Conservation aspects of karst waters in Namibia

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ABSTRACT

Aquatic habitats of karst origin in Namibia are generally small in area and few in number. Despite this, the fact that they include unusual habitat types like hypogean cave lakes, cenotes and flowing epigean springs, which are rare elsewhere in the country, lend them high conservation priority. Almost all important karst areas in southwestern Africa, and a major part of those in southern Africa, fall within the borders of Namibia. The aquatic fauna is poorly known but includes several endemics and some species of conservation concern. Main threats to karst waters include habitat destruction, invasive alien organisms and pollution.

INTRODUCTION

Karst is a collective name for a variety of landforms most commonly found in areas where the underlying geology consists mainly of rock types (usually limestone and/or dolomite) which are readily penetrated and dissolved by water. The high permeability of the substrate causes the bulk of precipitation to drain directly downwards to the water table, resulting in a virtual absence of surface drainage (few or no riverbeds). On its downward path, the water dissolves the rocks, typically forming caves and sinkholes. Where these bisect the water table, hypogean (underground) karst waters are found. Epigean (above-ground) karst waters take the form of strong, flowing springs, and are found wherever geology and/or topography force groundwater to the surface. Many handbooks are available which treat these processes in more detail; more recent works include Sweeting (1972, 1981), Bögli (1980), and Dreybrodt (1988). Important in the southwestern African context is the fact that the amount of precipitation may be a limiting factor to karst development: despite suitable geology, karst phenomena are usually relatively scarce and of lesser magnitude in more arid areas. The principal reference on the biological aspects of karst phenomena, though by now outdated, remains Vandel (1965).

DISTRIBUTION OF KARST IN NAMIBIA AND ADJACENT AREAS

Published information on karst distribution in Namibia is rather scarce. The information presented here is derived from a stereoscopic study of aerial photographs at a scale of 1 : 50 000 for virtually the whole of the country, visits to many karst phenomena, much groundwork in the areas mentioned, and questioning of numerous local inhabitants over the past thirteen years.

The Namibian Karstveld and its outliers

Well developed karst is found primarily in an area in northern Namibia, known as the "Karstveld". The earliest use of this name which I could trace is by Schultze (1910), who included most of the area between the Etosha Pan in the north, Outjo in the south, Grootfontein in the east and Kamandjab in the west in this region. Schultze's delimitation of the Karstveld has been used by most subsequent authors, except Jaeger (1921), who rightly included the eastern Kaokoveld in the Karstveld as well. In common usage today the name has become largely restricted to the Otavi Mountains and the area northwest of that as far as the Etosha National Park. In the latter region the best known and best developed karst phenomena occur.

The Karstveld as understood here is that area in northern Namibia (Fig. 1) where the geology consists mainly of outcrops and subcrops of dolomite and limestone of the Otavi Group (Damara Sequence). To a large extent this parallels Jaeger's area. Within the larger Karstveld, three subareas may be distinguished. Firstly, the Karstveld proper, which largely parallels Schultze's area, comprises the Otavi Mountains and the country westwards through the northern parts of Outjo District as far as Otjovasandu. This is the largest continuous tract of karst in the region, and it includes the majority of known major karst phenomena. The only two cenotes (refer section on abiotic features for definition) in the Karstveld, Lakes Otjikoto and Guinas, occur here, as do the hemi-cenotes of Aikab and Harasib, besides the hypogean waters of Dragon's Breath Cave, Aigamas Cave, Ghaub Cave and at least seven other caves known to me. Epigean springs of karst or probable karst origin in the area included Otavifontein, Rietfontein, Grootfontein, Farkfontein, Olifantfontein, Hoba, Gaub/Ganachaams, Saobis, Uitkomst, Awagobib, Gemsbocklaagte, Khusib, Nosib, Urupupa, Sissekab, Agab and Gobaub, to name but a few. While many of these springs remain strong, others have been depleted or destroyed through lowering of the groundwater level. Frequency of occurrence of karst phenomena in the Karstveld proper, decrease westwards with decreasing rainfall.

The second sub area of the Karstveld consists of a range of hills which branch off from the first subarea at Outjo and stretch westwards past Fransfontein. It includes very few known karst phenomena, and only one known hypogean water in the Twyfelfontein Wondergat (Sefton et al. 1985). Epigean springs of probable karst origin include Fransfontein and Gainatseb.

