KARST BIO-SPACE

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The following paper on "karst bio-space" is based on a concept introduced in a recently commissioned report on the cave fauna in Tasmania (Clarke 1997). The report was commissioned as one of a series of reports for the biodiversity component of the environment and heritage assessment for the Tasmanian and Commonwealth governments comprehensive regional assessment (CRA) process for Tasmanian forests. (The CRA process in itself is a preliminary stage in the negotiation of a Regional Forest Agreement (RFA) for Tasmania.) In this cave fauna report, Clarke (1997) describes a number of management recommendations for the conservation and protection of cavernicolous invertebrates in forested karst (and pseudokarst) areas of Tasmania including a range of prescriptive protection measures for karst catchments, karst surfaces and caves: the humanly enterable component of the karst bio-space.

Karst bio-space: an introduction

Karst bio-space can be defined as the sum-total of the actual or potential habitats and micro-habitats of all living species in karst. The karst bio-space is composed of the interconnected network of cracks, joints, pipes, vertical channels, tubes, voids, horizontal conduits and cavities (including caves), that have formed as a result of the long-term effect of all solutional processes in carbonate rock and subsequent geomorphic events. At any given time, depending on conditions of recharge (water input) and discharge (drainage), this honeycombed network of spaces or spongework may be air-filled, water-filled or alternating in between.

This network of air or water filled spaces can be inhabited throughout by invertebrate (and vertebrate) fauna and along with the minute spaces in the interstices of cave sediments and detritus can all be collectively termed as the karst bio-space. This paper focuses on the aquatic and terrestrial invertebrate species that inhabit the karst bio-space. Aquatic and terrestrial species have the potential to move freely and migrate throughout the bio-space following moisture and nutrient inputs.

The actual or potentially water-filled parts of the karst bio-space are commonly referred to as components of the karst aquifer or karst hydrological system. These include the layers of karstified rock in the unsaturated epikarstic region, the recharge or discharge waters of cave streams and the permanently flooded or saturated phreatic zone (Ford and Williams 1989; Jennings 1985). Carbonate rocks such as limestone are deposited in layers or beds; some layers may be more soluble and more permeable to water than others, causing selective solutional development of cavities or permitting bodies of water to be "perched" one above another. This has important implications for cavernicolous fauna particularly during periods of recharge, permitting greater mobility of aquatic species through the bio-space, and also "trapping" terrestrial species that may be forced into the unsaturated cavities of the epikarst region till recharge waters subside. During periods of significant recharge, drainage waters from swallets or surface seepage can feed separate hydrological systems and emerge at different effluxes or springs (Ingle-Smith 1974) providing an explanation for the fact that the same aquatic species may be present in adjoining hydrological systems within one karst area.

The predominantly air-filled cavities in the karst bio-space range in size from minuscule cracks and fissures to the fist-sized or smaller voids, sometimes described as microcaverns or microcaves (Howarth & Stone 1990; Holland 1994) and to the larger caves and passages that can be entered by humans. Biologists cannot effectively study the faunal component of microcaverns etc. and can only examine those caves that are accessible. It has been estimated that for most karst areas of the world, only 10% of all caves have surface openings or connections enabling underground exploration and

biological study (Curl 1958). The record of collections of invertebrate fauna from caves only represents a small proportion of the fauna in the total biospace of any given karst area with potentially many more species to be found, particularly in the small spaces of the epikarstic or groundwater (phreatic) zones which are not accessible.

The visible karst bio-space of caves includes all the visually more obvious micro-habitats for terrestrial species such as the exposed surfaces or small pores and cracks in cave walls, cave ceiling and other rock surfaces. However, even in large caves, there are many other less obvious habitats for invertebrate fauna. The minuscule interstitial spaces between dirt particles, sand grains, gravels, small stones or organic material deposited by floodwaters on cave floor substrate are all potentially habitat niches, along with the larger voids between rock fragments or the boulders in a rock fall chamber. Similarly the water-filled interstitia of bedload sands or gravels or streamside deposits maybe habitat niches for aquatic fauna, e.g. the tiny bathynellacean syncarid from saturated streamside sands in Western Grand Fissure of Exit Cave in the Ida Bay karst of southern Tasmania (Clarke 1997). Undersides of loose cobbles in a streambed may be the habitat for aquatic larvae or the feeding site of crangonyctoid amphipods and anaspidean syncarids, while the sides of more firmly wedged or "cemented" cobbles in a streamway or the silty organic substrate of the streambed could be occupied by small aquatic snails such as the minute 1-2mm long hydrobiid gastropods.

