Patterns of Distribution, Diversity and Endemism of Terrestrial Molluscs in South Africa

by

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PREFACE

The research work described in this thesis was carried out in the School of Biological and Conservation Sciences, University of KwaZulu-Natal, Durban from February 2002 to December 2007, under the supervision of Professor R.H. Slotow (University of KwaZulu-Natal) and co-supervision of Dr D.G. Herbert (Natal Museum, Pietermaritzburg).

These studies represent original work by the author and have not otherwise been submitted in any form for any degree or diploma to any tertiary institution. Where use has been made of the work of others it is duly acknowledged in the text.

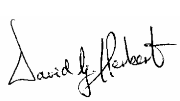
Vanashrie Govender

December 2007

As the candidate's supervisor I have approved this thesis for submission.

Signed:  Name: Prof. R.H. Slotow Date: 6 December 2007

As the candidate's supervisor I have approved this thesis for submission.

Signed:  Name: Dr D. G. Herbert Date: 6 December 2007

DEDICATION

To my dad

This project began with you. I wish you were with me to celebrate its ending.
You are sorely missed.

To my mum

You are my pillar of strength and inspiration.

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I wish to express a special thank you to my supervisors, Professor R.H. Slotow and Dr D.G. Herbert, for their advice, constructive criticism and especially their understanding when I struggled through difficult times. Moreover I thank them for sharing their knowledge and guiding me throughout the project.

I would like to express my heart-felt gratitude to my parents whose unwavering belief in me has accompanied me during every step of my life. Thank you for your unconditional love, your words of encouragement and steadfast support and most especially for your positive outlook on life.

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To God, who constantly challenged me and forced me out of my comfort zone, I say thank you for providing me with the opportunities to grow and for always being there. Nothing is possible without you.

ABSTRACT

Molluscs are an important component of South Africa's biodiversity. The assessment of distribution patterns and factors influencing the biogeographic distribution are an integral part of assessing the conservation status of molluscs and their conservation management needs. The existing terrestrial mollusc data from South Africa were assessed in terms of their value to biodiversity conversation planning and management. Although the data on terrestrial molluscs are incomplete and would be misleading in terms of identifying specific areas for protection, the data do illustrate significant patterns and trends of mollusc endemism and diversity, which can be used to improve biodiversity conservation and management efforts.

The distribution of molluscs across the South African landscape illustrated ten broad biogeographical patterns. Two of these patterns reflected ancient distribution patterns of molluscs and consisted of molluscs of the Gondwanaland/southern relict and Laurasian origins. Three biogeographic patterns occurred across the eastern regions. These patterns were defined as the tropical/subtropical east African, subtropical east of southern Africa and east African afromontane patterns. The biogeographic patterns in the west consisted of the characteristic temperate 'Mediterranean' Cape centre and the arid regions of northwestern Cape, Namibia and parts of Botswana. An additional biogeographic pattern identified as the nama karoo/central west was recognised. The final two biogeographical patterns described taxa that were widely distributed and taxa that exhibited disjunct distributions. Twenty-six families and forty-three genera were associated with more than one biogeographical pattern. The dominant biogeographic pattern was the tropical/subtropical east African component. Twenty-one families and forty-eight genera were associated with this biogeographical pattern. The east African Afromontane pattern was also a conspicuous biogeographic element in South Africa. Fewer families and genera were distributed in the western and central regions.

The distributions of terrestrial molluscs were influenced by a combination of various factors, which included the presence of rivers, the escarpment, altitude, humidity, precipitation, temperature and biomes. Rivers could possibly restrict the distribution of certain mollusc taxa but did not appear to be the dominant factor that influenced the distribution of molluscs across the landscape. In terms of the effect of temperature on the distribution of molluscs, the mean daily and mean annual temperatures appeared to have more of an influence on the distribution patterns than the mean daily maximum and minimum temperatures. Mean annual temperatures influenced the distribution of all families and genera. The mean daily maximum temperature appeared to have little or no effect on the distribution of mollusc taxa. Humidity and biomes also appeared to influence the distribution of taxa. The least inhabited biome was the succulent biome. Many mollusc taxa occurred in the wetter, warmer areas with high humidity levels.

Areas of high species richness and high endemic species richness in South Africa were identified using two systems of endemism, one based on distinctive gaps in the frequency distribution of terrestrial molluscs in South Africa and the other based on an existing classification of invertebrate endemism (Hamer & Slotow, 2002). Areas of high mollusc species richness and endemism were also compared to areas of high millipede species richness and endemism. The total number of South African mollusc endemics was 370 (83 % of 447 indigenous species). The dominant mollusc families in South Africa were Achatinidae, Charopidae, Streptaxidae, Subulinidae and Urocyclidae. The first system of endemism identified 56 site endemics (species with only one locality), 50 local endemics (0 < maximum distance < 60 km) and 145 regional endemics (60 km < maximum distance < 330 km). The Hamer & Slotow (2002) classification of endemism classed 67 species as site endemics (maximum distance between localities < 10 km), 47 as local (11 km < maximum distance < 70 km) endemics and 59 as regional endemics (71 km < maximum distance < 150 km). The analysis of mollusc data, with both systems of endemism, showed similar areas of high species and endemic species richness. Quarter-degree grid cells with highest species richness overlapped with grid cells with the highest number of endemic species. However these grid cells coincide with areas that have been intensively sampled and this bias limits the application of the data in conservation planning. The patterns of endemism for molluscs and millipedes within the provinces differed, indicating that the inclusion of a single taxon in conservation planning would inadequately reflect the diversity of invertebrates in South Africa. A preliminary list of specific priority endemic sites for terrestrial mollusc conservation was identified.

It is essential that the existing data on invertebrates be evaluated and used to identify key patterns and trends in invertebrate diversity as this will allow for the inclusion of invertebrates in biodiversity conservation planning and management. The analysis of the existing mollusc data identified biogeographical patterns that are important to conservation planning both at the local and national level as well as commonalities and differences between molluscs and millipede distributions. The analysis also highlighted the importance of municipal areas for conservation of hotspots of diversity, particularly in the eastern coastal areas of South Africa.

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CHAPTER 1
GENERAL INTRODUCTION

This chapter aims to introduce the concept of biological diversity, its importance and the threats facing biodiversity. Strategies to conserve biodiversity and the use of Geographic Information Systems (GIS) as an analytical tool in biodiversity research will also be introduced. Invertebrate diversity in general and the influence of various factors on the biogeography of biodiversity will be discussed first, followed by a brief discussion on mollusc diversity and biogeography. The chapter concludes by introducing the aims and objectives of the study.

1.1. Introduction

As the human population and industrialization increase, natural habitats are being converted from native ecosystems to agricultural land, resulting in an increase in the demand of the earth's biological resources and fragmentation of natural habitats (Meadows, 1985; Singh, 1990; Berger & Cunningham, 1994; Cole, 1994; Aber & Melillo, 2001). This has led to habitat loss and enormous changes to diversity at a number of levels throughout the world (Cole, 1994; May, 1994; Tilman, 2000; Aber & Melillo, 2001). On existing agricultural lands, genetic engineering and site enrichment through fertilization and irrigation are increasing with the rapid expansion of the human population and industrialization. The environmental burden placed on the earth's ecosystems can be noticed in the decline and extinction of species populations, and pollution loading to non-agricultural systems (Meadows, 1985; Erskine, 1987; Singh, 1990; Cumming, 1998; Aber & Melillo, 2001).

Although losses in habitat and species diversity could be halted, or even reversed (Cumming, 1998), it remains uncertain whether conservation initiatives will reduce the rate of biotic losses (Biodiversity Support Program, 1993; Berger & Cunningham, 1994). The loss in biodiversity is a major concern worldwide as it will have serious social, economical, aesthetic and ethical implications (Lovejoy, 1986; Erskine, 1987; Holloway & Stork, 1991; Heywood, 1995; Oates & Folmer, 1999). As a result there has been a dramatic increase in attempts to measure and identify the earth's biological diversity as well as to develop and implement strategies to effectively manage and conserve biodiversity (Holloway & Stork, 1991; Cole, 1994).

1.2. Defining biodiversity

Since the 1980s when the term biological diversity was first coined (Wilson, 1988), there have been many studies, which attempt to measure, quantify and describe the diversity of the world (Pearce & Moran, 1994; Jeffries 1997). Although widely used, the terms biological diversity and diversity have rarely been clearly defined (Solow *et al*., 1993; Williams & Gaston, 1994; Freitag & van Jaarsveld, 1995; Jeffries, 1997). Biological diversity (commonly shortened to biodiversity) was initially coined as an ecological term, which described the number of species in a study site or the distribution of the numbers of organisms among species. It has now come to hold a wider meaning in common usage, encompassing processes of evolution and extinction, especially as affected by human activity. Biodiversity therefore can be interpreted and analyzed at a variety of levels and scales (Faith, 1994; May, 1994; Noss & Cooperrider, 1994; Pearce & Moran, 1994; Aber & Melillo, 2001).

Broadly defined biodiversity refers to the range of variation or differences of organisms within the living world (Reid & Miller, 1989; Groombridge, 1992; Samways, 1993; Harper & Hawksworth, 1994; McNeely, 1994; Noss & Cooperrider, 1994; Cafaro & Primack, 2001). Biodiversity is used to describe the number, variety and variability of living organisms from all sources including terrestrial and aquatic ecosystems and the ecological complexes of which they are part. The ecological complexes are the intricate and interdependent relationships that often occur among coexisting organisms, including diversity within and between species as well as the diversity of the ecosystem (Groombridge, 1992; Biodiversity Support Program, 1993; Harper & Hawksworth, 1994; McNeely, 1994; Wessels *et al*., 1998). Biodiversity is usually defined in terms of biomes (e.g. tropical savanna or coastal wetland), ecosystems, genes (within species), species (species numbers), landscapes and the ecological and evolutionary processes that allow elements of biodiversity to persist over time (Westman, 1990; Ehrlich & Wilson, 1991; Holloway & Stork, 1991; Groombridge, 1992; Biodiversity Support Program, 1993; Cole, 1994; Harper & Hawksworth, 1994; McNeely, 1994; Noss & Cooperrider, 1994; Beck, 1998; Cafaro & Primack, 2001; Wessels *et al*., 2003; Driver *et al*., 2005).

Ecosystem diversity refers to the different ecological processes present within the ecosystems with respect to habitats, biotic communities and ecological processes. Genetic diversity represents the heritable variation within an organism, within and between populations as well as between species. Species diversity refers to the variety of living species both in terms of the number of species and relative abundances of species (Groombridge, 1992; Biodiversity Series 1, 1993; May, 1994; Noss & Cooperrider, 1994).

Biogeographical and ecological processes occur across space and time. In South Africa, biogeographical processes at a national scale are represented by the Great Escarpment and associated mountain ranges, biogeographic nodes, carbon sequestration areas and areas of biome resilience to climate change (Driver *et al*., 2005). The Great Escarpment is a major topographic feature of the South African landscape (Herbert & Kilburn, 2004). The mountain range is associated with altitudinal and climatic gradients and migration routes (Driver *et al*., 2005). Biogeographic nodes are defined as areas in which different types of vegetation coincide to create regions of ecologically important interactions. Regions where the current biome may persist in the face of climate change and under various climate change scenarios are termed areas of biome resilience to climate change. Ecological processes at the regional and local scale in South Africa include upland-lowland links, migration and dispersal corridors, sand movement corridors and interfaces between different soil types. In order to achieve biodiversity conservation, it is important to consider biodiversity patterns (habitats and species) as well as the ecological processes that allow these biodiversity patterns to persist over time (Driver *et al*., 2005).

1.3. Values in biodiversity conservation

Biodiversity is immensely important in forming the system which supports all life on earth and is therefore fundamental to the human well-being (Erskine, 1987; Hawksworth & Mound, 1991; Groombridge, 1992; Biodiversity Support Program, 1993; McNeely, 1994; Brussard *et al.*, 1997; Wessels *et al*., 2003). Over the past few years most studies on biodiversity have focused on the influence of diversity on ecosystems and ecological processes (Tilman, 1999). Purvis and Hector (2000) have estimated that 95 % of experimental studies support a positive relationship between diversity and ecosystem functioning although McCann (2000) has suggested that diversity does not drive this relationship.

Diversity of species plays a significant role in maintaining the integrity of the ecosystem (Hawksworth & Mound, 1991; Aber & Melillo, 2001). Higher levels of biodiversity have been shown to lead to an increase in productivity in plant communities, greater nutrition retention in ecosystems and greater ecosystem stability (Hawksworth & Mound, 1991; Biodiversity Support Program, 1993; Naeem *et al*., 1994; Solbrig, 1996; Schläpfer & Schmid, 1998; McCann, 2000; Tilman, 2000). Communities with higher species diversity exhibit a greater resistance and resilience to stresses such as disease, drought, war-events, human induced habitat degradation and fragmentation (Christensen, 1991; Biodiversity Support Program, 1993; Solbrig, 1996; Naeem & Li, 1997; Tilman, 1997; Chapin *et al*., 2000; Purvis & Hector, 2000; Aber & Melillo, 2001). The results obtained by McNaughton (1993) indicated a positive relationship between species diversity and the resilience of the ecosystem. Similarly data obtained during a severe drought in the Minnesota grasslands showed that the extent of the reduction in biomass was strongly related to the number of species present before the drought (Tilman & Downing, 1994). In effect higher species richness dampened the effect of the drought on productivity thus providing resistance to this form of stress. These results demonstrate that a crucial characteristic of communities with high biodiversity is the ability to either resist disturbances or to recover rapidly following unpredictable events (Biodiversity Series 1, 1993; van Jaarsveld & Chown, 1996; Aber & Melillo, 2001). Ecosystems rich in diversity can contribute to water economy, soil properties and climatic stability (Erskine, 1987; Solbrig, 1996; van Jaarsveld & Chown, 1996).

Communities with high diversity are considered to be more stable (Biodiversity Support Program, 1993). Many hypotheses have been suggested for this observation. One of these hypotheses is the negative covariance model which states that a more diverse ecosystem will have a greater chance of containing species, which are capable of replacing functionally important ones (McCann, 2000). The extent to which different species perform the same functions in a similar way suggests that physiological redundancy in species rich ecosystems would minimize the effects of the loss of any one species (Aber & Melillo, 2001). Another hypothesis, the averaging effect, suggests that in a more diverse ecosystem, the chances of some species responding preferentially to certain conditions and perturbations are greater (McCann, 2000). Ecologically diverse systems have a range of pathways for productivity and ecological processes such as nutrient and carbon cycling. If one of these pathways is damaged or destroyed, an alternative pathway may be used and thus maintain the function of the ecosystem. However if the diversity of ecosystems is greatly reduced, the functioning of the ecosystems is put at risk (Reid & Miller, 1989; Chapin *et al*., 2000). Communities with a high number of species may experience a greater number of weak interactions between species thus lessening the potentially destabilising strong interactions that would exist between species if there were only a few species present in the community (Ives *et al*., 1999; McCann, 2000).

Biodiversity is valued in different ways such as spiritually, economically, aesthetically, ethically, culturing and scientifically (Meadows, 1985; Groombridge, 1992; Biodiversity Support Program, 1993; Cole, 1994; Noss & Cooperrider, 1994). Biodiversity provides essential goods and services such as the provision of food and water, the regulation of land degradation, drought, floods and disease as well as the formation of soils and nutrient recycling (Wessels *et al*., 2003). Biological resources include genetic resources, organisms or parts thereof, populations, or any other biotic component of ecosystems with actual or potential use or value for humanity. Biological resources are elements of biodiversity that can be used directly from the environment (Ehrlich & Wilson, 1991; Biodiversity Support Program, 1993). In Africa, a large proportion of the population is directly dependent on biological resources for subsistence (Biodiversity Support Program, 1993; White Paper on Biodiversity, 1997).

The diversity and abundance of species inhabiting the natural ecological systems are often critical to the survival of the poorer, more marginal populations of the world. Throughout the world biological resources are of fundamental importance to human well-being and present trends strongly suggest that this importance is likely to continue in the future. The prospects for future development depend substantially on the preservation of biological resources. The loss of communities and species at one level can induce serious consequences elsewhere in the ecosystem thus affecting the capacity of ecosystems to provide society with a stable and sustainable supply of materials essential to maintaining life (Biodiversity Support Program, 1993; Tilman & Downing, 1994; Tilman *et al*., 1996; Levine & D'Antonio, 1999; McCann, 2000; Tilman, 2000).

1.4. Critical issues in biodiversity

Biodiversity has become a keyword for the integrity of the biological world and the loss of biodiversity is seen as a primary indicator of the impact of human society on the world (Aber & Melillo, 2001). The environment is heavily utilised by people resulting in an increasing rate of habitat destruction and fragmentation (Westman, 1990; Boussienguet, 1991; Holloway & Stork, 1991; Groombridge, 1992; Cole, 1994; McNeely, 1994; Bender *et al*., 1998; Herbert, 1998; Pimm & Lawton, 1998).

The critical issue facing biodiversity around the world is a loss of habitat or the degradation of natural habitats and ecosystems (Herbert, 1998; Wessels *et al.*, 2003; Driver *et al*., 2005). Most forms of human activity alter the distribution and abundance of species (Westman, 1990; Biodiversity Support Program, 1993; Aber & Melillo, 2001). The conversion of large areas of forests and woodlands to field crop agricultural areas together with the development of areas which were previously scarcely inhabited have resulted in the fragmentation of many African natural habitats, threatening the loss of many of the species they contain and the destruction of ecosystem function (Meadows, 1985; Erskine, 1987; Claridge, 1991; Holloway & Stork, 1991; Groombridge, 1992; Biodiversity Support Program, 1993; Samways, 1993; Cole, 1994; Noss & Cooperrider, 1994; Solbrig *et al.*, 1996; Herbert, 1998; Pimm & Lawton, 1998; Schläpfer *et al.*, 1998; van Rensburg *et al.*, 1999; Aber & Melillo, 2001; Wessels *et al.*, 2003).

Approximately 65 % of the original wildlife habitat of sub-Saharan Africa has been lost to various human activities such as intensive agricultural and industrial activity, exploitation of biological resources, population growth, migration pressure, commercial land-use practices, fragmented population of species and climatic changes (Meadows, 1985; Erskine, 1987; Westman, 1990; Claridge, 1991; Biodiversity Support Program, 1993; McNeely, 1994;

Samways *et al*., 1996; Solbrig, 1996; Bawa & Menon, 1997; Aber & Melillo, 2001). While some habitat loss may be inevitable, given the human population growth and the need for economic development, much of the present pattern of biodiversity, ecological degradation and biodiversity loss results from unnecessary or unintentional sources such as hunting, poaching, inappropriate agricultural methods, introduction of exotic species, the expansion of urban areas and permanent agricultural lands, the construction of infrastructure such as roads, the misuse of chemical fertilizers and pesticides (Meadows, 1985; Erskine, 1987; Westman, 1990; Claridge, 1991; Biodiversity Support Program, 1993; McNeely, 1994; Samways *et al*., 1996; Solbrig, 1996; Bawa & Menon, 1997; Aber & Melillo, 2001). For example commercial deforestation in southern Africa has resulted in massive clearing and transformation of ecosystems, with a serious loss of biodiversity. In some areas the equilibrium and homeostasis of many ecosystems has been shifted beyond a point of no return (Meadows, 1985; Biodiversity Support Program, 1993; Pimm & Lawton, 1998). While recent advances in agroforestry and other complex multispecies forms of agriculture incorporate some of the native species, changes in the natural landscape invariably results in a reduction in the number of species present (Aber & Melillo, 2001).

What can be observed and measured as the current assemblage of species and their distribution over the earth's surface is the result of the continuous processes of evolution and extinction of species (Aber & Melillo, 2001). Extinction has always been a natural part of the evolution of biodiversity. Although the rates of extinction are not constant over time, the current extinction rate exceeds the rate of any reasonable estimates of background extinction rates (Solow *et al.*, 1993; Wessels *et al.*, 2003). One of the consequences of environmental fragmentation and degradation is the loss of species through extinction (Solow *et al.*, 1993; Wessels *et al.*, 2003). It appears that humans are a major cause of the increased loss of species (Meadows, 1985; Groombridge, 1992; Noss & Cooperrider, 1994; Pimm & Lawton, 1998; Schläpfer *et al*., 1998; Wessels *et al.*, 1998; Getz *et al.*, 1999; Aber & Melillo, 2001). Significant megafauna extinction events in Australia and North America co-occur with the migration of humans to these continents and habitat perturbation (Meadows, 1985; Aber & Melillo, 2001). The total number of flora and fauna on the earth today is not known and therefore the rates of extinctions at the species level also cannot be clearly enumerated (McNeely, 1994; Aber & Melillo, 2001).

Meadows (1985) argued that the activities of man have resulted in a very different spatial arrangement of ecosystems in South Africa. Reducing the size of natural habitats results in a decrease in the population of each species, reduction of genetic diversity and limits the number of species a habitat can hold (Westman, 1990; McNeely, 1994). The extinction of species from complex food webs inevitably results in the loss of others before the ecosystem readjusts its equilibrium (Meadows, 1985). Many ecosystem processes occur at a naturally very slow rate and disturbances with in the ecosystem may take years to rectify (Meadows, 1985). Reducing the size of habitat by 90 % decreases the number of species that can be supported in the future by approximately 50 % (McNeely, 1994). Another estimate suggests that on average the loss of one plant species in the tropics is accompanied by a ten- to thirty-fold loss of other organisms dependent on it (Meadows, 1985).

In recent years, awareness has grown of the potentially disastrous consequences of the loss of biodiversity for the earth's ecological functions and the fulfillment of the basic human development needs. Africa's dependence on biological resources makes it particularly vulnerable. In the event of declining productivity as a result of environmental degradation, few alternative development pathways are immediately available and the financial resources for restoring the environment are limited. Environmental degradation that leads to the fragmentation and destruction of ecosystems must be viewed as a serious threat to Africa's future. Biological resources can only be preserved through the conservation and sustainable use of biodiversity (Biodiversity Support Program, 1993).

1.5. Patterns of biodiversity

Biogeographic studies attempt to identify, describe and explain the distribution patterns exhibited by plants and animals at the different local, regional, continental or global scales (Meadows, 1985; Burbidge, 1991; Hollander *et al.*, 1994; Simberloff, 1997; Aber & Melillo, 2001). A classic question in biogeography is what controls the pattern of species richness across the earth's ecosystems? The heterogeneity of the earth's surface together with its interaction with latitudinal effects and meteorology has provided a complex template on which biological diversity has evolved through time (Holloway & Stork, 1991). Generally species richness tends to increase from the poles to the tropics with the tropical moist forests being the richest areas and from low-productivity ecosystems to high-productivity ones. Species diversity in natural habitats is high in warm areas and decreases with increasing latitude and altitude. On land, diversity is usually higher in areas of high rainfall and lower in drier areas (Holloway & Stork, 1991; Chapman & Reiss, 1992; Groombridge, 1992; Aber & Melillo, 2001). This comparison can be observed across large climatic gradients and between major biome types (e.g. tropical forests are more diverse than tundra). However it may not be uniform across all groups of organisms and within a given vegetation type, the opposite trend may be seen (Aber & Melillo, 2001).

Within the continuous distribution pattern small or large gaps in species geographical ranges may be observed, and often it is these discontinuities or gaps in distribution, which intrigue scientists. However some species, such as the common reed *Phragmites communis,* a species of aquatic habitats across the globe and the bracken fern, *Pteridium aquilinum*, are considered more or less ubiquitous. Many distributional gaps are much wider and give rise to what are termed disjunct distributions. Disjunct distributions are those in which two or more populations of a taxon are exceptionally widely separated. An extreme case of disjunction is illustrated by those taxa which are exclusive to a particular area, and this is termed endemism. Endemism is usually applied to taxa with abnormally restricted distribution at the global, continental or regional scale (Meadows, 1985). Endemic species can be defined as native species, restricted or peculiar to a locality or region although they may be very abundant at that location (local endemics) (Biodiversity Support Program, 1993). Therefore any given area contributes to biological diversity through its richness in numbers of species and through endemism (or geographical uniqueness) of these species (Groombridge, 1992).

Biological diversity is strongly patterned on a geographical scale within each group, reflecting past biogeographic and climatic history of a region, which influences the uniqueness of certain floras and faunas (Holloway & Stork, 1991). Since the accumulation of species through evolution is a very long-term process, the age of an ecosystem type and the stability of that type, primary productivity, community structure or the existence of predictably repeatable disturbance regimes may also increase diversity (Aber & Melillo, 2001). The distribution and diversity patterns of species are a result of numerous ecological factors acting in space and time (Chapman & Reiss, 1992; Aber & Melillo, 2001). Palaeoclimatic, ecological and anthropogenic effects can act as major extinction filters (Lawes *et al*., 2000).

Processes which affect the distribution of individual organisms have consequences for the range and diversity of the species and are therefore of importance in biogeography (Chapman & Reiss, 1992). Different factors may operate at different scales in order to account for such distribution patterns (Meadows, 1985). For example the global pattern is probably determined mainly by temperature, moisture and historical factors. At a regional level, features of the environment such as suitable soil or rock types may be the controlling influences and at the local scale the availability of shade or the presence or absence of another species may determine the distribution of organisms (Meadows, 1985).

Habitat selection by an organism is based on many factors related to both the environment (abiotic) and to the interactions between conspecifics and between species (biotic) (Bond *et al.,* 1980; Mills, 1982; Rowe-Rowe & Meester, 1982, Lindenmayer *et al*., 1991; Christensen &

Persson, 1993; Ritter & Bednekoff, 1995; Warrick & Cypher, 1998; Reyers *et al*., 2001). The abiotic environment in which an organism lives depends on many factors such as geology (rock and soil types), topography (landscape), the altitude, gradient, fire, solar energy, cover, natural disasters and climate. Abiotic characteristics of habitat include the size of habitat, which affects the number of species that can live in it. Geomorphological characteristics such as topography, geological formations and soil types as well as the associated climate and vegetation either make up the diversity of a habitat or restrict it (Schaller, 1972; Western & Grimsdell, 1979; Bond *et al*., 1980; Rowe-Rowe & Meester, 1982; van Orsdol, 1984; Meadows, 1985; Gotceitas & Colgan, 1989; Joubert, 1989; Lindenmayer *et al*., 1991; Tilman, 1994; Davis, 1997; Aber & Melillo, 2001). The height and shape of the landscape can play an important part in the distribution of organisms. Relief not only induces vertical temperature changes but is also an important feature of soil formation and thus influences vegetation patterns (Schaller, 1972; Bond *et al*., 1980; Rowe-Rowe & Meester, 1982; van Orsdol, 1984; Meadows, 1985; Gotceitas & Colgan, 1989; Joubert, 1989; Chapman & Reiss, 1992; Tilman, 1994). Biotic factors include productivity, facilitation, mobility of organisms, diseases, the quality, quantity and distribution of food supply, the density and distribution of intra- and interspecific competitors and the distribution and density of predators (Western & Grimsdell, 1979; Bond *et al.,* 1980; Rowe-Rowe & Meester, 1982; Gillison & Brewer, 1985; Meadows, 1985; Bothma, 1989; Lindenmayer *et al*., 1991; Chapman & Reiss, 1992; Krebs & Davies, 1993; May, 1994; Freitag & van Jaarsveld, 1995; Ritter & Bednekoff, 1995; Aber & Melillo, 2001).

Southern Africa is a complex biogeographical region and over the past two million years the region has experienced as many as twenty climatic cycles each lasting approximately 100 000 years and mirroring periods of expansion and contraction of the glacial ice sheets at higher altitudes (van Bruggen, 1978; Eeley *et al*., 1999). Hyperthermal periods were generally characterized by warmer, wetter conditions and the expansion of the forest biome while hypothermal periods experienced cooler, drier climates and a reduction in the extent of forest (Eeley *et al*., 1999). Over most of southern Africa precipitation at the Last Glacial Maximum (LGM) varied from approximately 40-70 % of the present mean. Westerly winds are likely to have resulted in increased winter rainfall in the western part of the country but is unlikely to have had any major effect on patterns of rainfall in the eastern region. In the eastern regions cold, dry conditions prevailed during the winter, with strong winds and cold air drainage off the Drakensberg exacerbating the drying effect, especially in the southern areas where the escarpment lies closer to the coast. The ocean current off the east coast was cooler, weaker and shallower than at present, which resulted in lower temperatures and increased aridity in the eastern coastal regions. Cold inshore waters inhibited rain development on the coast, resulting in significantly more dry summer conditions than present. There was a fairly rapid amelioration of climatic conditions following the Last Glacial Maximum (approximately 18 000 BP). Wetter conditions became re-established over most of the area between 17 000 and 15 000 BP (Eeley *et al*., 1999). The period had experienced a general increase in temperature. During this time there appears to have been a significant regional variation in precipitation, with the Karoo and southern Cape regions being drier than at present and the Kalahari, the mountains of the western Cape and eastern region being considerably wetter (Eeley *et al*., 1999).

A large proportion of southern Africa forms a plateau with altitudes of over 1000 m in the eastern regions, where the Drakensberg range forms a high escarpment and the rainfall reaches a maximum (van Bruggen, 1978; Davis, 1997). The eastern region of southern Africa has a marked climatic and physical diversity (Eeley *et al*., 1999). Vegetation within southern Africa is diverse (van Bruggen, 1978; Low & Rebelo, 1996). The climate of southern Africa is strongly influenced by regional differences in the seasonal periodicity of rainfall (Davis, 1993). Rainfall in the region is strongly seasonal and mainly occurs in summer. Winter monthly rainfall varies from over 1000mm to very little and within a small area in the south-western Cape. There are also areas that experience year round rainfall. These areas lie between summer and winter rainfall regions (van Bruggen, 1978).

The conservation of ecological processes that sustain ecosystem structure and function and evolutionary processes that sustain lineages, biodiversity patterns and generate diversity are essential components of conservation area selection and for the achievement of long-term biodiversity conservation (Eeley *et al*., 2001; Fairbanks *et al.*, 2001; Reyers, 2004). Conservation planning has only recently begun to incorporate the spatial distribution of biological processes that maintain biodiversity (Lombard *et al*., 2003). An efficient strategy for the conservation of biodiversity is one in which a representative sample of the biodiversity pattern as well as the ecological and evolutionary processes that allow biodiversity to persist over time are conserved at the lowest cost (Westman, 1990; Noss & Cooperrider, 1994; Simberloff, 1997; Myers *et al*., 2000; Driver *et al*., 2005). This involves selecting conservation areas that are large enough to cover substantial biotic and environmental gradients and as many of the natural processes as possible (Fairbanks *et al.*, 2001). Information on the number and different types of species in an ecosystem as well as factors influencing the biogeographical distribution patterns form the basis for understanding how an ecosystem functions and thus how the addition or removal of a particular species or factor may alter the ecosystem. Knowing where a species or community exists and the processes that operate within a particular ecosystem enables key role players in conservation to recognize changes in it and to manage it (Lindenmayer *et al*., 1991; Goodman & Lanyon, 1994; New, 1995; Simberloff, 1997).

Every taxon has a particular geographical range and this geographical distribution pattern is an important characteristic of a taxon (van Wyk & Smith, 2001). Historical influences such as past climatic regimes and changes and geographical continuities and discontinuities in the landscape influence present day species distribution (van Bruggen, 1978; Lindenmayer *et al*., 1991; Davis, 1993; Herbert & Kilburn, 2004). Assessment of distribution patterns and factors influencing the biogeographic distribution or contributing to diversity are an integral part of assessing the biodiversity crisis and biodiversity conservation planning (Lindenmayer *et al*., 1991; Biodiversity Support Program, 1993; Hamer & Slotow, 2000; Fairbanks *et al.*, 2001). Accurate conservation planning requires intensive biological surveys across large areas and many different habitats but these data do not currently exist and will not be available over the short term. An understanding of the factors that influence patterns of speciation provides an insight into distribution patterns and such an understanding can direct conservation effort to where it is most necessary and effective (Slotow & Hamer, 2000) as well as assist with determining the appropriate management efforts for protected areas and corridor routes for migration (Lydeard *et al*., 2004).

The composition and distribution of molluscs has been influenced by the geological, climate and vegetational history of South Africa. An understanding of how mollusc distributions are presently influenced, how it has changed from the past and how it may change in the future will allow for the development of flexible conservation strategies that accommodate for the fluctuating pattern of distribution and for informed management decisions to be made to protect the mollusc diversity.

1.6. Policy and legislation

In Rio de Janeiro in June 1992, 157 countries attending the United Nations Conference on Environment and Development (UNCED) acknowledged the threat posed to the earth's biological diversity (Biodiversity Support Program, 1993; Ledger, 2001). The world recognised the necessity of ensuring continued economic growth but at the same time the importance of preserving and maintaining the biosphere. This meeting produced the "Convention on Biological Diversity (CBD)", the "Framework Convention on Climate Change", the "Rio Declaration on Environment and Development", the "Statement of Forest Principles" and "Agenda 21" (Ledger, 2001). The global action plan named "Agenda 21" was formed with the main aim of increasing the knowledge of the earth's biodiversity and sustainable development. In November 1995, South Africa joined other countries in ratifying the Convention on Biological Diversity (CBD) (UNEP, 1992; Crowe, 1996; Samways *et al.*, 1996; Ledger, 2001). South Africa has committed itself to developing and implementing a strategic plan for the conservation and sustainable use of biodiversity ensuring its existence for future generations. South Africa also has to ensure that there is a fair and equitable sharing of benefits derived from the use of genetic resources (UNEP, 1992; Crowe, 1996; van Jaarsveld & Chown, 1996).

In April 2001, the Minster of Environmental Affairs and Tourism of South Africa announced that as part of the government policy and programme on the Conservation of South Africa's Biological Diversity, a "National Biodiversity Strategy and Action Plan" would be implemented in the near future (The Government & Environmental Conservation, 2001). The report released by the government outlined its approach to South Africa's protected areas through a massive conservation strategy involving twenty-two initiatives, which will result in South Africa expanding its current protected areas. The "National Biodiversity Strategy and Action Plan" aims to produce a new finance model, improve the current institutional arrangements and encourage the participation of communities in the implementation of conservation programmes complemented by private sector participation and investments. The goal is to maximise benefits of South Africa's national heritage for all generations, through various activities, including the development of a classification for all protected areas (The Government & Environmental Conservation, 2001).

In September 2002, the "World Summit on Sustainable Development' (WSSD) was held in Johannesburg, South Africa. The summit was a ten-year review of the progress since the United Nations Conference on Environment and Development (UNCED) in 1992. The government of South Africa regards "Agenda 21" as a high priority and relevant to the African Renaissance. The implementation "Agenda 21" is increasingly being viewed as a standard against which countries are measured (Ledger, 2001).

The National Environmental Management Biodiversity Act 10 of 2004 (NEMBA) and the National Environmental Management Protected Areas Act 57 of 2003 provide powerful tools to address biodiversity conservation and management effectively and efficiently (Driver *et al*., 2005). The Biodiversity Act provides direction to the protection of biological diversity and gives effect to the Convention on Biodiversity to which South Africa is a signatory. The Biodiversity Act provides for the management and conservation of South Africa's biological diversity within the framework of the National Environmental Management Act 107 of 1998 (NEMA). The Biodiversity Act also provides for the sustainable use of indigenous biological resources and the fair and equitable sharing of benefits among stakeholders that arise from bioprospecting indigenous biological resources. The Act provides for co-operative governance in biodiversity management and conservation. The Act also provides for a National Biodiversity Framework and statutory biodiversity management plans for threatened ecosystems or species

(NEMBA 10, 2004; Driver *et al*., 2005). The Protected Areas Act 57 of 2003 provides a set of categories for protected areas. The Act provides a range of different protected area options that are available both for formal protection as well as more flexible biodiversity management. The Protected Areas Act also provides for any land, including private and communal land, to be declared a formal protected area, and allows for co-management of these protected areas by the landowner(s) or any suitable person or organisation (National Environmental Management Protected Areas Act 57, 2003; Driver *et al*., 2005).

South Africa is not only one of the most biologically diverse countries in the world (Meadows, 1985; Pienaar, 1991; White Paper on Biodiversity, 1997; Wessels *et al.*, 2003) but also supports a large variety of endemic species (Samways *et al.*, 1996; Hamer, 1997; van Rensburg *et al.*, 1999). However, there are many areas of research e.g. invertebrate studies in South Africa, that are poorly researched (Hamer & Slotow, 2002). An intense national effort will be required to ensure that South Africa fulfills its obligation to the Convention on Biodiversity. The goal will be to discover, describe and make an inventory of the species diversity in South Africa (UNEP, 1992). The information obtained cannot be translated into effective local conservation strategies without reference to a local landscape and species distribution patterns (van Rensburg *et al.*, 1999). The data have to be analysed and synthesised into predictive classification systems that reflect the history of the organism. This information needs to be organised in an efficiently retrievable form that best meets the needs of the country (UNEP, 1992).

The existing terrestrial mollusc data were assessed in terms of their value to biodiversity conservation planning and management. The study will contribute towards South Africa's commitment to the Convention on Biological Diversity by describing and making an inventory of molluscs and their distribution patterns in South Africa.

1.7. Biodiversity conservation and management

The primary conservation goal has up to recently mainly revolved around the creation and maintenance of formally designated protected areas (Pressey & Bedward, 1991; Biodiversity Support Program, 1993). However, the establishment of conservation areas was a haphazard affair with their establishment in remote, uninhabited areas of low economic or agricultural potential or in areas of high tourism potential. Their location, size and characteristics were determined more by chance and the idea that these were 'game reserves' set aside for preservation of large animals than by scientific principle (Meadows, 1985; Noss & Cooperrider, 1994; Margules & Pressey, 2000; Reyers & van Jaarsveld, 2000; Eeley *et al*., 2001; Reyers *et al*., 2001; Driver *et al*., 2005). Since the function of the ecosystem depends on more than a few large animals, the success of conservation is dependent on the management of the entire ecosystem (Meadows, 1985). Protected areas should promote the long-term survival of biodiversity by maintaining the natural processes and viable populations and excluding factors that threaten their persistence (Margules & Pressey, 2000).

The representation of maximum biodiversity in protected area systems, including the complete range of species and ecological processes, has become a central focus of biodiversity conservation and management (Freitag *et al*., 1997; Eeley *et al*., 2001). However, the efficient representation of all species in conservation planning is problematic (van Jaarsveld *et al*., 1998). The biodiversity of a region can never be fully observed and inventorised (Reyers *et al*., 2001) and as there are limits to the amount of land that can be set aside as reserves, selecting the appropriate areas is crucial for effective conservation (Kareiva, 1993; Armstrong, 2002; Lydeard *et al*., 2004). This involves identifying areas of high conservation value (Wessels *et al*., 2003; Reyers, 2004; Sólymos & Fehér, 2005). These would include areas with a high biodiversity or irreplaceability value, and those with high threat or vulnerability value (Myers *et al*., 2000; Eeley *et al*., 2001; Hamer & Slotow, 2002; Lydeard *et al*., 2004; Reyers, 2004). Areas that combine both important biodiversity elements and high current or future threats would be considered conservation priorities (Myers *et al*., 2000; Eeley *et al*., 2001; Hamer & Slotow, 2002; Lydeard *et al*., 2004; Reyers, 2004). Approaches used to measure the biodiversity value of an area include measures such as species richness hotspots, endemism and rarity hotspots, as well as complementary species richness (minimum areas required to represent all species once) and irreplaceability (Myers *et al*., 2000; Eeley *et al*., 2001; Hamer & Slotow, 2002; Lydeard *et al*., 2004; Reyers, 2004). Biodiversity hotspots are defined as regions that are exceptional rich in biodiversity, especially in endemic species, while being under severe threat (Myers *et al*., 2000; Purvis & Hector, 2000; Reyers *et al*., 2001; Lydeard *et al*., 2004; Sólymos & Fehér, 2005).

Limited resources are available for conservation efforts (Eeley *et al*., 2001; Reyers *et al*., 2001; Reyers, 2004; Sólymos & Fehér, 2005) and therefore not all areas identified as being important to biodiversity conservation will be formally protected immediately and many of these areas will have to rely on less formal management rather than formal protection. The identification of threats facing areas with a high conservation value will assist in determining which areas are likely to be affected the soonest if they remained unprotected (Eeley *et al*., 2001; Reyers, 2004).

Biological surveys and taxonomic studies have become an essential prerequisite for many land use decisions and for planning the management of nature conservation (Burbidge, 1991; Williams & Gaston, 1994; Wessels *et al.*, 1998; Lydeard *et al*., 2004). The advantages of biological surveys include the identification of endangered and/or endemic species or ecosystems, resolution of land-use conflicts, the design and better management of nature reserves, clarification of the status of species or ecosystems (e.g. rarity and specialized habitat requirements). This allows for research, management and the setting of priorities for more detailed research studies and conservation efforts (Burbidge, 1991; New, 1995; Balmford & Gaston; 1999; Lydeard *et al*., 2004). However, a complete survey of the diversity across the entire South Africa is difficult (Slotow & Hamer, 2000). Most of South Africa's biodiversity has yet to be identified, described and the geographical distributions of many of the species currently known to science are poorly understood (Crowe, 1996). Biodiversity surrogate information, such as richness of indicator taxa, endemism or higher taxon richness is one practical method to identify possible conservation areas (van Jaarsveld *et al*., 1998; Reyers & van Jaarsveld, 2000; Slotow & Hamer, 2000; Wessels *et al*., 2003).

The use of complementarity analysis and surrogate information is a strategy that is commonly used for assessing the distribution of species (Freitag & Mansell, 1997; Muller *et al*., 1997; van Jaarsveld *et al*., 1998; Margules & Pressey, 2000; Reyers & van Jaarsveld, 2000; Slotow & Hamer, 2000; Eeley *et al*., 2001; Sólymos & Fehér, 2005). The land area is divided into grids and complementary set of grids in which each taxon represented at least once is then identified (van Jaarsveld *et al*., 1998; Wessels *et al*., 2003). The complementarity principle aims to ensure that conservation areas represent all species efficiently and that rare species are included within conservation areas (van Jaarsveld *et al*., 1998). Van Jaarsveld *et al*. (1998) showed that complementary species sets did not coincide and overlapped little with higher taxon sites. The combination of complementarity analysis and surrogate information as a biodiversity conservation tool provides some perspective on the adequacy of the existing system by indicating which species are not adequately protected and appears to be appropriate for the conservation of focal taxa and reserve design but do not reflect the diversity of a wider suite of taxa (Freitag & Mansell, 1997; van Jaarsveld *et al*., 1998; Reyers & van Jaarsveld, 2000; Slotow & Hamer, 2000; Eeley *et al*., 2001; Lombard *et al*., 2003; Sólymos & Fehér, 2005). Biodiversity surrogates have however been shown to be unreliable and inefficient for the conservation of overall regional biodiversity (Freitag & Mansell, 1997; Muller *et al*., 1997; Reyers *et al*., 2001).

Systematic biodiversity conservation planning is a structured systematic approach that provides a foundation to the long-term biodiversity conservation (Margules & Pressey, 2000; Driver *et al*., 2005). Systematic conservation planning is based on three key principles. The first principle is based on the principle of representation. This entails conserving a representative sample of the biodiversity pattern (Driver *et al*., 2005). The second principle is based on conserving the ecological and evolutionary processes that allow biodiversity to persist over time (Driver *et al*., 2005). Thirdly systematic biodiversity planning involves the setting of quantitative biodiversity targets. These targets determine how much of each biodiversity feature should be conserved in order to maintain functioning landscapes (Driver *et al*., 2005).

Strategies for biodiversity conservation

The establishment of protected areas is a widely used technique for reducing anthropogenic threats to biodiversity (Reyers, 2004). However, formally protected areas alone are inadequate for effective biodiversity conservation and conservation goals require strategies for managing entire landscapes (Margules & Pressey, 2000; Driver *et al*., 2005). The South African National Spatial Biodiversity Assessment (NSBA) identified three key strategies for the conservation of biodiversity in South Africa (Driver *et al*., 2005). The first strategy aims to pursue opportunities that link biodiversity and socio-economic development in priority geographic areas. The second strategy aims to prevent further biodiversity loss by focusing emergency actions on threatened ecosystems. The third strategy is based on expanding the formal protected area network. The results of the National Spatial Biodiversity Assessment indicate that the protected area network within South Africa does not conserve a representative sample of South Africa's biodiversity (Driver *et al*., 2005). Many of the country's terrestrial ecosystems have no or extremely low levels of formal protection (Driver *et al*., 2005).

Five sets of actions were proposed within the National Spatial Biodiversity Assessment to reduce the loss of natural habitat and species in threatened ecosystems and to protect ecosystem functioning in priority areas. These included working with major land users such the agriculture, forestry, mining, infrastructure and property development sectors to develop and implement guidelines to minimise the loss and fragmentation of natural habitats; strengthen bioregional programmes; minimise the loss of habitat in threatened ecosystems; prevent and manage the spread of invasive alien species and expand the formal protected areas to achieve biodiversity targets (Driver *et al*., 2005).

There are currently numerous biodiversity conservation programmes being developed or implemented in South Africa (Hamer & Slotow, 2002). Bioregional programmes are multisectoral programmes that provide a framework for collaborative conservation action. The existing bioregional programmes include the Bioregional Approach to Protected areas in South Africa, Cape Action for People and the Environment (C.A.P.E.) in the Cape Floristic Region, the Succulent Karoo Ecosystem Programme (STEP), the Subtropical Thicket Ecosystem Programme (SKEP), the Maloti-Drakensberg Transfrontier Project, KZN C-plan for land use planning, the Biobase projects that forms part of the Strategic Environmental Analysis in Mpumalanga and the Limpopo Province and the GAP analysis project in Gauteng (Hamer & Slotow, 2002; Driver *et al*., 2005). The Wild Coast Conservation and Sustainable Development

Project and the National Grasslands Initiative are emerging bioregional programmes (Driver *et al*., 2005).

In South Africa six percent of land surface is under formal protection. This falls short of the IUCN's nominal recommendations of 10 % protected area coverage. South Africa lags behind the rest of sub-Saharan Africa, with Botswana achieving protected area coverage of 18.5 %, Mozambique 12.7 % and Namibia 12.4 % (Reyers *et al*., 2001; Driver *et al*., 2005). Fifteen percent of ecosystems in South Africa are well protected. Many of these well-protected areas are in the fynbos mountains and the savanna biome. The most severely under-protected ecosystems occur within the succulent karoo, the grasslands and the fynbos lowlands (Driver *et al*., 2005). Threats to biodiversity appear to be highest in the northern and eastern regions of South Africa while the established bioregional programmes are mainly concentrated in the southern parts of the country. Bioregional programmes in South Africa are mostly based on plant and certain vertebrate data and do not consider invertebrate diversity (Hamer & Slotow, 2002). Due to their small ranges many invertebrate taxa are more vulnerable to threats than vertebrate groups (Ponder, 1999; Hamer & Slotow, 2002). Additional bioregional programmes that cover all ecosystems that are under threat and programmes that include invertebrate taxa need to be established (Driver *et al*., 2005). Local and district municipalities in South Africa are key role players in bioregional programmes (Driver *et al*., 2005). However, biodiversity conservation is hampered by the lack of capacity at the local government level to include biodiversity conservation planning and the lack of reliable, up-to-date information about where ecosystems are most degraded or lost (Driver *et al*., 2005).

In order to effectively conserve biodiversity, there needs to be a collaborative relationship between government, scientists, local communities and the private sector supporting the conservation of biodiversity, the establishment of a well managed system of protected areas in the country including representative ecosystems and the widest possible range of a country's biodiversity, comprehensive database on soils, climate, topography, geology and biodiversity to monitor status and trends of species and ecosystems to predict the impact of future change. Decisions for planning conservation initiatives, identifying priorities and formulating management policies need to be based on careful analysis of available data (McNeely, 1994). The identification of molluscan hotspots in South Africa will improve conservation of molluscs and guide the establishment of new areas specifically related to molluscs.

Recent and historical data on distribution of terrestrial molluscs should be analysed to identify mollusc hotspots in South Africa, to ascertain increases and declines in mollusc populations and changes in the distribution patterns. This information will guide the geographic focus of mollusc conservation efforts (Lydeard *et al*., 2004).

1.8. Invertebrate monitoring and research

The importance of invertebrates in sustaining ecosystems has largely been ignored by researchers (Kirkpatrick & Brown, 1991; Cole, 1994; New, 1995). Like the rest of the world, southern Africa has placed a huge emphasis on vertebrate studies and as a result there is a large discrepancy in the research between vertebrates and invertebrates (Samways, 1993). There is an urgent need to change focus from conserving primarily conspicuous organisms to protecting all living organisms inhabiting the earth as well as ecosystems within which they evolved (Biodiversity Support Program, 1993). Information on groups such as mammals, birds and flowering plants is reasonably comprehensive (Hawksworth & Mound, 1991; Samways, 1993; Pearce & Moran, 1994; Heywood, 1995; Williams *et al.*, 1997) when compared to invertebrates. In terms of the number of species described for invertebrates, especially "megadiverse" groups such as arthropods, our knowledge is fragmented and effectively non-existent. There are many species still unknown to science (Lovejoy, 1986; Wilson, 1988; Hawksworth & Mound, 1991; Colwell & Coddington, 1994; Noss & Cooperrider, 1994; Gaston *et al.*, 1995; Coddington *et al.*, 1996; Crowe, 1996; Solbrig *et al.*, 1996; van Rensburg *et al.*, 1999).

Invertebrates, which may comprise as much as 95 % of biodiversity (Meyer *et al.*, 2000; Hamer & Slotow, 2002; Lydeard *et al.*, 2004), are mostly ignored in the biodiversity assessments and design of conservation areas. Their conservation in existing parks and reserves has been incidental (de Wet & Schoonbee, 1991; Holloway & Stork, 1991; Cole, 1994; New, 1995; Skerl & Gillespie, 1999; Armstrong, 2002; Hamer & Slotow 2002; Sólymos & Fehér, 2005). The assumption is that vegetation types and patterns of floral diversity will adequately reflect invertebrate diversity (Herbert, 1998; Hamer & Slotow, 2002). Invertebrate conservation in South Africa remains poorly researched except isolated contributions pertaining to specific groups or habitats. The lack of coordination with the local invertebrate research community together with the critical shortage of adequate data, funding and expertise are the main contributing factors to the exclusion of invertebrates (Herbert, 1998; Armstrong, 2002; Hamer & Slotow, 2002). Owing to the lack of available data and expertise as well as the perceived difficulties of dealing with such a diverse and abundant fauna, invertebrates are largely omitted from conservation planning. This is generally accepted because conservation of habitats, prioritised and identified based on the flora, should protect important invertebrates (Hamer & Slotow, 2002).

The knowledge of the taxonomy and distribution of invertebrates is highly inadequate resulting in the inability of scientists to identify many invertebrates to species level. In most situations databases for invertebrates are scattered, incomplete or non-existent (Pienaar, 1991; Hamer, 1997). Most of the existing baseline data on biodiversity are of limited usefulness because of inconsistencies in spatial and temporal scales as well as in duration and precision (Biodiversity Support Program, 1993). The lack of information on invertebrates does not allow for the construction of conservation plans. Therefore there needs to be an increased effort to collect more and better quality data on the biology and distributions of invertebrates as this is an integral part of assessing their conservation status and their possible need of management (Biodiversity Support Program, 1993).

1.9. Geographic Information Systems (GIS)

Concern over the rapid transformation of natural habitats and the loss of biological diversity has stimulated efforts in the cartographic analyses of species distributions and landscape characteristics (Conroy & Noon, 1996). Ecologists not only require information on the physical attributes such as soils, slope, aspect and climate of a reserve and the requirements and life cycles of the plants and animal communities found within the reserve (e.g. habitat, population, migration) but also on the socio-economic aspects of land use in or near the reserve (e.g. grazing areas and firewood collection patterns). The main problems faced by reserve managers are the lack of reliable information, insufficient financing and understaffing for processing the information that is available. To overcome these problems managers need tools for analysing and updating spatial information quickly and efficiently (Lang, 1998).

Geographic information systems (GIS) utilize computer-based techniques for storing, encoding, analysing or manipulating and displaying geographically referenced data (Haslett, 1990; Yonzon *et al.*, 1991; Fabricius & Coetzee, 1992; Biodiversity Support Program, 1993; Michelmore, 1994; Barr & Carter, 1995; Walpole, 2000). GIS uses two types of systems, the raster and vector based systems. Raster based systems record spatial information as points in a regular network of grid cells. The coverage or area is broken up into grid of pixels of a particular resolution. The vector based systems uses patterns of points, lines with specific magnitudes and directions and areas to represent data. Areas within interconnected vectors are polygons of varying shapes and sizes. Information about the contents of the polygons is stored separately as an attribute file (Haslett, 1990; Walpole, 2000).

It is an efficient and useful tool, which can analyse and display multiple data layers in analysing movements and patterns of species distribution (Simberloff, 1997; Kadmon & Heller, 1998;

Walpole, 2000). Maps produced using GIS provide powerful tools and can provide important regional information about species and habitat distribution (Cocks & Baird, 1991; Miller, 1994; Simberloff, 1997; Walpole, 2000). Its powerful analytical and predictive capabilities have a variety of applications in research and management. GIS is becoming a common tool for habitat classification, examination of habitat change, fragmentation, utilization, restoration and conservation (Pressey & Bedward, 1991; Biodiversity Support Program, 1993; Michelmore, 1994; Walpole, 2000). GIS with its high level of accuracy, has been used to model the habitat of a wide variety of species, in the analysis of species distribution, production of species richness maps (Cocks & Baird, 1991; Yonzon *et al.*, 1991; Biodiversity Support Program, 1993; Noss & Cooperrider, 1994; Walpole, 2000). These studies typically map occurrence of key environmental variables and develop overlays that suggest areas of potential habitat, which enable identification and prioritization of areas for conservation (Yonzon *et al.*, 1991; Walpole, 2000). Data layers often include elevation, soils, vegetation, topography, distances to watering areas, distance to roads and other human activities (Yonzon *et al.*, 1991). GIS also enables measurements within data sets (coverages or layers) (e.g. length of rivers and the average distance between waterpoints), allows spatial layers to be constructed from sample data points using interpolation techniques (e.g. construction of rainfall maps using data from rainfall gauges) and permits the classification of remotely sensed imagery with or without reference to data collected on the ground (Walpole, 2000). Therefore GIS allows the integration of different layers of habitat data to create more complex composite maps. The relationship between layers can be examined with appropriate statistical tests (Walpole, 2000).

Yonzon *et al*. (1991) used GIS to assess the habitat and estimate the population of Red Pandas in Langtang National Park in Nepal. Three factors, land use, land cover and elevation and direction of the slope were used to determine the core areas for panda habitation in the Park (Yonzon *et al*., 1991). The results provided an estimate of the population of pandas in the Park and the risk of local extinction based on the present land use in the Park. With the use of GIS and multivariate analysis, Kadmon & Heller (1998) determined that the patterns in land snail fauna variation in Israel were significantly correlated to underlying rainfall variation. Thus by using a series of overlaid maps aspects of spatial distribution of species can be understood (Noss & Cooperrider, 1994; Barr & Carter, 1995). These results indicate that the integration of GIS tools with standard multivariate techniques may serve as a valuable methodology for the identification and interpretation of regional patterns of faunal variation (Kadmon & Heller, 1998).

Therefore GIS has the capability of easily mapping and an analysis system, which can easily manage a number of geographical, ecological and biological sets (Haslet, 1990). The advent of

GIS has allowed scientists to discover patterns and relationships that were previously unrecognised and thus aiding them in making critical decisions. Spatial data can be inputted into an integrated system, where it can be organised, analysed and mapped resulting in more information and less conjecture to the problem solving process (Cocks & Baird, 1991; Herbert, 1998; Lang, 1998; Walpole, 2000). GIS has allowed scientists to obtain correlations between the range limits of flora and fauna and extremes of temperature, precipitation, wind and other factors (Barr & Carter, 1995) and can therefore be used to relate the distribution and diversity patterns of a species to biotic and abiotic factors. The biodiversity of a region can be estimated, mapped, analysed and predicted through the use of GIS. Investigating the patterns of movement of species can be informative regarding many issues including population regulation, local depletion, migration, habitat selection and reserve design (Conroy & Noon, 1996; Walpole, 2000).

In the current study, GIS was used as a tool for identifying distribution patterns of terrestrial molluscs in South Africa and the underlying biogeographical processes that influence these patterns.

1.10. Terrestrial Molluscs

Molluscs are some the most ancient of organisms inhabiting Earth. They can be found in the oldest Cambrian deposits, more than 500 million years BP. Molluscs are also among the most successful of all faunal groups. They are second only to insects in number of species (Kay, 1995). Molluscs play a significant role in ecosystem functioning and processes. They break down dead vegetation, produce soils, cycle nutrients and increase soil fertility. Molluscs are also used as tools, food, currency and medicine as well as items of art, worship and adornment (Kay, 1995).

South Africa has a rich and diverse terrestrial mollusc fauna. Five families, Dorcasiidae, Charopidae, Chlamydephoridae, Sculptariidae and Rhytididae, are considered to belong to the southern relict fauna. Chlamydephoridae are regarded as southern Africa's only endemic terrestrial molluscan family (Herbert, 1998). Six families, these being Achatinidae, Cerastidae, Charopidae, Streptaxidae, Subulinidae and Urocyclidae, dominate the southern Africa land molluscan fauna and together these families account for more than 75 % of the species. The remaining species belong to 21 other families. In few other regions in the world are there as many dominant families (van Bruggen, 1978; Herbert, 1998). High levels of endemism, relict taxa and explosive radiations of Charopidae (*Trachycystis*) and Streptaxidae (*Gulella*) can be observed (van Bruggen, 1978; Herbert, 1998). Fifteen genera are endemic to the subregion and endemism at the species level is estimated to be about 90 % (Herbert, 1998). Species diversity is high in indigenous forests, in the Mediterranean Cape fynbos and in the eastern moist woodland–savanna mosaic (Herbert, 1998).

Six families, Chlamydephoridae, Charopidae, Rhytididae, Streptaxidae, Urocyclidae and Veronicellidae contain species that are considered to be threatened and are included in the 2004 IUCN Red List (IUCN Red list, 2004). Fourteen species are listed in the 2004 IUCN Red List and these are *Chlamydephorus burnupi* (Smith, 1892), *Chlamydephorus dimidius* (Watson, 1915), *Trachycystis clifdeni* (Connolly, 1932), *Trachycystis haygarthi* (Melvill & Ponsonby, 1899), *Trachycystis placenta* (Melvill & Ponsonby, 1899), *Natalina beyrichi* (Martens, 1890), *Natalina wesseliana* (Kobelt, 1876), *Gulella aprosdoketa* (Connolly, 1939), *Gulella claustralis* (Connolly, 1939), *Gulella planti* (Pfeiffer, 1856), *Gulella puzeyi* (Connolly, 1939), *Gulella salpinx* (Herbert, 2002), *Sheldonia puzeyi* (Connolly, 1939) and *Laevicaulis haroldi* (Dundee, 1980).

Terrestrial mollusc species have adapted to a wide range of habitats. They are physiologically adapted to conditions or to inhabiting microclimatic refugia such as rock crevices and undersides of stones (Arad, 1993). There are no special techniques for collecting molluscs. Their activities depend on the ambient moisture (Arad, 1990). Consequently, most species are primarily nocturnal and spend the day hidden from the sun. They are usually found in cool, humid and shady places, under logs, stones and fallen bark within leaf-litter layer of forests and woodlands or in compost heaps (Herbert, 1997).

Molluscan distributions in South Africa are closely correlated with climatic variables particularly precipitation and temperature (van Bruggen, 1978; Herbert, 1997). The gradient in mean annual rainfall in South Africa ranges from east to west and most mollusc species are concentrated in the eastern, wetter regions of the country. The desert and semi-desert areas in the centre and western part of southern Africa contain a malacofauna that has strong endemic characteristics and are adapted to the arid areas (van Bruggen, 1978). Areas in central South Africa such as the Free State and Karoo contain very few molluscs, although the conditions in these areas are not as extreme as the condition in semi-deserts and deserts regions (van Bruggen, 1978).

Land snails are facing an unprecedented survival crisis resulting from loss of habitats, overexploitation and their poor dispersal capability and small ranges (Sólymos & Fehér, 2005). The lack of knowledge of the effects of disturbance on biodiversity is apparent for invertebrates, including molluscs. Terrestrial molluscs are a poorly studied invertebrate group in tropical forests. This is based mainly on the assumption, that terrestrial snails inhabiting indigenous rainforests are "generally neither diverse nor abundant" (de Winter & Gittenberger, 1998). This poses a serious problem as the lack of knowledge of the number and types of species that are present in a community severely limits the ability to predict the fate of that community under various anthropogenic stresses (U.S. National Report, 1995). Transformation and fragmentation of natural habitats in South Africa are probably the most significant factors likely to influence the survival of molluscs (Coppois, 1995; Herbert, 1997). The effect of habitat fragmentation on organisms with limited powers of dispersal such as molluscs is likely to be considerable in the long term (Herbert, 1997). As a result of their very limited vagility, the large areas of transformed land represent impenetrable barriers to mollusc distribution (Herbert, 1997). Areas of natural habitat in southern Africa are likely to experience a change in biome type due to the continuing climatic change and any significant change in the floral composition of a habitat is likely to have an effect on the molluscan fauna (Herbert, 1997).

Limited research has been done on African terrestrial molluscs and the knowledge of the group remains inadequate (Herbert, 1997). The ecology of most mollusc species and the ecological role these species play in ecosystem processes are relatively unknown (Lydeard *et al*., 2004). The majority of the studies of the molluscan fauna in South Africa have concentrated on the examination of molluscs from a taxonomic rather than a geographic perspective and have been concerned more with revisionary studies of specific molluscan groups in broader geographical areas (such as southern Africa or Africa) (Herbert, 1997). Therefore the taxonomy of certain groups may be well established but not of other groups. The known distributional and altitudinal ranges of many species are incomplete and reflect only the sites at which earlier workers collected (Herbert, 1997).

This study will contribute towards the understanding of the biogeography of the terrestrial molluscs in South Africa. The existing data were evaluated and used to identify patterns and trends in mollusc diversity within South Africa. These patterns and trends can be used to improve mollusc conservation and management within the country.

1.11. Aims and objectives

Chapter 2 provides a description of the general methods that were used to analyse the terrestrial mollusc data and the shortcomings of using museum data. Maps illustrating the temporal and spatial distribution of terrestrial mollusc sampling as well as species distribution in South Africa were created. Checklists of terrestrial mollusc species for each province within South Africa were also generated.

The aims of Chapter 3 were to identify the various molluscan biogeographical patterns that exist across South Africa and to assess the major biogeographic drivers that influence these distribution patterns at the family and genus levels. The specific objectives of the chapter were to identify the different biogeographic entities in South Africa, to classify the distributions of the terrestrial mollusc families and genera according to the different biogeographical entities and to assess the biogeographic patterns and factors influencing these biogeographic patterns across the families and genera.

The aim of Chapter 4 was to analyse species' distributions and the diversity of terrestrial molluscs in South Africa. The main objectives were to evaluate the existing data in terms of identifying areas of high terrestrial mollusc species richness and endemism, to compare mollusc and millipede species richness and endemism, to identify significant trends in diversity and endemism critical for effective biodiversity conservation and to make recommendations for the inclusion of invertebrates in biodiversity conservation planning.

The final chapter is a summary of the project and includes an assessment of the implications of this study for further terrestrial mollusc studies and recommendations for the conservation of terrestrial molluscs.

CHAPTER 2
ASSESSMENT OF THE SOUTH AFRICAN TERRESTRIAL MOLLUSC DATABASE AND CHECKLISTS OF MOLLUSCS WITHIN SOUTH AFRICA

2.1. Introduction

Permanently preserved reference collections (e.g. museum collections) are a crucial component of the information transfer system of biodiversity between different researchers in space and time (Hawksworth & Mound, 1991). They are essential for identification, as vouchers for application of names and vouchers for species used in research projects (Hawksworth & Mound, 1991). They form databases, which incorporate a colossal amount of information on distribution and seasonality. There is a need to harness this information as the production of maps and checklists from reference collections could contribute significantly to the management and conservation of biodiversity (Hawksworth & Mound, 1991).

