Eberhard, S.M. (2004) Ecology and hydrology of a threatened groundwater-dependent ecosystem: The Jewel Cave karst system in Western Australia. PhD thesis Murdoch University, Western Australia.

ABSTRACT

Groundwater is a significant component of the world's water balance and accounts for >90 % of usable freshwater. Around the world groundwater is an important source of water for major cities, towns, industries, agriculture and forestry. Groundwater plays a role in the ecological processes and "health" of many surface ecosystems, and is the critical habitat for subterranean aquatic animals (stygofauna). Over-abstraction or contamination of groundwater resources may imperil the survival of stygofauna and other groundwater-dependent ecosystems (GDEs). In two karst areas in Western Australia (Yanchep and Leeuwin-Naturaliste Ridge), rich stygofauna communities occur in cave waters containing submerged tree roots. These aquatic root mat communities were listed as critically endangered because of declining groundwater levels, presumably caused by lower rainfall, groundwater abstraction, and/or forest plantations. Investigation of the hydrology and ecology of the cave systems was considered essential for the conservation and recovery of these threatened ecological communities (TECs). This thesis investigated the hydrology and ecology of one of the TECs, located in the Jewel Cave karst system in the Leeuwin-Naturaliste Ridge. A multi-disciplinary approach was used to explore aspects pertinent to the hydrology and ecology of the groundwater system.

Thermoluminescence dating of the limestone suggested that development of the karst system dates from the Early Pleistocene and that caves have been available for colonization by groundwater-fauna since that time. Speleogenesis of the watertable maze caves occurred in a flank margin setting during earlier periods of wetter climate and/or elevated base levels. Field mapping and leveling were used to determine hydrologic relationships between caves and the boundaries of the karst aquifer. Monitoring of groundwater levels was undertaken to characterize the conditions of recharge, storage, flow and discharge. A hydrogeologic model of the karst system was developed.

The groundwater hydrograph for the last 50 years was reconstructed from old photographs and records while radiometric dating and leveling of stratigraphic horizons enabled reconstruction of a history of watertable fluctuations spanning the Holocene to Late Pleistocene. The watertable fluctuations over the previous 50 years did not exceed the range of fluctuations experienced in the Quaternary history, including a period 11,000 to 13,000 years ago when the watertable was lower than the present level.

The recent groundwater decline in Jewel Cave was not reflected in the annual rainfall trend, which was above average during the period (1976 to 1988) when the major drop in water levels occurred. Groundwater abstraction and tree plantations in nearby catchments have not contributed to the groundwater decline as previously suggested. The period of major watertable decline coincided with a substantial reduction in fire frequency within the karst catchment. The resultant increase in understorey vegetation and ground litter may have contributed to a reduction in groundwater recharge, through increased evapotranspiration and interception of rainfall. To better understand the relationships between rainfall, vegetation and fire and their effects on groundwater recharge, an experiment is proposed that involves a prescribed burn of the cave catchment with before-after monitoring of rainfall, leaf-area, ground litter, soil moisture, vadose infiltration and groundwater levels.

Molecular genetic techniques (allozyme electrophoresis and mitochondrial DNA) were used to assess the species and population boundaries of two genera and species of cave dwelling Amphipoda. Populations of both species were largely panmictic which was consistent with the hydrogeologic model. The molecular data supported the conclusion that both species of amphipod have survived lower watertable levels experienced in the caves during the Late Pleistocene. A mechanism for the colonization and isolation of populations in caves is proposed.

Multi Dimensional Scaling was used to investigate patterns in groundwater biodiversity including species diversity, species assemblages, habitat associations and biogeography. Faunal patterns were related to abiotic environmental parameters. Investigation of hydrochemistry and water quality characterized the ecological water requirements (EWR) of the TEC and established a baseline against which to evaluate potential impacts such as groundwater pollution.

The conservation status of the listed TEC was significantly improved by increasing the number of known occurrences and distribution range of the community (from 10 m^2 to > 2 x 10^6 m^2), and by showing that earlier perceived threatening processes (rainfall decline, groundwater pumping, tree plantations) were either ameliorated or inoperative within this catchment. The GDE in the Jewel Cave karst system may not have been endangered by the major phase of watertable decline experienced 1975–1987, or by the relatively stable level experienced up until 2000. However, if the present trend of declining rainfall in southwest Western Australia continues, and the cave watertable declines > 0.5 m below the present level, then the GDE may become more vulnerable to extinction.

The occurrence and distribution of aquatic root mat communities and related groundwater fauna in other karst catchments in the Leeuwin-Naturaliste Ridge is substantially greater than previously thought; however, some of these are predicted to be threatened by groundwater pumping and pollution associated with increasing urban and rural developments. The taxonomy of most stygofauna taxa and the distribution of root mat communities is too poorly known to enable proper assessment of their conservation requirements. A regional-scale survey of stygofauna in southwest Western Australia is required to address this problem. In the interim, conservation actions for the listed TECs need to be focused at the most appropriate spatial scale, which is the karst drainage system and catchment area. Conservation of GDEs in Western Australia will benefit from understanding and integration with abiotic groundwater system processes, especially hydrogeologic and geomorphic processes.