The formation of karst bio-space

Karst bio-space is initially formed by solution processes, plus the subsequent geomorphic acts of corrasion, erosion, deposition of sediment and collapse of weakened rock strata that in total are described as the process of karstification. Solution processes are basically either chemical or biochemical whereby slightly acidic percolation waters and throughflow waters dissolve the carbonate mineral component (typically calcium or magnesium carbonate) of rock types such as limestone and dolomite, as the waters pass through the rock strata. The acidic component in solution waters has three origins: firstly, carbonic acid derived from hydration of atmospheric carbon dioxide (CO_2), plus the CO_2 produced by biological process in soils (Ford & Williams 1989; Gillieson 1996; Jennings 1985), secondly, the humic and fulvic acids produced by rotting vegetation in soil and leaf litter (Ford & Williams 1989) and thirdly, the sulphuric acid derived from the weathering of pyritic limestones, interbedded shales and mineralised palaeokarst (Clarke 1993; 1995; Houshold 1995; James 1991; Jennings 1985; Osborne 1995).

In the classic model for karstification of carbonate rocks such as limestones, rainwater is lightly charged with atmospheric carbon dioxide forming a weak solution of carbonic acid. The concentration of carbonic acid is considerably enhanced as water subsequently seeps through soils absorbing additional CO_2 derived from the respiration of invertebrates, bacteria and the decay of soil organic matter, derived from the forest or other vegetation cover. Due to the important role played by decaying leaf litter and soil humus content in promoting solution, it is imperative that soils overlying limestone are not disturbed (Clarke 1997; Harding and Ford 1993; Lewis 1996).

Water enters the limestone through minuscule (often microscopic) pores, cracks, joints and bedding planes or into larger crevices such as fissures, solution-widened joints, other zones of rock "weakness" and swallets in what is referred to as the epikarstic region (under soil layers) in the unsaturated vadose zone (Ford & Williams 1988). This latter region is sometimes referred to as the endokarstic, unsaturated, vadose zone (Gillieson 1996). In this zone of free draining percolation or seepage water, a continuing process of solution slowly widens or expands drainage paths over a long period of time. Solution also occurs in the saturated phreatic zone (flooded zone) below the water table and a tubular network of water-filled conduits (Jennings 1985) provides further habitats for aquatic faunas. Drainage waters exit the limestone via predominantly horizontal floodwater channels

or conduits and further enlargement of both vertical and horizontal passages occurs through the erosive processes of abrasion and corrasion as gravels or other clastic materials are fluvially transported through the karst system. Some of this transported sediment is deposited in stream channels; the streambank gravels or cobbles and water-filled interstitial spaces provide a further habitat niche in the karst bio-space for aquatic species.

Caves and cave fauna with reference to invertebrate species in Tasmanian karsts

Caves represent the major component of the known karst bio-space and include a range of cave fauna species in many habitats. The cave fauna, particularly invertebrate species, are commonly referred to as cavernicoles; these can be simply defined as any animal living in a cave (Eberhard, *et al.* 1991). Described as cavernicolous species, these cover a wide range of invertebrate taxa with varying degrees of dependence on the subterranean habitat, ranging from those obligate species totally dependent on caves to opportunistic or accidental species that follow streamways into caves, or are washed in/ fall in, or simply carried in by air currents. The invertebrates which enter caves as parasites in the fur or skin of vertebrates or attached to other invertebrates, e.g. mites and ticks, can also be classified as accidental species. Animals that can only live in caves and nowhere else are sometimes referred to as obligates, because they are "cave-limited", totally dependent on the cave habitat and therefore obliged to live in that subterranean environment. Obligate species are usually confined to the dark zone of caves, formerly known as the troglic zone (Richards 1962) and sometimes described as the deep cave zone (Eberhard *et al.* 1991; Eberhard 1992) - often located in the inner or deeper parts of a cave, away from external influences, and normally considered to be a very stable, but humid environment with naturally low nutrient input. In this stable environment, there is a reduced seasonal definition of reproductive events, which are usually more related to micro-climate conditions within a particular habitat (Doran 1991). Many of the obligate cavernicoles are cryptic (or secretive) by nature, or by virtue of their preferred micro-habitat (as narrow wall crevices or the interstitial spaces in soil and streamside deposits) or due to their very small size (often <5mm) and may elude even the best of cave-biologist sleuths!

Individual species population numbers in caves are variable. Generally speaking, when obligate species become confined to one cave or a number of inter-connected caves of one contiguous karst or common hydrological system, population numbers are likely to be small (Culver 1986), particularly in the case of terrestrial species. Some cave species are only described from one or two specimens, sometimes only one gender. It is often difficult to locate mature males and/or mature specimens of either gender due to a range of factors including seasonality, moisture levels and food supply and species may be absent altogether or only represented by immature specimens and females, unless both gender are observed during a mating period.