This chapter provides a description of the general methods that were used to analyse the terrestrial mollusc data and the shortcomings of using museum data for biodiversity conservation planning. The aim of this chapter was to describe the temporal and spatial distribution of terrestrial mollusc sampling as well as to create maps illustrating the distribution of terrestrial mollusc species in South Africa. Mollusc species lists for each province within South Africa were also generated. The species distribution maps together with the species list form a checklist of the terrestrial molluscs that occur within South Africa.

2.2. Materials & Methods

A Microsoft Access database (10744 records) containing information on molluscs, mainly collected in southern Africa, was obtained from the Natal Museum (Pietermaritzburg). The database contained records from the years 1850 to 2004 and was compiled by Dr. D. G. Herbert. The collection also incorporates mollusc collections from the Transvaal and Albany museums (Herbert & Kilburn, 2004). Information such as names of families, genera, species, localities, coordinates, habitats, collection dates and additional comments was recorded in the database. Where possible specimens were identified to species level (9860 records) and the coordinates of each locality were captured into the spatially referenced database using Cartesian coordinates to the nearest minute. Recent locations were based on Geographic Positioning System readings, while the coordinates of localities, which were not recorded in the database, were estimated to the nearest minute by locating collecting localities on 1:250 000 scale maps. Two new columns viz. Indigenous/Exotic and Terrestrial/Freshwater were added to the database. Where the co-ordinates of a locality, the status and habitat of a species were unknown, an 'X' was recorded for that particular record. The latitude and longitude coordinates obtained from the 1:250 000 scale maps were recorded in degrees (deg.), minutes (min) and seconds (s) and were then converted into decimal degrees (ddeg.). Localities that were not precise (for example, Eastern Cape) and those species that occurred outside South Africa but were not recorded within South Africa were excluded from the analysis. Only records that had species identification were used (9266 records). The data were imported into Arcview 3.2 (ESRI). These records were overlaid on a map of South Africa. Where a record fell outside the boundaries of South Africa, the original database was consulted. Where possible, errors were corrected and records were remapped. Other corrections made to the database included spelling, incorrect family, genus, species and province names. The countries and provinces of the region are presented in Figure 2.1. The sampling locations and temporal distributions of all mollusc samples (Fig. 2.2 & Table 2.1) as well as the distributions of mollusc species were mapped (Appendix A). Checklists of mollusc taxa for each province within South Africa were also generated (Appendix B).

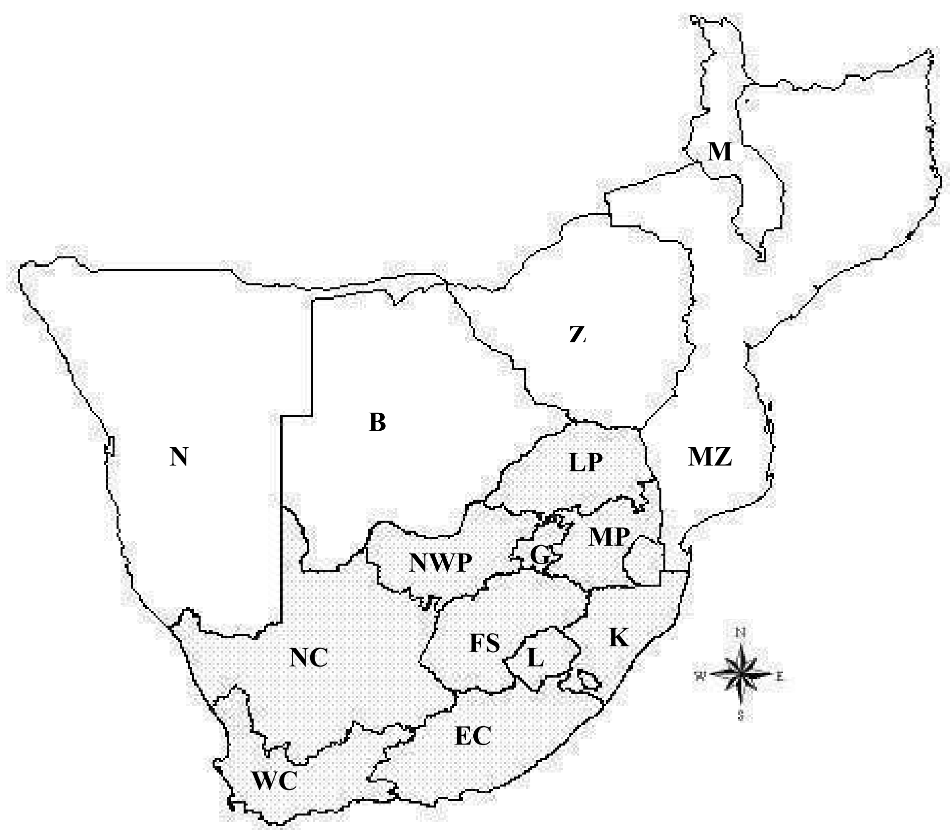
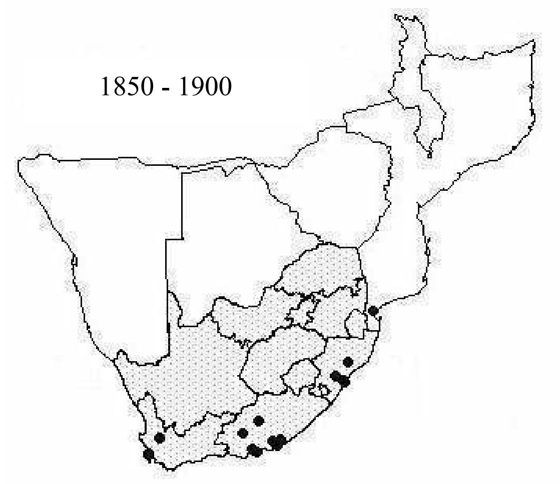


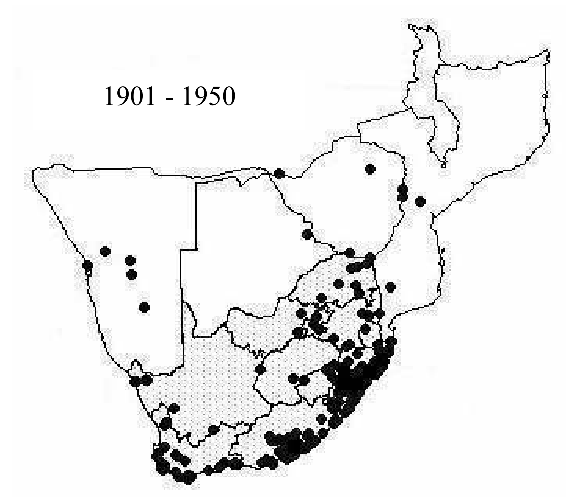
Fig. 2.1: Map of southern Africa and South African provinces. B = Botswana; N = Namibia; SA = South Africa; Z = Zimbabwe; M = Malawi; MZ = Mozambique; S = Swaziland; L = Lesotho, EC = Eastern Cape; FS = Free State; G = Gauteng; K = KwaZulu-Natal; MP = Mpumalanga; NC = Northern Cape; LP = Limpopo; NWP= North West Province; WC = Western Cape.

2.3. Results

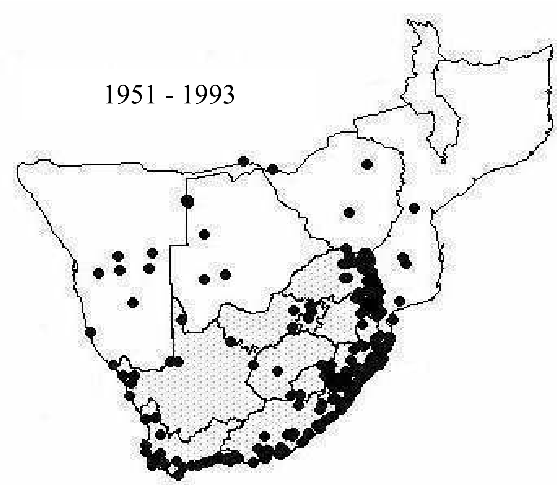
The distributions of 478 species were mapped (Appendix A). Thirty-one exotic and 447 indigenous species were recorded in South Africa. The highest number of indigenous species (251 species) was recorded in KwaZulu-Natal and the lowest number in the Free State (10 species) (Appendix B, Tables B.1 & B.9).



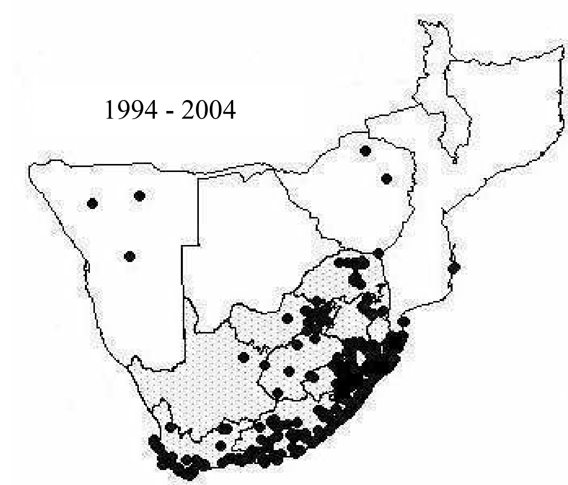
(a)



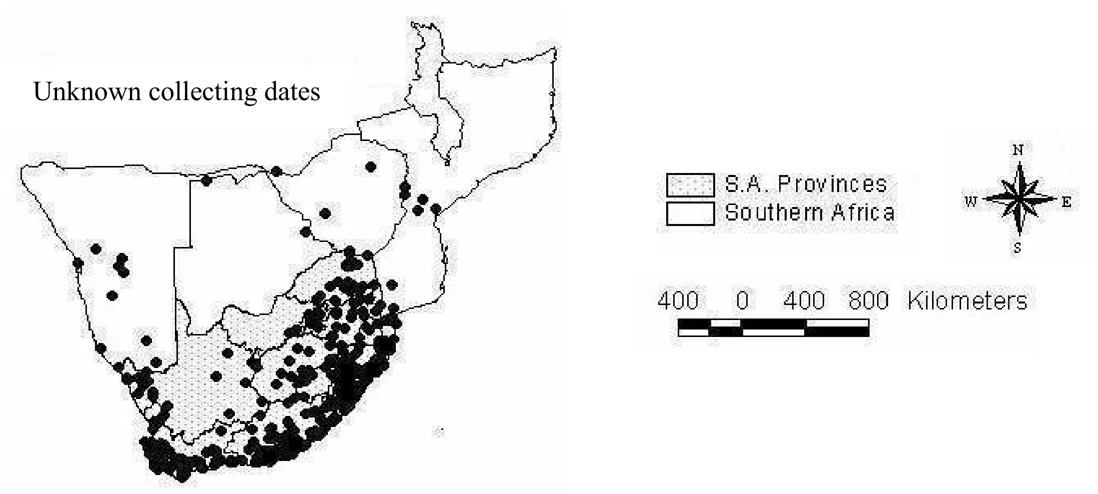
(b)



(c)



(d)



(e)
Fig. 2.2(a-e): Terrestrial mollusc sampling locations and temporal distribution of samples. Fig. 2.2(e) represents those samples that did not have collection dates.

Table 2.1: Number of mollusc samples per province.

Provinces	Area (km^2)	Number of samples					Total number of samples
		1850-1900	1901-1950	1951-1993	1994-2004	Unknown collecting dates	
Eastern Cape	171 221	8	185	80	530	647	1450
Free State	129 833	1	0	0	4	16	21
Gauteng	18 610	0	6	15	9	96	126
KwaZulu-Natal	92 285	5	1056	564	2089	1325	5039
Limpopo	122 434	0	14	157	154	42	367
Mpumalanga	78 238	0	12	199	5	24	240
Northern Cape	362 393	0	31	14	0	31	76
North West Province	116 123	0	3	1	10	16	30
Western Cape	129 578	0	38	64	69	149	320

Although the records were overlaid on a map of southern Africa the main focus of this study was the distribution of indigenous terrestrial molluscs within South Africa. Limited collecting of terrestrial molluscs was done in South Africa prior to 1900 with an increased sampling effort taking place from 1901 to 1950 (Fig. 2.2(a-b); Table 2.1). During 1951 to 1993 increased collecting occurred within the Kruger National Park (Fig. 2.2c; Table 2.1). Since 1994 the sampling effort in the Eastern Cape and Western Cape had received more attention (Fig. 2.2d; Table 2.1). Collecting effort in KwaZulu-Natal increased in 1901 and it is the most extensively sampled province (Fig. 2.2(b-e); Table 2.1). Approximately 31 % of the samples did not have a collection date associated with the sample (Fig. 2.2e; Table 2.1).

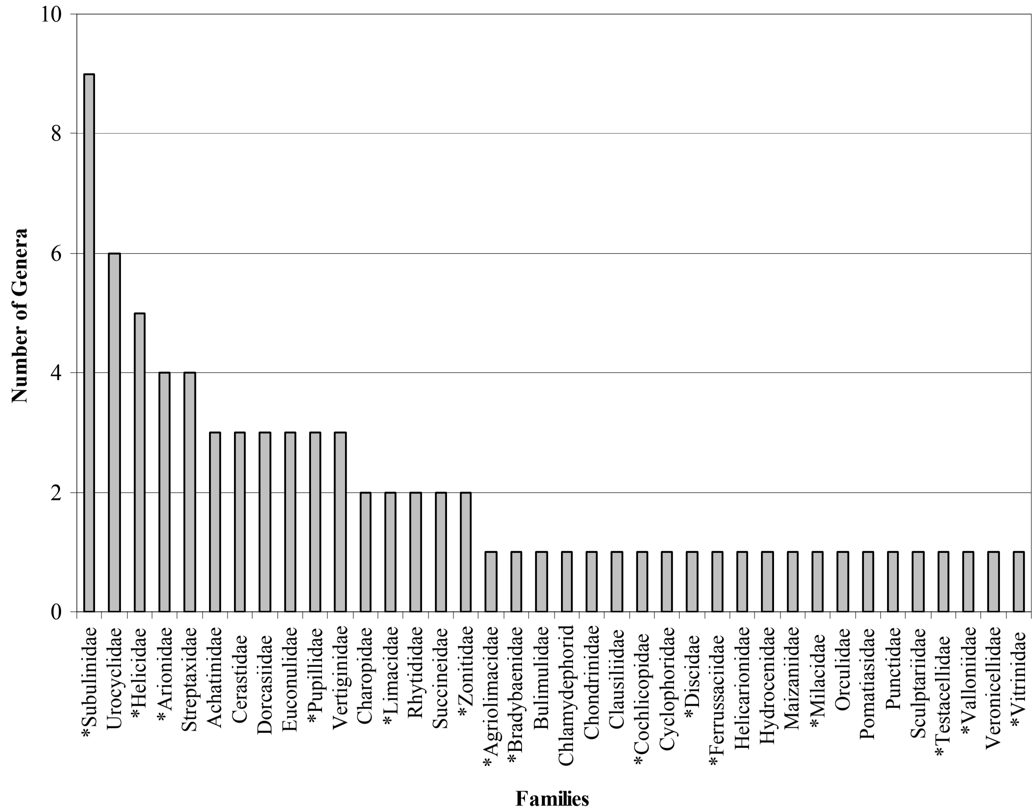


Fig. 2.3: Number of genera per terrestrial mollusc family. Families that contain exotic species are indicated by (*).

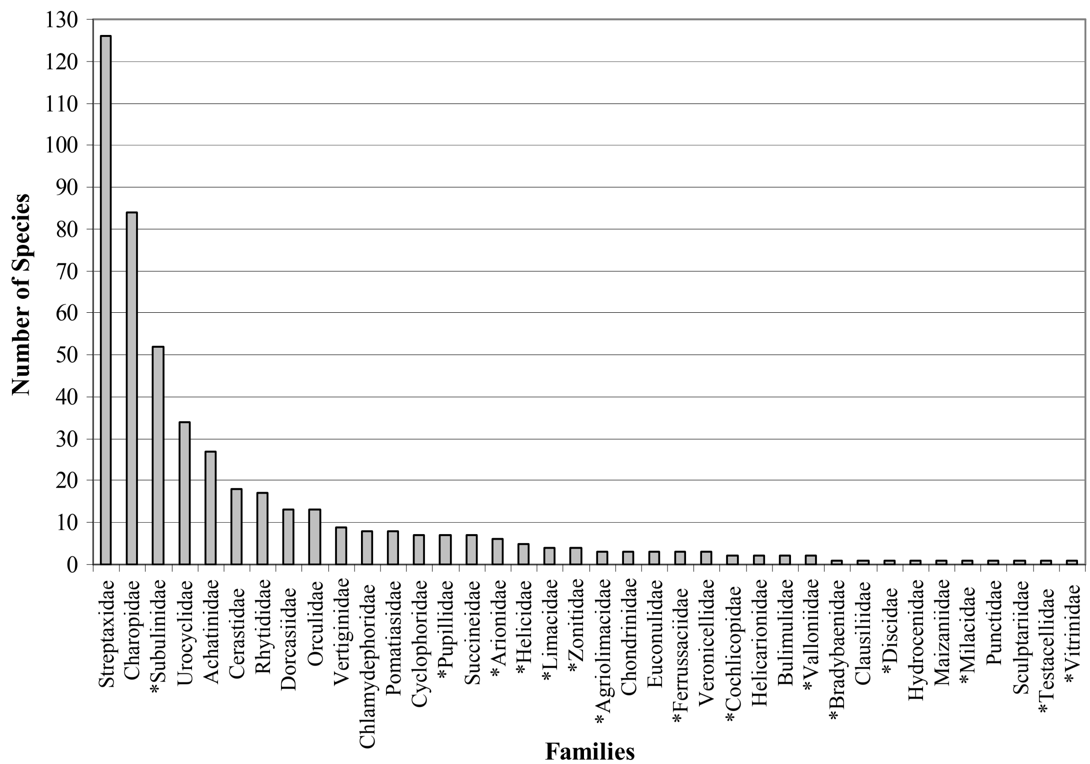


Fig. 2.4: Relative sizes of terrestrial mollusc families in terms of number of species. Families that contain exotic species are indicated by (*).

Twenty-one families, 54 genera and 266 species (251 indigenous and 15 exotic) species were recorded in KwaZulu-Natal (Appendix B.1). Gaps in the distribution of molluscs do exist in the central regions of South Africa, as well as parts of Mpumalanga, Limpopo, Free State, North West, Northern Cape, Western Cape and Eastern Cape.

Streptaxidae (123 species), Charopidae (84 species), Subulinidae (52 species), Urocyclidae (34 species) and Achatinidae (27 species) are the major terrestrial families that occur in South Africa (Fig. 2.4). They formed approximately 67 % of the total number of species occurring in South Africa.

2.4. Discussion

Van Bruggen (1978) estimated that approximately 650 indigenous species of land snails representing 73 genera and 27 families inhabit Southern Africa, this being the countries south of the Kunene and Zambezi Rivers. Herbert (1998) suggested that approximately 525 species of terrestrial molluscs occur in South Africa itself and more than 650 species in southern Africa. In southern Africa the approximate number of species per surface unit is high with an estimated 20 species per 100 000 sq km. The species density varies considerably within southern Africa with species density dependent on the variety of available ecological niches (van Bruggen, 1978).

Gaps in the distribution of molluscs do exist and these gaps in distribution could indicate the lack of suitable habitat for molluscs and therefore an absence of molluscs or areas that have not been surveyed (Fig. 2.2a-e). The various provinces in South Africa have not been sampled to the same degree and there is probably a bias suggesting greater specificity for a particular habitat (Herbert, 1997). KwaZulu-Natal was the most extensively sampled province in the country (Fig. 2.2a-e; Table 2.1) and this may to some extent demonstrate that sites where the catch per unit effort is higher are sites in which molluscs are more abundant (Herbert, 1997).

Christian Ferdinand Friedrich Krauss's publication, *Die Südafrikanischen Mollusken*, in 1848 was the first major work on South African malacology and a landmark in non-marine malacology research. Krauss described approximately forty species of terrestrial molluscs, which were collected by himself and Johan August Wahlberg (van Bruggen, 1978; Herbert & Kilburn, 2004). Henry Clifden Burnup's mollusc collection formed the nucleus of the mollusc collection of the Natal Museum of Pietermaritzburg (van Bruggen, 1978). Henry Burnup, a resident of Pietermaritzburg, worked with James Cosmo Mevill and John Henry Ponsonby during 1890-1909 and later with Matthew William Kemble Connolly. During the period 1905 to 1926, Burnup published eight papers on land molluscs in which he described many new species.

Burnup collected most intensively in the vicinity of Pietermaritzburg. He also collected from different parts of KwaZulu-Natal though his sites were largely determined by the availability of railway stations (van Bruggen, 1978; Herbert & Kilburn, 2004). Connolly published four major works on non-marine molluscs during 1912-1939. Limited mollusc collecting occurred during the period from 1939 to 1963 (van Bruggen, 1978). The increase in the number of mollusc samples collected from Limpopo and Mpumalanga during 1951-1993 (Table 2.1) may be attributed to A.C. (Dolf) van Bruggen who joined the Natal Museum in 1962. During 1962 to 1966 he undertook several collecting trips to areas including Kruger National Park, Northern Zululand and the Drakensberg. Limited mollusc sampling was undertaken in the intervening 30 years since van Bruggen left the Natal Museum in 1966. The increased number of samples from 1994 to 2004 (Table 2.1) was an indication of the renewed interest by the Natal Museum in terrestrial mollusc research in the mid 1990s. Terrestrial mollusc research, spearheaded by Dr. Dai Herbert, had once again become a major area of interest at the Natal Museum (Herbert & Kilburn, 2004).

The methodological approach proposed in this study may have several limitations, which have to be taken into account in interpreting the results. Firstly, while museum collections are the most concrete source of information for recognizing patterns of species distribution (Kadmon and Heller, 1998), they tend to be 'noisy' and are prone to different sources of bias in data collection. Museum collections are collected for different purposes and often in an opportunistic manner from locations that collectors expected to find what they are looking for or that were conveniently accessible thereby resulting in an under-representation of inaccessible areas or over-representation of attractive species (Conroy & Noon, 1996; Herbert, 1997; Kadmon & Heller, 1998; Dennis & Thomas, 2000; Margules & Pressey, 2000; Hamer & Slotow, 2002; Lombard *et. al*, 2003; Wessels *et al*., 2003). There is usually no measure of effort or intensity of collecting associated with the collection of data by taxonomists. Areas might have a low diversity because they have been poorly collected while other areas might have a high diversity because they have been surveyed repeatedly and intensively. Conservationists seldom have data to differentiate between poorly collected and low density areas. Conclusions derived from permanently preserved reference collections that do not have effort units associated with them should be conservative and preliminary (Slotow & Hamer, 2000).

As a result data derived from museum collections cannot be considered as a truly representative sample of the relevant fauna and are of limited use for management and conservation planning. Yet for many taxa, museum collections are the only source of information for large-scale patterns of species distribution (Kadmon & Heller, 1998; Hamer & Slotow, 2002). If used carefully they may provide valuable information on patterns of floristic and faunal variation.

Another aspect that requires careful consideration is the spatial resolution of the grid used to construct the cell x species matrix. Choosing too high a resolution may result in grid cells containing amounts of information that are too limited, while choosing a too low resolution may result in cells that are spatially heterogeneous in their environmental conditions (Kadmon and Heller, 1998). Data from historical collections should be interpreted correctly to ensure that the data accurately reflect regional and local species diversity (Lydeard *et al*., 2004).

CHAPTER 3
BIOGEOGRAPHICAL PATTERNS OF TERRESTRIAL SOUTH AFRICAN MOLLUSCS

3.1. Introduction

An understanding of taxon distributions and the factors that influence or contribute to diversity is becoming increasingly important in terms of the biodiversity crisis and conservation planning (Hamer & Slotow, 2000). The primary conservation goal has, up to recently, mainly revolved around the creation and maintenance of formally designated protected areas (Pressey & Bedward, 1991; Biodiversity Support Program, 1993; Fairbanks *et al.*, 2001). The establishment of conservation areas was a haphazard affair with their establishment in remote, uninhabited areas of low economic or agricultural potential. Their location, size and characteristics were determined more by chance and the idea that these were 'game reserves' set aside more for preservation of large animals than by scientific principle (Meadows, 1985; Noss & Cooperrider, 1994; Fairbanks *et al*., 2001). Since the function of the ecosystem depends on more than a few large animals, the success of conservation is dependent on the management of the entire ecosystem (Meadows, 1985; Fairbanks *et al*., 2001).

The conservation of ecosystem processes that sustain ecosystem structure and function and evolutionary processes that sustain lineages and generate diversity are essential components of conservation area selection and for the achievement of long-term biodiversity conservation (Fairbanks *et al.*, 2001). An efficient strategy for the conservation of biodiversity is one in which a representative sample of the biodiversity pattern, as well as the ecological and evolutionary processes that allow biodiversity to persist over time, are conserved at the lowest cost (Westman, 1990; Noss & Cooperrider, 1994; Simberloff, 1997; Myers *et al*., 2000; Fairbanks *et al.*, 2001; Driver *et al*., 2005). This involves selecting conservation areas that are large enough to cover substantial biotic and environmental gradients and as many of the natural processes as possible (Fairbanks *et al.*, 2001). Information on the number and different types of species in an ecosystem, as well as factors influencing the biogeographical distribution patterns, forms the basis for understanding how an ecosystem functions and thus how the addition or removal of a particular species or factor may alter the ecosystem. Knowing where a species or community exists and the processes that operate within a particular ecosystem enable key role players in conservation to recognize changes in it and to manage it (Goodman & Lanyon, 1994; New, 1995; Simberloff, 1997).

Biological diversity is strongly patterned on a geographical scale within each group, reflecting the past biogeographic and climatic history of a region, which influences the uniqueness of certain floras and faunas (Holloway & Stork, 1991). The distribution and diversity patterns of organisms are a result of numerous ecological factors acting in space and time (Chapman & Reiss, 1992; Aber & Melillo, 2001). Processes which affect the distribution of individual organisms have consequences for the range and diversity of the species and are therefore of importance in biogeography (Chapman & Reiss, 1992). Geomorphological characteristics such as topography, geological formations and soil types as well as the associated climate and vegetation either make up the diversity of a habitat or restrict it (Schaller, 1972; Western & Grimsdell, 1979; Bond *et al*., 1980; Rowe-Rowe & Meester, 1982; van Orsdol, 1984; Meadows, 1985; Joubert, 1989; Gotceitas & Colgan, 1989; Tilman, 1994; Aber & Melillo, 2001). In order for an animal to survive and breed it requires sufficient energy resources and how these resources are distributed, their quantity and quality, can determine where an animal chooses to settle and for how long (Western & Grimsdell, 1979; Stephens & Krebs, 1986; Chapman & Reiss., 1992; Krebs & Davies, 1993; Aber & Melillo, 2001). Different factors may operate at different scales in order to account for such distribution patterns (Meadows, 1985; Fairbanks *et al*., 2001). For example a global pattern is probably determined mainly by climate and historical factors. At a regional level, features of the environment such as suitable geology or biotic factors may be the controlling influences and at the local scale the availability of shade or the presence or absence of another species may determine the distribution of organisms (Meadows, 1985; Fairbanks *et al*., 2001).

Every taxon has a particular geographical range and this geographical distribution pattern is an important characteristic of a taxon (van Wyk & Smith, 2001). The aims of this chapter were to analyse the various molluscan biogeographical patterns that exist within South Africa and to assess the major biogeographic drivers that influence these distribution patterns at the family and genus level. The specific objectives of the chapter were to identify the different biogeographic entities in South Africa, to classify the distributions of the terrestrial mollusc families and genera according to the different biogeographical entities and to assess the biogeographic patterns and factors influencing these biogeographic processes across the families and genera. Assessment of distribution patterns and factors influencing the biogeographic distribution are an integral part of assessing the conservation status of molluscs and their conservation management needs (Biodiversity Support Program, 1993). This information can aid the geographic focus of conservation efforts as well as assist with determining the appropriate management efforts for protected areas and corridor routes (Lydeard *et al.*, 2004).

3.2. Materials and Methods

The Natal Museum's mollusc database was used to map the distributions of South African terrestrial mollusc families and genera (Appendices C & D). The distribution patterns of the South African terrestrial snail and slug fauna were divided into the following ten broad biogeographical entities:

1. Gondwanaland/southern relict faunal component:
   Families and genera associated with this component occur in Africa, Australia, New Zealand and South America. Species or ancestors of these families were present prior to the break up of Gondwanaland during the Triassic and Cretaceous period (Cracraft, 1974; Herbert & Kilburn, 2004). It included families that are endemic to each continent that may have differentiated after separation and isolation. The component also included families that may have a relationship with Laurasia elements or are now endemic to Laurasia but that were probably derived from ancestors in Gondwanaland (Cracraft, 1974). Southern relict faunas are found only in the southern hemisphere and have not spread to the northern hemisphere. In Africa the faunas are mainly found in southern Africa though the distributions of some species do extend north of Zambezi River (Herbert & Kilburn, 2004).
2. Laurasian component:
   Families and genera of the Laurasian component occurred in Africa, Asia and Europe. This component included taxa that have originated in North America and/or Eurasia (Cracraft, 1974).
3. Tropical/subtropical east African elements:
   Families and genera associated with the tropical/subtropical east African component were not restricted to South Africa. They consisted of tropical/subtropical and temperate affinities occurring to the east of escarpment between the temperate Cape region and tropical Indian Ocean coastal belt. Their distributions extended into central and east Africa (van Bruggen, 1978; Herbert, 1997; Herbert & Kilburn, 2004). The faunas were transitional elements associated with mid-summer rainfall areas (van Bruggen, 1978; Davis, 1997; Herbert, 1997).
4. East African afromontane component:
   The biota of afromontane affinities was largely associated with the Great Escarpment. They occurred in higher altitude parts of the region and in particular in the forests on the southern and south-eastern slopes. Families and genera generally occurred in both montane and mist-belt forests (Low & Rebelo 1996; Herbert & Kilburn, 2004) however species were not be confined to the forest and might be found in thickets, shrubby

vegetation in mountain passes and open grassy patches. It included high altitude specialists and those restricted to lower altitude mist-belt forest. The east African afromontane component also consisted of afromotane species that extended northwards in their distributions into the mountains of Mpumalanga and Limpopo Provinces as well as southern elements that extended into the Eastern Cape and occurred at a lower altitude (Herbert & Kilburn, 2004).

5. Subtropical east of southern Africa:
   These families and genera were restricted to the east of southern Africa. The fauna followed the southern Cape coast through KwaZulu-Natal and possibly extended into the southern Mozambique and Zimbabwe.
6. Nama karoo/central west component:
   Elements were associated with the interior of the Eastern Cape and central western areas of South Africa
7. The temperate 'Mediterranean' Cape component:
   Elements were associated with the Cape flora region of endemism including the fynbos and succulent karoo biomes. Their distributions were centred largely in the Cape and inhabited the winter rainfall regions (van Bruggen, 1978; Davis, 1997; Herbert, 1997; Herbert & Kilburn, 2004).
8. Elements of the arid regions of the north-western Cape, Namibia and parts of Botswana:
   These elements occupied the late summer rainfall area (Davis, 1997) and included the desert specialists (van Bruggen, 1978; Herbert, 1997; Herbert & Kilburn, 2004).
9. Ubiquitous/widely distributed elements:
   Ubiquitous/widely distributed elements extended northwards into the central and east Africa. These elements consisted of subtropical and tropical affinities that have a cosmopolitan distribution.
10. Disjunct distributions:
   Families and genera occurred in southern Africa, Europe and Asia but did not occur in between. Their distributions were not uniform.

The distribution patterns of twenty-seven terrestrial mollusc families (Table 3.1) and sixty genera (Table 3.2) were examined and grouped according to the different biogeographical components. The distribution patterns of families and genera were examined relative to base maps (coverages) containing biotic and abiotic environmental characteristics at a 1 min grid with Arcview 3.2 (ESRI). The following coverages were used (from Schulze *et al*., 1997): altitude, mean annual precipitation, seasonality of precipitation, mean daily temperature, mean annual temperature, mean daily maximum temperature, mean daily minimum temperature and January mean relative humidity. Vegetation types and biomes of South Africa were obtained from Low & Rebelo (1996) and major rivers (1:500000 coverage) from the Resource Quality Services (Department of Water Affairs and Forestry) (2005).

A biome is a broad ecological unit that represents major life zones of large natural areas. In South Africa biomes are defined mainly by vegetation structure and climate. The different vegetation types in South Africa are delimited into seven biomes, these being the forest, fynbos, grassland, nama karoo, savanna, thicket and succulent karoo biomes (Low & Rebelo, 1996). The locations of families and genera were mapped onto the coverages and factors that may restrict their distributions were examined. The limits of the following factors were considered to possibly influence the distributions of molluscs in South Africa if molluscs:

a. Did not occur beyond a river;
b. Did not extend beyond the Escarpment;
c. Did not occur in areas with mean annual precipitation <400 ml or >1500 ml;
d. Did not occur in areas with mean daily temperature range < 5 °C or > 27 °C;
e. Did not occur in areas with mean annual temperature range < 6 °C or > 23 °C;
f. Occurred in areas with mean daily maximum temperature < 28 °C;
g. Occurred in areas with mean daily minimum temperature > 4 °C;
h. Occurred between altitudes of 100 and 1700 m a.s.l;
i. Occurred in areas with January mean relative humidity > 50 %.

The identification and delimitation of the biogeographic components as well as the identification of factors restricting the distribution of terrestrial molluscs were mainly based on subjective assessments.

3.3. Results

3.3.1. Biogeographical patterns

The tropical/subtropical east African pattern was the most common pattern among the mollusc distribution patterns in South Africa. The distribution patterns of 21 families and 48 genera were classed into the tropical/subtropical east African biogeographic component (Tables 3.1 & 3.2). A strong east African afromontane pattern was also present with fewer families and genera exhibiting biogeographic patterns that were associated with the western and central regions of South Africa. Fourteen families and 18 genera were elements of the temperate ‘Mediterranean’ Cape component but they were not restricted to this classical area of Cape endemism. The distribution patterns of 3.7 % of families and 28 % of genera were defined by a single biogeographical component. The majority of the mollusc families (96.3 %) and genera (72 %) showed a mixed biogeographical pattern, i.e. the distribution patterns of these families and genera were defined by more than one biogeographical component (Table 3.3).

Forty-one percent of families and 53 % of genera were associated with two to three biogeographical patterns. The highest percentage of families (29.6 %) was associated with four biogeographical patterns. The distribution patterns of 6.6 % of genera crossed four biogeographical components. Twenty-six percent of families and 11.8 % of genera were associated with five or more biogeographical components. Fewer genera showed three or more biogeographical patterns and no genera displayed more than six biogeographical patterns (Table 3.3).

Table 3.1: Major biogeographical patterns at the mollusc family level.

Family	**Gondwanaland/southern relict element**	**Laurasia element**	**Tropical/subtropical east African element**	**Subtropical east of southern Africa**	**East African afromontane element**	**Nama karoo/central west region**	**Temperate Mediterranean Cape**	**Arid regions of NW Cape, Namibia & parts of Botswana**	**Disjunct**	**Ubiquitous**	**Total number of patterns**
Achatinidae			x		x	x	x	x		x	6
Arionidae		x					x		x		3
Bulimulidae	x					x					2
Cerastidae		x	x	x	x						4
Charopidae	x		x		x	x	x	x		x	7
Chlamydephoridae	x		x	x	x						4
Chondrinidae			x			x		x		x	4
Clausiliidae		x			x						2
Cyclophoridae			x		x		x				3
Dorcasiidae	x						x	x			3
Euconulidae			x	x	x						3
Ferussaciidae			x	x				x		x	4
Helicarionidae			x	x	x						3
Hydrocenidae			x		x		x			x	4
Maizaniidae			x	x							2
Orculidae		x			x		x		x		4
Pomatiasidae			x		x		x				3
Punctidae			x		x		x			x	4
Pupillidae			x		x	x	x	x	x	x	7
Rhytididae	x		x		x	x	x				5

Sculptariidae	x							x			2
Streptaxidae			x		x	x		x		x	5
Subulinidae			x		x	x	x	x		x	6
Succineidae			x			x	x	x		x	5
Urocyclidae			x		x	x	x				4
Veronicellidae			x								1
Vertginidae			x		x	x					3
Total number of families	6	4	21	6	18	11	14	10	3	10	

Table 3.2: Major biogeographical patterns at the mollusc genus level.

Genera	**Gondwanaland/southern relict element**	**Laurasia element**	**Tropical/ subtropical east African element**	**Subtropical east of southern Africa**	**East African afromontane element**	**Nama karoo/ central west region**	**Temperate Mediterranean Cape**	**Arid regions of NW Cape, Namibia & parts of Botswana**	**Disjunct**	**Ubiquitous**	**Total number of patterns**
Cochlitoma			x		x	x	x	x		x	6
Achatina			x								1
Burtoa			x								1
Metachatina			x	x							2
Ariopelta							x				1
Ariostralis							x				1
Oopelta							x				1
Prestonella						x					1
Edouardia			x	x	x						3
Rachis			x	x							2
Rhachistia			x	x							2
Afrodonta			x		x	x					3
Trachycystis			x		x	x	x	x		x	6
Chlamydephorus			x	x	x						3
Gastrocopta			x			x		x		x	4
Macroptychia					x						1
Chondrocyclus			x		x		x				3
Dorcasia								x			1
Trigonephrus							x	x			2
Tulbaghinia							x				1
Afroconulus					x						1
Afroguppya			x	x							2
Afropuctum			x								1
Cecilioides			x	x				x			3
Kaliella			x	x	x						3

Hydrocena			x		x		x				3
Maizania			x	x							2
Fauxulus					x		x				2
Tropidophora			x		x		x				3
Paralaoma			x		x		x				3
Lauria			x		x	x	x		x		5
Pupilla			x		x	x					3
Pupoides			x			x		x			3
Nata	x		x		x	x	x				5
Natalina	x		x		x	x	x				5
Sculptaria	x							x			2
Eustreptaxis			x	x							2
Gonaxis			x								1
Gulella			x		x	x		x			4
Streptostele			x								1
Coeliaxis				x							1
Curvella			x	x	x						3
Euonyma			x		x	x	x	x			5
Opeas			x		x			x			3
Pseudoglessula			x	x							2
Pseudopeas			x	x	x						3
Subulina			x					x			2
Xerocerastus			x					x			2
Oxyloma			x								1
Succinea			x			x	x	x		x	5
Atoxoniodes			x	x							2
Elisolimax			x	x							2
Sheldonia			x		x	x	x				4
Thapsia			x	x							2
Trochonanina			x								1
Urocyclus			x	x							2
Laevicaulis			x								1
Nesopupa			x		x	x					3
Pupisoma			x	x	x	x					4
Truncatellina			x		x	x					3
Total number of genera	3	0	48	19	26	17	18	14	1	4	

Table 3.3: Percentage of mollusc families (N = 21) and genera (N = 48) exhibiting single and multiple biogeographical patterns.

Number of different biogeographical patterns	**Percentage of families**	**Percentage of genera**
1	3.7	28.3
2	14.8	26.7
3	25.9	26.7

4	29.6	6.7
5	11.1	8.3
6	7.4	3.3
7	7.4	0
8	0	0
9	0	0
10	0	0

3.3.2. Factors influencing the biogeographic patterns of terrestrial mollusc families in South Africa

The distributions of six families appeared to be restricted by rivers. Cerastidae, Veronicellidae and Vertginidae reached their southern limit at the Gouritz River while the Groot Kei River possibly limited the southwards distribution of Maizaniidae. The Limpopo River might act as a barrier to the northwards spread of Cyclophoridae and Rhytididae. The distribution of thirteen families into the western and central areas of South Africa were possibly restricted by the central escarpment. Altitude had some effect on the distribution of nine families. Twenty families occurred in areas with a high January mean relative humidity. Mean annual precipitation appeared to also effect the distributions of eight families (Table 3.4). The distributions of all families were influenced by mean annual temperature. The mean daily temperature also had an effect on the distribution of seventeen families. Mean daily maximum and minimum temperature did not have an effect on the distribution of the families. No families were limited by mean daily maximum temperature and the distribution of only a single family, Maizaniidae, appeared to be limited by the mean daily minimum temperature. The family did not occur in areas with a mean daily minimum temperature below 8°C (Table 3.5).

Table 3.4: Altitude, January mean relative humidity and mean annual precipitation ranges at which terrestrial mollusc families occurred. Rivers and the Escarpment may limit the distribution of terrestrial mollusc families.

Family	Rivers	Escarpment	Altitude (m a.s.l.)	January mean relative humidity (%)	Mean annual precipitation (mm)
Achatinidae	Not limiting	Not limiting	0-3001	47-81	246-1796
Arionidae	Not limiting	Not limiting	15-1340	60-72	283-3345
Bulimulidae	Not limiting	Not limiting	838-1680	58-63	180-725
Cerastidae	Gouritz River southern limit	Possible barrier	0-1622	62-82	228-2031
Charopidae	Not limiting	Not limiting	0-3170	60-82	63-3345
Chlamydephoridae	Not limiting	Possible barrier	0-1981	60-82	547-1585
Chondrinidae	Not limiting	Not limiting	18-1830	60-77	242-1291
Clausiliidae	Not limiting	Possible barrier	580-2134	62-74	536-1845
Cyclophoridae	Possibly limited by the Limpopo River	Possible barrier	0-1920	62-82	269-1722
Dorcasiidae	Not limiting	Not limiting	0-1840	55-73	50-2776

Euconulidae	Not limiting	Possible barrier	0-2804	64-79	242-2031
Ferussaciidae	Not limiting	Possible barrier	12-1490	67-82	698-1291
Helicarionidae	Not limiting	Possible barrier	0-2134	65-81	630-1845
Hydrocenidae	Not limiting	Possible barrier	18-2804	62-82	470-1845
Maizaniidae	Possibly limited by the Groot Kei River	Possible barrier	1-669	74-82	670-1487
Orculidae	Not limiting	Possible barrier	0-2804	62-82	347-1585
Pomatiasidae	Not limiting	Possible barrier	0-1587	61-80	228-1487
Punctidae	Possibly limited by the Limpopo River	Possible barrier	18-2062	62-77	351-1346
Pupillidae	Not limiting	Not limiting	1-2084	57-80	122-1845
Rhytididae	Not limiting	Not limiting	0-3001	47-82	269-1741
Sculptariidae	Not limiting	Not limiting	0-1617	61	206
Streptaxidae	Not limiting	Not limiting	0-2804	60-82	320-2031
Subulinidae	Not limiting	Not limiting	0-1984	57-82	63-1722
Succineidae	Not limiting	Not limiting	0-1858	60-79	122-1291
Urocyclidae	Not limiting	Not limiting	0-2377	58-81	169-1561
Veronicellidae	Gouritz River southern limit	Possible barrier	0-1478	64-82	268-1431
Vertginidae	Gouritz River southern limit	Not limiting	0-2134	60-81	320-1845

Table 3.5: Temperature ranges at which terrestrial mollusc families occurred.

Family	Mean daily temperature range (°C)	Mean annual temperature range (°C)	Mean daily maximum temperature range (°C)	Mean daily minimum temperature range (°C)	Mean daily maximum temperature (°C)	Mean daily minimum temperature (°C)
Achatinidae	0-27	6-23	6-33	-7-22	33	-7
Arionidae	6-24	10-18	9-32	2-15	32	2
Bulimulidae	7-23	14-17	13-31	0-15	31	0
Cerastidae	9-27	13-23	15-33	0-21	33	0
Charopidae	2-26	7-22	8-32	-3-21	32	-3
Chlamydephoridae	6-26	13-22	14-32	-1-20	32	-1
Chondrinidae	7-27	14-23	14-33	0-22	33	0
Clausiliidae	7-21	13-17	14-28	0-16	28	0
Cyclophoridae	8-24	13-20	15-30	0-20	30	0
Dorcasiidae	4-25	10-20	8-33	0-17	33	0
Euconulidae	3-27	7-23	8-33	-2-22	33	-2
Ferussaciidae	10-25	16-21	18-30	2-20	30	2
Helicarionidae	10-25	13-21	14-31	0-20	31	0
Hydrocenidae	3-24	7-20	8-29	-2-20	29	-2
Maizaniidae	14-24	17-20	20-29	8-20	29	8
Orculidae	3-24	7-20	8-29	-2-20	29	-2
Pomatiasidae	9-27	14-23	16-33	1-22	33	1
Punctidae	7-24	13-20	14-29	0-19	29	0

Pupillidae	3-27	7-23	8-33	-2-22	33	-2
Rhytididae	0-26	6-22	7-32	-7-21	32	-7
Sculptariidae	11-25	19	20-33	3-17	33	3
Streptaxidae	3-27	7-22	8-33	-2-21	33	-2
Subulinidae	7-27	11-23	12-33	0-22	33	0
Succineidae	7-26	13-22	14-33	0-21	33	0
Urocyclidae	5-27	11-23	12-33	-1-22	33	-1
Veronicellidae	9-27	16-23	18-33	0-22	33	0
Vertginidae	7-26	12-22	14-31	0-21	31	0

The distributions of families were also influenced by the rainfall seasons and biomes. The distributions of eleven families were not influenced by the seasonality of precipitation. Eighteen families occurred in areas that received rainfall all year round. Ten families occurred within areas, which exhibited two to three rainfall seasons. Arionidae occurred in areas with all year rainfall and winter rainfall. The distribution of the family did not extend into the summer rainfall areas. Bulimulidae occurred in the mid and very late summer rainfall areas and Sculptariidae only occurred in the late summer rainfall area. Thirteen families did not occur in the winter rainfall areas. Bulimulidae, Clausiliidae, Euconulidae, Ferussaciidae, Helicarionidae, Maizaniidae, Sculptariidae and Veronicellidae only occurred in the areas with summer rainfall seasons (Table 3.6).

Table 3.6: The occurrence of terrestrial mollusc families within the different rainfall seasons.

Family	**Seasonality of precipitation**						**Number of rainfall patterns**
	All year	**Winter**	**Early summer (December)**	**Mid summer (January)**	**Late summer (February)**	**Very late summer (March-May)**	
Achatinidae	x	x	x	x	x	x	6
Arionidae	x	x					2
Bulimulidae				x		x	2
Cerastidae	x		x	x	x	x	5
Charopidae	x	x	x	x	x	x	6
Chlamydephoridae	x		x	x	x	x	5
Chondrinidae	x		x	x	x	x	5
Clausiliidae				x	x	x	3
Cyclophoridae	x	x	x	x	x	x	6
Dorcasiidae		x			x	x	3
Euconulidae			x	x	x		3
Ferussaciidae			x	x	x		3
Helicarionidae			x	x	x		3
Hydrocenidae	x	x	x	x	x	x	6
Maizaniidae			x	x	x		3

Orculidae	x	x	x	x	x	x	6
Pomatiasidae	x	x	x	x	x	x	6
Punctidae	x	x	x	x	x		5
Pupillidae	x	x	x	x	x	x	6
Rhytididae	x	x	x	x	x	x	6
Sculptariidae					x		1
Streptaxidae	x		x	x	x	x	5
Subulinidae	x	x	x	x	x	x	6
Succineidae	x	x	x	x	x	x	6
Urocyclidae	x	x	x	x	x	x	6
Veronicellidae			x	x	x		3
Vertginidae	x		x	x	x	x	5
No. of families/season	18	14	22	24	25	19	

Table 3.7: The presence of terrestrial mollusc families across biomes.

Family	Biomes							Number of biomes
	Forest	**Fynbos**	**Grassland**	**Nama karoo**	**Savanna**	**Thicket**	**Succulent karoo**	
Achatinidae	x	x	x	x	x	x		6
Arionidae	x	x						2
Bulimulidae				x				1
Cerastidae	x	x			x	x		4
Charopidae	x	x	x	x	x	x	x	7
Chlamydephoridae	x		x		x	x		4
Chondrinidae	x	x	x	x	x	x		6
Clausiliidae	x							1
Cyclophoridae	x	x				x		5
Dorcasiidae		x		x		x	x	5
Euconulidae	x		x		x			3
Ferussaciidae	x		x		x	x		4
Helicarionidae	x		x		x	x		4
Hydrocenidae	x	x				x		5
Maizaniidae	x					x		4
Orculidae	x	x			x	x		5
Pomatiasidae	x	x	x	x	x	x		6
Punctidae	x	x	x		x	x		5
Pupillidae	x	x	x	x	x	x		6
Rhytididae	x	x	x	x	x	x		6
Sculptariidae					x			1
Streptaxidae	x	x	x	x	x	x		6
Subulinidae	x	x	x	x	x	x	x	7
Succineidae	x	x	x	x	x	x		6

Urocyclidae	x	x	x	x	x	x		6
Veronicellidae	x		x		x	x		5
Vertginidae	x	x	x	x	x	x		6
No. of families/biome	24	18	17	13	20	22	3	

The least number of families inhabited the succulent karoo biome. The widely distributed families, Charopidae and Subulinidae and the desert specialist, Dorcasiidae, were found within the succulent karoo biome. Majority of the families occurred within the forest and thicket biomes. Two families, Charopidae and Subulinidae, inhabited all biomes. Nine families occurred in six of the biomes except within the succulent karoo biome. Three families, Bulimulidae, Clausiliidae and Sculptariidae occurred within a single biome.

Table 3.8: Altitude, January mean relative humidity and mean annual precipitation ranges at which terrestrial mollusc genera occurred. Rivers and the Escarpment may limit the distribution of terrestrial mollusc genera.

Genera	**Rivers**	**Escarpment**	**Altitude (m a.s.l.)**	**January mean relative humidity (%)**	**Mean annual precipitation (mm)**
Cochlitoma	Possibly limited by the Limpopo River	Not limiting	0-3001	47-81	246-1796
Achatina	Possibly limited by the Mtamvuna River	Not limiting	0-1875	66-80	268-1249
Burtoa	Not limiting	Not limiting	390-1255	70	514
Metachatina	Possibly limited by the Limpopo River	Possible barrier	0-1338	67-79	592-1487
Ariopelta	Not limiting	Not limiting	472-1340	63-72	417-3345
Ariostralis	Not limiting	Not limiting	1340	72	3345
Oopelta	Not limiting	Not limiting	14-793	60-71	283-914
Prestonella	Not limiting	Not limiting	838-1680	58-63	180-725
Edouardia	Possibly limited by the Gouritz River	Possible barrier	0-1622	62-82	228-2031
Rachis	Not limiting	Possible barrier	32-512	70-73	383-935
Rhachistia	Not limiting	Possible barrier	0-1615	70-77	460-1170
Afrodonta	Possibly limited by the Limpopo and Gouritz Rivers	Possible barrier	0-3170	62-82	387-1585
Trachycystis	Not limiting	Not limiting	0-3170	60-82	63-3345
Chlamydephorus	Possibly limited by the Limpopo River	Possible barrier	0-1981	62-81	547-1585
Gastrocopta	Not limiting	Not limiting	18-1830	60-77	242-1291
Macroptychia	Possibly limited by the Limpopo River	Possible barrier	580-2134	62-74	536-1845
Chondrocyclus	Possibly limited by the Limpopo River	Possible barrier	0-1920	62-82	269-1722
Dorcasia	Not limiting	Not limiting	60-1714	59-67	70, 82, 336
Trigonephrus	Not limiting	Not limiting	0-1055	55-73	50-899
Tulbaghinia	Not limiting	Not limiting	179-1840	61-64	476-2776

Afroconulus	Possibly limited by the Limpopo River	Possible barrier	736-2804	64-74	786-2031
Afroguppya	Possibly limited by the Limpopo River	Possible barrier	0-1417	67-79	538-1291
Afropuctum	Possibly limited by the Limpopo River	Not limiting	210	69	242
Cecilioides	Phongola	Possible barrier	12-1490	67-82	698-1291
Kaliella	Not limiting	Possible barrier	0-2134	65-81	630-1845
Hydrocena	Not limiting	Possible barrier	18-2804	62-82	470-1845
Maizania	Possibly restricted by the Groot Kei River	Possible barrier	1-669	74-82	670-1487
Fauxulus	Possibly limited by the Limpopo River	Possible barrier	0-2804	62-82	347-1585
Tropidophora	Not limiting	Possible barrier	0-1587	61-80	228-1487
Paralaoma	Not limiting	Possible barrier	18-2062	62-77	351-1346
Lauria	Not limiting	Possible barrier	23-2804	60-76	320-1845
Pupilla	Not limiting	Not limiting	1-1890	57-80	320-1585
Pupoides	Not limiting	Not limiting	71-1258	60-73	122-853
Nata	Possibly limited by the Limpopo River	Not limiting	0-2062	60-82	269-1741
Natalina	Not limiting	Possible barrier	0-3001	47-82	304-1366
Sculptaria	Possibly restricted by the Auob River	Not limiting	1-1617	61	206
Eustreptaxis	Not limiting	Possible barrier	567-1875	73	820
Gonaxis	Not limiting	Possible barrier	100-491	70-72	373-663
Gulella	Not limiting	Not limiting	0-2804	60-82	320-2031
Streptostele	Not limiting	Possible barrier	247-652	71	460, 606
Coeliaxis	Possibly restricted by the Groot Kei River	Possible barrier	0-150	76-78	672-860
Curvella	Not limiting	Possible barrier	7-1952	67-80	412-1366
Euonyma	Not limiting	Not limiting	0-1920	57-82	218-1722
Opeas	Not limiting	Not limiting	0-1984	58-82	82-1561
Pseudoglessula	Possibly limited by the Limpopo River	Possible barrier	0-540	70-77	336-1249
Pseudopeas	Not limiting	Possible barrier	504-1858	62-75	600-1561
Subulina	Not limiting	Possible barrier	175-1702	69-71	268-757
Xerocerastus	Not limiting	Not limiting	1-1702	61-71	63-450
Oxyloma	Not limiting	Possible barrier	0-1323	64-79	658-1249
Succinea	Not limiting	Not limiting	18-1858	60-78	122-1291
Atoxoniodes	Possibly limited by the Thukela River	Possible barrier	0-614	72-76	731-1349
Elisolimax	Not limiting	Possible barrier	0-1120	68-81	538-1293
Sheldonia	Not limiting	Not limiting	0-2377	58-81	169-1561
Thapsia	Not limiting	Possible barrier	32-1120	70-73	436-1108
Trochonanina	Not limiting	Possible barrier	64-1130	67-72	228-896
Urocyclus	Not limiting	Possible barrier	16-205	75-79	927-1118
Laevicaulis	Possibly limited by the Gouritz River	Possible barrier	0-1478	64-82	268-1431

Nesopupa	Not limiting	Not limiting	0-1875	60-79	320-1293
Pupisoma	Possibly limited by the Gouritz River	Possible barrier	0-2134	62-81	351-1845
Truncatellina	Not limiting	Not limiting	18-2134	60-76	320-1845

Table 3.9: Temperature ranges at which terrestrial mollusc genera occurred.

Genera	Mean daily temperature range (°C)	Mean annual temperature range (°C)	Mean daily maximum temperature (°C)	Mean daily minimum temperature (°C)	Mean daily maximum temperature (°C)	Mean daily minimum temperature (°C)
Cochlitoma	0-26	6-22	6-32	-1-21	32	-1
Achatina	10-27	16-23	18-33	1-21	33	1
Burtoa	16-25	21	24-31	8-20	31	8
Metachatina	3-25	16-22	19-31	3-21	31	3
Ariopelta	6-21	10-16	9-28	2-14	28	2
Ariostralis	6-13	10	9-18	2-9	18	2
Oopelta	8-24	15-18	15-32	4-15	32	4
Prestonella	7-23	14-17	13-31	0-15	31	0
Edouardia	9-27	13-23	15-33	0-21	33	0
Rachis	15-26	20-23	22-32	7-21	32	7
Rhachistia	10-26	15-22	16-32	5-21	32	5
Afrodonta	2-25	7-21	8-32	-3-21	32	-3
Trachycystis	2-26	7-22	8-32	-3-21	32	-3
Chlamydephorus	6-26	13-22	14-32	-1-20	32	-1
Gastrocopta	7-27	14-23	14-33	0-22	33	0
Macroptychia	7-21	13-17	14-28	0-16	28	0
Chondrocyclus	8-24	13-20	15-30	0-20	30	0
Dorcasia	9-25	17-19	18-33	0-17	33	0
Trigonephrus	9-25	15-20	15-33	2-17	33	2
Tulbaghinia	4-24	10-18	8-32	0-16	32	0
Afroconulus	3-21	7-18	8-27	-2-16	27	-2
Afroguppya	13-26	18-22	21-32	6-21	32	6
Afropuctum	18-27	23	25-33	10-22	33	10
Cecilioides	10-25	16-21	18-30	2-20	30	2
Kaliella	7-25	13-21	14-31	0-20	31	0
Hydrocena	3-24	7-20	8-29	-2-20	29	-2
Maizania	14-24	17-20	20-29	8-20	29	8
Fauxulus	3-24	7-20	8-29	-2-20	29	-2
Tropidophora	9-27	14-23	16-33	1-22	33	1
Paralaoma	7-24	13-20	14-29	0-19	29	0
Lauria	3-23	7-19	8-30	-2-18	30	-2
Pupilla	7-24	13-20	14-30	0-20	30	0
Pupoides	11-27	17-23	19-33	3-22	33	3

Nata	6-26	11-22	12-32	-1-21	32	-1
Natalina	0-25	6-22	6-31	-7-21	31	-7
Sculptaria	11-25	19	20-33	3-17	33	3
Eustreptaxis	15-23	19	21-28	9-18	28	9
Gonaxis	16-27	21-22	24-33	8-21	33	8
Gulella	3-26	7-22	8-32	-2-21	32	-2
Streptostele	16-26	21-22	24-31	8-20	31	8
Coeliaxis	15-22	18	20-26	9-18	26	9
Curvella	9-26	14-22	14-32	1-21	32	1
Euonyma	7-26	11-22	12-33	0-21	33	0
Opeas	8-27	14-23	15-34	0-21	34	0
Pseudoglessula	15-26	21-22	23-32	7-21	32	7
Pseudopeas	8-22	13-19	15-28	1-18	28	1
Subulina	16-27	21-23	24-33	8-22	33	8
Xerocerastus	9-27	17-23	18-33	0-22	33	0
Oxyloma	9-25	16-21	18-29	0-21	29	0
Succinea	7-26	13-22	14-33	0-21	33	0
Atoxoniodes	15-25	19-22	21-30	8-20	30	8
Elisolimax	11-26	17-22	19-32	4-21	32	4
Sheldonia	5-26	11-22	12-32	-1-21	32	-1
Thapsia	12-26	18-22	19-32	5-21	32	5
Trochonanina	11-27	18-23	20-33	3-22	33	3
Urocyclus	15-24	20-21	22-29	9-20	29	9
Laevicaulis	9-27	16-23	18-33	0-22	33	0
Nesopupa	8-26	15-22	16-31	0-20	31	0
Pupisoma	7-26	12-22	15-31	0-21	31	0
Truncatellina	7-25	14-21	14-30	0-20	30	0

Table 3.10: The occurrence of terrestrial mollusc genera within the different rainfall seasons.

Genera	**Seasonality of precipitation**						**Number of rainfall seasons**
	All year	**Winter**	**Early summer (December)**	**Mid summer (January)**	**Late summer (February)**	**Very late summer (March-May)**	
Cochlitoma	x	x	x	x	x	x	6
Achatina			x	x	x		3
Burtoa			x				1
Metachatina			x	x	x		3
Ariopelta		x					1
Ariostralis		x					1
Oopelta	x	x					2
Prestonella				x		x	2
Edouardia	x		x	x	x	x	5

Rachis			x	x	x		3
Rhachistia			x	x	x		3
Afrodonta	x		x	x	x	x	5
Trachycystis	x	x	x	x	x	x	6
Chlamydephorus	x		x	x	x	x	5
Gastrocopta	x		x	x	x	x	5
Macroptychia				x	x	x	3
Chondrocyclus	x	x	x	x	x	x	6
Dorcasia		x			x	x	3
Trigonephrus		x				x	2
Tulbaghinia		x					1
Afroconulus				x	x		2
Afroguppya			x	x	x		3
Afropuctum				x			1
Cecilioides			x	x	x		3
Kaliella			x	x	x		3
Hydrocena	x	x	x	x	x	x	6
Maizania			x	x	x		3
Fauxulus	x	x	x	x	x	x	6
Tropidophora	x	x	x	x	x	x	6
Paralaoma	x	x	x	x	x		5
Lauria	x	x		x	x	x	5
Pupilla	x		x	x	x	x	5
Pupoides			x	x	x	x	4
Nata	x	x	x	x	x	x	6
Natalina	x	x	x	x	x	x	6
Sculptaria					x		1
Eustreptaxis				x			1
Gonaxis				x			1
Gulella	x		x	x	x	x	5
Streptostele				x			1
Coeliaxis	x		x				2
Curvella	x		x	x	x		4
Euonyma	x	x	x	x	x	x	6
Opeas	x		x	x	x	x	5
Pseudoglessula			x	x	x		3
Pseudopeas			x	x	x	x	4
Subulina				x			1
Xerocerastus		x		x	x		3
Oxyloma			x	x	x		3
Succinea	x	x	x	x	x	x	6
Atoxoniodes				x	x		2

Elisolimax			x	x	x		3
Sheldonia	x	x	x	x	x	x	6
Thapsia				x	x		2
Trochonanina			x	x			2
Urocyclus			x	x			2
Laevicaulis			x	x	x		3
Nesopupa	x		x	x	x	x	5
Pupisoma	x		x	x	x	x	5
Truncatellina	x		x	x	x	x	5
Number of genera/season	26	20	41	51	45	28	

Table 3.11: The presence of terrestrial mollusc genera across biomes.

Genera	Biomes							Number of biomes
	Forest	Fynbos	Grassland	Nama karoo	Savanna	Thicket	Succulent karoo	
Cochlitoma	x	x	x	x	x			5
Achatina			x		x	x		3
Burtoa					x			1
Metachatina	x				x	x		3
Ariopelta		x						1
Ariostralis		x						1
Oopelta	x	x					x	3
Prestonella	x			x				2
Edouardia	x	x	x		x	x		5
Rachis					x	x		2
Rhachistia	x				x	x		3
Afrodonta	x	x	x		x	x		5
Trachycystis	x	x	x	x	x	x	x	7
Chlamydephorus	x		x		x	x		4
Gastrocopta	x	x	x	x	x	x		6
Macroptychia	x							1
Chondrocyclus	x	x				x		3
Dorcasia				x	x		x	3
Trigonephrus		x		x		x	x	4
Tulbaghinia		x						1
Afroconulus	x							1
Afroguppya	x		x		x	x		4
Afropuctum					x			1
Cecilioides	x		x		x	x		4
Kaliella	x		x		x	x		4
Hydrocena	x	x				x		3
Maizania	x					x		2

Fauxulus	x	x	x		x	x		5
Tropidophora	x	x	x	x	x	x		6
Paralaoma	x	x	x		x	x		5
Lauria	x	x		x	x	x		6
Pupilla	x	x	x	x	x	x		6
Pupoides				x	x	x		3
Nata	x	x	x	x	x	x		6
Natalina	x	x	x	x	x	x		6
Sculptaria					x			1
Eustreptaxis					x			1
Gonaxis					x			1
Gulella	x	x	x	x	x	x		6
Streptostele					x			1
Coeliaxis	x					x		2
Curvella	x	x	x		x	x		5
Euonyma	x	x	x	x	x	x		6
Opeas	x	x	x	x	x	x		6
Pseudoglessula	x				x	x		3
Pseudopeas	x				x	x		3
Subulina					x			1
Xerocerastus					x		x	2
Oxyloma			x		x	x		3
Succinea	x	x	x	x	x	x		6
Atoxoniodes	x							1
Elisolimax	x		x		x	x		4
Sheldonia	x	x	x	x	x	x		6
Thapsia					x	x		2
Trochonanina					x			1
Urocyclus	x					x		2
Laevicaulis	x		x		x	x		4
Nesopupa	x		x	x	x	x		5
Pupisoma	x	x			x	x		4
Truncatellina	x	x	x	x	x	x		6
No. of genera/biome	41	27	27	19	46	41	5	

Table 3.12: Number of terrestrial mollusc genera limited by rivers, escarpment, altitude, humidity, precipitation and temperature.

