SEASONAL VARIATION IN ANURAN DIVERSITY AND ACTIVITY IN THE VREDEFORT DOME CONSERVATION AREA

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YUNIBESITI YA BOKONE-BOPHIRIMA
NORTH WEST UNIVERSITY
NOORDWES UNIVERSITEIT

Potchefstroomkampus

For My Parents

To whom I owe so much

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ABSTRACT

Seasonal variation in anuran diversity and activity in the Vredefort Dome conservation area

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On 14 July 2005 the Vredefort Dome was declared the 7th World Heritage Site of South Africa. Today it is generally accepted to be the oldest and largest meteorite impact site in the world. It was formed about 2020 million years ago when a meteorite as big as Table Mountain struck the earth at great speed, creating a crater of about 250 km in diameter and 40 km deep. Today, only the eroded remnants are visible northwest of the impact site. The geology and geography of the area has been studied in great detail, but we know relatively little about the ecology and animal diversity of the Vredefort Dome area.

Of the chordates, the amphibians are the least-known group of organisms in the area. The aims of the present study were to determine the species diversity, seasonal activity patterns, breeding behaviours, interaction of amphibians, and to verify the status of the amphibian chytrid, *Batrachochytrium dentrobatidis* in the Vredefort Dome area. Historical data collected during the South African Frog Atlas Project and other surveys indicated that the following species were present in this area: *Afrana angolensis, A. fuscigula, Breviceps adspersus, Bufo gutturalis, B. rangeri, B. poweri, Cacosternum boettgeri, Kassina senegalensis, Phrynobatrachus natalensis, Pyxicephalus adspersus, Schismaderma carens, Semnodactylus wealii, Strongylopus fasciatus, Tomopterna cryptotis* and *Xenopus laevis*.

As the study area covers only two quarter-degree grid cells it was decided to conduct this study on a finer scale to ensure a better resolution. Frogs were identified on the male chorus during the breeding season and on visual encounters. Tadpoles were also used to identify anuran species and to determine the presence of the amphibian chytrid. This monitoring stretched over a period of one year.

The following species were identified during the monitoring period: *Afrana angolensis, A. fuscigula, Breviceps adspersus, Bufo gutturalis, B. rangeri, B. poweri, Cacosternum boettgeri, Kassina senegalensis, Schismaderma carens, Strongylopus fasciatus, Tomopterna cryptotis, T. natalensis* and *Xenopus laevis*. Chytridiomycosis was identified in *Afrana angolensis* during the dry months of August, September, October and November.

OPSOMMING

Seisoenale veranderinge in die verspreiding en aktiwiteite van Amfibieë in die Vredefort Koepel bewarings area

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Op 14 Julie 2005 is die Vredefort Koepel tot die 7de Wêrelderfenisgebied in Suid-Afrika verklaar. Vandag word dit algemeen aanvaar dat dit die oudste en die grootste meteoriet inpakkrater in die wêreld is. Dit is ongeveer 2020 miljoen jaar gelede gevorm toe 'n meteoriet so groot soos Tafelberg die aarde teen 'n groot spoed getref het en 'n krater van 250 km in diameter en 40 km diep gevorm. Vandag is net die geërodeerde oorblyfsels sigbaar noord-wes van die inpak krater. Die geologie en geografie van die area is goed bestudeer maar relatief min is bekend van die ekologie en diversiteit van diere in die Vredefort area.

Van al die chordate, is die amfibieë die minste bekende groep organismes in die area. Die doel van die huidige studie was om die spesie diversiteit, seisoenale aktiwiteitpatrone, broei gedrag en interaksies van amfibieë te bepaal asook die status van die amfibiese chytrid swam, *Batrachochytrium dentrobatidis* in die Vredefort Koepel te bepaal. Historiese data versamel gedurende die Suid-Afrikaanse Padda Atlas Projek en ander navorsing toon dat die volgende spesies teenwoordig was: *Afrana angolensis, A. fuscigula, Breviceps adspersus, Bufo gutturalis, B. rangeri, B. poweri, Cacosternum boettgeri, Kassina senegalensis, Phrynobatrachus natalensis, Pyxicephalus adspersus, Schismaderma carens, Semnodactylus weallii, Strongylopus fasciatus, Tomopterna cryptotis* en *Xenopus laevis*.

Die studie area beslaan slegs twee kwart-graad selle en daarom is besluit om die studie area in kleiner selle te verdeel om sodoende 'n beter resolusie te verkry. Paddas was geïdentifiseer deur die roepe van mannetjies gedurende die broei seisoen en visuele voorkoms. Paddavisse was ook gebruik vir identifikasie van anura spesies asook om die teenwoordigheid van die amfibiese chytrid te bepaal. Monitering het oor 'n tydperk van een jaar gestrek.

Die volgende spesies is gedurende die studie tydperk geidentifiseer: *Afrana angolensis, A. fuscigula, Breviceps adspersus, Bufo gutturalis, B. rangeri, B. poweri, Cacosternum boettgeri, Kassina senegalensis, Schismaderma carens, Strongylopus fasciatus, Tomopterna cryptotis, T. natalensis* en *Xenopus laevis*. Chytridiomycosis was geïdentifiseer in *Afrana angolensis* gedurende die maande van Augustus, September, Oktober en November.

CHAPTER ONE

INTRODUCTION AND LITERATURE STUDY

1.1. Importance of Amphibians

The invasion of land by amphibians some 350 million years ago is perhaps one of the most dramatic events in animal evolution. Amphibians have undergone a remarkable adaptive radiation, and today the living groups exhibit a far greater diversity of modes of life history than any other group of vertebrates (Mattison, 1992). Extant amphibians are divided into three main groups; the order Gymnophiona or Apoda (wormlike, legless amphibians), the Caudata or Urodela (salamanders) and Anura or Salientia (frogs and toads) (Duellman & Trueb, 1986). In South Africa only representatives of the Anura are found.

Amphibians are important components in aquatic and terrestrial ecosystems, playing important roles in the ecosystems as prey and predator (Channing & Van Dijk, 1995; Branch & Harrison, 2004). Adults eat insects and other small invertebrates, while most tadpoles are primary consumers, feeding on algae and periphyton. In turn they are the food source for many other groups of animals. In addition to their ecological importance, amphibians are also important to mankind in several ways. These include the extraction of antibiotics from frog skin, hormone analogues, food (frog legs are a delicacy in some European countries), entertainment (frog jumping), laboratory experiments (including early pregnancy tests), insect control and use as environmental indicators (Channing, 2001; Carruthers, 1976). In recent times amphibians have frequently been the subject of news stories in the popular press, representing a renewed interest in this important taxon. This interest is a result of their uniqueness, importance to the environment and the puzzling rapid decline of amphibian numbers to such a level that several species are now officially extinct.

1.2. Declining Amphibian Populations

1.2.1 Global Declines

Amphibian populations are declining all over the world at an alarming rate. No single cause for declines has been identified (Kieseker *et al.*, 2001). Possible factors contributing to these declines are: habitat loss, global warming, the depletion of stratospheric ozone, chemical pollution, overexploitation by humans, introduction of exotic predators and infectious diseases (Weldon & Du Preez, 2004a). The IUCN Global Amphibian Assessment (2004) conducted a worldwide investigation into the conservation status of amphibians and concluded that 32.3% (1,856 species) of the 5,743 species known are globally threatened. Thirty-four species are considered to be Extinct and a further 7.4% (427 species) are Critically Endangered, 13.3% (761 species) Endangered, 11.6% (668 species) Vulnerable, 6.3% (359 species) Near Threatened, 38.4% (2,203 species) Least Concern and 22.5% (1,290 species) Data Deficient (see Appendix A for IUCN Red List Criteria). Amphibians are more threatened than any other animal group. There are 122 species believed to be possibly extinct (Stuart *et al.*, 2004).

1.2.2 Amphibian Declines in South Africa

At present very little is known about the stability of amphibian populations in South Africa. There is no evidence of a countrywide decline in amphibian populations in South Africa (Channing & Van Dijk, 1995). Decline in local population levels are known for *Afrana fuscigula* (Cape River Frog) in the Namaqualand and *Amietia vertebralis* (Large Mouth River Frog) in the Drakensberg escarpment (Weldon & Du Preez, 2004a).

The biggest factor contributing to amphibian declines in southern Africa seems to be habitat destruction. Habitat of frogs endemic to the Cape Flats, like the Cape Dainty Frog (*Cacosternum capense*), the Micro Frog (*Microbatrachella capensis*), and Gill's Platanna (*Xenopus gilli*) has been significantly reduced due to urbanisation (Channing, 2001). Most frogs are dependent on water for their survival, and are thus closely associated with water-bodies (Branch & Harrison, 2004). With the growth of human population, the demand for water also increases. More than one-third of our wetlands have been destroyed (Breen & Begg, 1989) while many of the remaining wetlands are threatened by water abstraction or pollution (Begg, 1990). Other threats to amphibians include: the introduction of exotic fish, pesticides and pollution, fire, siltation, dam construction, overgrazing, edaphic changes, food source, road kills, drought and hybridization (Branch & Harrison, 2004).

There are about 130 species of frogs and toads described in South Africa (Carruthers, 2001). During the Frog Atlas Project a Red Data List was compiled and includes four Critically Endangered, eight Endangered, eight Vulnerable, five Near Threatened and eight Data Deficient species (see Appendix A for IUCN Red List Criteria).

1.3 Amphibian Studies in South Africa

The historical study of amphibians in South Africa dates to the 18th century. The first person to describe a frog in South Africa was Carolus Linnaeus. He described the Cape Rain Frog (*Breviceps gibbosus)* in the region of Cape Town in 1758. Other contributions to the herpetology of South Africa came from researchers associated with the Natural History Museum in London. Notable contributors include J. Gray, A. Günther, G.A. Boulenger, H.W. Parker, A.G.C. Grandison, and B.T. Clarke (Channing, 2001). Dr. Andrew Smith was the most important amphibian biologist in South Africa before the First World War. He was based in the Cape and travelled the country, describing twenty-six species of frogs and toads. He also established the South African Museum in Cape Town and authored the book titled *The Zoology of South Africa* (Carruthers, 2001).

During the two World Wars, the influence of European researchers in South Africa began to decrease and South African scientists began to emerge as experts in South African amphibians. J. Hewitt in Grahamstown described 24 genera and species from 1913 to 1937. J. Power at McGregor Museum in Kimberly, V. FitzSimons at the Transvaal Museum in Pretoria, and A.C. Hoffman at the National Museum in Bloemfontein also made contributions. R. Laurent made the greatest contribution during the wars (Channing, 2001).

The period from the end of the Second World War up to 1971 led to the description of 27 genera. In this period J.C. Poynton took the lead in describing amphibians in southern Africa. Van Dijk published the first papers on southern Africa tadpoles in 1966 and 1971. Since 1972, technology played a more significant role in South African herpetology. Spectral analysis of vocalisations became a key to recognising cryptic species. N. Passmore and V. Carruthers were pioneers in the field of vocalisation (Passmore & Carruthers, 1995). More recently, DNA sequencing has become a crucial tool when comparing relatedness of populations or specimens and is an important new method for distinguishing between genera and cryptic species.

Books and guides published on frog research played an important role to advance amphibian studies. W. Rose wrote two books, *Veld and Vlei* (1929) and *The Reptiles and Amphibians of Southern Africa* (1950 and revised in 1962). J. Hewitt published a guide to vertebrates of the Eastern Cape Province in 1937. V. Wager produced a series of articles on frogs and published *The Frogs of South Africa* in 1965 and released a second edition in 1986. U. de V. Pienaar, N. Passmore and V. Carruthers published the book, *The Frogs of the Kruger National Park* in 1976. N. Passmore and V. Carruthers published *South African Frogs* in 1979, with a second edition in 1995. L. du Preez authored a *Field guide and key to the Frogs and Toads of the Free State* in 1996. In 2001 A. Channing published *Amphibians of Central and Southern Africa.* V. Carruthers also published *Frogs and Frogging in Southern Africa* (2001). Most recently, the status and biogeography of South African frogs was addressed by the Frog Atlas Project from 1996 – 2003, leading to the *Atlas and Red Data Book of the Frogs* *of South Africa, Lesotho and Swaziland* (2004) edited by L.R. Minter and co-workers.

1.4 Amphibian Chytrid in South Africa

Chytridiomycosis is an infectious disease that affects amphibians worldwide. It is caused by the chytrid fungus, *Batrachochytrium dendrobatidis*. The fungus was first discovered in dead and dying frogs in Queensland and Panama in 1998 (Berger *et al.,* 1998). Research since then has shown that the fungus is spread over five continents namely Africa, South America, North America, Europe, Australia, as well as throughout Central America and Oceania (Berger *et al.*, 1999a).

Until very recently, *B. dendrobatidis* was known in South Africa only from infections in *Xenopus laevis*, *Afrana fuscigula*, and *Strongylopus grayii*. These reports were only from the Western Cape and Northern Cape (Hopkins & Channing, 2003; Weldon, 2002). Weldon (2005) significantly increased our knowledge of amphibian chytrid in South Africa, confirming its presence in *Bufo robinsoni* (Springbok, Northern Cape), *Kassina senegelensis* (Kenton on Sea, Eastern Cape), *Afrana dracomontana* (Free State and Lesotho), *A. fuscigula* (Northern Cape), *A. angolensis* (Bela-bela, Limpopo), *Amietia vertebralis* (Free State and Lesotho), *Cacostenum boettgeri* (Kenton on Sea, Eastern Cape), *Strongylopus fasciatus* (Kenton on Sea, Eastern Cape), *Tomopterna cryptotis* and *T. natalensis* (Bela-bela, Limpopo), *Xenopus gilli* (Western Cape), *X. laevis* (Western Cape, Free State, Botswana, Kwazula-Natal and Northern Cape), *X. petersii* (Botswana) and *X. muelleri* (Swaziland). The earliest known record of *B. dendrobatidis* in the world is from South Africa in *X. laevis* collected in 1938 (Weldon *et al.*, 2004).

Amphibian chytrid is more common in South Africa than was originally thought. The status of this potentially deadly fungus, *B. dendrobatidis* is not known for most of South Africa.

1.5 Vredefort Dome: World Heritage Site

UNESCO (United Nations Education and Scientific Organization) is responsible for declaring world heritage sites. At the moment there are 812 heritage (natural and cultural) sites in the world. South Africa has only seven: three cultural, three natural and one of mixed cultural and natural heritage. They are: Greater St. Lucia Wetland Park (declared in 1999), Robben Island (1999), Cradle of Humankind (1999), Ukhahlamba/Drakensberg Park (2000), Mapungubwe Cultural Landscape (2003), Cape Floral Region (2004), and the most recent addition, the Vredefort Dome (2005); a natural heritage site. The Vredefort Dome Area received World Heritage Status on 14 July 2005 at the UNESCO's 29th World Heritage Committee meeting in Durban (Salmons, 2005).

The geology and geography of the area has been studied in great detail, but we know relatively little about the ecology and animal diversity of the Vredefort Dome area. Moreover, little is known of the diversity and life history of amphibians in the Vredefort Dome conservation area.

1.6 Study Proposal and Objectives

Little is known about either the anuran diversity of the Vredefort Dome or the status of the amphibian chytrid, *Batrachochytrium dendrobatidis* in this area. Historical data collected during the South African Frog Atlas Project (Minter *et al.* 2004) and other surveys, suggested that the following species could be expected in the Vredefort Dome Area: *Afrana angolensis, A. fuscigula, Breviceps adspersus, Bufo gutturalis, B. rangeri, B. poweri, Cacosternum boettgeri, Kassina senegalensis, Phrynobatrachus natalensis, Pyxicephalus adspersus, Schismaderma carens, Semnodactylus wealii, Strongylopus fasciatus, Tomopterna cryptotis* and *Xenopus laevis*.

The aims and objectives of this study were to:

- Determine the anuran diversity of the Vredefort Dome area.
- Study the impact of climatic factors on anuran distribution and behaviour.
- Study the life history of the anuran species of the Vredefort Dome area.
- Compile a tourist guide to the frogs and toads of the Vredefort Dome area.
- Determine the presence of the amphibian chytrid in the Vredefort Dome and whether it poses any threat to the anuran community in the area.

CHAPTER TWO

STUDY AREA

2.1 Geological Information

Since the earliest days meteorites fascinated man and meteorite impact craters on the earth received considerable attention. About 170 crater structures of possible impact origin have been identified worldwide (Reimold & Gibson, 2005). The Vredefort Dome area south-east of Potchefstroom, South Africa, is the oldest and largest meteorite impact site in the world. It was created some 2 023 million years ago when a gigantic meteorite of possibly 10 to 15 km in diameter, the size of Table Mountain, collided with the earth to form a massive impact crater (Anon., 2005). Some 70 km^3 of rock would have been vaporised in the impact. The original crater is estimated to have been 250 - 300 km in diameter, larger than the Sudbury impact structure in Canada, which is about 200 km in diameter (Gaylard, 2005). Today, only the eroded remnants are visible northwest of the impact site (Figure 2.1).

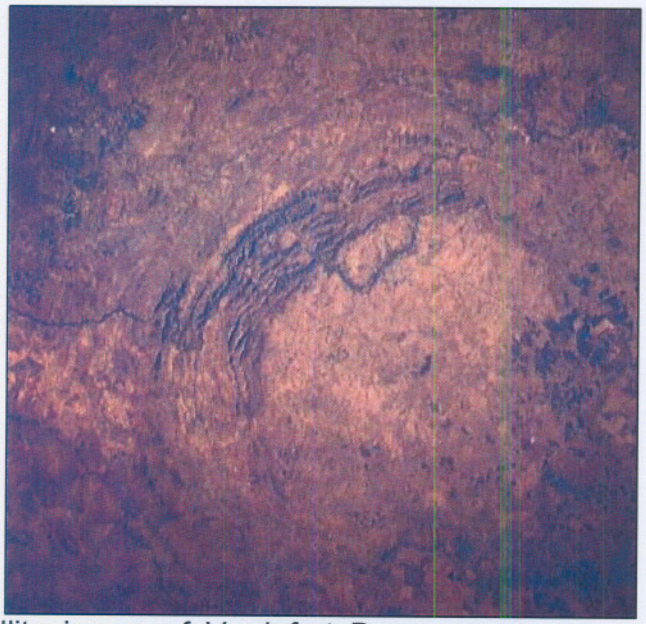


Figure 2-1 Satellite image of Vredefort Dome structure as seen from outer space (Source: Earth Sciences and image analysis laboratory, NASA Space Centre).

2.2 Vredefort Dome World Heritage Site - Location and Size

The Vredefort Dome World Heritage Site (VDWHS) is situated between 26°45' and 27°00' south latitude and 27°10' and 27°25' east longitude and covers an area of 30,108 Ha. There are no geographical boundaries to define the heritage site and the borders are defined by secondary roads. The nearest towns to the area are: Parys in the southeast, Vredefort in the south and Potchefstroom in the northwest. Venterskroon is a small settlement situated in the centre of the dome (Naudé, 2005). The Vaal River cuts through the site and is the provincial border between the North West Province and the Free State Province (Nel, 1927). (See Figure 2.2). The VDWHS is comprised of 149 private properties, 91 of which are located within the North West Province (18,859 ha), and 58 the Free State Province (11,252 ha). An additional 600 ha is state owned land (IUCN, 2005).

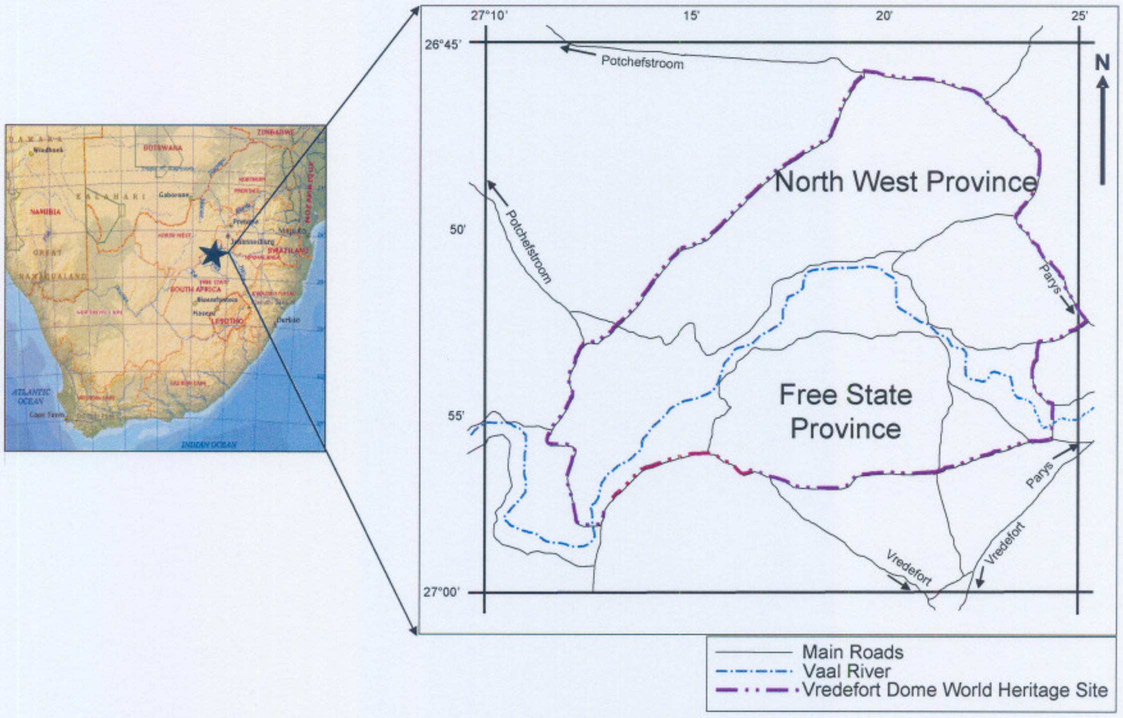


Figure 2-2 Map indicating the Vredefort Dome World Heritage Site

2.3 Topography

The altitude varies from 1 300 m to 1 692 m with an average of 1 500 m above sea level (Van Der Walt, 1984). The highest point is at Witkop, 1 692 m (Nel, 1927). The Free State side of the dome is less mountainous than the North West side. The impact of the meteorite was at an angle creating the more mountainous area to the north. The satellite image (Figure 2.1) clearly shows the semi-circles to the north.

2.4 Drainage

The dome is well drained, with rivers and smaller streams that eventually drain into the Vaal River. The soil type plays an important role in how well the dome is drained (See Section 2.7). The Vaal is perennial and flows from east to west, through the dome. Most of the streams only flow during the rainy season. Springs are rare (Nel, 1923). Most of the farm ponds are seasonal and only fill in the summer rainy season. These sites make ideal breeding areas for amphibians during the rainy season.

2.5 Climate

The distribution and activity of frogs and toads are usually determined by two ecological factors, namely rainfall and temperature (Du Preez, 1996).

2.5.1 Temperature

Temperatures are slightly higher in Potchefstroom than in Parys. The 10-year average daily maximum is 25.9°C and the average daily minimum is 10.0°C for the same period (Figure 2-3). The maximum daily temperature experienced during the study time was 36.6°C and the minimum was -4.5°C (SA Weather, 2006). Winter nights can occasionally drop to -10°C. Northern slopes are typically warmer than the southern slopes and the valleys are typically cooler at night than the higher grounds (Thornton & Feinstein, 2002).