Some aquatic species may have relatively large populations with a wide geographic dispersal range due to enhanced mobility in aquatic mediums. However, some aquatic species with abundant populations have low dispersal power as exemplified by the minute hydrobiid gastropods: aquatic snails which are known to often only live in small bodies of water (Eberhard 1992a). Hydrobiids have been recorded from single caves or cave systems in Tasmania (Ponder 1992), and in cave systems of the Ida Bay and Precipitous Bluff karsts, there are several populations of different species living sympatrically in the same cave stream (Clarke 1990c; 1997; Eberhard 1992b; 1995). In caves where the dominant hydrological regime is seepage or percolation water, rather than throughflow water, aquatic species appear to be less abundant, e.g. the small population of troglobitic (obligate) heterid isopods in A.F. (IB-110) at Ida Bay (Clarke 1989a; 1990c).

The mobility of cavernicolous invertebrates in the karst bio-space

The mobility of aquatic species is obviously governed by the extent of each localised hydrological regime, which is largely governed by the extent of permeable layers of the limestone. Carbonate rock outcrops often extend each side of a topographic ridgeline or surface divide and hence surface runoff or seepage waters may flow in different directions, not necessarily downslope. The concept of a surface watershed where drainage extends downslope in opposite directions is not applicable in karst areas; water may breach these surface divides draining "backwards" to emerge on the opposite side or surface ridges. Examples of surface divide breaches in forested karst areas of Tasmania include those in Cracroft (Clarke 1987a; Goede 1977), at Ida Bay in southern Tasmania (Clarke 1990c; Goede 1969), in the Junee-Florentine karsts (R. Eberhard 1994; 1996; Hume 1991) and at Mole Creek in northern Tasmania (Jennings & Sweeting 1959; Kiernan 1990). It appears likely that a similar breach in a surface divide occurs in the Hastings karst of southern Tasmania (Clarke 1997). Following rainfall events in the catchment of the Hastings karst, flood waters have been observed in Newdegate Cave (H-X7), and it is believed that these may be derived from the slopes of Adamsons Peak, an area northwest of the known karst area. High turbidity has also been recently reported in the floodwaters in Newdegate Cave and the flocculent clay may be emanating from logged lower slopes of Adamsons Peak or the recently logged upper reaches of Creekton Rivulet in the neighbouring valley north of the Hastings karst (Clarke 1997).

Terrestrial obligates are often less mobile and may only be known from very small populations in only one cave system (Holsinger 1963). Some of the pseudoscorpion species from caves in the Appalachian mountains of USA are known from less than ten individuals (Culver 1986; Holsinger 1988). In Tasmania, the blind carabid beetle *Goedetrechus mendumae* is only known from a small cavernous section of the karst bio-space in the Ida Bay karst system. When first discovered by cave biologists in the northwestern extremity of Exit Cave during early March 1969, *G. mendumae* was only known from two female specimens found in one small passage section; subsequent collections in late March and May (1969) from the same area yielded two males and two more females. In December 1974, a visiting beetle expert from Japan collected another 6-7 specimens from an adjoining passage and since then the beetle has not been reported (Clarke 1987b; 1991a), although the writer collected a single specimen in late March 1989 from Thun Junction (IB-020), a vertical cave system which connects directly into Exit Cave in the vicinity of the earlier collection sites. [Although currently listed as vulnerable species (Eberhard 1993), based on present knowledge *Goedetrechus mendumae* should be considered as an endangered species.]

Cave communities

Invertebrate communities in the karst bio-space (including both terrestrial & aquatic species) are composed of the sum total of all species found in caves, i.e. the troglobites/stygobites, troglophiles/stygophiles, trogloxenes/stygoxenes, accidentals (and parasites) which are all "bound" together by inter-related food chains. Many of those terrestrial species which fall into the categories of trogloxenic or accidental cavernicoles, are species which have an aquatic larval or nymphal stage in the cave streams or other permanent water bodies. Clarke (1997) records many of the accidental species commonly found in Tasmanian stream caves: e.g. Plecoptera (stone flies), Trichoptera (caddis flies), Ephemeroptera (mayflies), Odonata (dragonflies), Dipteran chironomids (midges), tipulids (crane flies), trichocerids (winter crane flies), culicids (mosquitoes), sciarids (fungus flies), and phorids (hunchback flies).

Each cave community has a restricted and disjunct distribution pattern that is not repeated and the community structure often varies between different cave systems of a single karst region (Eberhard *et*

al. 1991; Eberhard 1992c; Clarke 1997). The species diversity (richness) of cave communities includes the total range of species in all cave zones and all micro-habitats. Some cave communities include diverse assemblages with many obligate cave species, whereas some cave communities are predominantly composed of accidental species, mainly terrestrial species (see Table 1). Accidental species and trogloxenes are fundamental to survival of higher order cavernicoles, contributing to the nutrient input of cave ecosystems (see below) and enhancing the diversity and abundance of obligate species. Examples of species diversity or species richness and the variable numbers of aquatic and terrestrial species within cave communities of Tasmanian caves are given in Table 1 (following page).

