

**THE PRESENCE OF STYGOBITIC MACROINVERTEBRATES IN
KARSTIC AQUIFERS: A CASE STUDY IN THE CRADLE OF
HUMANKIND WORLD HERITAGE SITE**

by

Sayomi Tasaki

DISSERTATION

Submitted in fulfilment of the requirements for the degree

MASTER OF SCIENCE

in

ZOOLOGY

in the

FACULTY OF SCIENCE

at the

UNIVERSITY OF JOHANNESBURG

Supervisor: Dr. J.F. Durand

Co-Supervisor: Prof G.J. Steyn

October 2006

DEDICATION

To the memory of Juichi, my father, who taught me to think beyond my time and Dircy my mother who has being my greatest friend and supporter.

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ACKNOWLEDGMENTS

I would like to acknowledge the following:

Dr. W. F. Humphreys of the Western Australian Museum for his advice concerning preliminary literature.

Dr. Heather Mackay for motivating the need for a national research regarding groundwater linked systems.

Dr. F. Durand for embracing the initiation of the field studies linked to blind amphipods in cave habitats as a pioneer study field in South Africa.

Prof. G. J. Steyn for his academic leadership in the pioneer project regarding the ecology of blind amphipods in karstic cave systems, and his patience during for the extensive process of applied field work in the subterranean regions.

Ms. Hester Roets and Mr. Ebrahim Karim from the Graphic Studio at the University of Johannesburg for their excellent performance in the planning and designing of graphics and re-drawings.

Mr. Vernie Naidoo at the University of Johannesburg for his work in the photographic laboratory and help with equipment.

Dr. Jonathan Taylor from Northwest University for his advice concerning academic regulations for composing the scientific dissertation.

Dr. Andrew Graham of Postgraduate Writing Support in the Faculty of Education at the University of Johannesburg for his contribution towards English grammar review.

The Department of Geohydrology (DWAF) and the cooperation of Dr. Eddie van Wyk for help with geological data, and technical support with an automobile unit equipped with borehole camera technologies for experimental field assessments.

The Resource Quality Studies (DWAF) laboratories for sponsoring the water quality tests.

Professor Leon Van Rensburg from North West University at the School of Environmental Sciences for his academic support and conciliation of these studies.

The Water Research Commission for promoting financial support, particularly that granted by Dr. Kevin Pietersen and Dr. Stephen Mitchell. Their support has been a key component in the acquisition of scientific equipment needed to enable adequate work performance in this specific work field.

ABSTRACT

Subterranean ecosystems are regarded as the most extensive biome on earth, comprising terrestrial and aquatic systems - the latter constituting freshwater, anchialine and marine systems. This system plays a key role in the distribution and storage of freshwater, once it contains 97% of the world's total liquid freshwater (Chapter 1), which has been progressively explored in quality and amount. Initial observation of the subterranean environment began with speleological studies by the recognition of a typical fauna adapted to live inside caves. The first studies to provide information about aquatic subterranean fauna commenced in Slovenia, with the description of the *Proteus aguinus* by Laurenti in 1768. After an initial faunal classification by the Danish zoologist Schiödte (1849), the Austrian naturalist Schiner (1854) established the most commonly used classification for cave fauna and a great portion of modern research dealing with ecobiology of aquatic subterranean fauna has mostly evolved from the European biospeleology (Chapters 1 and 3).

Studies in biospeleology have made a significant contribution to the progressive knowledge in aquatic subterranean ecology, especially in those circumstances where the access of the underground through smaller voids (e.g. crevicular spaces) is not possible. Accessibility to the underground environment is in fact a negative factor that has led a large number of studies consider about subterranean fauna initially being limited to caves. Spatial constraint was (and still is) a limiting factor in accessing a diverse range of subsurface habitats, although during the last decade, modern research has been using advance technology as a tool to overcome the physical barriers to subterranean research.

For a long time the classification of subterranean aquatic organisms was an unclear subject, with the classification subterranean fauna mostly related to terrestrial cave fauna (troglofauna). The classification system dealing with aquatic subterranean groups (stygofauna) is more recent. A few nomenclature schemes have been proposed to describe these relationships, based on morphological, behavioural, and ecological adaptations of animals to the underground life and their level of relationship with groundwater (Chapter 4). The prefix "stygo" is suggested as the most descriptive to refer ecologically to a group of animals related to groundwater habitats. Groundwater related fauna (stygofauna) is comprised

by groups of animals encompassing aquatic surface, intermediate and subterranean habitats. They represent diverse group of animals that have different interactive relationships with the groundwater habitat. Some may transact between surface water and groundwater systems, while others spend the whole life cycle in the subterranean voids (Gibert et al., 1994). This transition zone between surface streams and groundwater is recognized as a critically important boundary or ecotone, constituted by a habitat that contains a reservoir of invertebrate fauna biodiversity.

It is therefore from the study of karst systems that most information on groundwater ecobiology is resourced, once the open structure of most karsts terrains promotes a number of caves, streams, crevices, sinkholes, and springs to allow human access. Karst systems are well fractured because of the relation between the rock mass and the action of meteoric water, as well as the dissolution rate of calcium carbonate rocks that high. The latter increases with time, producing a terrain with a great drainage potential (Chapter 2). Once porosity is high and the flow of percolating water is fast, it allows good vagility for subterranean fauna and nutrients, as well as penetration of contaminants. In subterranean karsts, much water saturates some areas inside rock spaces. The saturation in the rock in turn promotes large water pockets, known as aquifers. When these groundwater aquifers are found to be interconnecting with the adjacent ecosystems, they became active eco-hydrological components, due to their key participation in the surface-groundwater continuum.