In the far west of the Karstveld proper, in the Otjovasandu area, the dolomite outcrops are reduced to a single range of hills, the Dolomietberge, only, but widen again north of there to form the third subarea, namely the Kaokoveld karst. Karst phenomena do occur in the Kaokoveld, but information on them is presently limited to the as yet unpublished results of a single investigation; one cave locally believed to contain a water body was found to be dry, while reports of another hypogean water in the area have not yet been followed up. Many of the Kaokoveld springs, particularly Kaoko-Otavi, Ehomba, Ombombo, Otjikondavirongo, Sesfontein and Khowarib, may be of karst origin.

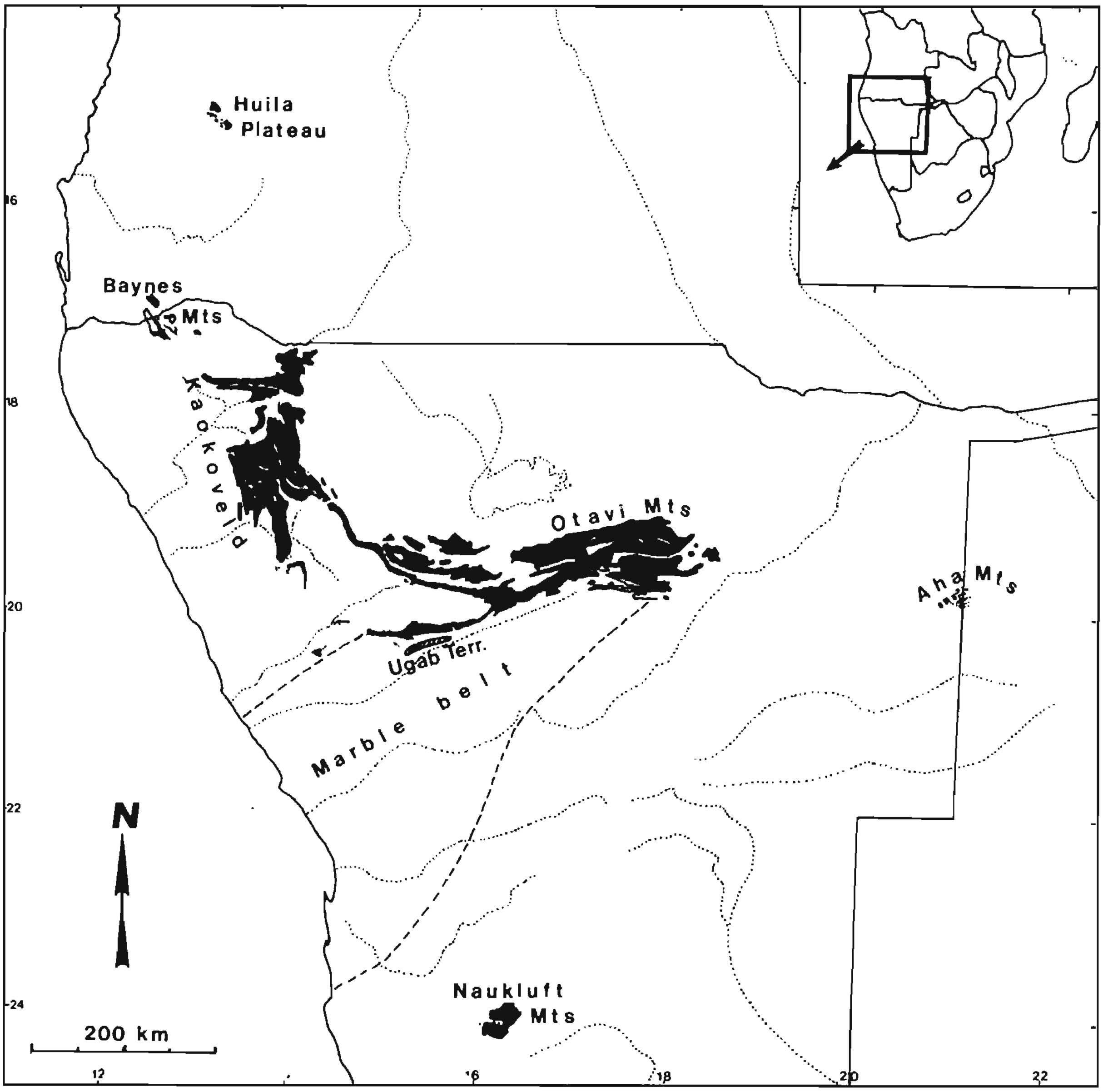

FIGURE 1: Extent of areas in southwestern Africa geologically suited to karst development. (Sources: Miller & Schalk 1974; de Carvalho 1980; Machacha & Mortimer 1984).

