig. 14.2 CCKS/HERI was called to consult on the sinkhole collapse that swallowed part of a street in Bowling Green, Kentucky, USA

The same holds true for many biological studies. Most ecosystem studies by IKG address surface communities (e.g., Zeng et al. 2007) and not true karst endogenous species. The majority of karst research institute reports on the management of true cave fauna examine biodiversity as a foundation for conservation (e.g. Moldovan et al. 2005). They have done little to date on the recovery of listed threatened and endangered karst species or White Nose Syndrome, the condition that began rapidly spreading through North America in 2006, devastating bat populations.

Karst research institutes frequently use show caves for research. Studies occur within and beyond the tourist areas. Most examine some fundamental issue of cave science, but few investigate how to best minimize the potential impacts of tourism (e.g., Racovita 1999). While IKG has probably conducted the most studies of all institutes on the impact of tourism on caves (e.g., Zhang and Zhu 2008), much remains to be learned.

14.3.2 Education and Publication

Most karst research institutes list “education” as one of their goals or at least as among their programs. But what is “education”? Within the context of how it is

organized and conducted by the institutes, it can be defined within three broad categories:

- (1) *Technical Education*. Seminars, lectures, workshops, and classes for undergraduate to professional level audiences interested in advanced, specialized information necessary for professional jobs that involve caves and karst. These programs provide formal credit for participation that may be applied to a degree and/or to continuing education requirements for a job or a professional or research license.
- (2) *Public Education*. Lectures, workshops, classes, and entertaining events that provide general, simplified or non-technical, cave and karst information for the public. This includes presentations to pre-college students because of the technical level of the content. The purpose of public education is to elevate society's general awareness of caves and karst, including their importance and vulnerability to human activities.
- (3) *Publications*. Publications are not usually considered an education category but an education tool. They are listed here as a category because they constitute an important program of nearly all of the institutes. "Publications" are not limited to printed books, journals, and newsletters, but include digitally produced media that relay similar information, such as Web sites, videos, interactive learning programs, and webinars. Publications reach out to people of all ages and knowledge levels, and are not restricted to only the technical or public education categories.

Half of the karst institutes include teaching as one of their mandates; ERIS does not, a result of its early origin when institutes were typically located at universities and their education component was assumed. Nearly all of these institutes are within a university and/or directly supported by a university, and consequently, they provide cave and karst educational support to the students in return. Romania's Babes-Bolyai University, which is affiliated with ERIS, and Slovenia's University of Nova Gorica, which is affiliated with KRI, are the only universities known to provide degrees in karst science. HERI and NCKRI are the only other institutes that offer specific university courses on cave and karst topics (several universities around the world offer cave and karst courses, but are not affiliated with a national karst research institute).

Nearly all institutes offer some form of technical education, as defined above. Most are occasional seminars offered outside of the typical university curriculum. Some are offered through affiliated universities. The longest-running and possibly the earliest university program is the series of week-long annual summer field courses offered through CCKS (HERI) since 1979 at Western Kentucky University. The course titles, such as "Cave Geology," "Cave Ecology," etc., span the range of major karst research topics, but karst resources management courses were not offered until "Management of Karst Aquifers" in 2002. Similarly, KRI's week-long International Karstological School focused on basic research topics since its start in 1993, until offering "Sustainable Management of Natural and Environmental Resources on Karst" in 2006 (Fig. 14.3).



Fig. 14.3 Students of KRI's annual international karstological school examine a stream flowing into a Slovenian cave

Most of the institutes provide public education through lectures, brochures, and books with stunning photos that highlight the beauty of caves and karst landscapes. Little specific information is available on these informal activities. From around 1990, karst management has increasingly become the focus of these efforts, especially in response to well publicized local karst problems. Public education's primary challenge is teaching people why they should care about the complicated, unfamiliar, and poorly understood topic of how caves and karst function. It must teach why caves and karst are important, while overcoming deeply held myths and superstitions, all within a typically 5–30 min presentation. This is where karst research institutes can excel, through programs honed to concisely yet effectively provide that information. Such programs can extend through communities in many ways as periodic reinforcement.

