IMPACTS ON CAVE FAUNA AND RECOMMENDED PROTECTION MEASURES IN FORESTED KARST AREAS OF TASMANIA

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Introduction

The following paper represents a brief summary of some of the major aspects of a recent report relating to the cave fauna of forested karst areas in Tasmania (Clarke 1997). A brief synopsis is given of some of the major impacts of forestry activity on karst surfaces and karst catchments and the impacts to caves from cave visitors, together with some of the consequential effects on cave fauna from both surface (forestry) and underground (caving) activities. This paper includes some of the recommendations from Clarke (1997) for protection of cavernicolous invertebrates in the significantly karstified areas of Tasmania: areas with recorded karst bio-space.

Impacts of forestry activity on karstand cave fauna

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

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

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

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

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

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

Protection measures for cave fauna in Tasmania

The following recommendations (and their sub-sections) generally fall into one of seven categories: cave invertebrate species protection, habitat protection (including caves, karst surface environments, adjoining landsand catchments), recommended amendments to the Forest Practices Code (FPC) of Tasmania (Forestry Commission 1993), changes in land tenure in some forested karst areas (including recommendations for reservation of some karst areas in Crown land and landcare programmes on private land), habitat restoration and enhanced breeding programmes, mechanisms to increase public awareness of the uniqueness and fragility of cave ecosystems and recommendations for further research and study to assist in broadening the knowledge base of cavernicolous faunas in Tasmania and in particular to promote the conservation and management of cave fauna.

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

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

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

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

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

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

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

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

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

Rehabilitation and habitatrestoration or enhanced breeding programmes

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

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

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

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

Habitat restorationin caves

Habitat restoration in caves is described by Gillieson (1996) as requiring a long time scale to achievesatisfactory results. Habitat restoration is already occurring in somecaves in forested areas of Tasmania where "no-go" areas have been defined by taping off areas in so-called "substrate protection zones" e.g. in caves of the Mole Creek karst: Kubla Khan (MC-001), Little Trimmer (MC-039) (Eberhard & Hamilton-Smith in press 1997) and in My Cave (MC-141). This course of habitat restoration is only useful if all the cave visitors have good intentions and don't overstep the line to get their good photo shots! Management plans for caves can assist the process, but once again unless the cave fauna are locked in (or the cave visitors are locked out), the process is reliant on voluntary compliance by the cave visitors (Hamilton-Smith &Eberhard, in press 1997) being prepared to do the right thing. Habitat restoration is also being conducted at Exit Cave in southern Tasmania, following closure and rehabilitation of Benders (limestone) Quarry which was generating sediment input and probably dilute concentrations of sulphuric acid into cave waters (Houshold1995).

The impact on cave fauna by cave visitors

Cave visitors can impact on the biological attributes of caves in various ways: by both deliberate or accidental means. In late December1996, the writer found a deliberately baited "fishingline" in Gunns Plains Tourist Cave; a piece of hay-bale twine tied around a piece of meat had been placed in the cave stream where the large Tasmanian freshwater crayfish: *Astacopsis gouldi* was known to frequent. Cave visitors have also been known to light fires in caves for warmth, apart from the more inadvertant acts of littering with food scraps, lollie wrappers and leaving behind clothing lint, plus the more deliberate discard of plastic wrappers or food containers, used torch batteries, spent carbide or human wastes.

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

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

Micro-habitatprotection as an aid to enhanced breeding

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

Breeding enhancement is unlikely to be successful unless the micro-habitats of threatened species are accurately defined and the source of threat is nullified or curtailed altogether. Ideally, these particular micro-habitats within caves should be closed off to access by cave users, unless artificial breeding colonies or underground laboratories are established, such as those in France. In Slovenia, over-collecting of the rare aquatic vertebrate: the salamander *Proteus* (the first troglobite ever described) lead to it becoming an endangered species; its continued existence is now only guaranteed because of protection in artificial breeding colonies outside of Slovenia (Humphries1993). Underground (cave) laboratories have the ability to ensure species survival because they can environmentally enhance the habitat niche of any rare and threatened species and monitor that immediate environment without the impacts of regular cave visitors to an unprotected site.

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

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

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

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

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

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