Families	Factors								
	Rivers	Escarpment	Altitude (m a.s.l.)	January mean relative humidity (%)	Mean annual precipitation (mm)	Mean daily temperature range (°C)	Mean annual temperature range (°C)	Mean daily maximum temperature (°C)	Mean daily minimum temperature (°C)
Achatinidae	3	1	2	3	2	2	4	0	1
Arionidae	0	0	3	3	2	3	3	1	0
Bulimulidae	0	0	1	1	1	1	1	0	0
Cerastidae	1	3	3	3	2	3	3	0	2
Charopidae	1	1	0	2	0	0	2	0	0
Chlamydephoridae	1	1	0	1	1	1	1	0	0
Chondrinidae	0	0	0	1	0	1	1	0	0
Clausiliidae	1	1	1	1	1	1	1	0	0
Cyclophoridae	1	1	0	1	0	1	1	0	0
Dorcasiidae	0	0	1	3	3	2	3	0	0
Euconulidae	3	2	3	3	3	2	3	1	2
Ferussaciidae	1	1	1	1	1	1	1	0	0
Helicarionidae	0	1	0	1	1	1	1	0	0
Hydrocenidae	0	1	0	1	1	0	1	0	0
Maizaniidae	1	1	1	1	1	1	1	0	1
Orculidae	1	1	0	1	0	0	1	0	0
Pomatiasidae	0	1	1	1	0	1	1	0	0
Punctidae	0	1	0	1	0	1	1	0	0
Pupillidae	0	1	1	3	1	2	3	0	0
Rhytididae	1	1	0	1	0	1	2	0	0
Sculptariidae	1	0	1	1	1	1	1	0	0
Streptaxidae	0	3	3	4	3	3	4	0	3
Subulinidae	2	5	3	8	5	8	8	1	0
Succineidae	0	1	1	2	1	2	2	0	3
Urocyclidae	1	5	5	6	5	6	6	0	3
Veronicellidae	1	1	1	1	0	1	1	0	0
Vertginidae	1	1	0	3	0	3	3	0	0

Table 3.13: Number of terrestrial mollusc genera influenced by the seasonality of precipitation.

Families	Seasonality of precipitation					
	All year	Winter	Early summer (December)	Mid summer (January)	Late summer (February)	Very late summer (March-May)
Achatinidae	1	1	4	3	3	1
Arionidae	1	3	0	0	0	0
Bulimulidae	0	0	0	1	0	1

Cerastidae	1	0	3	3	3	1
Charopidae	2	1	2	2	2	2
Chlamydephoridae	1	0	1	1	1	1
Chondrinidae	1	0	1	1	1	1
Clausiliidae	0	0	0	1	1	1
Cyclophoridae	1	1	1	1	1	1
Dorcasiidae	0	3	0	0	1	2
Euconulidae	0	0	1	3	2	0
Ferussaciidae	0	0	1	1	1	0
Helicarionidae	0	0	1	1	1	0
Hydrocenidae	1	1	1	1	1	1
Maizaniidae	0	0	1	1	1	0
Orculidae	1	1	1	1	1	1
Pomatiasidae	1	1	1	1	1	1
Punctidae	1	1	1	1	1	0
Pupillidae	2	1	2	3	3	3
Rhytididae	2	2	2	2	2	2
Sculptariidae	0	0	0	0	1	0
Streptaxidae	1	0	1	4	1	1
Subulinidae	4	2	6	7	6	3
Succineidae	1	1	2	2	2	1
Urocyclidae	1	1	4	6	4	1
Veronicellidae	0	0	1	1	1	0
Vertginidae	3	0	3	3	3	3

Table 3.14: Number of terrestrial mollusc genera within each biome

Families	Biomes						
	Forest	**Fynbos**	**Grassland**	**Nama karoo**	**Savanna**	**Thicket**	**Succulent karoo**
Achatinidae	2	1	2	1	4	2	0
Arionidae	1	3	0	0	0	0	1
Bulimulidae	1	0	0	1	0	0	0
Cerastidae	2	1	1	0	3	3	0
Charopidae	2	2	2	1	2	2	1
Chlamydephoridae	1	0	1	0	1	1	0
Chondrinidae	1	1	1	1	1	1	0
Clausiliidae	1	0	0	0	0	0	0
Cyclophoridae	1	1	0	0	0	1	0
Dorcasiidae	0	2	0	2	1	1	2
Euconulidae	2	0	1	0	2	1	0
Ferussaciidae	1	0	1	0	1	1	0
Helicarionidae	1	0	1	0	1	1	0
Hydrocenidae	1	1	0	0	0	1	0

Maizaniidae	1	0	0	0	0	1	0
Orculidae	1	1	1	0	1	1	0
Pomatiasidae	1	1	1	1	1	1	0
Punctidae	1	1	1	0	1	1	0
Pupillidae	2	2	1	3	3	3	0
Rhytididae	2	2	2	2	2	2	0
Sculptariidae	0	0	0	0	1	0	0
Streptaxidae	1	1	1	1	4	1	0
Subulinidae	6	3	3	2	7	6	1
Succineidae	1	1	2	1	2	2	0
Urocyclidae	4	1	2	1	4	4	0
Veronicellidae	1	0	1	0	1	1	0
Vertginidae	3	2	2	2	3	3	0

3.3.3. Factors influencing the biogeographic patterns of terrestrial mollusc genera in South Africa

Rivers were possible barriers to the distribution of twenty-one genera. Thirty-five genera were limited to the eastern side of the central escarpment. The distributions of thirty-two genera were influenced by altitude and fifty-eight genera appeared to be affected by the mean relative humidity. The mean annual precipitation had an effect on the distributions of thirty-five the genera (Table 3.8). The mean daily and mean annual temperatures influenced forty-nine genera and sixty genera respectively. Three genera were influenced by the mean daily maximum temperature and fifteen genera by the mean daily minimum temperatures (Table 3.9). Most genera occurred in areas that had a mid-summer rainfall season and within the savanna biome. Eleven genera were not influenced by the seasonality of precipitation. Ten genera occurred in areas that experienced a single precipitation season. Most genera occurred in the summer rainfall areas (Table 3.10). A single genus, *Trachycystis*, occurred in all biomes. Five genera occurred in the succulent karoo biome with the majority of genera (46) occurring in the savanna biome. Forty-one genera also inhabited the forest biome. Thirteen genera were restricted to a single biome. Ten genera occurred within the forest, fynbos, grassland, nama karoo, savanna and thicket biomes but did not occur within the succulent karoo biome (Table 3.11).

The distributions of molluscs were influenced by a combination of various factors, which included the presence of rivers, the escarpment, altitude humidity, precipitation, temperature and biomes. Rivers could possibly restrict the distribution of certain mollusc taxa but did not appear to be the dominant factor that influenced the distribution of molluscs across the landscape. In terms of the effect of temperature on the distribution of molluscs, the mean daily and mean annual temperatures appeared to have more of an influence on the distribution patterns than the mean daily maximum and minimum temperatures. Mean annual temperatures limited all families and genera. The mean daily maximum temperature appeared to have little or no effect on the distribution of mollusc taxa. Humidity and biomes also appeared to influence the distribution of taxa. The least inhabited biome was the succulent biome. Many mollusc taxa occurred in the wetter, warmer areas with high humidity levels.

3.3.4. Factors that drive similar biogeographic patterns among terrestrial mollusc families and genera

The Gondwanaland/southern relict families exhibited various biogeography patterns. Among the Gondwanaland/southern relict fauna, families such as Bulimulidae and Sculptariidae had a restricted distribution pattern as compared to Charopidae which was widely distributed across the landscape. The mean annual temperature restricted all Gondwanaland/southern relict families. The distribution of the Laurasian families appeared to be influenced by the mean relative humidity and mean annual temperatures.

Families and genera which showed the same biogeographic patterns, appeared to be influenced by the same ecological factors. However these families and genera, except for Euconulidae and Helicarionidae and *Nata*, *Natalina, Macroptychia* and *Afroconulus,* occupied different biomes. The Euconulidae and Helicarionidae families were both restricted to the eastern biogeographic areas of South Africa. These families were confined to the early to late summer rainfall areas and to the forest, fynbos, savanna and thicket biomes. Their distributions also appeared to be influenced by humidity and mean annual temperatures. Genera *such as Edouardia, Chlamydephorus, Kaliella, Curvella and Pseudopeas,* which were confined to the eastern zones, were restricted to these biogeographic zones by humidity, mean daily temperature and mean annual temperature and the escarpment. *Macroptychia* and *Afroconulus* were restricted to the East African afromontane zone by the forest biome, the Limpopo River, the escarpment, altitude, humidity, mean annual precipitation and mean annual temperature. The genera occupied the mid to late summer rainfall areas with *Macroptychia* also occurring within the very late summer rainfall area. Tropical/subtropical east African elements such as *Achatina*, *Burtoa*, *Afropuctum*, *Gonaxis*, *Streptostele*, *Oxyloma* and *Laevicaulis* were influenced by humidity, mean daily temperature and mean annual temperature. *Metachatina, Rachis, Rhachistia, Afroguppya, Maizania, Eustreptaxis, Atoxoniodes, Elisolimax, Thapsia, Pseudoglessula* and *Urocyclus* were restricted to the tropical/subtropical east African and subtropical east of southern Africa zones by the escarpment, altitude, humidity and mean annual temperature. Cyclophoridae and Pomatiasidae were restricted to the tropical/subtropical east African, east African afromontane and temperate ‘Mediterranean’ Cape biogeographic zones by humidity, mean daily temperature and mean annual temperature. *Chondrocyclus, Hydrocena,* *Tropidophora* and *Paralaoma* also occupied the tropical/subtropical east African, east African afromontane and temperate 'Mediterranean' Cape biogeographic zones but their distributions appeared to be restricted by the escarpment and mean annual temperature

Tropical/subtropical east African elements such as *Subulina* and *Xerocerastus* which also occupied the arid regions of north-western Cape, Namibia and parts of Botswana were possibly influenced by humidity, mean daily temperature, mean annual temperature and mean annual precipitation. *Afrodonta, Pupilla, Nesopupa* and *Truncatellina* did not occur within the winter rainfall area and appeared to be restricted to the tropical/subtropical east African, east African afromontane and nama karoo/central west regions by humidity and mean annual temperature. The *Nata* and *Natalina* genera did not occur in the succulent karoo biome and their distributions were possibly limited by the mean annual temperature range. Families such as Achatinidae and Subulinidae, which occupied the same biogeographic zones and were influenced by the mean annual temperature as well as occurring in all summer rainfall areas, did show differences in the biomes that were occupied. Subulinidae inhabited all biomes and Achatinidae did not occupy the succulent karoo biome. Widely distributed genera, *Cochlitoma* and *Trachycystis,* occurred in all summer rainfall areas but their distributions were restricted by mean annual temperatures. *Trachycystis* occupied all biomes and *Cochlitoma* did not inhabit the thicket and succulent karoo biomes.

Hydrocenidae and Punctidae showed the same biogeographic patterns but inhabited different rainfall areas. Hydrocenidae occurred in all rainfall areas and Punctidae did not occur in the late summer rainfall areas. The families were influenced by humidity and mean annual temperature. Temperate 'Mediterranean' Cape elements, *Ariopelta, Ariostralis, Oopelta* and *Tulbaghinia*, were influenced by humidity and mean annual temperatures. *Ariopelta, Ariostralis* and *Oopelta* occupied only the winter rainfall areas and the fynbos biome. *Oopelta* occupied the winter rainfall and all year rainfall areas as well as the forest, fynbos and succulent karoo biomes.

3.4. Discussion

In South Africa molluscs on the whole were widely distributed. The distribution patterns of mollusc families and genera did show definite limits to distribution at the family and genus levels. The distribution patterns of the snail and slug fauna within South Africa showed six broad biogeographic centres, these being the arid western and central areas consisting of the north western Cape, Namibia and parts of Botswana, the temperate Mediterranean Cape zone, the nama karoo/central west zone and the tropical/subtropical east African zone, subtropical east of southern Africa and the East African afromontane areas which collectively made up the eastern, warmer summer rainfall region. Gondwanaland/southern relict fauna and Laurasian elements also occurred within these regions as well as mollusc taxa that exhibited widely distributed and disjunct distribution patterns. The distribution patterns of the palaeogenic invertebrates showed two main areas that were occupied by these taxa, these being a Cape Centre and an Eastern Highlands Centre. A transitional zone situated between the two centres was identified as ecologically unfavourable to palaeogenic invertebrates (Stuckenberg, 1962). Herbert (1997) divided South Africa into three regions with respect to its indigenous slug fauna, these being, an arid central and western area with no terrestrial slugs; a cool, winter-rainfall, Mediterranean region (Cape) with only endemic species and a warmer, summer-rainfall region with transitional endemics and more widespread tropical species (Herbert, 1997).

The distribution of mollusc in southern Africa reflects a bipolar pattern, consisting of elements of northern origin intermixed with elements of a southern origin (van Bruggen, 1980). Six families, Bulimulidae, Dorcasiidae, Charopidae, Chlamydephoridae, Sculptariidae and Rhytididae are considered to belong to the Gondwanaland/southern relict fauna, these being fauna which mainly occur in the southern hemisphere (van Bruggen, 1978 & 1980; Herbert, 1998). Many of these taxa are concentrated in the southern areas of the continents and in Africa this is almost the typical distribution of these families (van Bruggen, 1978). Corresponding groups elsewhere in the southern continents are not as much restricted to the southern parts as the representatives of the African southern relict families. The limited fossil records indicate that these genera have existed here at least since the Palaeocene period and were never present in the northern hemisphere with the exception of Charopidae (van Bruggen, 1978; Herbert, 1998; Herbert & Kilburn, 2004). The absence of both fossil and recent northern hemisphere temperate records for the southern relict families Bulimulidae, Sculptariidae, Dorcasiidae, Rhytididae and Chlamydephoridae may indicate that these taxa have arisen in Gondwanaland and have spread northward from there with various degrees of success (van Bruggen, 1978; Herbert, 1998; Herbert & Kilburn, 2004). The nearest relatives are species occurring in Australia, New Zealand or South America and other fragments of the ancient supercontinent of Gondwana. The success of the spread northward appears to be limited with the southern relict families in Africa having progressed little beyond the Zambezi River (about 15 ºS latitude). The southern African representatives of these southern relict families appear to be either adapted to temperate conditions or are desert specialists, being prevented from migrating northward by either considerably warmer or moister climatic conditions. The southward migration of phylogenetically more advanced (younger), species-rich fauna from the tropics such as Achatinidae, Cerastidae, Streptaxidae, Subulinidae and Urocyclidae may have also influenced the distributional range of the southern relict families (van Bruggen, 1978; Herbert & Kilburn, 2004). The family Bulimulidae is a typical example of a southern relict family whose distribution was restricted to the southern areas of Southern Africa. The family, represented by *Prestonella*, occurred only within the nama karoo/central west zone. In southern Africa the distribution patterns of some mollusc taxa such as the Holarctic family, Arionidae and the Palaearctic family, Orculidae, do not have a Gondwanaland origin but represent relict elements of families with northern (Laurasian) distribution patterns (van Bruggen, 1980). There is a strong tropical element among terrestrial molluscs in South Africa. Many of these mollusc taxa were mainly confined to the south-eastern regions of Africa (van Bruggen, 1969 & 1978). Some groups have extended their distribution westwards by adapting to the semi-arid environment of the central and western parts of southern Africa (van Bruggen, 1969 & 1978).

The geographical distributions of South African molluscs are influenced by a number of interrelated variables, which constitute the physical and biological environments (van Bruggen, 1978; Herbert, 1997; Herbert & Kilburn, 2004). Physical variables include climate (temperature and rainfall), altitude, aspect and geology. Historical influences such as past climatic regimes and changes and geographical continuities and discontinuities in the landscape influence present day species distribution (van Bruggen, 1978; Herbert & Kilburn, 2004). A large proportion of southern Africa forms a plateau with altitudes of over 1000 m in the eastern regions, where the Drakensberg range forms a high escarpment and the rainfall reaches a maximum. Many mollusc families and genera are restricted to the east of the Drakensberg escarpment. An important biological variable that influences the distribution patterns of mollusc is vegetation, which in turn is influenced by the physical environment including its geology, topography and climate (Herbert & Kilburn, 2004).

The present or absent of vegetation types within a region appears to influence the distribution of certain mammals and invertebrates such as molluscs, millipedes and dung beetles (Davis, 1993; Wells, 1995; Ceballos *et al*., 1998; Hamer & Slotow, 2000). Vegetation type was the principal factor that influenced the composition and spatial distribution patterns of dung beetles in the south-western Cape region whereas annual temperature and rainfall were of much less importance (Davis, 1993 & 1994). A large number of endemic molluscs are dependent on indigenous vegetation (Wells, 1995). Mollusc diversity and abundance is high in indigenous forests, in the Mediterranean Cape fynbos and in the eastern moist woodland–savanna mosaic (van Bruggen, 1978; Herbert, 1998; Herbert & Kilburn, 2004). The fynbos biome had a relatively high number of mollusc taxa but most mollusc taxa occurred in the forest, savanna and thicket biomes. The succulent karoo and nama karoo biomes have a much less diverse slug and snail fauna than other biomes. The forest biome in southern Africa is considered to contain the majority of locally known land snails. The savanna biome is considered less malocologically diverse because it experiences low rainfall, very high temperatures and provides very little shelter and food for molluscs (van Bruggen, 1978). Molluscs that do occur in savanna biomes tend to be concentrated in more sheltered localities found within the biome. Representatives of purely tropical families such as Achatinidae and Streptaxidae hardly inhabit fynbos vegetation. Veld fires, which commonly occur during the dry summer season, may affect molluscan life adversely in the fynbos biome (van Bruggen, 1978). The nama karoo and succulent karoo biomes of the arid and semi-arid areas of southern Africa harbour a number of sharply delimited and widely distributed endemic genera that are adapted to life in arid areas (van Bruggen, 1978).

A significant portion of indigenous forests occurs outside formally protected areas (van Wyk, 1994; Low & Rebelo, 1996; Ceballos *et al*., 1998; Herbert, 1998; Tattersfield, 1998). The forest and thicket biomes in South Africa contained the most number of terrestrial mollusc families and the second highest number of genera. Most genera occurred in the savanna biome. Forested habitats are among the most species rich habitats of the world (Dinerstein & Wikramanayake, 1993; Franklin, 1993; Ceballos *et al*., 1998). Approximately 83 % of mollusc species in east Africa occur in forest habitats (Tattersfield, 1998). Indigenous forest types such as the coastal lowland forest in KwaZulu-Natal are considered important habitat types for mollusc conservation (van Wyk, 1994; Herbert, 1998). The continual reduction and fragmentation of coastal forest could possibly result in a significant decrease in molluscan fauna (Tattersfield, 1998). It may be possible to conserve local faunal diversity in relatively small patches of indigenous vegetation that are not subjected to strong edge effects (Tattersfield, 1998). However, small areas are more likely to be devastated by natural disasters than large areas and they are also very susceptible to changes outside their boundaries (Ponder, 1995). Further research is required on the long term viability of molluscan populations in very small indigenous vegetation fragments which are exposed to strong edge effects and have less stable micro-climates than large patches of vegetation (Tattersfield, 1998). This could aid in determining if conservation efforts should be focused on conserving a small number of large areas containing indigenous vegetation or if conservation programmes should be directed at large areas with indigenous vegetation as well as smaller more widely distributed areas with indigenous vegetation (Tattersfield, 1998).

Climate, in particular rainfall patterns and temperature, influences distributional patterns of many species including molluscs (van Bruggen, 1969 & 1978; Wardell-Johnson & Roberts, 1993; Kadmon & Heller, 1998; Herbert & Kilburn, 2004; Lobo *et al*., 2006). The gradient in mean annual rainfall in South Africa ranges from east to west and most species were concentrated in the eastern, wetter regions such as KwaZulu-Natal (van Bruggen, 1969; 1978). The desert and semi-desert areas in the centre and western part of southern Africa exhibit a specially adapted malacofauna that has strong endemic characteristics. Areas in the Free State and Karoo contain very few molluscs, although conditions in these areas are not as extreme as the condition in semi-desert and desert regions (van Bruggen, 1978). Rainfall appeared to be the main limiting factor for genera like *Xerocerastus* (van Bruggen, 1969). However, lower rainfall does not prevent the distribution of some molluscs (van Bruggen, 1973). These species are resistant to semi-arid climates and are able survive by inhabiting the sheltered localities (van Bruggen, 1982).

Factors other than rainfall are important in determining the distribution of land snails in the Mediterranean region (Kadmon & Heller, 1998). The effect of temperature on the distribution of molluscs is difficult to assess without physiological experimentation. It is unclear if temperature itself is a limiting factor to mollusc distribution or which temperature limit most influences the distribution of molluscs (Herbert & Kilburn, 2004). Altitude and temperature appear to influence the distribution of certain mollusc groups (van Bruggen, 1978; Herbert, 1997). The diversity of forest vertebrates in the Pacific Northwest is strongly associated with elevation (Franklin, 1993). In Africa areas with arid conditions and cold winters are considered unsuitable for terrestrial operculates (van Bruggen, 1982). In southern Africa the distribution of the millipede genus, *Doratogonus*, may be influenced by low rainfall and minimum temperatures (Hamer & Slotow, 2000). High mean annual temperatures, little annual precipitation and high values of aridity on the Iberian Peninsula seem to favour two *Jekelius* species (Coleoptera: Geotrupidae) (Lobo *et al*., 2006). The mean annual temperature appeared to be the most influential factor on the distribution of mollusc. The mean daily maximum temperature and mean daily minimum temperature had limited or no influence on the distribution of molluscs.

Rivers act as barriers to dispersal and play a role in delineating species ranges (Pounds & Jackson, 1981; Ayres & Clutton-Brock, 1992; Lobo *et al*., 2006). Rivers that are most effective as barriers are large rivers that change their courses least often (Pounds & Jackson, 1981; Gascon *et al*., 2000). However, rivers may not shape the distribution patterns of species and may also not be the major drivers of species diversification (Gascon *et al*., 2000). The areas along the rivers may function as "green corridors" and promote the transfer of different faunal elements (Sólymos & Fehér, 2005). The Great (Groot) Kei River valley, the Great Fish River valley and the Limpopo River valley were identified as significant ecological barriers, which delimit the distributions of many invertebrate groups (Stuckenberg, 1962; Hamer & Slotow, 2000). Major rivers such as the Limpopo River may delimit the distributions of species within the millipede genus, *Doratogonus*. The habitat of the Limpopo River valley appeared to be unsuitable habitat for certain mollusc taxa such as *Fauxulus* and may limit the distribution of molluscs northwards (Stuckenberg, 1962; van Bruggen, 1973; van Bruggen & Meredith, 1983).

Rivers appeared to pose as a barrier to the distribution of certain mollusc taxa. However, few terrestrial mollusc records were available for Mozambique and Zimbabwe.

The distribution patterns of mollusc taxa illustrated distinctive biogeographical zones within South Africa. These biogeographic zones together with the identified factors that influence distribution patterns provide an opportunity to identify and protect connectivity across a mosaic of mollusc habitats. The eastern regions of South Africa can be divided into three biogeographic entities. Collectively the eastern biogeographic entities cover a large area and are the dominant biogeographic components associated with the mollusc distribution. The distributions of molluscs were influenced by a combination of various factors, which included the presence of rivers, the escarpment, altitude humidity, precipitation and temperature. Biomes appeared to play a key role in influencing the distributions of molluscs. However, the identification of factors influencing the distribution of terrestrial molluscs was based on subjective assessments and these are therefore preliminary assessments that need to be further tested.

The processes, which drive mollusc distributions within and across the biogeographical zones, need be considered in biodiversity conservation plans. Further research needs to be conducted to determine critical sites for the long-term conservation of a representative sample of the South African mollusc fauna. The long-term survival of mollusc taxa with limited ranges maybe enhanced by including these taxa within large protected areas such as national parks (Ponder, 1995). Wildlife distribution corridors, small "island" reserves and wildlife refuges might not be as desirable as larger conservation areas as they possibly contain less genetic diversity and their long term viability is less certain (Ponder, 1995). However, these might be the only options achievable to conserve mollusc taxa (Ponder, 1995). Therefore, distribution corridors within each of the biogeographic zones must be identified and linked to core protected areas. Transformation and fragmentation of natural habitats in South Africa are probably the most significant factors likely to influence the survival of molluscs (Emberton, 1995; Herbert, 1997 & 1998; Warren *et al*., 2001). Any significant change in average temperatures and in biome composition as a result of climate change is likely to have a dramatic effect on the distribution of molluscan fauna (Herbert, 1997; 1998). There needs to be an increased effort to collect more and better quality data on the biology and distributions of mollusc as this is an integral part of assessing their conservation status and their possible need for management (Biodiversity Support Program, 1993).

CHAPTER 4
PATTERNS OF MOLLUSC SPECIES RICHNESS AND ENDEMISM IN SOUTH AFRICA

4.1. Introduction

The primary conservation goal for protecting biodiversity is based specifically on designating large areas to be protected from activities that result in species extinctions (Pressey & Bedward, 1991; Biodiversity Support Program, 1993; Kareiva, 1993). As there are limits to the amount of land that can be set aside as reserves, selecting the appropriate areas is crucial for effective conservation (Kareiva, 1993). This involves the identification of areas with unusually high species richness, high levels of rare or threatened species or endemics and, in the case of Myers *et al*.'s widely accepted concept of global hotspots, the level of threat (Myers *et al*., 2000; Purvis & Hector, 2000). Unfortunately many decisions concerning biodiversity conservation planning are made without data, inadequate resources and insufficient time to conduct careful inventories (Kareiva, 1993).

Species richness, i.e. the number of species in a defined area, such as a particular habitat, is the simplest estimate of diversity (Pomeroy & Dranzoa, 1997). Animal species richness can be predicted from actual observations, distributional data (range maps) or inferred from vegetation (habitat) maps and models relating abundance or presence/absence to vegetation cover attributes and physical features (Conroy & Noon, 1996). However land acquisition aimed exclusively at maximising the number of species on protected lands is likely to miss rare or endemic species i.e. those species most likely to be threatened by habitat destruction (Kareiva, 1993). Endemic species can be defined as native species, restricted or peculiar to a locality or region (local endemics) although they may be very abundant at that location (Biodiversity Support Program, 1993). According to Ponder (1999) the definition of endemism is user-defined and can be adapted to meet the needs of specific research projects, questions and taxa. Therefore any given area contributes to biological diversity through its richness in numbers of species and through endemism of these species (Groombridge, 1992). Thus when considering conservation priorities, species richness should wherever possible, be combined with other measures such as the presence of rare or endemic species (Kareiva, 1993; Pomeroy & Dranzoa, 1997).

The numerous biodiversity conservation initiatives being developed and implemented in South Africa require and are based on biological data, particularly data on areas of high endemism and diversity (Hamer & Slotow, 2002). However, the majority of these projects such as the Cape Action Plan for People and the Environment (C.A.P.E.) mainly use data on plants and vertebrate groups to identify priority areas for conservation (Hamer & Slotow, 2002; Pressey *et al*., 2003).

Invertebrates, which may comprise as much as 95 % of biodiversity, are generally excluded from biodiversity assessments and the design of conservation areas (Myers *et al.,* 2000; Hamer & Slotow, 2002). This can be largely attributed to the lack of available data, expertise and the perceived difficulties of dealing with such a large and diverse assemblage of organisms, as well as to the assumption that conservation of habitats, prioritised and identified based on vertebrate species diversity, vegetation types and patterns of floral diversity, will adequately cater for biodiversity in general including invertebrates (Kareiva, 1993; McNeely, 1994; Herbert, 1998; Hamer & Slotow, 2002).

In the light of the increased attention on biodiversity conservation and prioritisation of key areas, a critical review of existing data is required (Margules & Pressey, 2000). The knowledge of the taxonomy and distribution of invertebrates is highly inadequate resulting in the inability of scientists to identify invertebrates to species level. In most situations databases for invertebrates are scattered, incomplete or non-existent (Pienaar, 1991; Hamer, 1997). Most of the existing baseline data on biodiversity is of limited utility because of inconsistencies in the spatial and temporal scales as well as in the duration and precision (Biodiversity Support Program, 1993). Therefore these databases are considered to be of limited use to conservationists (Hamer, 1997). Few South African invertebrate databases have been assessed in terms of conservation planning value, exceptions being for dung beetle fauna (Koch *et al*., 2000), millipedes (Hamer & Slotow, 2002) and the southern ocean mollusc database (SOMBASE) (Griffiths *et al*., 2003).

Molluscs are some the most ancient of organisms inhabiting Earth. They can be found in the oldest Cambrian deposits, more than 500 million years BP. Molluscs are also among the most successful of all faunal groups. They are second only to insects in number of species (Kay, 1995). Molluscs play a significant role in ecosystem functioning and processes. They break down dead vegetation, produce soils, cycle nutrients and increase soil fertility. Molluscs are also used as tools, food, currency and medicine as well as items of art, worship and adornment (Kay, 1995). They are a characteristic and unique element of South Africa's biodiversity and it is therefore important that their conservation is given adequate attention (Herbert, 1998). Limited research has been done on African terrestrial molluscs and the knowledge of the group remains inadequate. The majority of the studies of the molluscan fauna in South Africa have concentrated on the examination of molluscs from a taxonomic rather than a geographic perspective and have been concerned more with revisionary studies of specific molluscan groups in broader geographical areas (such as southern Africa or Africa) (Herbert, 1997). Therefore the taxonomy of certain groups may be well established but not of other groups. The known distributional and altitudinal ranges of many species are incomplete and reflect only the sites at which earlier workers collected (Herbert, 1997).

The distribution patterns of molluscs can be compared to other invertebrate groups such as millipedes. Molluscs and millipedes have restricted distributions as a result of their limited powers of dispersal (Herbert, 1997; Hamer & Slotow, 2000; Hamer & Slotow, 2002). These ground dwelling organisms exhibit high levels of endemism in South Africa (Herbert, 1998; Hamer & Slotow, 2002). Therefore the same methodology used to identify areas of high millipede species richness and endemism can be used to evaluate the existing mollusc data in terms of their value to biodiversity conservation planning and management.

The aim of this chapter was to analyse species distributions and diversity of terrestrial molluscs in South Africa. The main objectives were to evaluate the existing data in terms of identifying areas of high terrestrial mollusc species richness and endemism, to compare mollusc and millipede species richness and endemism, to identify significant trends in diversity and endemism critical for effective biodiversity conservation and to make recommendations for the inclusion of invertebrates in biodiversity conservation planning.

4.2. Materials and Methods

The existing mollusc database from the Natal Museum (Pietermaritzburg) was assessed in accordance with procedures explained in Chapter 2. For Chapter 4 only locations of indigenous terrestrial mollusc species of South Africa were used in the analysis.

Endemism was defined at a number of scales following the approach of Ponder (1999) and Hamer & Slotow (2002). The maximum range for each species was obtained by measuring the straight-line distance between the two most widely separated locality records for any species with the distance calculator in Arcview. These values were then plotted to display the frequency distribution of these ranges (Fig. 4.1). Two systems of endemism were used to define range-restricted endemics. Firstly, the data were examined for logical breakpoints in range area distributions. Distinctive gaps in the distribution that could indicate natural breaks were observed. The degrees of endemism were separated into four classes:

- *Site endemics* included all species with only one locality.
- *Local endemics* included all species with distances greater than 0 km and less than 60 km separating the two most widely spaced localities.

- *Regional endemics* included all species with distances greater than 60 km and less than 330 km separating the two most widely spaced localities.
- *National endemics* included all species restricted to South Africa.

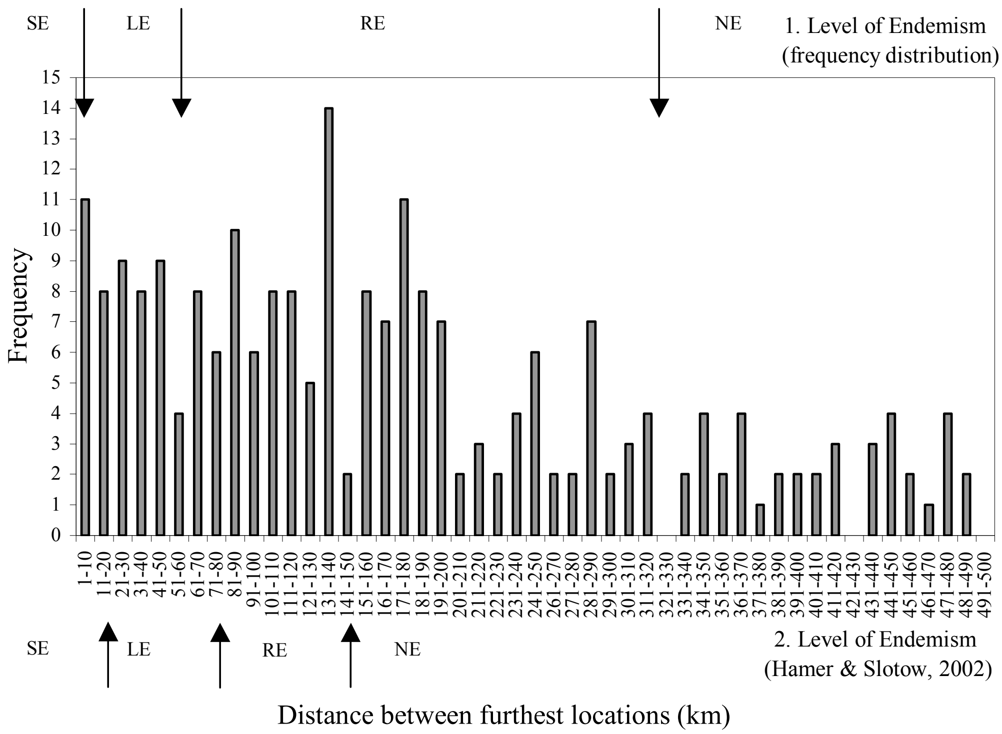


Fig. 4.1: Size of distribution ranges of South African terrestrial indigenous molluscs. Frequency distribution of the maximum distance between the two most widely spaced localities for each species was recorded. The frequency of species recorded from a single locality (0 km) is not represented in this figure. Two systems of endemism (see text) were used to define range-restricted endemics. SE = site endemic; LE = local endemic; RE = regional endemic and NE = national endemic.

A second system of endemism was defined according to Hamer & Slotow (2002). The degrees of endemism for the Hamer & Slotow (2002) system were defined as follows:

- *Site endemics* included all species with only one locality, and those including more than one locality, but with less than 10 km separating the two most widely spaced localities.
- *Local endemics* included all species with distances between 11 and 70 km separating the two most widely spaced localities.
- *Regional endemics* included all species with distances between 71 and 150 km separating the two most widely spaced localities.
- *National endemics* included all species restricted to South Africa.

Although a natural break at 150 km in the mollusc distribution coincided with the natural break for millipedes (Fig. 4.1) and thus the regional endemic class would be similar for the molluscs and millipedes, the distinctive break in distribution at 330 km was used as it allowed for comparison of results between millipede and mollusc diversity, distribution and endemism. Each species was given a unique number and the data were mapped using Arcview 3.2 with Spatial Analyst (ESRI) and projected in Transverse Mercator, WGS 84. Counts per quarter-degree grid cell were made using neighbourhood statistics function (UNIQUE) in Arcview. For species richness, this counted the number of species per grid cell. For endemism richness, the number of site endemics per grid cell was counted. A wider range of endemics was not included in this summation because more than one grid cell will be included in each species' range. Although the counts of endemics per grid cell are an underestimate of the number of endemics that might occur in each grid cell, over counting through repeated counting of the same species in more than one cell was avoided.

Data were extracted by exporting the Arcview data files as ASCII Raster files. The relationship between the number of site endemics and species richness was examined using Spearman correlation. All statistical tests were performed using the SPSS statistical computer program. As the number of endemics would be expected to increase with the number of species at any locality (Hamer & Slotow, 2002), residual analysis was used to assess whether certain grid cells displayed greater endemism than was expected, by removing the effect of species richness. A linear regression analysis was performed with species richness as the independent variable, and the number of endemics as the dependent variable. The unstandardised residuals were saved. Positive residuals indicate a higher number of endemics for that given species richness than would be expected, and negative residuals indicate fewer endemics for that given species richness than would be expected (Hamer & Slotow, 2002). These residual values were then exported into Arcview and mapped.

Regions of endemism based on a combination of site, local and regional endemics were mapped using a kernel home range analysis (Worton, 1989; Seaman & Powell, 1996). The output grid cell extent of 1 km and a LSCV (h) factor of 50 km were used. Zones of endemism were selected based on visual interpretation of the overall distribution patterns and possible barriers (e.g. rivers & mountains) to distribution. A G-test was used to compare the observed values (i.e. the sum of site, local and regional endemics) for mollusc and millipede endemism within the provinces. The alpha value for all the tests was 0.05.

4.3. Results

Areas of high richness included Pietermaritzburg with over 68 species in a quarter-degree grid cell with Durban and Port Shepstone having between 60-67 species each and East London, Grahamstown, Hillcrest, Krantzkloof, Pinetown, Scottburgh, Umgababa, Winklespruit, Dargle, Curry's Post, Balgowan, Dukuduku Forest, St. Lucia and Mapelane 51-59 species each (Fig. 4.2). A total of 478 terrestrial mollusc species were recorded in the database of which 447 were indigenous and 31 exotic. Twenty-seven terrestrial indigenous families and sixty genera were recorded. Achatinidae (3 genera and 27 species), Streptaxidae (4 genera and 123 species), Charopidae (2 genera and 84 species), Subulinidae (9 genera and 52 species), and Urocyclidae (6 genera and 34 species) were the dominant families.

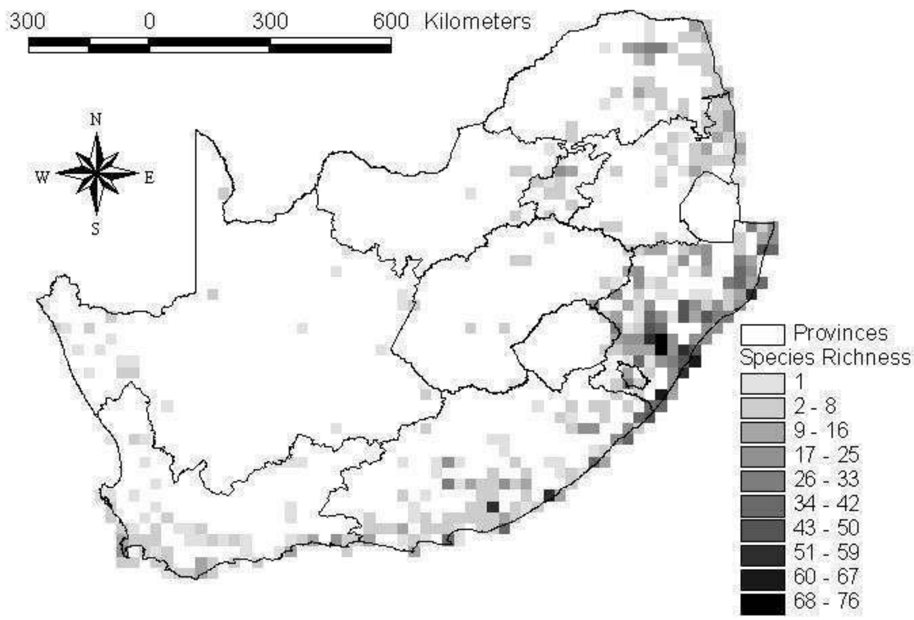


Fig. 4.2: Species richness distribution of indigenous South African terrestrial molluscs in quarter-degree grid cells.

Areas of high millipede species richness included Pietermaritzburg with over 40 species in a quarter-degree grid cell, followed by the Cape Peninsula/Cape Town area, Cathkin Peak in the Drakensberg and Kranskop in the Tugela Valley with 20-40 species each (Hamer & Slotow, 2002). The comparison of results obtained for millipede richness (Hamer & Slotow, 2002) and mollusc richness indicated that certain areas such as Pietermaritzburg (76 mollusc species) and Kranskop (46 mollusc species) exhibited both high millipede and mollusc species richness. The Drakensberg (9-33 mollusc species) region and Cape Peninsula/Cape Town area (9-25 mollusc species) showed a lower species richness for molluscs than for millipedes. Durban (62 mollusc species) and Port Shepstone (65 mollusc species) also showed a high mollusc species richness.

The areas for mollusc and millipede species richness differed slightly with areas within KwaZulu-Natal and Eastern Cape having a higher mollusc species richness and the Western Cape showing a higher millipede species richness.

Eighty-three percent of mollusc species were endemic to South Africa. Thirteen percent (56) of species were found at only at a single locality. Twenty-four percent (50 species) had maximum distances between furthest localities of between 0 and 60 km and 56 % (145) of species were classified as regional endemics (greatest distance between any two localities < 330 km) (Table 4.1).

Table 4.1: Levels of endemism at the species level.

	Number of species			Cumulative % of total number of species		
	SA mollusc endemism		SA millipede endemism	SA mollusc endemism		SA millipede endemism
	System[a]	System[b]		System[a]	System[b]	
Site endemics	56	67	243	12.5	15.0	50.2
Local endemics	50	47	102	23.7	25.5	71.3
Regional endemics	145	59	44	56.2	38.7	80.4
National endemics	119	197	41	82.8	82.8	88.8
Total endemics[1]	370	370	430			
Non-endemics[2]	77		54			
Total indigenous species	447		484			
Exotic species	31					

Two systems of endemism were used to define range-restricted mollusc endemics. The first system (a) was defined using distinctive gaps in the frequency distribution and the second system of endemism (b) was defined using Hamer & Slotow (2002). See text for details. Level of endemism in South African millipedes was obtained from Hamer & Slotow (2002). [1]Total endemics = Sum of site, local, regional & national endemics. [2]Non-endemics = indigenous species whose distributional ranges extend outside of South Africa.

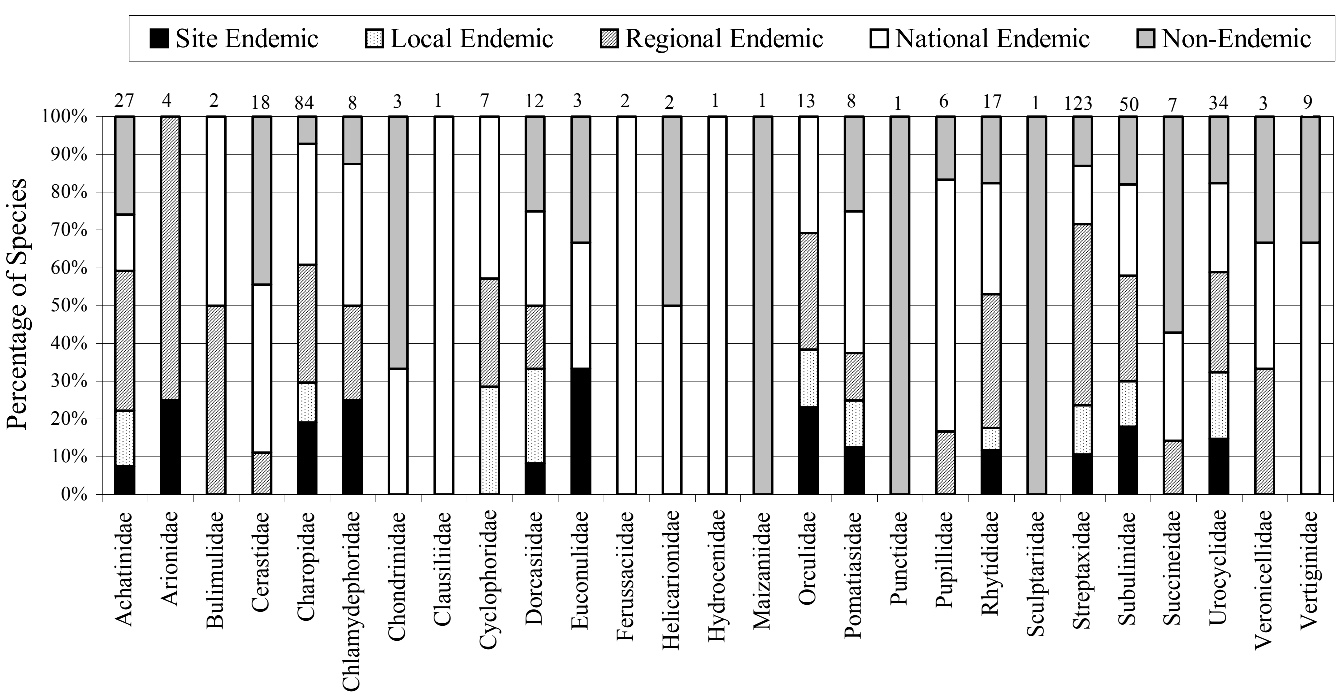
Using the endemic categories classified by Hamer & Slotow (2002), fifteen percent (67) of mollusc species were defined as site endemics, i.e. species that were found at a single locality, or with more than one locality but localities not separated by more than 10 km (Table 4.1). Twenty-six percent (47 species) had maximum distances between furthest localities of between 10 and 70 km. Approximately 39 % of species were classified as regional endemics (furthest distance between any two localities < 150 km). The major difference between the two definitions of endemism classes can be seen in the number of regional and national endemics recorded with a smaller number of regional endemics recorded using the definitions by Hamer & Slotow (2002). However this was expected, as the criteria for the endemic classes were different. In contrast, 89 % of millipede species were endemic to South Africa (Hamer &

Slotow, 2002). The cumulative percentage of site endemic (50 %) and local endemic (71 %) species of millipedes (Hamer & Slotow, 2002) was higher than that recorded for molluscs.

Results obtained using endemic classes defined by Hamer & Slotow (2002) were essentially not different from results obtained using the first set of definitions. The differences between the definitions can be observed in the percentage of endemics present in each family. Using the definitions by Hamer & Slotow (2002), the family Cyclophoridae did contain site endemics and families Achatinidae, Charopidae, Streptaxidae and Rhytididae contained a larger percentage of site endemics (Fig. 4.3b).

The families Arionidae, Bulimulidae, Cyclophoridae and Orculidae exhibited range-restricted endemism, with the distribution of their indigenous terrestrial species restricted to South Africa. Arionidae and Orculidae comprised of more than 20 % of site endemics (Fig. 4.3a). Site endemics were not recorded for fifteen families, these being Bulimulidae, Cerastidae, Chondrinidae, Clausiliidae, Cyclophoridae, Ferussaciidae, Helicarionidae, Hydrocenidae, Maizaniidae, Punctidae, Pupillidae, Sculptariidae, Succineidae, Veronicellidae and Vertiginidae (Fig. 4.3a).

(a)



(b)

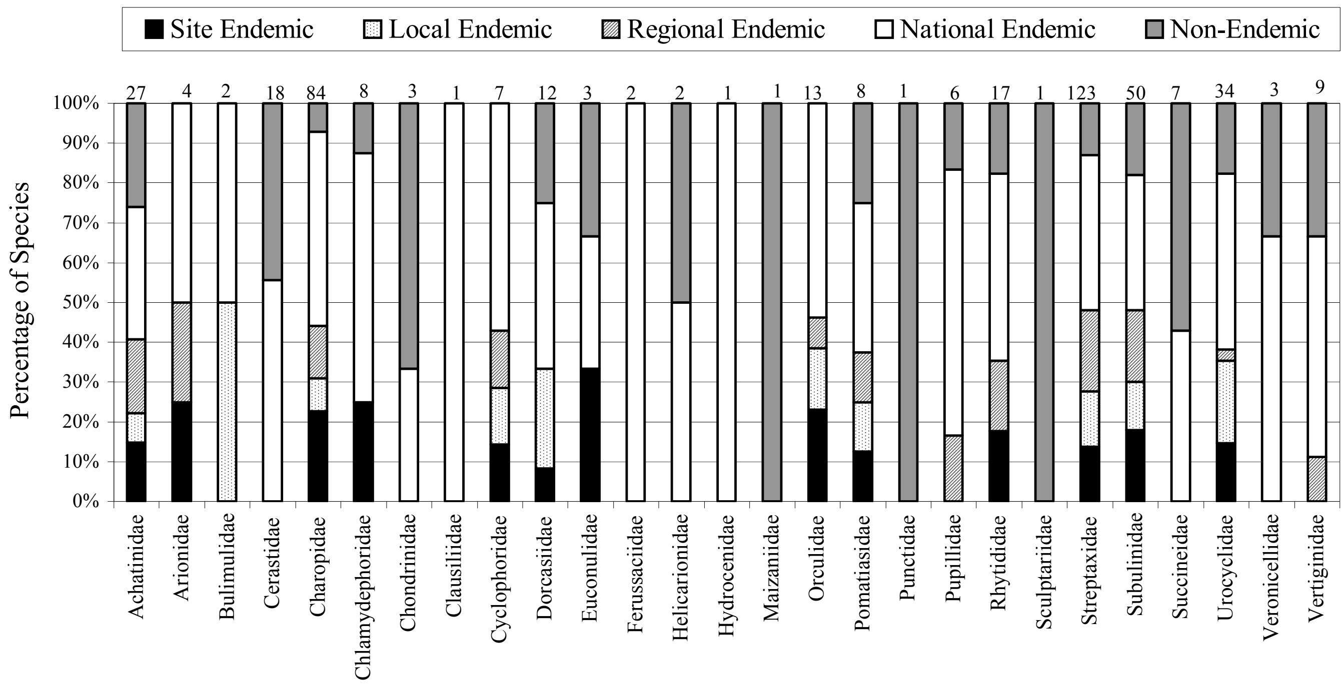


Fig. 4.3: Endemism categories for indigenous terrestrial mollusc families, were defined using (a) natural break points in frequency distribution (see text), and (b) Hamer & Slotow (2002). Figures above each bar indicate the number of species (excluding exotics) present in the database for each family.

The quarter-degree grid cells of South Africa with the highest number of site endemics based on observed distinctive gaps in the frequency distribution of molluscs (Fig. 4.4a) and the Hamer & Slotow (2002) classification of endemism (Fig. 4.4b) were the same as those for species richness thus illustrating that endemism 'hotspots' overlap with species richness 'hotspots'. There was a significant correlation between the number of species in a grid cell and the number of endemic species with single localities (Spearman correlation: $r_s = 0.235$, $n = 385$, $P < 0.001$).

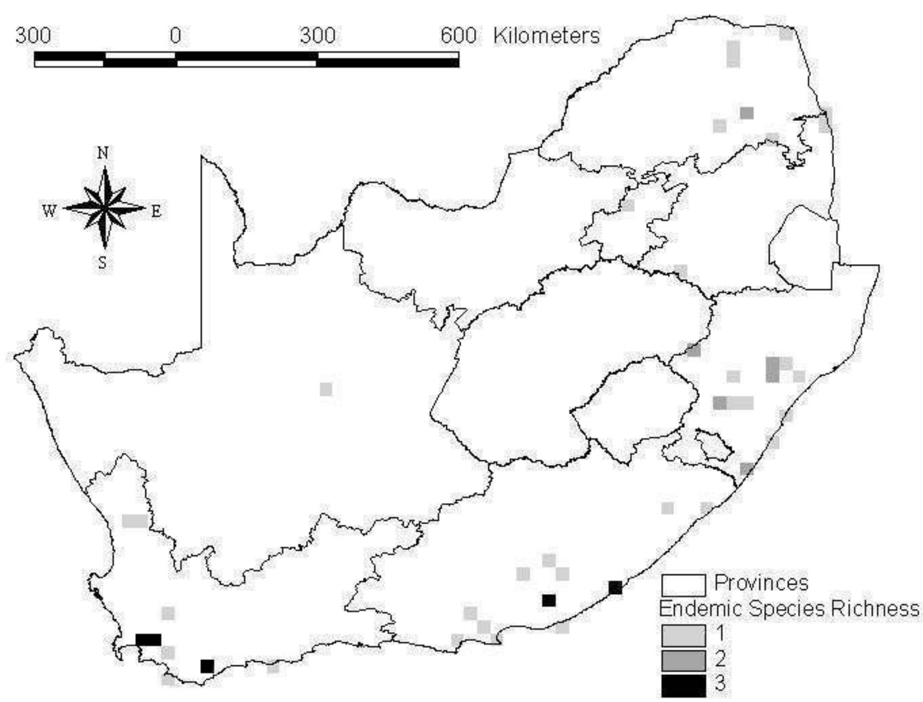
The comparison of the two classification systems of site endemism indicated that both systems identified the areas around Bredasdorp, Grahamstown, East London and Hottentots Holland Nature Reserve as areas of high site endemic richness. Port Elizabeth, Western Cape Peninsula, Pietermaritzburg and the Drakensberg have higher site endemic richness when endemic classes were defined by Hamer & Slotow (2002). There was also a significant correlation between the number of species in a grid cell and the number of site endemics (Spearman correlation: $r_s = 0.288$, $n = 385$, $P < 0.001$) using the Hamer & Slotow (2002) endemism classification.

When analysing distribution patterns it is more informative to look for high endemism and not only consider species richness (Kareiva, 1993; Pomeroy & Dranzoa, 1997; Hamer & Slotow, 2002). Therefore species richness was factored out using residual analysis. For the first system of endemism (defined using the frequency distribution of molluscs), the resultant grid cells showed the areas within Western, Eastern and Northern Cape, Limpopo, Mpumalanga, Gauteng and KwaZulu-Natal as having higher than expected levels of site endemism (Fig. 4.5a). Dargle, van Reenen, Shilwane District, East London, Grahamstown, Bredasdorp, Hottentots Holland Nature Reserve exhibited higher than expected levels of site endemism. Well-sampled areas within KwaZulu-Natal and Transkei exhibited lower levels of site endemism than predicted by species richness. These areas included Pietermaritzburg, Durban, Kranzkloof Nature Reserve, Pinetown, Umbogintwini, Sodwana Bay, Lake Sibaya, Mapelane, St. Lucia, Port St Johns, Mkambati Nature Reserve and Mzamba.

The Hamer & Slotow (2002) system of endemism showed the following areas within the Western, Eastern and Northern Cape, Limpopo, Mpumalanga, Gauteng and KwaZulu-Natal as having higher than expected levels of site endemism (Fig. 4.5b): Pietermaritzburg, Dargle, van Reenen, Cathedral Peak, Shilwane, Transkei, East London, Grahamstown, Port Elizabeth, Bredasdorp, Hottentots Holland Nature Reserve and Cape Town. Areas within KwaZulu-Natal and Eastern Cape exhibited lower levels of endemism than predicted by species richness.

The Western and Eastern Cape exhibited higher than expected levels of endemism for both millipedes and molluscs. KwaZulu-Natal showed lower levels of endemism than predicted by species richness for both molluscs and millipedes.

(a)



(b)

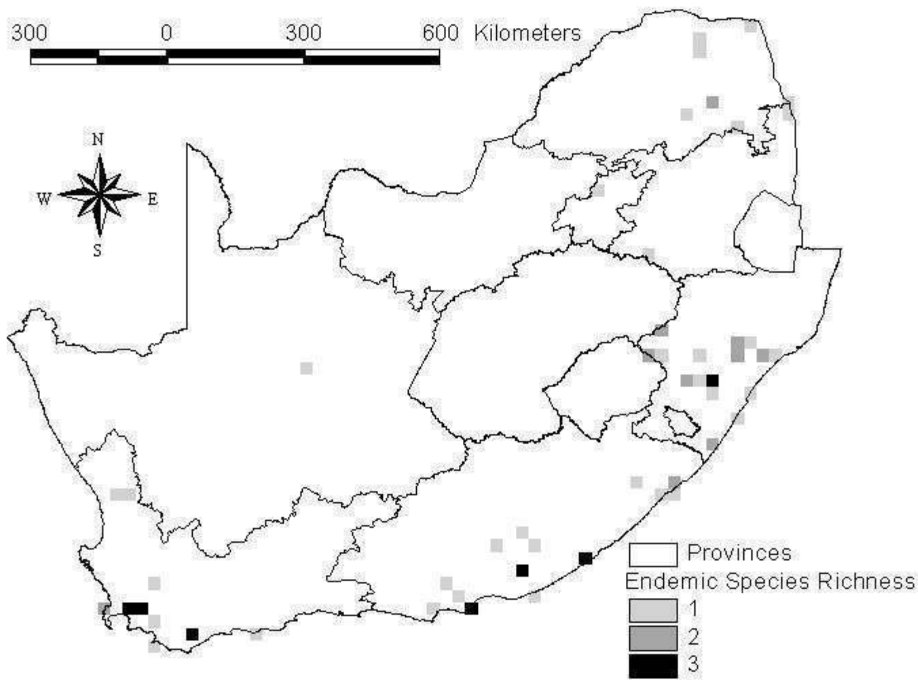
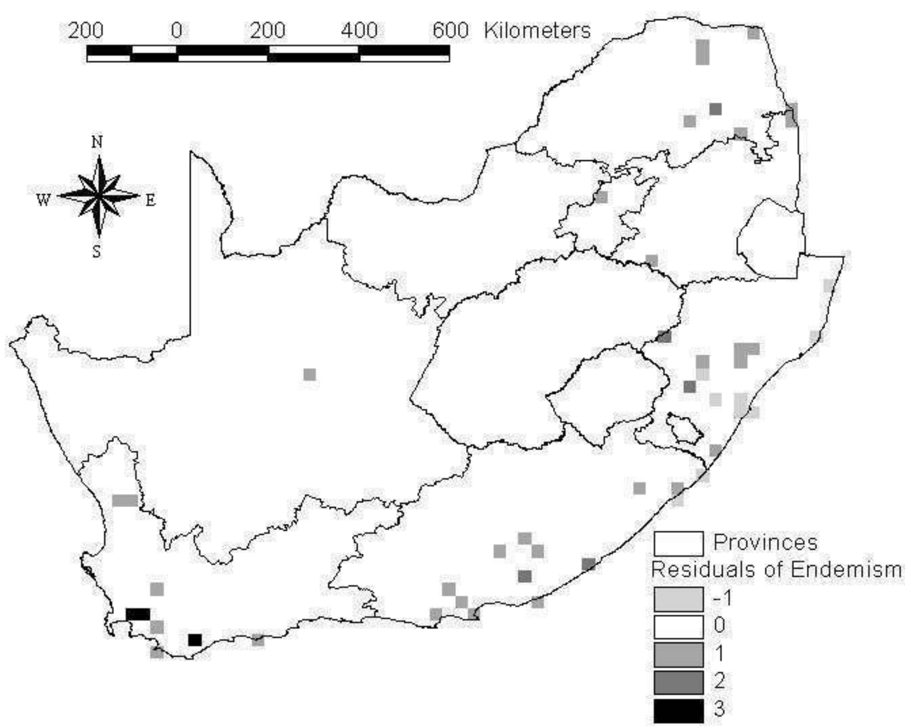


Fig. 4.4: Species richness of site endemics, (a) species recorded from a single locality (frequency distribution) and (b) species recorded from a single locality and with a maximum distance between the two most widely spaced localities < 10 km (Hamer & Slotow, 2002) in quarter-degree grid cells.

(a)



(b)

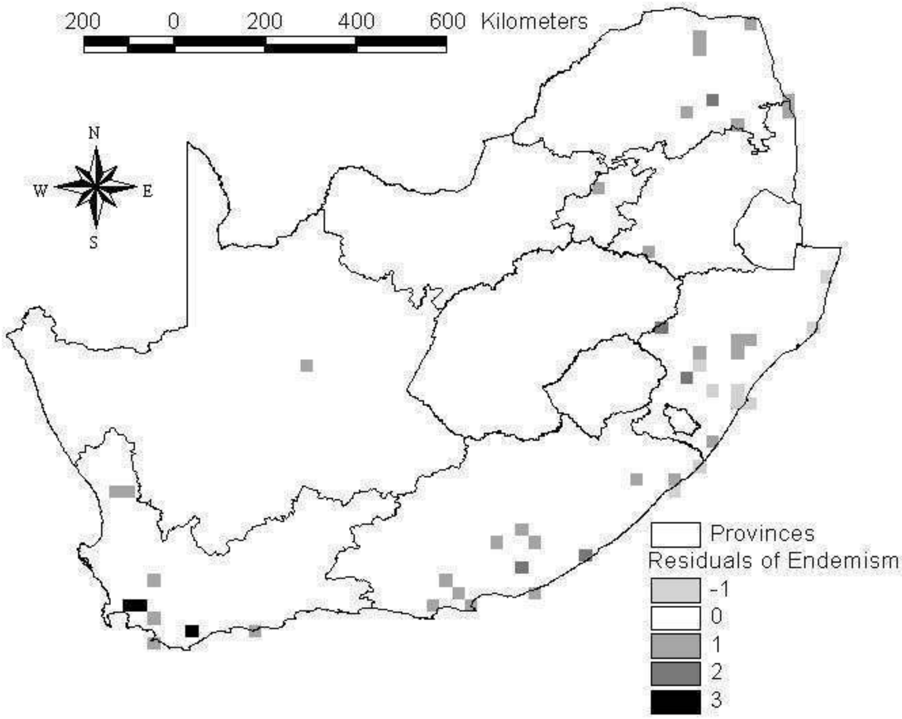
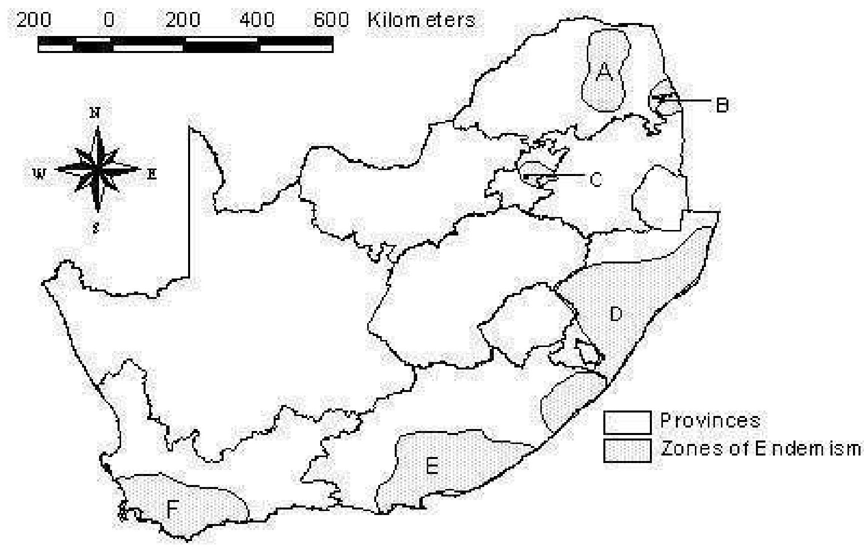


Fig. 4.5: Levels of observed site endemism relative to predictions from species richness in quarter-degree grid cells. Values are unstandardised residuals from regression of site endemism against species richness. Negative values indicate a lower endemism than expected from species richness, and positive values indicate a higher than expected endemism. Levels of endemism defined according to (a) the frequency distribution and (b) Hamer & Slotow (2002). See text for details.

There were several important zones of endemism within the country (Fig. 4.6; Table 4.2). Broad zones of endemism were identified using a combination of site, local and regional endemics (Fig. 4.6a). These zones fell within Limpopo, Mpumalanga, Gauteng, KwaZulu-Natal, Eastern Cape and Western Cape. The combination of site and local endemics defined narrower zones of endemism (Fig. 4.6b). Although the broad KwaZulu-Natal/Eastern Cape zone extended into Maputaland, a Maputaland zone was not identified as an area of high mollusc endemism (Fig. 4.6a & b). Similar zones of endemism were obtained with both systems of endemism (Fig. 4.6) indicating that the Hamer & Slotow (2002) system of endemism can be used to identify preliminary areas of high levels of mollusc endemism. However, due to incomplete sampling coverage, zonal borders should be interpreted with caution.