Cave ecosystems and food sources

Fundamental to the cave ecosystem and its constituent biota is the maintenance of stream flows, water volumes and moisture levels (particularly in the dark zone), together with the input of natural organic food sources. The importance of water balance and stress to cave invertebrates due to water loss has been well documented in numerous scientific studies (Culver 1982; Hüppop 1985; Humphreys & Collis 1990; Doran 1991).

Table 1: A list of 27 selected caves from karst areas in Tasmania, which have the most cave fauna records showing the respective numbers of aquatic and terrestrial species based on data in Clarke (1989c; 1990b) and RFA Cave Fauna database (Clarke 1997).

Cave number	Cave name	Occurrence records	Aquatic Species	Terrestrial spp.
BH-008	Main Drain	38	4	25
BH-203	Thylacine Lair	110	7	81
CP-006	APPM Cave	11	0	11
CP-037	Philrod Cave	28	5	17
E-201	Sherrills Cave	47	0	32
F-034	Kutikina Cave	76	6	43
FG-201	Flowery Gully Cave	62	1	45
G-X3	Rum Pot	26	2	17
GP-001	Gunns Plains Cave	77	9	42
H-214	King George V Cave	124	5	30
IB-010	Mystery Creek Cave	104	5	45
IB-014	Exit Cave	154	10	50
IB-110	Arthurs Folly	64	14	24
JF-004	Khazad Dum	51	6	33
JF-006	Cashion Creek Cave	72	0	25
JF-036	Growling Swallet	49	4	23
L-004	Mostyn Hardy Cave	87	13	45
MC-001	Kubla Khan	63	5	54
MC-032	Baldocks Cave	46	1	17
MC-052	Scotts Cave	47	3	19
NL-003	Spider Den	71	1	45
PB-001	Damper Cave	73	7	32
PB-004	Cueva Blanca	43	5	23
PB-006	Bauhaus	67	3	32
R-202	Glue Passage Cave	31	3	20
VF-X2	Salisbury River Cave	33	3	22
WE-X1	Campers Cavern	30	0	25

Organic matter from epigean sources provides the basic food resource for most cave ecosystems; exceptions could include those caves where cavernicolous species rely partly or entirely on the faecal deposits of vertebrate mammals, including bat guano in mainland Australian caves (Howarth and Stone 1990), or rely on the growth of plants such as fungi in low light regions or dark zones (Eberhard 1988). Organic matter, which may consist of tree roots, fragments of living green plants, detritus, faecal matter, animal remains (including vertebrate carcasses), other invertebrate organisms including eggs and larvae (Holsinger 1988). Most the organic matter from epigean (surface) sources is transported underground by streams, swallets, percolation seepage waters, air currents or gravity fall. Due to more or less constant temperatures and the reduced seasonality effect, some aquatic species have prolonged larval stages or larvae present all year round providing a more constant food supply for other higher order organisms. Trichopteran philoptamid larvae have been observed in parts of Exit Cave almost all year round, in a dark zone region almost two kilometres from the nearest known horizontal entrance (Clarke 1997).

Because of its isolation from external influences and relative distance from epigean environmental conditions, the dark zone of the cave where most obligates live, receives comparatively little nutrient input, apart from the limited dregs of food sources carried in by streams or air currents. The total darkness prevents any photosynthetic activity and there are virtually no "primary producers", except for chemosynthetic autotrophic micro-organisms which synthesise organic materials (Daoxian 1989; Holsinger 1988); these probably have relatively little input into the energetics of cave ecosystems (Holsinger 1988). A low nutrient input in the dark zone is the main reason why cave ecosystems and their cave communities are considered unique entities with either rich or significant faunal assemblages in what may be considered as a "closed ecosystem" (Sullivan 1971). In this part of the cave, everything is recycled, so live specimens, dead remains or waste products (including faecal pellets) of one organism become the food source of another organism in the immediate food chain component of the larger food web.

For example, during a recent visit to Exit Cave, in southern Tasmania, in November 1996, four aquatic obligates (all believed to be troglobitic stygobites) were observed in close proximity to each other within a short (metre long) stream section of Western Passage: anaspidean syncarids, crangonyctoid amphipods, paludicolan flatworms and tiny 1mm long hydrobiid gastropods. This section of feeder passage to the main cave lies in the dark zone approximately two kilometres from the nearest horizontal entrances: Exit Cave efflux (IB-014) or Valley Entrance (IB-120) and well over one kilometre downstream from the nearest vertical entrance: Halfway Hole (IB-136). Microscopic examination of live specimens of the hydrobiid molluscs collected in natural cave waters in November 1996, indicated that these small snails yielded a massive amount of minute elongate cigar-shaped/oval-shaped faecal pellets (approximately one-tenth of a millimetre long) which appeared to be being consumed by other micro-organisms, possibly bacteria, and in the cave environment these pellets would probably be a major food source for the other aquatic troglobites (Clarke 1997).