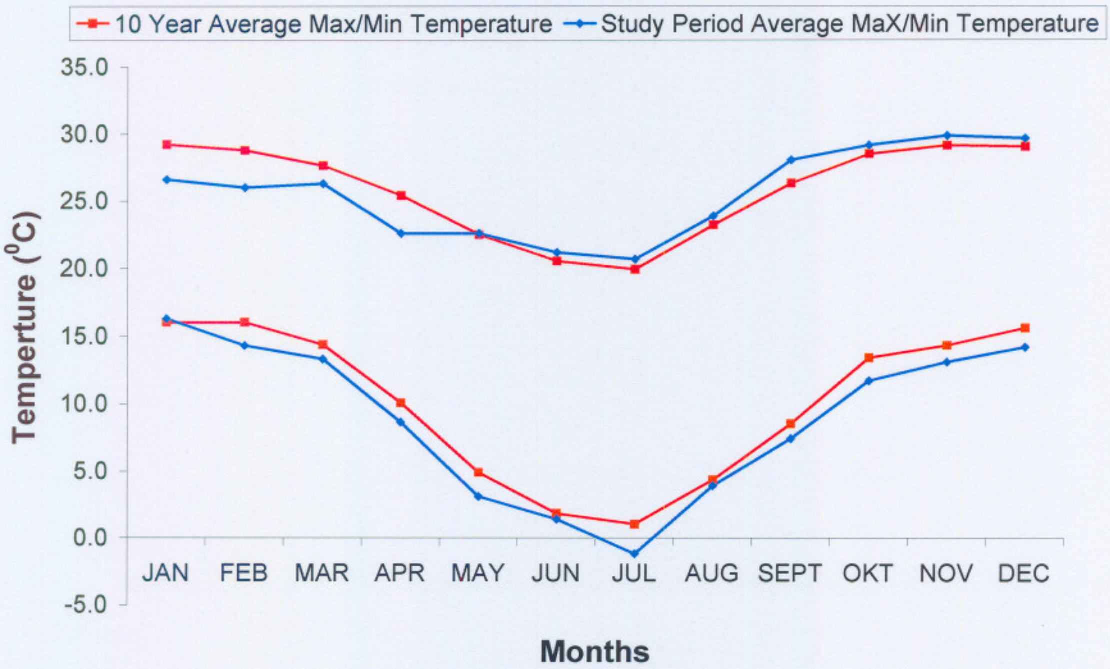


Figure 2-3 Graph showing the maximum and minimum temperature over the past 10 years in the study area and temperature during the study period (SA Weather Service, 2006).

2.5.2 Rainfall

The mean annual rainfall decreases from east to west. Parys has a 10-year average of 640.8 mm, while Potchefstroom has 521.4 mm (SA Weather, 2006). More than 80% of annual rainfall is in the months from October to March. December, January and February are the months with the highest rainfall (Figure 2-4). The rain is usually in the form of thunderstorms (Van Der Walt, 1984).

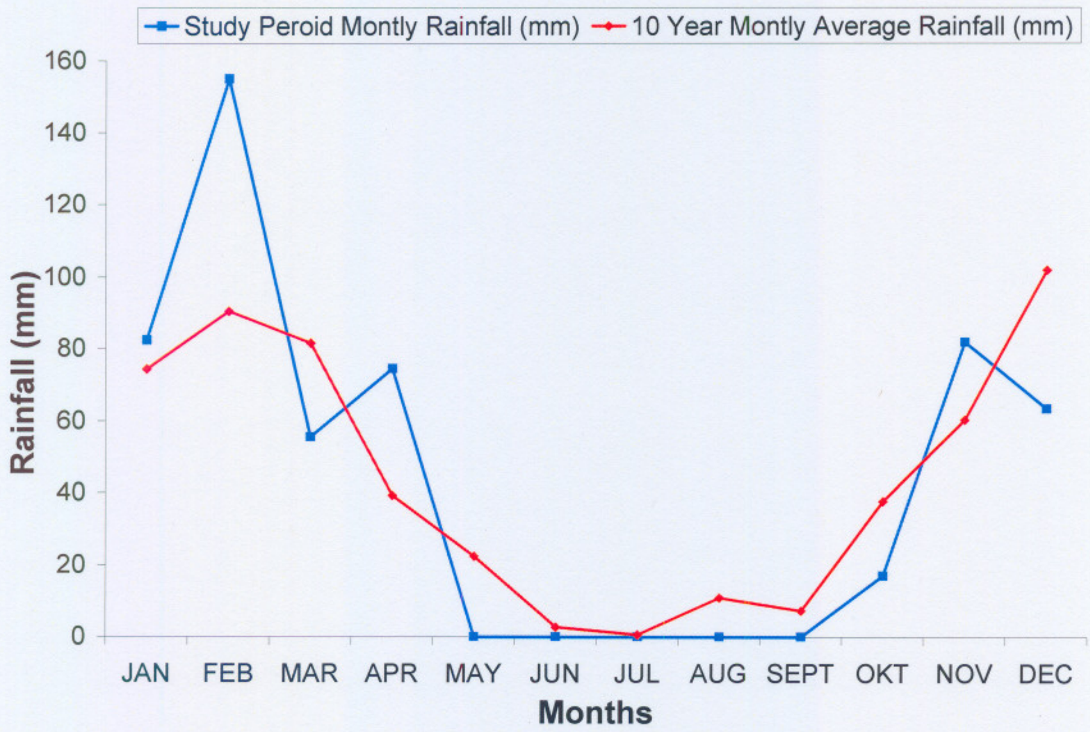


Figure 2-4 Graph showing the monthly average rainfall over the past 10 years in the study area and rainfall during the study period (SA Weather Service, 2006).

2.6 Vegetation

2.6.1 Natural vegetation

According to Acocks (1988) this area consists of sour grassveld, but because of the rocky hills it is more a typical Bankenveld (Figure 2.5). According to Bredenkamp & Van Rooyen, 1996 this vegetation type has been renamed to 'Rocky Highveld Grassland'. It is a transition type between typical grassland and bushveld. Habitats within this veld type include rocky mountains, hills, ridges and plains of quartzite as experienced in the north western part of the dome (Bredenkamp & Van Rooyen, 1996).

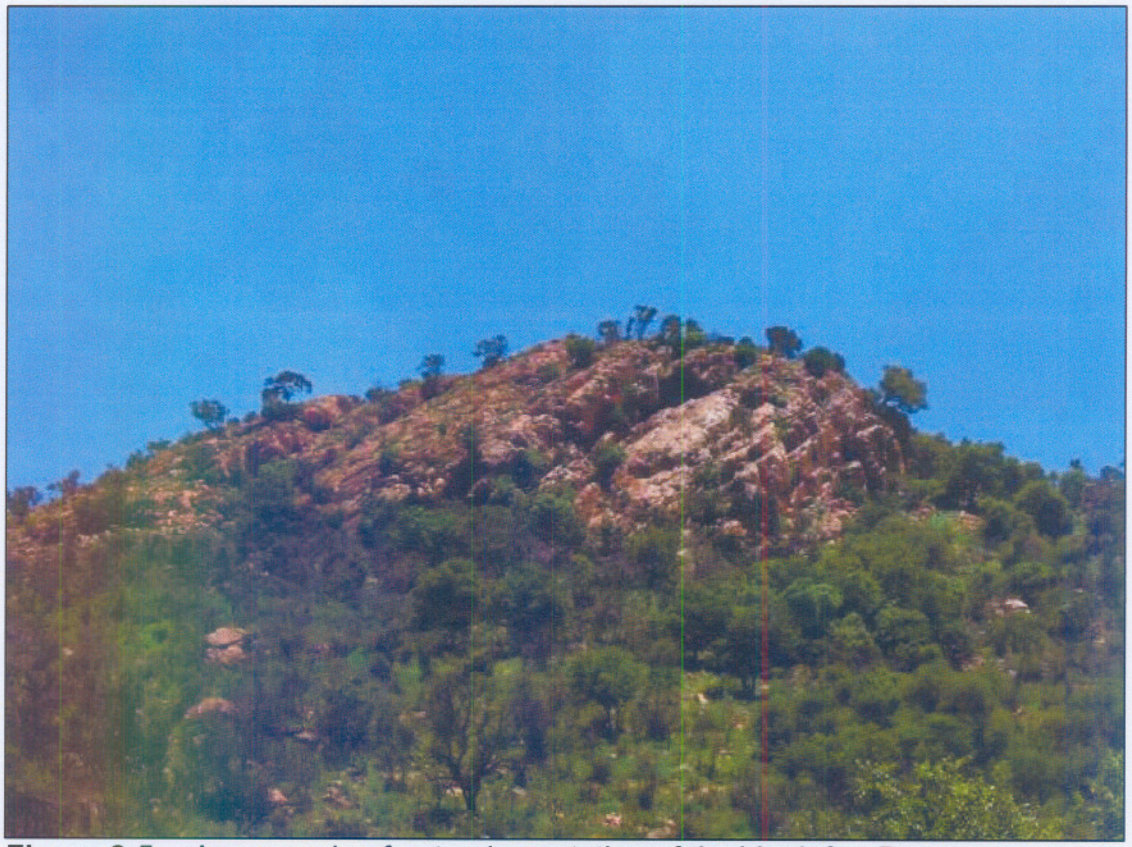


Figure 2-5 An example of natural vegetation of the Vredefort Dome.

2.6.2 Agriculture

Due to the shallow, rocky soils, maize production is limited (Bredenkamp & Van Rooyen, 1996). Most of the study area has no or very limited arable land potential, except along the Vaal River and on the flat areas in the Free State (Thornton & Feinstein, 2002). Cattle production does occur, although the sour grass species result in a low nutrient status in winter and additional sources of nutrients are needed (Bredenkamp & Van Rooyen, 1996). Steep slopes make grazing difficult or inaccessible to cattle. The carrying capacity in many cases is quite low at a requirement of approximately seven hectare for a Large Animal Unit (Thornton & Feinstein, 2002).

Figure 2-6 Agriculture (cattle farming and maize production) in the Vredefort Dome.

2.7 Soil types

According to Bates (1992) the type of soil plays a role in the distribution of some amphibians, like the Bushveld Rain frog (*Breviceps adspersus),* which is a burrowing species. The quartzite ridges consist mostly of steep rock outcrops. These ridges also consist of shallow rocky grounds with no remarkable plateau. The quartzite formation is responsible for a lot of sandy ground. Dundee-grounds (nonhydric soil) are present near the Vaal River, while more Hutton-ground (dystrophic soil) is present further from the river (Van Der Walt, 1984).

2.8 Tourism

Although the VDWHS has significant tourism potential, the area is not yet known as a local or foreign tourism destination. The average percentage of foreign tourists for the North West Province is about 8.4% of all foreign tourists in 2005 and 8.2% of all foreign tourists for the Free State (SA Tourism Index, 2005). Domestic tourism visitors in the North West were 6.7% of all domestic visitors; similarly the percentile for the Free State was 3.4% domestic visitors for the first half of (SA Domestic Tourism Report, 2005). The study area is an ideal breakaway for weekends and for business conferences. There are numerous guesthouses, resorts, teambuilding facilities, adventure farms and game reserves in the area (Thornton & Feinstein, 2002). The new conservation status of this area will undoubtedly drastically increase the tourism potential.

2.9 Monitoring Site Description

The National Frog Atlas Project conducted between 1996 and 2003 based its scale on a quarter-degree grid, each measuring 15 minutes latitude by 15 minutes longitude (Minter *et al.*, 2004). The complete Vredefort Dome area falls over two of these cells. In this study each quarter-degree cell was divided into nine smaller grid cells, each measuring 5 minutes latitude by 5 minutes longitude to attain better spatial resolution (Figure 2-7). Amphibians were sampled in each of these cells monthly over a period of one year. During the breeding season of November 2004 and February 2005 thirteen permanent monitoring sites and fifteen temporary sites were selected. Permission to collect tadpoles was obtained from 9 of the 15 permanent sites. The other six farmers do not live on their farms and attempts to make contact were futile. Temporary sites (e.g. roadside ponds) depended on the rainfall and thus could not be used as permanent sites.

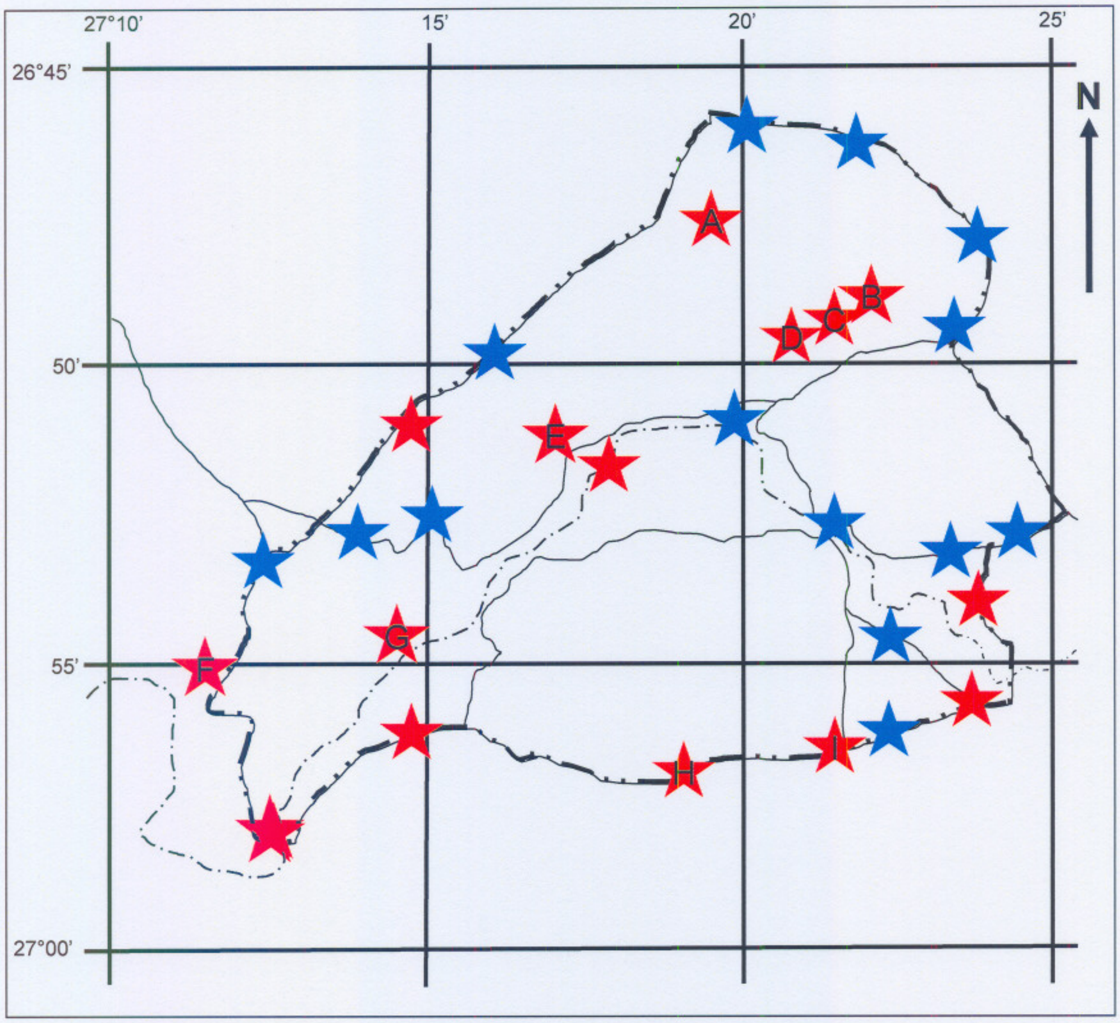


Figure 2-7 Division of study area into smaller grid cells and indication of monitoring sites. Permanent sites are indicated by a red star and temporary site with a blue star. Sites A – I are also indicated.

Tables 2-1 to 2-9 give some physical information of these permanent monitoring sites. The information was recorded once during the study period. Sites were chosen on their availability, accessibility (roads), permanent water throughout the year and permission obtained from landowners. As far as possible sites representing dams, ponds, rivers/streams and vleis were chosen to have a wide variety of habitats.

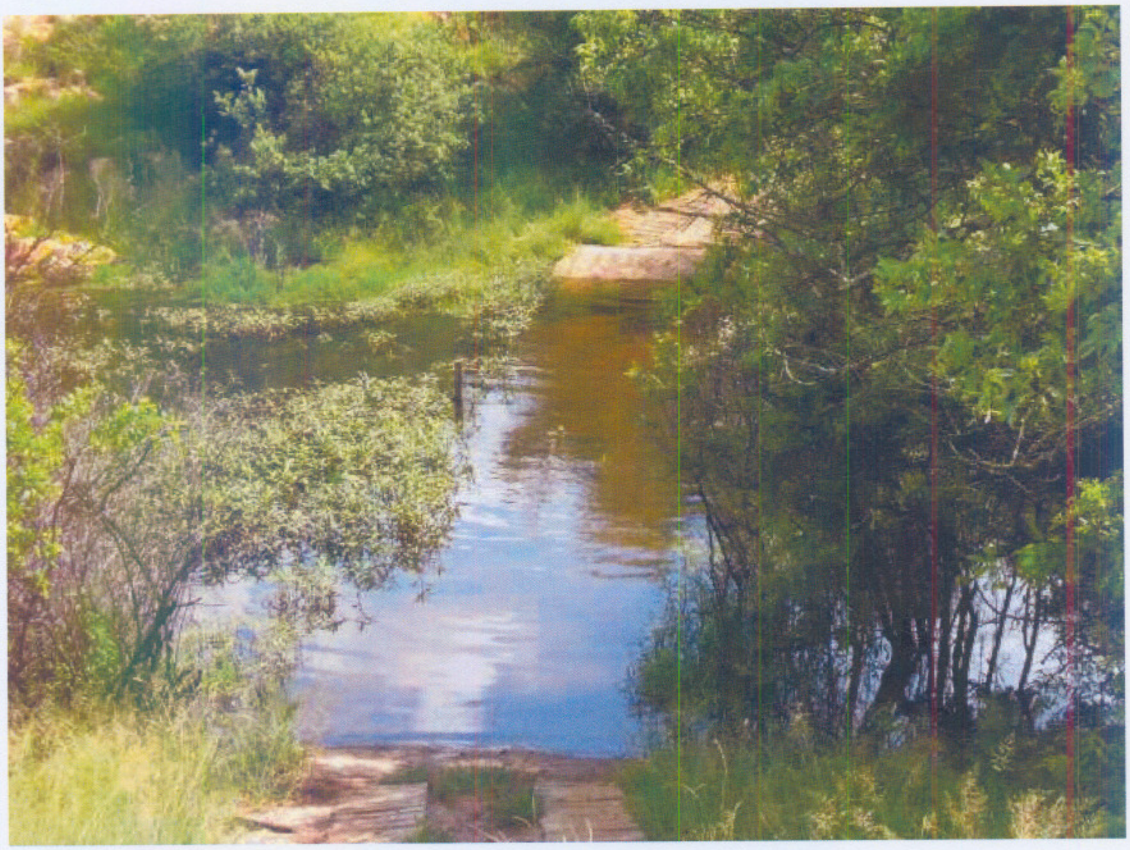
Table 2-1 Physical information of Site A.

SITE A

Locality coordinates	26°47'49" S 27°19'15" E
Locality name	Mooinooiensfontein
Locality description	Pond, with an eastern inlet and a western dam wall
Source of Water	Rain, spring
Surface area	1000 m^2
Water depth	1 m
Secci depth	80 mm
Water quality	pH = 5.6 Water Temperature = 26.8°C DO = 47.5
Vegetation	80 % grasses and some aquatic vegetation, no trees
Other Animals observed:	Cattle, small rodents, wetland birds, fish (*Clarius garipinus* and *Barbus* sp.)
Land use	Farming (cattle and maize production)

Table 2-2 Physical information of Site B

SITE B



Locality coordinates	26°49'35" S 27°22'30" E
Locality name	Berhaka Eco 4 x 4 Trail
Locality description	Weir in mountain stream, water dammed up forming a vlei. Concrete drift.
Source of water	Rain, mountain stream
Surface area	100 m^2
Water depth	860 mm
Secci depth	Bottom, 860 mm
Water quality	pH = 5.2 Water temperature = 25.3°C DO = 44.3
Vegetation	Trees, a lot of aquatic plants and grasses
Other animals observed	Wetland birds, cattle
Land use	Farming (cattle) and eco-tourism (4x4 Trails)

Table 2-3 Physical information of Site C

SITE C	
	
Locality coordinates	26°49'43" S 27°22'49" E
Locality name	Bluegumwoods (dam)
Locality description	Pond
Source of water	Rain, mountain stream
Surface area	1500 m^2
Water depth	1-2 m
Secci depth	370 mm
Water quality	pH= 6.8 Water temperature = 24.8°C DO = 37.2
Vegetation	Blue gum trees, water grasses, mainly grass on banks and reeds
Other animals observed	Wetland birds, horses, cattle, fish (*Microptersus dolemieu* and *Tilapia* sp.)
Land use	Farming (cattle) and tourism (fishing and camping)

Table 2-4 Physical information of Site D

SITE D

Locality coordinates	26°49'50" S 27°21'40" E
Locality name	Bluegumwoods (river)
Locality description	Mountain stream, with some deeper pools, flowing throughout the year
Source of water	Rain, upstream pond, stream
Surface area	150 m^2
Water depth	100 – 200 mm
Secci depth	Bottom, clear water
Water quality	pH= 6.8 Water temperature = 24.8°C DO = 37.2
Vegetation	Some trees and mostly covered by grasses
Other animals observed	Butterflies, horses, cattle
Land use	Farming (cattle and goats)

Table 2-5 Physical information of Site E

SITE E

Locality coordinates	26°51'26" S 27°17'03" E
Locality name	Thabela Thabeng
Locality description	Mountain stream, with some deeper pools, flowing throughout the year
Source of water	Rain, spring, mountain stream
Surface area	150 m^2
Water depth	100 – 200 mm
Secci depth	Bottom, clear water
Water quality	pH= 4.6 Water temperature = 23.7°C DO = 24.5
Vegetation:	Grasses and some bigger trees and bushes
Other animals observed	Baboons
Land use	Tourism (hiking, mountain biking and camping)

Table 2-6 Physical information of Site F

SITE F

Locality coordinates	26°55'34" S 27°11'27" E
Locality name	Elgro Bridge
Locality description	River, with some deeper pools, flowing throughout the year
Source of water	Rain, springs, mountain streams
Surface area	75 m^2
Water depth	10 – 70 cm
Secci depth	Bottom, clear water
Water quality	pH= 5.1 Water temperature = 22.4°C DO = 43
Vegetation	Grasses, aquatic vegetation and some bushes and trees
Other animals observed	Horses, birds, fish (*Clarius garipinus, Barbus* sp. and *Tilapia* sp.)
Land use	Tourism

Table 2-7 Physical information of Site G

SITE G

Locality coordinates	26°54'55" S 27°14'33" E
Locality name	Waterfall (De Kroons)
Locality description	Mountain stream, with some deeper pools, flowing only in rainy season
Source of water	Rain, fountain, mountain stream
Surface area	50 m^2
Water depth	100 mm, pools – 1000 mm
Secci depth	Bottom, clear water
Water quality	pH= 5.1 Water temperature = 22.4°C DO = 43
Vegetation	Trees, some grasses and smaller bushes
Other animals observed	Baboons
Land use	Hiking and camping

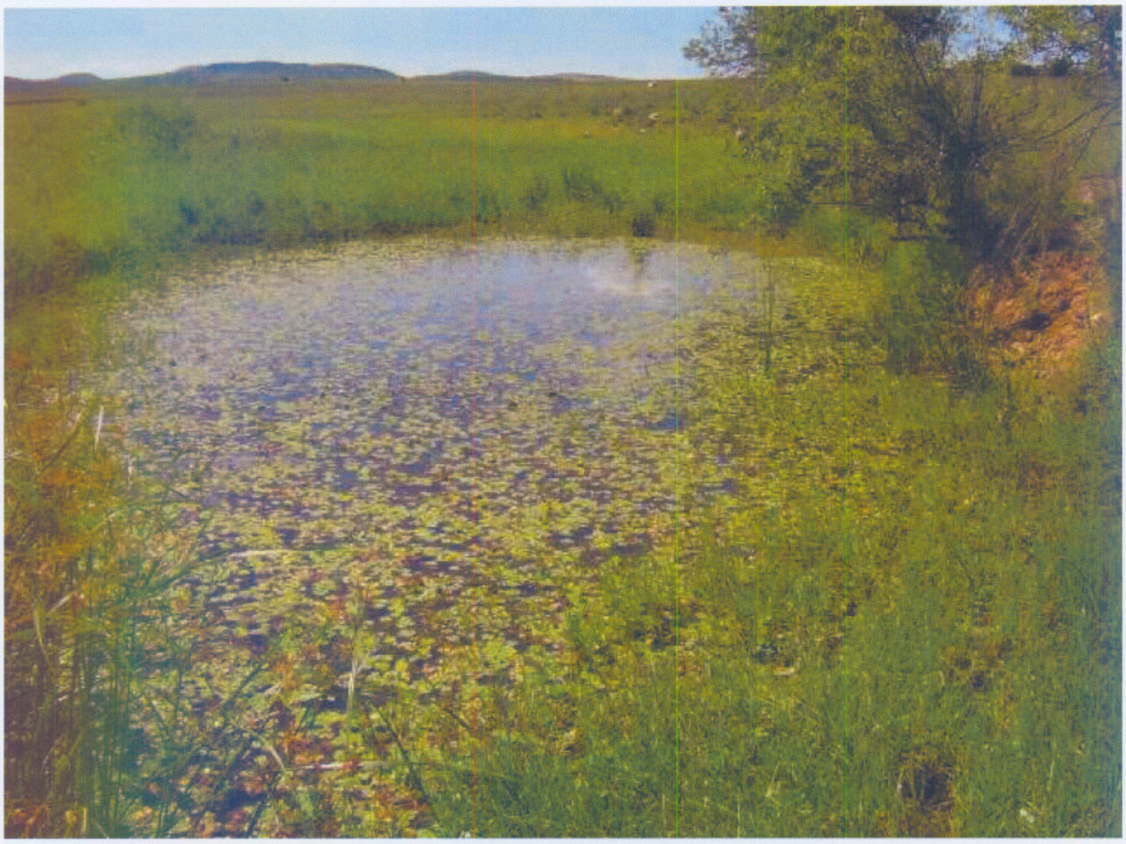
Table 2-8 Physical information of Site H

SITE H

Locality coordinates	26°57'11" S 27°19'14" E
Locality name	Dampoort I
Locality description	Pond, vlei
Source of water	Rain
Surface area	100 m^2
Water depth	300 mm
Secci depth	200 mm, except after big rains
Water quality	pH= 8.1 Water temperature = 23°C DO = 13
Vegetation	Banks is covered by grasses, aquatic vegetation
Other animals observed	*Tilapia* sp.
Land use	Farming (cattle and maize production)

Table 2-9 Physical information of Site I

SITE I



Locality coordinates	26°56'51" S 27°20'54" E
Locality name	Dampoort II
Locality description	Pond, vlei
Source of water	Rain
Surface area	50 m^2
Water depth	300 mm
Secci depth	200 mm
Water quality	pH= 5.2 Water temperature = 23.5°C DO = 30
Vegetation	Banks are covered by grasses and bushes, aquatic vegetation
Other animals observed	Birds (Hamerkop and Heron)
Land use	Farming (cattle and maize production)

CHAPTER THREE

MATERIALS AND METHODS

3.1 Sampling schedule

Prior to the study period, possible sites for monitoring were identified through night driving (see Section 3.2.4). This was done in the months of November 2004 until February 2005. Once sites were identified (see Section 2.9, Chapter 2) sampling was done during the first week of every month. Sampling started in March 2005 and ended in February 2006, giving a one 12-month cycle. After heavy rain, trips to the Dome were made to visit temporary sites that were formed by the accumulation of water in topographic depressions. Figure 3-1 indicates the order in which fieldwork was conducted each month.