(a)



(b)

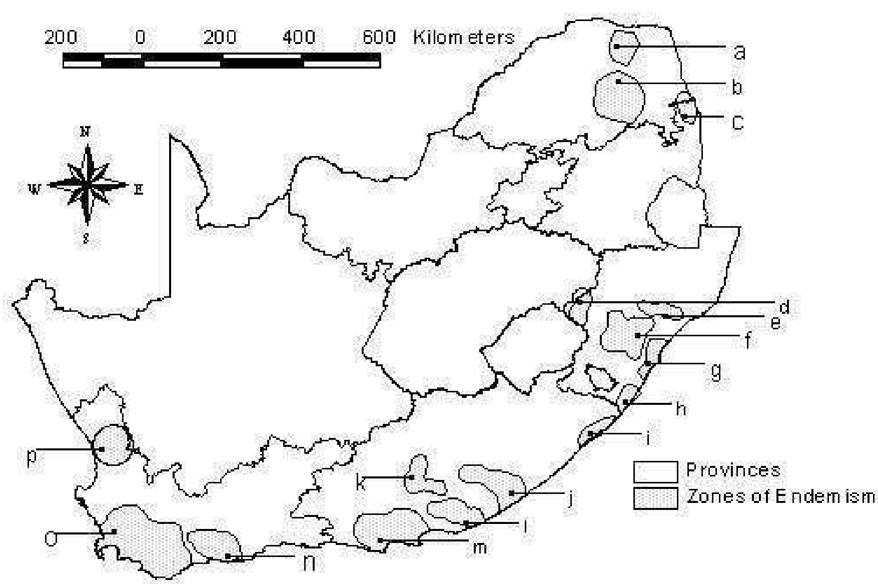


Fig. 4.6: Preliminary definition of areas with high levels of mollusc endemism ((a) site, local & regional endemics & (b) site & local endemics) in South Africa based on the Hamer & Slotow (2002) definitions of endemism. A = Limpopo; B = Limpopo/Mpumalanga; C = Gauteng; D = KwaZulu-Natal; E = Eastern Cape; F = Western Cape; a = Northern Limpopo; b = Southern Limpopo; c = Limpopo/Mpumalanga; d = Drakensberg; e = Thukela basin; f = KwaZulu-Natal Midlands; g = Coastal KwaZulu-Natal; h = Southern KwaZulu-Natal; i = Transkei; j = East London; k = Eastern Cape interior; l = Port Alfred; m = Port Elizabeth; n = Riversdale; o = Western Cape & p = Vredendal. Details of endemism for each region and province are provided in Tables 4.2 and 4.3.

Table 4.2: Patterns of endemism of molluscs in South Africa broken down by zones of endemism.

Regions of endemism	Site endemics[1]	Local endemics[2]	Regional endemics[3]	Total site & local endemics[4]
Eastern Cape - East London	5 (5)	0 (0)	14 (8)	5 (5)
Eastern Cape - Interior region	1 (1)	1 (3)	11 (4)	2 (4)
Eastern Cape - Port Alfred/Grahamstown	4 (4)	5 (5)	16 (8)	9 (9)
Eastern Cape - Port Elizabeth	4 (6)	3 (1)	10 (5)	7 (7)
Eastern Cape/Transkei	1 (3)	5 (5)	16 (5)	6 (8)
KwaZulu-Natal - Coastal region	2 (2)	3 (3)	28 (9)	5 (5)
KwaZulu-Natal - Drakensberg	2 (4)	2 (0)	6 (0)	4 (4)
KwaZulu-Natal Midlands	5 (9)	6 (5)	37 (13)	11 (14)
KwaZulu-Natal - Thukela Basin	4 (5)	3 (3)	26 (8)	7 (8)
KwaZulu-Natal - Southern region	2 (2)	2 (3)	17 (7)	4 (5)
Limpopo/Mpumalanga	2 (2)	0 (0)	1 (1)	2 (2)
Limpopo - Northern region	2 (2)	0 (2)	5 (0)	2 (4)
Limpopo - Southern region	3 (3)	3 (3)	2 (0)	6 (6)
Western Cape - Southern region	9 (1)	10 (8)	18 (6)	19 (9)
Western Cape - Riversdale/Stillbaai	1 (11)	2 (2)	2 (1)	3 (13)
Western Cape - Vredendal	1 (1)	1 (1)	0 (0)	2 (2)
Total	48 (61)	46 (44)	209 (75)	94 (105)

[1]Site, [2]local and [3]regional endemics were obtained from two systems of endemism. The first system was obtained from the frequency distribution of molluscs and the second (indicated within parenthesis) was based on Hamer & Slotow (2002). See text for details. [4]The total site & local endemics were summed (excluding regional endemics) to emphasize the number of extreme range-restricted endemics for conservation planning purposes.

The *G*-test was used to compare the patterns of mollusc and millipede endemism within the provinces of South Africa. There was a significant difference in the patterns of mollusc and millipede endemism for both systems of endemism, these being endemism defined using breaks in the frequency distribution of molluscs (G_8 = 28.885, P < 0.05) and the Hamer & Slotow (2002) endemism classification (G_8 = 25.333, P < 0.05). Endemism classes defined using the frequency distribution of molluscs in South Africa, showed that the Western Cape southern zone had the highest number of endemics consisting of nine site endemics and ten local endemics (Table 4.2). All provinces, except for the Free State and North West Province contained site endemic species. Gauteng as well as Free State and the North West Province did not contain local endemics. The North West Province contained no range-restricted endemics. The Free State and North West Province contained regional endemics. KwaZulu-Natal had the highest percentage of endemic species (37.94 %) (Table 4.3).

Table 4.3: Patterns of endemism of terrestrial mollusc in the provinces of South Africa.

Province	Site endemics[1]	Local endemics[2]	Regional endemics[3]	Percentage of total site, local & regional endemics[4]	Percentage total site, local & regional millipede endemics[5]
Eastern Cape	16 (21)	16 (15)	51 (23)	29.4 (31.6)	15.4
Free State	0 (0)	0 (0)	2 (0)	0.7 (0.0)	0.8
Gauteng	1 (1)	0 (0)	5 (2)	2.1 (1.6)	2.7
KwaZulu-Natal	17 (22)	18 (16)	72 (30)	37.9 (36.4)	47.7
Limpopo	7 (7)	3 (5)	9 (1)	6.7 (7.0)	6.2
Mpumalanga	3 (3)	1 (1)	13 (2)	6.0 (3.2)	6.7
Northern Cape	1 (1)	1 (1)	0 (0)	0.7 (1.1)	0.8
North West	0 (0)	0 (0)	0 (3)	0.0 (1.6)	2.4
Western Cape	11 (13)	13 (11)	22 (9)	16.3 (17.7)	17.3

[1]Site, [2]local and [3]regional endemics were obtained from two systems of endemism. The first system was obtained from the frequency distribution of molluscs and the second (indicated within parenthesis) was based on Hamer & Slotow (2002). See text for details. [4]The percentage of total site, local & regional mollusc endemics per province. [5]The percentage of total site, local & regional millipede endemics in each province as recorded by Hamer & Slotow (2002).

The Hamer & Slotow (2002) endemic classes listed the KwaZulu-Natal Midlands zone as the area with the highest number of endemics. The KwaZulu-Natal Midlands zone had nine site and five local endemics (Table 4.2). KwaZulu-Natal had the highest percentage of endemic species (36.36 %) containing 22 site endemics, 16 local and 30 regional endemics (Tables 4.3). The Hamer & Slotow (2002) system also did not list site endemics in the Free State and North West Province. The North West Province and Gauteng did not contain local endemics whereas the Free State contained no site, local or regional endemics (Tables 4.3).

The mollusc frequency distribution and the Hamer & Slotow (2002) classification system identified KwaZulu-Natal as the province with the highest number of site endemics. Higher percentages of site, local and regional endemics (total endemics) were recorded in the Eastern, Western and Northern Cape using the Hamer & Slotow (2002) classification system (Table 4.3).

KwaZulu-Natal had the highest percentage of endemic species for both molluscs and millipedes. The KwaZulu-Natal Midlands contained the most site and local millipede endemics (Hamer & Slotow, 2002). The KwaZulu-Natal Midlands zone was also identified by the Hamer & Slotow (2002) classification system as having the highest number of site and local mollusc endemics as compared to the mollusc frequency distribution system, which identified the Western Cape southern zone has having the highest number of site and local mollusc endemics. The North West Province and Free State contained no site and local endemic species of mollusc as compared to one site and two local millipede endemics recorded in Free State and nine site and no local millipede endemics in North West Province (Hamer & Slotow, 2002). The coastal provinces along the eastern and southern regions of South Africa had a higher percentage of mollusc and millipede endemics than the inland and western provinces (Table 4.3).

The Eastern Cape and Limpopo provinces had a higher percentage of mollusc endemics than millipede endemics when endemism was defined according to the frequency distribution of molluscs. The Hamer & Slotow (2002) endemism classification also identified the Eastern Cape and Limpopo provinces as well as the Northern Cape as provinces, which exhibited a higher percentage of mollusc endemics than millipede endemics (Table 4.3).

Zones of high mollusc endemism in the Eastern Cape and KwaZulu-Natal occurred within areas that contained high millipede endemism (Hamer & Slotow, 2002). The Eastern Cape and KwaZulu-Natal most likely contain many separate zones of endemism (Hamer & Slotow, 2002). The Western Cape zone contained both high levels of mollusc and millipede endemics. The Vredendal and Riversdale/Stilbaai zones were identified as areas of high mollusc endemism but were not identified as areas of high millipede endemism. The mollusc endemic zones within the Limpopo province were similar to the N.E. Mountain millipede endemic zone. No areas of high mollusc endemism were identified in the Northern Cape, Free State, Gauteng and the North West provinces. The Northern Cape and Free State also did not contain any regions of high millipede endemism (Hamer & Slotow, 2002).

A preliminary list of specific priority sites for mollusc conservation (those thirty sites with the highest levels of endemism based on scores assigned to different endemism categories) is presented in Tables 4.4 and 4.5. Although the scores for the priority sites differ, the same twenty-five areas were identified as priority sites by both systems of endemism. The top ten sites that were identified by the mollusc frequency distribution were East London, Durban, Mfongosi, Grahamstown, Port Shepstone, Umkomaas, Port St Johns, Eshowe, Kranskop and Pietermaritzburg. The Hamer & Slotow (2002) system of endemism did not identify Umkomaas and Kranskop as two of the top ten priority sites, identifying instead East London, Port St Johns, Mfongosi, Port Shepstone, Grahamstown, Durban, Eshowe, Pietermaritzburg, Port Elizabeth and Port Alfred as the top ten priority sites for mollusc conservation. Port Elizabeth and Port Alfred were identified in place of Umkomaas and Kranskop.

Table 4.4: Preliminary list of 30 priority sites for terrestrial mollusc endemism. Localities were scored according to the number of species in the different endemism categories (frequency distribution, see text) that were present at a particular locality. The following number of points was allocated to the different endemic classes: site endemics = **15**; local endemics = **10**; regional endemics = **5**; national endemics = **1**. The total areas of the different localities vary and have not been accounted for in the prioritization process.

Location	Site endemic	Local endemic	Regional endemic	National endemic	Score
East London (EC)	3	0	11	20	120
Durban (KZN)	0	2	13	20	105
Mfongosi (KZN)	2	1	10	13	103
Grahamstown (EC)	2	2	6	16	96
Port Shepstone (KZN)	1	2	8	20	95
Umkomaas (KZN)	1	0	13	13	93
Port St Johns (EC)	0	4	6	19	89
Eshowe (KZN)	1	1	10	11	86
Kranskop (KZN)	1	0	10	15	80
Pietermaritzburg (KZN)	0	2	7	19	74
Hluhluwe Game Reserve (KZN)	0	1	9	16	71
Port Elizabeth (EC)	0	2	7	16	71
Port Alfred (EC)	1	2	3	18	68
Dargle (KZN)	1	0	7	16	66
Krantzkloof Nature Reserve (KZN)	0	1	9	11	66
Port Shepstone area, Marble Delta (KZN)	1	0	6	20	65
Karkloof (KZN)	0	0	9	19	64
Karkloof, Leopard's Bush (KZN)	0	0	9	18	63
van Reenen (KZN)	2	0	4	13	63
Isipingo (KZN)	0	0	10	12	62
Mkambati Nature Reserve (EC)	0	1	7	16	61
Pinetown (KZN)	0	1	8	10	60
Grahamstown, Fern Kloof (EC)	3	1	0	4	59
Mzamba (EC)	0	1	7	13	58
Cradock (EC)	0	1	7	9	54
Port Shepstone, Natal Portland Cement Nature Reserve (KZN)	0	1	6	13	53
Durban, Pigeon Valley Park (KZN)	0	2	5	7	52
Dargle, Nhlosane (KZN)	2	0	2	10	50
Hottentots Holland Nature Reserve, Landdroskloof (WC)	3	0	1	0	50
Grahamstown, Mountain Drive (EC)	1	0	5	7	47

Table 4.5: Preliminary list of 30 priority sites for terrestrial mollusc endemism. Localities were scored according to the number of species in the different endemism categories (as defined by Hamer & Slotow, 2002) that were present at a particular locality. The following number of points was allocated to the different endemic classes: site endemics = **15**; local endemics = **10**; regional endemics = **5**; national endemics = **1**. The total areas of the different localities vary and have not been accounted for in the prioritization process.

Location	Site endemic	Local endemic	Regional endemic	National endemic	Score
East London (EC)	3	0	6	25	100
Port St Johns (EC)	1	4	2	22	87
Mfongosi (KZN)	2	2	3	19	84
Port Shepstone (KZN)	1	2	5	23	83
Grahamstown (EC)	2	2	2	20	80
Durban (KZN)	0	2	4	29	69
Eshowe (KZN)	2	0	4	17	67
Pietermaritzburg (KZN)	1	1	4	22	67
Port Elizabeth (EC)	2	0	3	20	65
Port Alfred (EC)	1	2	2	19	64
Mkambati Nature Reserve (EC)	0	3	3	18	63
Grahamstown, Fern Kloof (EC)	3	1	0	4	59
Port Shepstone area, Marble Delta (KZN)	1	0	3	23	53
Umkomaas (KZN)	1	0	3	23	53
Mzamba (EC)	0	2	3	16	51
Hottentots Holland Nature Reserve, Landdroskloof (WC)	3	0	1	0	50
Kranskop (KZN)	1	0	2	23	48
Hluhluwe Game Reserve (KZN)	0	1	3	22	47
Pietermaritzburg, Chase Krantzes (KZN)	1	2	1	7	47
van Reenen (KZN)	2	0	0	17	47
Cradock (EC)	0	3	0	14	44
Port Alfred (Kowie) (EC)	1	2	1	3	43
Dargle (KZN)	1	0	1	22	42
Dargle, Nhlosane (KZN)	2	0	0	12	42
Port Edward (KZN)	0	2	3	6	41
Durban, Pigeon Valley Park (KZN)	0	2	2	10	40
Simonstown (WC)	0	3	1	5	40
Isipingo (KZN)	0	0	4	18	38
Krantzkloof Nature Reserve (KZN)	0	1	2	18	38
Pietermaritzburg, Town Bush (KZN)	1	1	1	7	37

4.4. Discussion

There is an urgent need to change focus from primarily conserving conspicuous organisms to protecting all living organisms inhabiting the Earth as well as the ecosystems within which they evolved (Biodiversity Support Program, 1993). Invertebrates, which may comprise as much as

95 % of biodiversity, are mostly ignored in biodiversity assessments and the selection of conservation areas (de Wet & Schoonbee, 1991; Holloway & Stork, 1991, Biodiversity Support Program, 1993; Cole, 1994; New, 1995; Skerl & Gillespie, 1999; Myers *et al*., 2000; Hamer & Slotow, 2002). Like the rest of the world, southern Africa has placed a huge emphasis on vertebrate studies and as a result there is a large discrepancy between the research on vertebrates and invertebrates (Samways, 1993). Invertebrate conservation in existing parks and reserves has been incidental (de Wet & Schoonbee, 1991; Holloway & Stork, 1991; Cole, 1994; New, 1995; Skerl & Gillespie, 1999; Hamer & Slotow, 2002). This can be largely attributed to the lack of available data, funding, expertise and the perceived difficulties of dealing with such a large and diverse assemblage of organisms, as well as to the assumption that conservation of habitats, prioritised and identified based on vertebrate species diversity, vegetation types and patterns of floral diversity will adequately reflect those of the underlying diversity, i.e. invertebrates (Kareiva, 1993; McNeely, 1994; Herbert, 1998; Hamer & Slotow, 2002).

This assumption has been challenged by researchers who have demonstrated that there was little congruence between different taxa (van Jaarsveld *et al*., 1998; Hamer & Slotow, 2002). Areas containing high species richness for one group are generally unlikely to coincide with the species rich areas for other taxa (Kareiva, 1993). York (1999) found that forest type and growth stages, which are currently used for conservation planning in New South Wales, Australia, are inadequate surrogates for patterns of diversity and distribution of terrestrial invertebrate groups. Therefore, areas designated for the protection of plants and mammals will not always overlap with important areas for other taxa (Van Jaarsveld *et al*., 1998). Since the functioning of the ecosystem depends on more than just the conspicuous organisms, the success of biodiversity conservation is dependent on the management and preservation of the entire ecosystem (Meadows, 1985). Many invertebrate taxa have very small ranges and are therefore inherently more vulnerable to threats than vertebrates (Ponder, 1999). Therefore it is important that invertebrates are considered in biodiversity conservation planning (Hamer & Slotow, 2002).

An understanding of invertebrate species distributions, and the factors that influence or contribute to invertebrate diversity and areas of endemism is becoming increasingly important in terms of the biodiversity crisis and conservation planning (Hamer & Slotow, 2002), simply because ignoring a major component of biodiversity from conservation planning and management strategies will lead to the extinction of a large proportion of global biodiversity (Hamer & Slotow, 2002). Although the data for invertebrates are incomplete and the reliability as well as sampling probabilities are unknown and likely to vary among taxa and habitats (Biodiversity Support Program, 1993; Conroy & Noon, 1996; Hamer & Slotow, 2002), meaningful trends and patterns can be identified for consideration in biodiversity management and conservation efforts, provided that shortcomings are recognised and taken into account (Hawksworth & Mound, 1991; Hamer & Slotow, 2002). As shown by Koch *et al*. (2000) and Hamer & Slotow (2002) invertebrate data can be used to highlight important conservation issues.

Species richness is considered to be a main constituent of species diversity (May, 1994; Mourelle & Ezcurra, 1996). The identification of areas with high levels of species richness is a simple and convenient approach for planning and setting biodiversity conservation priorities (Claridge, 1991; Freitag & van Jaarsveld, 1995; Hamer & Slotow, 2002). This analysis of existing data on terrestrial molluscs has identified several quarter-degree grid cells with high numbers of species. Many of these quarter-degree cells occurred within KwaZulu-Natal (Fig. 4.2). However, bias in the data collection needs to be taken into account before areas with high species richness can be prioritized for biodiversity conservation. Areas of high species richness can be explained by collecting bias and ignoring these shortcomings in the data could result in considerable error (Hamer & Slotow, 2002). Accessibility and reward for sampling efforts are important factors in sampling bias (Herbert, 1997; Kadmon & Heller, 1998; Dennis & Thomas, 2000; Margules & Pressey, 2000; Hamer & Slotow, 2002). For example, Pietermaritzburg might have a high level of species richness due to the fact that sites within the area were favoured by scientists based at the Natal Museum in Pietermaritzburg, and as a result this area was sampled more intensely than others. The same applies for Grahamstown and East London which are both historical centres of malacological activity. As demonstrated by Dennis & Thomas (2000), a recorder's home ranges had a major influence on the number of species of British butterflies recorded per grid square. This implies that though these localities did have high levels of species richness, if other areas were as intensively sampled, these areas might show equal or higher levels of species richness (Hamer & Slotow, 2002). The impact of collecting effort on species richness has also been documented for South African dung beetles (Koch *et al*., 2000) and millipedes (Hamer & Slotow, 2002), where well-sampled grid cells had a high number of species recorded. As a result this approach has a limited application for conservation planning (Hamer & Slotow, 2002).

Species richness has been used as a base data set for monitoring changes over time and in the identification of conservation priority areas (Claridge, 1991; Freitag & van Jaarsveld, 1995). However, any given area contributes to biological diversity not only through its richness in numbers of species but also through endemism (or geographical uniqueness) of these species (Groombridge, 1992). Therefore a straightforward count of the number of species only provides a partial indication of biological diversity (Groombridge, 1992; May, 1994). Hamer & Slotow (2002) suggest that in terms of biodiversity conservation, areas with high levels of endemism are more valued than those that are simply species rich, as the number of endemics in each grid cell can be recognised as a realistic estimation or an underestimate of the number of endemic species present. Quarter-degree grid cells with highest levels of endemic molluscs (Fig. 4.4a & b) overlapped with those areas of high species richness (Fig. 4.2). South African molluscs showed relatively high levels of endemism (83 % of species are national endemics). Thirteen to fifteen percent (56-67) were site endemics species and 24-26 % (47-50) were local endemics. However, levels of mollusc endemism were slightly lower than those recorded for millipedes, of which 89 % were restricted to South Africa. The proportion of millipede species restricted to small areas was exceptionally high with 50 % (243 species) being site endemics and 71 % (102 species) local endemics (Hamer & Slotow, 2002). This may in part reflect the fact that molluscs are more popular organisms amongst amateurs and have thus been sampled somewhat more extensively.

Well-sampled areas, which exhibited lower than expected endemism, were probably areas that have been surveyed recently. Recent surveys have been carried out with a more thorough approach than earlier assessments. Thus, as far as possible recent species list represents a total inventory of species present in a particular area. This approach of sampling for all species was preferred to the historical approach where common species were generally not collected and only the rare and interesting species were collected and added to the species list. These species list would have fewer common species and the endemics make up a greater proportion of the total species. The levels of observed endemism relative to predictions from species richness highlights the need for collections which are representative of the entire local fauna, this being a complete species inventory.

As a result of limited powers of dispersal, South Africa's terrestrial molluscan fauna exhibits a high level of endemism (Herbert, 1997; 1998). High levels of endemism, relictual taxa and explosive radiations of Charopidae (*Trachycystis*) and Streptaxidae (*Gulella*) can be observed. Fifteen genera are endemic to the subregion and endemism at the species level is estimated to be about 85 % (van Bruggen, 1978; Herbert, 1998; Herbert & Kilburn, 2004). Species diversity is high in indigenous forests, in the Mediterranean Cape fynbos and in the eastern moist woodland–savanna mosaic (Herbert, 1998).

Differences in the numbers of range-restricted endemics could illustrate the effect of climate and vegetation on the species distribution, the lack of collecting and collecting bias. Additional surveys could reveal a higher number of site and local mollusc endemics especially in regions were no or limited sampling has occurred and in habitats with high levels of diversity. This is certainly the case for the genus *Sheldonia* (Urocyclidae) for which at least seven undescribed, range-restricted species are known (Herbert & Moussalli unpublished data). The preliminary list of priority areas (Tables 4.4. & 4.5) for mollusc conservation based on endemism data was greatly influenced by collecting bias as well as by localities having different spatial areas. Further surveys and inventories will undoubtedly add additional sites to the list and change the ranking of others (Hamer & Slotow, 2002).

Regions of high mollusc endemism appeared to be similar to areas that exhibit high millipede endemism but the results of the *G*-test showed that there was a difference between the patterns of endemism for mollusc and millipedes within South Africa. Areas exhibiting high mollusc endemism within KwaZulu-Natal and the Eastern Cape occurred within the Maputaland-Pondoland Region. The Maputaland-Pondoland Region is a very diverse and species rich region (van Wyk, 1994) which together with the Cape Floristic and Succulent Karoo Regions are considered to be the 'regional' centres of plant endemism in South Africa (van Wyk & Smith, 2001). South Africa contains three principal 'regions' and many 'centers' of plant endemism (van Wyk & Smith, 2001). 'Centres' of plant endemism such as the Albany Centre, Drakensberg Alpine Centre, Pondoland Centre and the Soutpansberg Centre cover more localised areas and are considered to be lower ranking endemic sites than the 'regional' centres of plant endemism (van Wyk & Smith, 2001).

Zones of high mollusc endemism fell within the smaller endemic centres including the Albany Centre in the Eastern Cape, Drakensberg Alpine Centre and the Pondoland Centre. A Maputaland endemic zone was not identified for the molluscs (Fig. 4.6b). Herbert (1997) identified a southeast African endemic zone and a Maputaland-Transkei endemic zone for indigenous slugs in South Africa. The Thukela basin, KwaZulu-Natal Midlands, Coastal KwaZulu-Natal, Southern KwaZulu-Natal, Transkei, East London, Port Alfred and Port Elizabeth zones fell within the Maputaland-Transkei and the southeast African endemic slug regions (Fig. 4.6b). Herbert & Kilburn (2004) identified six molluscan biogeographical sub-regions in the eastern region of Southern Africa. All of the mollusc endemic zones in KwaZulu-Natal and one zone in the Eastern Cape fell within four of the biogeographical sub-regions, these being the Afromontane, Central KwaZulu-Natal coast, Thukela Basin and the Pondoland-southern KwaZulu-Natal region. However, the north-eastern Zululand and Afromontane regions identified by Herbert & Kilburn (2004) are reflective of the broader affinities of the fauna of the areas concerned rather than endemism, whereas the Mpumalanga-Swaziland, Central KwaZulu-Natal coast, Thukela Basin and the Pondoland-southern KwaZulu-Natal regions are defined largely by the occurrence of endemic species within these regions (Herbert & Kilburn, 2004). Fairbanks *et al*. (2001) have described five avian communities within KwaZulu-Natal, these being Maputaland, East coast, Drakensberg, central Zululand and central-southern Midlands.

Zones of high mollusc endemism in KwaZulu-Natal were spread across four of the avian communities but did not fall within the Maputaland community.

Nine broad priority areas for conservation action were identified by Driver *et al*. (2005). The mollusc endemic zones fell within the Succulent Karoo, Cape Floristic region, Albany Thicket and Wild Coast, Maputaland-Pondoland, Southeastern Escarpment and the Northeastern Escarpment. The Eastern Cape interior, Limpopo/Mpumalanga and northern Limpopo zones did not fall into any of the priority areas identified for conservation action (Fig. 4.6). The nine priority areas were ranked according to the combined level of future pressures on biodiversity. Pressures on biodiversity appear to be highest in the northern and eastern parts of the country with the Maputaland-Pondoland region ranked second on the priority list. The Northeastern Escarpment was ranked 5th, Albany Thicket and Wild coast 6th, Southeastern Escarpment 7th, Cape Floristic region 8th and the Succulent Karoo region was ranked 9th on the priority list (Driver *et al*., 2005).

Although there are currently numerous biodiversity conservation programmes being developed or implemented in South Africa, many areas will not be covered by current and future conservation plans. The majority of these projects mainly use data on plants and vertebrate groups to identify priority areas for conservation (Hamer & Slotow, 2002). Thus it is unlikely that formal conservation areas could be set up to protect endemic species of molluscs and their conservation in existing and future conservation areas will be incidental. At the regional scale (Fig. 4.5a & b; Table 4.2), the Cape Peninsula and parts of the Western Cape with high levels of endemism will be conserved through planned or implemented conservation activities such as the Cape Peninsula National Park, C.A.P.E. Project (Hamer & Slotow, 2002). However, there is a need to establish additional bioregional programmes as current bioregional programmes are mainly established in the southern parts of South Africa (Driver *et al*., 2005). Land-use planning and conservation issues in South Africa are dealt with at the municipal governmental level. The large number of endemics within the Pietermaritzburg area will thus be the responsibility of the local government or regional council. Within Pietermaritzburg several important areas are considered as nature reserves while other areas that contribute to the high levels of endemism have no conservation status. Several areas with high levels of species richness and endemism (including protected areas) are threatened by alien invasive vegetation, arson fires, development and agriculture (Hamer & Slotow, 2002).

The majority of Africa's biodiversity exists outside of the protected area system (Biodiversity Support Program, 1993; Crowe, 1996; Hamer & Slotow, 2002) and there is a need for all key role players in conversation to recognise the importance of biodiversity conservation outside formally protected areas (Hamer & Slotow, 2002). The development and implementation of appropriate strategies and management plans for unprotected areas is extremely important (Meadows, 1985; Biodiversity Support Program, 1993; Crowe, 1996; Hamer & Slotow, 2002).

Although the use of the existing data may be misleading in terms of identifying specific priority areas, they do illustrate significant trends and patterns of biodiversity (Hamer & Slotow, 2002). The analysis of mollusc data using both systems of endemism showed similar areas of high species richness and endemism indicating that the Hamer & Slotow (2002) classification of endemism can be used to define areas of high mollusc species richness and endemism. Significantly, the endemism patterns of molluscs in South Africa differed from those of millipedes suggesting that surrogacy will not be an effective approach for animals of low vagility and thus the inclusion of a single invertebrate taxon in biodiversity conservation planning will not adequately reflect the diversity, distribution and endemism patterns of less mobile invertebrates. Biodiversity conservation planning based on data for vertebrates and plants is also unlikely to conserve a significant amount of mollusc or invertebrate diversity (Hamer & Slotow, 2002). It would be impossible to include all invertebrates in biodiversity conservation planning but an effort should be made to include a representative suite (in terms of functionality, mobility, longevity, habitat specialists) (Hamer & Slotow, 2002). A preliminary list of specific priority sites for mollusc conservation was compiled. These sites should be incorporated into the reserve network where possible and management plans must be reviewed to include the conservation and protection of the mollusc taxa within these sites.

The continued loss of mollusc diversity is detrimental to ecosystems and ultimately the welfare of humankind (Kay, 1995). Transformation and fragmentation of natural habitats in South Africa are probably the most significant factors likely to influence the survival of molluscs (Coppois, 1995; Herbert, 1997). The effect of habitat fragmentation on molluscs is likely to be considerable in the long term. As a result of their very limited vagility, the large areas of transformed land separating populations of anthropophobic molluscs inhabiting more or less pristine habitats effectively represent impenetrable barriers (Herbert, 1997). Furthermore large areas of natural habitat in southern Africa are likely to experience a change in vegetation due to the continuing climatic change. Any significant change in the floral composition of a habitat is likely to have a dramatic effect on the molluscan fauna (Herbert, 1997). The protection of natural habitats is vitally important for the conservation of molluscs and other soil invertebrates (Hamer & Slotow, 2002).

The number of species threatened with extinction far outstrips available conservation resources and the situation looks set to deteriorate further (Myers *et al.*, 2000). If biodiversity conservation is to be effective, invertebrates cannot be excluded from planning or management activities, as they frequently play a significant role in maintaining ecosystem functioning and integrity (Horwitz *et al*. 1999; Hamer & Slotow, 2002). The loss of invertebrates is likely to impact upon many species, which play essential roles in ecosystem processes. This loss could lead to the degradation of ecosystems both inside and outside of protected areas. The patterns of invertebrate diversity and distribution thus need to be considered in conservation planning (Hamer & Slotow, 2002).

As a result, it has become essential to accept incomplete data and adopt methods for making the most of what is known to science or can be discovered from new biological surveys (Margules & Pressey, 2000). The lack of information on invertebrates does not allow for the construction of conservation plans. There needs to be an increased effort to collect more and better quality data on the biology and distributions of invertebrates as this is an integral part of assessing their conservation status and their possible need for management (Biodiversity Support Program, 1993). Permanently preserved reference collections (e.g. museum collections) are a crucial component in the transfer of biodiversity information between different researchers in space and time (Hawksworth & Mound, 1991) provided they are databased and georeferenced. Although the reliability and sampling intensity of inventory data are unknown and likely to vary among taxa and habitats (e.g. intense sampling in habitats surrounding universities and museums) (Conroy & Noon, 1996), collections are essential for identification, as repositories for vouchers for application of names and to house vouchers of species used in research projects (Hawksworth & Mound, 1991). They form databases, which incorporate a colossal amount of information on distribution and seasonality. There is a need to harness this information since the production of maps and checklists from reference collections could contribute significantly to the management and conservation biodiversity (Hawksworth & Mound, 1991). Gaps in spatial and taxonomic knowledge should be addressed. Red List evaluation of certain threatened species should be undertaken as a matter of urgency (Hamer & Slotow, 2002). This kind of information is fundamental to identifying project sites and planning projects (Biodiversity Support Program, 1993).

CHAPTER 5
CONCLUSION

Invertebrates may comprise as much as 95 % of biodiversity (Myers *et al*., 2000; Hamer & Slotow, 2002; Lydeard *et al*., 2004) and excluding this major component of biodiversity from conservation planning and management strategies will inevitably lead to the extinction of a large proportion of global biodiversity (Hamer & Slotow, 2002). Distribution data for most invertebrates are incomplete but provided that shortcomings with the data are recognised and taken into account, meaningful trends and patterns can be discerned and these should be considered in biodiversity conservation efforts (Hamer & Slotow, 2002).

Every taxon has a particular geographical range and this geographical distribution pattern is an important characteristic of a taxon (van Wyk & Smith, 2001). The long-term conservation of biodiversity requires maintaining viable populations of all indigenous species in natural patterns of abundance as well as the representation of the ecological and evolutionary processes that contribute to the shaping and maintaining biodiversity patterns (Noss & Cooperrider, 1994; Fairbanks *et al.*, 2001; Eeley *et al*., 2001; Reyers, 2004; Driver *et al*., 2005). The assessment of distribution patterns and factors influencing biogeographic distributions are an integral part of assessing the conservation status of molluscs and their management needs. This information can aid the geographic focus of conservation efforts as well as assist with determining the appropriate management efforts for protected areas and corridor routes (Lydeard *et al*., 2004).

The overall goals of systematic conservation planning are to maintain representation and persistence of all elements of biodiversity (Margules & Pressey, 2000; Driver *et al*., 2005). In order to accomplish these goals specific and preferably quantitative targets that represent a biodiversity pattern have to be set. Targets allow conservation programmes to focus on different scales, take into account natural processes as well as biodiversity patterns and reflect the needs of species and landscapes for protection (Margules & Pressey, 2000). Most systematic conservation planning efforts have chosen areas on the basis of occurrence of species. The spatial extent of communities and habitat types has also been used as conservation targets (Margules & Pressey, 2000).

The existing South African mollusc data were assessed in terms of their value to biodiversity conversation planning and management. The diversity of molluscs in South Africa was examined at two scales, firstly across regions and secondly by species localities. Areas of high mollusc species richness and endemism were identified for protection. A preliminary examination of physical and biotic elements that affect the distribution of mollusc families and genera across the landscape was conducted.

The distribution of molluscs across the South African landscape illustrated ten broad biogeographical patterns. Two of these patterns reflected ancient distribution patterns of molluscs and consisted of molluscs of the Gondwanaland/southern relict and Laurasian origins. Three biogeographic patterns occurred across the eastern regions. These patterns were defined as the tropical/subtropical east African, subtropical east of southern Africa and east African afromontane patterns. The biogeographic patterns in the west consisted of the characteristic temperate 'Mediterranean' Cape centre and the arid regions of northwestern Cape, Namibia & parts of Botswana. An additional biogeographic pattern identified as the nama karoo/central west was recognised. The last two biogeographical patterns described taxa that were widely distributed and taxa that exhibited disjunct distributions. Twenty-six families and forty-three genera were associated with more than one biogeographical pattern. The dominant biogeographic pattern was the tropical/subtropical east African component. Twenty-one families and forty-eight genera were associated with this biogeographical pattern. The east African Afromontane pattern was also a conspicuous biogeographic element in South Africa. Smaller numbers of families and genera were distributed in the western and central regions.

The distributions of molluscs were thought to be influenced by a combination of various factors, which included the presence of rivers, the escarpment, altitude humidity, precipitation, temperature and biomes. Rivers could possibly restrict the distribution of certain mollusc taxa but did not appear to be the dominant factor that influenced the distribution of molluscs across the landscape. In terms of the effect of temperature on the distribution of molluscs, the mean daily and mean annual temperatures appeared to have more of an influence on the distribution patterns than the mean daily maximum and minimum temperatures. Mean annual temperatures influenced the distribution of all families and genera. The mean daily maximum temperature appeared to have little or no effect on the distribution of mollusc taxa. Humidity and biomes also appeared to influence the distribution of taxa. The least inhabited biome was the succulent biome. Many mollusc taxa occurred in the wetter, warmer areas with high humidity levels.

The distribution patterns of molluscan taxa illustrated distinctive biogeographical zones within South Africa. As there are limits to the amount of land that can be set aside as reserves, selecting the appropriate areas is crucial for effective conservation (Kareiva, 1993). This involves the identification of areas with unusually high species richness and endemicity levels, areas with high levels of rare or threatened species or areas which are rich in biodiversity, especially in endemic species, while being under severe threat (Myers *et al*., 2000; Purvis &

Hector, 2000). Any given area contributes to biological diversity not only through its richness in numbers of species but also through endemism (or geographical uniqueness) of these species (Groombridge, 1992). Species richness and endemism can be used as a base dataset for monitoring changes over time and in the identification of conservation priority areas (Claridge, 1991; Freitag & van Jaarsveld, 1995).

Areas of high species richness and high endemic species richness in South Africa were identified using two systems of endemism, one based on distinctive gaps in the frequency distribution of terrestrial molluscs in South Africa and the other based on an existing classification of invertebrate endemism (Hamer & Slotow, 2002). The total number of South African mollusc endemics was 370 (83 % of 447 indigenous species). The dominant mollusc families in South Africa are Achatinidae, Charopidae, Streptaxidae, Subulinidae and Urocyclidae. The first system of endemism identified 56 site endemics (species with only one locality), 50 local endemics (0 < maximum distance < 60 km) and 145 regional endemics (60 km < maximum distance < 330 km). The Hamer & Slotow classification of endemism classed 67 species as site endemics (maximum distance between localities < 10 km), 47 as local (11 km < maximum distance < 70 km) endemics and 59 as regional endemics (71 km < maximum distance < 150 km). The analysis of mollusc data, with both systems of endemism, showed similar areas of high species and endemic species richness. Quarter-degree grid cells with highest species richness overlapped with grid cells with the highest number of endemic species. However these grid cells coincide with areas that have been intensively sampled and this bias limits the application of the data in conservation planning. The patterns of endemism for molluscs and millipedes within the provinces differ indicating that the inclusion of a single taxon in conservation planning would inadequately reflect the diversity of invertebrates in South Africa.

Although the data on molluscs are incomplete and may be misleading in terms of identifying specific areas for protection, the data did illustrate significant patterns and trends of mollusc endemism and diversity, which could be used to improve biodiversity conservation and management efforts. The analysis of existing mollusc data illustrated the spread of mollusc across the landscape and allowed for the identification of mollusc biogeographic patterns across South Africa. Several areas were assessed for their conservation value and sites of high mollusc species richness and high mollusc endemism were identified. A preliminary list of specific priority sites for mollusc conservation was compiled. The broad biogeographic patterns and areas of high mollusc species richness and endemism offer an opportunity to provide adequate representation within conservation programmes. The biogeographic regions and sites of high mollusc species richness and endemism allow for the identification of landscape linkages, mollusc habitats and corridors for mollusc movement. Landscape linkages can provide for daily and seasonal movements of molluscs and allows for range shifts of mollusc taxa over long distances especially in response to climate change (Noss & Cooperrider, 1994).

The South African National Biodiversity Assessment identified the moist grasslands, Maputaland-Pondoland, Bushveld-Bankenveld and central grasslands centres as the top four priority areas for conservation in South Africa (Driver *et al*., 2005). Three of these areas the moist grasslands, Bushveld-Bankenveld and central grasslands centres are situated in the northern regions of South Africa and west of the escarpment (Driver *et al*., 2005). The grassland biome is considered less malocologically diverse and most mollusc taxa occur in wetter, warmer regions east of the escarpment (van Bruggen, 1978; Herbert & Kilburn, 2004). The South African National Biodiversity Assessment did not identify the nama karoo/central west region as a priority area for conservation (Driver *et al*., 2005). However, this was a conspicuous mollusc biogeographic zone and centre of endemism. Pressure on biodiversity from the spread of invasive alien plants, fragmentation of natural habitats, increase in population and conversion of natural habitat to other land uses such as crop agriculture, mining and afforestation appear to be highest in the northern and eastern parts of South Africa (Driver *et al*., 2005). Nine zones of mollusc endemism were identified in the northern and eastern regions of the country. Bioregional plans and provincial spatial diversity plans across the Limpopo province and KwaZulu-Natal need to take into account areas of importance to mollusc conservation. It is essential that the existing data on invertebrates be evaluated and used to identify key patterns and trends in invertebrate diversity as this will allow for the inclusion of invertebrates in biodiversity conservation planning and management.

Environmental management plans for areas that were identified as priority sites for mollusc conservation within each province should be reviewed to incorporate measures to maintain and protect mollusc diversity. Centres of high mollusc species richness and endemism need to be incorporated into the reserve network (Noss & Cooperrider, 1994). There needs to be an increased effort to collect more and better quality data on the biology and distributions of molluscs as this is an integral part of assessing their conservation status and their possible need for management. Although museum collections are the most concrete source of information for recognizing patterns of species distribution (Kadmon and Heller, 1998), they tend to be 'noisy' and are prone to different sources of bias in data collection since they have been collected for different purposes and often in an opportunistic manner from locations that collectors expected to find what they are looking for or that were conveniently accessible thereby resulting in an under-representation of inaccessible areas or over-representation of attractive species (Herbert, 1997; Kadmon & Heller, 1998; Dennis & Thomas, 2000; Margules & Pressey, 2000; Hamer &

Slotow, 2002). As a result data derived from museum collections cannot be considered as a truly representative sample of the relevant fauna. Yet for many taxa, museum collections are the only source of information for large-scale patterns of species distribution. If used carefully they may provide valuable information on patterns of floristic and faunal variation. Another aspect that requires careful consideration is the spatial resolution of the grid used to construct the cell x species matrix. Choosing a too high resolution may result in grid cells containing amounts of information that are too limited, while choosing a too low resolution may result in cells that are spatially heterogeneous in their environmental conditions (Kadmon and Heller, 1998). Conclusions derived from permanently preserved reference collections that do not have effort units associated with them should be conservative and preliminary (Slotow & Hamer, 2000).

However, the existing mollusc data allowed for the identification of biogeographical patterns that are important to conservation planning both at the local and national level as well as factors that influenced the distribution of molluscs across the South African landscape. These factors, which drive the distribution of molluscs within South Africa, need to be taken in account when developing biodiversity conservation plans. The assessment of the mollusc data has shown that the inclusion of invertebrates in conservation planning changes the picture at both the local and national levels. This study has also highlighted the commonalities and differences between molluscs and millipede distributions and the importance of municipal areas for conservation of hotpots of diversity, particularly in the eastern coastal areas of South Africa.

An understanding of how mollusc distribution is presently influenced, how it has changed from the past and how it may change in the future will allow for the development of flexible conservation strategies that accommodate for the fluctuating pattern of distribution and for informed management decisions to be made to protect mollusc diversity. Continual monitoring and inventory is needed to improve the data on the existing distribution and abundance of mollusc across South Africa as well as to gain a picture of the changes in mollusc abundance and distribution and the factors that contribute to these changes (Noss & Cooperrider, 1994). Further research needs to be conducted to determine critical sites for the long-term conservation of a representative sample of the South African molluscan fauna. Future studies should identify and assess the future and present threats facing molluscs in South Africa. Together with the data on the distribution of molluscs, areas important to mollusc conservation can be identified. The extent to which molluscs are represented in the existing protected area network needs to be assessed. The existing reserve network in South Africa should be compared with the areas of high mollusc species richness and endemism to determine if existing reserves cover these areas. Unprotected and underrepresented mollusc hot spots are areas that warrant immediate conservation action (Noss & Cooperrider, 1994). Distribution corridors within each of the biogeographic components must be identified and linked to core protective areas. The likelihood of species becoming extinct without conservation actions has to be also assessed. These studies will help to focus mollusc conservation efforts in areas and on features that are most at risk.

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APPENDIX A

Appendix A: Checklist and distribution maps of terrestrial mollusc species in South Africa

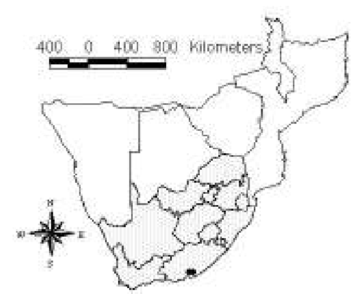
Thirty-eight families, 79 genera and 478 species of terrestrial molluscs (excluding Ellobiidae and Truncatellidae) were recorded in South Africa. Of the 478 species, 447 were indigenous species and 31were exotic species. Only families with representatives mapped in this thesis were listed, those marked (*) were introduced or contain some introduced species. Fourteen species were considered to be threatened and are included in the 2004 IUCN Red List.

CLASS: GASTROPODA

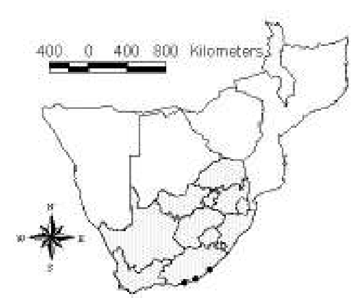
SUBCLASS: PROSOBRANCHIA

Family: Cyclophoridae

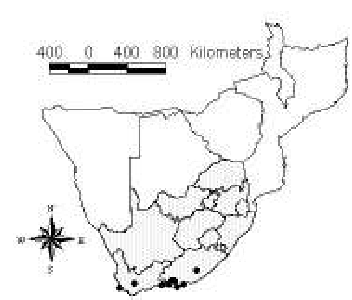
Species: *Chondrocyclus alabastris* (Craven, 1880)
Distribution: Along the Eastern Cape coast.



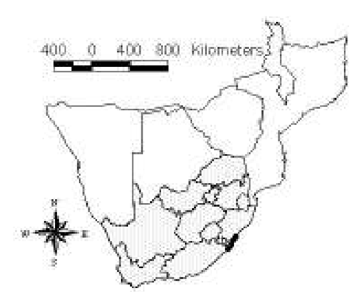
Species: *Chondrocyclus bathrolophodes* Connolly, 1929
Distribution: Eastern Cape coast.



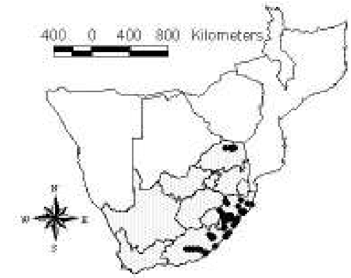
Species: *Chondrocyclus convexiusulus* (Pfeiffer, 1855)
Distribution: Coastal areas of Eastern Cape and Western Cape.



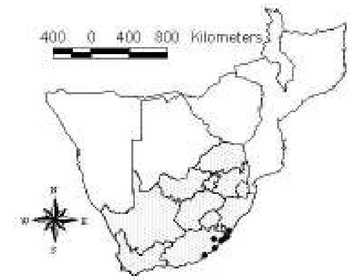
Species: *Chondrocyclus exsertus* (Melvill & Ponsonby, 1903)
Distribution: Coastal distribution in southern KwaZulu-Natal.



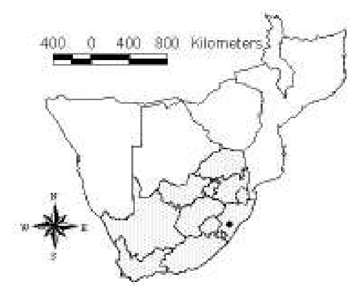
Species: *Chondrocyclus isipingoensis* (Sturany, 1898)
Distribution: Coastal and interior areas of South Africa (Eastern Cape, Limpopo and KwaZulu-Natal).



Species: *Chondrocyclus putealis* Connolly, 1939
Distribution: Coastal areas of the Eastern Cape and into southern KwaZulu-Natal.

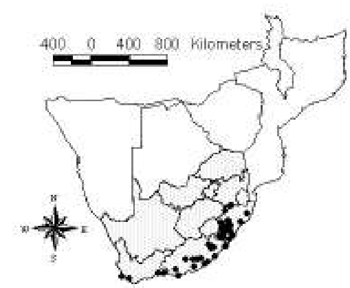


Species: *Chondrocyclus trifimbriatus* Connolly, 1939
Distribution: Interior of KwaZulu-Natal.



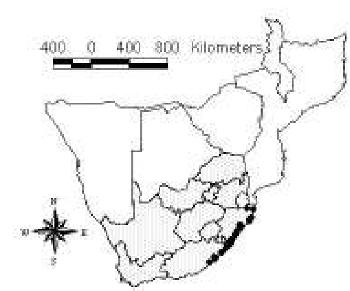
Family: Hydrocenidae

Species: *Hydrocena noticola* Benson, 1856
Distribution: KwaZulu-Natal, Eastern Cape and the Western Cape peninsula.



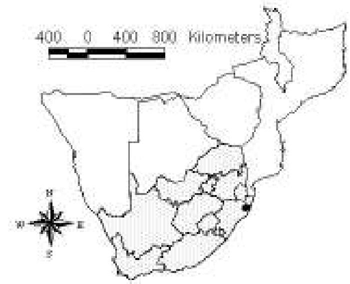
Family: Maizaniidae

Species: *Maizania wahlbergi* (Benson, 1852)
Distribution: Along the coast of KwaZulu-Natal and Eastern Cape.

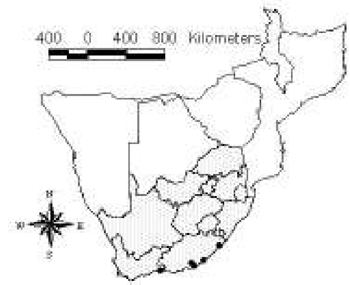


Family: Pomatiasidae

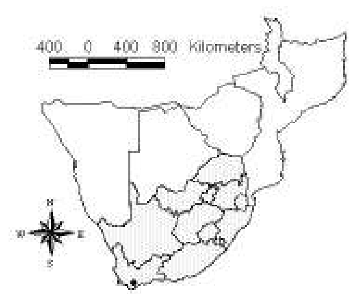
Species: *Tropidophora comburens* (Melvill & Ponsonby, 1903)
Distribution: Northern KwaZulu-Natal.



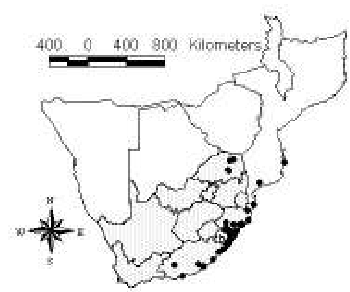
Species: *Tropidophora foveolata* (Melvill & Ponsonby, 1895)
Distribution: Coastal areas of the Eastern and Western Cape.



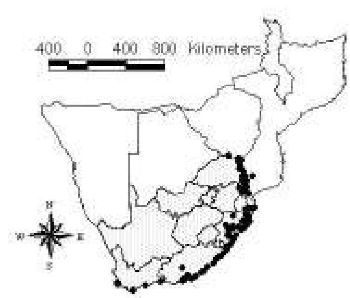
Species: *Tropidophora hartvigiana* (Pfeiffer, 1862)
Distribution: Western Cape.

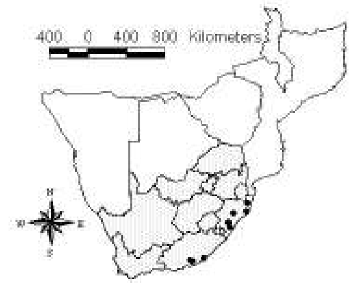


Species: *Tropidophora insularis* (Pfeiffer, 1852)
Distribution: Eastern Cape, Limpopo, KwaZulu-Natal as well as in Mozambique

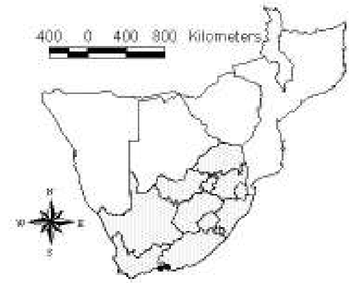


Species: *Tropidophora ligata* (Müller, 1774)
Distribution: Extends from Limpopo, into Mpumalanga, KwaZulu-Natal, Eastern Cape and reaches the Western Cape. The species is also occurs in Mozambique.

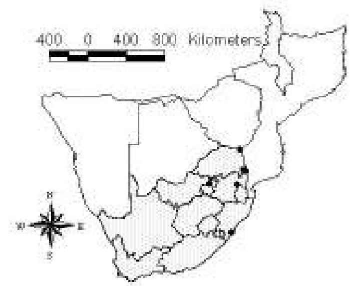




Species: *Tropidophora plurilirata* Fulton, 1903
Distribution: KwaZulu-Natal and Eastern Cape.



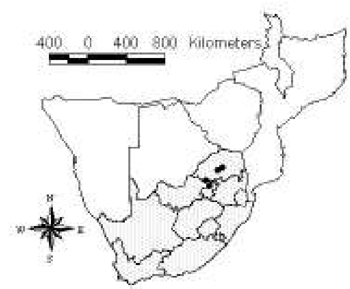
Species: *Tropidophora sarcodes* (Pfeiffer, 1856)
Distribution: Western and Eastern Cape.



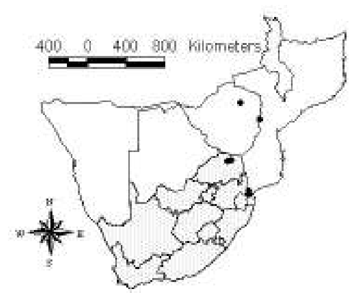
Species: *Tropidophora transvaalensis* (Melvill & Ponsonby, 1891)
Distribution: KwaZulu-Natal, Gauteng, Limpopo and Mpumalanga.

SUBCLASS: PULMONATA

Family: Achatinidae

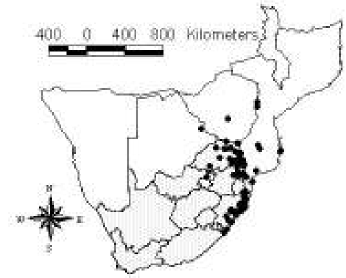


Species: *Achatina bisculpta* Smith, 1878
Distribution: Interior of South Africa within the North West Province, Gauteng and Limpopo.

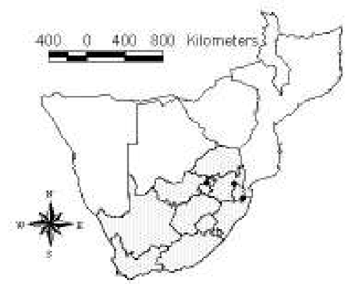


Species: *Achatina craveni* Smith, 1881
Distribution: Mozambique, Zimbabwe and the Limpopo province of South Africa.

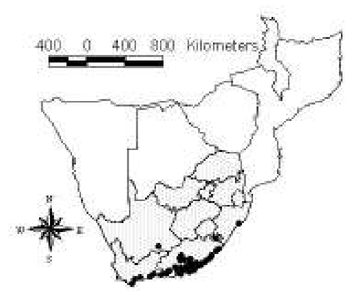
Species: *Achatina immaculata* Lamarck, 1822
Distribution: Eastern distribution in southern Africa. The species was recorded within Gauteng, Limpopo, Mpumalanga, KwaZulu-Natal, Botswana, Zimbabwe and Mozambique.



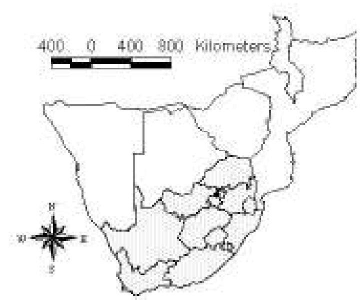
Species: *Achatina smithii* Craven, 1880
Distribution: Mpumalanga, Gauteng and the northern areas of KwaZulu-Natal.



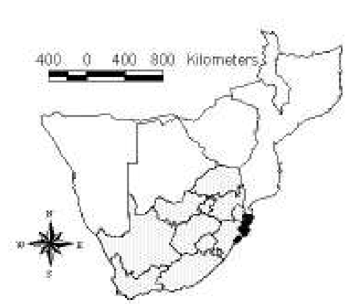
Species: *Achatina zebra* (Bruguière, 1792)
Distribution: KwaZulu-Natal, Eastern Cape, Western Cape and Northern Cape.

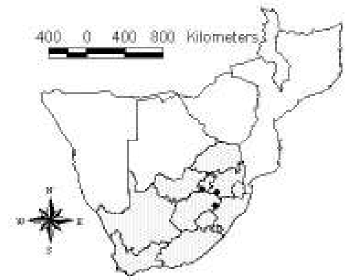


Species: *Cochlitoma penestes* Melvill & Ponsonby, 1893
Distribution: Gauteng

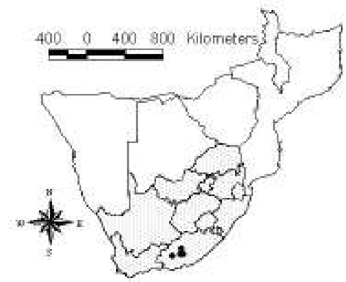


Species: *Cochlitoma churchilliana* (Melvill & Ponsonby, 1895)
Distribution: Coastal distribution in the northern KwaZulu-Natal and into Mozambique.

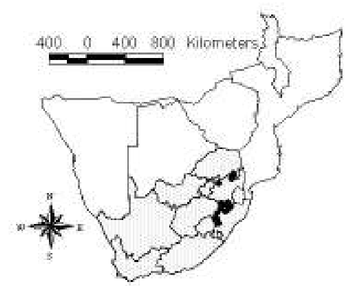




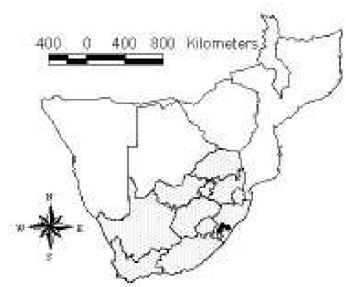
Species: *Cochlitoma cinnamomea* (Melvill & Ponsonby, 1894)
Distribution: Distributed in the interior provinces of South Africa, these being the Free State, Mpumalanga and Gauteng.



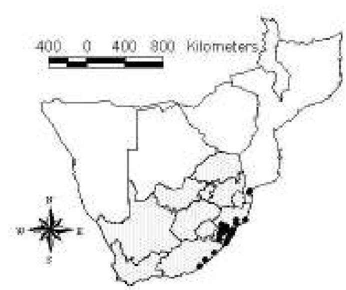
Species: *Cochlitoma crawfordi* (Morelet, 1889)
Distribution: Interior of the Eastern Cape.



Species: *Cochlitoma dimidiata* (Smith, 1878)
Distribution: Mpumalanga, Limpopo and KwaZulu-Natal.

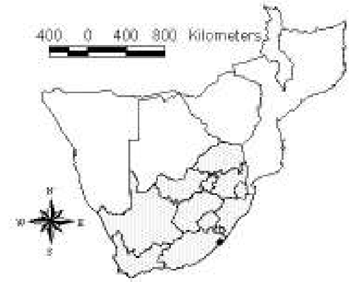


Species: *Cochlitoma drakensbergensis* (Melvill & Ponsonby, 1897)
Distribution: KwaZulu-Natal.

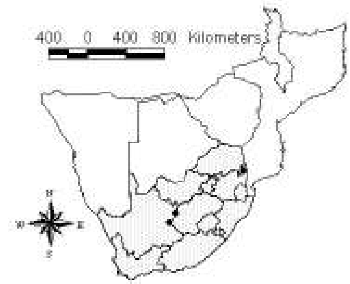


Species: *Cochlitoma granulata* (Krauss, 1848)
Distribution: *C. granulata* is distributed along the eastern parts of southern Africa. The species is found in the Eastern Cape, KwaZulu-Natal and Mozambique.

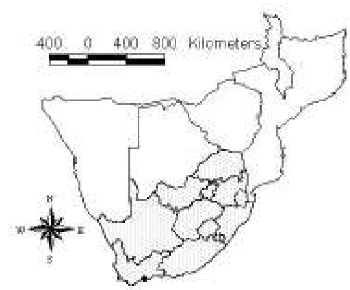
Species: *Cochlitoma limitanea* Bruggen, 1984
Distribution: Coastal areas of the Eastern Cape.



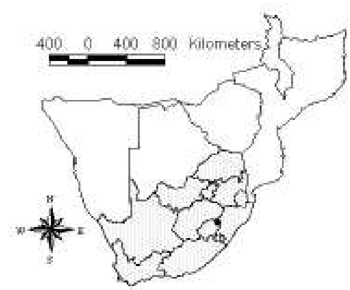
Species: *Cochlitoma livingstonei* (Melvill & Ponsonby, 1897)
Distribution: Mpumalanga (Kruger National Park) and Northern Cape.



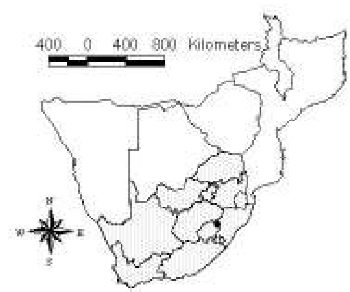
Species: *Cochlitoma marinae* Sirgel, 1989
Distribution: Western Cape coast.



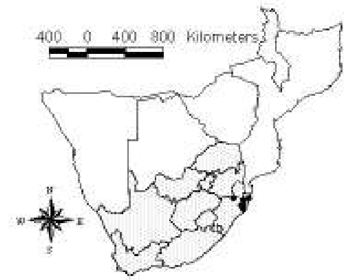
Species: *Cochlitoma montistempli* Bruggen, 1965
Distribution: Along the Drakensberg Mountain of KwaZulu-Natal.



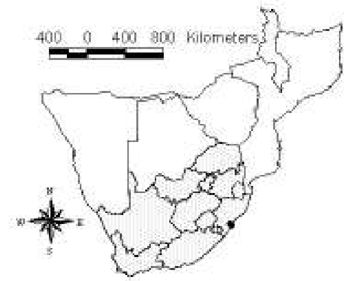
Species: *Cochlitoma omissa* Bruggen, 1965
Distribution: Along the Drakensberg Mountain of KwaZulu-Natal.



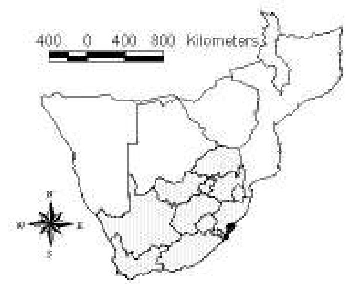
Species: *Cochlitoma parthenia* (Melvill & Ponsonby, 1903)
Distribution: Northern KwaZulu-Natal.



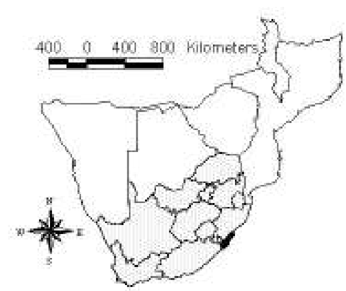
Species: *Cochlitoma pentheri* (Sturany, 1898)
Distribution: KwaZulu-Natal.



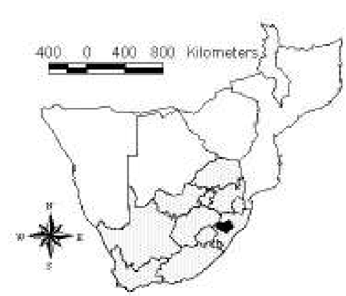
Species: *Cochlitoma semidecussata* (Pfeiffer, 1846)
Distribution: Southern coast of KwaZulu-Natal.



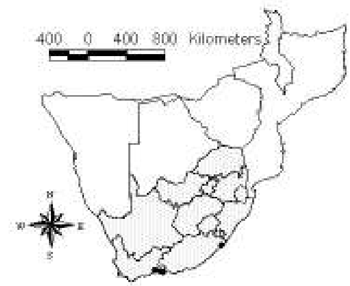
Species: *Cochlitoma semigranosa* (Pfeiffer, 1861)
Distribution: Coastal areas of southern KwaZulu-Natal.



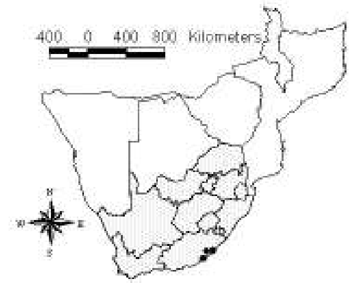
Species: *Cochlitoma simplex* (Smith, 1878)
Distribution: Interior of KwaZulu-Natal.



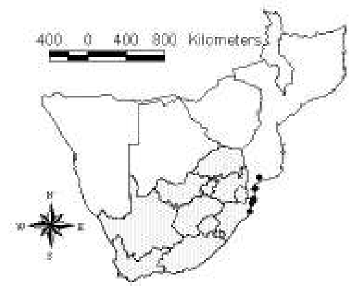
Species: *Cochlitoma ustulata* (Lamarck, 1821)
Distribution: Coastal areas of the Eastern Cape and Western Cape.



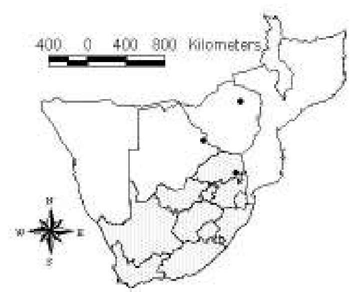
Species: *Cochlitoma varicosa* (Pfeiffer, 1861)
Distribution: Coastal areas of the Eastern Cape.