Many caves (or karst areas) contain significant populations of invertebrate species which comprise complex and diverse cave communities composed of aquatic and/or terrestrial species (Eberhard 1992c). Invertebrate species in Tasmanian cave communities live in a predominantly (and naturally) low level nutrient environment dependent on natural organic input from the surface systems and nutrient recycling within the respective cave ecosystem. Most cave ecosystems are very fragile and easily susceptible to disturbance from both surface impacts or "within" cave visitor impacts (Clarke 1989b; 1997). Fundamental to the viability of these cave communities is the stability of a moisture regime: either a constant supply of "clean" unpolluted stream waters with natural nutrient input and/or percolation (seepage) waters which maintain natural cave air humidity in a stable environment with low evapotranspiration rates.

The biological importance and conservation significance of cave faunas in karst bio-space

The cave communities include many obligate (cave restricted) species which have specialised troglomorphic adaptations enabling species to live in total darkness in the stable low nutrient environments. Separated from their surface ancestors, many of these cavernicolous invertebrates in karst areas include phylogenetic or distributionally isolated relicts which have evolved in subterranean environments over a considerable period of time, possibly dating back to a geomorphic era in the subterranean biospace before the development of the caves they now live in (Holsinger 1988; Richards and Ollier 1976). Due to separation of karst areas or contiguous cave (drainage) systems within a karst area, genetic isolation has occurred and speciation of cavernicolous faunas indicates high levels of endemicity. Most of these obligate species can be considered as rare and threatened species (Clarke 1997) with actual categorisation to a conservation status dependent on individual species population dynamics, level of habitat protection and otherwise known or potential habitat threats or disturbances to the karst bio-space.

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KARST BIO-SPACE - a GLOSSARY of TERMS

Abbreviations and conventions

Syn. = synonym (word with same meaning);
Cf. = confer (compare) with the following term which is not identical but related to it;
A word in brackets on the left-hand side (in upper case) is commonly used in conjunction with the following or preceding word without altering the meaning;
A word underlined is defined elsewhere in this list.

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ACCIDENTAL: (n.) An animal accidentally living in a cave, usually either fallen or washed in, but can include those carried in: i.e., parasites on mammals, other vertebrates or invertebrates. Used for both aquatic and terrestrial species.

ADAPTATION: An inherited structural, functional or behavioural characteristic of an organism which improves its chances for survival and reproduction in a particular microhabitat or environment. (See also troglomorphic adaptations.)

ANTENNAE: Pair of "feelers" on heads of crustaceans, insects and other invertebrates that function as sensory organs.

AQUATIC: Pertaining to organisms that live in water.

AQUIFER: A body of rock capable of allowing subterranean water to be stored, transmitted or issue yield as discharge and also capable of absorbing recharge.

ARAGONITE: A less common crystalline form of calcium carbonate belonging to the orthorhombic crystal class, dimorphous with calcite, but denser than calcite.

BACTERIA: Unicellular microscopic plant organisms, sometimes aggregated in filaments, which can manufacture their own food without sunlight; probably important in caves as decomposers and perhaps as chemosynthetic autotrophs.

BIOGEOGRAPHY: The study of the geographical distribution of animals and plants over the globe. Cf. zoogeography and phytogeography

BIO-SPACE: The separated or interconnected network of "spaces" as air or water-filled cracks, pipes, vertical channels, tubes, voids or microcaverns, horizontal conduits and larger cavities including caves that are inhabited by invertebrates, including in the interstitial medium and saturated zone.

BIOSPELEOLOGY: The scientific study of plant or animal organisms living in caves; usually applied to studies of cavernicoles.

BIOTA: Sum total of all plants and animals.

BIOTIC: Pertaining to biota.

CALCITE: The commonest calcium carbonate ($CaCO_3$) mineral and the main constituent of limestone, with different crystal forms in the hexagonal-rhombohedral crystal subsystem; dimorphous with aragonite.

CATCHMENT: The area drained by various sized watercourses including dolines.

CAVE: A natural subterranean cavity (or series of cavities) large enough to be humanly enterable, commonly formed by solution of carbonate rock in karst, but may also be formed by wind, fluvial erosion or collapse (see "Pseudokarst"). It may be an air-filled or water-filled cavity. Syn. cavern.

CAVE COMMUNITY: All the cavernicolous animals (and plants) that live together in cave habitats, "bound" together by food chains and other inter-related processes.