Only three institutes have defined education programs that make public education a major priority: ERIS, SISK, and NCKRI. ERIS' public education efforts are focused through the Emil Racovita Speleological Museum in Cluj, Romania. While a significant portion of the museum is dedicated Emil Racovita, it also includes rooms with information on cave exploration equipment and techniques, cave and speleothem restoration methods, the creation of ERIS, cave biology, and reasons and means for protecting cave and karst environments. The museum also hosts a weekly public lecture series on cave and karst topics.

SISK has a public lecture series and teaching program, but also sells a unique set of cave and karst education tools for teachers within two compact, sturdy suitcases. Materials in the first suitcase focus on the theory of cave and karst development, and includes course notes, teacher's guide, bibliography, list of relevant Web sites, games, puzzles, photos, and rock samples for discussion, and a CD with two PowerPoint presentations. The second suitcase contains equipment and instructions for six experiments:

- (1) Limestone dissolution;
- (2) Speleothem formation;
- (3) Infiltration of water into karst aquifers;
- (4) Karst groundwater networks and spring discharge;
- (5) Transmission of pollutants in karst aquifers;
- (6) Karst recharge areas.

NCKRI's Education Program is scheduled to begin in 2011. Cave and karst management is fully integrated, as reflected by the draft mission statement: *NCKRI's Educational Program works to increase the perception, awareness, and knowledge of caves and karst to result in careful and responsible stewardship* (NCKRI 2010b). NCKRI has hired an Education Director who works to better include cave and karst instruction at universities, as well as through the gamut of public education methods. Key efforts of its Education Program are to add cave and karst knowledge into the national education standards, and to work cooperatively or expand on existing teacher-teacher programs to more quickly and widely disseminate karst information. Project Underground (1993) and the American Cave Conservation Association are among the few organizations that offer cave and karst curricula to teachers, and NCKRI is working with both to cooperate with and/or integrate those efforts (NCKRI 2010c).

14.3.3 Independent Advisor and Arbiter

A poorly publicized and often private function of karst research institutes is to provide expert advice and insight on questions involving caves and karst. This service is based solely on the institutes' existing experience and information and is separate from the institutes' research role, where they might conduct studies to resolve an issue. The topics in these circumstances are almost always related to cave and karst management and fall into one or more of three categories: Planning, problem-solving, and dispute resolution.

Members of karst research institutes often serve on technical committees to assist in creating research programs and management plans for caves and karst areas. NCKRI (2010c) discusses its activities, including examples involving karst management and related planning:

- The Executive Director sits on the Aquifer Science Advisory Panel of the Edwards Aquifer Authority (a regional governmental agency in Texas, U.S.A.,

charged with the protection, study, and management of that major karst aquifer) to review research and proposals by the agency and advise on improvements for the agency to better meet its goals.

- The Education Director works on a U.S. Forest Service (USFS) cave and karst management plan writing committee; the plan is expected to become the USFS national cave and karst management plan.
- The Education Director serves on a committee of Carlsbad Municipal Schools; the committee gained the City of Carlsbad recognition as one of the “Top 100 Communities for Young People” by the America’s Promise Alliance.
- The Academic Program Director is a member of the NASA Advisory Council Committee on Planetary Protection and the National Academy of Sciences COMPLEX committee.

Most of the time, this type of assistance is informal, undocumented, and provided through personal communications in response to specific questions.

Institutes also participate in problem-solving missions. The situations frequently require urgent action, are often potentially or truly legally and/or politically sensitive, and information on an institute’s involvement is generally unpublished or not published within the readily accessible literature. NCKRI (2010c) offers one example as its Executive Director serves on a committee to evaluate the risk of a potential catastrophic sinkhole collapse and to explore what can be done to prevent it. Depending on the issue and urgency, and the time, funds, and information needed to solve the problem, an institute may be the only or primary group contacted, or it may be part of a committee.