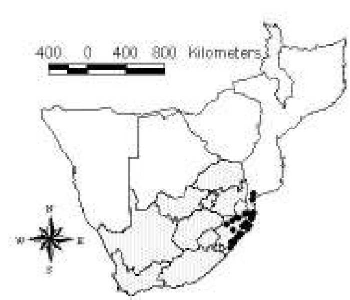
Species: *Cochlitoma vestita* (Pfeiffer, 1855)
Distribution: Coastal parts of northern KwaZulu-Natal and into Mozambique.



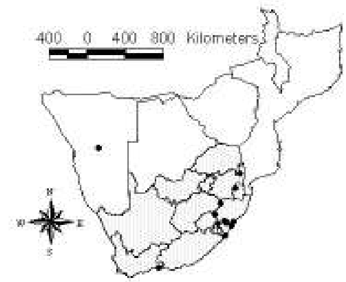
Species: *Burtoa nilotica* (Pfeiffer, 1861)
Distribution: Limpopo province of South Africa, Botswana and Zimbabwe.



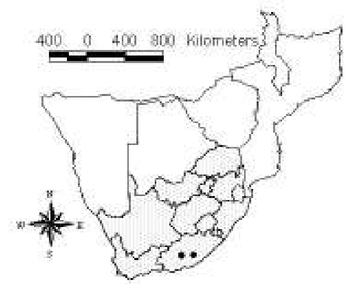
Species: *Metachatina kraussi* (Pfeiffer, 1626)
Distribution: Extends from KwaZulu-Natal into Mozambique.



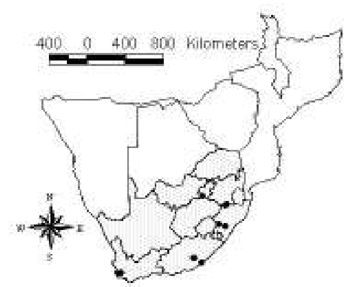
*Family: Agriolimacidae



Species: **Deroceras laeve* (Müller, 1774)
Distribution: Mpumalanga, KwaZulu-Natal, Western Cape, Swaziland and Namibia.

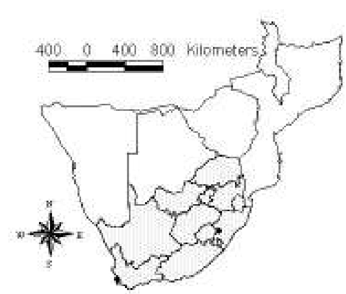


Species: **Deroceras panormitanum* (Lesson & Pollonera, 1882)
Distribution: Eastern Cape.

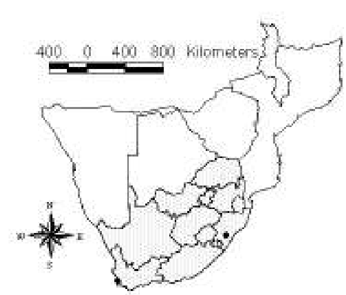


Species: **Deroceras reticulatum* (Müller, 1774)
Distribution: Western Cape, Eastern Cape, KwaZulu-Natal and Free State.

Family: Arionidae

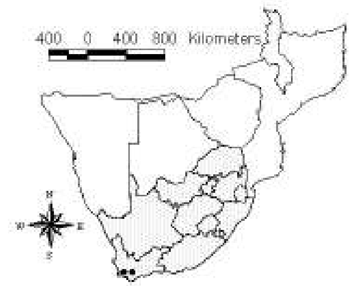


Species: **Arion hortensis* Férussac, 1819
Distribution: Western Cape and KwaZulu-Natal.

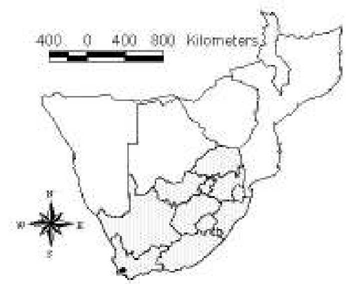


Species: **Arion intermedius* (Norman, 1852)
Distribution: Western Cape and KwaZulu-Natal.

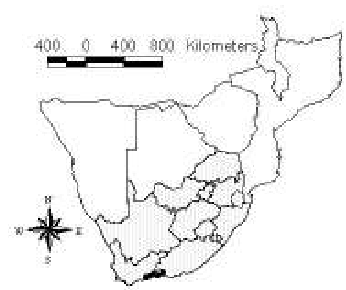
Species: *Ariopelta capensis* (Krauss, 1848)
Distribution: Western Cape



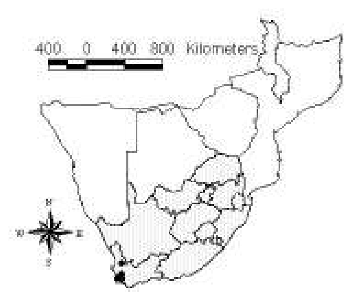
Species: *Ariostralis nebulosa* Sirgel, 1985
Distribution: Western Cape



Species: *Oopelta capensis* Pallonera, 1909
Distribution: Western Cape

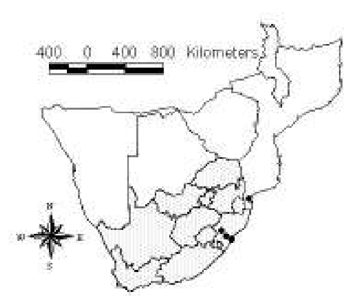


Species: *Oopelta nigropunctata* Morch, 1867
Distribution: Western Cape



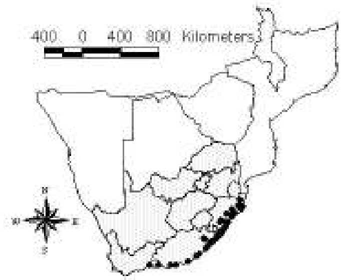
*Family: Bradybaenidae

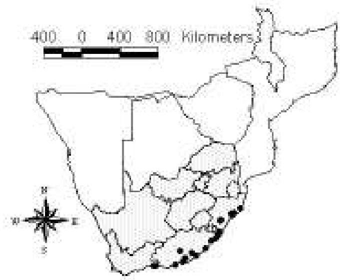
Species: **Bradybaena similaris* (Férussac, 1821)
Distribution: KwaZulu-Natal



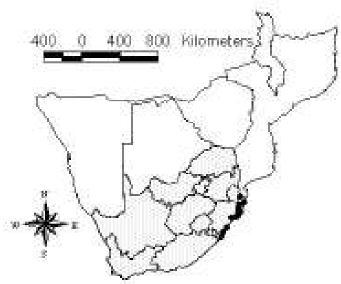
Family: Cerastidae

Species: *Edouardia arenicola* (Benson, 1856)
Distribution: KwaZulu-Natal, Eastern Cape and Western Cape.

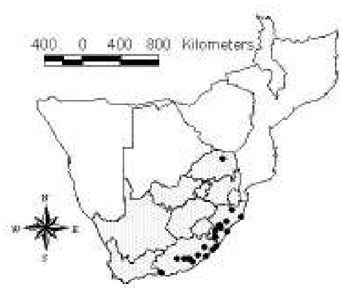




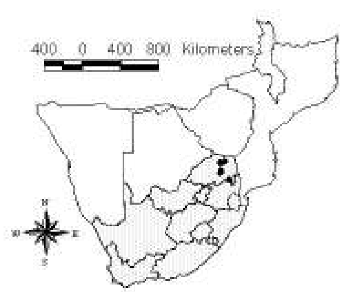
Species: *Edouardia carinifera* (Melvill & Ponsonby, 1897)
Distribution: KwaZulu-Natal, Eastern Cape and Western Cape.



Species: *Edouardia conulus* (Reeve, 1849)
Distribution: Coastal areas of KwaZulu-Natal.

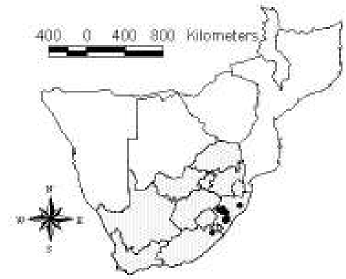


Species: *Edouardia dimera* (Melvill & Ponsonby, 1901)
Distribution: Eastern Cape, KwaZulu-Natal and Limpopo.

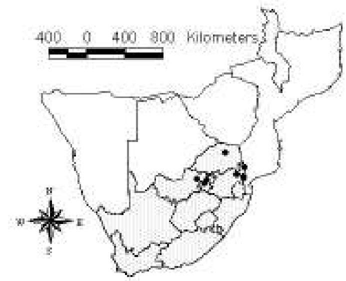


Species: *Edouardia drakensbergensis* (Smith, 1877)
Distribution: Found in the northern areas of South Africa, within the Limpopo province.

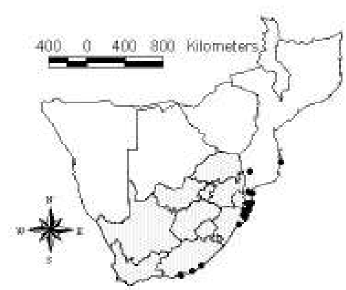
Species: *Edouardia maritzburgensis* (Melvill & Ponsonby, 1893)
Distribution: Interior of the Eastern Cape and KwaZulu-Natal.



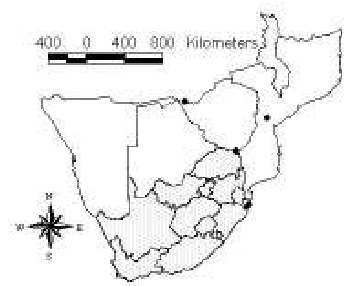
Species: *Edouardia mcbeaniana* (Burnup, 1905)
Distribution: Distributed within the northern interior regions of South Africa. The species was recorded in Limpopo, Mpumalanga, North West Province and Gauteng.



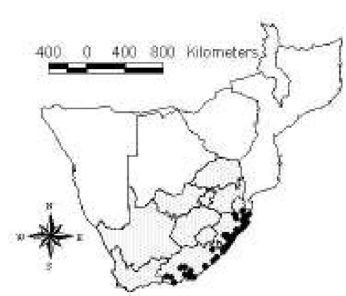
Species: *Edouardia meridionalis* (Pfeiffer, 1848)
Distribution: Coastal distribution within the Eastern Cape and northern KwaZulu-Natal and into Mozambique



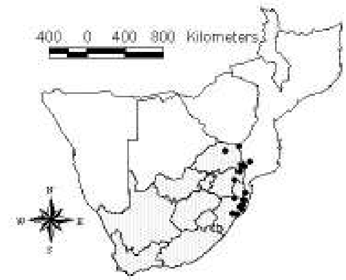
Species: *Edouardia metuloides* (Smith, 1899)
Distribution: Limpopo, northern KwaZulu-Natal, Mozambique and Zimbabwe.



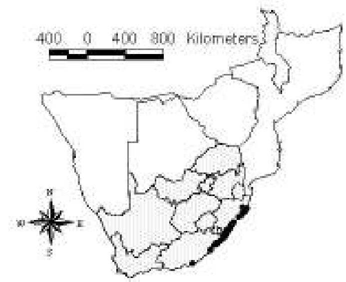
Species: *Edouardia natalensis* (Pfeiffer, 1846)
Distribution: Eastern provinces of South Africa, these being the Eastern Cape and KwaZulu-Natal.



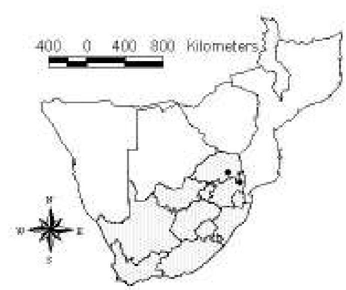
Species: *Edouardia sordidula* (Martens, 1897)
Distribution: KwaZulu-Natal, Limpopo, Mpumalanga and Mozambique.



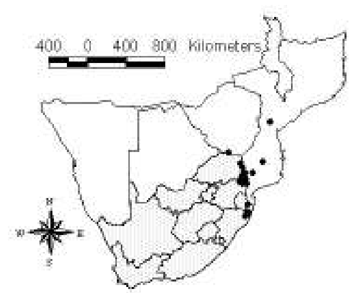
Species: *Edouardia spadicea* (Pfeiffer, 1846)
Distribution: Coastal distribution in the Eastern Cape and KwaZulu-Natal.



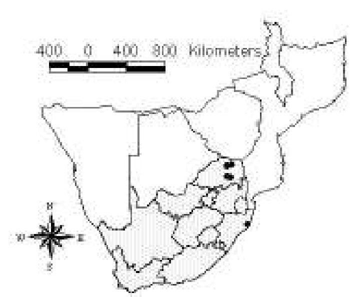
Species: *Edouardia transvaalensis* (Melvill & Ponsonby, 1893)
Distribution: Limpopo and Mpumalanga.



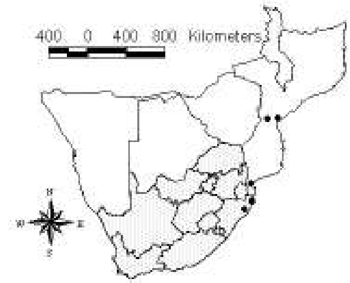
Species: *Rachis jejuna* (Melvill & Ponsonby, 1893)
Distribution: Mozambique, KwaZulu-Natal, Limpopo and Mpumalanga boundary with Zimbabwe.



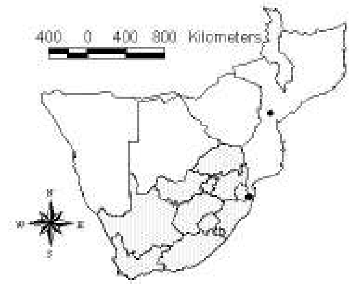
Species: *Rhachistia chiradzuluensis* (Smith, 1899)
Distribution: KwaZulu-Natal and Limpopo.



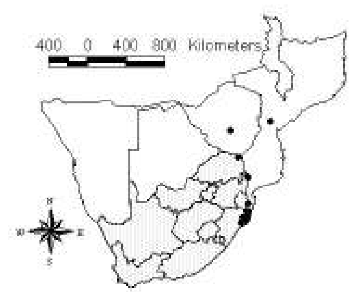
Species: *Rhachistia dubiosa* (Sturany, 1898)
Distribution: Northern KwaZulu-Natal and Mozambique.



Species: *Rhachistia melanacme* (Pfeiffer, 1855)
Distribution: Mozambique and KwaZulu-Natal.

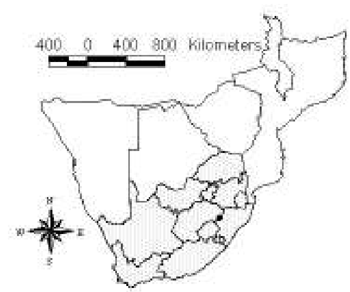


Species: *Rhachistia sticta* (Martens, 1859)
Distribution: Northern KwaZulu-Natal, Limpopo, Mpumalanga, Mozambique and Zimbabwe.

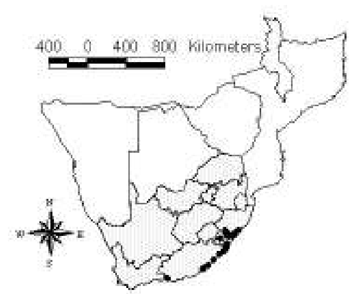


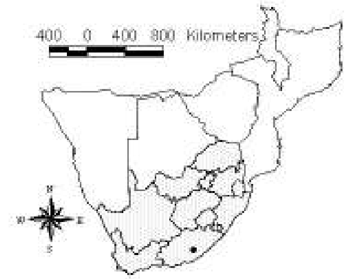
Family: Charopidae

Species: *Afrodonta acinaces* Connolly, 1933
Distribution: Drakensberg region of KwaZulu-Natal.

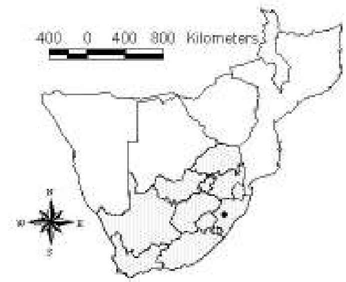


Species: *Afrodonta bilamellaris* Melvill & Ponsonby, 1908
Distribution: KwaZulu-Natal and along the coastal areas of the Eastern Cape.

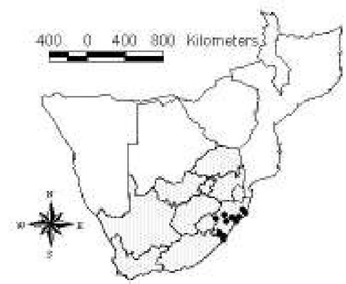




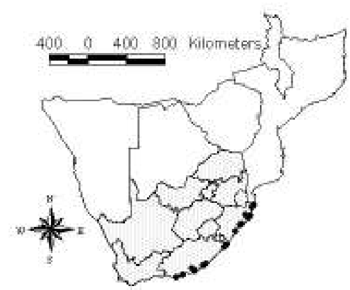
Species: *Afrodonta bimunita* Connolly, 1939
Distribution: Eastern Cape



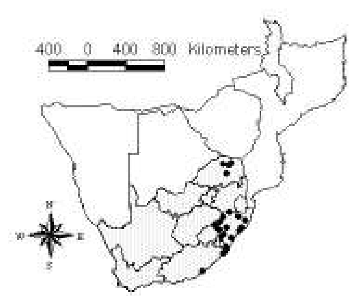
Species: *Afrodonta burnupi* Connolly, 1933
Distribution: KwaZulu-Natal.



Species: *Afrodonta connollyi* Solem, 1970
Distribution: KwaZulu-Natal.

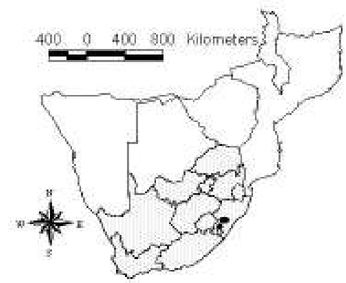


Species: *Afrodonta farquhari* (Burnup, 1912)
Distribution: KwaZulu-Natal and Eastern Cape.

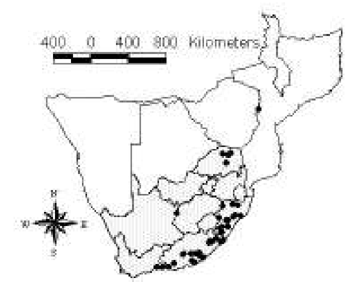


Species: *Afrodonta inhluzaniensis* (Burnup*,* 1912)
Distribution: Wide distribution in KwaZulu-Natal. The species is also found in the central northern areas of Limpopo and has a limited distribution along the coast of the Eastern Cape.

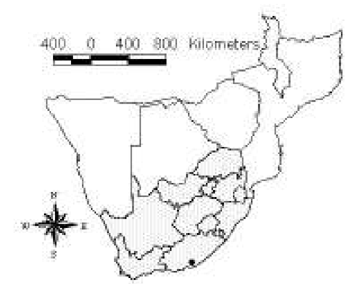
Species: *Afrodonta introtuberculata* Connolly, 1933
Distribution: Interior of KwaZulu-Natal.



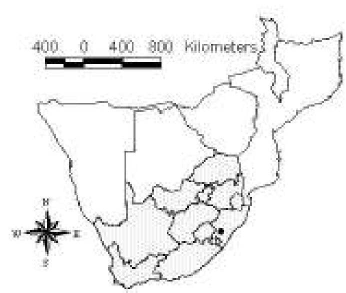
Species: *Afrodonta novemlamellaris* (Burnup, 1912)
Distribution: Eastern Cape, KwaZulu-Natal and Mozambique. Limited distribution in the Western Cape, Northern Cape and Limpopo.



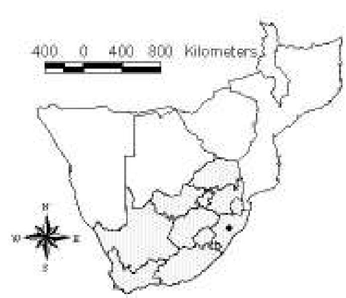
Species: *Afrodonta perfida* (Burnup, 1907)
Distribution: Eastern Cape.



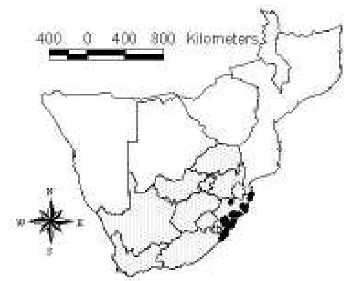
Species: *Afrodonta trilamellaris* Melvill & Ponsonby, 1908
Distribution: KwaZulu-Natal.



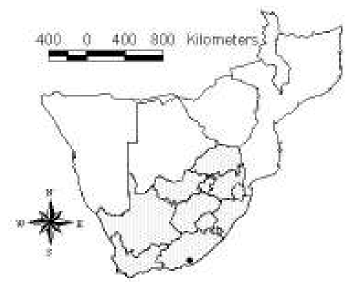
Species: *Afrodonta unilamellaris* Connolly, 1933
Distribution: Interior of KwaZulu-Natal.



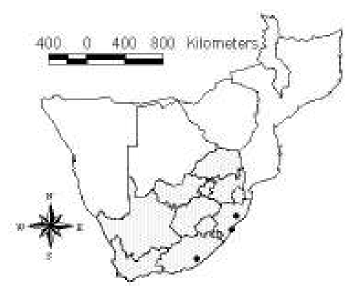
Species: *Trachycystis aenea* (Krauss, 1848)
Distribution: KwaZulu-Natal and Eastern Cape.



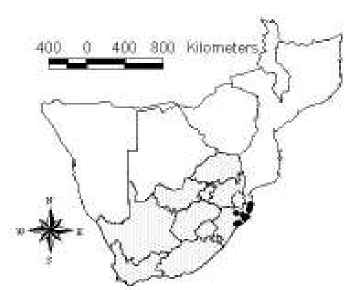
Species: *Trachycystis alcocki* (Melvill & Ponsonby, 1895)
Distribution: Eastern Cape.



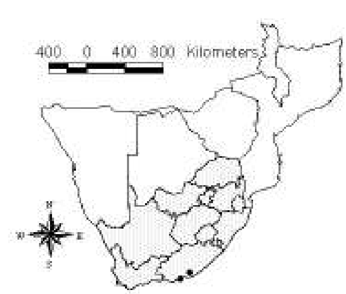
Species: *Trachycystis aprica* (Krauss, 1848)
Distribution: Limited distribution in both the Eastern Cape and KwaZulu-Natal.



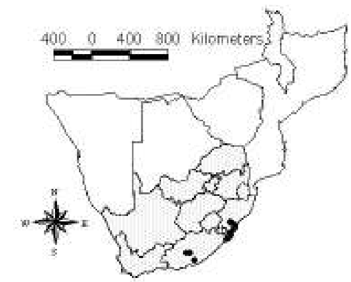
Species: *Trachycystis ariel* (Preston, 1910)
Distribution: Northern KwaZulu-Natal.



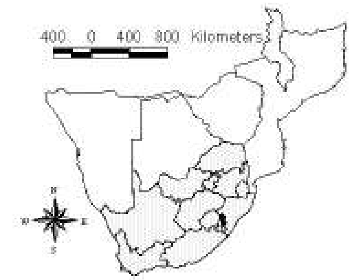
Species: *Trachycystis aulacophora* (Ancey, 1890)
Distribution: Eastern Cape.



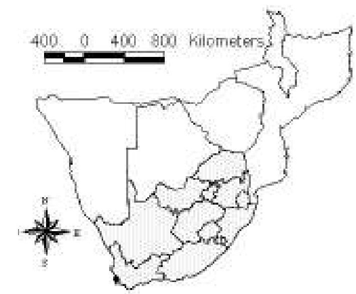
Species: *Trachycystis bathycoele* (Melvill & Ponsonby, 1892)
Distribution: Southern KwaZulu-Natal and Eastern Cape.



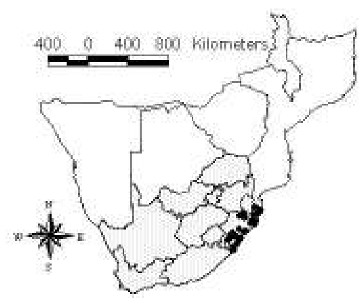
Species: *Trachycystis bifoveata* Connolly, 1932
Distribution: Interior regions of KwaZulu-Natal.



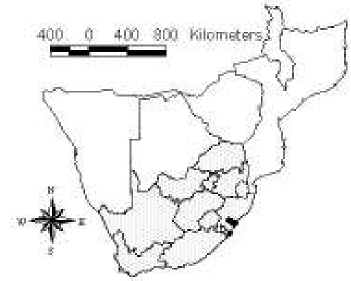
Species: *Trachycystis bisculpta* (Benson, 1851)
Distribution: Western Cape.



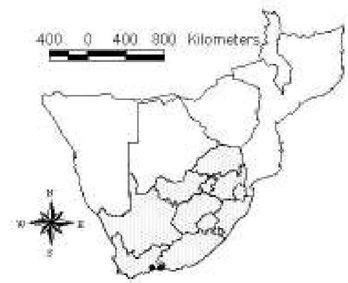
Species: *Trachycystis burnupi* (Melvill & Ponsonby, 1892)
Distribution: KwaZulu-Natal.



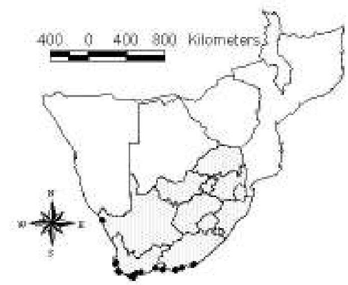
Species: *Trachycystis calorama* Melvill & Ponsonby, 1899
Distribution: KwaZulu-Natal.



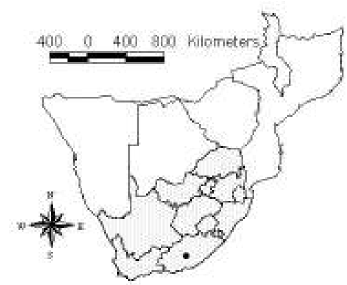
Species: *Trachycystis cancellata* (Connolly, 1925)
Distribution: Coastal areas of the Western Cape.



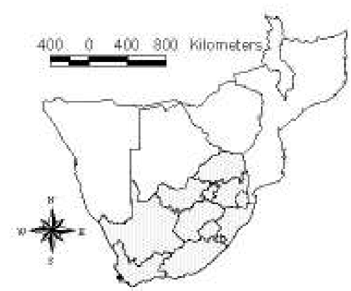
Species: *Trachycystis capensis* (Pfeiffer, 1841)
Distribution: Coastal distribution along Eastern Cape, Western Cape and Northern Cape.



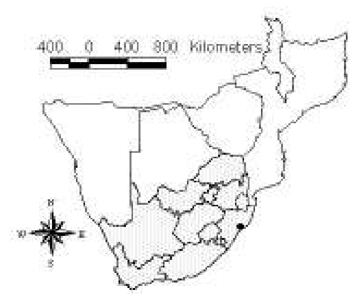
Species: *Trachycystis centrifuga* Melvill & Ponsonby, 1903
Distribution: Eastern Cape.



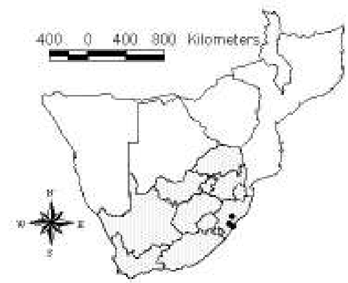
Species: *Trachycystis charybdis* (Benson, 1856)
Distribution: Western Cape.



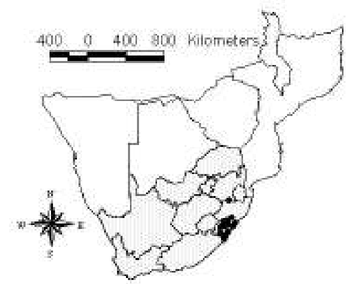
Species: *Trachycystis clifdeni* Connolly, 1932
Distribution: KwaZulu-Natal.
Threatened – IUCN Red list 2004



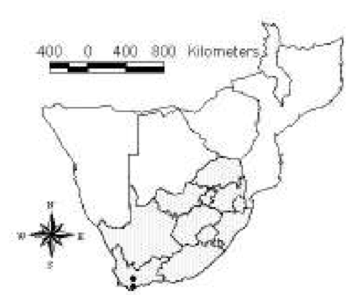
Species: *Trachycystis conica* Connolly, 1939
Distribution: KwaZulu-Natal.



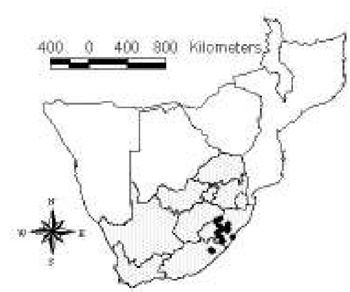
Species: *Trachycystis conisalea* (Melvill & Ponsonby, 1892)
Distribution: KwaZulu-Natal.



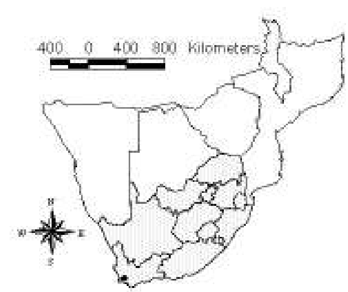
Species: *Trachycystis connollyi* Melvill & Ponsonby, 1909
Distribution: Western Cape.



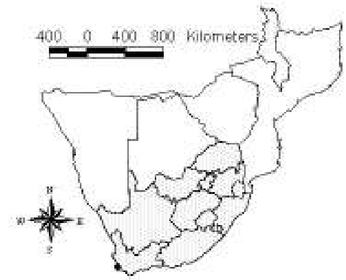
Species: *Trachycystis contabulata* Connolly, 1932
Distribution: KwaZulu-Natal and Eastern Cape.



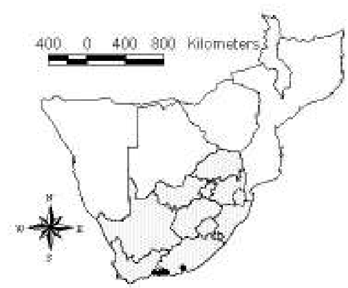
Species: *Trachycystis contrasta* Sirgel, 1980
Distribution: Western Cape peninsula.



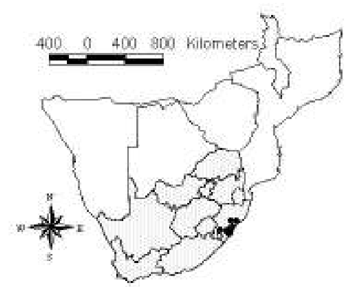
Species: *Trachycystis cosmia* (Pfeiffer, 1852)
Distribution: Western Cape peninsula.



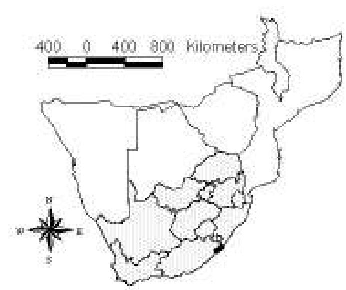
Species: *Trachycystis delicata* (Melvill & Ponsonby, 1895)
Distribution: Eastern Cape and Western Cape.



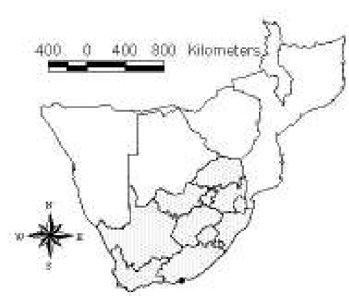
Species: *Trachycystis ectima* (Melvill & Ponsonby, 1899)
Distribution: KwaZulu-Natal.



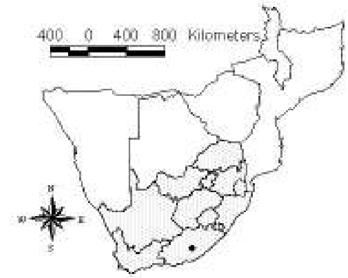
Species: *Trachycystis falconi* Connolly, 1939
Distribution: Coast of Eastern Cape (ponderland region).



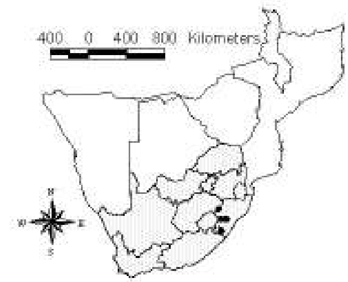
Species: *Trachycystis farquhari* (Melvill & Ponsonby, 1892)
Distribution: Eastern Cape.



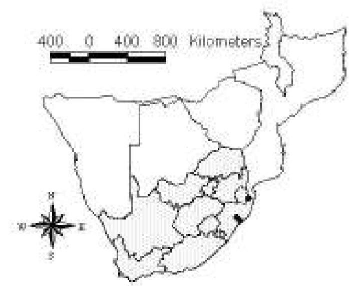
Species: *Trachycystis felina* Connolly, 1932
Distribution: Eastern Cape.



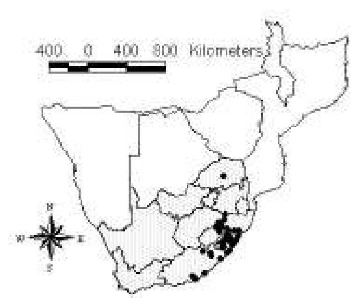
Species: *Trachycystis ferarum* Connolly, 1932
Distribution: Central KwaZulu-Natal.



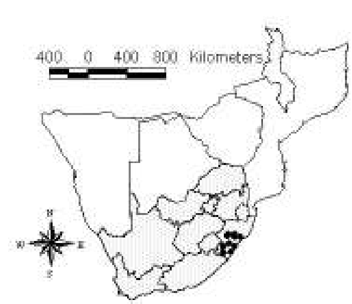
Species: *Trachycystis fossula* Connolly, 1927
Distribution: KwaZulu-Natal



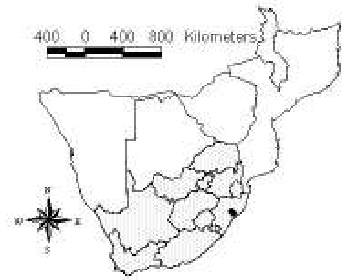
Species: *Trachycystis glanvilliana* (Ancey, 1893)
Distribution: Limpopo, KwaZulu-Natal and Eastern Cape.



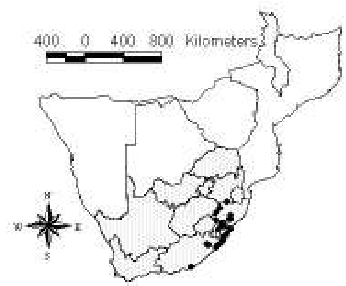
Species: *Trachycystis glebaria* Melvill & Ponsonby, 1903
Distribution: KwaZulu-Natal.



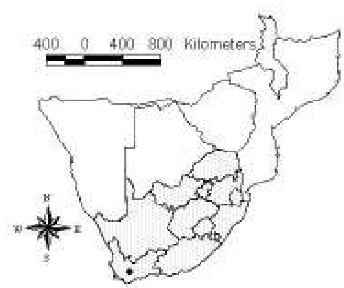
Species: *Trachycystis haygarthi* (Melvill & Ponsonby, 1899)
Distribution: KwaZulu-Natal.
Threatened – IUCN Red list 2004



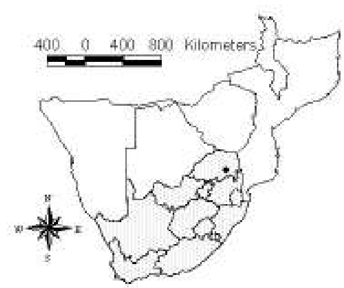
Species: *Trachycystis inclara* (Morelet, 1889)
Distribution: KwaZulu-Natal and Eastern Cape.



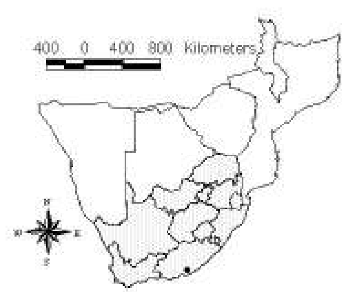
Species: *Trachycystis jucunda* Connolly, 1929
Distribution: Western Cape.



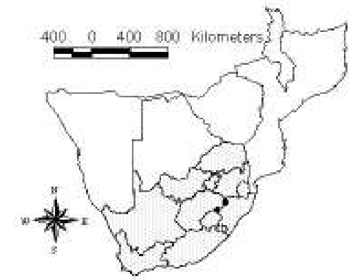
Species: *Trachycystis junodi* Connolly, 1922
Distribution: Limpopo.



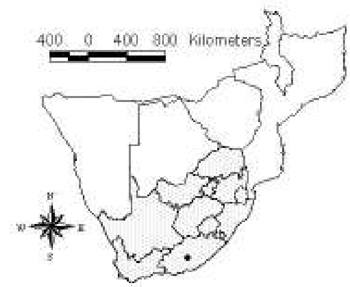
Species: *Trachycystis kincaidi* Connolly, 1932
Distribution: Eastern Cape.



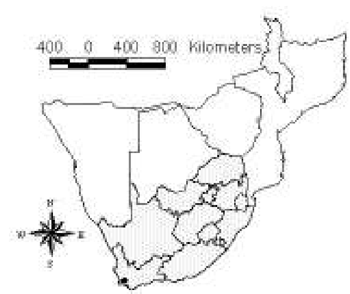
Species: *Trachycystis langi* Bruggen, 1994
Distribution: Drakensberg range in KwaZulu-Natal.



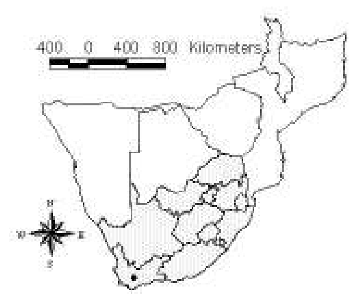
Species: *Trachycystis laticostata* Melvill & Ponsonby, 1903
Distribution: Eastern Cape.



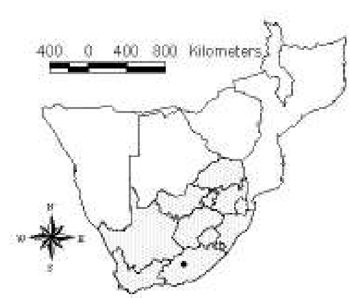
Species: *Trachycystis leucocarina* Sirgel, 1980
Distribution: Western Cape peninsula.



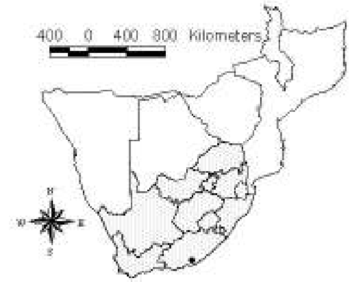
Species: *Trachycystis lightfootiana* (Melvill & Ponsonby, 1909)
Distribution: Western Cape.



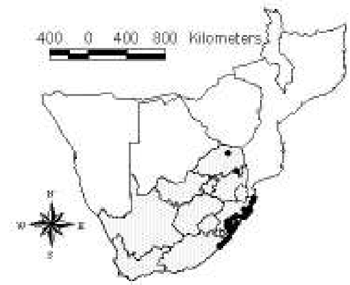
Species: *Trachycystis lignicola* Melvill & Ponsonby, 1898
Distribution: Eastern Cape.



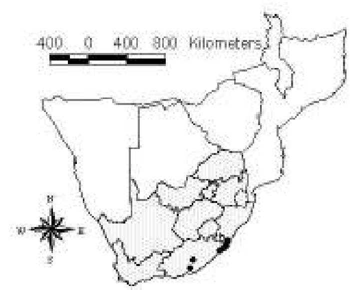
Species: *Trachycystis liricostata* (Melvill & Ponsonby, 1891)
Distribution: Eastern Cape.



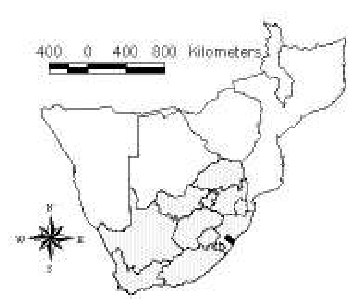
Species: *Trachycystis loveni* (Krauss, 1848)
Distribution: KwaZulu-Natal, Eastern Cape and Limpopo.



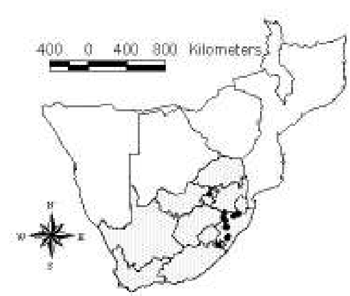
Species: *Trachycystis lunarls* Connolly, 1939
Distribution: Southern coast of KwaZulu-Natal and Eastern Cape.



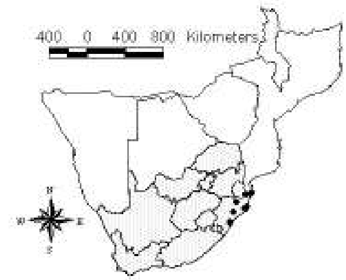
Species: *Trachycystis lygaea* Melvill & Ponsonby, 1892
Distribution: KwaZulu-Natal.



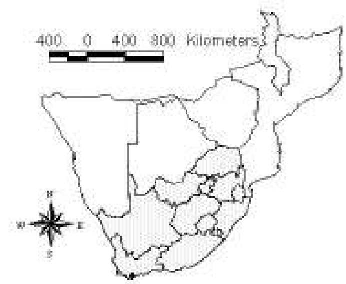
Species: *Trachycystis mcbeani* Connolly, 1932
Distribution: Gauteng and KwaZulu-Natal.



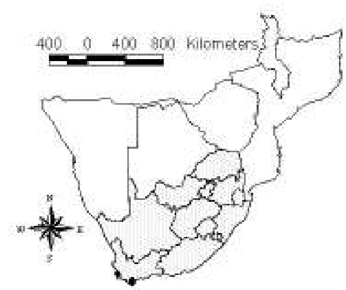
Species: *Trachycystis mcdowelli* Connolly, 1922
Distribution: Scattered distribution in KwaZulu-Natal.



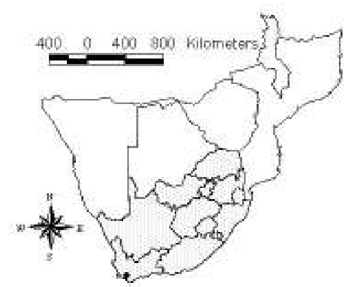
Species: *Trachycystis mediocris* Connolly, 1939
Distribution: Western Cape.



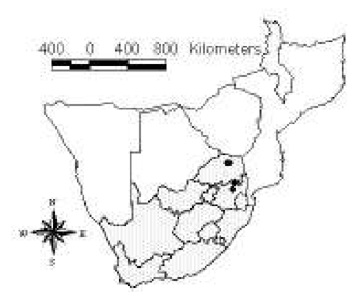
Species: *Trachycystis menkeana* (Pfeiffer, 1842)
Distribution: Western Cape peninsula.



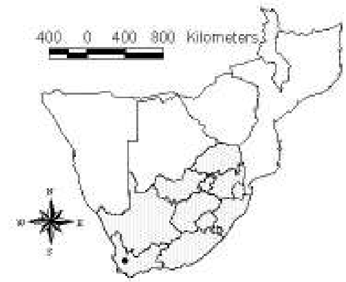
Species: *Trachycystis metallakter* Connolly, 1912
Distribution: Western Cape.



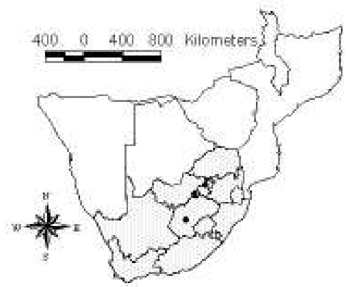
Species: *Trachycystis montissalinarum* Bruggen, 2002
Distribution: Mpumalanga and Limpopo.



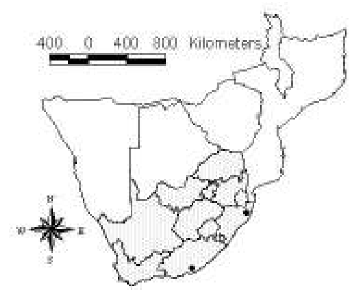
Species: *Trachycystis oconnori* (Preston, 1912)
Distribution: Western Cape.



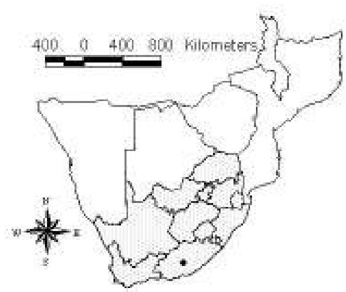
Species: *Trachycystis ordinaria* Melvill & Ponsonby, 1908
Distribution: Free State, North West and Gauteng.



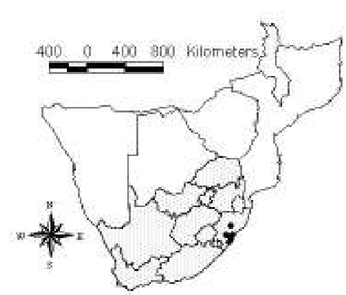
Species: *Trachycystis oreina* Melvill & Ponsonby, 1903
Distribution: Eastern Cape and KwaZulu-Natal.



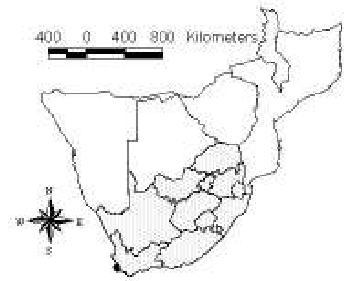
Species: *Trachycystis patera* Melvill & Ponsonby, 1903
Distribution: Eastern Cape.



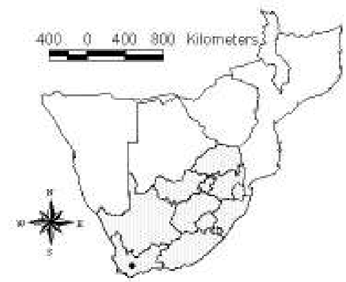
Species: *Trachycystis permeata* (Melvill & Ponsonby, 1904)
Distribution: KwaZulu-Natal.



Species: *Trachycystis perplicata* (Benson, 1851)
Distribution: Western Cape peninsula.



Species: *Trachycystis petrobia* (Benson, 1851)
Distribution: Western Cape.



Species: *Trachycystis placenta* (Melvill & Ponsonby, 1899)
Distribution: KwaZulu-Natal.
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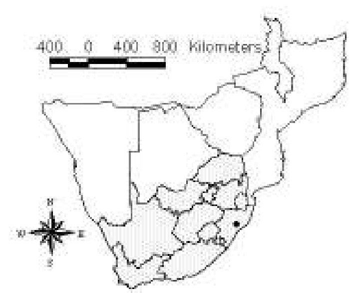
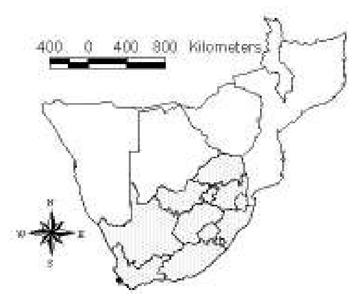
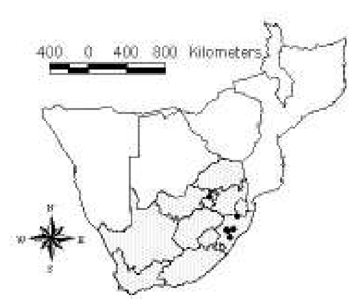


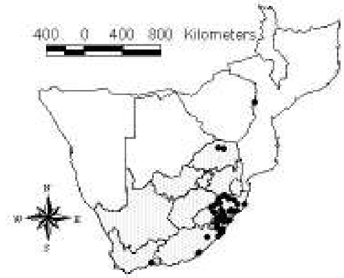
Species: *Trachycystis prionacis* (Benson, 1864)
Distribution: Western Cape peninsula.



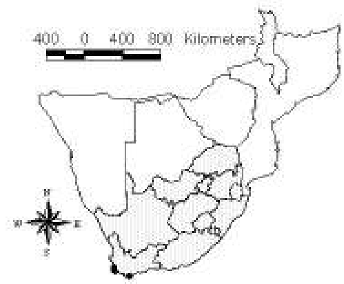
Species: *Trachycystis rivularis* (Krauss, 1848)
Distribution: KwaZulu-Natal and Gauteng.



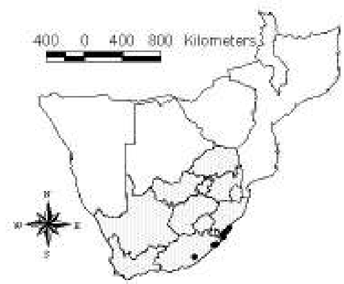
Species: *Trachycystis rudicostata* Connolly, 1923
Distribution: Widely distributed within KwaZulu-Natal and has a limited distribution in the Eastern Cape, Western Cape and Limpopo. Also occurs in Mozambique.



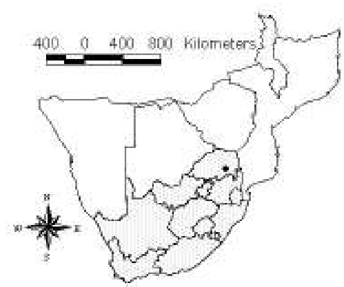
Species: *Trachycystis sabuletorum* (Benson, 1851)
Distribution: Western Cape peninsula.



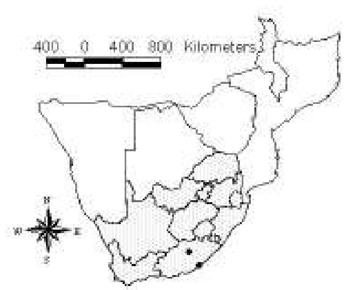
Species: *Trachycystis scolopendra* Melvill & Ponsonby, 1903
Distribution: KwaZulu-Natal and Eastern Cape.



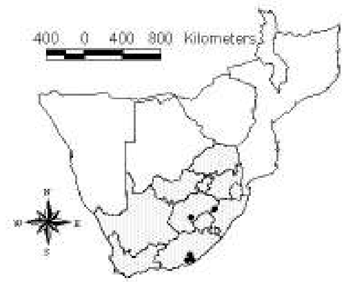
Species: *Trachycystis shilwaneensis* Connolly, 1922
Distribution: Limpopo.



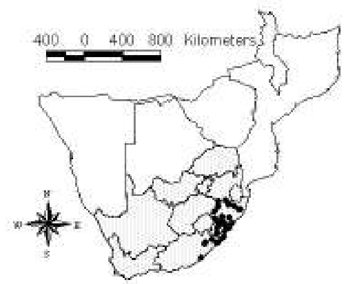
Species: *Trachycystis simplex* Melvill & Ponsonby, 1903
Distribution: Eastern Cape.



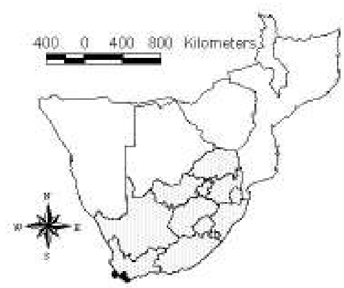
Species: *Trachycystis spissicosta* Melvill & Ponsonby, 1907
Distribution: Free State, KwaZulu-Natal and Eastern Cape.



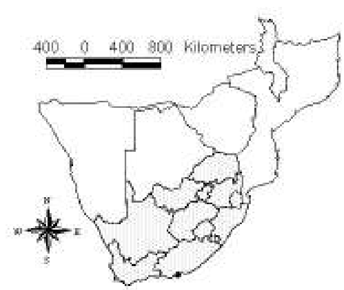
Species: *Trachycystis subpinguis* Connolly, 1922
Distribution: KwaZulu-Natal and has a limited distribution into the Eastern Cape.



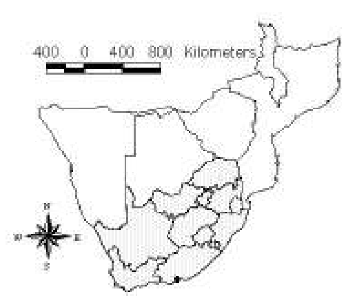
Species: *Trachycystis tollini* (Benson, 1856)
Distribution: Western Cape peninsula.



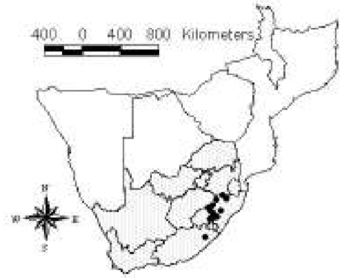
Species: *Trachycystis turmalis* (Morelet, 1889)
Distribution: Eastern Cape.



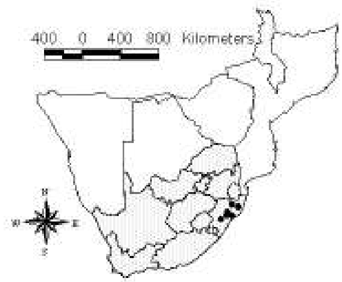
Species: *Trachycystis uitenhagensis* (Pfeiffer, 1846)
Distribution: Eastern Cape.



Species: *Trachycystis venatorum* Connolly, 1932
Distribution: Interior of KwaZulu-Natal and the Eastern Cape.

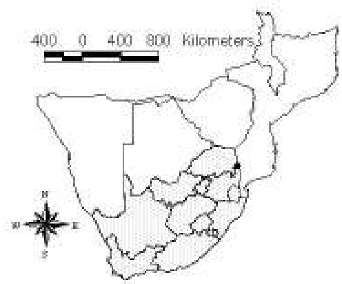


Species: *Trachycystis watsoni* Connolly, 1939
Distribution: Central and northern areas of KwaZulu-Natal.



Family: Chlamydephoridae

Species: *Chlamydephorus bruggeni* Forcart, 1967
Distribution: Kruger National Park, within the Limpopo province.



Species: *Chlamydephorus burnupi* (Smith, 1892)
Distribution: KwaZulu-Natal, Eastern Cape and within Lesotho.
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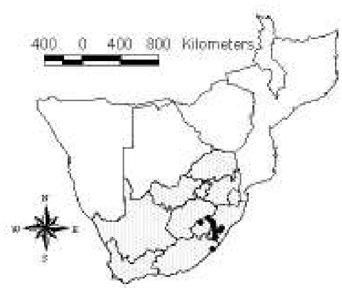
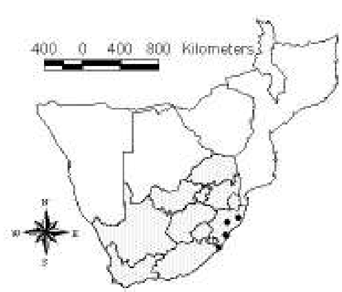
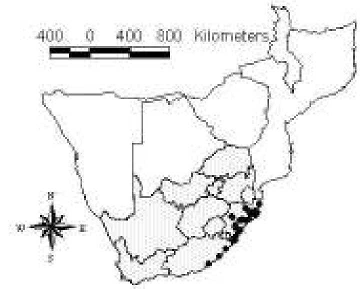


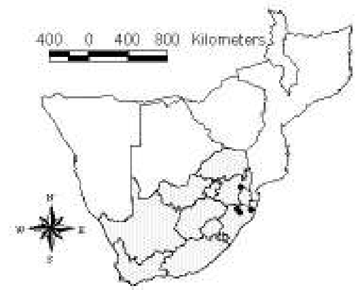
Species: *Chlamydephorus dimidius* (Watson, 1915)
Distribution: KwaZulu-Natal
Threatened – IUCN Red list 2004



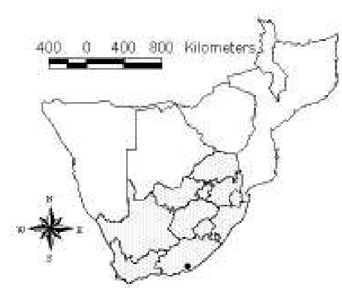
Species: *Chlamydephorus gibbonsi* Binney, 1879
Distribution: KwaZulu-Natal and Eastern Cape coast.



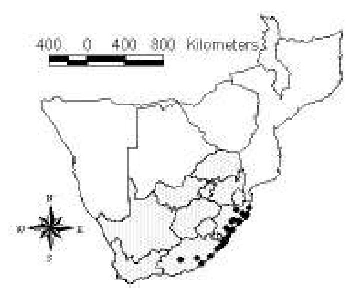
Species: *Chlamydephorus lawrencei* (Forcart, 1963)
Distribution: Mpumalanga and KwaZulu-Natal.



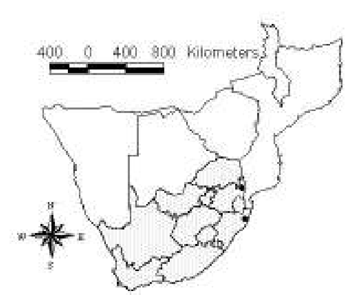
Species: *Chlamydephorus parva* Watson, 1915
Distribution: Eastern Cape.



Species: *Chlamydephorus sexangulus* (Watson, 1915)
Distribution: KwaZulu-Natal and Eastern Cape.

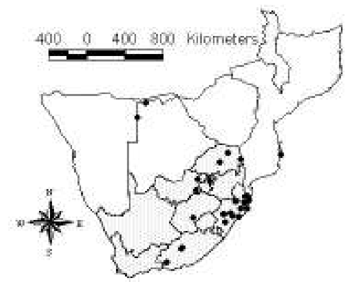


Species: *Chlamydephorus watsoni* Forcart, 1967
Distribution: KwaZulu-Natal and Mpumalanga.

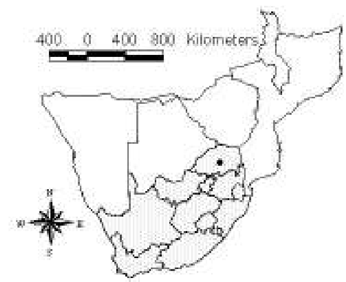


Family: Chondrinidae

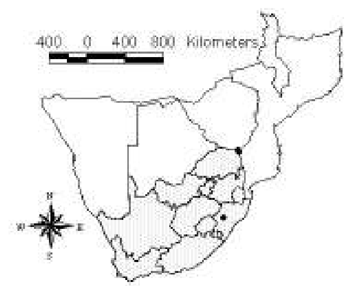
Species: *Gastrocopta damarica* (Ancey, 1888)
Distribution: Eastern Cape, KwaZulu-Natal, Limpopo, Gauteng, Free State and the North West province.



Species: *Gastrocopta duplicata* (Preston, 1911)
Distribution: Limpopo.

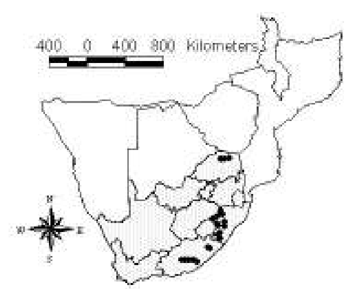


Species: *Gastrocopta thomasseti* Pilsbry, 1829
Distribution: KwaZulu-Natal and Limpopo.



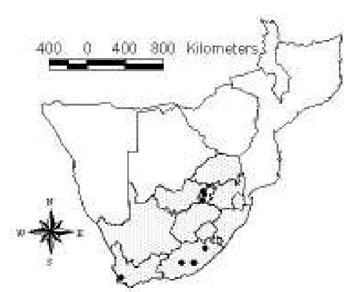
Family: Clausiliidae

Species: *Macroptychia africana* (Melvill & Ponsonby, 1899)
Distribution: Limpopo, KwaZulu-Natal and Eastern Cape.

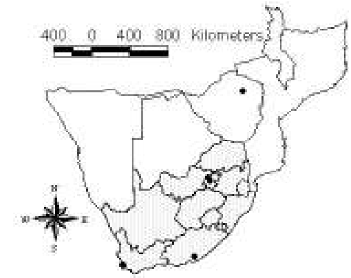


***Family: Cochlicopidae**

Species: **Cochlicopa lubrica (Müller, 1774)*
Distribution: Gauteng, Free State, Eastern Cape and the Western Cape peninsula.

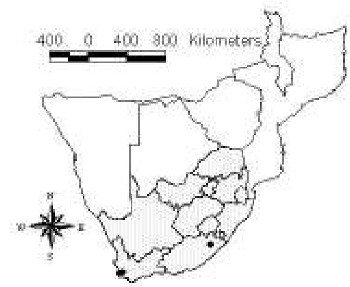


Species: **Cochlicopa lubricella* (Porro, 1838)
Distribution: Gauteng, Eastern Cape and the Western Cape peninsula as well as in Zimbabwe.



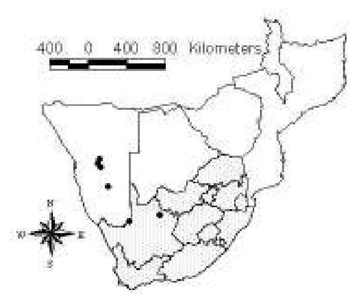
*Family: Discidae

Species: **Discus rotundatus* (Müller, 1774)
Distribution: Eastern Cape and the Western Cape penisula.

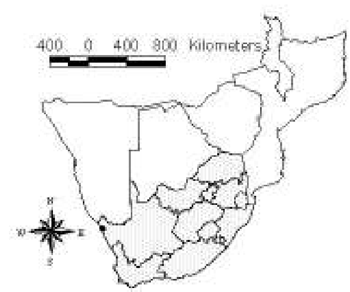


Family: Dorcasiidae

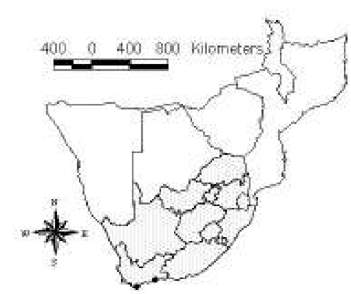
Species: *Dorcasia alexandri* Gray, 1838
Distribution: Interior of Namibia and in the Northern Cape.



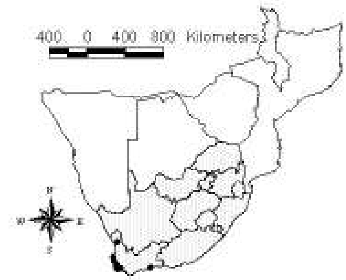
Species: *Dorcasia coagulum* (Martens, 1889)
Distribution: Coast of the Northern Cape.



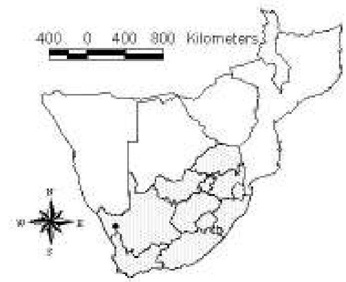
Species: *Trigonephrus ambiguosus* (Ferussac, 1821)
Distribution: Western Cape coast.



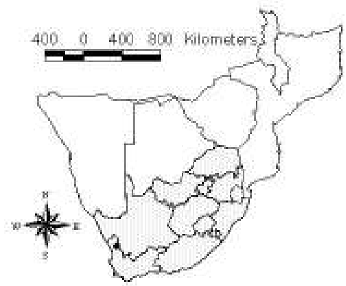
Species: *Trigonephrus globulus* (Müller, 1774)
Distribution: Coastal areas of the Western Cape.



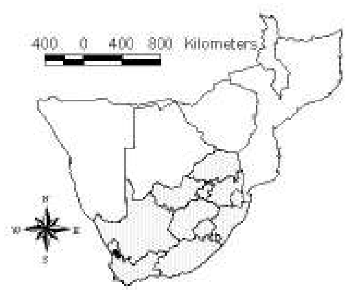
Species: *Trigonephorus gypsinus* (Melvill & Ponsonby, 1891)
Distribution: Northern Cape.