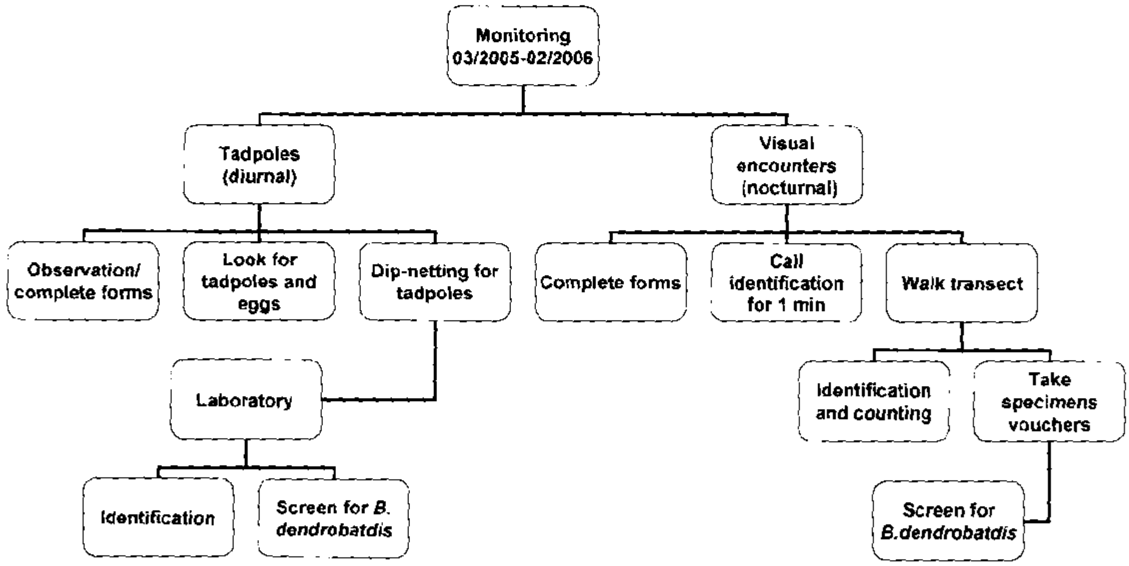


Figure 3-1 Flow diagram indicating the order in which fieldwork was conducted every month.

3.2 Anuran Sampling Methods

3.2.1 Dip-net Sampling

Upon arriving at a site or a temporary roadside pond, the water body was swept with a dip net for tadpoles. The frame of the dip net measured 300 x 250 mm and the net had a mesh size of 2 mm. Sweeping was done among aquatic vegetation, underneath overhanging vegetation and in open waters (Figure 3-2). Sweeping was done for 5-10 minutes at each site. Tadpoles were placed in a labelled container and taken to the laboratory for identification and screening for amphibian chytrid infection. To avoid disturbance of adult frogs, tadpole collection was done during the day to minimise the influence of tadpole sampling on nocturnal visual encounter surveys.

Figure 3-2 Dip-net sampling.

3.2.2 Visual Encounter Sampling

At each permanent site a transect of 50 m was marked out along the site. Upon arriving at the start of the transect, calling males were recorded for 1 minute. Calling individuals were identified to species level by comparison with a recording of South African frog calls, and each species was scored based on the call intensity. The scoring system consisted of 0 = none, 1 = individuals (sporadic), 2

= individuals (no overlapping), 3 = some overlapping calls, 4 = overlapping calls, and 5 = continuous chorus. After the 1 minute aural survey, the transect was visually searched for amphibians. All frogs that were spotted on either side within two meters from the transect line were identified and recorded. Some specimens were collected and taken back to the laboratory for proper identification and screening for chytrid (see Section 3.3). At temporary sites, such as roadside pools, quarry holes etc., only visual encounters and call identifications were made (Figure 3-3).

Figure 3-3 Visual encounter of *Afrana angolensis* in a mountain stream.

3.2.3 Aquatic *Xenopus* Traps

Funnel bucket traps were constructed from 20 L plastic buckets. Each bucket was fitted with a standard small road cone as a funnel and air holes were drilled in the bottom of the bucket. Traps were baited with chicken livers and the bucket placed upside down (Figure 3.4). They were set in water at a depth of about 300 mm near the edge of the water, with a part of the bucket sticking out to allow breathing space for the trapped animals. The concept is that the frogs will sense the bait and move through the funnel into the trap, from which they cannot escape again. Captured animals were transferred into labelled containers, half-filled with water from the site and taken to the laboratory to be screened for amphibian chytrid. This sampling method was mainly used to capture *Xenopus laevis*, because this fully aquatic species is often missed by other detection methods (e.g., visual encounter and aural surveys). This procedure was only done once during the monitoring period at each of the permanent sites.

Figure 3-4 Bucket trap, set to capture *Xenopus laevis.*

3.2.4 Night driving

After rainstorms, night driving was done on the main roads in the study area. The main roads were driven slowly (20 – 40 km/h) with open windows to listen for calling male frogs. The vehicle was also stopped every five kilometres to listen for choruses. Frog calls were recorded and identified. All encountered frogs found on the road was identified and captured for amphibian chytrid screening. This technique worked well for identifying breeding areas and potential sampling sites.

3.3 Data Collected

Fieldwork forms (Appendix B) were used to note down all data obtained. Data included the date, time, locality coordinates, site description, and weather. The reverse side of the fieldwork forms were used for other observations and comments. Separate forms were used for visual encounters and tadpole sampling. Observations included checking for tadpole behaviour, egg clutches, frogs in amplexus, predation, etc. Once during the study period additional information was gathered: water quality (temperature, dissolved oxygen and the pH), site description, water body size, water visibility (Secci depth), water depth, and photos of the sites were taken.

3.4 Identification of Specimens

3.4.1 Adults

The following field guides were used to identify frogs upon visual encounter; *Frogs and Frogging in Southern Africa* (Carruthers, 2001), *Field guide and Key to the Frogs and Toads of the Free State* (Du Preez, 1996), and *South African Frogs: A Complete Guide* (Passmore & Carruthers, 1995). If a frog could not be identified it was taken back to the laboratory for confirmation of identification by Prof. Louis du Preez, the supervisor of the study. Frog calls were identified by comparing them to recorded calls on the CD provided with the field guide, *Frogs and Frogging in Southern Africa*. If call identification could not be done, call recordings were made and identified and verified by Prof. Louis du Preez.

3.4.2 Tadpoles

Tadpoles were identified by keys provided by Van Dijk (1966, 1971) and Lambiris (1989). *Field guide and Key to the Frogs and Toads of the Free State* (Du Preez,

1996) and *Amphibians of Central and Southern Africa* (Channing, 2001) were also used.

3.5 Screening for *Batrachochytrium dendrobatidis*

3.5.1 Wet mounts

Adult frogs were placed in separate labelled containers with a bit of water. Sloughed skin from the feet was used for the diagnosis of chytridiomycosis. These were mounted on a microscope slide and stretched out in a drop of sterile water and covered with a cover slip. The slides were examined under a compound microscope for the presence of sporangia containing zoospores. If sloughed skin was not recovered, a toe clipping was used. The clipping consisted of a toe and a piece of webbing. The bone was removed under a dissection microscope and the remaining skin stretched out. It was covered with a cover slip and examined under a compound microscope.

Tadpoles were sedated with an MS222 solution. Mouthparts were removed under a dissection microscope and placed on a microscope slide with a drop of sterile water and covered with a cover slip. Only the bottom jaw and tooth rows were examined under a compound microscope for the presence of amphibian chytrid zoosporangia. Identification of *Batrachochytrium dendrobatidis* in sloughed skin and mouthparts of tadpoles were made on the presence of sporangia clusters in the keratinised layers of the epidermis, which are typically circular, thick-walled, and may contain septae and zoospores. They also possess discharge papillae.

Sporangia density was calculated for each infected tadpole. The method described in Weldon (2005) was used to quantify the infections. Sporangia were counted for every field on the longest x-axis and y-axis. The diameter of the microscope field of the 40 x objective was measured with a slide graticule and the area of the microscope fields was calculated with the following equation: πr^2.

The mean number of sporangia observed per field view was calculated. Knowing the field area, the sporangia/field was converted to sporangia/mm^2.

3.5.2 Histology

Histological examination was used to screen skin samples of the *X. laevis* caught in the bucket traps. Toe clippings were taken from these specimens. These toe clippings were decalcified in a Perreni's fixative for 18 hours. The skin tissue was dehydrated in a graded alcohol series, elucidated in xylene and impregnated with paraffin wax at 60°C (Figure 3-5). The tissues were embedded in paraffin wax blocks using a SLEE MPS/P2 embedding centre.

A Reickert-Jung 2050 automated microtome was used to section the tissues at 6 μm. Sections were stretched on a heated bath (45°C) and transferred to microscope slides. Slides were dried overnight in an oven at 35°C. Slides were routinely stained in Mayer's haematoxylin and counter stained in eosin (Figure 3-6). Cover slips were glued on the microscope slides with Entellan rapid mounting medium. Slides were then examined under a compound microscope.

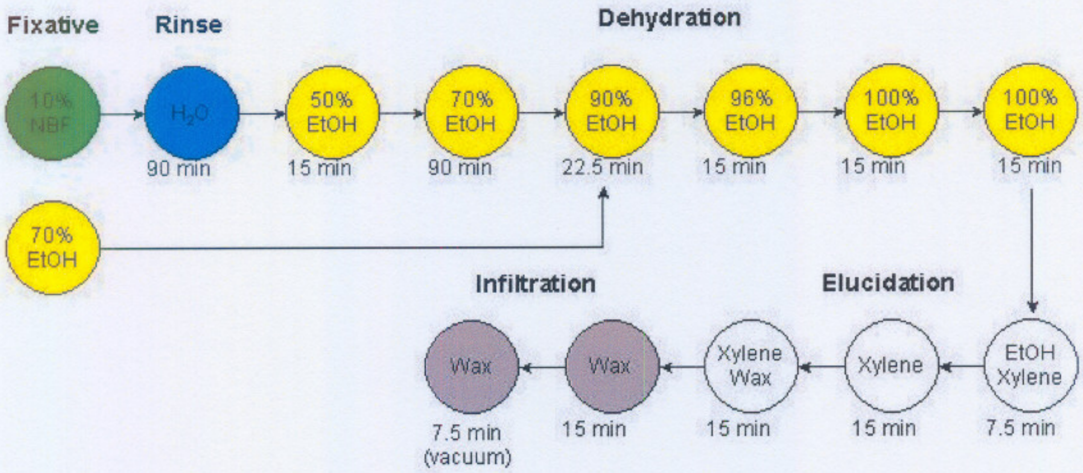


Figure 3-5 Processing procedures for the preparation of histological slides. Diagram obtained from Weldon (2005).

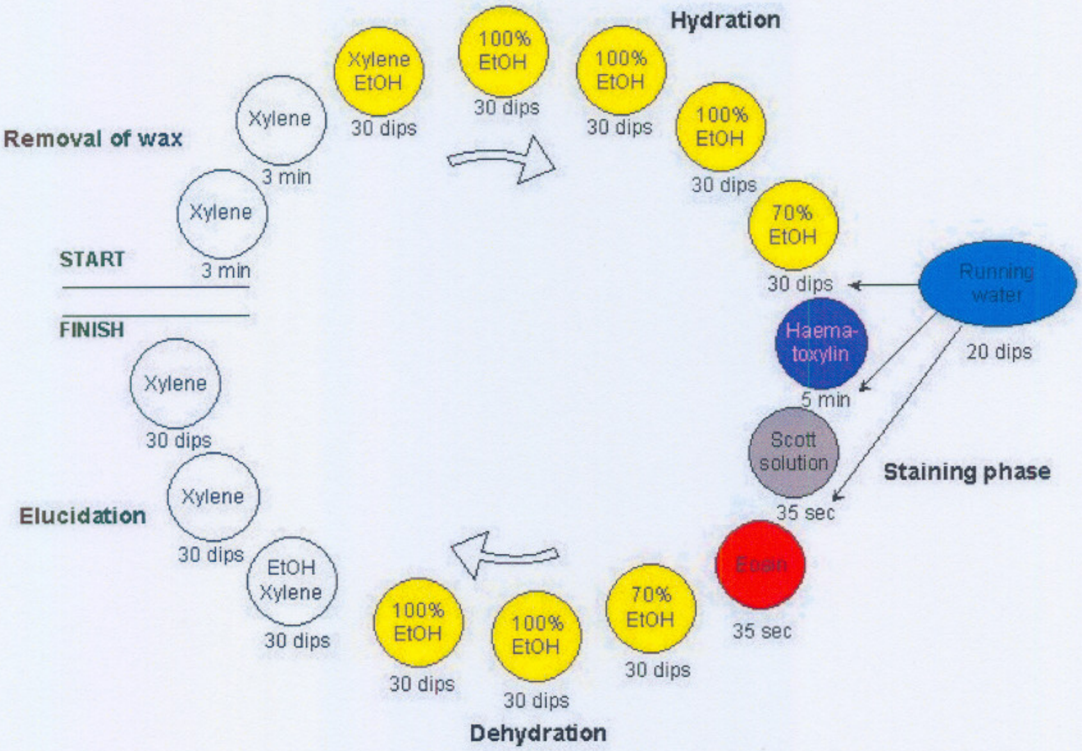


Figure 3-6 Histology staining procedure with haematoxylin and eosin. Diagram obtained from Weldon (2005).

The methods described by Berger *et al.,* (1999b) were used to identify chytridiomycosis in histological material. Dr. Weldon provided training in the diagnosis of *B. dendrobatidis* based on his experience in the field. Key features that are used to identify *B. dendrobatidis* on histological sections:

1. **Morphology** - Sporangia form discharge papillae through which the zoospores are released (Berger *et al.,* 1999a). Zoospores of *B. dendrobatidis* are waterborne, can live up to 24 hours and are infectious to frogs and tadpoles. Zoospores are unwalled and require water for dispersal. Swimming distance of zoospores is small, less than 20 mm, suggesting that they are unable to actively swim long distances to find a

host. This is the most likely explanation for the clustering of sporangia on the skin of amphibians (Piotrowski *et al.*, 2004).

2. **Size of sporangia** - They are about 3-5 μm in diameter with a posteriorly-directed flagellum (19-20 μm) (Longcore *et al.*, 1999).
3. **Position in skin** - Sporangia are restricted to the keratinised layer of the epidermis, the *stratum corneum* of adult frogs and keratinised mouthparts of tadpoles (Longcore *et al.*, 1999).
4. **Reaction in skin** - Sloughing and erosions of the superficial epidermis of the feet and other areas, slight roughening of the surface with minute skin tags, occasional small ulcers or haemorrhage and hyperkeratosis (Berger *et al.*, 1999a).

3.6 Measurements and Preservation of Specimens

Adult frogs' snout-to-vent length (SVL) was measured with a dial Vernier calliper. Tadpoles' total length, from mouth to the tip of the tail, was measured and their Gosner stage determined. All specimens were preserved in neutral buffered formalin (10% NBF) or 70% EtOH.

3.7 Data Analysis

Sigmaplot 2002 for Windows version 8.02, NCSS 2004 and Microsoft Excel were used for the data analysis.

CHAPTER FOUR

SYSTEMATIC ACCOUNTS

4.1 Introduction

Although the systematics of South African frogs received significant attention in the past, there are still some species that are being described from time to time. Currently there are 33 genera and 130 species known from South Africa (Carruthers, 2001). Detailed ecological and monitoring studies are, however, seriously lacking. Most conservation areas have amphibian species lists, but other than basic inventories, amphibian research in most protected areas in South Africa has been minimal. Prior to this study, no comprehensive study of amphibians has been undertaken in the Vredefort Dome area. Consequently, little is known about the frog diversity in this important World Heritage Site. The aim of this chapter is to provide systematic accounts and conservation status of the anuran species present in the Vredefort Dome.

During the study, 13 species were recorded representing five families. The most dominant family was Ranidae with six species. The most commonly-encountered genera are *Afrana*, *Xenopus* and *Bufo*.

4.2 Systematic checklist and index to the frogs and toads of the Vredefort Dome World Heritage Site

In a comprehensive paper by Darrel Frost and co-workers that has just seen the light (Frost *et al.*, 2006) some drastic changes were suggested to amphibian classification. The normal practice is to first see how generally suggested changes are accepted before applying these. In this light we decided to stick to the old classifications system in this thesis.

The genera are arranged in alphabetical order within the families. Common names are given below the scientific name. Abbreviations following the names indicate the language of origin, viz.: A= Afrikaans; E = English; P = SePedi; X =

Xhosa; and Z = Zulu. Each account is accompanied by photograph (supplied by L.H du Preez) of a representative specimen. Standard formats are used for each species: *Description, Life History Observations, Distribution* and *Conservation.* The following literature was consulted, and much of the information presented in this chapter was drawn from these sources to aid in the description of species: *Amphibians of Central and Southern Africa* (Channing, 2001), *Atlas and Red Data Book of the Frogs of South Africa, Lesotho and Swaziland* (Minter *et al.*, 2004), *Field guide and Key to the Frogs and Toads of the Free State* (Du Preez, 1996), and *South African Frogs: A Complete Guide* (Passmore & Caruthers, 1995). Van Dijk (1971; 1984) and Lambiris (1989) were consulted for tadpole descriptions. Distribution maps indicate the localities where visual encounters occurred (red star), call identifications were made (blue square) and tadpoles were found (orange circle). The IUCN criteria for al the species are Least Concern (see Appendix A for IUCN Red List Criteria).

Class: **AMPHIBIA**

Order: **ANURA**

Family: **BUFONIDAE** Gray, 1825

Genus: *Bufo* Laurenti, 1768

- *B. gutturalis* Power, 1927
- *B. poweri* Hewitt, 1935
- *B. rangeri* Hewitt, 1935

Genus: *Schismaderma* Smith, 1849

- *S. carens* (Smith, 1848)

Family: **HYPEROLIIDAE** Laurent, 1943

Genus: *Kassina* Girard, 1853

- *K. senegalensis* (Duméril & Bibron, 1841)

Family: **MICROHYLIDAE** Gunther, 1859

Genus: *Breviceps* Merrem, 1820

- *B. adspersus* Peters, 1882

Family: **PIPIDAE** Gray, 1825

Genus: *Xenopus* Wagler, 1827

- *X. laevis* (Daudin, 1802)

Family: **RANIDAE** Gray, 1825

Genus: *Afrana* Dubois, 1992

- *A. angolensis* Bocage, 1866
- *A. fuscigula* Duméril & Bibron, 1841

Genus: *Cacosternum* Boulenger, 1887

- *C. boettgeri* (Boulenger, 1882)

Genus: *Strongylopus* Tschudi, 1838

S. fasciatus (Smith, 1849)

Genus: *Tomopterna* Duméril & Bibron, 1841

T. cryptotis (Boulenger, 1907)

T. natalensis (Smith, 1849)

4.3 Species Accounts

Family: **Bufonidae** Gray, 1825

4.3.1 ***Bufo gutturalis*** Power, 1927 (Figure 4-1)

Common names: Guttural Toad (E), Gorrelskurwepadda (A), Ixoxo or Isogode (X)

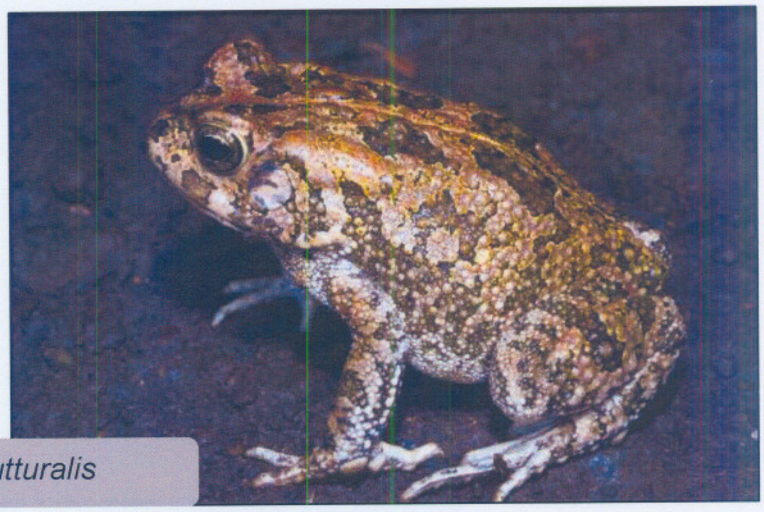


Figure 4-1 Adult *Bufo gutturalis*

Description

This species is typified by a heavy build. Body length may reach 97 mm. The colour on the dorsum varies from pale brown to dark olive, with symmetrical dark patches or blotches. A pair of dark patches on the snout, combined with a second pair of blotches behind the eyes leave a pale cross-shape running from the nostril to the back of the head and from eye to eye. There is a pair of prominent and elongated parotid glands situated behind the eyes. A thin vertebral line is usually present in younger individuals. The rear of the thighs is infused with red spots that are especially prominent in breeding animals. The dorsal skin is covered in large warts. The abdomen is creamy white. Breeding males have a dark throat.

The tadpole is small, up to 25 mm long. This species is typically black in colour with iridescent spots. There is no pigmentation across the anterior throat region.