Based on a literature review and personal communications, which cannot be cited due to legal issues, it appears that karst institutes seldom function as arbiters of disputes. The disputes commonly revolve around whether an action was sufficient to protect a cave or karst resource, or if an individual’s use of the resource impinges on the rights of others. Governmental institutes are more likely to be involved in such matters, as well as in planning and problem-solving. The specifically designated roles of each governmental institute and the legal codes of their countries affect the institutes’ positions as advisors, arbiters, and regulatory authorities.

14.3.4 Data Archive

Every national karst research institute maintains a data archive of speleological information, whether or not this is listed as a goal or program. Institutes function on information; a data archive is not optional. However, some institutes expand and/or focus on this task.

The IIS archive is a traditional library, possibly the world’s largest karst collection, with over 70,000 items catalogued. Creation and maintenance of the library was one of original goals of the IIS. Like most traditional libraries, its materials are primarily used by those who can physically access the location. Until the creation of the Italian Speleological Society, the IIS library also contained the

database of Italian caves. Other institutes which currently host cave databases, or work collaboratively with the organizations that do, include KRI, SISK, and UISK.

The problem with traditional libraries and paper-based archives is that karst science is an intrinsically multidisciplinary field of study that is poorly indexed and difficult to access. While there is a significant body of internationally useful literature, important works remain largely unknown or inaccessible. Some of the more difficult-to-access documents include maps, databases, technical reports, graduate theses and dissertations, images, video, and government publications. Also, karst-related documents published in less-accessible languages are hard to retrieve or find. Consequently, two of the newer institutes, while building their traditional libraries, are also creating virtual cave and karst libraries for easy international use and access.

Speleogenesis (www.speleogenesis.info) is the official Web site of the UIS Commission on Karst Hydrogeology and Speleogenesis. While officially a UIS activity and supported by many commission members, it is unofficially powered by UISK and its Executive Director, Dr. Alexander Klimchouk, who chairs the commission. The Speleogenesis site functions as an on-line journal but also provides free on-line access to a cave and karst bibliographic search engine, theses and dissertations, several journals, a glossary of terms, and an atlas of morphologies found in caves. While some of the linked journals include papers on karst management, Speleogenesis is focused on the theoretical aspects of cave origin and karst hydrogeology.

NCKRI is also developing a virtual library, the Karst Information Portal (KIP) (www.karstportal.org), with partners from the University of South Florida, University of New Mexico, and UIS. Also supported by UISK and Speleogenesis, KIP was created in 2007 and specifically designed to address the information access and management problems presented by traditional libraries. It provides an open-access global portal as an on-line gateway to karst information and services. About 5,600 documents on all cave/karst-related topics were available via KIP in mid-2010, including theses, dissertations, databases, bibliographies, images, gray literature, maps, and 39 journals from 11 countries. Considerable information is available on cave and karst management. KIP's usage is increasing dramatically, with a projected doubling in 2010 from 2009 (NCKRI 2010c).

14.3.5 Funding Generator and Provider

In principle, national karst research institutes, as recognized authorities and productive entities, should readily generate funds to build their research programs and to support others. Unfortunately, that has not generally been the case. Institute directors interviewed for this chapter were asked, "What would you like your institute to do that it is currently unable to do, and what is preventing your institute from meeting those goals?" Their uniform hope was for additional funding to better sustain and grow their programs.

Measuring the financial success of the institutes is difficult. They need to be evaluated relative to their individual goals and circumstances. Fundamentally, they are all successful since they sustain their current activities. HERI, KRI, KWI, and NCKRI are discussed below as examples; they provide significant contrasts in measuring the current success and likely growth as future funding generators and providers.

HERI is arguably the most financially successful institute. It may not have the largest budget, but it employs several people, and continues to find funds to expand its general and student research programs, locally and internationally. While it hosts conferences and a summer field school that build cooperation and scientific knowledge, the funds HERI generates are primarily directed inward to support additional students and programs.

KRI is also clearly successful as evidenced by its large staff, diverse research program, prolific publications program, periodic conferences, and annual International Karstological School. Like HERI, its funding is primarily directed inward, as is necessary for an organization to survive and flourish, but grants are also given internationally for students to attend their annual school.