Separated from the Kaokoveld karst and northwest of it lie the Baynes and Tchamalindi Mountains, respectively south and north of the Cunene River. Due to their inaccessibility, nothing is known at present of the extent of karst development there. Far northwards in Angola the limestones of the Huila Plateau have also been correlated with the Otavi group of the Karstveld (Kröner & Correia 1980). I have been unable to trace specific information on possible karst development in this area, but the relatively high rainfall there suggests that karst may be well developed.

East of the Karstveld proper the dolomites disappear under the Kalahari sand, to appear briefly again in the Aha Mountains on the Namibia-Botswana border. A cave and sinkholes are known on the Botswana side (Cooke & Baillieul 1974). None are at present known on the Namibian side. None contain water bodies. Some epigean waters in the area west of the Aha Mountains and south of Tsumkwe, e.g. Nama and Gautscha Pans, may be of karst origin.

Namibian karst outside the Karstveld

Adjacent to and south of the Outjo-Fransfontein branch of the Karstveld lies the limestone plateau known as the Ugab Terraces. A few small caves are known here, but none contain water bodies. Many springs are found, all along the southern edge of the plateau.

South of the Karstveld lies a wedge-shaped tract of land stretching from south of the Otavi Mountains across Otjiwarongo, Kalkfeld, Omaruru and Karibib to Swakopmund, and becoming progressively wider southwards. Among other rock formations, marbles are especially common in this area. Marble, being metamorph limestone, can also give rise to karst phenomena, though never on the same scale as limestone itself. Minor karst phenomena are found throughout this area, which may be called the Marble Belt. They decrease in size and frequency with lower rainfall southwestwards, but small caves may be found even in the Namib Desert, e.g. the Rössing West Cave (von Wrede 1970) and Husabgrot. Only one, Gifgat (= Batshole) in the Namib-Naukluft Park, is known to contain water. Springs are generally scarce in the Marble Belt, and it is not possible to say which of those that do occur may be of karst origin. At least the town of Otjiwarongo derives a major portion of its water supply from boreholes in the marbles.

To the south the Marble Belt is bordered by the Kuiseb schists (Damara Sequence). To the south of this again, a narrow belt occurs in which marbles may again be found (not marked on Figure 1). Very few karst phenomena occur here, but one that does, Naos Cave, includes a small hypogean lake. South again of the previous area, lie the Naukluft Mountains which consist largely of dolomites and limestones. Due to the relatively low rainfall here, karst development is poor. A few small caves are known, but none contain hypogean waters. All the many springs of the Naukluft are of karst origin.

Much of the southern half of Namibia is covered by limestones of the Nama Group, stretching from the Huns Mountains northwards as far as the Mariental-Kalkrand area, and then northeastwards as far as Witvlei and Gobabis. Due to the relatively low rainfall over much of the south, karst development is virtually non-existent. A notable exception is Arnhem Cave, in the northeastern and highest rainfall area, which includes hypogean water bodies.

Dolomites of the Gariep Complex are common in the Namib Desert south of Lüderitz. Karst development is absent due to the combination of low rainfall, which inhibits karst formation, and high rate of sand movement, which probably ensures that any subterranean cavities which do form will be rapidly filled as soon as they open to the surface. It is worth mentioning, though, that just 9 km south of the Orange River the Annisfontein Wondergat includes a hypogean water body (Blacquiere 1969).

Southern African regional perspective

Elsewhere in southern Africa, notable karst areas are the Transvaal dolomites (with which I here lump the dolomites of southeastern Botswana and northern Zimbabwe), the limestones of the Kaap Plateau in the northern Cape Province, and the Cango Valley and Bredasdorp limestones in the far southern Cape Province.

Table 1 indicates that 98% of karst areas in southwestern Africa, and 52% of karst areas in southern Africa, lie within the borders of Namibia. Within Namibia, 91% of karst areas lie in the Karstveld. Areas with relatively low karst potential, e.g. the Marble Belt, have been omitted from the table. Though actual karst waters and other karst phenomena form a very small part of these large areas, it is still clear that the main responsibility for conserving the karst lies with the people of Namibia.