The oral discs lack inferior papillae and have two superior tooth rows, one complete and one divided. There are complete inferior tooth rows. The tip of the tail is transparent and blunt.

Life history observations

Calling males were heard at most of the permanent and temporary sites along roads throughout the study area. Males started calling in September and continued until February. Males were calling while partly concealed (e.g., under vegetation) or drifting on vegetation. These breeding preferences correspond with previous reports (Carruthers 1976, 2001).

Tadpoles were collected at Mooinooiensfonten and Bluegumwoods (dam). Large clutches of eggs were observed in January at Mooinooiensfontein. Egg clutches consisted of a double string of black eggs, which was laid among vegetation. Thousands of small *B. gutturalis* froglets were observed in November at Bluegumwoods (dam).

Distribution

This species has a wide distribution in the north-eastern parts of South Africa. It is known from Kwazulu-Natal, Mpumalanga, Gauteng, central Limpopo, eastern North West and the northern and eastern Free State provinces, and Swaziland (Du Preez *et al.*, 2004a). This species is absent from the southern parts of South Africa (Channing, 2001).

This species has a wide distribution in the study area and visual encounters were made at the following sites: Mooinooiensfontein, Bluegumwoods (dam), Bluegumwoods (river), Thabela Thabeng, Grootkoppe, Waterfall, and on the main roads (Figure 4-2). Call identification was made at most temporary sites along the main roads in both the North West and Free State sides of the Vaal River.

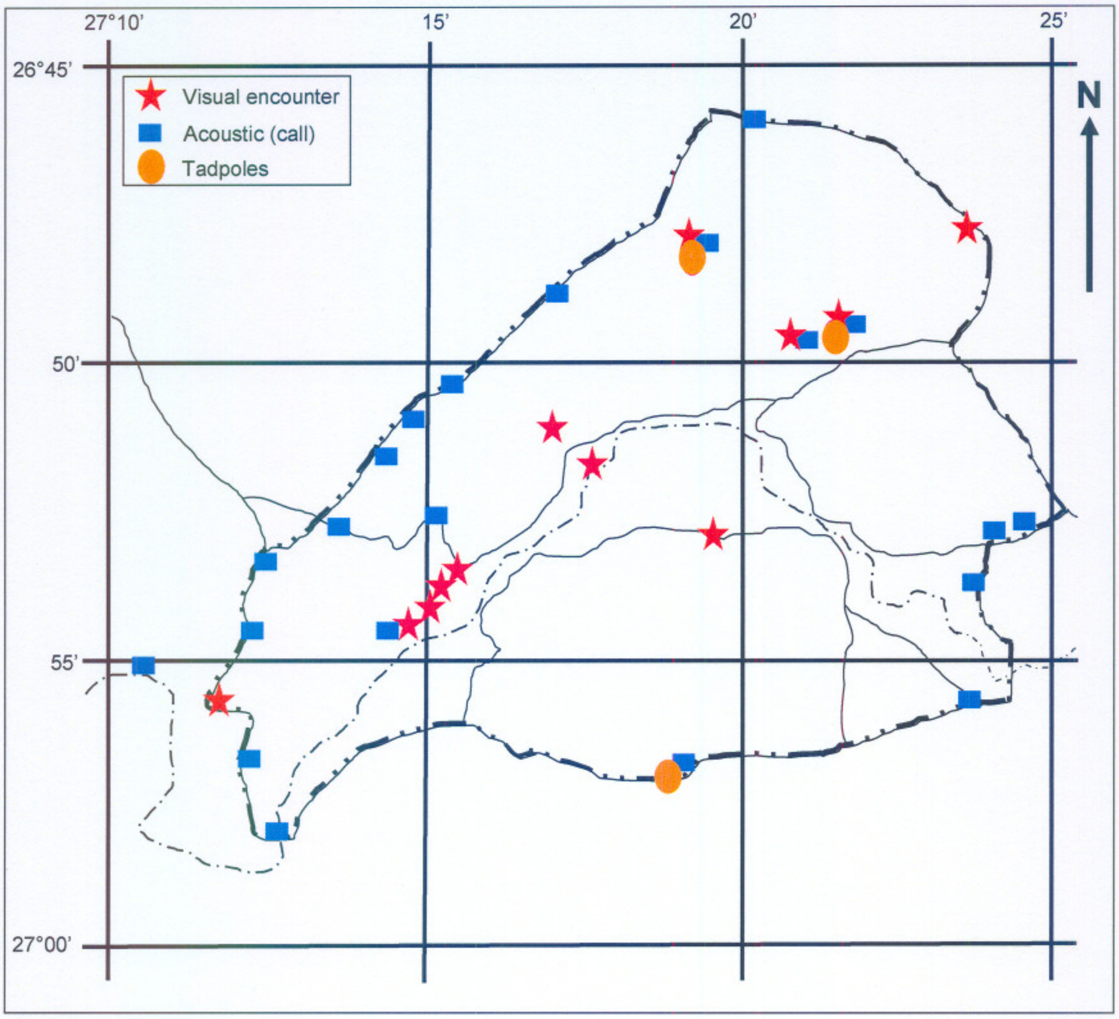


Figure 4-2 Distribution map of *Bufo gutturalis* in the study area.

Conservation Status

This is one of the most abundant species in the Vredefort Dome. Their IUCN conservation status is Least Concern and no conservation measures are required. *Bufo gutturalis* is widely distributed in Southern Africa and is presently well protected in numerous national parks, nature reserves and other protected areas (Du Preez *et al.*, 2004a). Guttural Toads were frequently observed on roads in the study area and many dead specimens were observed on roads. The number of Guttural Toads killed annually on roads should not have a major impact on the abundance of this species.

4.3.2 ***Bufo poweri*** Hewitt, 1935 (Figure 4-3)

Common names: Western Olive Toad (E), Power se Skurwepadda (A)

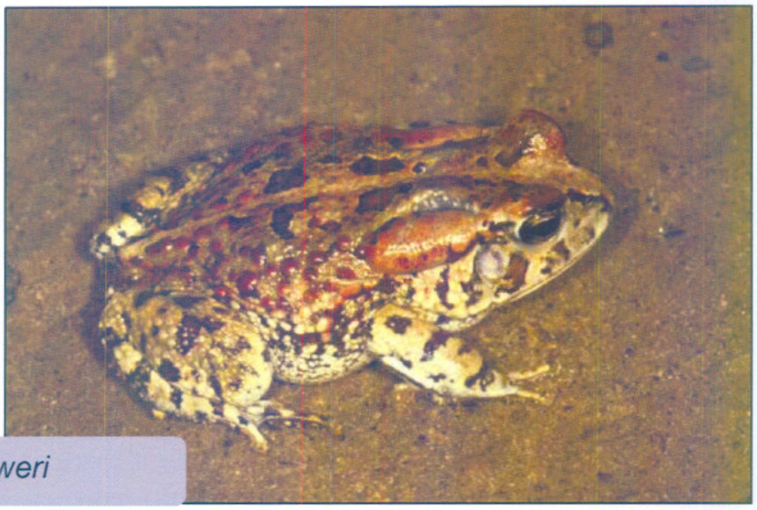


Figure 4-3 Adult *Bufo poweri*

Description

The toad can reach a length of about 86 mm. Females can reach a length of 100 mm. The parotid gland is prominent and the tympanum is less than half the diameter of the eye. The back is covered with large warts. Two pairs of symmetrical blotches appear on the back. The tip of the snout is free of any markings. And the blotches behind the eyes do not fuse. The colour varies from olive to brown, with red markings in the thighs and the groins.

The tadpole is similar to those of *B. gutturalis*. The only difference is the pigmentation on the abdomen. Pigmentation extends more or less uniformly over abdomen and they are densely pigmented with melanophores. It is difficult to distinguish between the eggs of *B. poweri* and *B. gutturalis*. The tail is more than two thirds pigmented and the abdomen is heavily pigmented. The fin is shallow and ends blunt.

Life history observations

Males were heard calling from September to February. Clutches of eggs were observed at Mooinooiensfontein. Egg clutches had the same appearance than those of *B. gutturalis*. It consisted of a double string of black eggs laid among vegetation. Tadpoles were also collected at Mooinooiensfontein in January and February.

Distribution

B. garmani and *B. poweri* share the same geographical distribution, although the population in the western part of South Africa is assigned to *B. poweri* and the population to the east to *B. garmani* (Du Preez *et al.*, 2004b). These two species are morphologically similar and are only distinguished by their call (Du Preez. 1996). The combined distribution includes the North West Province, northern Free State, Gauteng, Mpumalanga, the eastern Limpopo and the northern Kwazula-Natal (Du Preez *et al.*, 2004b).

Most of the specimens were found in the western, central and northern parts of the study area (Figure 4-4). Adults were found at the following sites: Mooinooiensfontein, Thabela Thabeng, and on the road to Schoemansdrift and Leeufontein. Call identifications were made at a few sites along the main roads: Vaalriver and at Mooinooiensfontein.

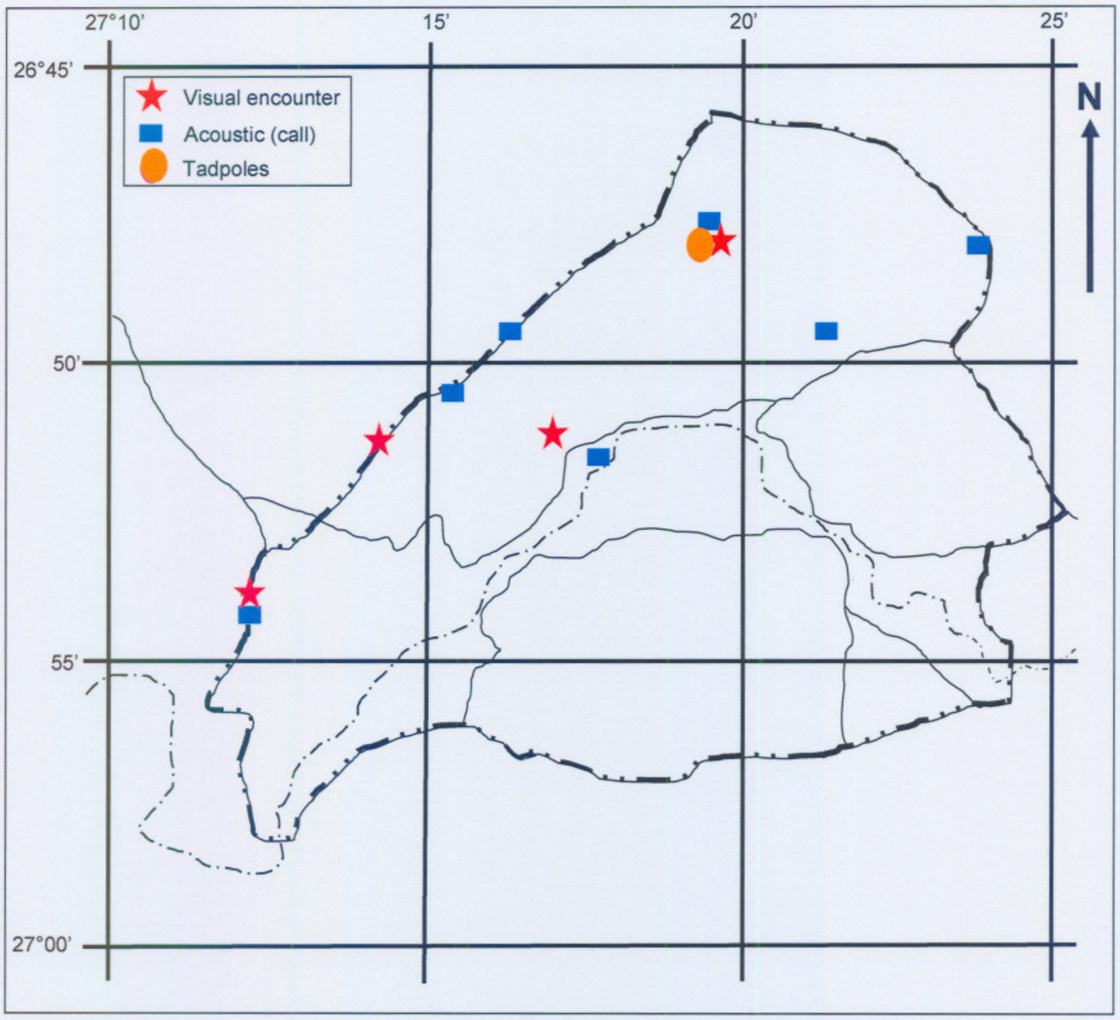


Figure 4-4 Distribution map of *Bufo poweri* in the study area.

Conservation Status

Only a few individuals of this species were found north of the Vaal River in the Vredefort Dome. It is protected in many conservation areas including Augrabies Falls, Vaalbos and Pilansberg national parks, Kgalagadi Transfronteir Park, and Sandveld and Botsalano nature reserves (Du Preez *et al.*, 2004b).

4.3.3 *Bufo rangeri* Hewitt, 1935 (Figure 4-5)

Common names: Raucous Toad (E), Lawaaipadda (A)

Figure 4-5 Adult *Bufo rangeri*

Description

This is a large toad and may reach a length of 100 mm. Females may reach a length of up to 115 mm. The colour on the back varies from olive-grey to brown. The tympanum is clearly visible. The snout is free of any markings. A dark bar is present between the eyes, which is rarely separated along the midline. The parotid glands are large and conspicuous. No red infusions are present on the thighs of this species. The ventral side is granular and whitish. Males' throats are darkly pigmented.

Tadpoles reach 25 mm in length. This species is dark-brown in colour. Pigmentation over the caudal muscles is confined to the upper two-thirds along the full length of the tail. The tail ends blunt.

Life history observations

Bufo rangeri was found calling in close vicinity to *B. gutturalis*. Males started to call in September and continued until February. Males called from partly concealed areas among vegetation or drifting on aquatic vegetation. Eggs are similar to those of the Guttural Toad and are laid in long strands around vegetation in deeper water.

Distribution

Bufo rangeri occurs in all provinces of South Africa and in both Lesotho and Swaziland. This species is generally widespread but is absent from the Central Karoo region. In the arid Northern Cape and North West province, it is restricted to the Gariep and Vaal rivers (Cunningham, 2004).

This species was found throughout most of the study area (Figure 4-6), especially in close vicinity of water and on roads. Visual encounters were made at: Berhaka, Mooinooiensfontein, Thabela Thabeng, Waterfall, and along the main roads.

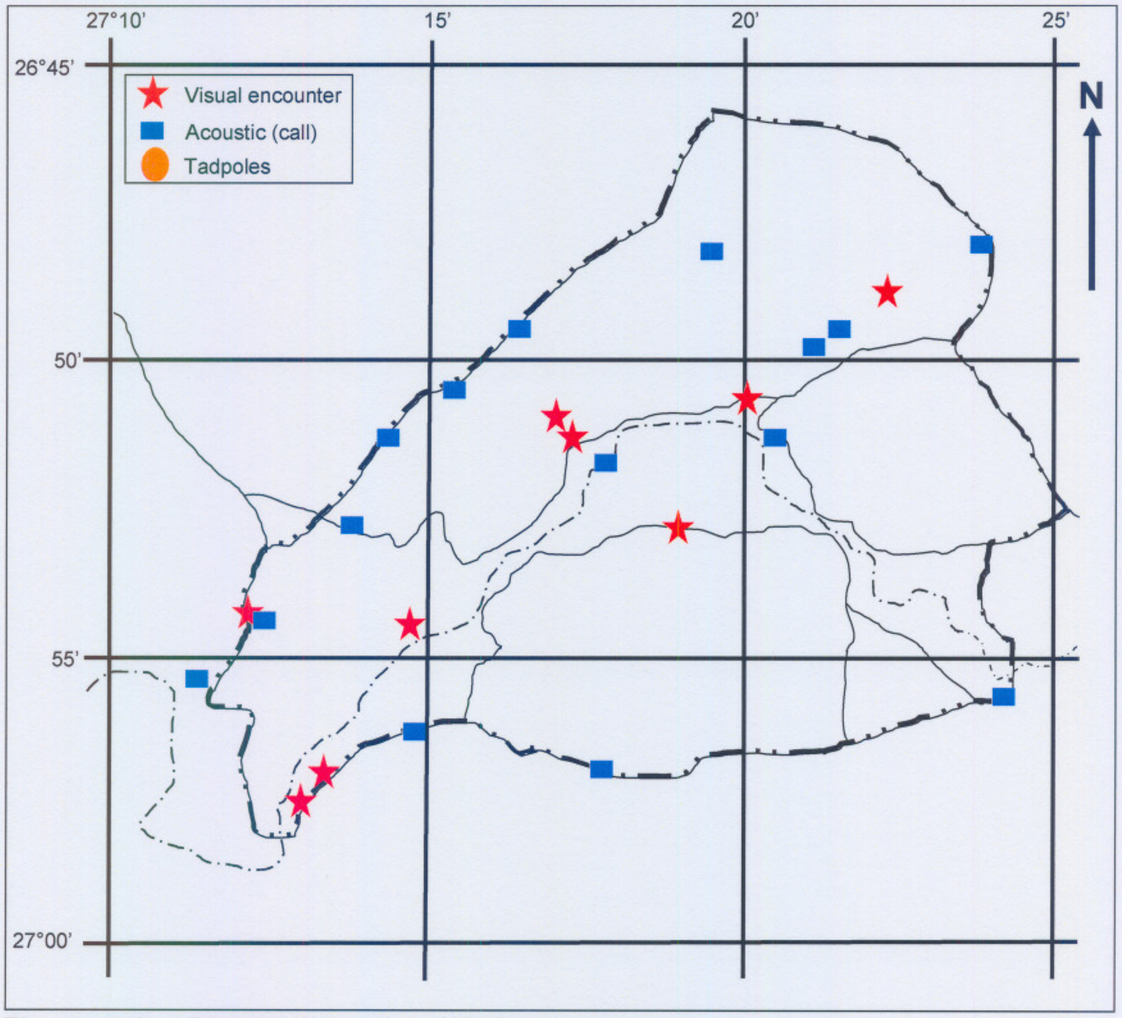


Figure 4-6 Distribution map of *Bufo rangeri* in the study area.

Conservation Status

This widely-distributed species in the Vredefort Dome does not require protection. *Bufo rangeri* is well protected in other conservation areas (Cunningham, 2004).

4.3.4 *Schismaderma carens* (Smith, 1848) (Figure 4-7)

Common names: Red Toad (E), Rooiskurwepadda (A)

Figure 4-7 Adult *Schismaderma carens*

Description

The size of this toad is moderate to large; with a body length of about 86 mm. Its body has a more slender build than other toads. A tarsal fold is present. The dorsal skin is smoother than that of other toads and there is a distinct glandular ridge running from above the tympanum to the hind leg. The tympanum is large and round. Parotids are not visible. The back is dark-red to red-brown in colouration, with a pair of small dark brown marks on the lower back. The ground colour is pale brown, often pinkish. The abdomen is creamy-white with scattered small dark spots. The throats of males are darker pigmented.

The tadpoles are large, up to 35 mm, and black. The tadpoles differ from other *Bufo* tadpoles in having a prominent flap of skin on the head. The flap of skin extends from the eye to midway along the top of the body and it is well supplied with capillaries and functions as a respiratory organ.

Life history observations

Males started to call after heavy rains in December until February. In December, amplecting pairs were observed in the water during early evening and several males were calling from the periphery of the water-body. Later the same night, over a 100 amplecting pairs was observed, while males were calling from shallow water or drifting on aquatic vegetation. The frogs were not disturbed by the close presence of recording equipment. Blackish eggs were laid in a double string among aquatic vegetation. The following month thousands of schooling tadpoles were observed at the breeding site. Predation by herons and hamerkop was observed at Dampoort II.

Distribution

In South Africa *S. carens* is found in the North West province, northern Free State, Gauteng, Limpopo Province, northern and eastern Mpumalanga, Swaziland and Kwazula-Natal (Minter & Theron, 2004).

This species was found throughout the study area, except for the northern corner (Figure 4-8). Most specimens were encountered on the public and private roads. This species is more common in the more rocky parts of the study area. Visual encounters were made at: Thabela Thabeng, Waterfall, and Dampoort II.

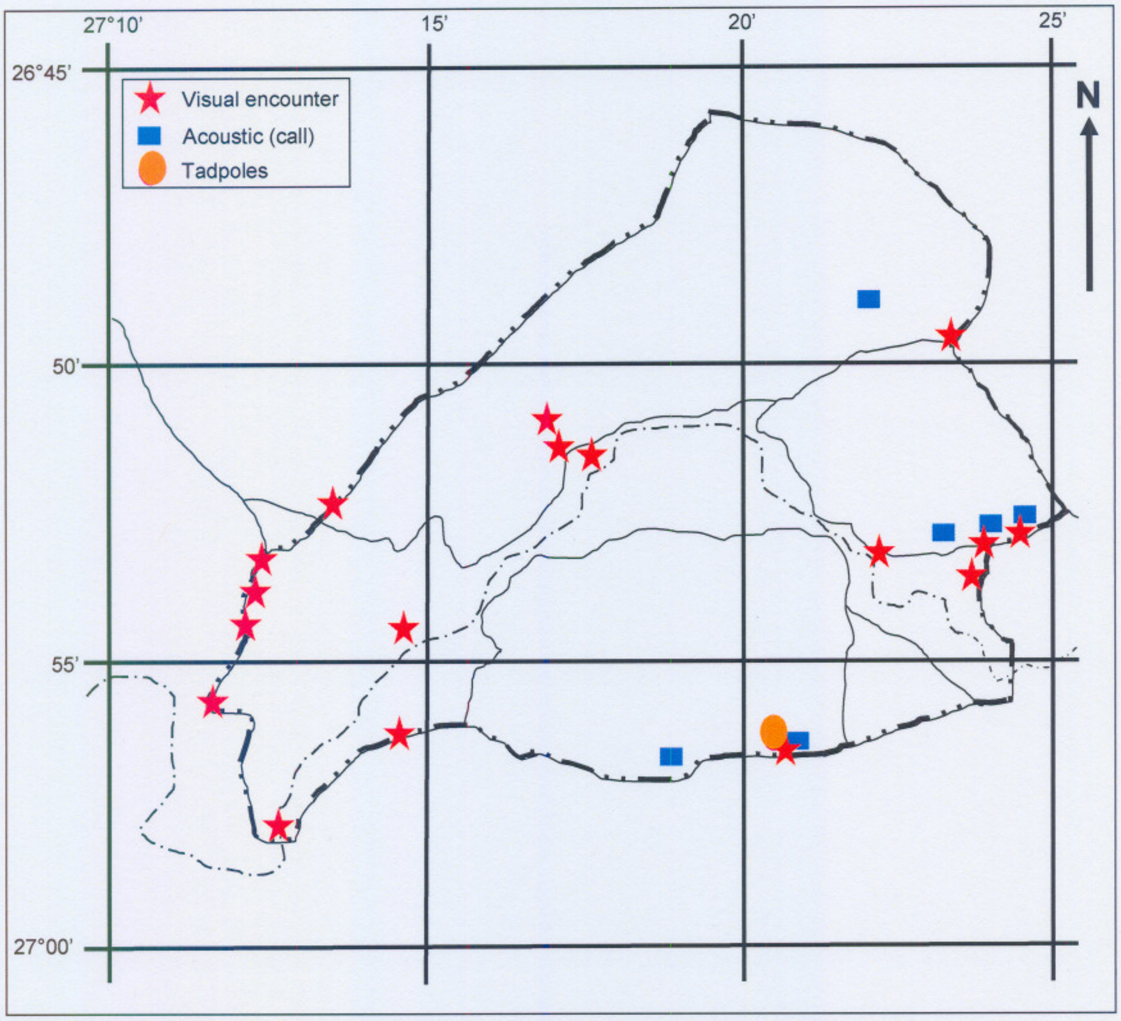


Figure 4-8 Distribution map of *Schismaderma carens* in the study area.

Conservation Status

Schismaderma carens is not threatened in the Vredefort Dome or elsewhere in Southern Africa. It occurs in numerous areas. This species is well adapted to human environments and tadpoles can survive in slightly polluted water (Minter & Theron, 2004). The only concern is the large amount of juveniles and adult frogs found on the roads exposing them to possible mortality.