Groundwater has different degrees of importance, depending on the available sources of surface water. In many countries it supplies a significant proportion of urban and rural drinking water, industrial, and agricultural. Yet, groundwater systems are “hidden”, difficult in access and to study (Chapter 4, 5 and 7), consequently the recognition of the groundwater aquifer as a natural resource that needs to be protected is largely ignored. Moreover, studies in the ecobiology and distribution of stygobitic invertebrates (Chapter 5), and the need to identify a frame of methods for quality assessment and the suitability of groundwater invertebrates as bioindicative elements, has not been developed (Chapter 6).

Finally, strong management and public education programs are required to emphasize the need for a better understanding of the nature of groundwater resources, their participation and

complexity (Chapter 8), with the conceptualization of the groundwater aquifer integrity as an ecosystem still receiving little attention in South Africa.

GLOSSARY

Anchialine:

Habitats consisting of water bodies of haline water, with restricted exposure to open air, sometimes linked via subterranean connections to the sea.

Anoxic:

Used of a habitat devoid of molecular oxygen.

Allopatric:

Used of species or populations occupying a geographical area different from that of another species of population.

Allochthonous;

Originating outside and transported into a given system or area; exogenous.

Aphotic:

An environment or a habitat deprived of sunlight of biological significant intensity.

Aquifers:

All rocks capable of transmitting water to some degree through the pore spaces between mineral particles.

Apomorphic:

Derived from and differing from an ancestral condition.

Amphibiontic:

Related to amphibiotic; having transitory life stages between surface and subsurface domains.

Ecotone:

The transition zone between adjacent communities or biomes; tension zone.

Epigean:

The surface environment as opposed to the subsurface environment.

Gene flow:

The exchange of genetic factors within and between populations by interbreeding or migration.

Groundwater:

Subsurface water at psometric level (hydrological); water that is resident times constituting the subsurface hydrosphere (exological).

Groundwater dependent ecosystems:

Systems in which groundwater has some degree of participation or influence.

Hyporheos:

Hyporheic zone, interstitial spaces within the sediments of a stream bed; a transition zone between surface water and groundwater.

Hypogean:

The subterranean environment as opposed to the surface environment.

Karst:

A term originated from pre-indoeuropean origins, from the term *Karra* meaning geological stone. A geological formation composed of carbonate rocks (CaCO_3), including the magnesium carbonate and all relatives that are greatly soluble by water erosion.

Parapatric:

Pertaining to populations whose geographic ranges are contiguous but not overlapping, so that gene flow between them is possible

Photic zone:

An area that has enough solar penetration for photosynthesis.

Phreatic zone:

Layer(s) of soil or rock below piezometric surface (water table) in which voids are permanently saturated with groundwater.

Phyletic;

Pertaining to a line of direct descent, or a course of evolution.

Plesiomorphic:

Pertaining to an ancestral character within the taxa being considered, in contrast to the derived (apomorphic) stage; used of ancestral or primitive characters or character state; having similar shape or structure.

Psychrophile stygobite:

Oligibate aquatic subterranean forms thriving in lower temperatures.

Relict species:

Population of organisms separated from a parent population by some vicariant event.

Stygo (n):

Prefix referring to groundwater habitats, the groundwater biotope.

Stygobiont:

Animal inhabiting the various types of groundwater.

Stygobite:

Species that are specialized subterranean forms, obligatory hypogean. Some are widely distributed in all kinds of groundwater systems(both karst and alluvia), and sometimes they are found very close to the surface (benthic).

Stygofauna:

Fauna inhabiting the various types of groundwater in different degrees of relationship. Numerous names are in use for subsets of this system, mostly based on habitat type.

Sympatric:

Used of populations, species or taxa occurring together in the same geographical area; the populations may occupy the same habitat (biotic sympatric) or different habitats (neighbouring sympatry) within the same geographical area; sympatric; cf.allopatric, dichopatric, parapatric.

Stereotropism:

An orientation response to a contact stimulus; haptotropism; thigmotropism.

Thigmotactism:

An orientation response to touch or a contact stimulus; stereotropism

Troglos:

Assemblage of organisms inhabiting underground voids; often restricted to the 'terrestrial' organisms in air-filled voids.

Troglomorphic:

Pertaining to morphological, behavioural and physiological and other characters that are convergent in subterranean populations.

Troglobite:

Species which do not exist outside caves; they may, however, occur in the superficial underground compartment or in the upper hypogean zone.

Troglobiont:

Animal inhabiting the various types of subterranean spaces; sometimes restricted to air-filled voids; and hence terrestrial as opposed to aquatic species.

Troglobiont stygobiont(s):

Obligate inhabitants of underground waters found in caves.

Vicariant event:

The division of the biota or taxon through the development of a natural barrier.

Vadose zone:

Layers of soil or rock where water is found above the piezometric surface (water table); zone of vertical circulation of meteoric water, through cracks and fissures (percolation water).

Vugs: Void, subterranean spaces, crevices.

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