CAVE ECOLOGY: The study of the interaction and relationships between cave organisms and their environment, e.g. energy input from surface, climatic influences, etc. (See also cave ecosystem and cave community.)

CAVE ECOSYSTEM: The ecological system formed by the interaction of the biotic community with its abiotic environment; in biospleleological terms: the coacting organisms of the cave community with their subterranean bio-space environment.

CAVERNICOLE: An (invertebrate) animal which normally lives in caves; includes accidentals, trogloxenes, troglophiles and troglobites and their aquatic equivalents: stygoxenes, stygophiles, and stygobites.

i.e. corrosion and abrasion
CRYPTIC: (adj.) Term used to describe cavernicoles which may be difficult to locate, due to being very small (often <5mm) or secretive by nature or virtue of their preferred habitat, e.g. in narrow wall crevices or the interstitial spaces in soil and streamside deposits.
CONDUIT: An underground stream course completely filled with water and under hydrostatic pressure or a circular or elliptical passage inferred to have been such a stream course.

CONTIGUOUS KARST: The interconnected air-filled or water-filled solutional or hydrological network of space/s in any area of karstified carbonate rock.

CORRASION: The wearing away of bedrock or loose sediment by mechanical action of moving agents, especially water.
DARK ZONE: The insulated (inner) stable part of a cave shielded from external factors where conditions remain relatively constant all year round including a relatively constant temperature that approximates the annual surface mean and high humidity (often near saturation point) with a very low rate of evaporation and in Tasmanian caves, this zone is also characterised by low nutrient input. Syn. "troglic" zone; "deep cave" zone.

DECOMPOSERS: Living things, chiefly bacteria and fungi, that live by extracting energy from tissues of dead animals and plants.

DETRITUS: Aggregate of fragments from organic structures, as detached or broken-down tissues; small pieces of dead and decomposing plants and animals.

DISCHARGE: The outflow drainage of aquifer waters.

DISJUNCT (VICARIANT) DISTRIBUTION PATTERN: Relates to the separate occurrences of corresponding species in separate karst areas; these species are related to a (now extinct) once widespread surface-dwelling common ancestor. Cf: Distributional Relict, Phylogenetic.

DISTRIBUTIONAL RELICT: Relates to a species surviving in an area isolated from the main or original distribution area usually as a result of intervention of broad scale environmental events such as glaciation or continental drift, e.g. Gondwanan relict or Pangean relict species.

DOLINE: A closed depression, often basin-shaped or roughly conical, funnel-shaped depressions, usually formed in the karst land surface of carbonate rock area, as a result of solution or collapse of underlying carbonate rock strata. Dolines have a simple but variable form, e.g. cylindrical, conical, bowl or dish-shaped, and may vary in size dimensions from a few metres to many hundreds of metres wide. Dolines also include sinkholes, which are sites of sinking water that drain underground in karst.

DOLOMITE: (1) A mineral consisting of the double carbonate of magnesium and calcium, CaMg(CO3)2.
(2) A carbonate rock made chiefly of dolomite mineral.

EFFLUX: Place of outflow for karst waters from aquifer; often applied to place where cave stream emerges. Cf: resurgence, spring.

ENDEMIC(ITY): Pertaining to genera or species that are native to a particular area; often only found in one particular cave, hydrological system or karst area.

ENDOGEAN: Pertaining to the faunal domain (usually for terrestrial species) in the region immediately beneath the surface, i.e. within the soil or under plant litter. Cf: epigean; hypogean.

ENDOKARSTIC: Subterranean region in karst, below near-surface epikarstic zone, includes the "upper" unsaturated, vadose zone with free draining seepage water and streamway floodwaters plus the "lower" saturated, phreatic zone within static water table or slow flow flooded zone.

ENTRANCE ZONE: The interface between surface and subterranean (underground) environments leading internally into the twilight zone.

EPIGEAN: Pertaining to the biological domain at the surface or above it, including streams.

EPIKARSTIC: Pertaining to the upper/ outer layer of karstified carbonate rock in the unsaturated zone, immediatlely below the soil layer.

EROSION: The wearing away of bedrock or sediment by mechanical and chemical actions of all moving agents such as rivers, wind and glaciers at the surface or in caves.

EVAPOTRANSPIRATION: A process by which water is lost from a catchment or karst surface which includes evaporation of water from wet surfaces as well as transpiration of water from trees and plants.

FISSURE: An open crack in rock or soil.

FLOCCULANT: Syn. suspended sediment.

FLUVIAL: Pertaining to processes of flowing water. Cf. lotic.

FOOD CHAIN: A series of plants or animals linked together by their food relationships or a specific nutrient and energy pathway. (See also food web.)

FOOD WEB: An interlocking system of separate food chains in any (cave) community.