Family: **HYPEROLIIDAE** Laurent, 1943

4.3.5 *Kassina senegalensis* (Duméril & Bibron, 1841) (Figure 4-9)

Common names: Bubbling Kassina (E), Borrelvleipadda (A)

Figure 4-9 Adult *Kassina senegalensis*

Description

The body may reach a length of about 52 mm and is of slender build. The eyes are yellow with vertical pupils. The body surface is smooth. The back is usually yellowish brown to grey in colouration. Three dark brown/black stripes are present on the back. The abdomen is white, while the throat of males is dark. The toes are only slightly webbed.

This species has a very large tadpole that may reach lengths of 80 mm. The tadpole is dark, with grey to bright red fins. The body and tail fin are very deep. The tail fin is the deepest in the middle of the tail. The beak is heavy and prominent.

Life history observations

Males started calling after the first rains in October and continued until late February. Early evenings the adults called far from any water but moved closer to the water during late evenings. A calling male was encountered about 100 m from any water while it was raining one evening. Tadpoles were collected from Dampoort I and Dampoort II in January and February.

Distribution

This species is common in all provinces except for the Western Cape, central and western parts of the Northern Cape Province and the western part of the Eastern Cape Province (Weldon & Du Preez, 2004b).

Although this species is widely distributed in the study area, it was more frequently heard than seen (Figure 4-10). Adults were collected at Thabela Thabeng and on Venterskroon road near Site C. Visual observations were made at Berhaka and a temporary site (quarry hole). One individual was found crossing the main road at Site C.

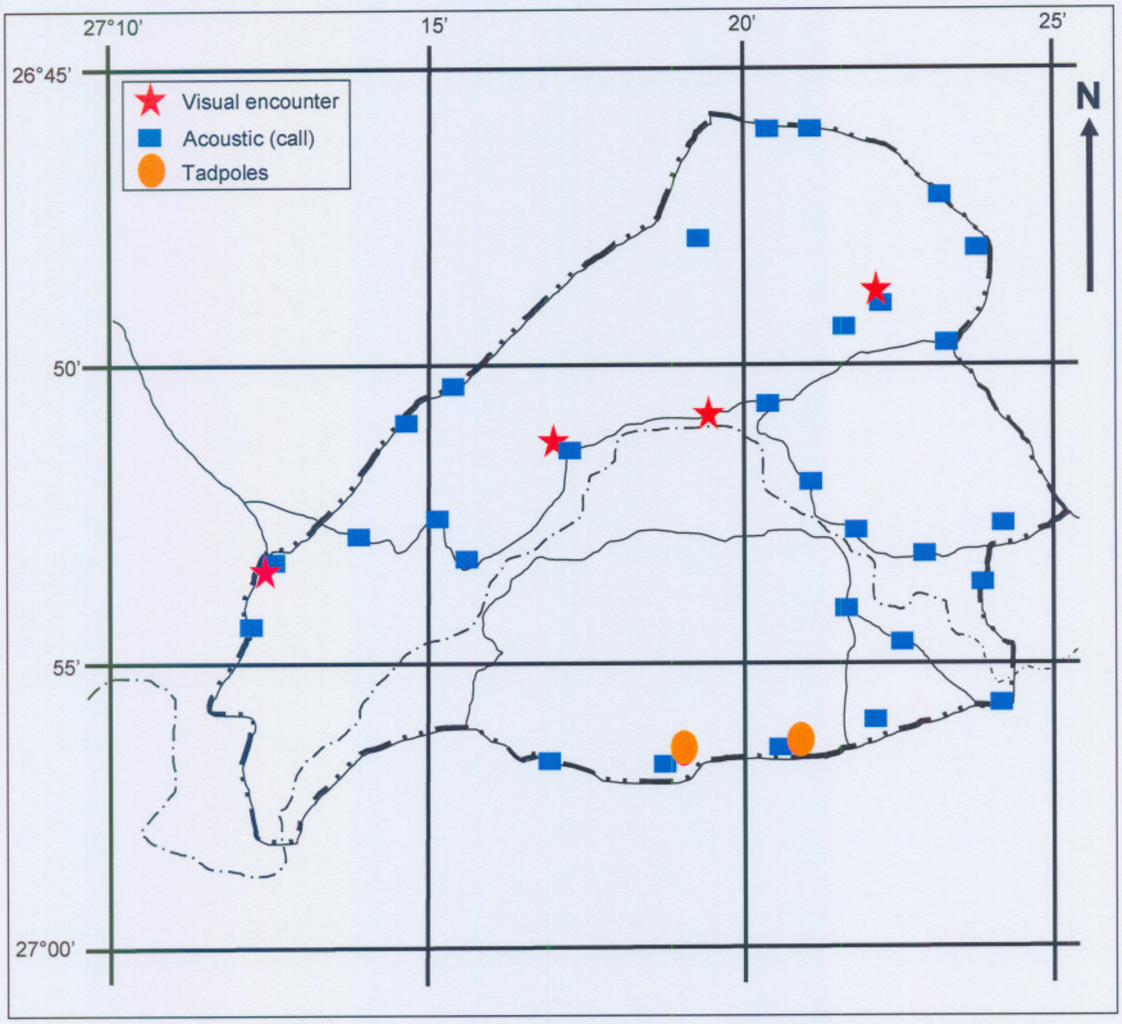


Figure 4-10 Distribution map of *Kassina senegalensis* in the study area.

Conservation Status

This is a widely distributed species in the Vredefort Dome, as well as the rest of Southern Africa. It does not require conservation attention. Males hide among vegetation or underneath rocks when calling, which makes collection difficult. This would explain why more individuals were recorded by their call than by visual encounter.

Family: **MICROHYLIDAE** Gunther, 1859

4.3.6 ***Breviceps adspersus*** Peters, 1882 (Figure 4-11)

Common Names: Bushveld Rain Frog (E), Bosveld Reënpadda (A), Senanatswi (P), iSinana (Z)

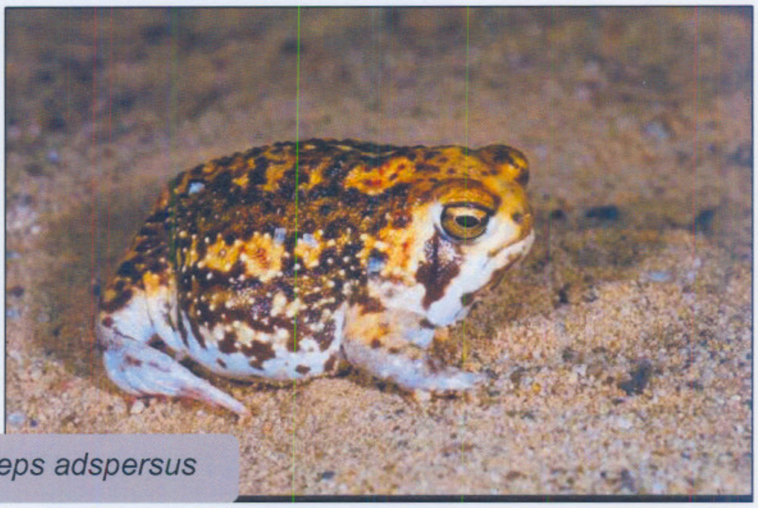


Figure 4-11 Adult *Breviceps adspersus*

Description

Females reach a length of about 60 mm, while the males are much smaller. The abdomen is smooth, but the dorsum is rough. The tympanum is not visible. The dorsal ground colour varies from orange-brown to dark brown with symmetrically arranged spots. The dorsal surface is granular and smooth. The venter is cream coloured and in males the throat is dark. This species is characterised by their swollen bodies and flattened faces. The pupil is horizontal. A broad black stripe runs from the eye to the armpit. Limbs are very short and the feet have well-developed metatarsal tubercles on the heels. The toes lack webbing. The metatarsal tubercles are used to burrow backwards into the ground. The frogs do not generally hop or jump, but rather walk.

Life history observations

Males were heard calling in December until February.

Distribution

Breviceps adspersus occurs in most of the Limpopo Province, North West, the northern parts of the Free State, the eastern parts of the Northern Cape, Gauteng, Mpumalanga, central and eastern Swaziland, and the lower parts of Kwazula-Natal (Minter, 2004).

Breviceps adspersus was found in the central and north-eastern areas of the study area (Figure 4-12). Only calling males were found and no specimens were collected.

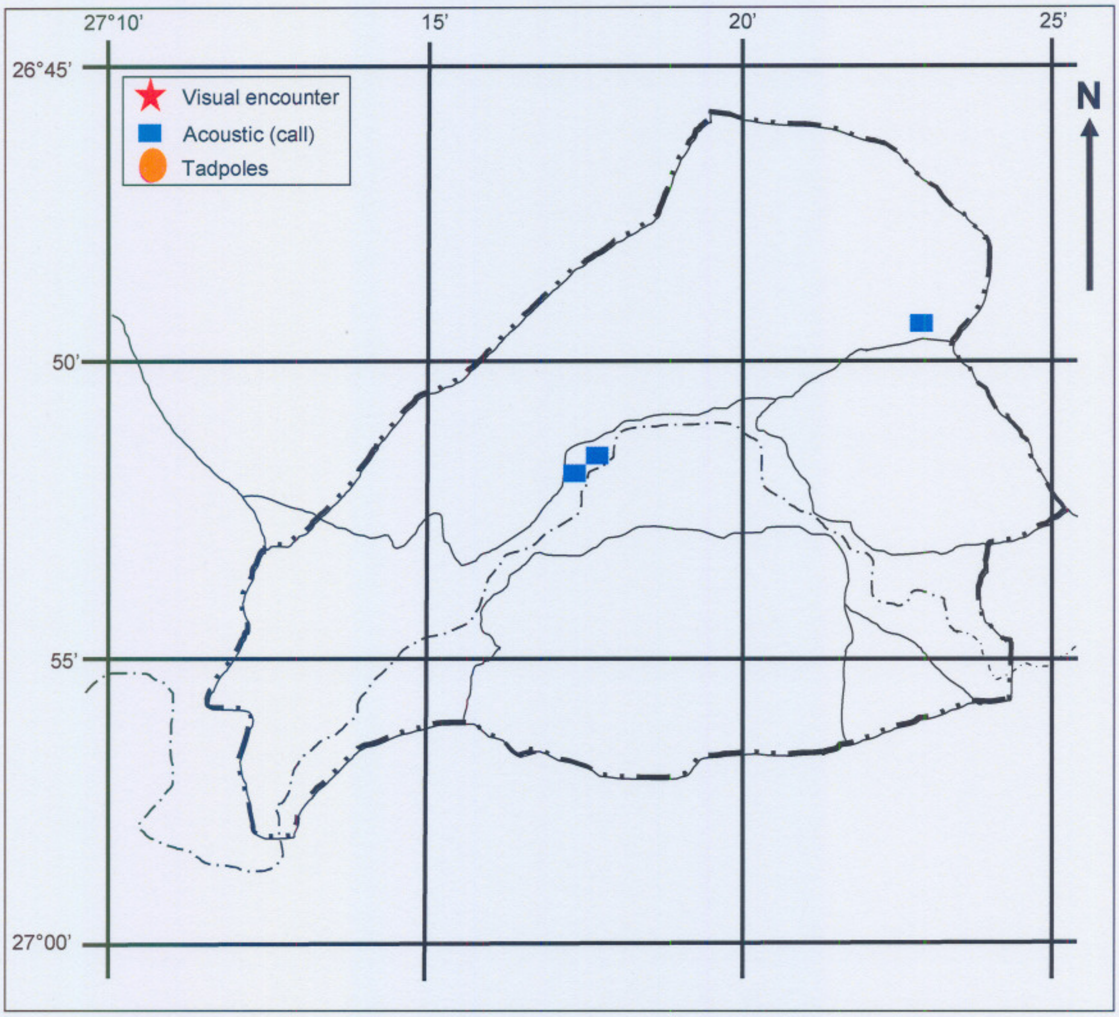


Figure 4-12 Distribution map of *Breviceps adspersus* in the study area.

Conservation Status

Previous studies on *B. adspersus* indicate that this species is highly fossorial and only emerges after extended periods of rain (Minter, 2004). Since the fieldwork for this study was not necessarily planned to coincide with these conditions, it is not surprising that *B. adspersus* was observed only three times. The distribution can be more widespread than what is indicated by the data collected. An accurate conservation status could not be estimated for the Vredefort Dome, because of a lack of data. No conserving for this species is necessary in the area. In the wider South Africa it seems as if this species is not at risk (Minter, 2004).

Family: **PIPIDAE** Gray, 1825

4.3.7 *Xenopus laevis* (Daudin, 1802) (Figure 4-13)

Common names: African Clawed Toad (E), Common Platanna (E), Gewone Platanna (A), Ngova, Udlela (X)

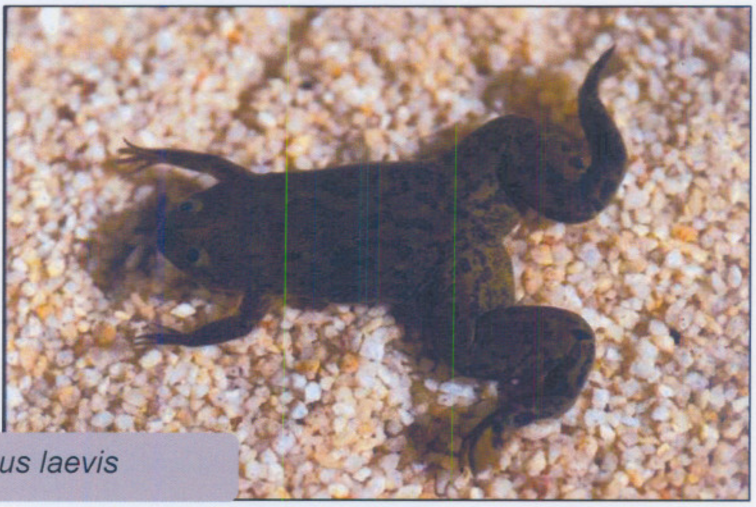


Figure 4-13 Adult *Xenopus laevis*

Description

All *Xenopus* species are adapted to an aquatic existence. Their bodies are dorso-ventrally flattened and streamlined. A tympanum, tongue, vocal cords and moveable eyelids are absent. The eyes and nostrils are situated superiorly and anteriorly, allowing the frogs to suspend with only the anterior tip of the head breaking the surface. This species has muscular hind limbs, with extensive webbing between the toes, making them powerful swimmers. The skin is smooth with sensory organs that look like "stitches" along the sides of the body and around the eyes and mouth.

The common platanna is normally up to 100 mm in length, with exceptionally large females of 147 mm. As in most anuran species the female is larger than the male. Ventral colouration differs from white to yellow. Darker belly markings are uncommon. The back is dark brown/grey with scattered darker blotches.

Eggs hatch rapidly into tadpoles. The tadpole has a long tail and fin. The head is flattened and transparent. It possesses tentacles resembling a small catfish. Tadpoles may reach 80 mm in length. Tadpoles are filter feeders and keratodonts and rostrodonts are absent.

Life history observations

The tail tip vibrates constantly, maintaining the tadpole in a head-down position. Tadpoles were collected in the months from December until February. Young post-metamorphic individuals were collected from Berhaka and Bluegumwoods, while dip-netting for tadpoles.

Distribution

This species occurs widely in sub-Saharan Africa (Channing, 2001). The distribution includes all of the nine provinces. It is absent in extremely arid areas, including the Kalahari and Bushmanland in the Northern Cape Province. *Xenopus laevis* are also absent in the low-lying parts of Limpopo and Mpumalanga (Measey, 2004).

Xenopus laevis is found throughout the study area (Figure 4-14). Most specimens were collected with bucket traps in permanent water bodies. Some post-metamorphic individuals were collected while dip-netting for tadpoles. One specimen was found in a muddy, temporary roadside pool. Adults were found throughout the year. Specimens were collected from: Berhaka, Bluegumwoods (dam), Bluegumwoods (river), Thabela Thabeng, Elgro, Dampoort I, and Dampoort II. Adult *X. laevis* were also observed at the Waterfall and Lesotho spruit.

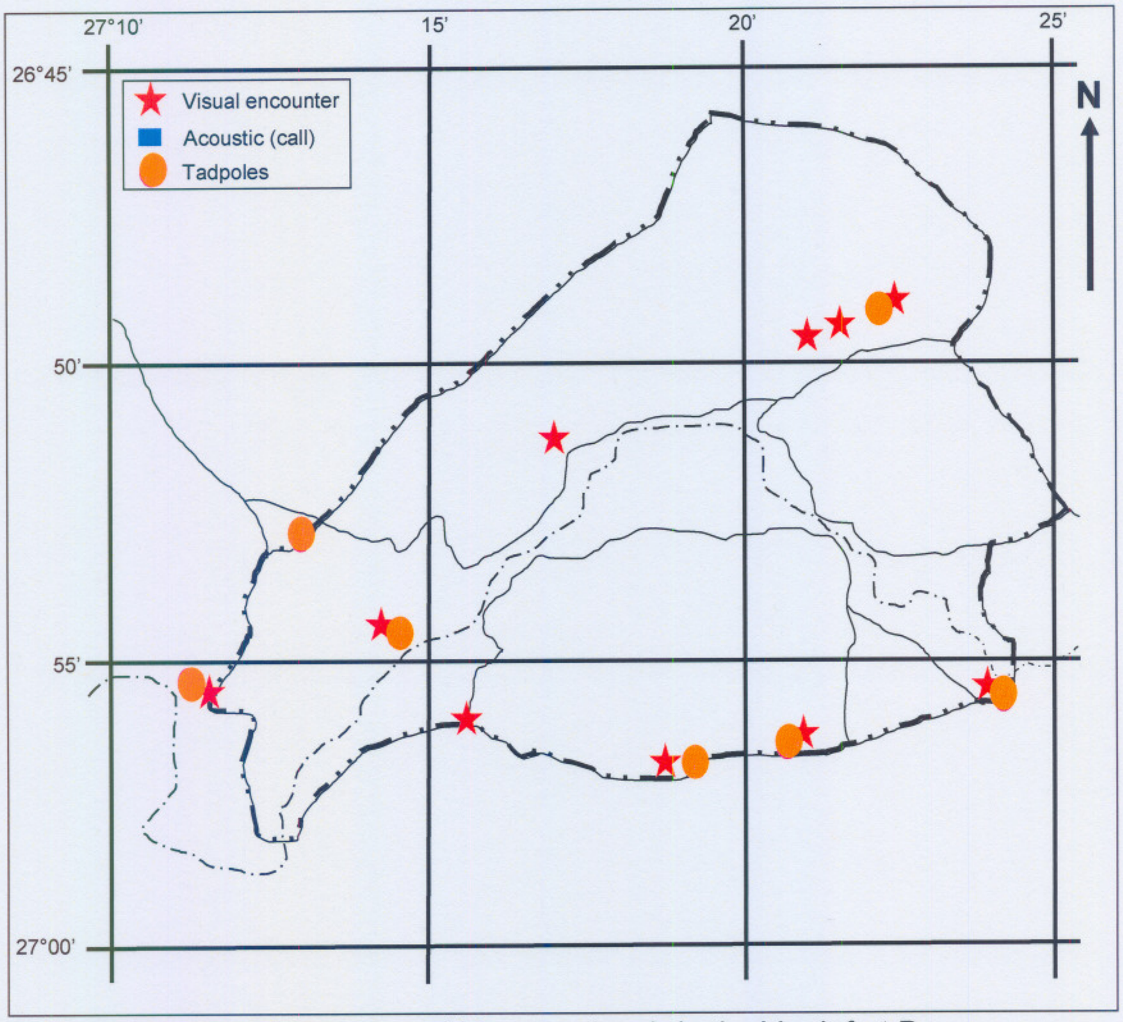


Figure 4-14 Distribution map of *Xenopus laevis* in the Vredefort Dome.

Conservation Status

Xenopus laevis is widespread in the study region and throughout southern Africa and is not in need of conservation action. This species adapts well to human disturbance. They are present in most of the water bodies in the Vredefort Dome. Migration between sites does occur. No *Xenopus* were collected from Site A (Mooinooiensfontein). This could be due to the presence of Sharp Tooth Catfish (*Clarias gariepinus*). *Xenopus* was collected at Bluegumwoods (dam), although the dam is stocked with Florida Black Bass. Catfish may prey more heavily on platannas than bass. Introduction of sport fish must be controlled otherwise *Xenopus* populations could go locally extinct as shown by data.

Family: RANIDAE Gray, 1825

4.3.8 ***Afrana angolensis*** Bocage, 1866 (Figure 4-15)

Common names: Common River Frog (E), Gewone Rivierpadda (A).

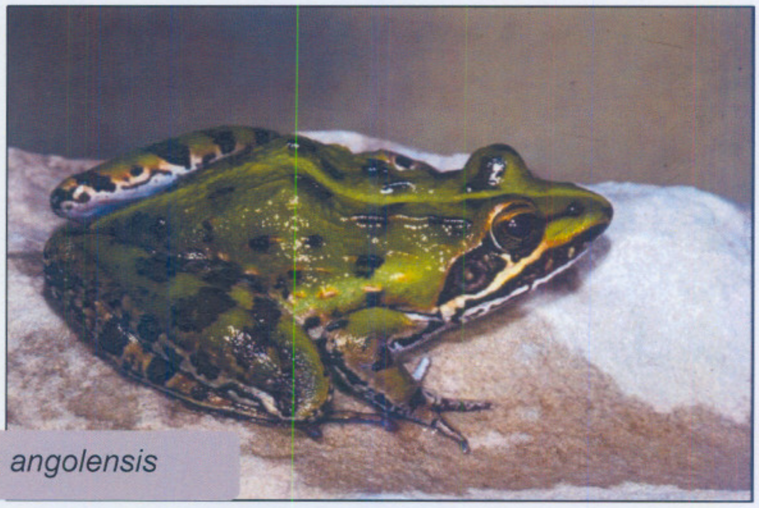


Figure 4-15 Adult *Afrana angolensis*

Description

The body may reach a length of up to 75 mm, although large females may be 90 mm in length. The head is narrow and the snout is pointed. Viewed from above the eyes are not contained in the outline of the head. The legs are long and muscular, with extensive webbing between toes. The skin is smooth. Colour varies from dark brown to green with darker blotches scattered over the back. A pale dorsal stripe is usually present. The lower surface is pale, sometimes with a darker mottling on the throat. The toes are extensively webbed, except for the two distal phalanges of the longest toe.

The tadpole is large and may reach a length of 80 mm. The tadpole is brown with darker patches scattered over the body. The fin is deepest just behind the middle of the tail and terminates in a sharp point.

Life history observations

Males called throughout the year, but calling peaked between May and September. During the rainy season only a few specimens were heard calling. Their calls were overpowered by other species, such as *B. gutturalis* in the rainy season. Tadpoles were consistently collected throughout the year and were found at all of the permanent sites. Tadpoles varied from small to large, with the biggest specimen 87.60 mm in length.

Distribution

This is a widespread species. It occurs mainly in the eastern half of South Africa, from the eastern border of the Western Cape Province, the eastern and southern Eastern Cape Province, the whole of Kwazula-Natal, Limpopo, Gauteng, Free State, North West Province and the northern Cape Province (Channing, 2004a).

This is the most abundant species in the Vredefort Dome (Figure 4-16). It is present throughout the year and is widespread in the area. It prefers the more permanent water bodies. Visual encounters were made at most of the sites: Berhaka, Bluegumwoods (river), Bluegumwoods (dam), Thabela Thabeng, Waterfall, Dampoort I and Dampoort II. Visual encounters were also made at the Vaal river. A few individuals were seen during daytime sitting on the banks close to water at Thabela Thabeng and Waterfall. Upon approaching at many of the sites individuals jumped into water. Two specimens were collected while they crossed the road at Thabela Thabeng and near Schoemansdrift.