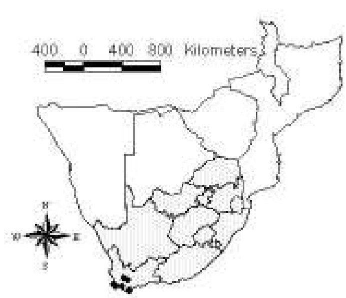
Species: *Trigonephrus heliocaustus* Connolly, 1929
Distribution: Western Cape.

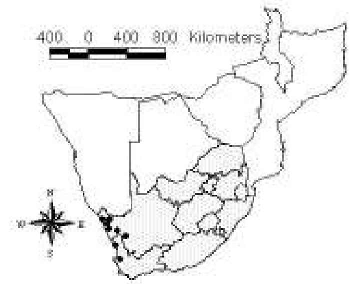


Species: *Trigonephrus latezonatus* Connolly, 1929
Distribution: Western Cape.

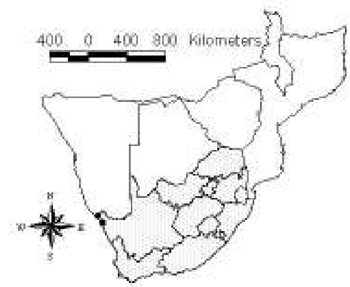


Species: *Trigonephrus lucanus* (Müller, 1774)
Distribution: Western Cape.

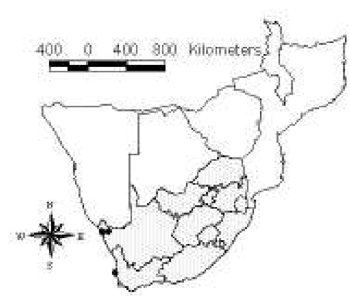




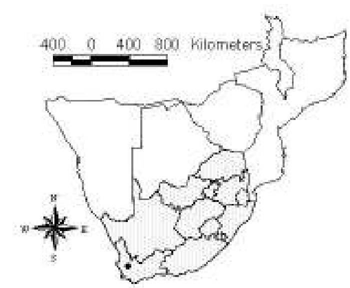
Species: *Trigonephrus namaquensis* (Melvill & Ponsonby, 1891)
Distribution: West coast of South Africa within the Northern Cape and Western Cape.



Species: *Trigonephrus porphyrostoma* (Melvill & Ponsonby, 1891)
Distribution: Coast of the Northern Cape.

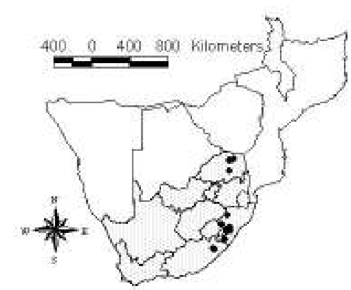


Species: *Trigonephrus rosaceus* (Müller, 1774)
Distribution: Western Cape and Northern Cape.



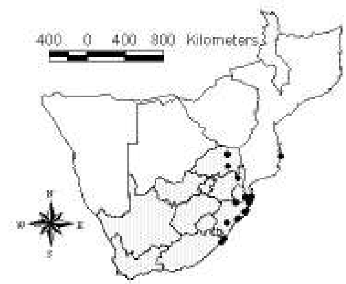
Species: *Tulbaghinia isomeriodes* (Melvill & Ponsonby, 1898)
Distribution: Western Cape.

Family: Euconulidae

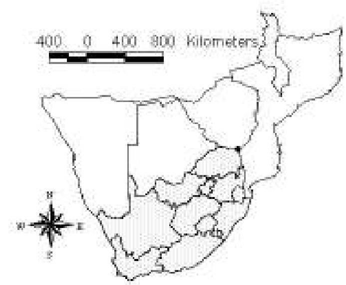


Species: *Afroconulus diaphanus* (Connolly, 1922)
Distribution: Interior of Limpopo, KwaZulu-Natal and Eastern Cape.

Species: *Afroguppya rumrutiensis* (Preston, 1911)
Distribution: Limpopo, Mpumalanga, KwaZulu-Natal, Eastern Cape and Mozambique.

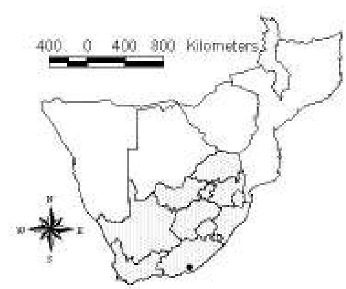


Species: *Afropuctum seminium* (Craven, 1880)
Distribution: Limpopo

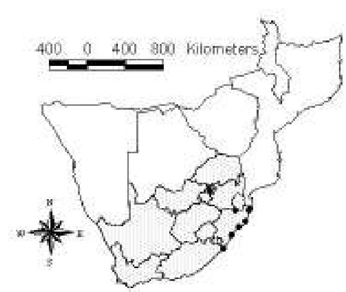


***Family: Ferrussaciidae**

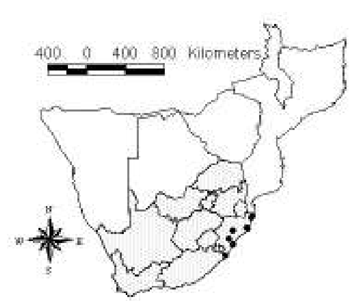
Species: **Cecilioides acicula* (Müller, 1774)
Distribution: Eastern Cape.



Species: *Cecilioides gokweanus* (Boettger, 1870)
Distribution: Gauteng and the KwaZulu-Natal coast.

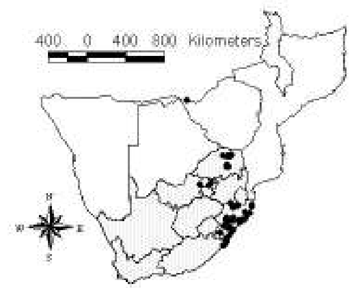


Species: *Cecilioides pergracllis* Connolly, 1939
Distribution: KwaZulu-Natal.

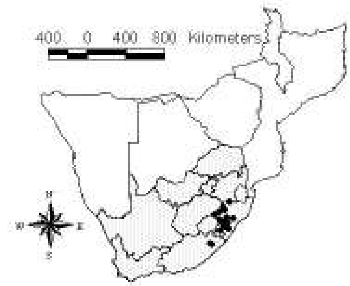


Family: Helicarionidae

Species: *Kaliella barrakporensis* (Pfeiffer, 1854)
Distribution: Eastern Cape, KwaZulu-Natal, Limpopo, North West, Gauteng and Zimbabwe.

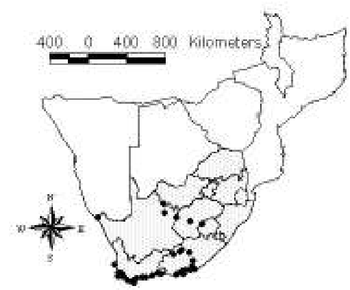


Species: *Kaliella euconuloides* Melvill & Ponsonby, 1908
Distribution: Inland areas of KwaZulu-Natal and Eastern Cape.

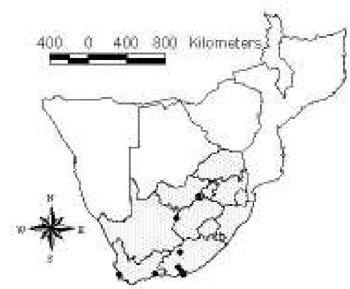


***Family: Helicidae**

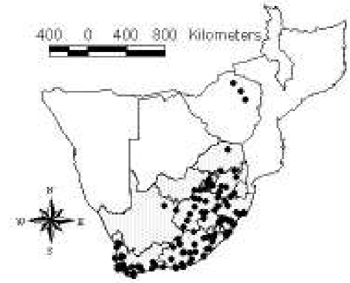
Species: **Cochlicella barbara* (Linnaeus, 1758)
Distribution: Eastern Cape, Western Cape, Northern Cape and Free State.



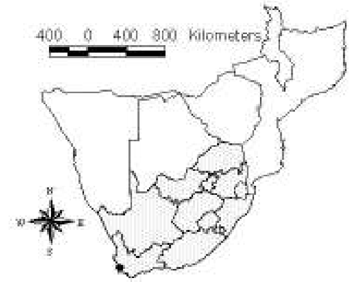
Species: **Eobania vermiculata* (Müller, 1774)
Distribution: Eastern Cape, Western Cape, Northern Cape and North West.



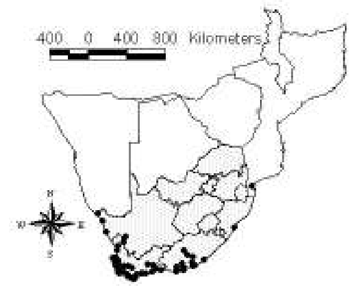
Species: **Helix aspersa* Müller, 1774
Distribution: Occurs in South Africa, Lesotho and Zimbabwe. Widely distributed in South Africa



Species: **Otala punctata* (Müller, 1774)
Distribution: Western Cape.

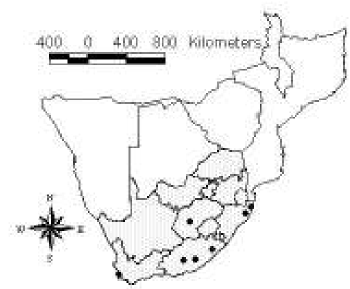


Species: **Theba pisana* (Müller, 1774)
Distribution: KwaZulu-Natal, Eastern Cape, Western Cape, Northern Cape and Mozambique.

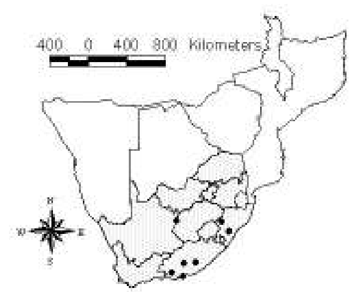


***Family: Limacidae**

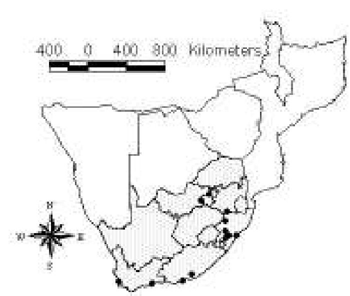
Species: **Lehmannia nyctelia* (Bourguignat, 1861)
Distribution: Free State, Western Cape, Eastern Cape and on the northern coast of KwaZulu-Natal.



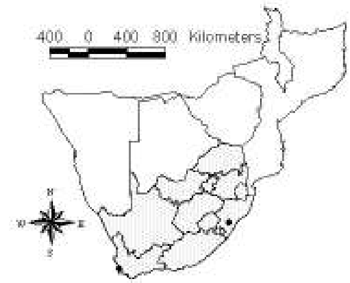
Species: **Lehmannia valentiana* (Férussac, 1823)
Distribution: KwaZulu-Natal, Eastern Cape and Northern Cape.



Species: **Limax flavus* Linnaeus, 1758
Distribution: KwaZulu-Natal, Eastern Cape, Western Cape, Gauteng and Mpumalanga.

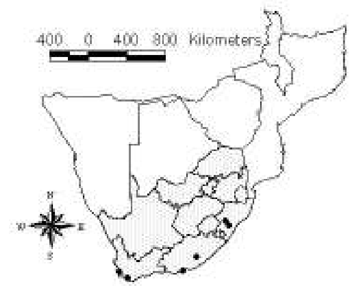


Species: **Limax maximus* Linnaeus, 1758
Distribution: KwaZulu-Natal and Western Cape.



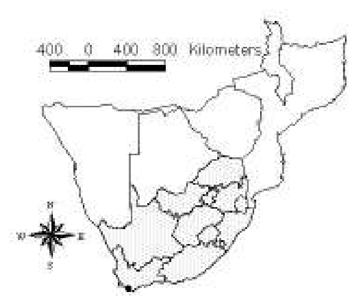
***Family: Milacidae**

Species: **Milax gagates* (Draparnaud, 1801)
Distribution: KwaZulu-Natal, Eastern Cape and Western Cape.

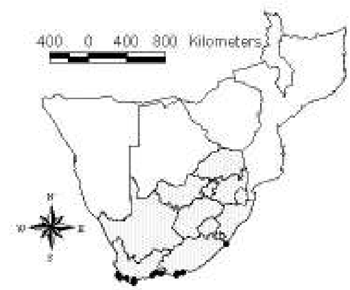


Family: Orculidae

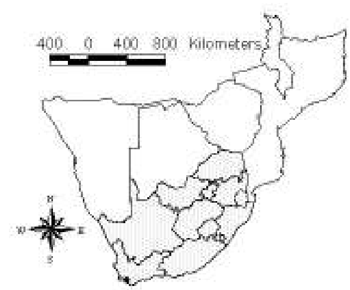
Species: *Fauxulus burnupianus* Pilsbry, 1928
Distribution: Western Cape peninsula.



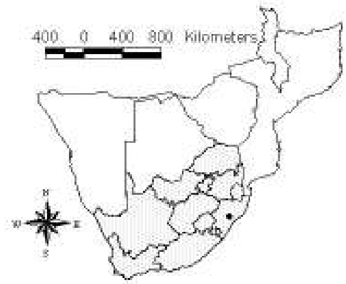
Species: *Fauxulus capensis* (Kuster, 1841)
Distribution: Coastal areas of the Eastern Cape and Western Cape.



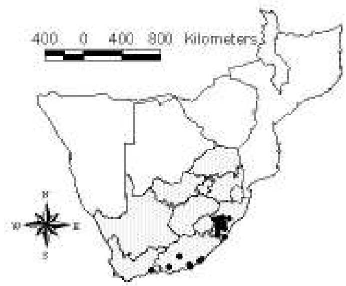
Species: *Fauxulus crawfordianus* Melvill & Ponsonby, 1903
Distribution: Western Cape peninsula.



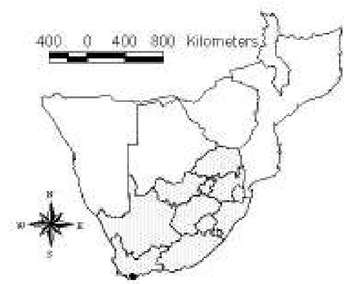
Species: *Fauxulus falconianus* Pilsbry, 1929
Distribution: KwaZulu-Natal.



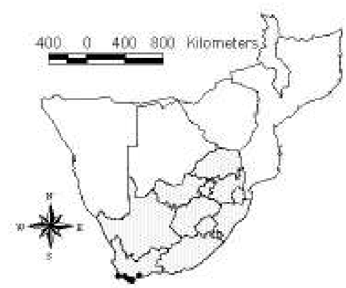
Species: *Fauxulus glanvilleanus* (Ancey, 1888)
Distribution: Western Cape, in the Eastern Cape as well as in the southern region of KwaZulu-Natal



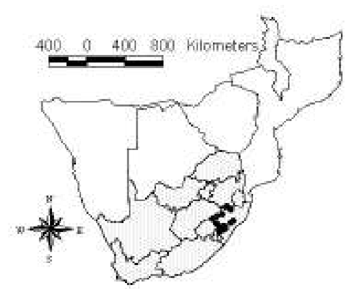
Species: *Fauxulus kurri fortidentata* Connolly, 1939
Distribution: Coastal areas of the Western Cape.



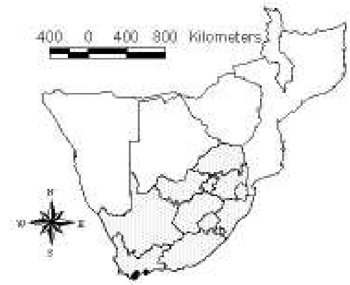
Species: *Fauxulus layardi* (Benson, 1856)
Distribution: Western Cape peninsula.



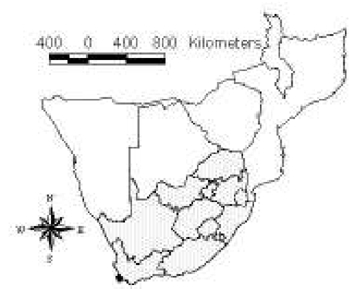
Species: *Fauxulus mcbeanianus* Melvill & Ponsonby, 1901
Distribution: Interior of KwaZulu-Natal.



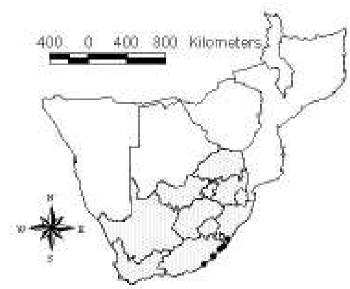
Species: *Fauxulus ovularis* (Kuster, 1841)
Distribution: Coastal areas of the Western Cape.



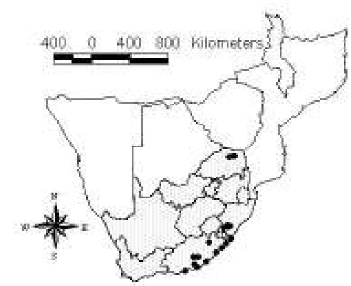
Species: *Fauxulus pamphorodon* (Benson, 1864)
Species: Western Cape peninsula.



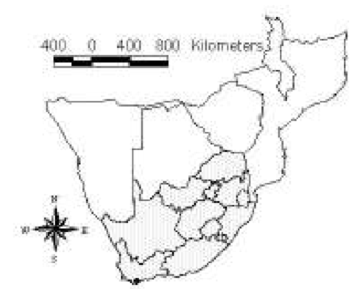
Species: *Fauxulus pereximius* (Melvill & Ponsonby, 1897)
Distribution: Coastal areas of KwaZulu-Natal and Eastern Cape.



Species: *Fauxulus ponsonbyanus* (Morelet, 1889)
Distribution: Limpopo, southern KwaZulu-Natal and Eastern Cape.

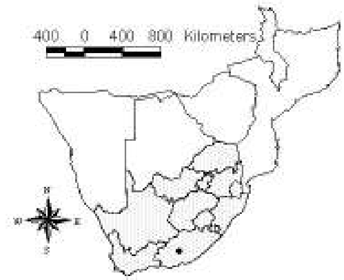


Species: *Fauxulus pycnochilus* Connolly, 1939
Distribution: Western Cape coast.

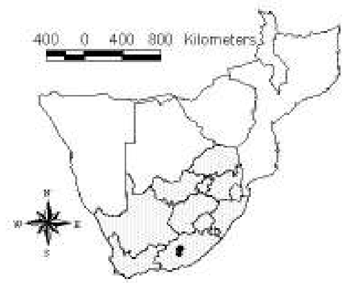


Family: Bulimulidae

Species: *Prestonella bowkeri* (Sowerby, 1889)
Distribution: Interior of the Eastern Cape.

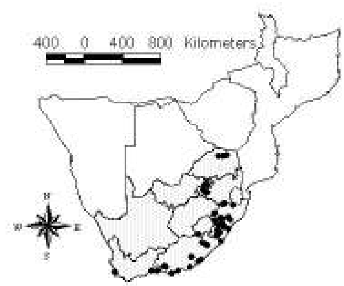


Species: *Prestonella nuptialis* (Melvill & Ponsonby, 1894)
Distribution: Interior of the Eastern Cape.



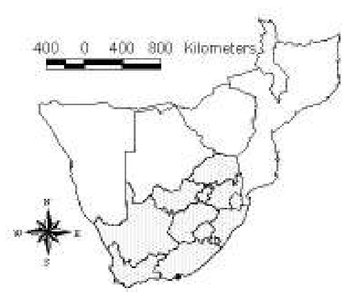
Family: Punctidae

Species: *Paralaoma hottentota* (Melvill & Ponsonby, 1891)
Distribution: Limpopo, Gauteng, KwaZulu-Natal, Eastern Cape and Western Cape.

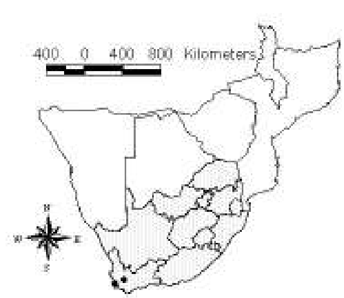


***Family: Pupillidae**

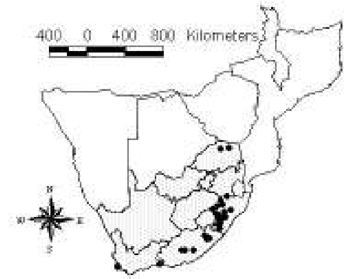
Species: *Lauria cryptoplax* (Melvill & Ponsonby, 1899)
Distribution: Eastern Cape coast.



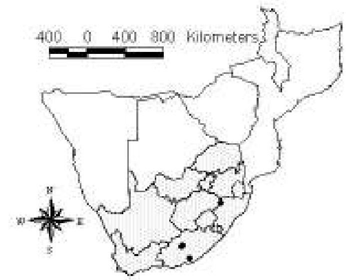
Species: **Lauria cylindracea* (da Costa, 1778)
Distribution: Western Cape.



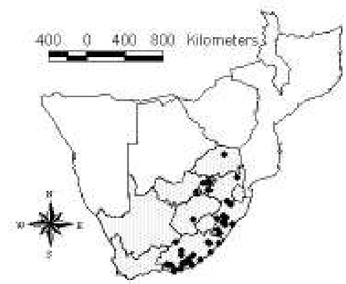
Species: *Lauria dadion* (Benson, 1864)
Distribution: Limpopo, KwaZulu-Natal, Eastern and Western Cape.



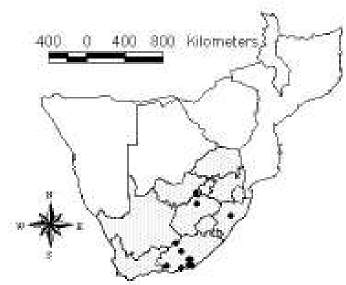
Species: *Lauria farquhari* (Melvill & Ponsonby, 1898)
Distribution: KwaZulu-Natal and Eastern Cape.



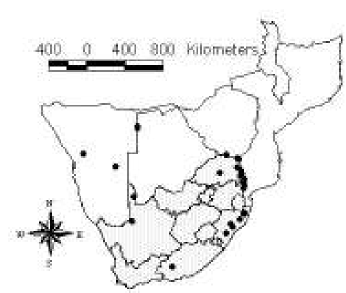
Species: *Pupilla fontana* (Krauss, l848)
Distribution: North West, Limpopo, Mpumalanga, Gauteng, KwaZulu-Natal, Eastern Cape and Free State provinces.



Species: *Pupilla tetrodus* (Boettger, 1870)
Distribution: Eastern Cape, Free State, KwaZulu-Natal and the North West province.

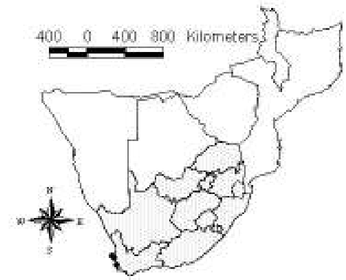


Species: *Pupoides calaharicus* (Boettger, 1886)
Distribution: Limpopo, Mpumalanga, KwaZulu-Natal, Northern Cape and Eastern Cape, Zimbabwe, Botswana and Namibia.

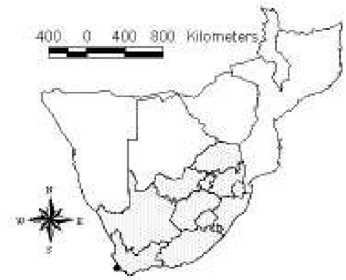


Family: Rhytididae

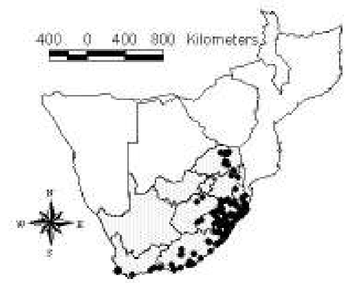
Species: *Nata dumeticola* (Benson, 1851)
Distribution: Western Cape peninsula.



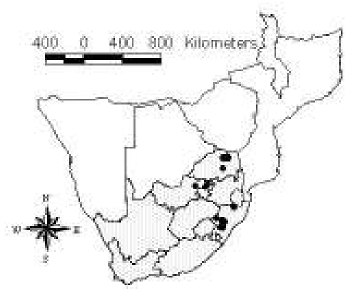
Species: *Nata tarachodes* (Connolly, 1912)
Distribution: Western Cape peninsula.



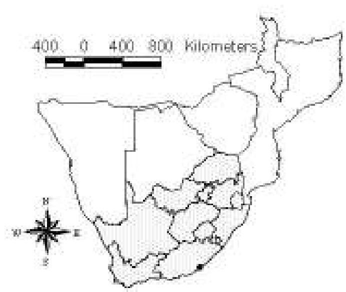
Species: *Nata vernicosa* (Krauss, 1848)
Distribution: Widely distributed in KwaZulu-Natal. The species also occurs in the Eastern Cape, Mpumalanga, Limpopo, Western Cape, Free State, Swaziland and Lesotho.



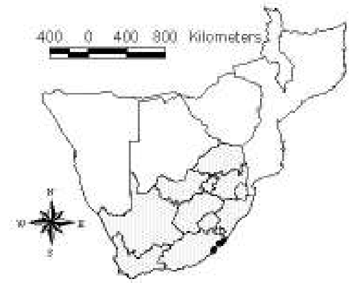
Species: *Nata viridescens* (Melvill & Ponsonby, 1891)
Distribution: North West, Gauteng, Limpopo and interior of KwaZulu-Natal.



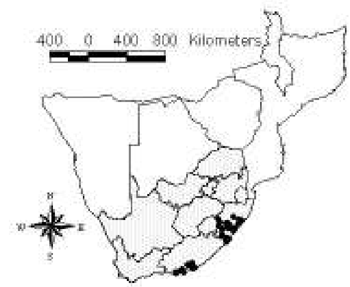
Species: *Natalina arguta* Melvill & Ponsonby, 1907
Distribution: Eastern Cape coast.



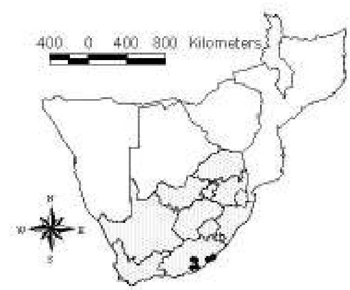
Species: *Natalina beyrichi* (Martens, 1890)
Distribution: Eastern Cape
Threatened – IUCN Red list 2004



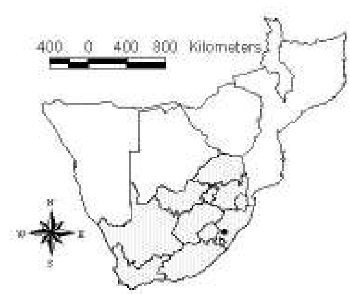
Species: *Natalina cafra* (Férussac, 1821)
Distribution: KwaZulu-Natal and Eastern Cape.



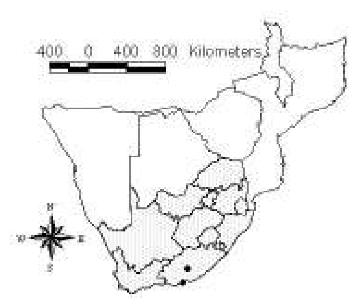
Species: *Natalina compacta* Connolly, 1939
Distribution: Eastern Cape.



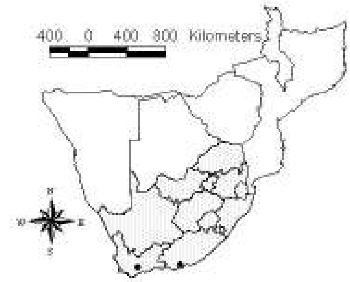
Species: *Natalina inhluzana* (Melvill & Ponsonby, 1894)
Distribution: KwaZulu-Natal.



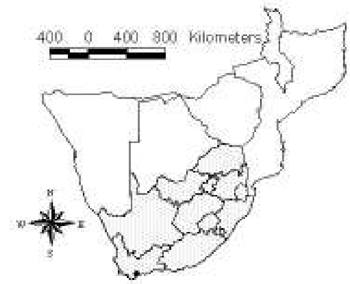
Species: *Natalina knysnaensis* (Pfeiffer, 1845)
Distribution: Eastern Cape.



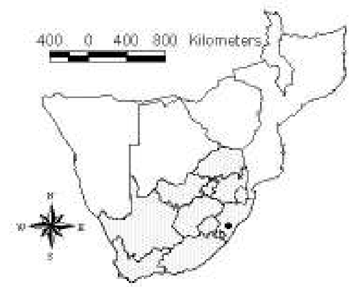
Species: *Natalina kraussi* (Pfeiffer, 1846)
Distribution: Eastern Cape and Western Cape.



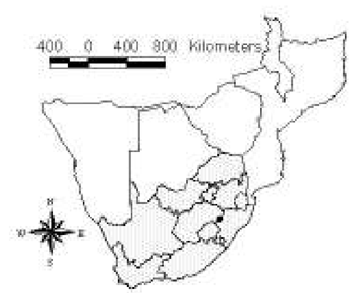
Species: *Natalina liliacea* Preston, 1912
Distribution: Western Cape coast.



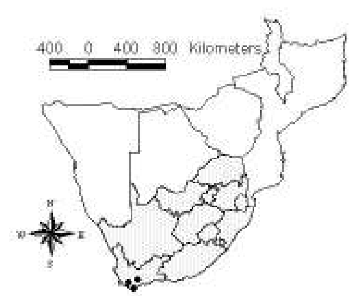
Species: *Natalina quekettiana* (Melvill & Ponsonby, 1893)
Distribution: KwaZulu-Natal.



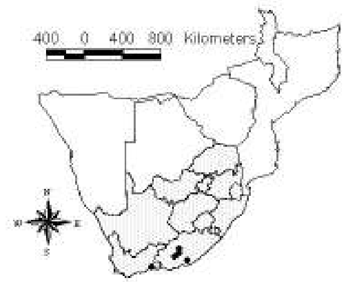
Species: *Natalina reenenensis* Connolly, 1939
Distribution: Drakensberg region, KwaZulu-Natal.



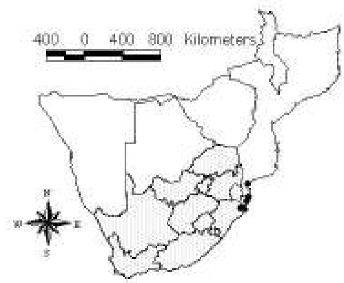
Species: *Natalina schaerfiae* (Pfeiffer, 1861)
Distribution: Western Cape coast.



Species: *Natalina trimeni* (Melvill & Ponsonby, 1892)
Distribution: Eastern Cape and Western Cape.

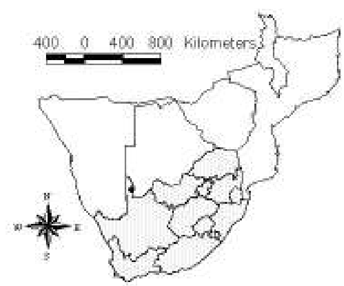


Species: *Natalina wesseliana* (Kobelt, 1876)
Distribution: Extending from the northern KwaZulu-Natal coast into the Mozambique.
Threatened – IUCN Red list 2004



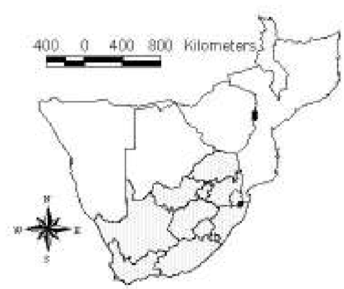
Family: Sculptariidae

Species: *Sculptaria namaquaensis* Zilch, 1939
Distribution: Northern Cape.

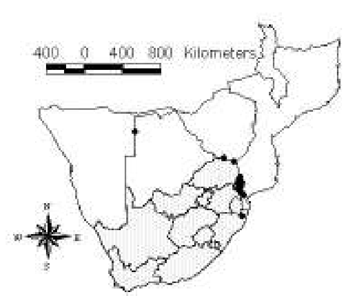


Family: Streptaxidae

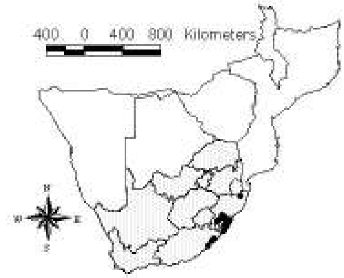
Species: *Eustreptaxis elongatus* (Fulton, 1899)
Distribution: Northern KwaZulu-Natal and Mozambique.



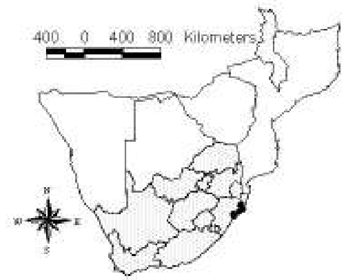
Species: *Gonaxis gwandaensis* (Preston, 1912)
Distribution: Northern KwaZulu-Natal, Mpumalanga, Limpopo, Botswana, Zimbabwe and Mozambique.



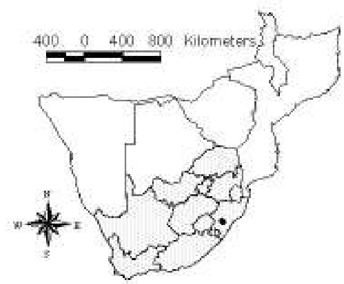
Species: *Gulella adamsiana* (Pfeiffer, 1859)
Distribution: KwaZulu-Natal and Eastern Cape.



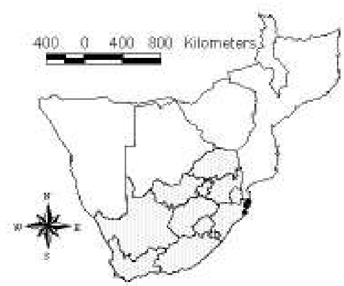
Species: *Gulella aliciae* (Melvill & Ponsonby, 1907)
Distribution: Coastal areas of northern KwaZulu-Natal.



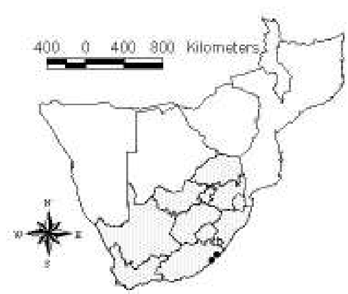
Species: *Gulella alutacea* Connolly, 1932
Distribution: Interior of KwaZulu-Natal.



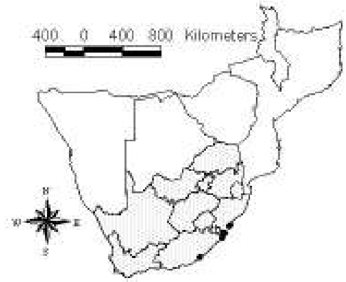
Species: *Gulella appletoni* Bruggen, 1975
Distribution: Northern coastal areas of KwaZulu-Natal.



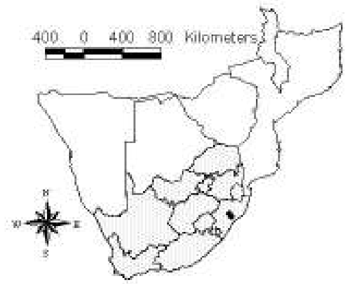
Species: *Gulella aprosdoketa* Connolly, 1939
Distribution: Coastal area of the Easte Cape.
Threatened – IUCN Red list 2004



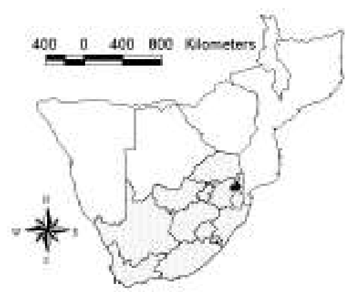
Species: *Gulella arnoldi* (Sturany, 1898)
Distribution: South coast of KwaZulu-Natal and Eastern Cape.



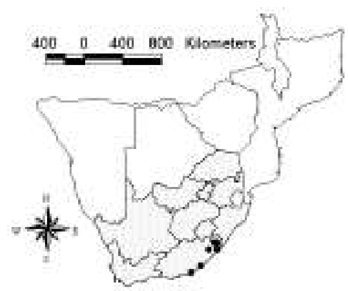
Species: *Gulella barbarae* Connolly, 1929
Distribution: KwaZulu-Natal.



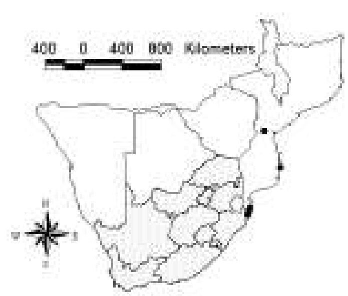
Species: *Gulella barnardi* Bruggen, 1965
Distribution: Mpumalanga.



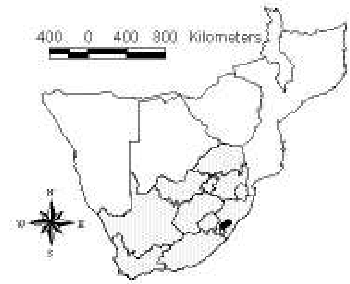
Species: *Gulella bowkerae* (Melvill & Ponsonby, 1892)
Distribution: Eastern Cape.



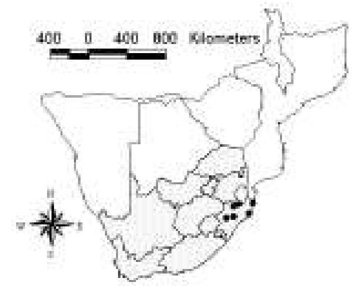
Species: *Gulella browni* Bruggen, 1969
Distribution: Northern coastal areas of KwaZulu-Natal and Mozambique.



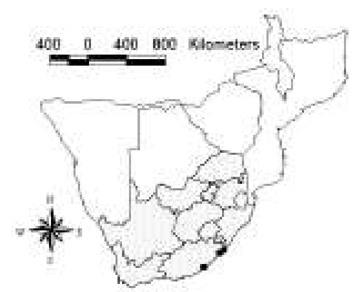
Species: *Gulella burnupi* (Melvill & Ponsonby, 1897)
Distribution: Interior of southern KwaZulu-Natal.



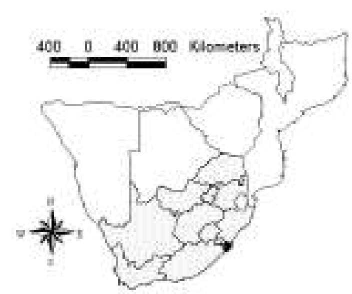
Species: *Gulella bushmanensis* Burnup, 1926
Distribution: Northern and central areas of KwaZulu-Natal.



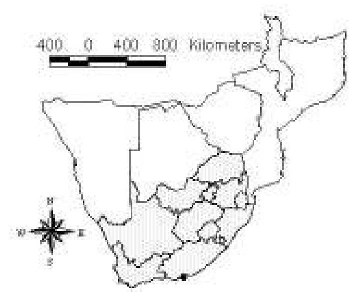
Species: *Gulella cairnsi* (Melvill & Ponsonby, 1897)
Distribution: Eastern Cape coast.



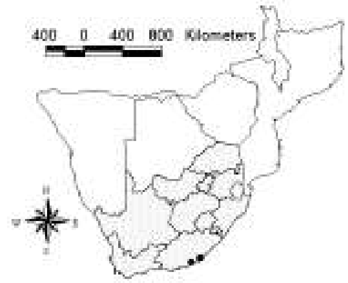
Species: *Gulella calopasa* (Melvill & Ponsonby, 1903)
Distribution: Southern coastal region of KwaZulu-Natal.



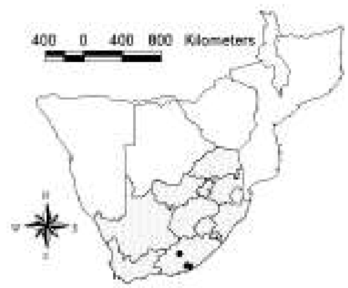
Species: *Gulella candidula* (Morelet, 1889)
Distribution: Eastern Cape



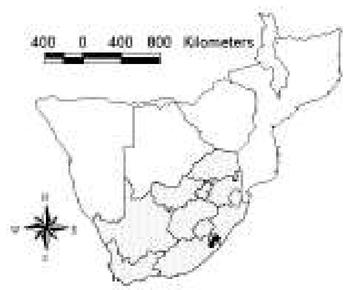
Species: *Gulella caryatis* (Melvill & Ponsonby, 1898)
Distribution: Eastern Cape.



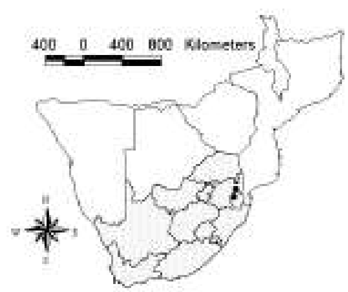
Species: *Gulella chi* Burnup, 1926
Distribution: Eastern Cape coast.



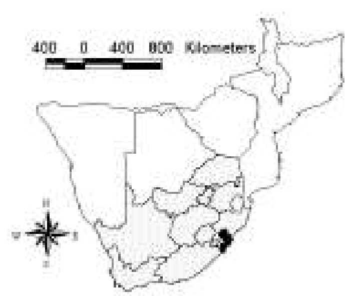
Species: *Gulella claustralis* Connolly, 1939
Distribution: Eastern Cape and KwaZulu-Natal.
Threatened – IUCN Red list 2004



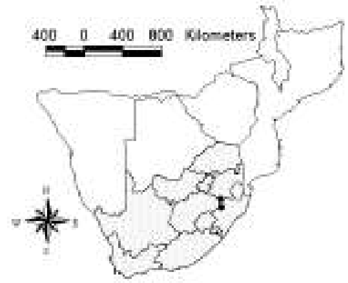
Species: *Gulella collicola* Bruggen, 1966
Distribution: Mpumalanga and Swaziland.



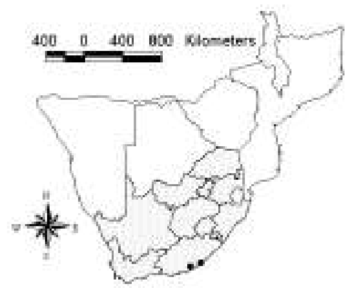
Species: *Gulella columnella* (Melvill & Ponsonby, 1901)
Distribution: Southern KwaZulu-Natal.



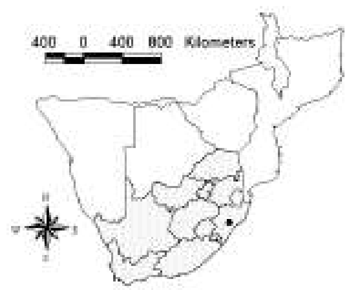
Species: *Gulella connollyi* (Melvill & Ponsonby, 1909)
Distribution: Drakensberg area of KwaZulu-Natal.



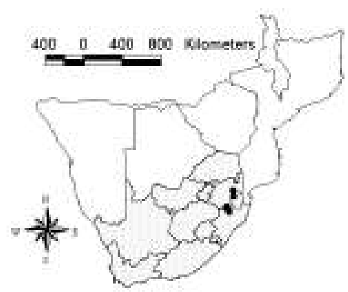
Species: *Gulella consobrina* (Ancey, 1892)
Distribution: Eastern Cape coast.



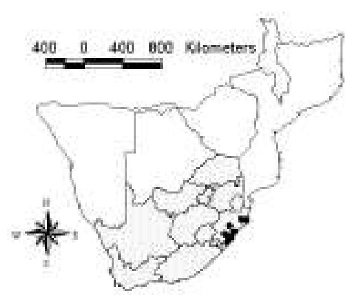
Species: *Gulella contingens* Burnup, 1925
Distribution: Interior of KwaZulu-Natal.



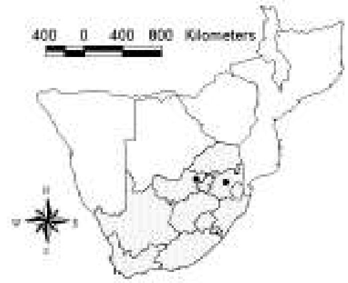
Species: *Gulella contraria* Connolly, 1932
Distribution: Interior of KwaZulu-Natal, Mpumalanga and Swaziland.



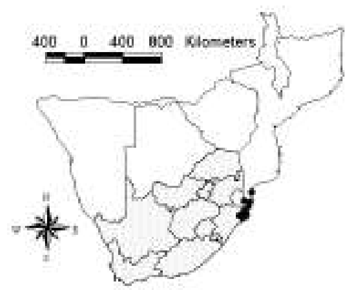
Species: *Gulella crassidens* (Pfeiffer, 1859)
Distribution: KwaZulu-Natal.



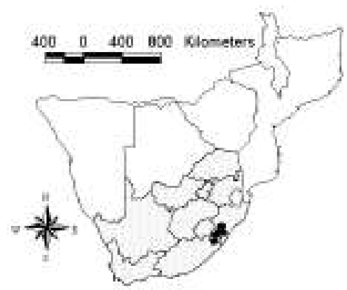
Species: *Gulella crassilabris* (Craven, 1880)
Distribution: North West province and Mpumalanga.



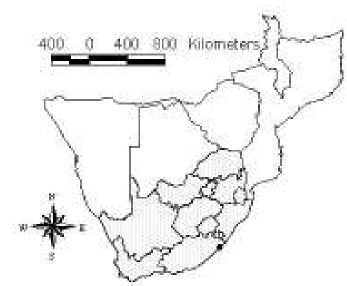
Species: *Gulella daedalea* (Melvill & Ponsonby, 1903)
Distribution: Extending from the northern coastal areas of KwaZulu-Natal into Mozambique.



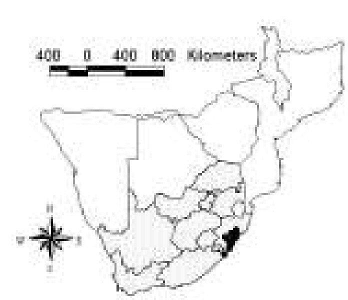
Species: *Gulella darglensis* (Melvill & Ponsonby, 1908)
Distribution: Southern KwaZulu-Natal and Eastern Cape.



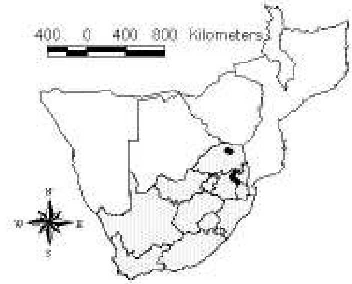
Species: *Gulella dejae* Bursey & Herbert, 2004
Distribution: Eastern Cape.



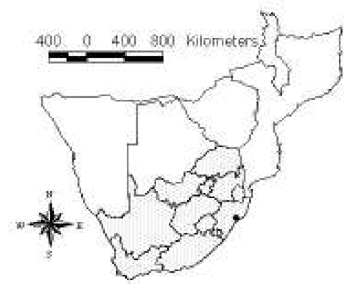
Species: *Gulella delicatula* (Pfeiffer, 1856)
Distribution: KwaZulu-Natal.



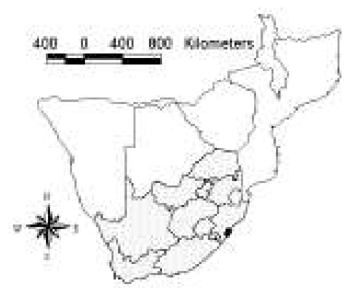
Species: *Gulella deviae sp. n.* Herbert ms
Distribution: Limpopo and Mpumalanga.



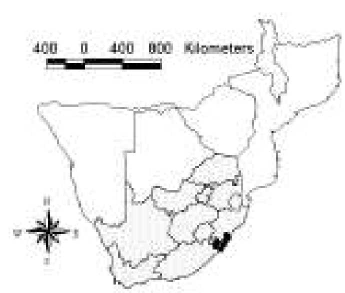
Species: *Gulella dextrorsa* Burnup, 1925
Distribution: KwaZulu-Natal.



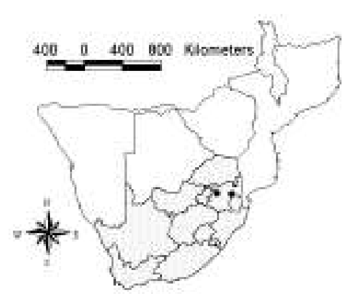
Species: *Gulella digitalis* Connolly, 1939
Distribution: South coast of KwaZulu-Natal.



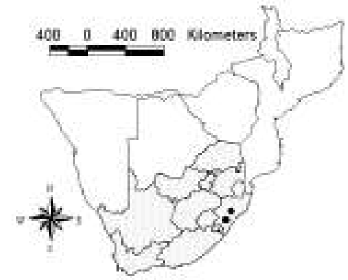
Species: *Gulella discrepans* (Sturany, 1898)
Distribution: Southern KwaZulu-Natal and Eastern Cape.



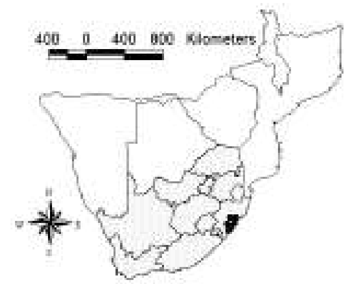
Species: *Gulella distincta* (Melvill & Ponsonby, 1893)
Distribution: Mpumalanga.



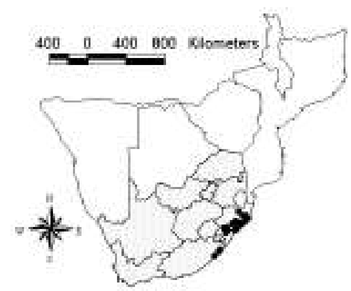
Species: *Gulella drakensbergensis* (Melvill & Ponsonby, 1893)
Distribution: Interior of KwaZulu-Natal.



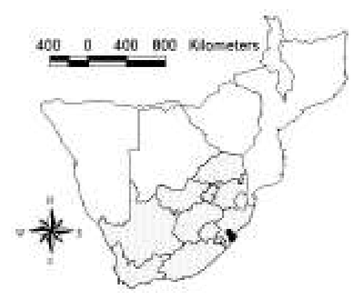
Species: *Gulella dunkeri* (Pfeiffer, 1855)
Distribution: KwaZulu-Natal.



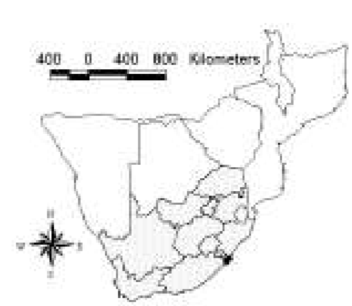
Species: *Gulella elliptica* (Melvill & Ponsonby, 1898)
Distribution: KwaZulu-Natal and the Eastern Cape coast.



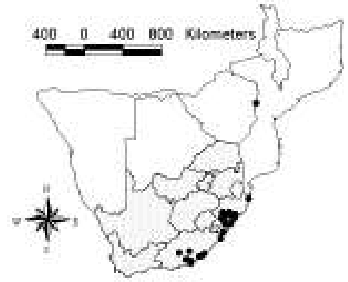
Species: *Gulella euthymia* (Melvill & Ponsonby, 1893)
Distribution: Southern KwaZulu-Natal.



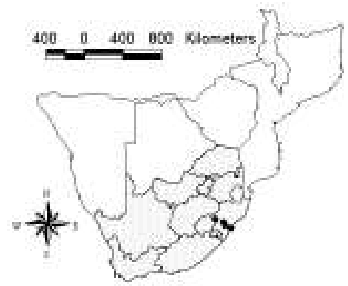
Species: *Gulella falconi* Burnup, 1925
Distribution: Southern coast of KwaZulu-Natal and Eastern Cape.



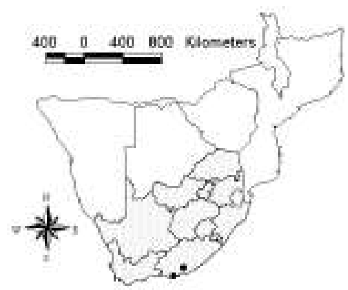
Species: *Gulella farquhari* (Melvill & Ponsonby, 1895)
Distribution: KwaZulu-Natal, Eastern Cape and Mozambique.



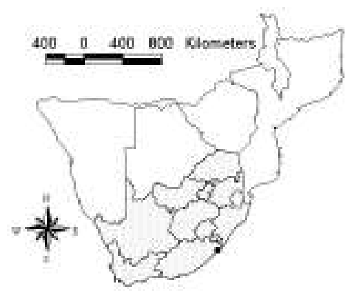
Species: *Gulella formosa* (Melvill & Ponsonby, 1898)
Distribution: KwaZulu-Natal.



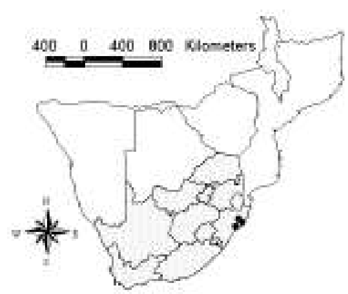
Species: *Gulella framesi* Burnup, 1926
Distribution: Eastern Cape coastal area.



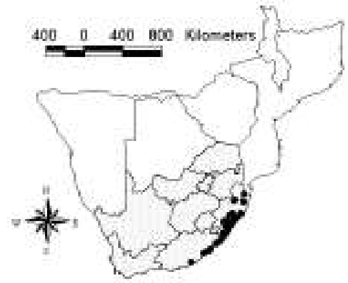
Species: *Gulella fraudator* Connolly, 1939
Distribution: Eastern Cape coast.



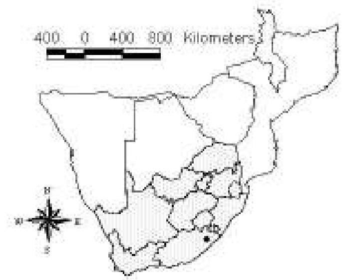
Species: *Gulella genialis* (Melvill & Ponsonby, 1903)
Distribution: Northern KwaZulu-Natal.



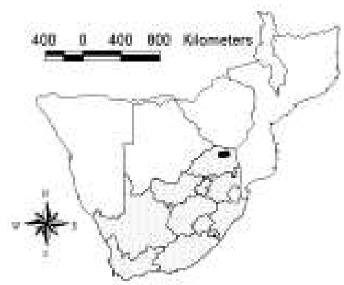
Species: *Gulella gouldi* (Pfeiffer, 1855)
Distribution: Eastern Cape coast and KwaZulu-Natal.



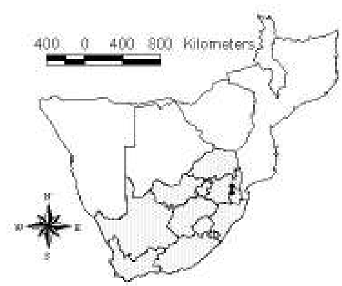
Species: *Gulella hamerae* Bursey & Herbert, 2004
Distribution: Eastern Cape



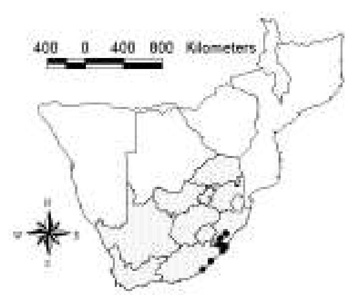
Species: *Gulella harriesi* Burnup, 1926
Distribution: Central and northern areas of Limpopo.

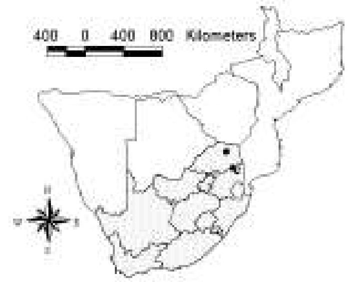


Species: *Gulella herberti* Bruggen, 2004
Distribution: Swaziland and Mpumalanga.

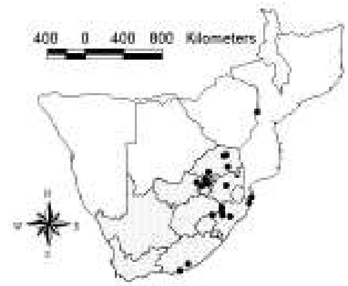


Species: *Gulella himerothales* (Melvill & Ponsonby, 1903)
Distribution: Southern KwaZulu-Natal and Eastern Cape coast.

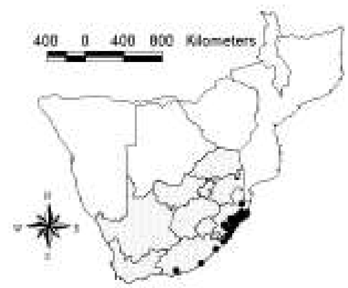




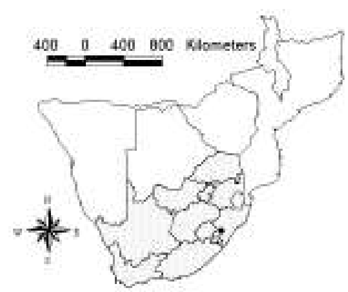
Species: *Gulella incurvidens* Bruggen, 1972
Distribution: Limpopo.



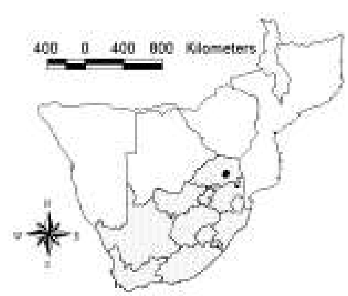
Species: *Gulella infans* (Craven, 1880)
Distribution: Mozambique, KwaZulu-Natal, Mpumalanga, Gauteng, Limpopo, Eastern Cape and the North West province.



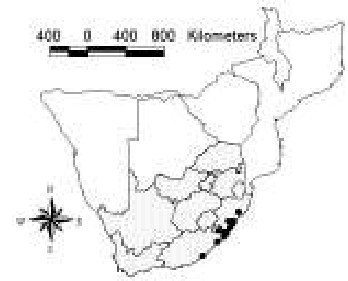
Species: *Gulella infrendens* (Martens, 1866)
Distribution: KwaZulu-Natal and the coastal areas of Eastern Cape.



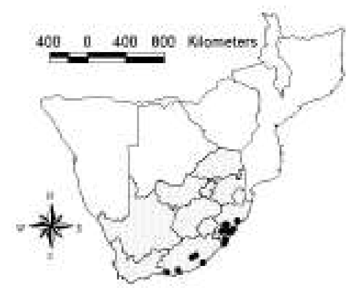
Species: *Gulella inhluzaniensis* (Burnup, 1914)
Distribution: Interior of KwaZulu-Natal.



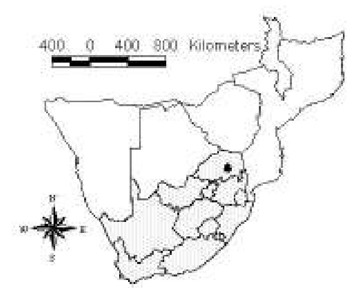
Species: *Gulella inobstructa* Bruggen, 1965
Distribution: Limpopo.



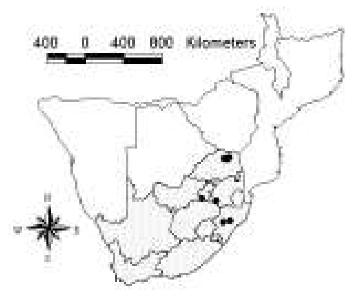
Species: *Gulella instabilis* (Sturany, 1898)
Distribution: KwaZulu-Natal and Eastern Cape.



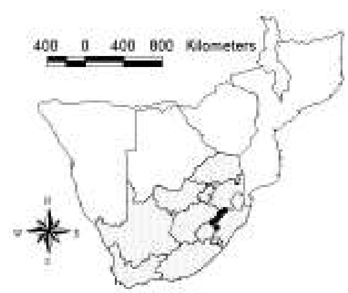
Species: *Gulella isipingoensis* (Sturany, 1898)
Distribution: KwaZulu-Natal and in the Eastern Cape.



Species: *Gulella johannae sp. n. ms van Bruggen* Bruggen ms
Distribution: Limpopo.

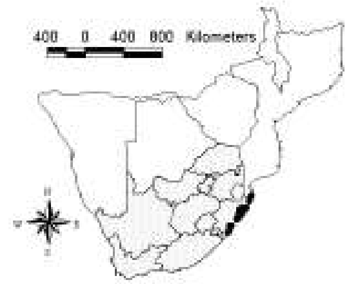


Species: *Gulella johannesburgensis* (Melvill & Ponsonby, 1907)
Distribution: KwaZulu-Natal, Limpopo, Mpumalanga and Gauteng.

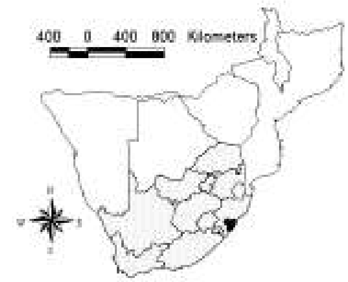


Species: *Gulella juxtidens* (Melvill & Ponsonby, 1899)
Distribution: Central and northern KwaZulu-Natal; along the Drakensberg range.

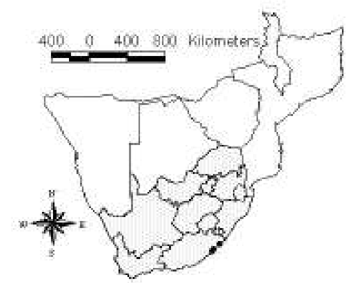
Species: *Gulella kosiensis* (Melvill & Ponsonby, 1908)
Distribution: KwaZulu-Natal.



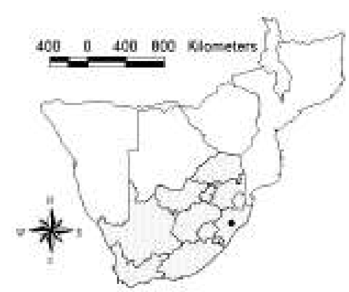
Species: *Gulella kraussi* (Pfeiffer, 1855)
Distribution: KwaZulu-Natal.



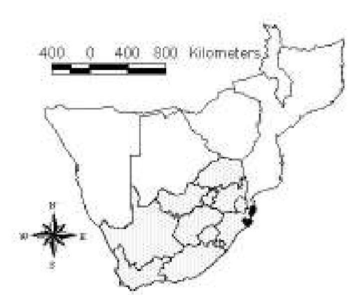
Species: *Gulella latimerae* Bursey & Herbert, 2004
Distribution: Eastern Cape.



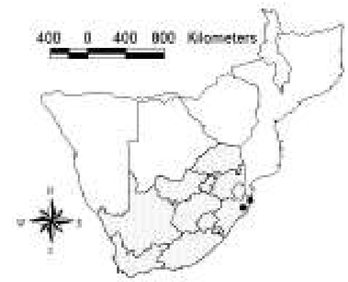
Species: *Gulella leucocion* Connolly, 1929
Distribution: KwaZulu-Natal.



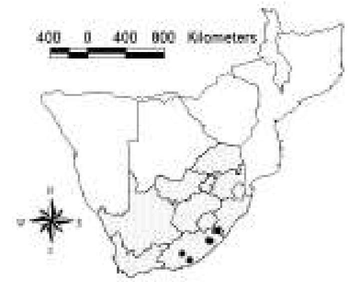
Species: *Gulella lindae sp. n.* Herbert ms
Distribution: Northern KwaZulu-Natal.



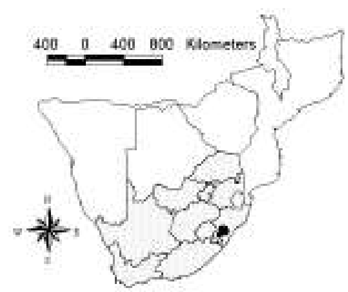
Species: *Gulella linguidens* Connolly, 1939
Distribution: Northern KwaZulu-Natal.



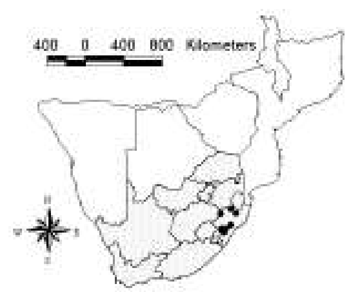
Species: *Gulella mariae* (Melvill & Ponsonby, 1892)
Distribution: Eastern Cape and the interior of KwaZulu-Natal.