KWI does not have a staff or a regular income source, and possibly has one of the smallest budgets, but it still stands as a successful funding generator and provider. This institute hosts one of the world's most successful and respected karst conference series. High quality, scientifically valuable publications are produced through each event. Additionally, while its income may be irregular, KWI has the financial stability to provide an annual scholarship to support student thesis or dissertation research.

NCKRI receives more annual funding than most karst research institutes, but currently lacks a grant program. During its early history, NCKRI sponsored three visiting scholars, but its funds are presently directed inward to build its headquarters, buy equipment, and hire additional staff. Its newest employee is an Advancement Director, hired to help increase and diversify its funding sources. Once its critical start-up construction, purchases, and hiring are completed, NCKRI plans to establish a grants program and find other ways of directing funds outward to support cave and karst research.

14.3.6 Collaboration

While the stature of the national karst research institutes has not yet generally produced money for significant external funding of programs and projects, it is a proven catalyst for collaboration to facilitate those activities. Institute collaborations can be defined as four general categories: Volunteers, conferences, projects, and agreements.

Volunteers. Most of the volunteers and vital partners for karst research institutes are cavers and cave scientists, people whose life-long passion and dedication is to caves. When karst institutes organize research or other projects, they are the first to assist. Cavers and cave scientists are often the only ones with the abilities to reach remote and difficult areas of caves to collect data, make observations, and install research

equipment. For example, caves and sinkholes are used worldwide as trash dumps, threatening cave ecosystems and human drinking water supplies. Cavers especially have the skills required to enter and clean those dangerous and disgusting sites. From 2004 to 2009, SISK cleaned more than 100 of the most polluted cave and karst sites in Switzerland. They provided the leadership and coordination, and cavers supplied most of the muscle and skill.

Conferences. In recent years, fewer conferences have been planned by single organizations, especially if the organization is a karst research institute. The institutes understand the value of collaboration and pooling resources. Other organizations often become involved to connect with an event that is larger than their individual ability to host. They gain prestige by association with the institute. Conversely, when other organizations host a conference, they seek institute sponsorships, not just for financial support, but for the validation that increases attendance and assistance. For example, the UIS' 15th International Congress of Speleology in 2009 is widely considered North America's most significant speleological conference. Part of its high attendance and success resulted from its sponsorship by HERI, KWI, and NCKRI, and the direct participation of the directors and staff from several other institutes who coordinated sessions, symposia, and other functions.

Projects. Historically, collaborative projects among karst research institutes, as well as with other organizations, were limited by politics and technology. As political barriers fall and the Internet makes international communication easy and inexpensive, institutes work increasingly with other organizations. Uncommon, but gaining in frequency, joint projects between institutes and other organizations focus on karst management. The most significant collaborative environmental karst project initiated to date by a karst research institute is the China Environmental Health Project (CEHP), organized by HERI and supported by the U.S. Agency for International Development, two Chinese universities, and other prominent organizations. The purpose of CEHP is to develop and enhance the quality of public health in China by finding solutions to karst water access and quality issues and coal-related air quality degradation. A key element of the project is engaging and training Chinese scientists, students, local governments, citizens, and Chinese environmental NGOs to meet and sustain the project's goals.

Agreements. While karst research institutes are increasingly seeking to collaborate on conferences, projects, and other activities, formal cooperative agreements for long-term collaboration are new. In 2010, NCKRI signed memoranda of understanding with ERIS, KRI, and UISK (NCKRI 2010c) to establish and formalize a foundation for closer inter-institute cooperation, exchange of information, publications, students, and scholars, open access to conferences, workshops, etc., and to cooperate in developing research, management, and educational projects, programs, and conferences whenever practical. NCKRI has also begun developing a collaborative memorandum with the U.S. Department of the Interior, which in turn would facilitate developing partnerships and projects with the Department's bureaus (e.g., Bureau of Land Management, National Park Service, U.S. Fish and Wildlife Service, U.S. Geological Survey). On the other side of the world, IRCK was recently developed through an agreement between IKG and UNESCO (IRCK 2010).