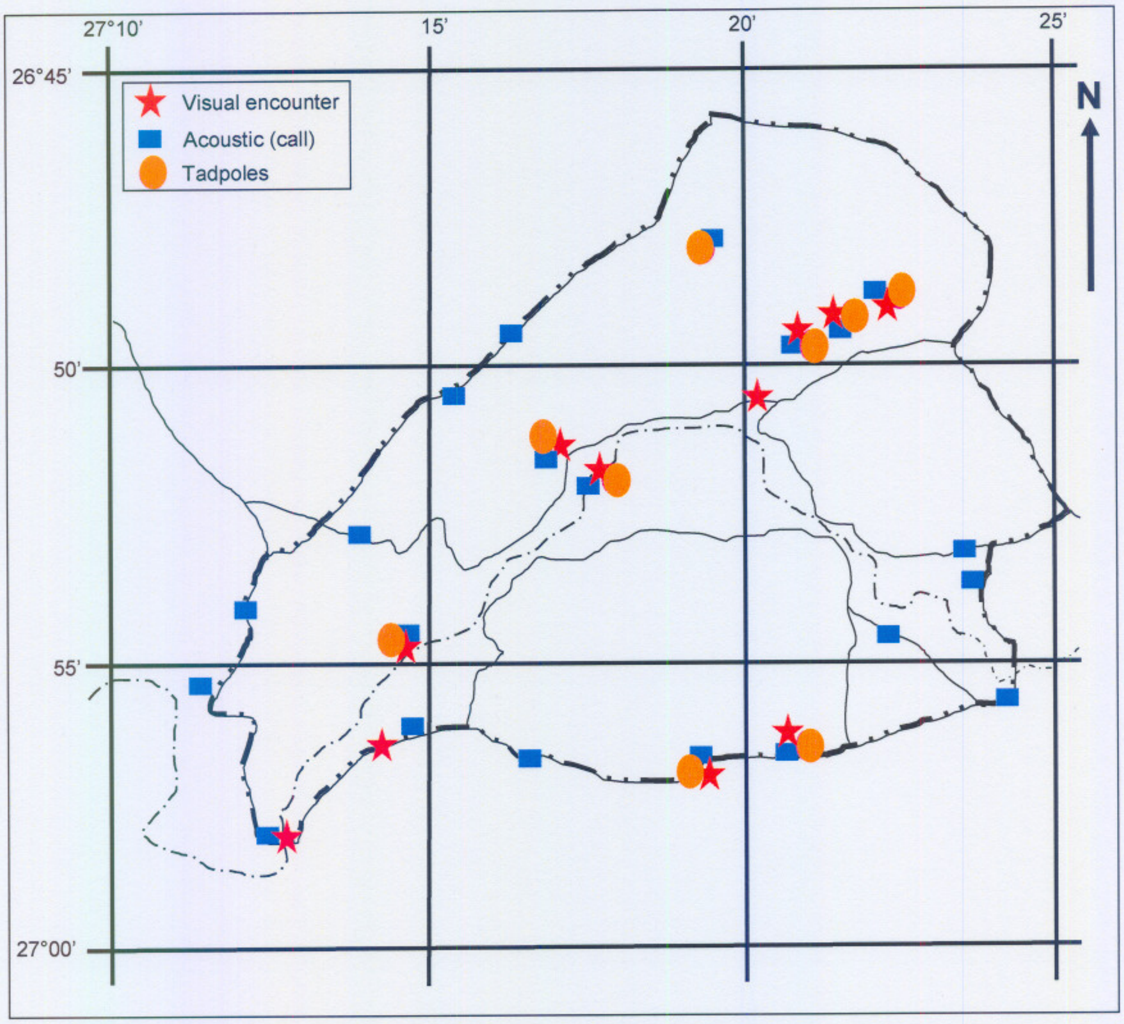


Figure 4-16 Distribution of *Afrana angolensis* in the study area.

Conservation Status

Afrana angolenis is not threatened in the Vredefort Dome. It is widely distributed in Southern Africa and is found in most rivers, dams, ponds, and wetlands (Channing, 2004a).

4.3.9 ***Afrana fuscigula*** Duméril & Bibron, 1841 (Figure 4-17)

Common Names: Cape River Frog (E), Kaapse Rivierpadda (A)

Figure 4-17 Adult *Afrana fuscigula*

Description

This is a large frog, with the male up to 75 mm long and the female reaching 125 mm. These frogs are similar in overall appearance to most other species of the genus, except for the head which is wider than *A. angolensis.* The eyes are contained within the outline of the head if viewed from above. The tympanum is large. The back has a green or brown background colour, with darker blotches and a lighter vertebral stripe that are common. The abdomen is white and the throat region is usually darker. Webbing between toes is extensive with only one phalanx of the longest toe free of webbing.

The tadpole may reach a length of 89 mm. They are mostly brown in colouration with some darker spots. The abdomen is white. The upper half of the tail fin and the last fifth of tail are dark pigmented. The dorsal fin differs from *A. angolensis* by rising from the base of the trunk in a much steeper angle.

Life history observations

The only places where males were heard calling was at Lesotho spruit in December. Tadpoles were collected at Bluegumwoods in January and February.

Distribution

This species is known from northern and eastern South Africa to the Western Cape Province and Namaqualand (Channing, 2004b).

This species was found in the north-eastern and south-eastern corners of the studied area (Figure 4-18). Only tadpoles were collected at Bluegumwoods and a few males were heard calling at Lesotho spruit.

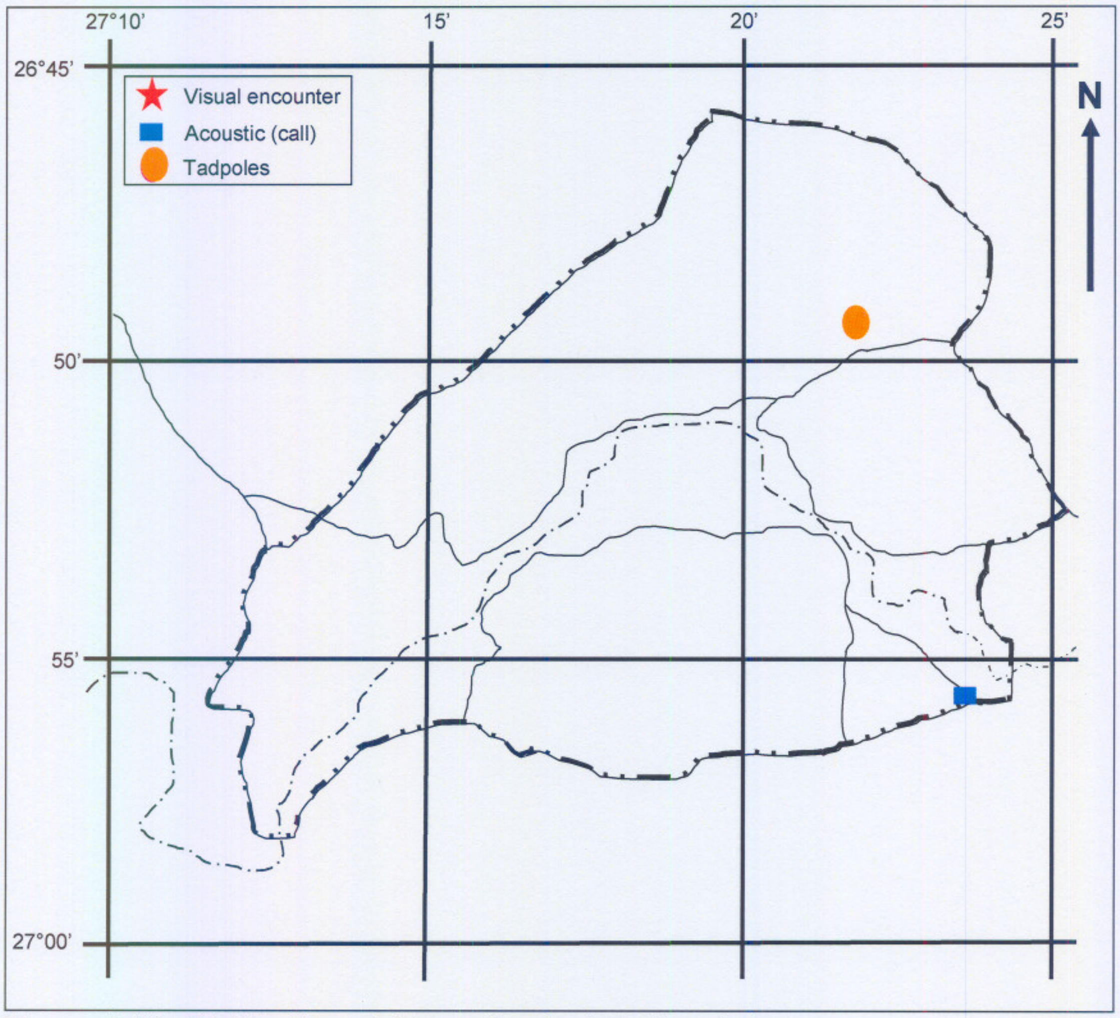


Figure 4-18 Distribution of *Afrana fuscigula* in the study area.

Conservation Status

Although this species is not in abundant in this area, no concern of conserving it. Elsewhere in South Africa it is widely spread and is not threatened and no special conservation measures are required in the study area or the rest of South Africa (Channing, 2004b).

4.3.10 ***Cacosternum boettgeri*** (Boulenger, 1882) (Figure 4-19)

Common names: Common Caco (E), Boettger's Dainty Frog (E), Gewone Blikslanertjie (A).

Figure 4-19 Adult *Cacosternum boettgeri*

Description

This is a small slenderly-built frog that seldom exceeds 23 mm in length. The body consists of a narrow head and starts to widen at the belly region. The arms and legs are slender. The skin is smooth with some rounded warts. Dorsal colouring varies form bright green to brown. A dark vertebral line is present. A dark line is present extending from the tip of the snout through the eye to the armpit, forming a mask. The abdomen is white with scattered dark spots. The throat of males is darker than that of females. No webbing is present between the toes.

The tadpoles are small and may reach a length of 28 mm. The body is oval-shaped and flattened. The tail terminates in a sharp tip.

Life history observations

Males were heard calling mostly after heavy rains. They called from partly concealed areas on the edge of the water. Males usually start calling in September and continue until early March. Tadpoles were collected only in February at Dampoort I.

Distribution

This is one of the most widespread and abundant frog species in South Africa. The species is present in all the provinces, but is absent in Namaqualand, the Lesotho highlands, and along the Mpumalanga escarpment (Scott, 2004).

They were found throughout the entire study area (Figure 4-20). Specimens were collected from Berhaka and at some roadside pools. They called after big rains at temporary and permanent sites. Males called from October until March.

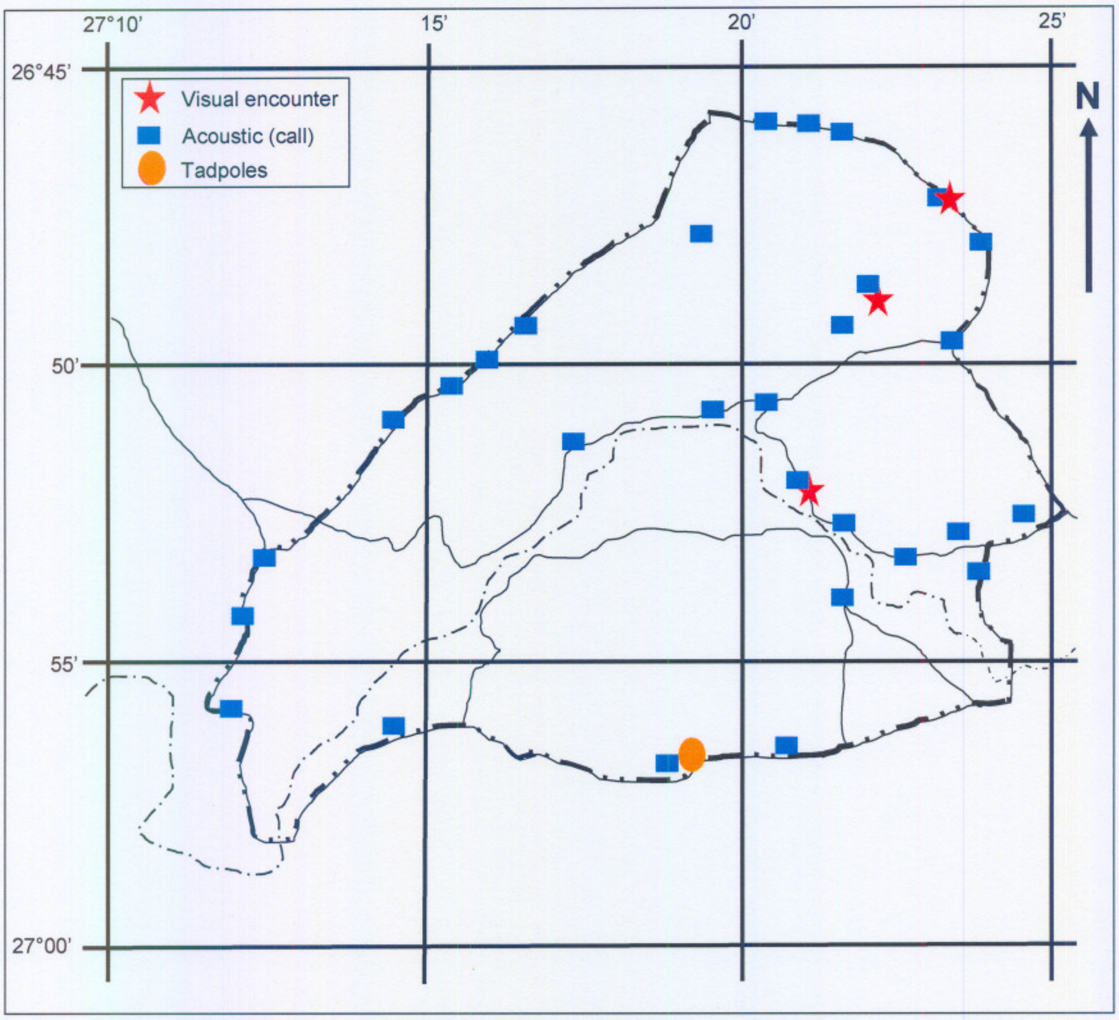


Figure 4-20 Distribution map of *Cacosternum boettgeri* in the study area.

Conservation Status

There is no need for conservation. After heavy rains this species abundantly appears at temporary pools. In the whole of South Africa it is not threatened and no special conservation measures are needed (Scott, 2004).

4.3.11 ***Strongylopus fasciatus*** (Smith, 1849), (Figure 4-21)

Common Names: Striped Stream Frog (E), Gestreepte Langtoonpadda (A).

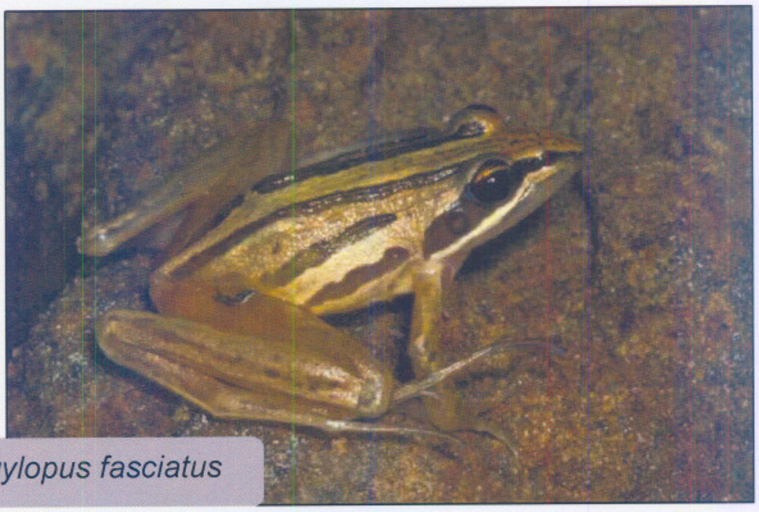


Figure 4-21 Adult *Strongylopus fasciatus*

Description

The body may reach a length of about 50 mm. It is a slender frog with a pointed head and streamlined body. The colouring on the back varies from silver-yellow to brown, with two dark stripes extending from the snout to vent. Other longitudinal stripes may be divided or broken up. The abdomen is smooth and white. The throat and groin are usually yellow in males. Webbing is present and the fourth toe is very long and extends past the eye when the frog is sitting. The extreme length of the toes and the moderate to weekly webbed feet are characteristic of this species.

The robust tadpoles may reach a length of up to 70 mm. It is overall brown with darker flecks. The tail is blunt and is usually darkly coloured.

Life history observations

Only a single male was heard calling at a quarry hole next to the road in December.

Distribution

This species is found in the wetter, relatively temperate part of southern Africa. Its range extends from the Western Cape coast, through the Eastern Cape to Kwazulu-Natal. It is also found on the escarpment of Mpumalanga and Limpopo provinces. They have a scattered distribution in the Free State, Gauteng, North West and Limpopo provinces (Boycott, 2004).

Strongylopus fasciatus was only identified on its call in December at a quarry hole in the south-western corner of the Vredefort Dome conservation area (Figure 4-22).

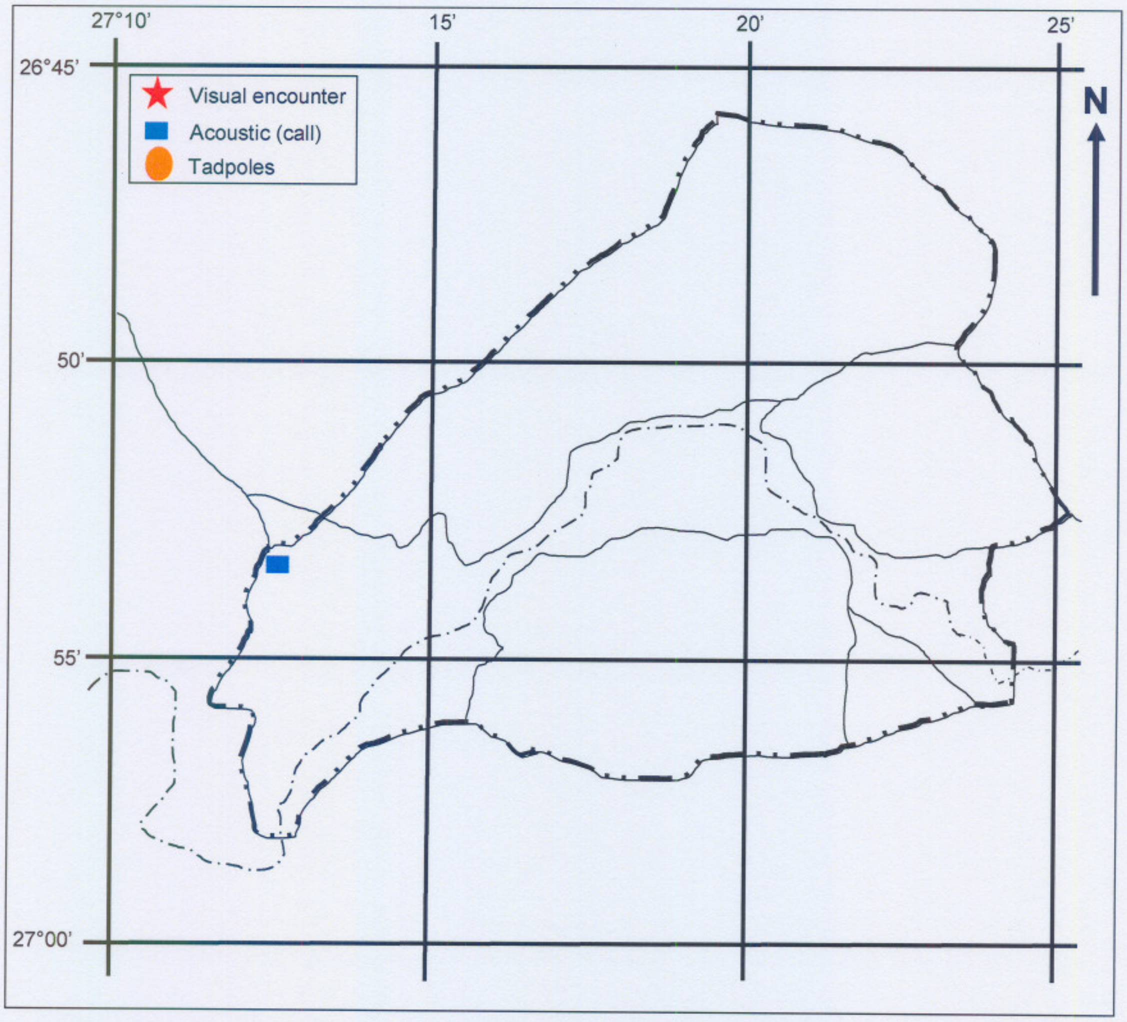


Figure 4-22 Distribution map of *Strongylopus fasciatus* in the study area.

Conservation Status

Only one specimen was heard calling, indicating that this species is not abundant in this area. Although this species was not found in abundance there is no concern to conserve it in this area. It is widespread in the rest of South Africa and is not threatened (Boycott, 2004).

4.3.12 *Tomopterna cryptotis* (Boulenger, 1907) (Figure 4-23)

Common names: Cryptic Sand Frog (E), Trillersandpadda (A).

Figure 4-23 Adult *Tomopterna cryptotis*

Description

This is a small, heavily-built frog, with the male up to 45 mm and the female up to 58 mm in length. The inner metatarsal tubercle is flattened and large and is used for digging in sandy soil. The skin on the back is smooth with a few warts. The colour varies from light-grey to olive green or orange-brown. A thin vertebral stripe is sometimes present. The abdomen is white and the throats of males are darker. Feet are moderately webbed.

The tadpoles are large and robust, reaching 35 mm in length. They are brown, sometimes with darker markings. The body is rounded and the tail ends in a blunt tip. There are two divided rows of supra-keratodonts present.

Life history observations

Calls were heard at most of the permanent and temporary sites. Males started to call in October and continued until February. They were usually calling in the presence of *C. boettgeri*. Tadpoles were collected at the Waterfall in January and February.

Distribution

This species occurs in the central highlands of Southern Africa (Channing, 2001). They are found in most of the Free State, North West, Guateng, Limpopo, Mpumulanga, eastern Northern Cape and northern Kwazula-Natal (Channing, 2004d).

They are widely spread over the entire study area (Figure 4-24). Specimens were seen at Berhaka, Waterfall, and at a roadside pond on the road to Schoemansdrift.

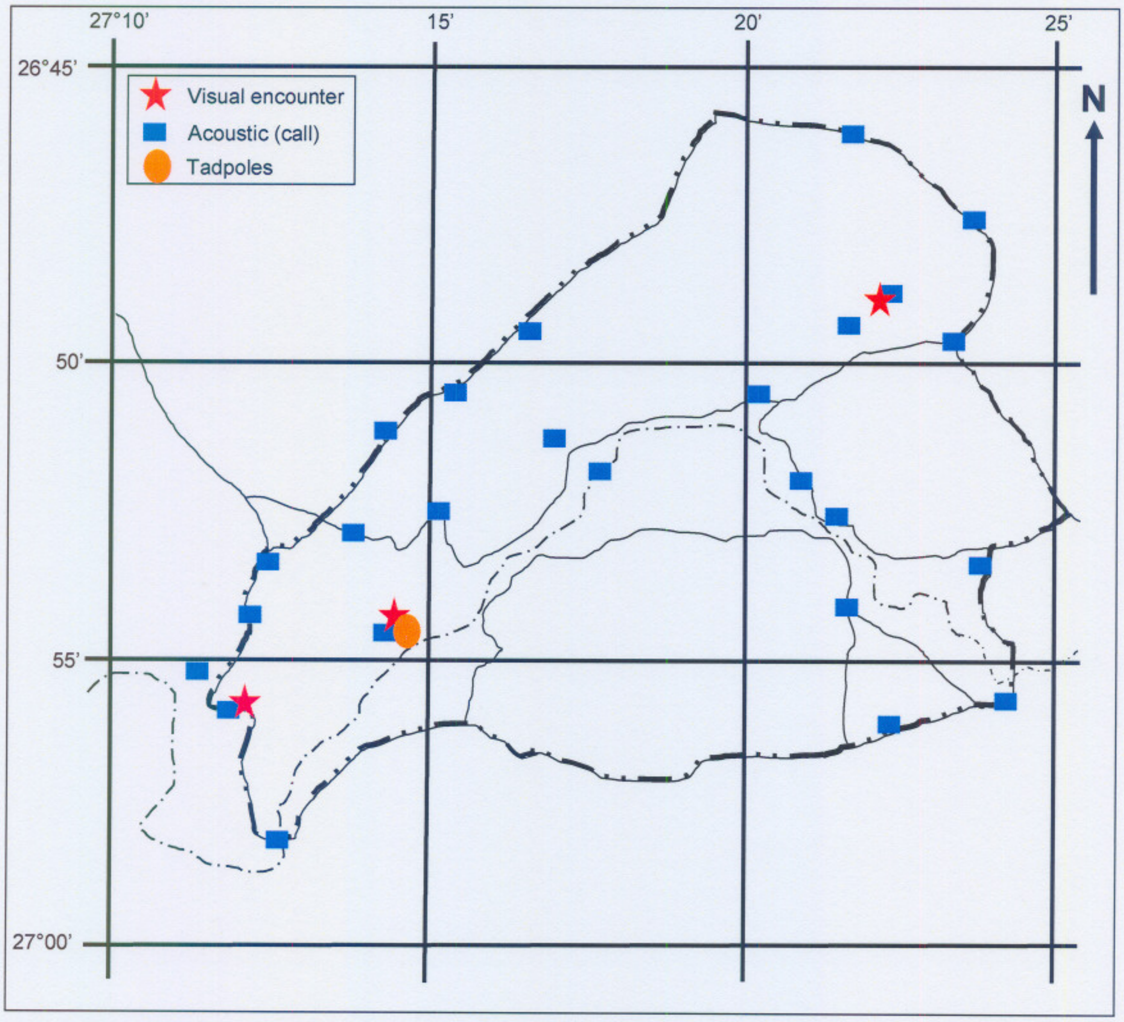


Figure 4-24 Distribution map of *Tomopterna cryptotis* in the study area.