TABLE 1: Approximate surface area, in square kilometers, of karst regions in southern Africa. Due to limited personal experience the accuracy of area estimates outside Namibia is inversely corellated to the distance of the region from Namibia. Sources as for Figure 1: Zimbabwe additionally based on Haughton (1968).

	Namibia	Angola	Botswana	RSA	Zimbabwe	Total
Karstveld, Proper	10794					10794
" Outjo branch	1038					1038
" Kaokoveld	7494					7494
Baynes-Tchamalindi Mts	287	± 80				± 367
Huila Plateau		±180				± 180
Aha Mts	152		±60			± 212
Ugab Terraces	413					413
Naukluft Mts	944					944
Transvaal dolomites			±900	± 6000	±3000	± 9900
Kaap Plateau				±7000		± 7000
Kango Valley				± 300		± 300
Bredasdorp limestones				± 2000		± 2000
Total:	21122	±260	± 960	±15300	± 3000	±40642

DOMINANT ABIOTIC FEATURES

Hypogean waters

Common karst phenomena in the Karstveld include dolines, which are rocky depressions, which may or may not lead to sinkholes. Sinkholes may include laterally developed horizontal cave systems, which may in turn contain cave lakes. Sinkholes may also be completely waterfilled, to form sinkhole lakes (cenotes). Hemi-cenotes are cenotes with fairly small openings relative to the size of their water surfaces. Sinkholes and cenotes eventually fill up through erosion to form shallow flat-bottomed "craters" called poljes. Many of the turf pans (low-lying areas of deep, black soil which hold water in the rainy season) which dot the Karstveld probably represent a further, final stage of sinkhole erosion (Schneiderhöhn 1920). Conversely, swallow holes, which represent the first stages of sinkhole development, are as common in places. At least one place is known which changes from partial sinkhole to turf pan and back from year to year. The karst in northern Namibia is obviously still very much an active system. Of all the above, only cenotes and cave lakes can be considered permanent aquatic habitats, while turf pans are important seasonal wetlands.

TABLE 2: Some physical parameters of the better known hypogean waters of the Karstveld. (Sources. 1: Sefton et al. 1986; 2: J. Martini, unpublished data; 3: A. Penney, unpublished data; 4: J. Irish & E. Marais, unpublished data; 5: Penney et al. 1988; 6: Jaeger 1921; 7: J. Irish, aerial photo analysis; 8: Blacquiere 1968.)

Name	Type	Surface area	Max. recorded water depth	Ave. depth	Approx. volume	Source
Dragon's	cave lake	1.9ha	98m	60m	1140000m^3	1,2,3
Aikab	hemi-cenote	0.89ha	58m	37m	329300m^3	4
Guinas	cenote	0.66ha	130m	105m	693000m^3	5
Otjikoto	cenote	±0.51ha	58m	45m	229500m^3	6,7
Harasib	hemi-cenote	±0.32ha	63m	?	201600m^3	8
Aigamas	cave lake	0.016ha+?	70m	60	9600m^3	1,6

Table 2 shows that hypogean waters may be very deep and include large volumes of water. Minimum volume in the table was roughly calculated by multiplying surface area with average depth. Most hypogean waters occur in dome-shaped chambers, which increase in size below the water surface, making these inevitable underestimates. Actual surface area at any one time, therefore, also depends on the water table level. The remarkably large volume of the lake in Dragon's Breath Cave (the largest known hypogean lake in the world), is by no means exceptional; the water burst which caused the Kombat Mine Disaster in 1988 may be calculated from contemporaneous media reports on the strength and duration of the flow to have had a volume of around four million cubic metres. Such very large water volumes may exist in submerged cave systems, but it is unlikely (on purely structural grounds) that other single chambers of the same or larger size as Dragon's Breath exist in the Namibian karst.

Besides those mentioned above, at least eight other hypogean waters in the Karstveld, and four in the rest of the country, are known to me personally or through reliable reports. They are all smaller and less well known, and details are withheld in the interest of conservation. Total surface area of all known cave lakes and cenotes in Namibia probably does not exceed 10 ha.

The Namibian Ministery of Water Affairs is in possession of unpublished water quality data from more than 300 boreholes in the Karstveld (S.J. de Wet, pers. comm.).