GUANO: Large accumulations of dung, often partly mineralized, including rock fragments, animal skeletal material and products of reactions between excretions and rock. In caves, derived from bats and to a lesser extent from birds.

HABITAT: The immediate surroundings (in the specific bio-space) of plants or animals (cavernicoles), with everything necessary for life of the organism that normally lives there.

HYPOGEAN: Pertaining to the subterranean domain below the endogean, including the dark zone of caves.

HYPORHEOS: Pertaining to water flowing over streambeds in lotic environments.

INTERSTITIAL MEDIUM: Air or water-filled spaces between grains of sand, fine gravel or detritus.

INVERTEBRATES: Animals without backbones. Includes the annelids (worms), molluscs (snails) and arthropods found in caves. (See also macroinvertebrates).

KARST: Terrain with special landforms and drainage characteristics due to greater solubility of certain rocks (notably carbonate rocks such as limestone, dolomite or magnesite) in natural waters. Derived from the geographical name "krs" from part of the karst terrain in Slovenia.

KARSTIFICATION: A periodic or cyclic process, where phases of active solutional development of karst are followed by infilling of karst conduits and voids, depending on global climatic regimes.

LARVA(E): The active immature, but self-sustaining and independent stage of invertebrate species, prior to assuming the characteristic features of an adult form.

LIMESTONE: A sedimentary rock consisting mainly of calcium carbonate, (CaC03), derived from the accumulated deposition (and fossilisation) of the calcareous remains of marine or freshwater organisms.

LOTIC: Pertaining to the aquatic environment of running water.

MACROINVERTEBRATES: Larger invertebrates that are visible to the naked eye.

MAGNESITE: Usually considered as a mineral, but in geomorphic terms as a form of magnesium carbonate rock (cf: dolomite) with varying amounts of magnesium, calcite or iron and may be susceptable to karst solution processes, e.g. the magnesite karst at Savage River in northwestern Tasmania.

MICROCAVERNS: Predominantly air-filled cavities ranging in size from "fist" sized voids or smaller, usually referring to those bio-space voids in the epikarstic region of the unsaturated zone and can be considered to include all cavities that are not large enough to be defined as caves. Syn. microcaves.

MICROCLIMATE: The climate (i.e. temperature, humidity, air movements, etc.) of a restricted area or space, e.g. of a cave or on a lesser scale of the space beneath stones in a cave. (See microhabitat).

MICROHABITAT: The individual faunal habitat or niche within a larger (cave) environment; maybe used to encompass broad regions such as the dark zone or smaller defined habitat niches,where environmental conditions differ from those in a surrounding area, e.g. under logs, in wall crevices or in the interstitial medium.

NETWORK: A complex pattern of repeatedly connecting passages in a cave.

NICHE: An organism's place in the cave ecosystem: where it lives, what it consumes, what consumes it and how it interacts with all biotic and abiotic factors.

NYMPH: Pertaining to a juvenile form, particularly related to juvenile insects without wings or with incomplete wings.

OBLIGATE: Pertaining to a species which is unable to live outside the cave environment, often found in the dark zone and may display troglomorphic adaptations.

ORGANIC: Of biological origin. Syn. biogenic.

PALAEOKARST: "Fossil" karst: cave or karst features remnant from a previous phase or period of karstification, characterised by the presence of ancient (buried) deposits, as lithified cave fills or (bone) breccias.

PARASITE: An organism which at some stage in its life history derives its food from the tissues of another organism; in cave ecosystems, the Acarina (ticks and mites) are commonly found as parasites on other invertebrates or vertebrates.

PERCOLATION WATER: Water moving mainly downwards through pores, cracks and tight fissures in the unsaturated epikarstic zone and vadose zone; may also relate to water draining underground from a swallet or streamsink.

PHREATIC ZONE: Zone usually below the water table where voids or tubes in the rock are completely saturated with water. Syn. saturated zone.

PHYLOGENETIC: Pertaining to an ancient lineage with a long history of development for the species. Viz. race history.

POPULATION: Individuals of a species in a given locality which potentially form a single interbreeding group separated by physical barriers from other such populations (e.g. populations of the same species in two quite separate caves).

PSEUDOKARST: Terrain with landforms (including caves) which resemble those of karst but are not the product of karst solution processes.

PUPA(E): The inactive stage in the life history of certain insects during which the larva undergoes a gradual reorganisation of its tissues in the process of metamorphosis to becoming an adult.

RECHARGE: The process involving the input or intake (absorption) of water into the zone/s of saturation in karst aquifers; also relates to the quantity of water added to the saturation zone.

RESURGENCE: A spring where a stream, which has a course higher up on the surface, reappears lower down at the surface.

SATURATED ZONE: The zone below the water table, composed of the shallow phreatic zone, deep phreatic (or bathyphreatic) zone and stagnant phreatic zone. Syn. phreatic zone.