Conservation Status

This is a widely distributed species in the Vredefort Dome and does not need any conservation measures. *Tomopterna cryptotis* is widespread in South Africa and does not require any conservation action (Channing, 2004d).

4.3.13 ***Tomopterna natalensis*** (Smith, 1849) (Figure 4-25)

Common names: Natal Sand Frog (E), Natalse Sandpadda (A).

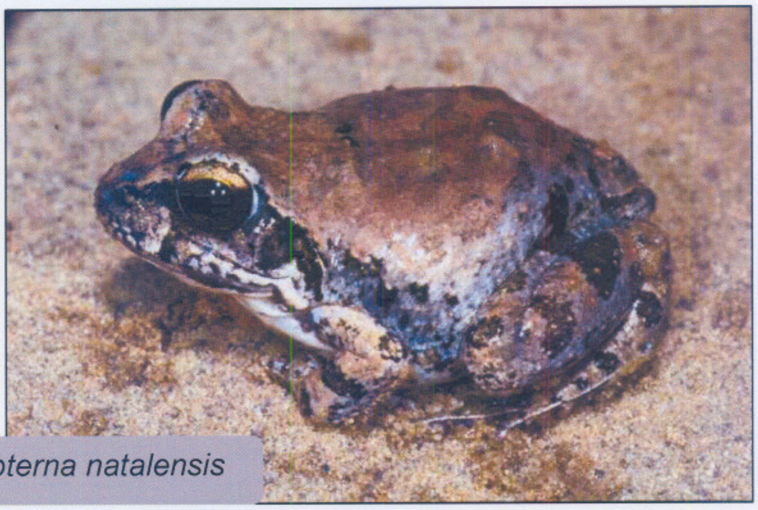


Figure 4-25 Adult *Tomopterna natalensis*

Description

This is a robust little frog. Males reach a length of 39 mm, while females can be up to 44 mm in length. Like *T. cryptotis* this species has a large inner metatarsal tubercle used for digging. The dorsal colour varies from grey to dark red-brown. There is no vertebral stripe present. Webbing is reduced.

Tadpoles reach a length of 36 mm. The body is dark with scattered golden spots. The belly is a pale gold colour. Tadpoles are distinguished from *T. cryptotis* in the number of rows of supra-keratodonts. *Tomopterna natalesis* has three to four, while *T. cryptotis* only has two.

Life history observations

Males called from October until February, especially after heavy rains. Tadpoles were collected from the Elgro site. Tadpoles were large and grey to black in colouration.

Distribution

This species is found in most of Limpopo, Mpumalanga, Gauteng and Kwazula-Natal, as well as eastern parts of the North West and Eastern Cape provinces

(Channing, 2004e). The species is uncommon in the Free State, and is restricted to the central, eastern and north-eastern part of the Free State (Du Preez, 1996).

It was found in most of the study area, except in the northern and southern parts (Figure 4-26). Visual encounters were made at the Berhakas, Waterfall and near Schoemanshof.

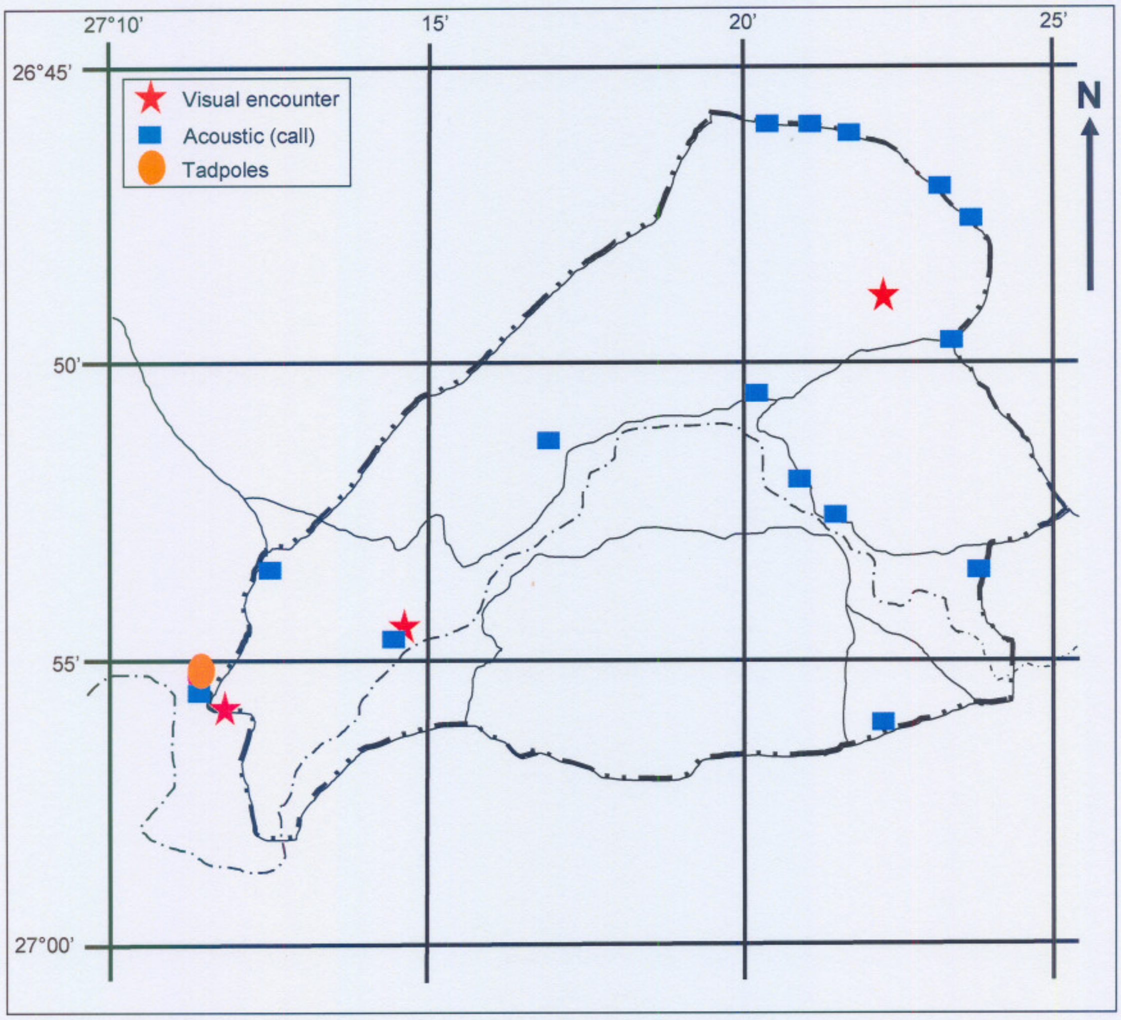


Figure 2-26 Distribution map of *Tomopterna natalensis* in the study area.

Conservation Status

This is a widely distributed species in the Vredefort Dome and does not need any conservation action. Elsewhere in South Africa it seems as if this species is widespread and it does not need any conservation action (Channing, 2004e).

CHAPTER FIVE

SEASONAL VARIATION IN ANURAN SPECIES COMPOSITION

5.1 Seasonal variation in species composition

5.1.1 Species diversity

During the study period March 2005 - February 2006 thirteen different anuran species belonging to five families were encountered. Recorded species were: *Afrana angolensis, A. fuscigula, Breviceps adspersus, Bufo gutturalis, B. rangeri, B. poweri, Cacosternum boettgeri, Kassina senegalensis, Schismaderma carens, Strongylopus fasciatus, Tomopterna cryptotis, T. natalensis* and *Xenopus laevis.* See chapter four for a detailed list of the different species.

5.1.2 Seasonal Variation in Species Encountered

Figure 5-1 indicates the variation in species encountered in the four seasons; summer (December, January, February), autumn (March, April, May), winter (June, July, August), and spring (September, October, November). Average numbers of species encountered during the three months periods were calculated. Species encountered was greatest in summer (10.67 ± 0.33). Species encountered then declined through autumn (3.33 ± 0.88) to a minimum of two species in winter (1.67 ± 0.33). During spring, species encountered increased again (4.67 ± 0.88), but not to levels seen in summer.

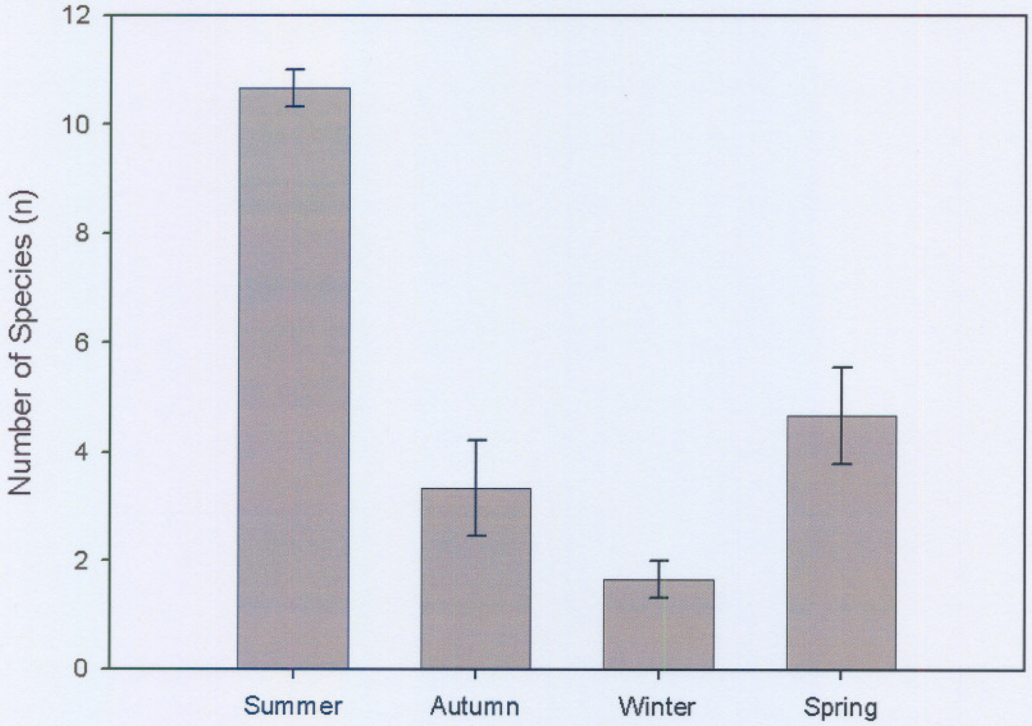


Figure 5-1 Histogram with standard deviation showing seasonal variation in the number of species that was active during the study period.

5.1.3 Correlation between Ecological Factors and Species Encountered

Species encountered increased with an increase in temperature and rainfall (Figure 5-2). Grey bars represent the study period and the turquoise shaded area represents the months prior to the study period when a pilot study was conducted. The variation in species encountered appeared to reflect variation in rainfall and temperature. As the rainfall and temperature declined, so too did species encountered. Eleven of the thirteen species were found in the months of December and January, while July only produced one species.

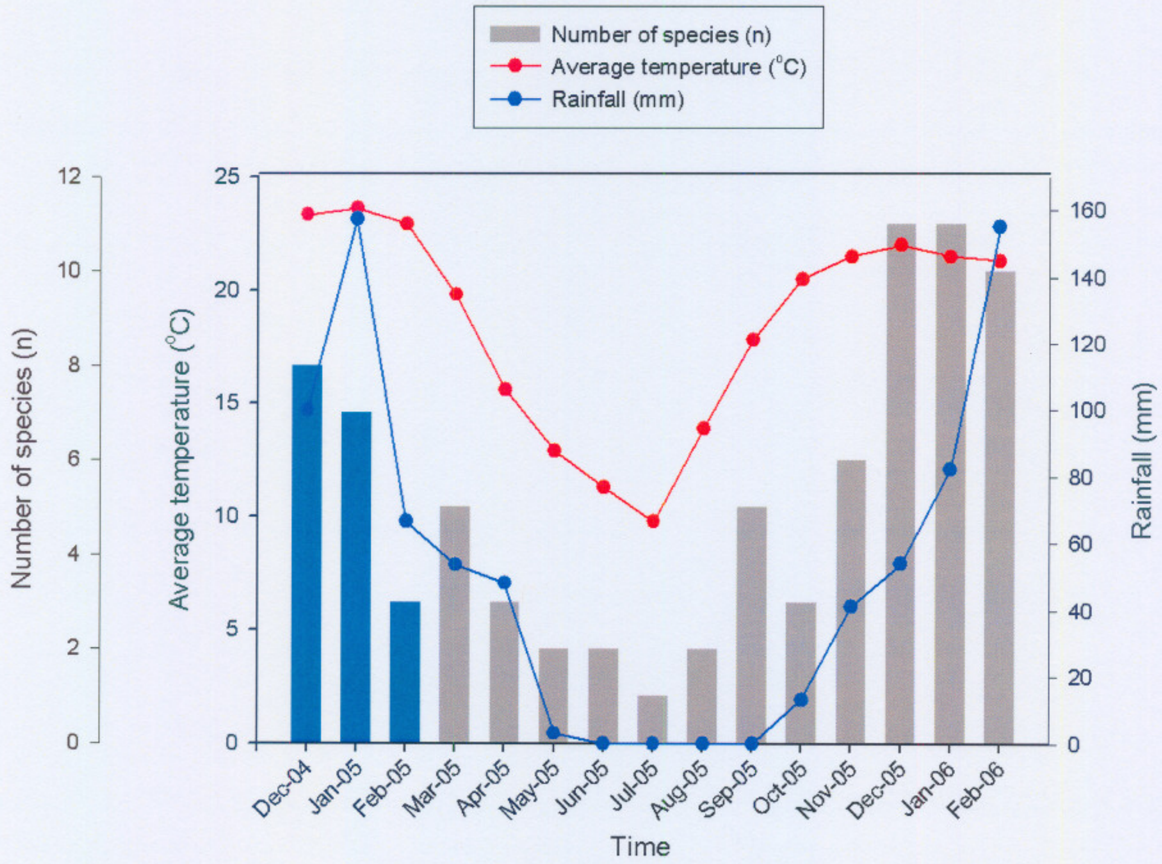


Figure 5-2 Bar graph showing the relation between numbers of species found and ecological factors (rainfall and average monthly temperature).

To know whether any correlation between the temperature and number of species encountered each month does exist a linear regression was drawn (Figure 5-3). The R-Squared value (0.6617) indicates that there is indeed a correlation between temperature and species.

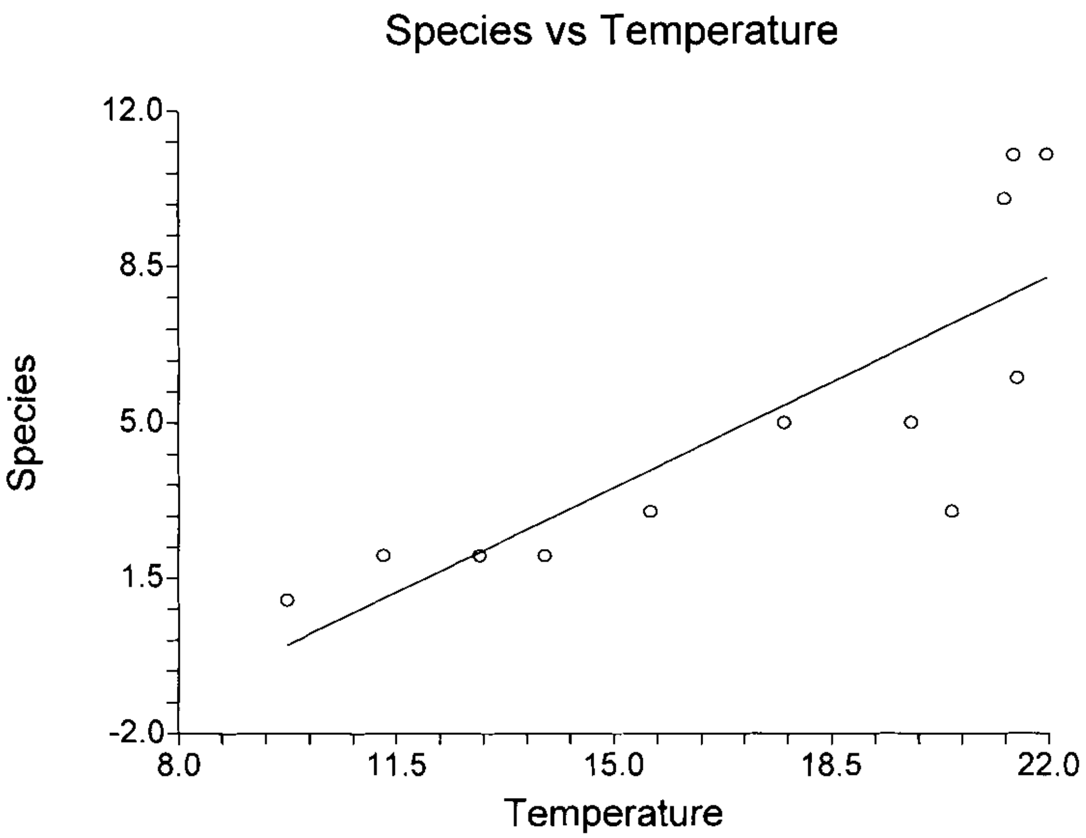


Figure 5-3 Linear regression plot of the number of species encountered and the average temperature (R-Squared = 0.6617).

The same test was performed for rainfall and the number of species found (Figure 5-4). The R-square value indicates that there is indeed a significant correlation between the rainfall and the number of species found.

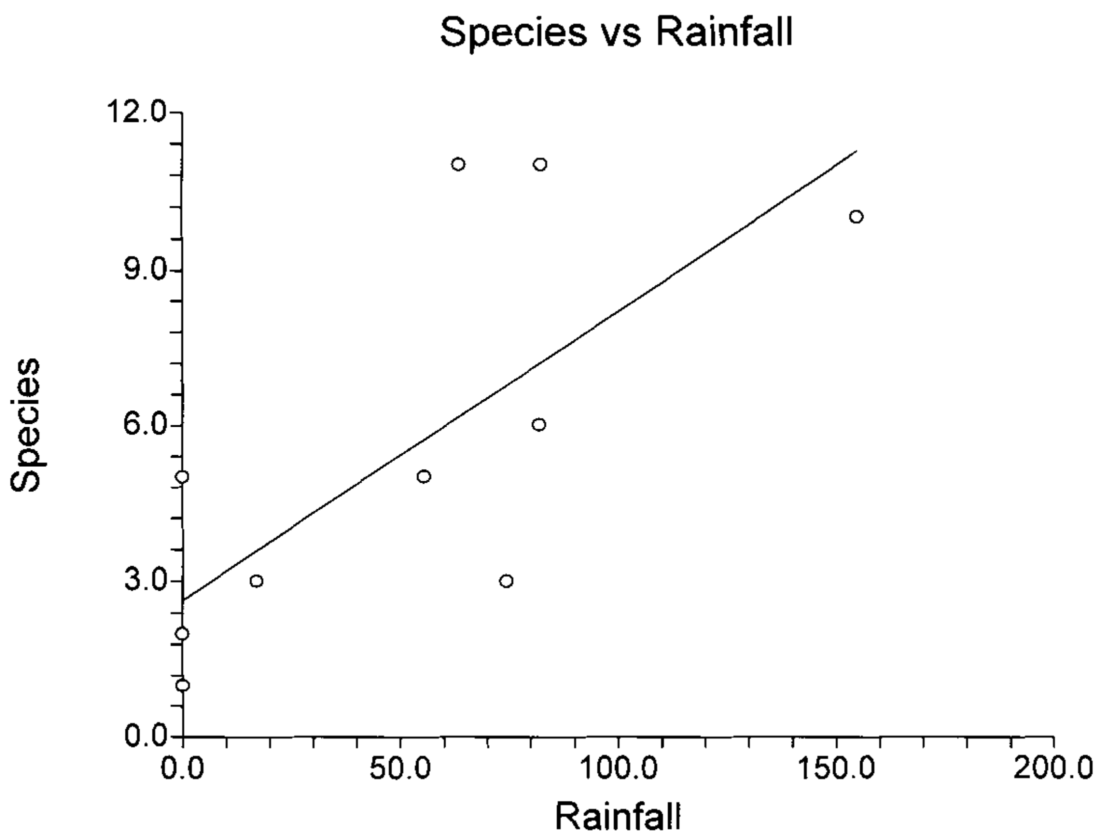


Figure 5-4 Linear Regression Plot of the number of species encountered and the average rainfall (R-Squared = 0.5616).

5.1.4 Species encountered for two different techniques used

5.1.4.1 Visual Encounters

Most of the visual encounters were made in the summer months (Figure 5-4) during the peak of the rainy season, corresponding with the breeding season of most species of frogs. The most abundant species in the summer were *Afrana angolensis, Bufo gutturalis* and *Shcismaderma carens*. The only species present in all four of the seasons were *A. angolensis* and *Xenopus laevis* (Figure 5-5 and 5-6). *Afrana angolensis* breeding peaks in early winter, but this species was present throughout the year. Although *X. laevis* was present in all the seasons it does not imply that it breeds throughout the year. The first *X. laevis* tadpoles encountered were in December, indicating that during the study period they started breeding in the early summer months. The first species to appear after the first rains were *B. gutturalis, B. rangeri* and *S. carens* (Figure 5-7). These species are summer rainfall breeders and only stop breeding in autumn at the start of the dry season.

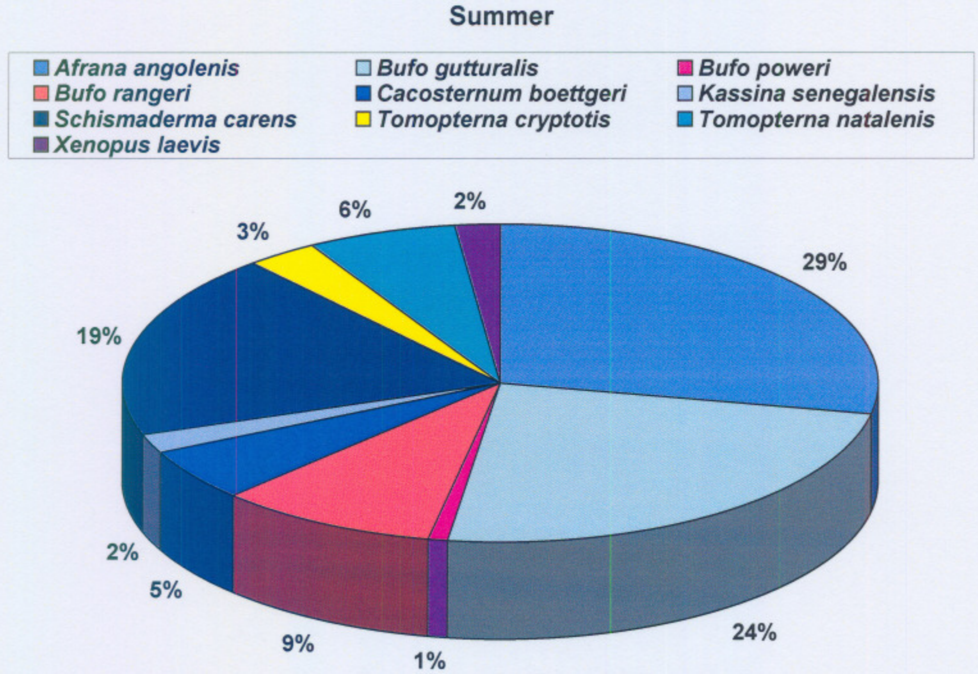


Figure 5-5 Pie chart showing species composition expressed as a percentage of the total number of individuals encountered during the summer.