14.4 The Future of National Karst Research Institutes

Since the mid-1970s, the number of national cave and karst research institutes has increased on a near-exponential trend (Fig. 14.4). Except for CSS' decline in the mid-1960s, the institutes have demonstrated steady growth and important accomplishments. As a group, their series of successful projects, publications, conferences, and increasing influence in mainstream science and regulatory arenas, have served as impetus for the creation of new institutes. The prolific ease of international communication through the Internet has concurrently served to widely publicize the institutes' successes and raise awareness of their value in other countries.

Because caves and karst are important resources in dozens of countries, the emergence of new national karst research institutes should continue for decades. But what other trends and changes are likely to occur? The synthesis provided by this chapter, and observations of related academic, scientific, social, and political trends, suggest the following set of predictions for the next 20–30 years.

14.4.1 *Karst Institutes Will Increasingly Develop Hybrid Organizational Structures*

The success of two relatively new institutes (HERI and NCKRI), one of which is still adjusting to its recent organizational change, may not constitute a reliable statistical trend for concluding that hybrid karst research institutes will become more common in the future. However, the short but highly productive record of these institutes is hard to ignore. The flexibility to work easily with more groups, pursue more diverse

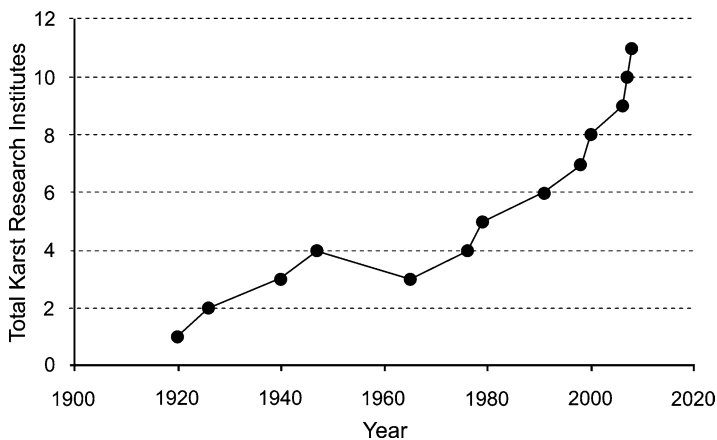


Fig. 14.4 Changes in the number of national karst research institutes over time

sources of income, and create a broader array of programs to support cave and karst research, education, and management is readily apparent. But the creation of such an institute and its initial administration to assure its activities are legal, fiscally sound, and effective is difficult. Once this hurdle is passed, a young institute will likely to find itself partnered with a well-established governmental agency, university, corporation, or the other organization that will help propel the institute to attain its goals.

14.4.2 Karst Institutes Will Predominantly Focus on Karst Management Issues

When ERIS was established as the world's first national karst research institute in 1920, the following terms were largely unknown: Carrying capacity, endangered species, groundwater contamination, human-induced land subsidence, overdraw-ing of aquifers, sustainable usage. Times have changed, and these and many other terms are now commonly applied to describe the modern world's environmental management problems.

Karst aquifers are the most vulnerable to pollution, and karst regions pose a complex set of ecosystem and engineering challenges unlike any seen in other ter-rains. The appearance of multiple karst management conferences in the U.S.A. in the 1980s resulted from management, not academic interests, as populations grew into karst regions, degrading and depleting their karst resources, while accelerating karst processes like sinkhole collapse.

But research into the theoretic aspects of cave and karst development will continue. The topics have not been exhausted but have expanded from newer and far more in-depth insights offered by modern technology. They are also important in solving management problems, but "problems" require mandates and funding to fix. National karst research institutes, as recognized authoritative bodies, should be increasingly selected as the natural choices to receive money to address environ-mental management problems in karst and conduct research to create or improve policies for the prevention and remediation of karst-related problems.

14.4.3 Technical and Public Education Will Become Prominent Karst Institute Programs

As karst management problems increase, there should be an increased demand for technical and general karst information. Most consultants and regulators who work in karst areas receive little information on the subject during their formal education and are either self-taught on the job or supplement their education by attending karst con-ferences, workshops, and seminars. Karst research institutes will likely expand their education programs to meet this growing need for information. First, they will likely expand their ranges and frequency of technical education activities (e.g., conferences,

workshops, etc.). Next, they will probably introduce accurate cave and karst information into formal school and university curricula at all levels. Similarly, the institutes will probably expand their public education activities, in response to the public's interest in recent karst-related problems and to develop a better public awareness of karst to prevent some environmental problems in the future.