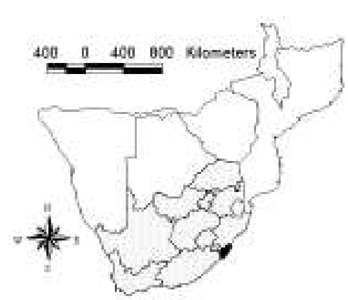
Species: *Gulella maritzburgensis* (Melvill & Ponsonby, 1893)
Distribution: Interior in KwaZulu-Natal.



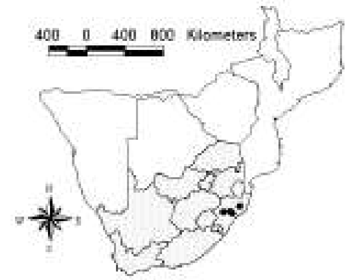
Species: *Gulella melvilli* (Burnup, 1914)
Distribution: Interior of KwaZulu-Natal.



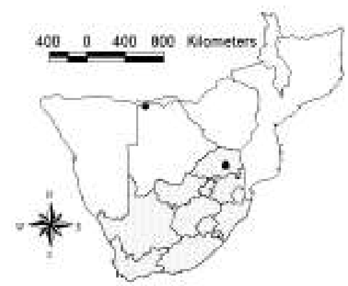
Species: *Gulella menkeana* (Pfeiffer, 1853)
Distribution: Southern coast of KwaZulu-Natal and the northern parts of the Eastern Cape coast.



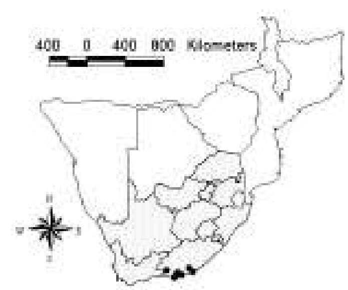
Species: *Gulella mfongosiensis* Burnup, 1925
Species: Northern interior of KwaZulu-Natal



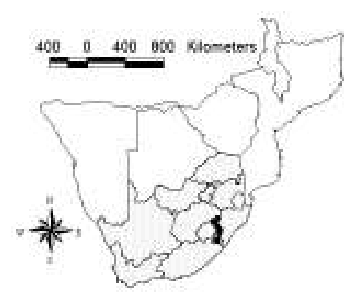
Species: *Gulella miniata* (Krauss, 1848)
Distribution: Limpopo and northern area of Botswana.



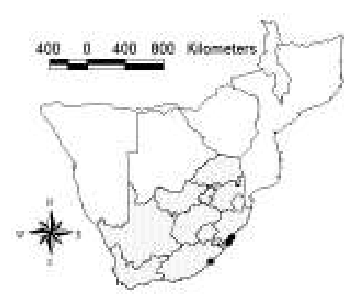
Species: *Gulella minuta* (Morelet, 1889)
Distribution: Eastern Cape coast.



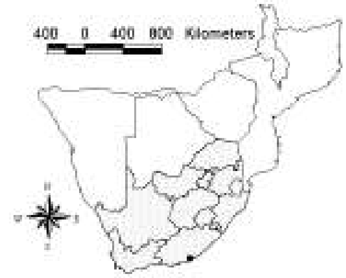
Species: *Gulella mooiensis* (Burnup, 1914)
Distribution: Central and southern Drakensberg KwaZulu-Natal.



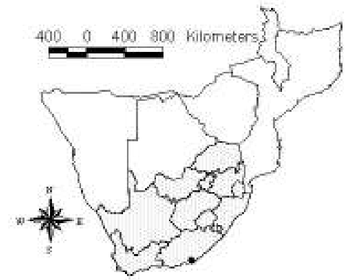
Species: *Gulella multidentata* (Sturany, 1898)
Distribution: Southern coast of KwaZulu-Natal and the Eastern Cape coast.



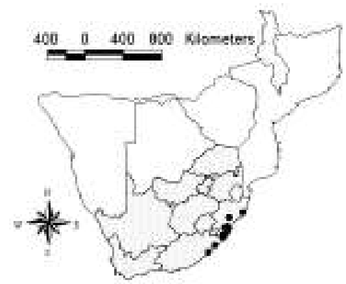
Species: *Gulella munita* (Melvill & Ponsonby, 1892)
Distribution: Eastern Cape



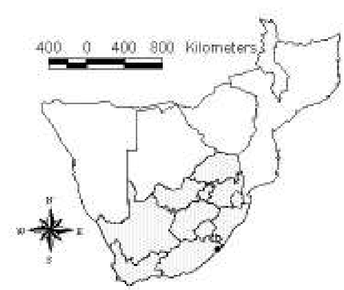
Species: *Gulella munuta* (Melvill & Ponsonby, 1892)
Distribution: Eastern Cape coast.



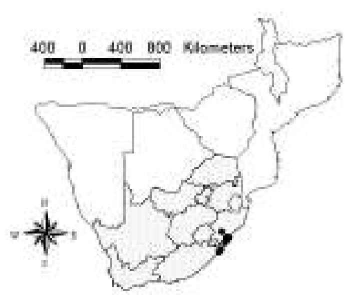
Species: *Gulella natalensis* (Craven, 1880)
Distribution: KwaZulu-Natal and Eastern Cape.



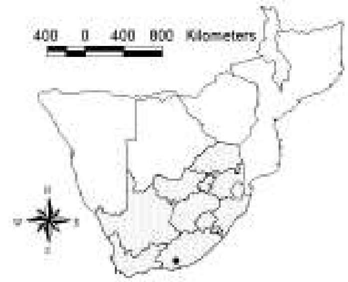
Species: *Gulella newmani* Bursey & Herbert, 2004
Distribution: Eastern Cape.



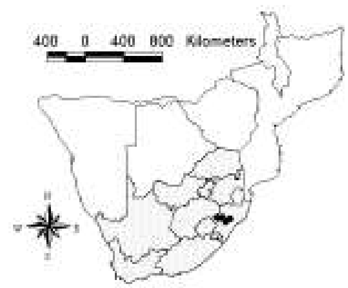
Species: *Gulella obovata* (Pfeiffer, 1855)
Distribution: KwaZulu-Natal and Eastern Cape coast.



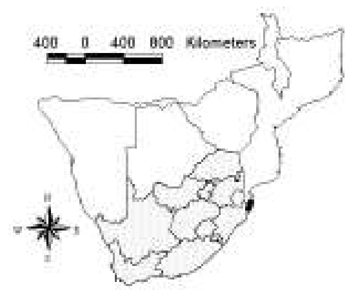
Species: *Gulella obstructa* Bruggen, 1965
Distribution: Eastern Cape.



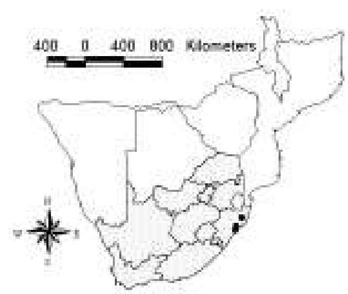
Species: *Gulella orientalis* Connolly, 1929
Distribution: Interior of KwaZulu-Natal.



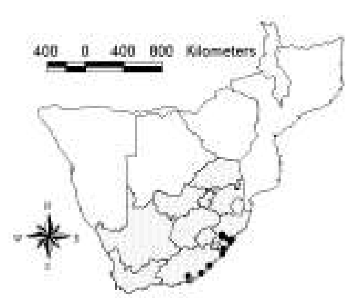
Species: *Gulella peakei continentalis* Bruggen, 1975
Distribution: Northern coast of KwaZulu-Natal.



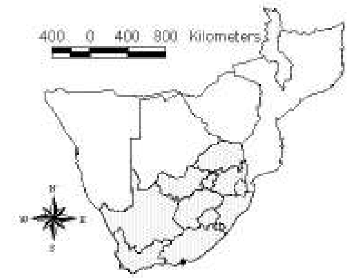
Species: *Gulella penningtoni* Burnup, 1925
Distribution: KwaZulu-Natal coast.



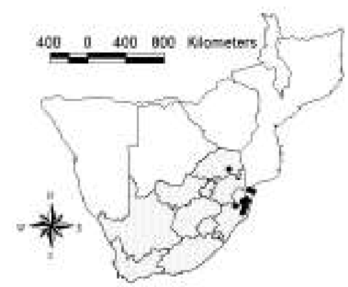
Species: *Gulella pentheri* (Sturany, 1898)
Distribution: Southern KwaZulu-Natal and Eastern Cape coast.



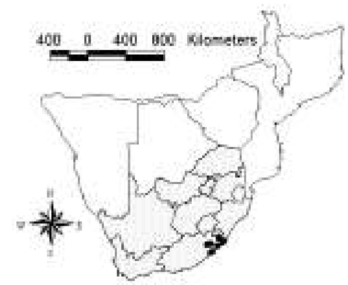
Species: *Gulella pentodon* (Morelet, 1889)
Distribution: Eastern Cape coast.



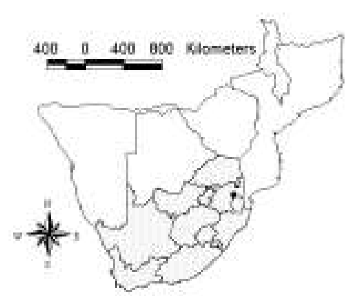
Species: *Gulella perissodonta* (Sturany, 1898)
Distribution: Limpopo, northern KwaZulu-Natal into Mozambique.



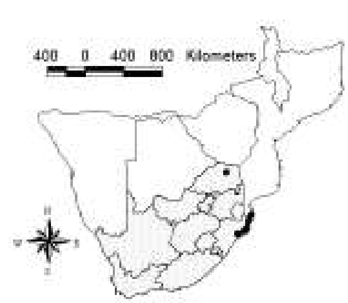
Species: *Gulella perplexa* Connolly, 1939
Distribution: Eastern Cape.



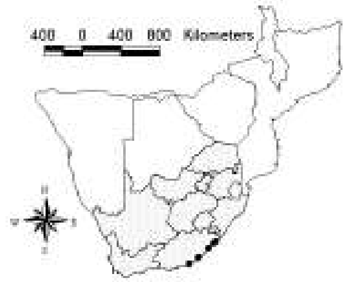
Species: *Gulella perspicua* (Melvill & Ponsonby, 1893)
Distribution: Mpumalanga.



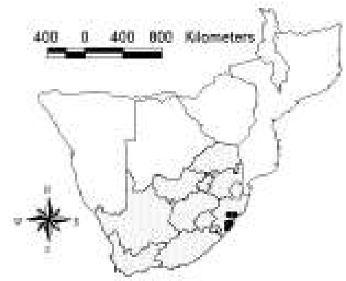
Species: *Gulella perspicuaeformis* (Sturany, 1898)
Distribution: Limpopo and the northern coastal areas of KwaZulu-Natal.



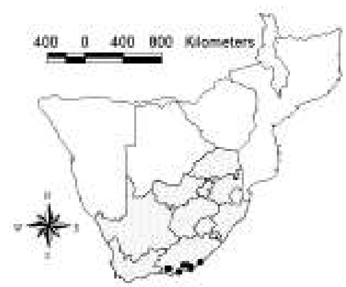
Species: *Gulella phyllisae* Burnup, 1925
Distribution: Coastal area of the Eastern Cape.



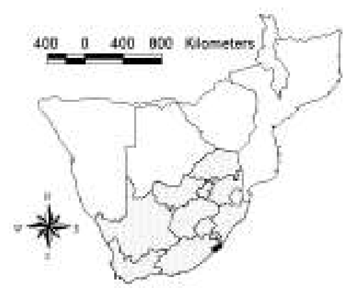
Species: *Gulella planti* (Pfeiffer, 1856)
Distribution: KwaZulu-Natal.
Threatened – IUCN Red list 2004



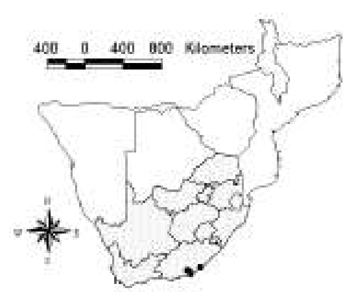
Species: *Gulella polita* (Melvill & Ponsonby, 1893)
Distribution: Coastal areas of the Eastern
Cape.



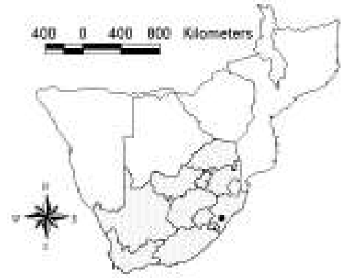
Species: *Gulella pondoensis* Connolly, 1939
Distribution: Eastern Cape coast.



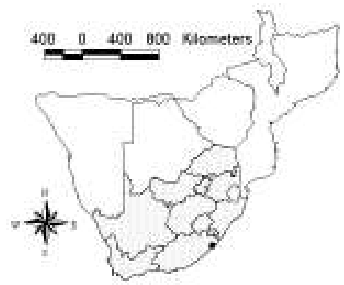
Species: *Gulella ponsonbyi* (Burnup, 1914)
Distribution: Coastal regions of the Eastern Cape.



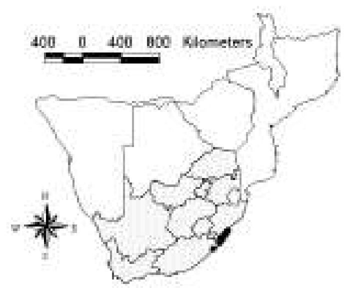
Species: *Gulella pulchella* (Melvill & Ponsonby, 1893)
Distribution: Interior of KwaZulu-Natal.



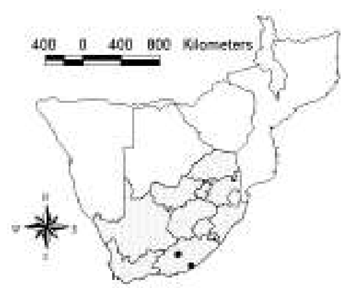
Species: *Gulella puzeyi* Connolly, 1939
Distribution: Eastern Cape coast.
Threatened – IUCN Red list 2004



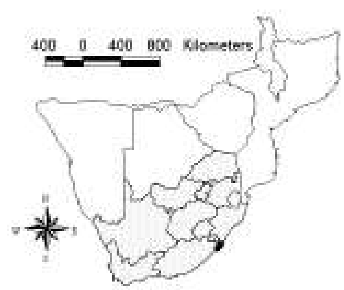
Species: *Gulella queketti* (Melvill & Ponsonby, 1896)
Distribution: Coastal areas of KwaZulu-Natal and Eastern Cape.



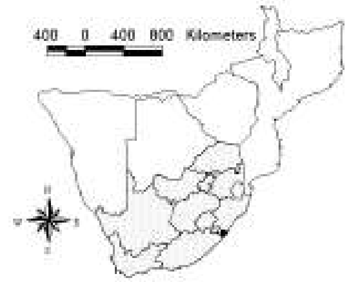
Species: *Gulella rogersi* (Melvill & Ponsonby, 1898)
Distribution: Eastern Cape.



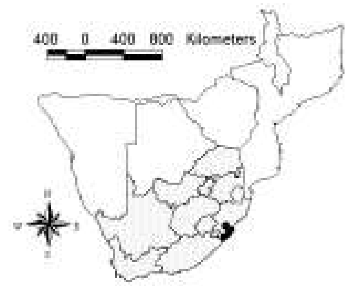
Species: *Gulella rumpiana* Connolly, 1932
Distribution: KwaZulu-Natal and Eastern Cape.



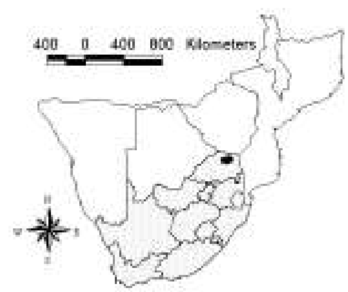
Species: *Gulella salpinx* Herbert, 2002
Distribution: Southern coast of KwaZulu-Natal.
Threatened – IUCN Red list 2004



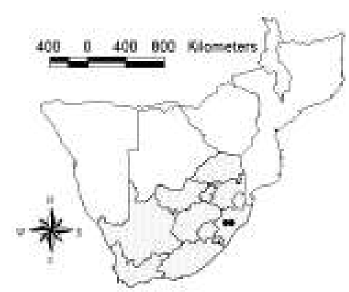
Species: *Gulella separata* (Sturany, 1898)
Distribution: Southern KwaZulu-Natal.



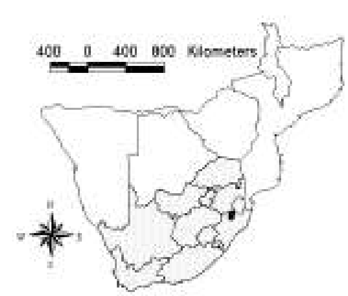
Species: *Gulella sibasana* Connolly, 1922)
Distribution: Northern areas of Limpopo.



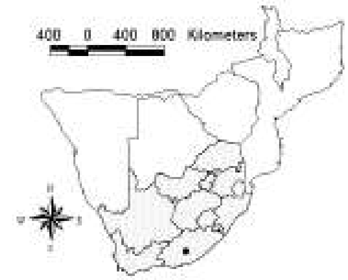
Species: *Gulella subframesi* Connolly, 1929
Distribution: Interior of KwaZulu-Natal.



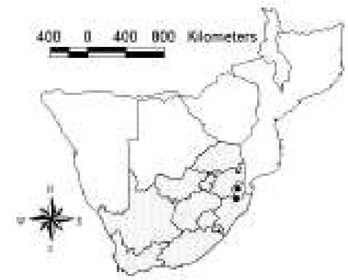
Species: *Gulella subkraussi* Connolly, 1932
Distribution: Northern interior of KwaZulu-Natal.



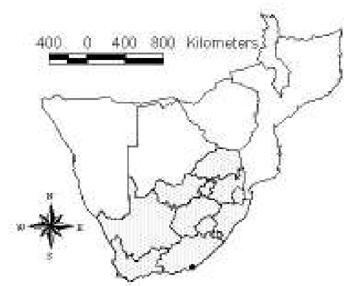
Species: *Gulella swaziensis* Connolly, 1932
Distribution: Northern KwaZulu-Natal and Swaziland.



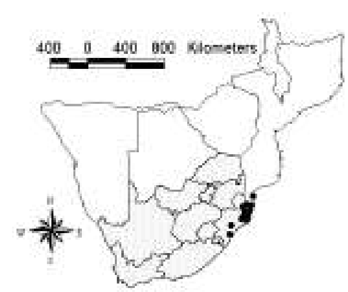
Species: *Gulella sylvia* (Melvill & Ponsonby, 1903)
Distribution: Interior of the Eastern Cape.



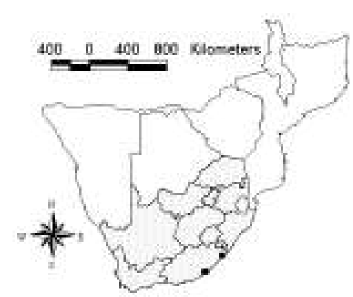
Species: *Gulella tharfieldensis* (Melvill & Ponsonby, 1893)
Distribution: Eastern Cape coast.



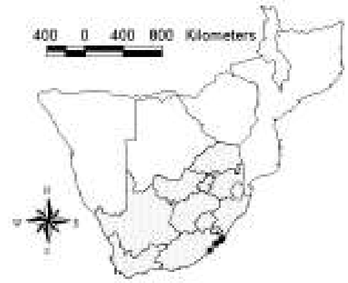
Species: *Gulella triglochis* (Melvill & Ponsonby, 1903)
Distribution: KwaZulu-Natal and extending into Mozambique



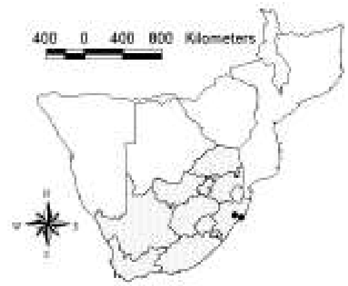
Species: *Gulella tripodium* Connolly, 1939
Distribution: Eastern Cape coast.



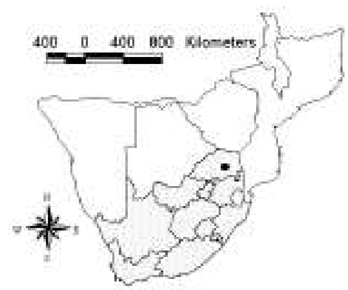
Species: *Gulella umzimvubuensis* Burnup, 1925
Distribution: Eastern Cape coast.



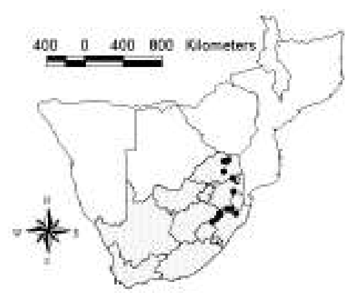
Species: *Gulella vallaris* (Melvill & Ponsonby, 1907)
Distribution: Northern coast of KwaZulu-Natal.



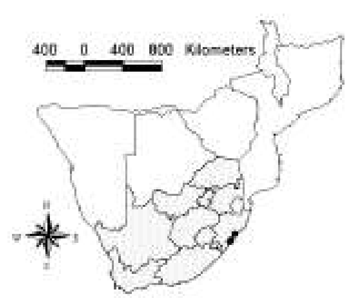
Species: *Gulella verdcourti* Bruggen, 1966
Distribution: Limpopo.



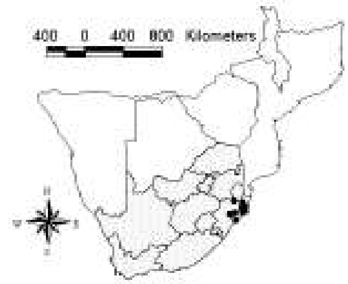
Species: *Gulella viae* Burnup, 1925
Distribution: Along the northern Drakensberg (KwaZulu-Natal), Mpumalanga and Limpopo.



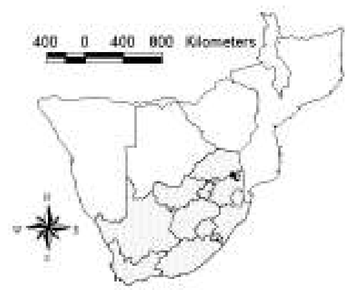
Species: *Gulella wahlbergi* (Krauss, 1848)
Distribution: Coast of KwaZulu-Natal.



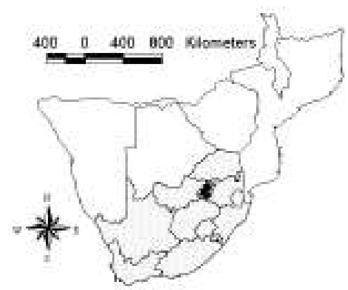
Species: *Gulella warrenii* (Melvill & Ponsonby, 1903)
Distribution: Northern KwaZulu-Natal.



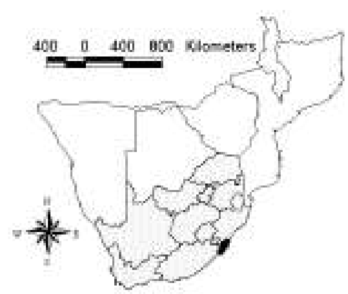
Species: *Gulella wendalinae* Bruggen, 1975
Distribution: Limpopo.



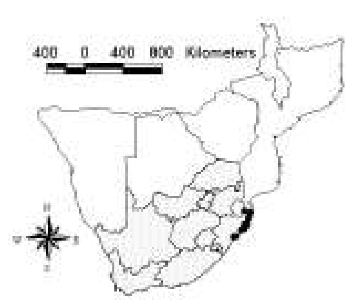
Species: *Gulella xysila* (Melvill & Ponsonby, 1907)
Distribution: Widely distributed in Gauteng.



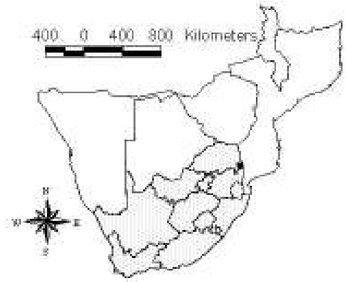
Species: *Gulella zelota* (Melvill & Ponsonby, 1907)
Distribution: Coastal distribution in southern KwaZulu-Natal and Eastern Cape (ponderland region).



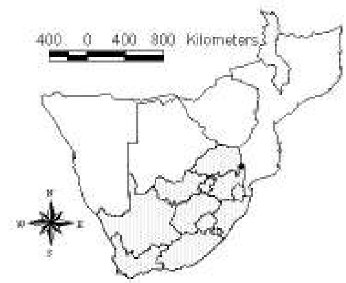
Species: *Gulella zuluensis* Connolly, 1932
Distribution: Northern coast of KwaZulu-Natal.



Species: *Streptostele herma* Connolly, 1912
Distribution: Mpumalanga (within the Kruger National Park).

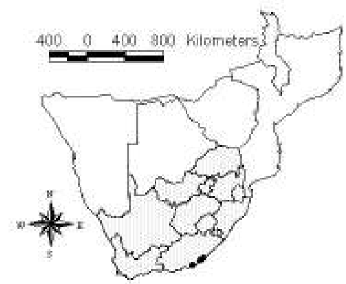


Species: *Streptostele sanctuarii* Bruggen, 1966
Distribution: Mpumalanga (within the Kruger National Park).

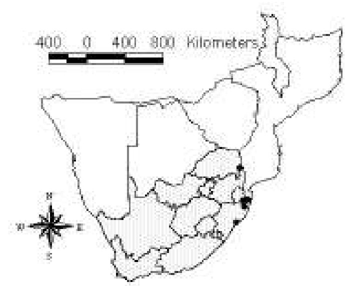


***Family: Subulinidae**

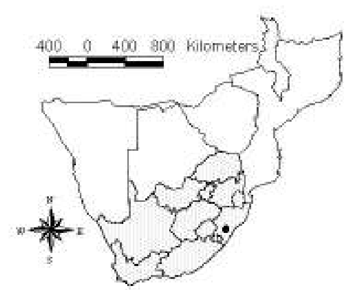
Species: *Coeliaxis blandi* (Pfeiffer, 1852)
Distribution: Eastern Cape coast.



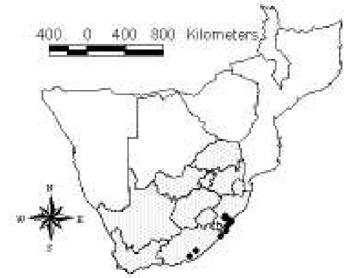
Species: *Curvella amicitiae* Bruggen, 1968
Distribution: Limpopo (within the Kruger National Park) and KwaZulu-Natal.



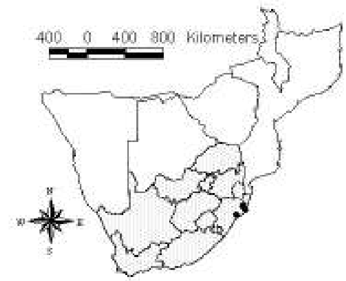
Species: *Curvella caloglypta* Melvill & Ponsonby, 1901
Distribution: Interior of KwaZulu-Natal.



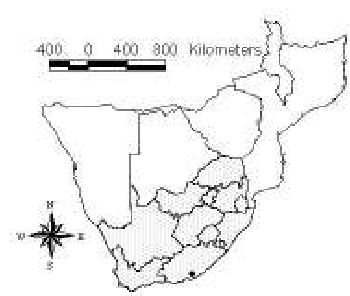
Species: *Curvella catarractae* (Melvill & Ponsonby, 1897)
Distribution: Southern KwaZulu-Natal and Eastern Cape.



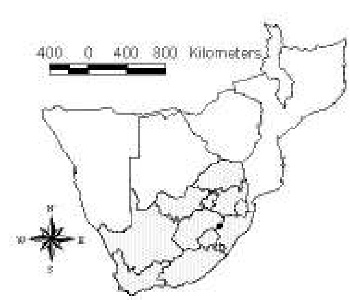
Species: *Curvella croslyi* Burnup, 1905
Distribution: North coast KwaZulu-Natal.



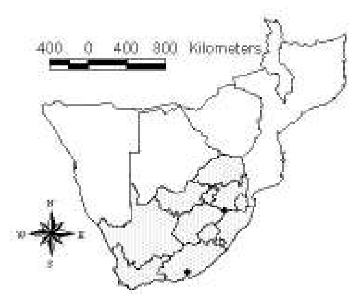
Species: *Curvella elevata* Burnup, 1905
Distribution: Eastern Cape.



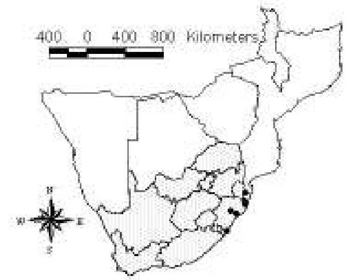
Species: *Curvella euglypta* Connolly, 1939
Distribution: Drakensberg area, KwaZulu-Natal.



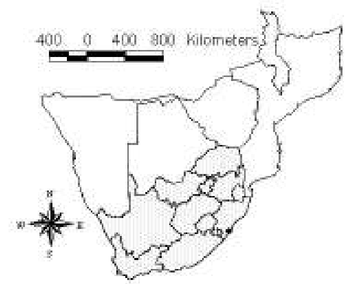
Species: *Curvella majubana* Connolly, 1910
Distribution: Eastern Cape and the Drakensberg (KwaZulu-Natal).



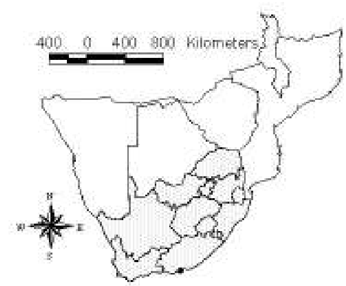
Species: *Curvella saundersae* Connolly, 1910
Distribution: KwaZulu-Natal**.**



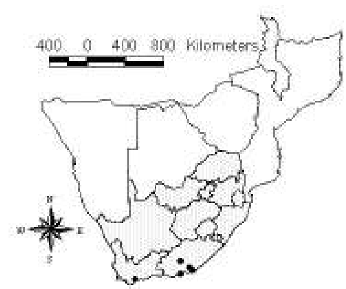
Species: *Curvella sinuosa* Melvill & Ponsonby, 1897
Distribution: South coast of KwaZulu-Natal.



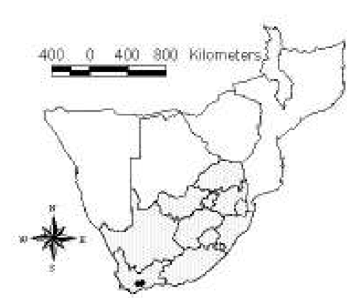
Species: *Curvella straminea* Burnup, 1905
Distribution: Eastern Cape coast.



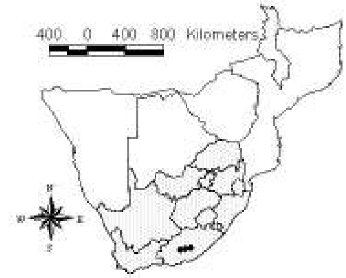
Species: *Euonyma acus* (Morelet, 1889)
Distribution: Western Cape coast and Eastern Cape.



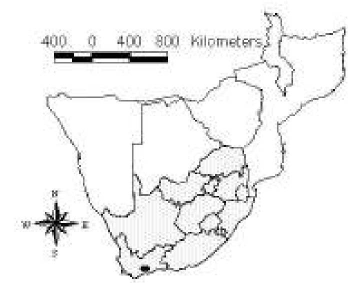
Species: *Euonyma barnardi* Connolly, 1929
Distribution: Western Cape



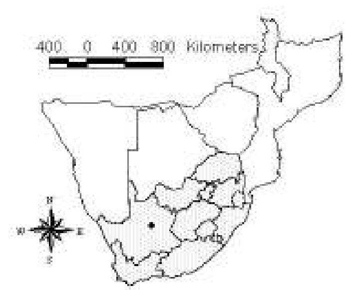
Species: *Euonyma cacuminata* (Melvill & Ponsonby, 1892)
Distribution: Interior of the Eastern Cape.



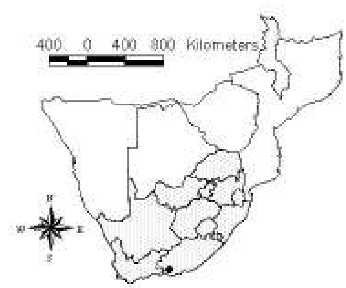
Species: *Euonyma decipiens* Connolly, 1929
Distribution: Western Cape



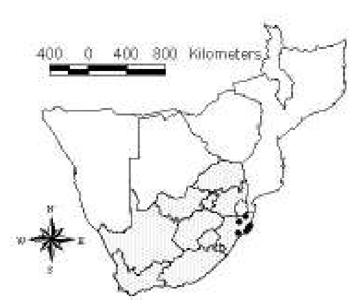
Species: *Euonyma gouldi* (Pfeiffer, 1855)
Distribution: Northern Cape.



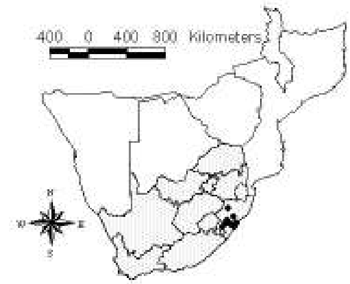
Species: *Euonyma laeocochlis* (Melvill & Ponsonby, 1896)
Distribution: Eastern Cape.



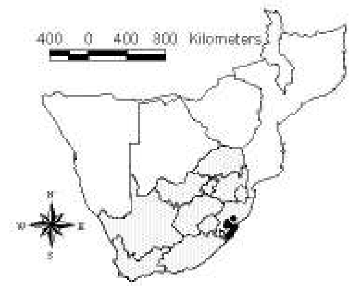
Species: *Euonyma lanceolata* (Pfeiffer, 1854)
Distribution: Northern areas of KwaZulu-Natal.



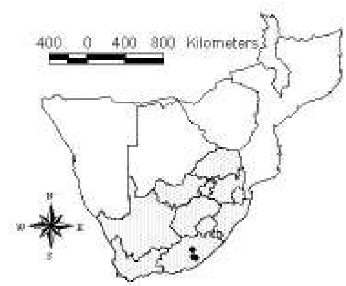
Species: *Euonyma lymneaeformis* (Melvill & Ponsonby, 1901)
Distribution: KwaZulu-Natal.



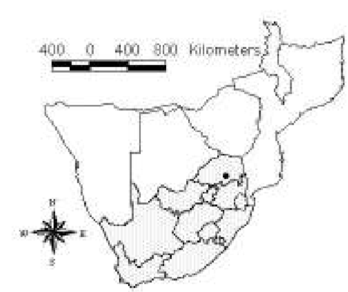
Species: *Euonyma natalensis* (Burnup, 1905)
Distribution: KwaZulu-Natal.



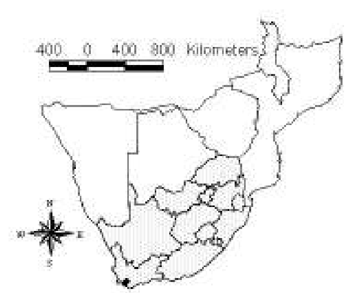
Species: *Euonyma platyacme* Melvill & Ponsonby, 1907
Distribution: Interior of the Eastern Cape.



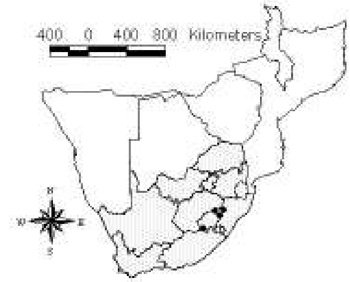
Species: *Euonyma pruizenensis* Connolly, 1910
Distribution: Limpopo



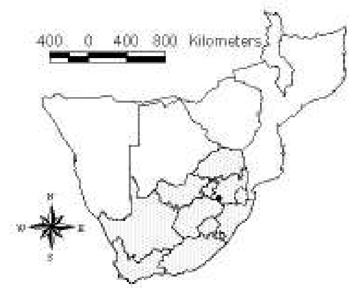
Species: *Euonyma purcelli* (Melvill & Ponsonby, 1910)
Distribution: Western Cape peninsula.



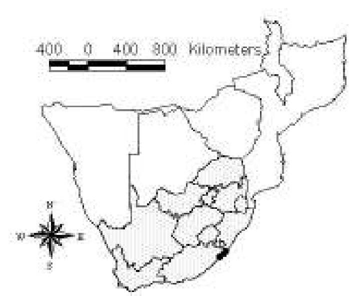
Species: *Euonyma siliqua* Connolly, 1910
Distribution: Found along the Drakensberg (KwaZulu-Natal) and Lesotho.



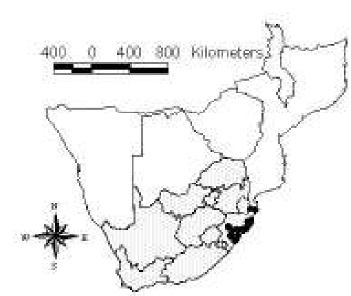
Species: *Euonyma standeri* Connolly, 1910
Distribution: Mpumalanga.



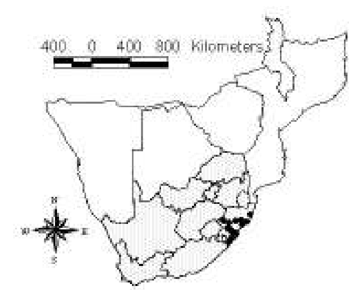
Species: *Euonyma terebraeformis* Connolly, 1923
Distribution: Coastal areas of KwaZulu-Natal and Eastern Cape.



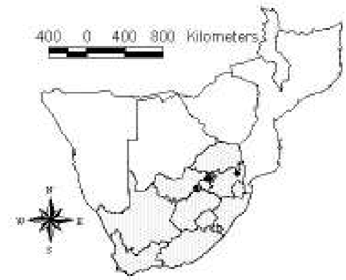
Species: *Euonyma tugelensis* (Melvill & Ponsonby, 1897)
Distribution: KwaZulu-Natal.



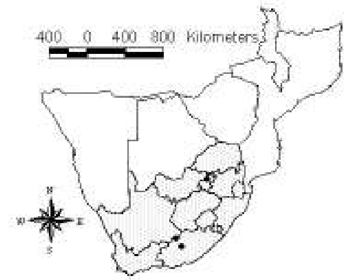
Species: *Euonyma turriformis* (Krauss, 1848)
Distribution: KwaZulu-Natal.



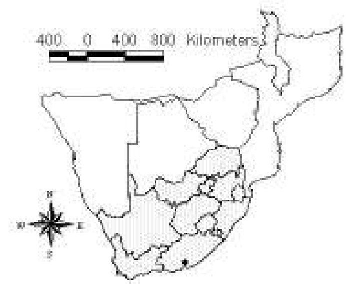
Species: *Euonyma unicornis* Connolly, 1910
Distribution: Gauteng and interior of the Eastern Cape.



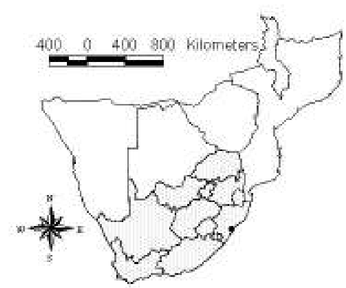
Species: *Euonyma varia* Connolly, 1910
Distribution: Mpumalanga, Gauteng and North West.



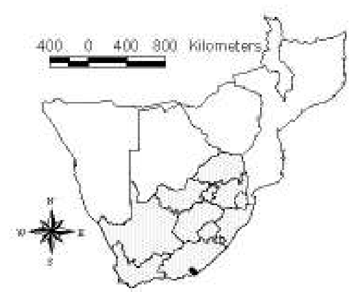
Species: *Opeas albaniense* Connolly, 1919
Distribution: Eastern Cape.



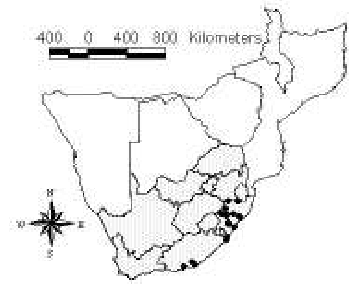
Species: *Opeas annipacis* Connolly, 1919
Distribution: KwaZulu-Natal coast.



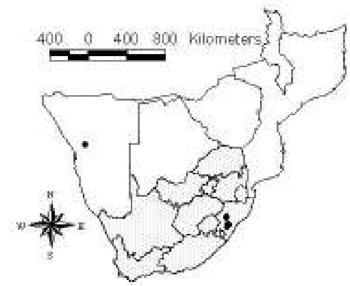
Species: *Opeas crawfordi* (Melvill & Ponsonby, 1893)
Distribution: Eastern Cape coast.



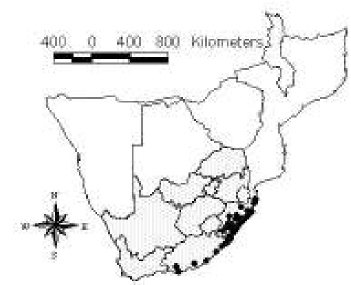
Species: *Opeas crystallinum* (Melvill & Ponsonby, 1896)
Distribution: KwaZulu-Natal and Eastern Cape.



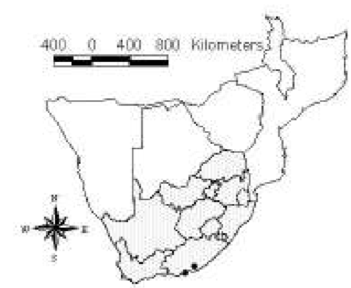
Species: *Opeas eulimoides* (Preston, 1909)
Distribution: Namibia and the interior of KwaZulu-Natal.



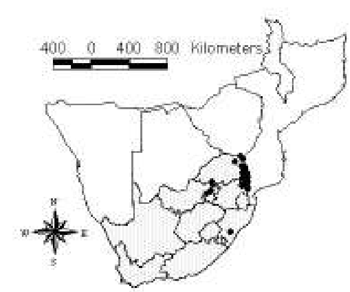
Species: *Opeas florentiae* (Melvill & Ponsonby, 1901)
Distribution: Widely distributed in KwaZulu-Natal and has a coastal distribution in the Eastern Cape.



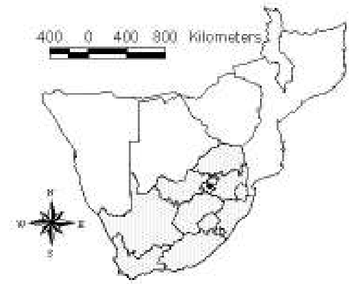
Species: *Opeas lepidum* Connolly, 1910
Distribution: Eastern Cape coast.



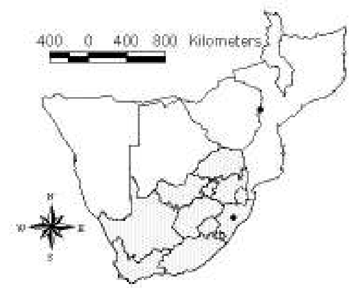
Species: *Opeas lineare* (Krauss, 1848)
Distribution: KwaZulu-Natal, Gauteng,
Limpopo and Mpumanlaga (widely distributed in the Kruger National Park).



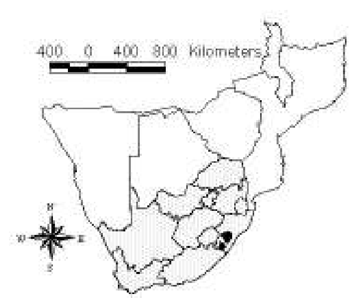
Species: *Opeas mcbeani* Melvill & Ponsonby, 1903
Distribution: Gauteng.



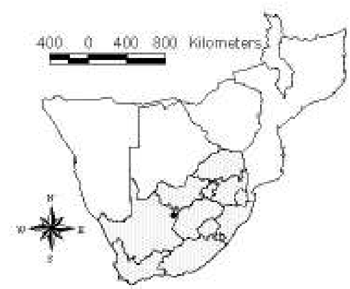
Species: *Opeas peringueyi* Connolly, 1923
Distribution: KwaZulu-Natal and Mozambique.



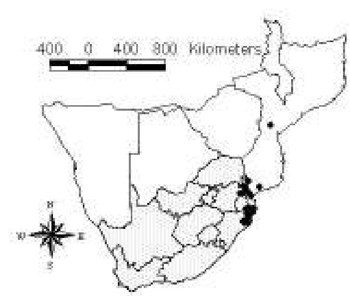
Species: *Opeas strigile* (Melvill & Ponsonby, 1901)
Distribution: Interior of KwaZulu-Natal**.**



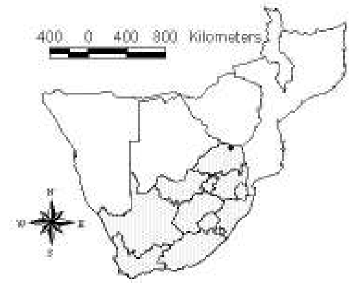
Species: *Opeas sublineare* Boettger, 1910
Distribution: Northern Cape.



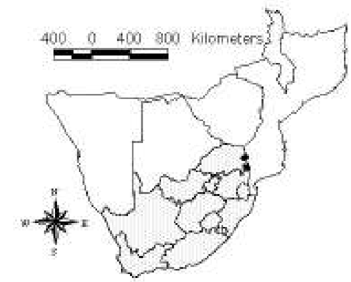
Species: *Pseudoglessula boivini* (Morelet, 1860)
Distribution: Mozambique, northern KwaZulu-Natal and Mpumalanga (southern areas of the Kruger National Park).



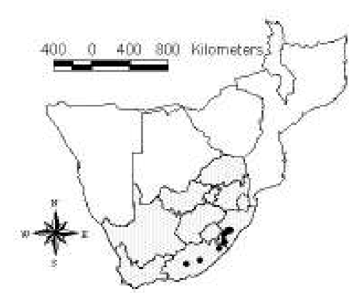
Species: *Pseudoglessula haackei* Bruggen, 1966
Distribution: Northern region of Limpopo province.



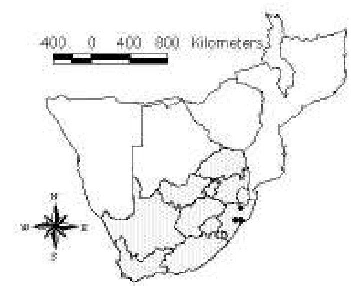
Species: *Pseudoglessula hamiltoni* Bruggen, 1966
Distribution: Limpopo and Mpumalanga (within the Kruger National Park).



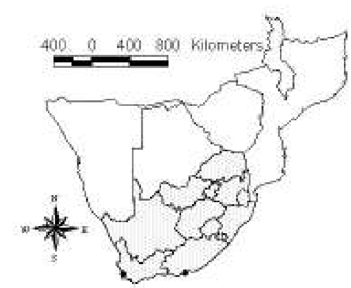
Species: *Pseudopeas burnupi* (Connolly, 1919)
Distribution: KwaZulu-Natal and Eastern Cape.



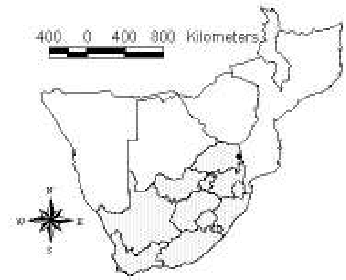
Species: *Pseudopeas tenue* (Connolly, 1923)
Distribution: KwaZulu-Natal.



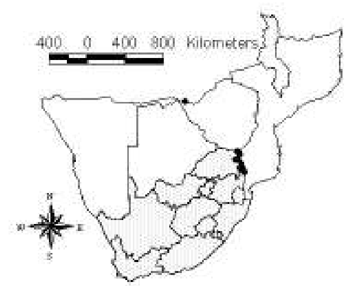
Species: **Rumina decollata* (Linnaeus, 1758)
Distribution: Western Cape coast and Eastern Cape coast.



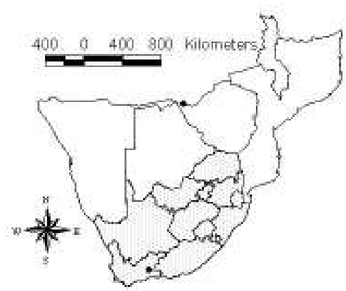
Species: *Subulina gracillima* Connolly, 1919
Distribution: Limpopo (Kruger National Park).



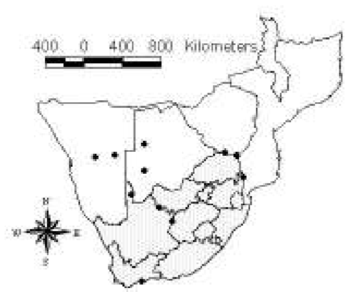
Species: *Subulina mamillata* (Craven, 1880)
Distribution: Limpopo, Mpumalanga (Kruger National Park) and northern Zimbabwe.



Species: **Subulina octona* (Bruguiere, 1789)
Distribution: Western Cape and Zimbabwe.

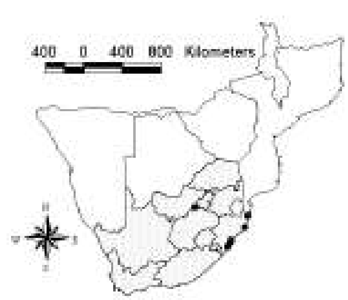


Species: *Xerocerastus burchelli* (Gray, 1834)
Distribution: Limpopo, Mpumalanga (Kruger National Park), Northern and Western Cape provinces of South Africa as well as in Botswana and Namibia.

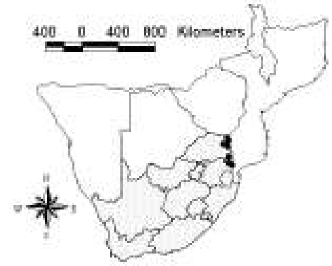


Family: Succineidae

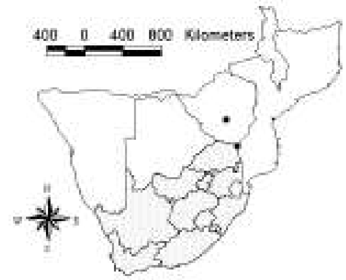
Species: *Oxyloma patentissima* (Pfeiffer, 1853)
Distribution: Coast of KwaZulu-Natal and North West.



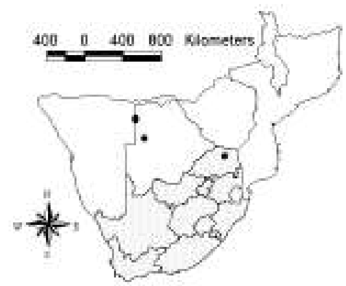
Species: *Succinea africana* Krauss, 1848
Distribution: Limpopo and Mpumalanga (within the Kruger National Park).



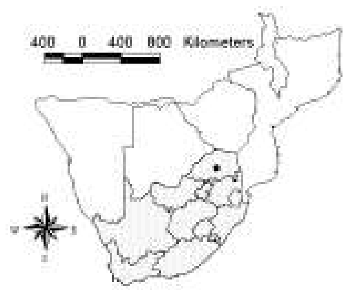
Species: *Succinea arboricolor* Connolly, 1912
Distribution: Limpopo (Kruger National Park) and Zimbabwe.



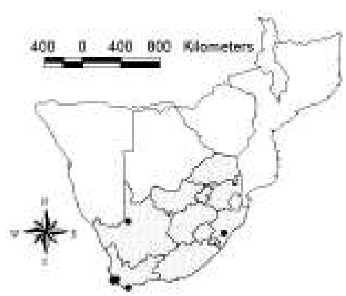
Species: *Succinea badia* Morelet, 1868
Distribution: Limpopo and Botswana.



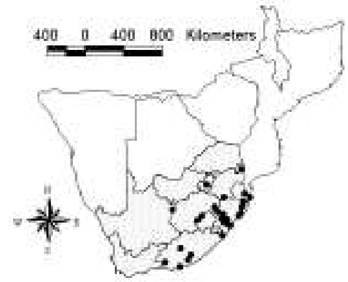
Species: *Succinea dakaensis* Sturany, 1898
Distribution: Limpopo.



Species: *Succinea exarata* Krauss, 1848
Distribution: Northern Cape, KwaZulu-Natal and the Western Cape peninsula.

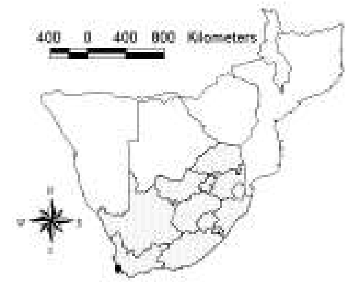


Species: *Succinea striata* Krauss, 1848
Distribution: More widely distributed than the other species of this genus. Occurs in Northern Cape, Gauteng, Free State, Mpumalanga, KwaZulu-Natal, Eastern Cape and Lesotho.



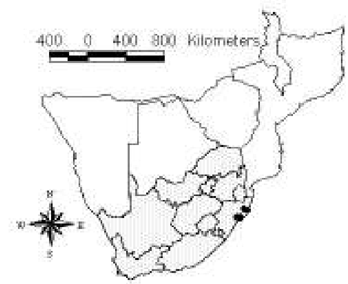
***Family: Testacellidae**

Species: **Testacella maugei* Ferussac, 1819
Distribution: Western Cape.

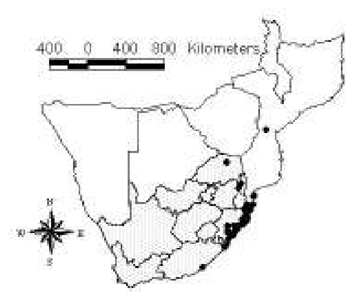


Family: Urocyclidae

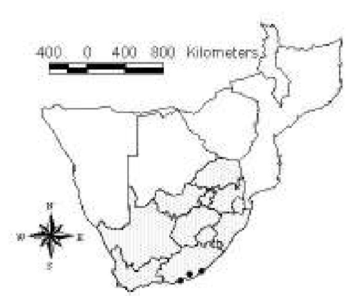
Species: *Atoxonoides meridionalis* (Forcart, 1967)
Distribution: KwaZulu-Natal



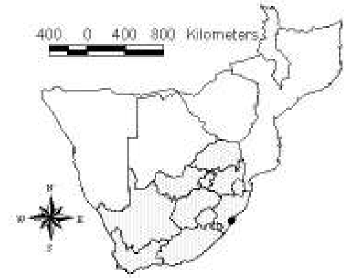
Species: *Elisolimax flavescens* (Keferstein, 1866)
Distribution: East of southern Africa within Limpopo, Mpumalanga, KwaZulu-Natal, Eastern Cape and Mozambique



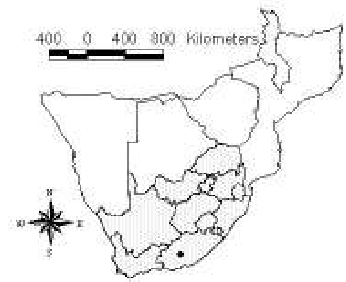
Species: *Sheldonia aloicola* (Melvill & Ponsonby, 1890)
Distribution: Eastern Cape coast.



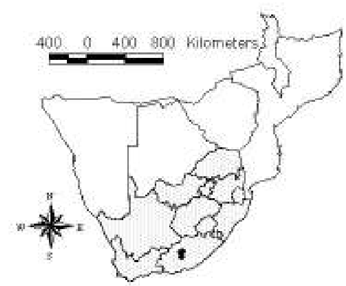
Species: *Sheldonia ampliata* (Melvill & Ponsonby, 1899)
Distribution: KwaZulu-Natal coast.



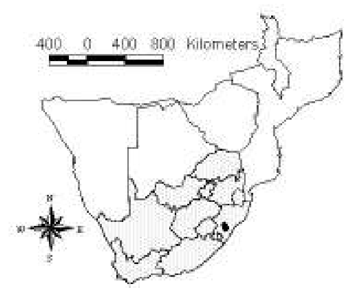
Species: *Sheldonia arnotti* (Benson, 1864)
Distribution: Interior of the Eastern Cape.



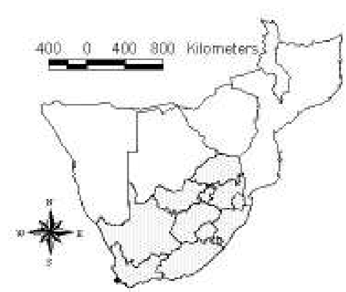
Species: *Sheldonia asthenes* (Melvill & Ponsonby, 1907)
Distribution: Interior of the Eastern Cape.



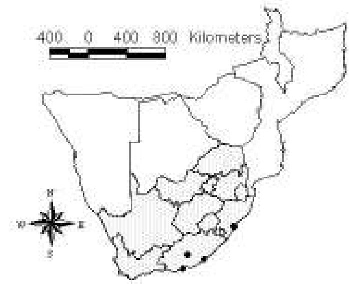
Species: *Sheldonia bicolor* (Goodwin-Austin, 1914)
Distribution: Interior of KwaZulu-Natal.



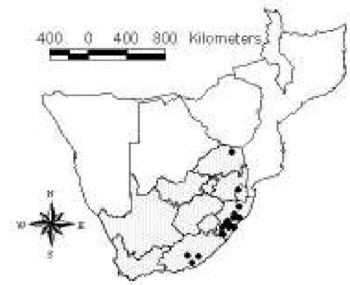
Species: *Sheldonia capsula* (Benson, 1864)
Distribution: Western Cape peninsula.



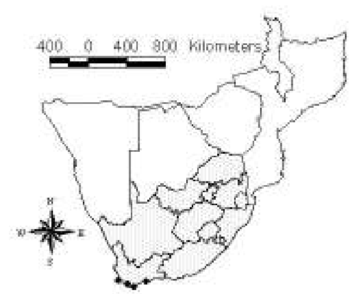
Species: *Sheldonia cingulata* (Melvill & Ponsonby, 1890)
Distribution: Eastern Cape and KwaZulu-
Natal coast.



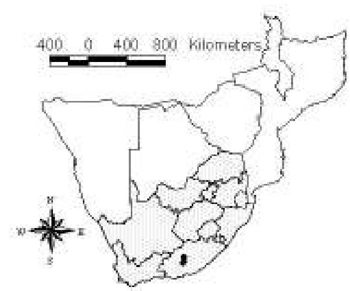
Species: *Sheldonia cornea* (Pfeiffer, 1846)
Distribution: Eastern Cape, KwaZulu-Natal, Limpopo and Swaziland.



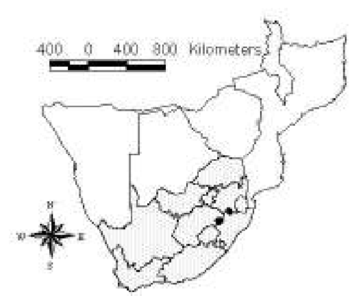
Species: *Sheldonia cotyledonis* (Benson, 1850)
Distribution: Western Cape coast.



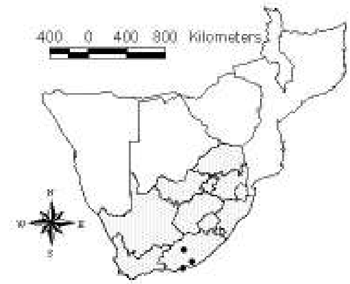
Species: *Sheldonia crawfordi* (Melvill & Ponsonby, 1890)
Distribution: Interior of the Eastern Cape.



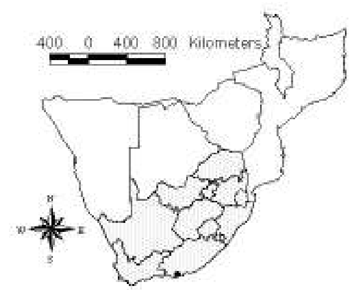
Species: *Sheldonia fuscicolor* (Melvill & Ponsonby, 1892)
Distribution: Free State, KwaZulu-Natal and Mpumalanga.



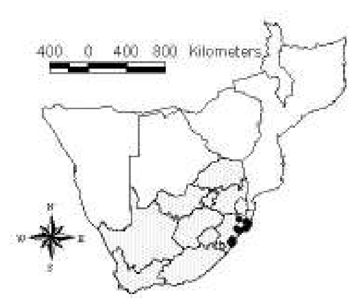
Species: *Sheldonia hewitti* Connolly, 1912
Distribution: Eastern Cape coast.



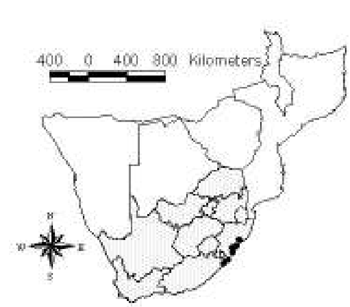
Species: *Sheldonia hudsoniae* (Benson, 1864)
Distribution: Eastern Cape.



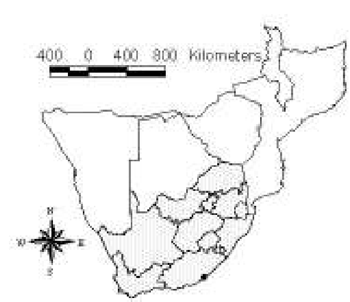
Species: *Sheldonia inuncta* (Melvill & Ponsonby, 1899)
Distribution: KwaZulu-Natal.



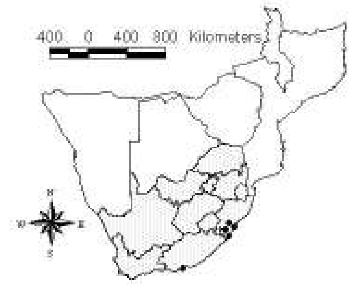
Species: *Sheldonia leucospira* (Pfeiffer, 1856)
Distribution: KwaZulu-Natal coast and into the Eastern Cape



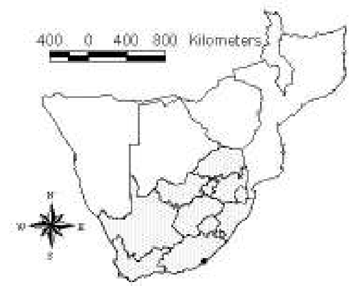
Species: *Sheldonia lightfooti* Connolly, 1939
Distribution: Eastern Cape coast.



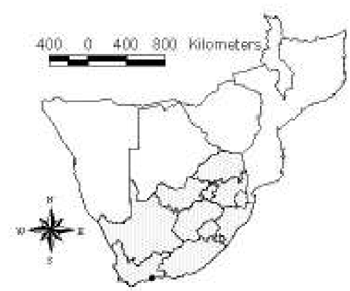
Species: *Sheldonia natalensis* (Pfeiffer, 1846)
Distribution: Eastern Cape coast and southern KwaZulu-Natal.



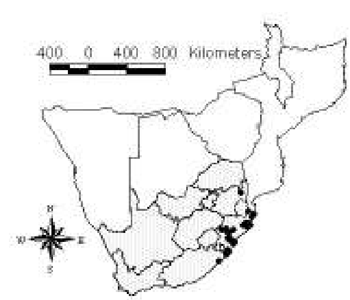
Species: *Sheldonia orientalis* (Goodwin-Austin, 1914)
Distribution: Eastern Cape coast.



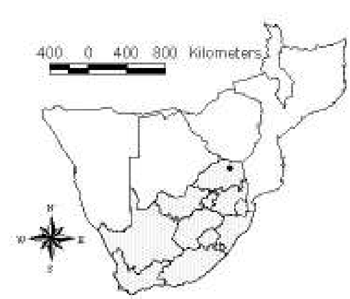
Species: *Sheldonia phytostylus* (Benson, 1864)
Distribution: Western Cape coast.



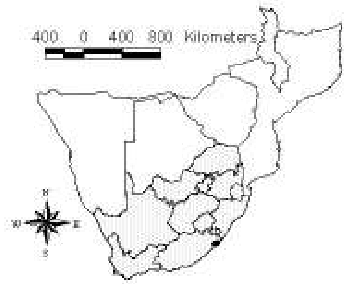
Species: *Sheldonia poeppigii* (Pfeiffer, 1846)
Distribution: Mpumalanga and Eastern Cape coast. The species is widely distributed in KwaZulu-Natal.



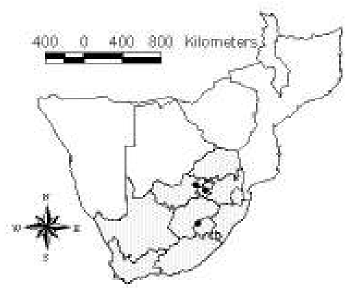
Species: *Sheldonia pumilio* (Melvill & Ponsonby, 1909)
Distribution: Interior of Limpopo.