Published information on further abiotic aspects of Karstveld waters is almost totally restricted to the works of Jaeger (1921) and Schneiderhöhn (1920). Important from a conservation viewpoint is the fact that there is as yet no evidence that any two hypogean water bodies are directly connected, despite persistent anecdotes to that effect, e.g. the oft-repeated rumours of connections between Otjikoto and Guinas. On a regional scale, subterranean waters lie at different levels and fluctuate independently; and these fluctuations are not correlated to rainfall in any simple way (Jaeger 1921). On a local scale, my own observations in the Harasib/Nosib area during July 1986, 1987 and 1988 and April 1989 and 1991 indicate a constant lowering of 2-3 m p.a. in the level of the water table in all caves in the area. Rainfall in this period was fairly normal The lowering of the groundwater paralleled what farmers in the area found in their boreholes, and they firmly believed that water extraction by the Karstveld Water Scheme was to blame for this. Whatever the reason, this discrepancy between regional and local groundwater trends may imply that Karstveld groundwater also occurs in relatively independent "compartments", as in the Transvaal karst (Brink 1979). Though I have no positive evidence to this effect, its possible conservation implications are profound and would bear keeping in mind during planning of large scale utilisation of Karstveld water. Another fact with bearing on this, is that water analyses from Dragon's Breath Cave have indicated that the hypogean waters recharge very slowly (J. Martini, pers. comm).

Epigean waters

Information on abiotic aspects of epigean karst waters is limited. Van Wyk & Hamman (1969) published an analysis of water from Otavifontein, which they considered typical of Karstveld springs. Karst water is often high in soluted limestone, which is deposited in the spring and results in the water issuing from the top of a mound, as e.g. at Gobaub and Agab in the Etosha National Park.

Total surface area of all known karst-related springs probably does not exceed 5 ha. It follows that water habitats in the Karstveld represent a tremendously restricted, fragmented habitat.

DOMINANT BIOTIC FEATURES

From the biotic viewpoint, the aquatic karst fauna parallels the abiotic division into hypogean and epigean waters, consisting of the fauna of groundwater in solution cavities on the one hand, and that of permanent springs and their associated vegetation on the other hand.

The subterranean aquatic fauna is badly known, but is receiving attention. The rate of endemism here is high, with many species restricted to single caves only. A well known species is the blind cave catfish *Clarias cavernicola*, which is endemic to Aigamas Cave. It is considered to be endangered (Skelton 1987a), and the total population numbers only some 150-200 individuals (Penney 1988). Referring to Table 2, the very small size and volume of Aigamas, compared to other known hypogean waters, emphasises the vulnerability of this habitat.

At least six stygobiotic (= living in groundwater) amphipods of the family Ingolfiellidae are known. *Stygobarnardia caprellinoides* and *Trogloleleupia eggerti* are both fairly widespread in groundwater in at least the Tsumeb/Otavi area, where they are regularly pumped to the surface from boreholes. *T. dracospiritus* is endemic to Dragon's's Breath Cave only, and *T. gobabis* to Arnhem Cave (Griffiths 1989). An endemic species from Naos Cave is being described (C. Griffiths, pers. comm.) and another has been collected from Twyfelfontein Wondergat recently. Irish (in press) discusses biology and energy flow in one Namibian hypogean lake.

The cenote-living Guinas Tilapia, *Tilipia guinasana*, originally endemic to Lake Guinas only, but subsequently introduced to Lake Otjikoto, is another species of conservation concern (Skelton 1987a).

Turning to epigean springs, the fauna may be divided into two categories. The first includes all the common, widespread opportunistic aquatic animals, such as the various invertebrates, amphibians and terrapins. These are the animals which can be found in any farm dam, and are the ones that have received the most attention thus far. For more information, refer especially to Curtis (1991). There are no species of conservation concern, and on present knowledge, no endemic species, except possibly the Naukluft frogs.

The second category of epigean aquatic fauna includes the potentially very interesting vegetation-associated fauna of karst springs, and the cryptic interstitial fauna of the ground/water interface. These faunas are completely unknown at present, though they almost certainly do occur. Due to the restricted nature of the habitat, high rates of endemism are to be expected here.

REAL AND POTENTIAL CONSERVATION PROBLEMS

Water is a valuable resource in a predominantly arid country like Namibia, and the utilisation of vast groundwater resources like that of the karst can probably not be stopped. On the short term, utilisation of karst waters will inevitably conflict with their conservation. In the long run, utilisers and conservationists should have similar goals, namely keeping a natural resource as healthy as possible. Starting from this common ground, it should be possible to develop viable compromises which will meet the needs of all concerned.