SEEPAGE WATER: Syn. percolation water.

SINKHOLE: A word of American origin used to describe sites of sinking water in a carbonate rock (karst) area; often formed in a doline. Sinkholes also include swallets.

SOLUTION: In karst study, the change of bedrock from the solid state to the liquid state by combination with water. In physical solution the ions of the rock go directly into solution without transformation. In chemical solution acids take part, especially the weak carbonic acid formed by hydration of carbon dioxide (CO2).

SPECIES: A group of (invertebrate) animals that have a high degree of similarity and are actually or potentially interbreeding populations reproductively isolated from other such groups by their biology, not simply by physical barriers. Cf. speciation.

SPRING: A natural flow of water from rock or soil onto the land surface or into a body of surface water. Syn. rising.

STREAMSINK: A point at which a surface stream disappears underground; may be empty into a collapse feature, cave feature such as shaft or be the gradual downward percolation through streambed gravels or boulders. Cf. swallet.

STYGOBIONT: A term originally coined to describe the aquatic obligates in subterranean groundwaters and cave streams (i.e., the stygofauna), particularly relevant to species with troglomorphies that are restricted to groundwater habitats, i.e., the aquatic troglobites and phreatobia (phreatobites). The term is now expanded to cover the aquatic equivalents of terrestrial cavernicoles in karstic groundwaters: stygobites, stygophiles and stygoxenes and also covers aquatic species in alluvial groundwaters.

STYGOBITE: An obligate aquatic species of hypogean waters with troglomorphic adaptations, an aquatic equivalent of a (terrestrial) troglobite. Cf. stygobiont. In the expanded definition, stygobites also include the obligatory hypogean forms present in alluvial groundwaters, sometimes found very close to the surface and the phreatobites: stygobites which are restricted to the deep groundwater substrata of alluvial aquifers.

STYGOFAUNA: Ecologically descriptive term covering (aquatic) groundwater fauna.

STYGOPHILE: A facultative stygobiont, usually lacking troglomorphies, and considered as the aquatic equivalent of a (terrestrial) troglophile. In the expanded definition relating to porous aquifers, stygophiles are divided into three categories: occasional hyporheos, essentially the larvae of aquatic insects (which require an aerial epigean stage to complete their life cycle); amphibites, whose life cycle requires the use of both surface and groundwater systems; and permanent hyporheos - the diverse assemblage of species present in all life stages in the groundwater or benthic habitats.

STYGOXENE: An habitual stygobiont (aquatic species) which spends only part of its life cycle in cave waters and returns periodically to the epigean domain for food.

SUBTERRANEAN: Pertaining to underground environments (in karst).

SUSPENDED SEDIMENT: Small particles of insoluble organic or inorganic matter suspended in the water column. Syn. flocculant, suspended solid.

SWALLET: Usually related to karst, may be considered as a form of sinkhole, but could refer to a streamsink; (often associated with a cave entrance) and is one of the major entry points for recharge waters that drain underground in carbonate rock areas such as limestone. Swallets may empty directly into open or choked cave features such as shafts or avens, or simply be a zone of gradual downward percolation from the base of a streambed.

TERRESTRIAL: Pertaining to animals living on "land" surfaces in epigean, endogean or hypogean environments.

TRANSITION ZONE: Region between the twilight zone and dark zone where no there is no visible light, but some external factors from the entrance environment may still be apparent, e.g. seasonally fluctuating air temperatures.

TROGLOBITE: An (obligate) cavernicole unable to live outside the cave environment; usually defines an obligate species with troglomorphic adaptations. The term is usually restricted to terrestrial species, but sometimes aquatic obligates maybe referred to as aquatic troglobites.

TROGLOMORPHIC ADAPTATIONS: Adaptations to the cave environment, particularly for species living in the dark zone e.g. lengthening of appendages including antennae, loss of pigment; modification of eyes; modified olfactory sensory organs (for "sniffing" out prey and mates etc.); extra sensory structures e.g. elongated legs used as feelers and sometimes modified chelicerae (the grasping organs used to hold prey foods etc. and reduced metabolic rate are all considered adaptations to the dark zone of caves.

TROGLOXENE: A terrestrial cavernicole which spends only part of its life cycle in caves and returns periodically to the epigean domain for food.

TURBIDITY: Relates to the muddiness, cloudiness or "milkiness" of water and usually reflects the amount of suspended sediment in the water.

TWILIGHT ZONE: The outer part of a cave in which daylight penetrates and gradually diminishes to zero light, where transition zone takes over.

UNSATURATED (VADOSE) ZONE: The component of the karst hydrographic zone including endogean region in soil and the subterranean subcutaneous epikarst and free draining percolation water where voids in the rock are partly filled with air and through which water descends under gravity.