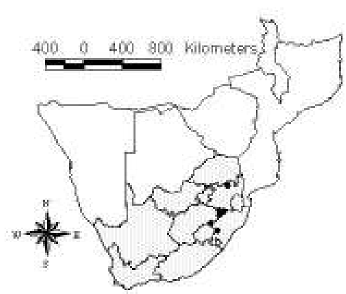
Species: *Sheldonia puzeyi* Connolly, 1939
Distribution: Eastern Cape coast
Threatened – IUCN Red list 2004



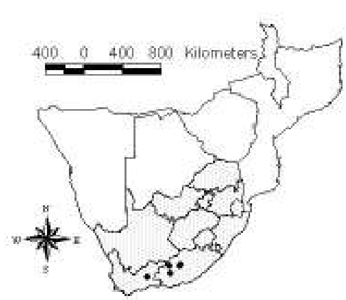
Species: *Sheldonia symmetrica* (Craven, 1880)
Distribution: North West, Gauteng and Lesotho.



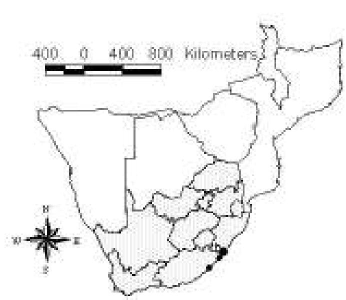
Species: *Sheldonia transvaalensis* (Craven, 1880)
Distribution: Mpumalanga and along the Drakensberg in KwaZulu-Natal.



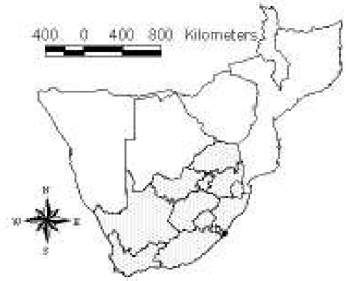
Species: *Sheldonia trotteriana* (Benson, 1848)
Distribution: Western and Eastern Cape.



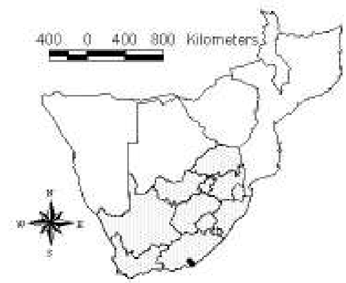
Species: *Sheldonia vitalis* (Melvill & Ponsonby, 1908)
Distribution: South coast of KwaZulu-Natal and along the coast of the Eastern Cape.



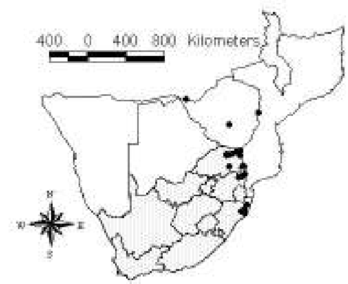
Species: *Sheldonia warreni* Connolly, 1939
Distribution: South coast of KwaZulu-Natal.



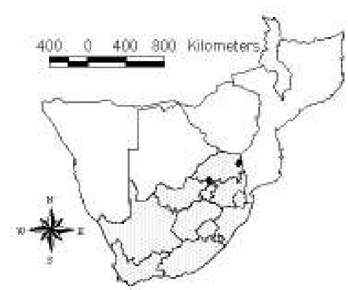
Species: *Sheldonia zonamydra* (Melvill & Ponsonby, 1890)
Distribution: Eastern Cape coast.



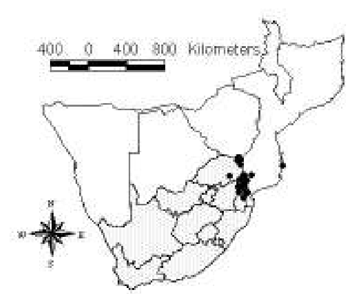
Species: *Thapsia pinguis* (Krauss, 1848)
Distribution: Northern KwaZulu-Natal, Limpopo, Mpumalanga and Zimbabwe.



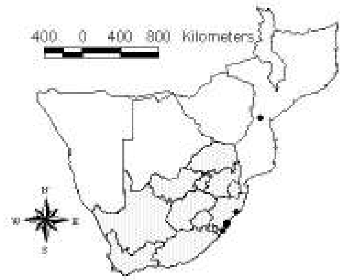
Species: *Trochonanina thermarum* (Melvill & Ponsonby, 1909)
Distribution: Limpopo.



Species: *Trochonanina mozambicensis* (Pfeiffer, 1855)
Distribution: Limpopo, Mpumalanga (widely distributed in the Kruger National Park), Mozambique and Swaziland.

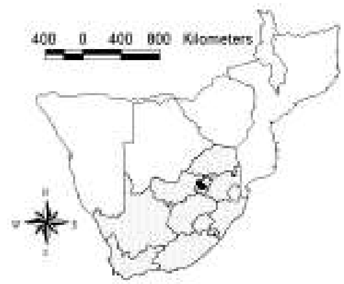


Species: *Urocyclus kirkii* Gray, 1864
Distribution: Mozambique and KwaZulu-Natal coast.

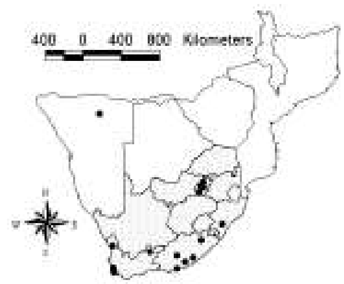


***Family: Valloniidae**

Species: **Vallonia costata* **(**Müller, 1774)
Distribution: Gauteng

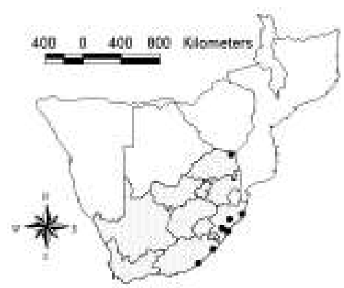


Species: **Vallonia pulchella* (Müller, 1774)
Distribution: Gauteng, KwaZulu-Natal, Eastern and Western Cape as well as in Namibia.

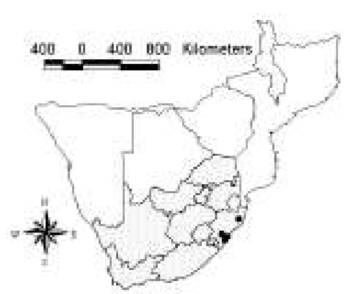


Family: Veronicellidae

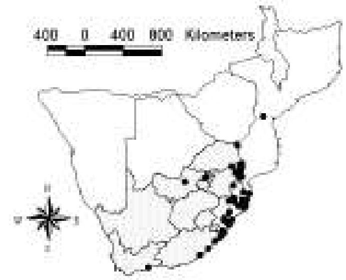
Species: *Laevicaulis alte* (Férussac, 1821)
Distribution: Limpopo, Eastern Cape and KwaZulu-Natal.



Species: *Laevicaulis haroldi* Dundee, 1980
Distribution: KwaZulu-Natal.
Threatened – IUCN Red list 2004

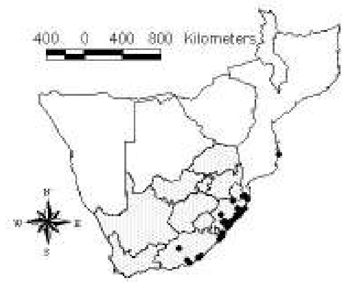


Species: *Laevicaulis natalensis natalensis* (Krauss, 1848)
Distribution: Limpopo, Mpumalanga, North West, Gauteng, Western Cape, Eastern Cape and KwaZulu-Natal provinces of South Africa as well as in Swaziland and Mozambique.

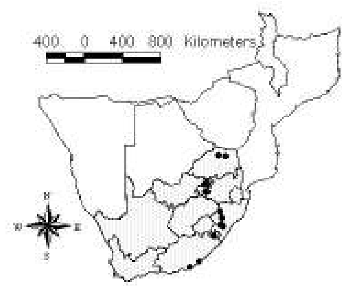


Family: Vertiginidae

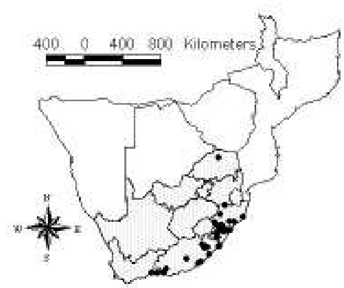
Species: *Nesopupa farquhari* Pilsbry, 1917
Distribution: Eastern Cape, KwaZulu-Natal and Mozambique.



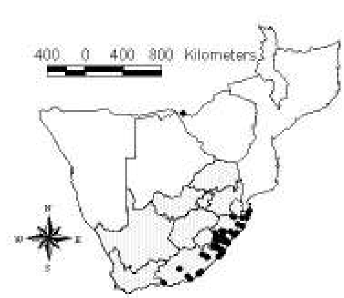
Species: *Nesopupa griqualandica* (Melvill & Ponsonby, 1893)
Distribution: KwaZulu-Natal, Eastern Cape, Gauteng and Limpopo.



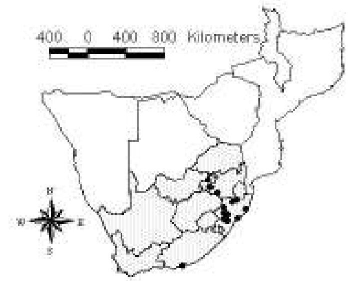
Species: *Pupisoma harpula* (Reinhardt, 1886)
Distribution: Limpopo, KwaZulu-Natal, Eastern Cape and marginal distribution into the Western Cape.



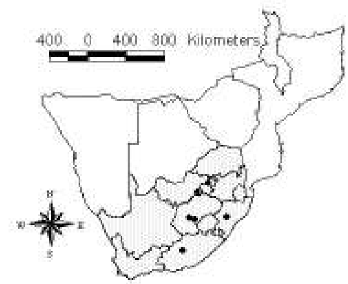
Species: *Pupisoma orcula* (Benson, 1850)
Distribution: KwaZulu-Natal, Eastern Cape and Zimbabwe.



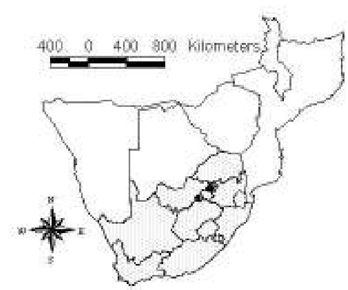
Species: *Truncatellina iota* (Melvill & Ponsonby, 1894)
Distribution: KwaZulu-Natal, Eastern Cape, Mpumalanga and Gauteng.



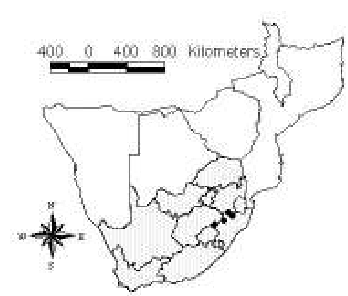
Species: *Truncatellina perplexa* Connolly, 1939
Distribution: KwaZulu-Natal, Eastern Cape, North West, Gauteng and Free State



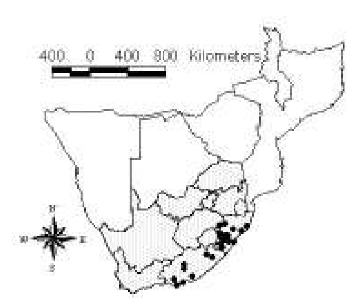
Species: *Truncatellina pretoriensis* (Melvill & Ponsonby, 1893)
Distribution: North West and Gauteng



Species: *Truncatellina pygmaeorum* (Pilsbry & Cockerell, 1933)
Distribution: Interior of KwaZulu-Natal.

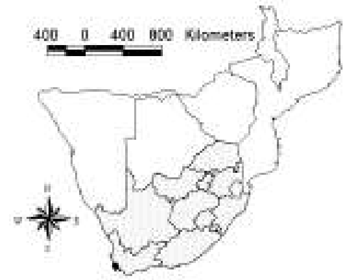


Species: *Truncatellina sykesii* (Melvill & Ponsonby, 1893)
Distribution: KwaZulu-Natal and Eastern Cape.



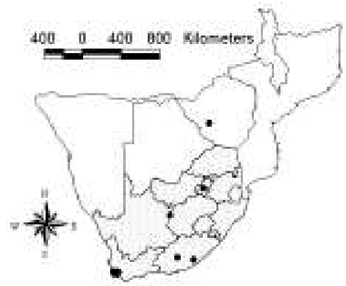
***Family: Vitrinidae**

Species: **Vitrea crystalline* (Müller, 1774)
Distribution: Western Cape.

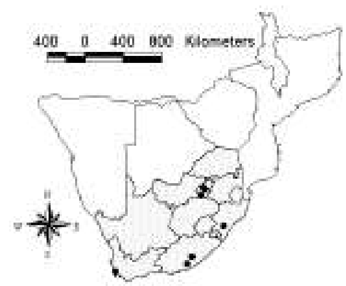


***Family: Zonitidae**

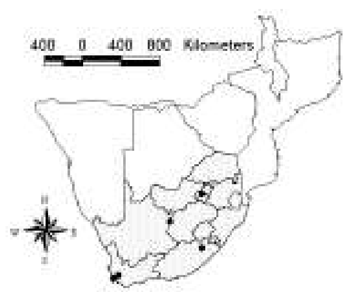
Species: **Oxychilus alliarius* (Miller, 1822)
Distribution: Gauteng, KwaZulu-Natal, Eastern and Western Cape.



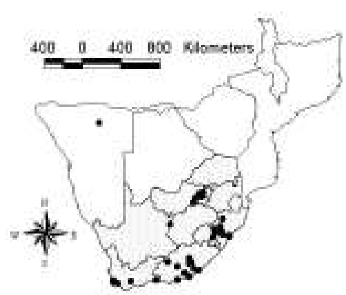
Species: **Oxychilus cellarius* (Müller, 1774)
Distribution: Gauteng, Eastern Cape, Western Cape, Northern Cape and Zimbabwe.



Species: **Oxychilus draparnaudi* (Beck, 1837)
Distribution: Gauteng, Eastern Cape, Western Cape and Northern Cape.



Species: **Zonitoides arboreus* (Say**,** 1817)
Distribution: North West, Gauteng, KwaZulu-Natal, Eastern Cape, Western Cape and Northern Cape. Also recorded from Namibia.



APPENDIX B

Appendix B: Checklist of terrestrial mollusc species within South African provinces

Families	Genera	Species	KwaZulu-Natal	Eastern Cape	Western Cape	Northern Cape	North West Province	Free State	Gauteng	Limpopo Province	Mpumlanaga
Achatinidae	*Burtoa*	*nilotica*								x	
	Cochlitoma	*bisculpta*					x		x	x	
	Cochlitoma	*churchilliana*	x								
	Cochlitoma	*cinnamomea*						x			x
	Cochlitoma	*craveni*								x	
	Cochlitoma	*crawfordi*		x							
	Cochlitoma	*dimidiata*	x							x	x
	Cochlitoma	*drakensbergensis*	x								
	Cochlitoma	*granulata*	x	x							
	Cochlitoma	*immaculata*	x						x	x	x
	Cochlitoma	*limitanea*		x							
	Cochlitoma	*livingstonei*				x					x
	Cochlitoma	*marinae*			x						
	Cochlitoma	*montistempli*	x								
	Cochlitoma	*omissa*	x								
	Cochlitoma	*parthenia*	x								
	Cochlitoma	*penestes*							x		
	Cochlitoma	*pentheri*	x								
	Cochlitoma	*semidecussata*	x								
	Cochlitoma	*semigranosa*	x								
	Cochlitoma	*simplex*	x								
	Cochlitoma	*smithii*	x						x		x
	Cochlitoma	*ustulata*		x	x						
	Cochlitoma	*varicosa*		x							
	Cochlitoma	*vestita*	x								
	Cochlitoma	*zebra*	x	x	x	x					
	Metachatina	*kraussi*	x								
Agriolimacidae	**Deroceras*	*laeve*	x		x						x
	**Deroceras*	*panormiitanum*		x							
	**Deroceras*	*reticulatum*	x	x	x			x			
Arionidae	**Arion*	*hortensis*	x		x						
	**Arion*	*intermedius*	x		x						
	Ariopelta	*capensis*			x						
	Ariostralis	*nebulosa*			x						
	Oopelta	*capensis*			x						
	Oopelta	*nigropunctata*			x						
Bradybaenidae	**Bradybaena*	*similaris*	x								
Bulimulidae	*Prestonella*	*bowkeri*		x							
	Prestonella	*nuptialis*		x							
Cerastidae	*Edouardia*	*arenicola*	x	x	x						
	Edouardia	*carinifera*	x	x	x						

	Edouardia	*conulus*	x								
	Edouardia	*dimera*	x	x						x	
	Edouardia	*drakensbergensis*								x	
	Edouardia	*maritzburgensis*	x	x							
	Edouardia	*mcbeaniana*					x		x	x	x
	Edouardia	*meridionalis*	x	x							
	Edouardia	*metuloides*	x							x	
	Edouardia	*natalensis*	x	x							
	Edouardia	*sordidula*	x							x	x
	Edouardia	*spadicea*	x	x							
	Edouardia	*transvaalensis*								x	x
	Rachis	*jejuna*	x							x	x
	Rhachistia	*chiradzuluensis*	x							x	
	Rhachistia	*dubiosa*	x								
	Rhachistia	*melanacme*	x								
	Rhachistia	*sticta*	x							x	x
Charopidae	*Afrodonta*	*acinaces*	x								
	Afrodonta	*bilamellaris*	x	x							
	Afrodonta	*bimunita*		x							
	Afrodonta	*burnupi*	x								
	Afrodonta	*connollyi*	x								
	Afrodonta	*farquhari*	x	x							
	Afrodonta	*inhluzaniensis*	x	x						x	
	Afrodonta	*introtuberculata*	x								
	Afrodonta	*novemlamellaris*	x	x	x	x				x	
	Afrodonta	*perfida*		x							
	Afrodonta	*trilamellaris*	x								
	Afrodonta	*unilamellaris*	x								
	Trachycystis	*aenea*	x								
	Trachycystis	*alcocki*		x							
	Trachycystis	*aprica*	x	x							
	Trachycystis	*ariel*	x								
	Trachycystis	*aulacophora*		x							
	Trachycystis	*bathycoele*	x	x							
	Trachycystis	*bifoveata*	x								
	Trachycystis	*bisculpta*			x						
	Trachycystis	*burnupi*	x								
	Trachycystis	*calorama*	x								
	Trachycystis	*cancellata*			x						
	Trachycystis	*capensis*		x	x	x					
	Trachycystis	*centrifuga*		x							
	Trachycystis	*charybdis*			x						
	Trachycystis	*clifdeni*	x								
	Trachycystis	*conica*	x								
	Trachycystis	*conisalea*	x								
	Trachycystis	*connollyi*			x						
	Trachycystis	*contabulata*	x	x							
	Trachycystis	*contrasta*			x						
	Trachycystis	*cosmia*			x						
	Trachycystis	*delicata*		x	x						

	Trachycystis	*ectima*	x								
	Trachycystis	*falconi*		x							
	Trachycystis	*farquhari*		x							
	Trachycystis	*felina*		x							
	Trachycystis	*ferarum*	x								
	Trachycystis	*fossula*	x								
	Trachycystis	*glanvilliana*	x	x						x	
	Trachycystis	*glebaria*	x								
	Trachycystis	*haygarthi*	x								
	Trachycystis	*inclara*	x	x							
	Trachycystis	*jucunda*			x						
	Trachycystis	*junodi*								x	
	Trachycystis	*kincaidi*		x							
	Trachycystis	*langi*	x								
	Trachycystis	*laticostata*		x							
	Trachycystis	*leucocarina*			x						
	Trachycystis	*lightfootiana*			x						
	Trachycystis	*lignicola*		x							
	Trachycystis	*liricostata*		x							
	Trachycystis	*loveni*	x	x						x	
	Trachycystis	*lunaris*	x	x							
	Trachycystis	*lygaea*	x								
	Trachycystis	*mcbeani*	x						x		
	Trachycystis	*mcdowelli*	x								
	Trachycystis	*mediocris*			x						
	Trachycystis	*menkeana*			x						
	Trachycystis	*metallakter*			x						
	Trachycystis	*montissalinarum*								x	x
	Trachycystis	*ordinaria*				x	x	x	x		
	Trachycystis	*oreina*	x	x							
	Trachycystis	*oconnori*			x						
	Trachycystis	*patera*		x							
	Trachycystis	*permeata*	x								
	Trachycystis	*perplicata*			x						
	Trachycystis	*petrobia*			x						
	Trachycystis	*placenta*	x								
	Trachycystis	*prionacis*			x						
	Trachycystis	*rivularis*	x						x		
	Trachycystis	*rudicostata*	x	x	x					x	
	Trachycystis	*sabuletorum*			x						
	Trachycystis	*scolopendra*	x	x							
	Trachycystis	*shilwaneensis*								x	
	Trachycystis	*simplex*		x							
	Trachycystis	*spissicosta*	x	x				x			
	Trachycystis	*subpinguis*	x	x							
	Trachycystis	*tollini*			x						
	Trachycystis	*turmalis*		x							
	Trachycystis	*uitenhagensis*		x							
	Trachycystis	*venatorum*	x	x							
	Trachycystis	*watsoni*	x								

Chlamydephoridae	*Chlamydephorus*	*bruggeni*								x	
	Chlamydephorus	*burnupi*	x	x							
	Chlamydephorus	*dimidius*	x								
	Chlamydephorus	*gibbonsi*	x	x							
	Chlamydephorus	*lawrencei*	x								x
	Chlamydephorus	*parva*		x							
	Chlamydephorus	*sexangulus*	x	x							
	Chlamydephorus	*watsoni*	x								x
Chondrinidae	*Gastrocopta*	*damarica*	x	x			x	x	x	x	
	Gastrocopta	*duplicata*								x	
	Gastrocopta	*thomasseti*	x							x	
Clausiliidae	*Macroptychia*	*africana*	x	x						x	
Cochlicopidae	**Cochlicopa*	*lubrica*		x	x			x	x		
	**Cochlicopa*	*lubricella*		x	x				x		
Cyclophoridae	*Chondrocyclus*	*alabastris*		x							
	Chondrocyclus	*bathrolophodes*		x							
	Chondrocyclus	*convexiusulus*		x	x						
	Chondrocyclus	*exsertus*	x								
	Chondrocyclus	*isipingoensis*	x	x						x	
	Chondrocyclus	*putealis*	x	x							
	Chondrocyclus	*trifimbriatus*	x								
Discidae	**Discus*	*rotundatus*		x	x						
Dorcasiidae	*Dorcasia*	*alexandri*				x					
	Dorcasia	*coagulum*				x					
	Trigonephrus	*ambiguosus*			x						
	Trigonephrus	*globulus*			x						
	Trigonephrus	*gypsinus*				x					
	Trigonephrus	*heliocaustus*			x						
	Trigonephrus	*latezonatus*			x						
	Trigonephrus	*lucanus*			x						
	Trigonephrus	*namaquensis*			x	x					
	Trigonephrus	*porphyrostoma*				x					
	Trigonephrus	*rosaceus*			x	x					
	Tulbaghinia	*isomeriodes*			x						
Euconulidae	*Afroconulus*	*diaphanus*	x	x						x	
	Afroguppya	*rumrutiensis*	x	x						x	x
	Afropuctum	*seminium*								x	
Ferrussaciidae	**Cecilioides*	*acicula*		x							
	Cecilioides	*gokweanus*	x						x		
	Cecilioides	*pergracilis*	x								
Helicarionidae	*Kaliella*	*barrakporensis*	x	x			x		x	x	
	Kaliella	*euconuloides*	x	x							
Helicidae	**Cochlicella*	*barbara*		x	x	x		x			
	**Eobania*	*vermiculata*		x	x	x	x				
	**Helix*	*aspersa*	x	x	x	x		x	x	x	x
	**Otala*	*punctata*			x						
	**Theba*	*pisana*	x	x	x	x					
Hydrocenidae	*Hydrocena*	*noticola*	x	x	x						
Limacidae	**Lehmannia*	*nyctelia*	x	x	x			x			
	**Lehmannia*	*valentiana*	x	x		x					

	**Limax*	*flavus*	x	x	x		x		x		x
	**Limax*	*maximus*	x		x		x				
Maizaniidae	*Maizania*	*wahlbergi*	x	x							
Milacidae	**Milax*	*gagates*	x	x	x						
Orculidae	*Fauxulus*	*burnupianus*			x						
	Fauxulus	*capensis*		x	x						
	Fauxulus	*crawfordianus*			x						
	Fauxulus	*falconianus*	x								
	Fauxulus	*glanvilleanus*	x	x	x						
	Fauxulus	*kurri fortidentata*			x						
	Fauxulus	*layardi*			x						
	Fauxulus	*mcbeanianus*	x								
	Fauxulus	*ovularis*			x						
	Fauxulus	*pamphorodon*			x						
	Fauxulus	*pereximius*	x	x							
	Fauxulus	*ponsonbyanus*	x	x						x	
	Fauxulus	*pycnochilus*			x						
Pomatiasidae	*Tropidophora*	*comburens*	x								
	Tropidophora	*foveolata*		x	x						
	Tropidophora	*hartvigiana*			x						
	Tropidophora	*insularis*	x	x						x	
	Tropidophora	*ligata*	x	x	x					x	x
	Tropidophora	*plurilirata*	x	x							
	Tropidophora	*sarcodes*		x	x						
	Tropidophora	*transvaalensis*	x						x	x	x
Punctidae	*Paralaoma*	*hottentota*	x	x	x				x	x	
Pupillidae	*Lauria*	*cryptoplax*		x							
	**Lauria*	*cylindracea*			x						
	Lauria	*dadion*	x	x	x					x	
	Lauria	*farquhari*	x	x							
	Pupilla	*fontana*	x	x			x	x	x	x	x
	Pupilla	*tetrodus*	x	x			x	x			
	Pupoides	*calaharicus*	x	x		x				x	x
Rhytididae	*Nata*	*dumeticola*			x						
	Nata	*tarachodes*			x						
	Nata	*vernicosa*	x	x	x			x		x	x
	Nata	*viridescens*	x				x		x	x	
	Natalina	*arguta*		x							
	Natalina	*beyrichi*		x							
	Natalina	*cafra*	x	x							
	Natalina	*compacta*		x							
	Natalina	*inhluzana*	x								
	Natalina	*quekettiana*	x								
	Natalina	*knysnaensis*		x							
	Natalina	*kraussi*		x	x						
	Natalina	*liliacea*			x						
	Natalina	*reenenensis*	x								
	Natalina	*schaerfiae*			x						
	Natalina	*trimeni*		x	x						
	Natalina	*wesseliana*	x								

Sculptariidae	*Sculptaria*	*namaquaensis*				x					
Streptaxidae	*Eustreptaxis*	*elongatus*	x								
	Gonaxis	*gwandaensis*	x							x	x
	Gulella	*adamsiana*	x	x							
	Gulella	*aliciae*	x								
	Gulella	*alutacea*	x								
	Gulella	*appletoni*	x								
	Gulella	*aprosdoketa*		x							
	Gulella	*arnoldi*	x	x							
	Gulella	*barbarae*	x								
	Gulella	*barnardi*									x
	Gulella	*bowkerae*		x							
	Gulella	*browni*	x								
	Gulella	*burnupi*	x								
	Gulella	*bushmanensis*	x								
	Gulella	*cairnsi*		x							
	Gulella	*calopasa*	x								
	Gulella	*candidula*		x							
	Gulella	*caryatis*		x							
	Gulella	*chi*		x							
	Gulella	*claustralis*	x	x							
	Gulella	*collicola*									x
	Gulella	*columnella*	x								
	Gulella	*connollyi*	x								
	Gulella	*consobrina*		x							
	Gulella	*contingens*	x								
	Gulella	*contraria*	x								x
	Gulella	*crassidens*	x								
	Gulella	*crassilabris*					x				x
	Gulella	*daedalea*	x								
	Gulella	*darglensis*	x	x							
	Gulella	*dejae*		x							
	Gulella	*delicatula*	x								
	Gulella	*deviae*								x	x
	Gulella	*dextrorsa*	x								
	Gulella	*digitalis*	x								
	Gulella	*discrepans*	x	x							
	Gulella	*distincta*									x
	Gulella	*drakensbergensis*	x								
	Gulella	*dunkeri*	x								
	Gulella	*elliptica*	x	x							
	Gulella	*euthymia*	x								
	Gulella	*falconi*	x	x							
	Gulella	*farquhari*	x	x							
	Gulella	*formosa*	x								
	Gulella	*framesi*		x							
	Gulella	*fraudator*		x							
	Gulella	*genialis*	x								
	Gulella	*gouldi*	x	x							
	Gulella	*harriesi*								x	

	Gulella	*hamerae*		x							
	Gulella	*herberti*									x
	Gulella	*himerothales*	x	x							
	Gulella	*incurvidens*								x	
	Gulella	*infans*	x	x			x		x	x	x
	Gulella	*infrendens*	x	x							
	Gulella	*inhluzaniensis*	x								
	Gulella	*inobstructa*								x	
	Gulella	*instabilis*	x	x							
	Gulella	*isipingoensis*	x	x							
	Gulella	*johannae sp. n. ms van Bruggen*								x	
	Gulella	*johannesburgensis*	x						x	x	x
	Gulella	*juxtidens*	x								
	Gulella	*kosiensis*	x								
	Gulella	*kraussi*	x								
	Gulella	*latimerae*		x							
	Gulella	*leucocion*	x								
	Gulella	*lindae*	x								
	Gulella	*linguidens*	x								
	Gulella	*mariae*	x	x							
	Gulella	*maritzburgensis*	x								
	Gulella	*melvilli*	x								
	Gulella	*menkeana*	x	x							
	Gulella	*mfongosiensis*	x								
	Gulella	*miniata*								x	
	Gulella	*minuta*		x							
	Gulella	*mooiensis*	x								
	Gulella	*multidentata*	x	x							
	Gulella	*munita*		x							
	Gulella	*natalensis*	x	x							
	Gulella	*newmani*		x							
	Gulella	*obovata*	x	x							
	Gulella	*obstructa*		x							
	Gulella	*orientalis*	x								
	Gulella	*peakei continentalis*	x								
	Gulella	*penningtoni*	x								
	Gulella	*pentheri*	x	x							
	Gulella	*pentodon*		x							
	Gulella	*perissodonta*	x							x	
	Gulella	*perplexa*		x							
	Gulella	*perspicua*									x
	Gulella	*perspicuaeformis*	x							x	
	Gulella	*phyllisae*		x							
	Gulella	*polita*		x							
	Gulella	*pondoensis*		x							
	Gulella	*ponsonbyi*		x							
	Gulella	*planti*	x								
	Gulella	*puzeyi*		x							
	Gulella	*pulchella*	x								

	Gulella	*queketti*	x	x							
	Gulella	*rogersi*		x							
	Gulella	*rumpiana*	x	x							
	Gulella	*salpinx*	x								
	Gulella	*separata*	x								
	Gulella	*sibasana*								x	
	Gulella	*subframesi*	x								
	Gulella	*subkraussi*	x								
	Gulella	*swaziensis*	x								
	Gulella	*sylvia*		x							
	Gulella	*tharfieldensis*		x							
	Gulella	*triglochis*	x								
	Gulella	*tripodium*		x							
	Gulella	*umzimvubuensis*		x							
	Gulella	*vallaris*	x								
	Gulella	*verdcourti*								x	
	Gulella	*viae*	x							x	x
	Gulella	*wahlbergi*	x								
	Gulella	*warrenii*	x								
	Gulella	*wendalinae*								x	
	Gulella	*xysila*							x		
	Gulella	*zelota*	x	x							
	Gulella	*zuluensis*	x								
	Streptostele	*herma*									x
	Streptostele	*sanctuarii*									x
Subulinidae	*Coeliaxis*	*blandi*		x							
	Curvella	*amicitiae*	x							x	
	Curvella	*caloglypta*	x								
	Curvella	*catarractae*	x	x							
	Curvella	*croslyi*	x								
	Curvella	*elevata*		x							
	Curvella	*euglypta*	x								
	Curvella	*majubana*	x	x							
	Curvella	*saundersae*	x								
	Curvella	*sinuosa*	x								
	Curvella	*straminea*		x							
	Euonyma	*acus*		x	x						
	Euonyma	*barnardi*			x						
	Euonyma	*cacuminata*		x							
	Euonyma	*decipiens*			x						
	Euonyma	*gouldi*			x						
	Euonyma	*laeocochlis*		x							
	Euonyma	*lanceolata*	x								
	Euonyma	*lymneaeformis*	x								
	Euonyma	*natalensis*	x								
	Euonyma	*platyacme*		x							
	Euonyma	*pruizenensis*								x	
	Euonyma	*purcelli*			x						
	Euonyma	*siliqua*	x								
	Euonyma	*standeri*									x

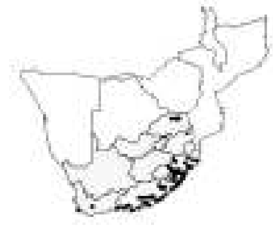
	Euonyma	*terebraeformis*	x	x							
	Euonyma	*tugelensis*	x								
	Euonyma	*turriformis*	x								
	Euonyma	*unicornis*		x					x		
	Euonyma	*varia*					x		x		x
	Opeas	*albaniense*		x							
	Opeas	*annipacis*	x								
	Opeas	*crawfordi*		x							
	Opeas	*crystallinum*	x	x							
	Opeas	*eulimoides*	x								
	Opeas	*florentiae*	x	x							
	Opeas	*lepidum*		x							
	Opeas	*lineare*	x						x	x	x
	Opeas	*mcbeani*							x		
	Opeas	*peringueyi*	x								
	Opeas	*strigile*	x								
	Opeas	*sublineare*				x					
	Pseudoglessula	*boivini*	x								x
	Pseudoglessula	*hamiltoni*								x	x
	Pseudoglessula	*haackei*								x	
	Pseudopeas	*burnupi*	x	x							
	Pseudopeas	*tenue*	x								
	**Rumina*	*decollata*		x	x						
	Subulina	*gracillima*								x	
	Subulina	*mamillata*								x	x
	**Subulina*	*octona*			x						
	Xerocerastus	*burchelli*			x	x				x	x
Succineidae	*Oxyloma*	*patentissima*	x				x				
	Succinea	*africana*								x	x
	Succinea	*arboricolor*								x	
	Succinea	*badia*								x	
	Succinea	*dakaensis*								x	
	Succinea	*exarata*	x			x					
	Succinea	*striata*	x	x		x		x	x		x
Testacellidae	**Testacella*	*maugei*			x						
Urocyclidae	*Atoxoniodes*	*meridionalis*	x								
	Elisolimax	*flavescens*	x	x						x	x
	Sheldonia	*aloicola*		x							
	Sheldonia	*ampliata*	x								
	Sheldonia	*arnotti*		x							
	Sheldonia	*asthenes*		x							
	Sheldonia	*bicolor*	x								
	Sheldonia	*capsula*			x						
	Sheldonia	*cingulata*	x	x							
	Sheldonia	*cornea*	x	x						x	
	Sheldonia	*cotyledonis*			x						
	Sheldonia	*crawfordi*		x							
	Sheldonia	*fuscicolor*	x					x			x
	Sheldonia	*hewitti*		x							
	Sheldonia	*hudsoniae*		x							

	Sheldonia	*inuncta*	x								
	Sheldonia	*leucospira*	x	x							
	Sheldonia	*lightfooti*		x							
	Sheldonia	*natalensis*	x	x							
	Sheldonia	*orientalis*		x							
	Sheldonia	*phytostylus*			x						
	Sheldonia	*poeppigii*	x	x							x
	Sheldonia	*pumilio*								x	
	Sheldonia	*puzeyi*		x							
	Sheldonia	*symmetrica*					x		x		
	Sheldonia	*transvaalensis*	x								x
	Sheldonia	*trotteriana*		x	x						
	Sheldonia	*vitalis*	x	x							
	Sheldonia	*warreni*	x								
	Sheldonia	*zonamydra*		x							
	Thapsia	*pinguis*	x							x	x
	Trochonanina	*mozambicensis*								x	x
	Trochonanina	*thermarum*								x	
	Urocyclus	*kirkii*	x								
Valloniidae	**Vallonia*	*costata*							x		
	**Vallonia*	*pulchella*	x	x	x				x		
Veronicellidae	*Laevicaulis*	*alte*	x	x						x	
	Laevicaulis	*haroldi*	x								
	Laevicaulis	*natalensis natalensis*	x	x	x		x		x	x	x
Vertiginidae	*Nesopupa*	*farquhari*	x	x							
	Nesopupa	*griqualandica*	x	x					x	x	
	Pupisoma	*harpula*	x	x	x					x	
	Pupisoma	*orcula*	x	x							
	Truncatellina	*iota*	x	x					x		x
	Truncatellina	*perplexa*	x	x					x		
	Truncatellina	*perplexa*					x	x	x		
	Truncatellina	*pretoriensis*					x		x		
	Truncatellina	*pygmaeorum*	x								
	Truncatellina	*sykesii*	x	x							
Vitrinidae	**Vitrea*	*crystallina*			x						
Zonitidae	**Oxychilus*	*alliarius*	x	x	x				x		
	**Oxychilus*	*arboreus*	x								
	**Oxychilus*	*cellarius*		x	x	x			x		
	**Oxychilus*	*draparnaudi*		x	x	x			x		
	**Zonitoides*	*arboreus*		x	x	x	x		x		
Total no. of families			31	32	27	10	16	12	21	21	17
Total no. of genera			54	50	41	18	16	13	24	39	29
Total no. of species			266	207	101	25	20	15	40	80	53
No. of indigenous species			251	187	75	17	16	10	30	79	50
No. of exotic species			15	20	26	8	4	5	10	1	3

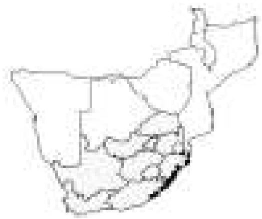
APPENDIX C

Appendix C: Distribution patterns of indigenous South African terrestrial mollusc families

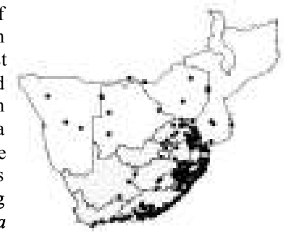
Family: Cyclophoridae (1 genus, 7 species)
Distribution: Cyclophoridae was represented in South Africa by the genus *Chondrocyclus*. *Chondrocyclus* (seven species) was recorded from South Africa in the following provinces Limpopo, KwaZulu-Natal, Eastern Cape and Western Cape.



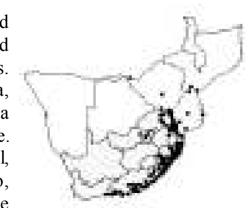
Family: Maizaniidae (1 genus, 1 species)
Distribution: The family Maizaniidae (genus: *Maizania*; species: *Maizania wahlbergi*) was distributed along the coast of KwaZulu-Natal and Eastern Cape.



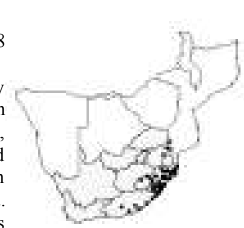
Family: Achatinidae (4 genera, 27 species)
Distribution: Achatinidae was recorded in all southern African countries and was widely distributed in the eastern regions of South Africa. Achatinidae was recorded in KwaZulu-Natal, Eastern Cape, on the coast of the Western Cape, Limpopo and Mpumalanga. It has a limited distribution in the Northern Cape, Gauteng with a single locality in the Free State and the North West Province. Achatinidae is represented by four genera, these being *Achatina* (four species), *Cochlitoma* (twenty-one species) *Burtoa* (one species) and *Metachina* (one species). Twenty-seven species were recorded in South Africa.



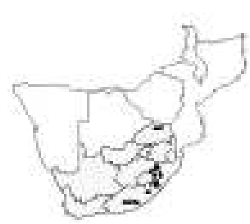
Family: Cerastidae (3 genera, 18 species)
Distribution: Cerastidae was distributed mainly to the east of southern Africa and did not extend into the central western regions. This family was recorded in South Africa, Mozambique and Zimbabwe. The family has a marginal distribution into the Western Cape. The family was found in KwaZulu-Natal, Eastern Cape, Mpumalanga, Limpopo, Gauteng and the North West Province. The distributions of three genera (*Edourdia*, *Rhachistia* and *Rhachis*) and eighteen species were recorded and map.



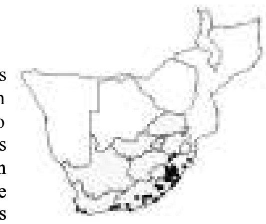
Family: Chlamydephoridae (1 genus, 8 species)
Distribution: Chlamydephoridae was mainly distributed on the eastern regions of southern Africa. The family occurred in KwaZulu-Natal, Eastern Cape, Mpumalanga, Limpopo and Lesotho. Chlamydephoridae did not occur in the central and western areas of South Africa. Eight species representing the genus *Chlamydephorus* were recorded within South Africa.



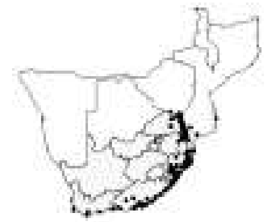
Family: Clausiliidae (1 genus, 1 species)
Distribution: Clausillidae, consisting of a single genus *Macroptychia*, was recorded from the interior of Limpopo, KwaZulu-Natal (Drakensberg) and Eastern Cape (Transkei). *Macroptychia africana* was the only species of this family that was recorded in South Africa.



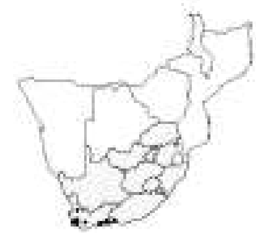
Family: Hydrocenidae (1 genus, 1 species)
Distribution: Hydrocenidae (genus *Hydrocena*) had a southern distribution and occurred from KwaZulu-Natal into the Eastern and Western Cape. It was not found in the central parts of South Africa. The only species recorded for the family is *Hydrocena noticola* and it was distributed along KwaZulu-Natal, Eastern Cape and the Western Cape peninsula.



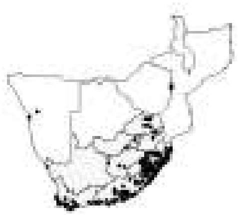
Family: Pomatiasidae (1 genus, 8 species)
Distribution: Pomatiasidae, consisting of a single genus, *Tropidophora* and eight species was mainly distributed in the eastern parts of southern Africa. The family was recorded in Mozambique and in the Limpopo, Mpumalanga, Gauteng, KwaZulu-Natal, Eastern Cape and Western Cape provinces of South Africa.



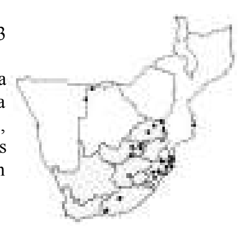
Family: Arionidae (3 genera, 4 species)
Distribution: The family Arionidae, consisted of three genera (*Ariopelta, Ariostralis* and *Oopelta*) and four species, was recorded in the interior of KwaZulu-Natal and coastal areas of the Western Cape.



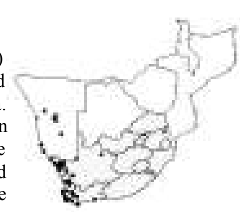
Family: Charopidae (2 genera, 84 species)
Distribution: The family, Charopidae, was recorded in Namibia, Mozambique and South Africa. Charopidae, represented by *Afrodonta* and *Trachycystis*, was recorded in all provinces of South Africa except in Mpumalanga. Eighty-four species were recorded.



Family: Chondrinidae (1 genus, 3 species)
Distribution: Chondrinidae had a scattered distribution in southern Africa and occurred within South Africa, Mozambique and Botswana. One genus and three species occurred within South Africa.



Family: Dorcasiidae (3 genera, 13 species)
Distribution: Dorcasiidae was distributed over the western parts of southern Africa. Its distribution occurred from the Western and Northern Cape into Namibia. Three genera (*Dorcasia, Trigonephrus* and *Tulbaghinia*) and twelve species were recorded within South Africa.



Family: Euconulidae (3 genera, 3 species)
Distribution: Euconulidae was represented by three genera, *Afroconulus, Afroguppya and Afropuctum* (each containing a single species). The family was mainly distributed on the eastern parts of southern Africa, within Mozambique, Limpopo, Mpumalanga, KwaZulu-Natal and Eastern Cape.

Family: Ferrussaciidae (1 genus, 3 species)
Distribution: The family occurred in Gauteng, KwaZulu-Natal and Eastern Cape.

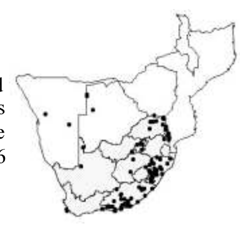
Family: Helicarionidae (1 genus, 2 species)
Distribution: The distribution of Helicarionidae (genus *Kaliella*) distribution extended from Zimbabwe, into Limpopo, North West, Gauteng, KwaZulu-Natal and Eastern Cape. The family showed an eastwards distribution and did not appear to extend into the western areas of South Africa. Two species these being *Kaliella barrakpoerensis* and *Kaliella euconuloides* were recorded within South Africa.

Family: Orculidae (1 genus, 13 species)
Distribution: A single genus, *Fauxulus* and thirteen species of the family, Orculidae, occurred in South Africa. The family was distributed in the northern areas of Limpopo, in the interior of KwaZulu-Natal and along the coastal areas of the Eastern and Western Cape.

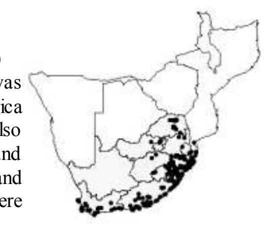
Family: Bulimulidae (1 genus, 2 species)
Distribution: Bulimulidae consisting of a single genus, *Prestonella* occurred in the interior of the Eastern Cape and Lesotho. Two species, *Prestonella bowkeri* and *Prestonella nuptialis* are found in the Eastern Cape.

Family: Punctidae (1 genus, 1 species)
Distribution: The family, Punctidae (genus: *Paralaoma*; species: *Paralaoma hottentota*) occurred in Limpopo, Gauteng, KwaZulu-Natal, Eastern Cape and Western Cape.

Family: Pupillidae (3 genera, 6 species)
Distribution: Pupillidae is widely distributed in South Africa, occurring in all provinces as well as in Botswana and Namibia. Three genera (*Lauria*, *Pupilla* and *Pupoides*) and 6 species occur in South Africa.



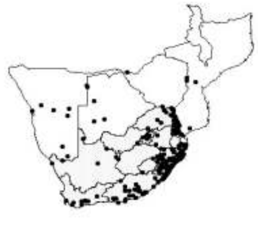
Family: Rhytididae (2 genera, 17 species)
Distribution: The family, Rhytididae, was recorded in all provinces of South Africa except in the Northern Cape. The family also occurred in Lesotho, Swaziland and Mozambique. Two genera (*Nata* and *Natalina*) and seventeen species were recorded within South Africa.



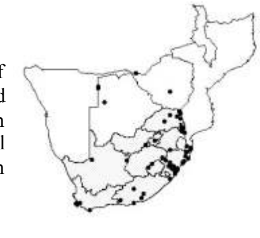
Family: Sculptariidae (1 genus, 1 species)
Distribution: The family, Sculptariidae, occurred in the western regions of southern Africa. The genus, *Sculptaria*, occurred in Namibia and in the Northern Cape of South Africa. A single species, *Sculptaria namaquaensis*, was recorded in the Northern Cape.

Family: Streptaxidae (4 genera, 123 species)
Distribution: Streptaxidae (consisting of four genera and 123 species) was recorded from the North West, Gauteng, Mpumalanga, Limpopo, KwaZulu-Natal and Eastern Cape provinces of South Africa. The family also occurred in Botswana, Mozambique, Zimbabwe and Swaziland.

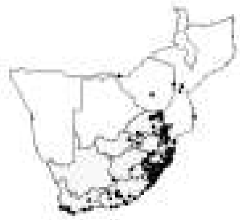
Family: Subulinidae (8 genera, 50 species)
Distribution: The family, Subulinidae is widely distributed in southern Africa, occurring in all countries within the region. In South Africa the family is not recorded from the Free State province.



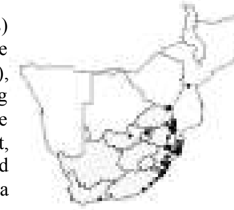
Family: Succineidae (2 genera, 7 species)
Distribution: Succineidae, consisting of two genera (*Oxyloma* and *Succinea*) and seven species, was widely distributed in South Africa and was recorded in all provinces. The family also occurred in Botawana, Zimbabwe and Lesotho.



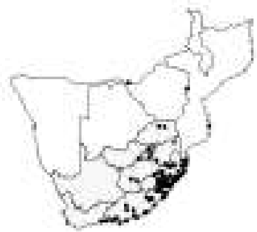
Family: Urocyclidae (6 genera, 34 species)
Distribution: The family, Urocyclidae (six genera and thirty-four species), occurred in the North West, Gauteng, Limpopo, Mpumalanga, KwaZulu-Natal, Eastern and Western Cape provinces of South Africa. Urocyclidae also occurred in Lesotho, Swaziland, Mozambique and Zimbabwe. The family was not recorded from the central and western areas of South Africa.



Family: Veronicellidae (1 genus, 3 species)
Distribution: Veronicellidae, (single genus: *Laevicaulis* and three species), exhibited an eastward distribution occurring in the Limpopo, Mpumalanga (in the Kruger National Park), North West, Gauteng, Western Cape, Eastern Cape and KwaZulu-Natal provinces of South Africa as well as in Swaziland and Mozambique.



Family: Vertiginidae (3 genera, 9 species)
Distribution: Vertiginidae, represented by three genera and nine species, occurted in the Limpopo, Mpumalanga, North West, Gauteng, Free State, Western Cape, Eastern Cape and KwaZulu-Natal provinces of South Africa as well as in Zimbabwe and Mozambique.



APPENDIX D

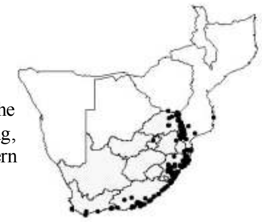
Appendix D: Distribution patterns of terrestrial mollusc genera in South Africa

Family: Cyclophoridae
Genus: *Chondrocyclus* (7 species)
Distribution: South Africa (Limpopo, KwaZulu-Natal, Eastern Cape and Western Cape).

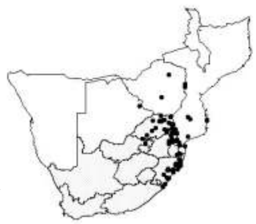
Family: Hydrocenidae
Genus: *Hydrocena* (1 species)
Distribution: Southern distribution and occurs from KwaZulu-Natal into the Eastern and Western Cape.

Family: Maizaniidae
Genus: *Maizania* (1 species)
Distribution: Along the coast of KwaZulu-Natal and Eastern Cape.

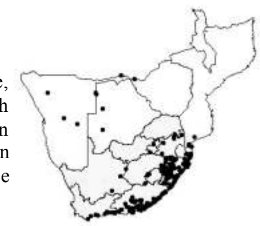
Family: Pomatiasidae
Genus: *Tropidophora* (8 species)
Distribution: Mozambique and in the Limpopo, Mpumalanga, Gauteng, KwaZulu-Natal, Eastern Cape and Western Cape provinces of South Africa.



Family: Achatinidae
Genus: *Achatina* (4 species)
Distribution: Widely distributed and is recorded in all southern African countries. It has a limited distribution in the interior of South Africa, mostly occurring in the eastern parts of the country. Recorded in all provinces of South Africa except in the Free State.



Genus: *Cochlitoma* (21 species)
Distribution: Mozambique, Zimbabwe, South Africa and Lesotho. Within South Africa, *Archachatina* is recorded in KwaZulu-Natal, Eastern Cape, Western Cape, Mpumalanga, Northern Cape and Free State.



Genus: *Burtoa* (1 species)
Distribution: Limpopo province of South Africa, Botswana and Zimbabwe.

Genus: *Metachatina* (1 species)
Distribution: KwaZulu-Natal and Mozambique.

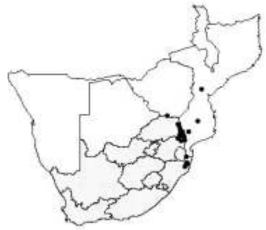
Family: Arionidae
Genus: *Ariopelta* (1 species)
Distribution: Western Cape

Genus: *Ariostralis* (1 species)
Distribution: Western Cape

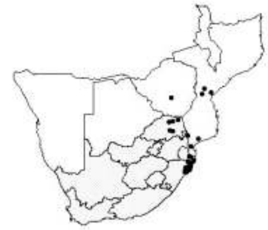
Genus: *Oopelta* (2 species)
Distribution: Western Cape

Family: Cerastidae
Genus: *Edouardia* (13 species)
Distribution: Wide distribution along the eastern areas of southern Africa. Recorded within South Africa, Mozambique and Zimbabwe. In South Africa, *Edourdia* was recorded in the following provinces, KwaZulu-Natal, Eastern Cape, Western Cape, Mpumalanga, Limpopo, Gauteng and the North West Province.

Genus: *Rachis* (1 species)
Distribution: KwaZulu-Natal, Limpopo, Mpumalanga, Mozambique and Zimbabwe

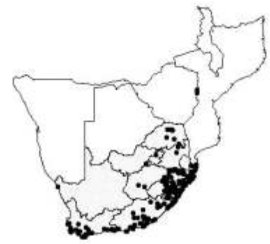


Genus: *Rhachistia* (4 species)
Distribution: Mozambique, KwaZulu-Natal, Limpopo, Mpumalanga and Zimbabwe.



Family: Charopidae (2 genera, 84 species)
Genus: *Afrodonta* (12 species)
Distribution: KwaZulu-Natal, Eastern Cape, Western Cape, Northern Cape, Limpopo and Mozambique.

Genus: *Trachycystis* (73 species)
Distribution: South Africa and Mozambique. This genus has a wide distribution within South Africa and is recorded within all provinces except in the Mpumalanga province



Family: Chlamydephoridae (1 genus, 8 species)
Genus: *Chlamydephorus* (8 species)
Distribution: Eastern Cape, KwaZulu-Natal, Limpopo, Mpumalanga and Lesotho.

Family: Chondrinidae (1 genus, 3 species)
Genus: *Gastrocopta* (3 species)
Distribution: Gauteng, Eastern Cape, KwaZulu-Natal, Limpopo, Free State and the North West province.

Family: Clausiliidae (1 genus, 1 species)
Genus: *Macroptychia* (1 species)
Distribution: Limpopo, KwaZulu-Natal and Eastern Cape.

Family: Dorcasiidae (3 genera, 13 species)
Genus: *Dorcasia* (2 species)
Distribution: Namibia and Northern Cape.

Genus: *Trigonephrus* (9 species)
Distribution: Northern Cape and Western Cape.

Genus: *Tulbaghinia* (1 species)
Distribution: Western Cape.

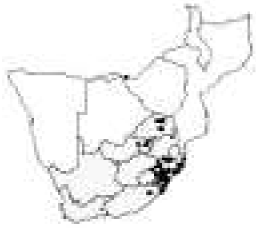
Family: Euconulidae (3 genera, 3 species)
Genus: *Afroconulus* (1 species)
Distribution: Interior of Limpopo, KwaZulu-Natal and Eastern Cape.

Genus: *Afroguppya* (1 species)
Distribution: Limpopo, Mpumalanga, KwaZulu-Natal, Eastern Cape and Mozambique

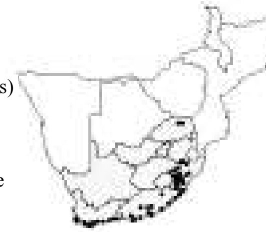
Genus: *Afropuctum* (1 species)
Distribution: Limpopo

Family: Ferrussaciidae (1 genus, 3 species)
Genus: *Cecilioides* (3 species)
Distribution: Gauteng, KwaZulu-Natal and Eastern Cape.

Family: Helicarionidae (1 genus, 2 species)
Genus: *Kaliella* (2 species)
Distribution: Eastern Cape, KwaZulu-Natal, Limpopo, North West, Gauteng and Zimbabwe

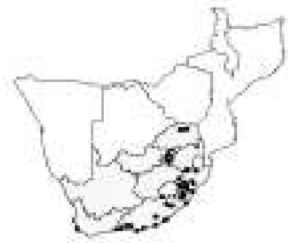


Family: Orculidae (1 genus, 13 species)
Genus: *Fauxulus* (13 species)
Distribution: Northern areas of Limpopo, in the interior of KwaZulu-Natal and along the coastal areas of the Eastern and Western Cape.

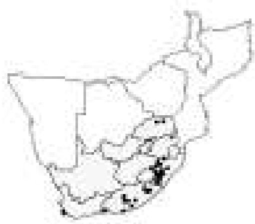


Family: Bulimulidae (1 genus, 2 species)
Genus: *Prestonella* (2 species)
Distribution: Interior of the Eastern Cape and Lesotho.

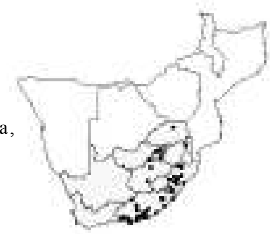
Family: Punctidae (1 genus, 1 species)
Genus: *Paralaoma* (1 species)
Distribution: Limpopo, Gauteng, KwaZulu-Natal, Eastern Cape and Western Cape.



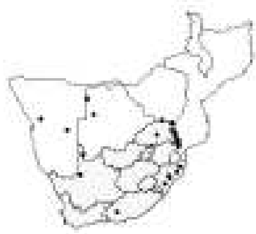
Family: Pupillidae (3 genera, 6 species)
Genus: *Lauria* (3 species)
Distribution: Limpopo, KwaZulu-Natal, Eastern Cape and Western Cape.



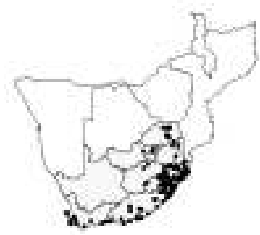
Genus: *Pupilla* (2 species)
Distribution: Limpopo, Mpumalanga, Gauteng, KwaZulu-Natal, Eastern Cape, Free State and the North West province



Genus: *Pupoides* (1 species)
Distribution: Limpopo, Mpumalanga, KwaZulu-Natal, Northern Cape and Eastern Cape, Botswana and Namibia.

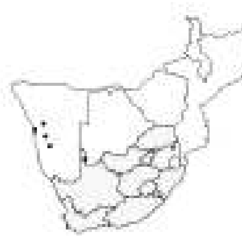


Family: Rhytididae (2 genera, 17 species)
Genus: *Nata* (4 species)
Distribution: Occurs in all provinces of South Africa except in the Northern Cape. The genus also occurs in Swaziland and Lesotho.



Genus: *Natalina* (13 species)
Distribution: Western Cape, Eastern Cape, KwaZulu-Natal and Mozambique.

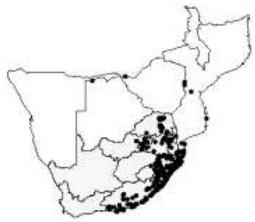
Family: Sculptariidae (1 genus, 1 species)
Genus: *Sculptaria* (1 species)
Distribution: Namibia and Northern Cape of South Africa.



Family: Streptaxidae (4 genera, 123 species)
Genus: *Eustreptaxis* (1 species)
Distribution: Northern KwaZulu-Natal and Mozambique.

Genus: *Gonaxis* (1 species)
Distribution: Northern KwaZulu-Natal, Mpumalanga, Limpopo, Botswana, Zimbabwe and Mozambique.

Genus: *Gulella* (119 species)
Distribution: Widely distributed in the east of South Africa, North West, Gauteng, Mpumalanga, Limpopo, KwaZulu-Natal and Eastern Cape. Also occurs in Swaziland, Botswana, Zimbabwe and Mozambique.



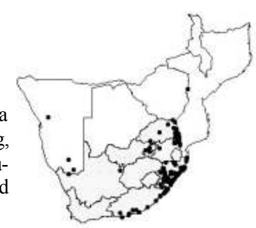
Genus: *Streptostele* (2 species)
Distribution: Mpumalanga (within the Kruger National Park) province of South Africa and Zimbabwe.

Family: Subulinidae (9 genera, 52 species)
Genus: *Coeliaxis* (1 species)
Distribution: Eastern Cape coast.

Genus: *Curvella* (11 species)
Distribution: Limpopo (within the Kruger National Park), KwaZulu-Natal and Eastern Cape.

Genus: *Euonyma* (16 species)
Distribution: Western Cape, Eastern Cape, Northern Cape, North West, Gauteng, Mpumalanga and widely distributed in KwaZulu-Natal.

Genus: *Opeas* (13 species)
Distribution: Limpopo, Mpumanlaga (Kruger National Park), Gauteng, Northen Cape, Eastern Cape, KwaZulu-Natal as well as in Mozambique and Namibia.

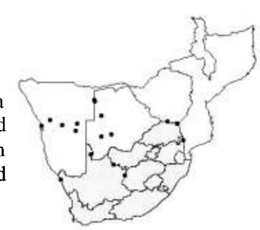


Genus: *Pseudoglessula* (3 species)
Distribution: Mozambique, northern KwaZulu-Natal, Mpumalanga (Kruger National Park) and Limpopo.

Genus: *Pseudopeas* (2 species)
Distribution: KwaZulu-Natal and Eastern Cape.

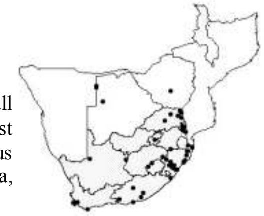
Genus: *Subulina* (4 species)
Distribution: Botswana, Zimbabwe and Namibia. In South Africa recorded from Limpopo, Mpumalanga and the Western Cape.

Genus: *Xerocerastus* (1 species)
Distribution: Limpopo, Mpumalanga (Kruger National Park), Northern and Western Cape provinces of South Africa as well as in Botswana and Namibia.



Family: Succineidae (2 genera, 7 species)
Genus: *Oxyloma* (1 species)
Distribution: Coast of KwaZulu-Natal, North West and Zimbabwe.

Genus: *Succinea* (6 species)
Distribution: Occcurs in all provinces except the North West province of South Africa. Genus was also recorded from Botawana, Zimbabwe and Lesotho.



Family: Urocyclidae (6 genera, 34 species)
Genus: *Atoxonoides* (1 species)
Distribution: KwaZulu-Natal

Genus: *Elisolimax* (1 species)
Distribution: East of southern Africa within Limpopo, Mpumalanga, KwaZulu-Natal, Eastern Cape and Mozambique

Genus: *Sheldonia* (30 species)
Distribution: North West, Gauteng, Limpopo, Mpumalanga, Western Cape, and Eastern Cape. Widely distributed in KwaZulu-Natal. Also occurs in Swaziland and Lesotho.

Genus: *Thapsia* (1 species)
Distribution: Northern KwaZulu-Natal, Limpopo, Mpumalanga and Zimbabwe.

Genus: *Trochonanina* (2 species)
Distribution: Limpopo, Mpumalanga (widely distributed in the Kruger National Park), Mozambique and Swaziland.

Genus: *Urocyclus* (1 species)
Distribution: Mozambique and KwaZulu-Natal coast.

Family: Veronicellidae (1 genus, 3 species)
Genus: *Laevicaulis* (3 species)
Distribution: Limpopo, Mpumalanga (in the Kruger National Park), North West, Gauteng, Western Cape, Eastern Cape and KwaZulu-Natal provinces of South Africa as well as in Swaziland and Mozambique.

Family: Vertiginidae (3 genera, 9 species)
Genus: *Nesopupa* (2 species)
Distribution: KwaZulu-Natal, Eastern Cape, Gauteng, Limpopo, Zimbabwe and Mozambique.

Genus: *Pupisoma* (2 species)
Distribution: Limpopo, KwaZulu-Natal, Eastern Cape and limited distribution into the Western Cape. Also recorded from Zimbabwe.

Genus: *Truncatellina* (5 species)
Distribution: KwaZulu-Natal, Eastern Cape, Gauteng, Mpumalanga, North West and Free State.