Probably the most serious threat facing karst waters, is that of habitat destruction. This includes the injudicious extraction of groundwater, which may cause springs to dry up and destroy any endemic fauna they may have had. A sad case of habitat destruction is that of Otavifontein, which was concreted over; this action destroyed a unique population of the fish *Pseudocrenilabrus philander*, before the latter could be properly studied (Twentyman-Jones 1988)

In other areas, extraction of groundwater has led to an increase in its salinity. This possibility has been neither noticed nor investigated in the Karstveld to date.

A second major problem is that of invasive alien species. Here Lake Otjikoto is a sad example. Otjikoto may originally have had no fish, alternatively, only *Pseudocrenilabris philander* may have been present. At an unknown later date, *Tilapia guinasana* was introduced from Guinas, to the detriment of *P. philander* populations. Still later, *Oreochromis mossambicus* was introduced, again competing with *T. guinasana* (Skelton 1987a,b). Even exotic and aquarium fish like *Tincta tincta*, *Poecilia reticulata* and *Xiphophorus helleri* have been recorded as introduced to Otjikoto (Bruton & Merron 1985).

The mollusc *Lymnaea columella* is an alien which occurs in waters in the Grootfontein area, but is apparently not invasive (B.A. Curtis, pers. comm.).

Water pollution is a potential problem which is not serious at present, but which could have a devastating effect in view of the restricted size of many of the habitats. Many of the hypogean waters are used for irrigation, and e.g. Lakes Otjikoto and Guinas are surrounded by cultivated fields. Pesticides used here may find their way into the lakes. Pesticides may also act indirectly on hypogean water environments via insectivores like bats, who defecate in caves, and whose guano may be an important food source to e.g. *Clarias cavernicola*, *Trogloleleupia dracospiritus* and *T. gobabis*. Even diesel fuel leaking from pumps may pollute the restricted hypogean waters.

TABLE 3: Resource evaluation of karst waters in Namibia.

		epigean and hypogean waters	
Resource value:	water	Medium	High
	soil	Low	Low
	salt	Zero	Zero
	animals	High	Low
	plants	Medium	Zero
	endangered spp.	Low (High?)	High
System value:	flood attenuation	Zero	Zero
	aquifer recharge	Low	High
	water quality modifier	Low	Low
	aesthetics	High	High
	social attributes	Low (High?)	Low
	atmosphere quality modifier	Zero	Zero

DISCUSSION AND RECOMMENDATIONS

Table 3 represents a resource evaluation of karst waters, according to the scheme proposed in his keynote address at the 1988 Wetlands Workshop by Prof. Breen. I conclude that the special nature of the habitat results in the existence of a very particular karst water fauna, but at the same time renders the fauna extremely vulnerable. Irresponsible exploitation of karst water may exterminate the fauna, but scientifically grounded utilisation should be possible.

The following future action is proposed:

1. That the vulnerability of karst water be taken into account in formal and informal development actions.
2. That gathering of information on all biotic and abiotic aspects of karst water be continued. Obvious lacunae here are information on the cryptic fauna of springs, and the stygobiotic fauna of unsampled subterranean waters, besides more detailed geohydrological information than the broad inferences available at present.
3. That conservation areas should be created in those cases where they may serve a purpose only. Experience with caves worldwide has shown that the mere proclamation of a conservation area, without concurrent access control, often serves only to advertise it and invite vandalism. On the other hand, secrecy as to location is a tried and trusted conservation method, particularly for those hypogean waters which already protect themselves to a large extent simply by being inaccessible to direct interference. In the case of epigean waters, which are directly accessible, and which are subjected to more direct exploitation than hypogean waters, creation of conservation areas may serve to alleviate immediate problems. There are no hard and fast rules, though, and each case should be approached on individual merit.
4. That the conservation of karst water be included in an overall conservation *cum* utilisation water strategy for Namibia, which will manage water resources in such a way that the geohydrological processes which drive the karst are kept healthy and intact. Such a strategy will address a major problem which arises with the creation of conservation areas for hypogean waters, namely that they can conceivably be destroyed by events (e.g. pollution or water extraction) which take place outside their borders. A judicious strategy may even obviate the necessity of creating numerous such tiny conservation areas, and free the money and manpower needed to manage the latter for more pressing conservation needs.

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