14.4.4 Karst Institutes Will Increase Their Support of Digital Open Access Karst Libraries and the Creation of Virtual Karst Research Tools

Paper books and documents will long be collected and archived by karst research institutes, but the institutes' physical libraries of those materials will be used less over time. Reports from the American Library Association (2010) and other sources offer mixed statistics on library usage. Most sources report that book circulation has increased in U.S. public libraries, apparently because nearly 100% of academic, public, and school libraries in the U.S. are connected to the Internet for staff and public use. Sixty-seven percent of U.S. libraries report they are the only provider of free public access to computers and the Internet in their communities, and their public computer and Wi-Fi use increased in 2009 by more than 70%. In contrast, some academic libraries report dramatic declines in book circulation as more research by students and teachers is conducted on-line.

As computers and on-line access become more available to general society, and as more books and information become freely accessible on the Internet, book usage at public libraries will probably decline as seen at academic libraries. For karst research institutes to be effective in their education programs, they will need to provide abundant, easy-to-access, accurate, and state-of-the-art information on the Internet for public and technical use. KIP is designed to serve as a one-stop source for all cave and karst information needs. While its use is rapidly growing, it is too early to say if it will achieve its goal of becoming the primary international karst information source. Additional documents are steadily added, but the development of research tools has been slow and to date depends mostly on volunteer efforts. A planned multi-language interface and search capability will increase its international use, although target dates for their implementation have not yet been announced.

14.4.5 Karst Institute Funding Will Increase Through Diversification of Services and Perceived Increase in Value

Historically, karst institutes have been funded mostly through grants and government appropriations to conduct basic research. In the future, as institutes expand their scope into karst management and become more publicly visible and valued,



Fig. 14.5 NCKRI conducts geophysical surveys to map subsurface karst hydrogeology and to evaluate the potential for collapse or subsidence

funding opportunities should also expand. Karst institutes will increasingly be hired to consult and advise on karst management issues. They may be called to develop and sell specialized equipment or software, or rent existing equipment and the services to operate it (Fig. 14.5). Expanded educational programs will lead to increased sales of books, videos, and other educational materials published by the institutes. All of the institutes, especially non-profits, will be positioned to receive more funding from grants, bequests, fund-raising events, and general donations. As long as the institutes continue to produce and share valuable results with existing and potential sponsors and partners, funding should continue or increase.

14.4.6 Karst Institutes Will Formally Link for Greater Effectiveness and Better Use of Limited Resources

“Strength in numbers” is a long-held truism but it has only recently been implemented among karst research institutes. Since 2000, a few collaborations and cooperative agreements have developed, and a comprehensive means of connecting all karst institutes, national or not, has started to emerge. In 2006, Dr. Alexander Klimchouk of UISK, led an international effort to create the International Cave and

Karst Research Institutions Network (ICKRIN). It was proposed as a collaboration of cave and karst research institutes, working together to build a network that would facilitate cooperation and partnership through the sharing of resources, results, experiences, and opportunities. Essentially, ICKRIN would be an organization of karst research organizations that would supplement, not compete, with any cave exploration, management, education, or research groups (www.speleogenesis.info). The proposal was discussed among some institute directors and at a few conferences (e.g., Groves 2007), but limited time and resources among its principle organizers has limited its development.

In 2010, Dr. Tadej Slabe, Executive Director of KRI, began developing the Karstological Academy (KA), and worked with Dr. Klimchouk and Dr. George Veni, NCKRI Executive Director, on its mandate and structure. Tentatively, KA will encompass the proposed function of ICKRIN, using resources already in place for KA. It may be expanded in the future to include individual karst scientists, if this course of action would not inadvertently weaken other organizations. No matter the ultimate fate and form of ICKRIN and KA, national karst research institutes will grow in number and prominence in the next few decades, along with a deeper collaboration among them.

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