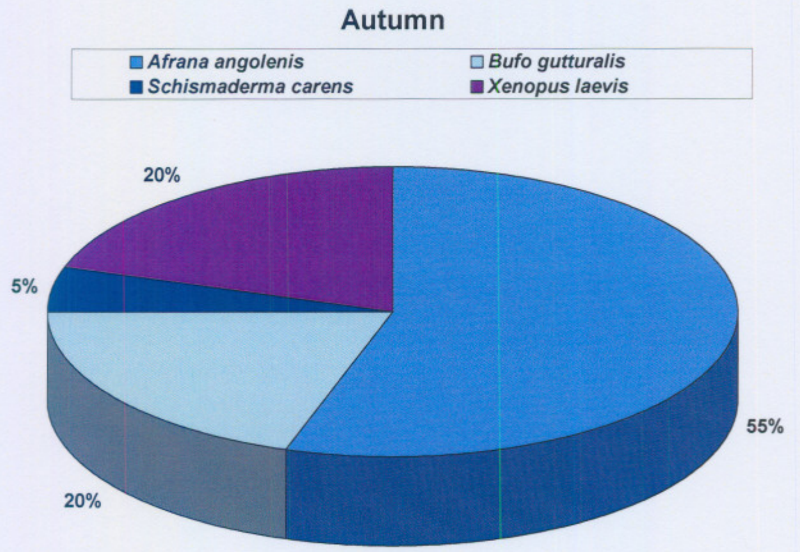


Figure 5-6 Pie chart showing species composition expressed as a percentage of the total number of individuals encountered during the autumn.

Figure 5-7 Pie chart showing species composition expressed as a percentage of the total number of individuals encountered during the winter.

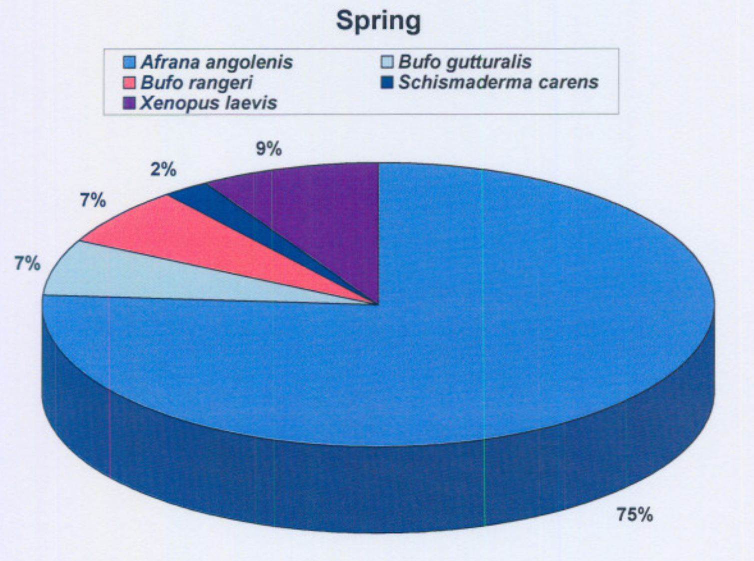


Figure 5-8 Pie chart showing species composition expressed as a percentage of the total number of individuals encountered during the spring.

5.1.4.2 Tadpoles

The highest diversity of tadpoles was found after the first rains, from December 2005 until February 2006. A total of nine different species of tadpoles were collected during this period (Figure 5-9). The most dominant species during summer were *X. laevis, A. angolensis, Tomopterna natalensis*, *T. cryptotis* and *S. carens.* Tadpoles of only a single species, *A. angolensis*, were seen during autumn, winter, and spring.

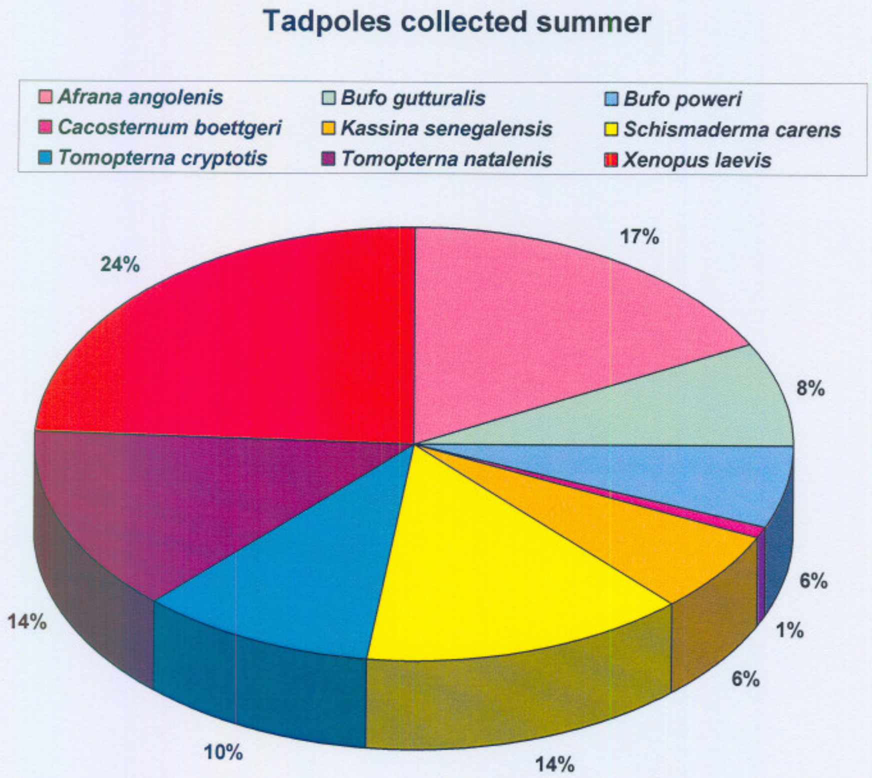


Figure 5-9 Pie chart showing species composition expressed as a percentage of the total number of tadpoles encountered during the summer.

5.2 Site Specific Species Richness

The highest amphibian diversity occurred at Site E (Thabela Thabeng) with nine different species and the lowest diversity at Site D (Bluegumwoods –river) with four species (Figure 5-10).

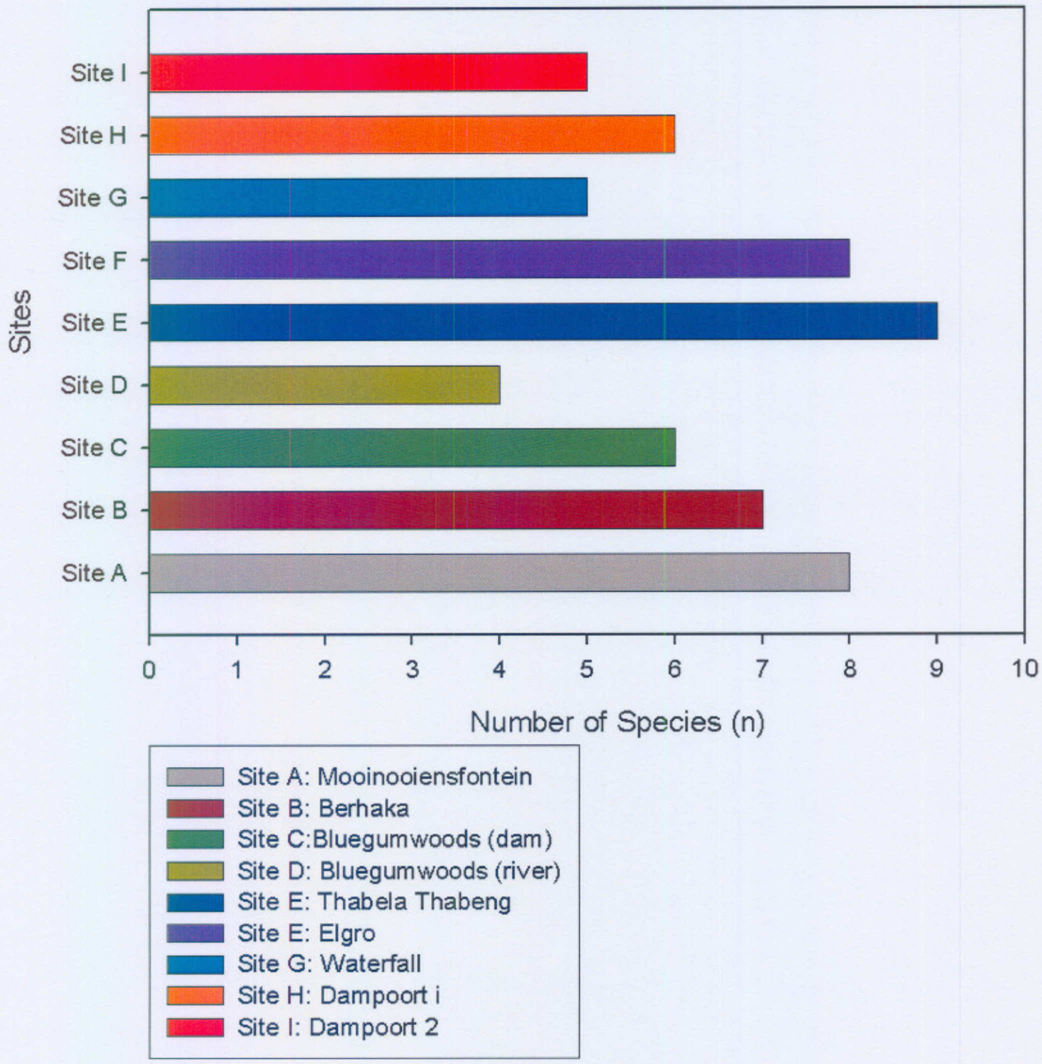


Figure 5-10 Bar graph indicating the site-specific species richness, summed over all surveys.

Several species of tadpoles were frequently found at the same site (Figure 5-11). Based on species occurrences, *X. laevis* and *A. angolensis* occurred with the most other species, while *Tomopterna natalenis, T. cryptotis,* and *B. poweri* occurred with the least.

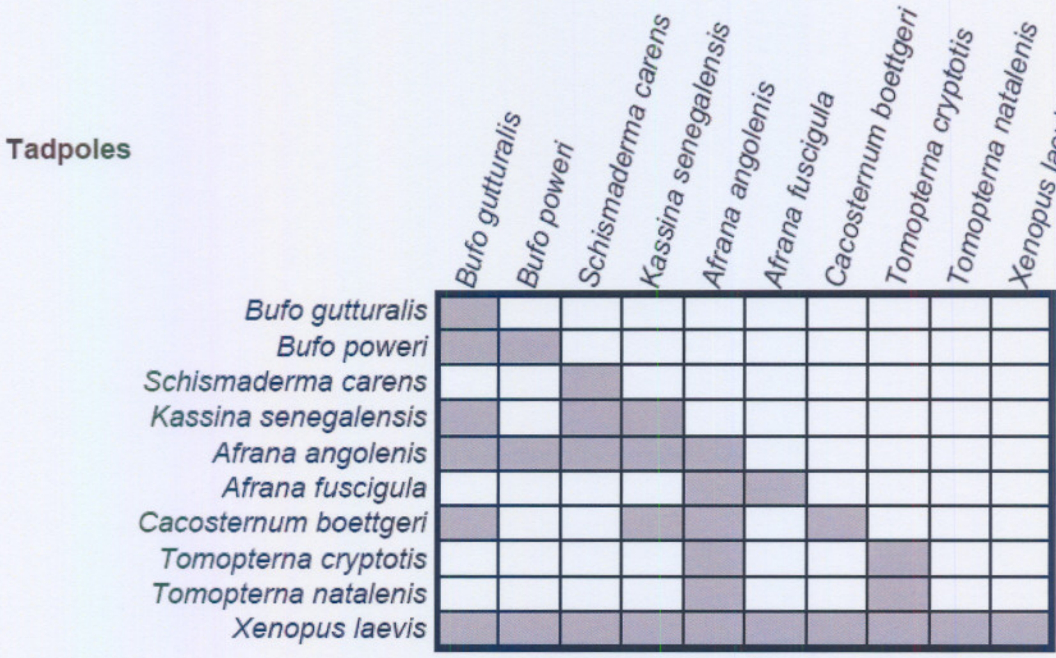


Figure 5-11 Matrix of tadpole species occurring synoptically. Grey shading indicated species that was found at the same site, compiled over all surveys.

5.3 Proportion of Species Detected by each Technique

The number of species encountered for each technique was converted into a percentage of the total individuals for the specific month. Then an average percentage for the whole of the study period was calculated for each technique (Table 5-1).

Visual encounters (as indicates in Table 5-1) were the most effective technique used over the 12-month period (responsible for detecting 84% of species), followed by call identification (55% of species) and then the tadpole survey (47% of species). During the autumn and winter months (March – August) visual encounters proved to be the best method of sampling frogs, with a success of 100% of species encountered. During the breeding season (December – February) call identification (73 – 91% of species) was the best technique and the collecting of tadpoles (90% of species) proved to be best method in February after most of the frogs had bred.

Some species can only be detected with a single technique; e.g. *Breviceps adspersus* does not have an aquatic breeding cycle and will only be detected with call identification and visual encounters.

Table 5-1 Percentage effectiveness of each technique over the study period.

	Mar-05	Apr-05	May-05	Jun-05	Jul-05	Aug-05	Sep-05	Oct-05	Nov-05	Dec-05	Jan-06	Feb-06	TAverage
Visual encounters	80	100	100	100	100	100	60	67	83	64	82	70	84%
Call	40	33	50	50	0	50	80	67	50	73	91	80	55%
Tadpoles	20	33	50	50	100	50	20	67	17	18	45	90	47%

Figure 5-12 indicates that throughout the year the best method of observing amphibians in the Vredefort Dome is visual encounters. Call identification proved to be the best technique to identify frogs during the breeding season (November, December and January) and after the breeding season (February) the sampling of tadpoles proved to be the best.

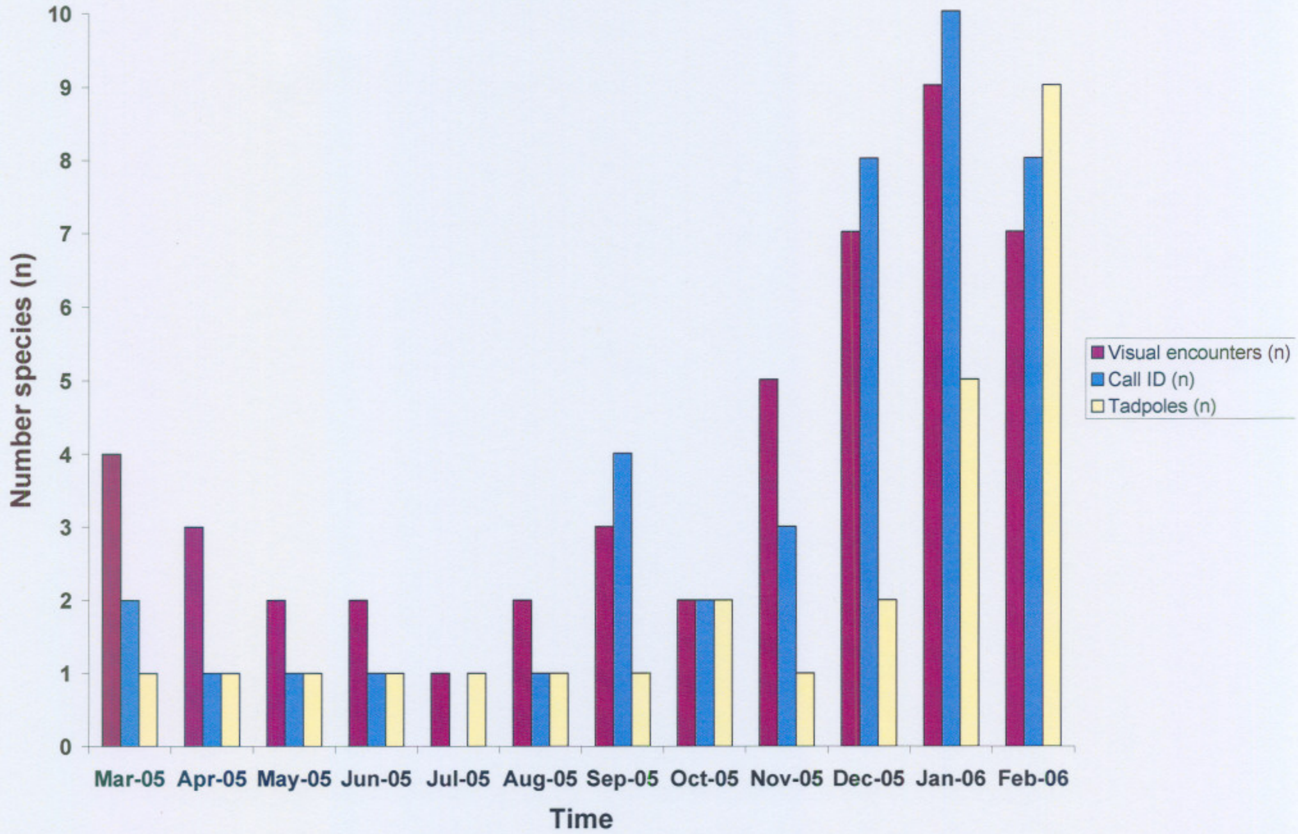


Figure 5-12 Total number of species identified for each of the three techniques during monthly surveys in the study area.

CHAPTER SIX

CHYTRIDIOMYCOSIS SURVEY

6.1 Infection data

Nine different species of tadpoles were collected, representing three of the five families found in the Vredefort Dome area. Sporangia only grow in the keratinised epidermis of post-metamorphic amphibians and keratinised mouthparts of tadpoles (Longcore *et al.*, 1999). Larvae of the family Pipidae do not have keratinised mouth parts and cannot be infected with the amphibian chytrid. Only one species of tadpole, *Afrana angolensis*, was infected with *Batrachochytrium dendrobatidis* (Table 6-1). Of all the adult frogs that were screened for chytridiomycosis, only two species, *Afrana angolensis* and post-metamorph *Xenopus laevis*, were infected.

Table 6-1 Summary of tadpoles screened for chytridiomycosis

Species		No. Infected/no. examined
Bufonidae		
	Bufo gutturalis	0/12
	Bufo poweri	0/10
	Schismaderma carens	0/27
Ranidae		
	Afrana angolensis	20/257
	Afrana fuscigula	0/22
	Cacosternum boettgeri	0/2
	Tomopterna cryptotis	0/15
	Tomopterna natalenis	0/31
Hyperoliidae		
	Kassina senegalensis	0/7

6.2 Prevalence

6.2.1 Prevalence per site

Afrana angolensis tadpoles were abundant and present at most of the sites during the study period and the only species found to be infected with chytridiomycosis. Chytrid was detected in *A. angolensis* at four of the nine sites (44.4% of sites) at which this species was found. The highest prevalence of chytrid was at Site F (22.4% of examined individuals), then Site E (6.52% of examined individuals), Site G (5.88% of examined individuals), and the lowest at Site B (5.26% of examined individuals). Average prevalence for the species from infected sites was 7.78%. The aquatic habitat was similar in the sites in which chytrid was detected namely mountain streams with clear water and with some deeper pools. In contrast, no infected tadpoles were found in any of the bigger more permanent water bodies.

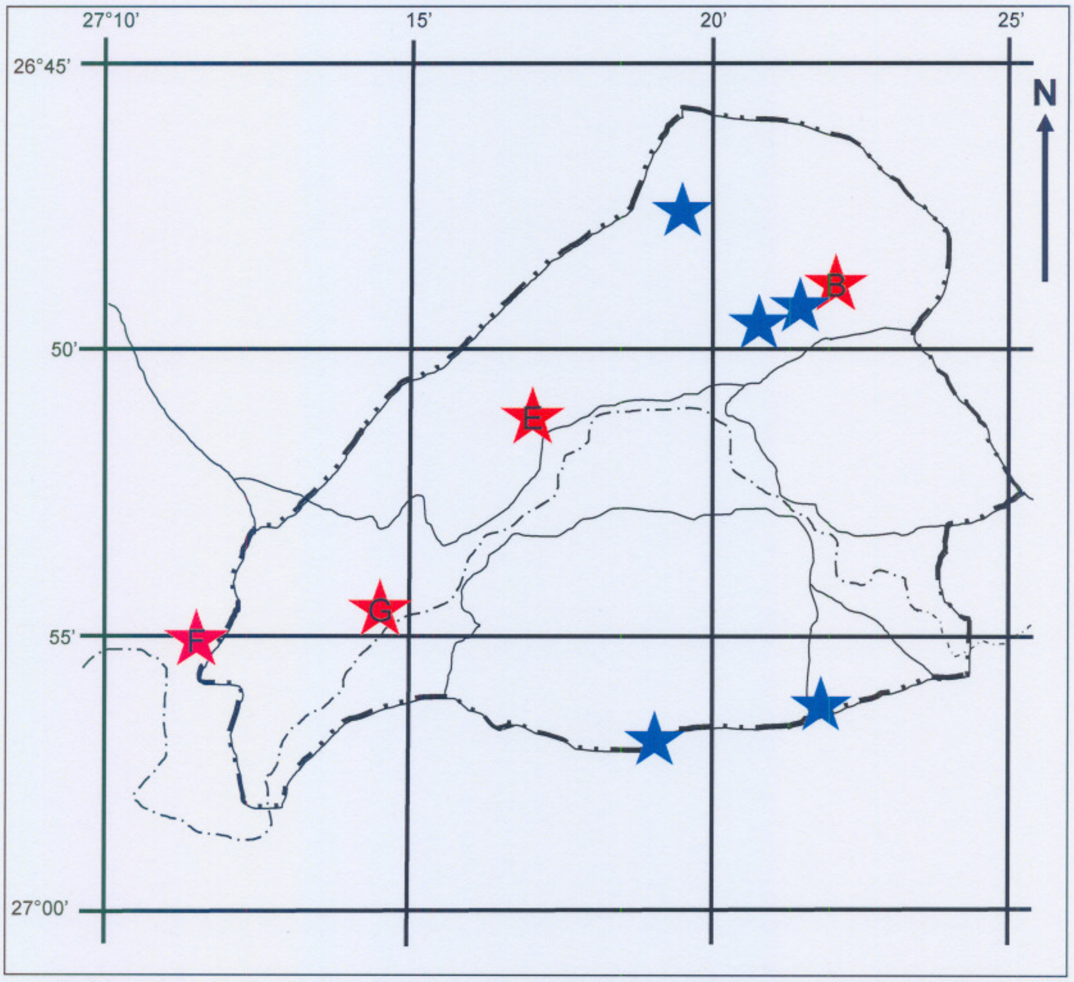


Figure 6-1 Map indicating infected sites (red star) and non-infected sites (blue star).

6.2.2 Prevalence over time

Detection of *B. dendrobatidis* was seasonal, since infection was only detected during the months of August, September, October and November. The lowest prevalence was in August (7.14%) and increased to a relatively-high prevalence in November (23.3%) (Figure 6-2). These months usually signify the end of the dry season when surface water is least abundant. In 2005, rainfall first started to increase from October and at the same time the infections reached a peak and disappeared as the first significant rains started in December.

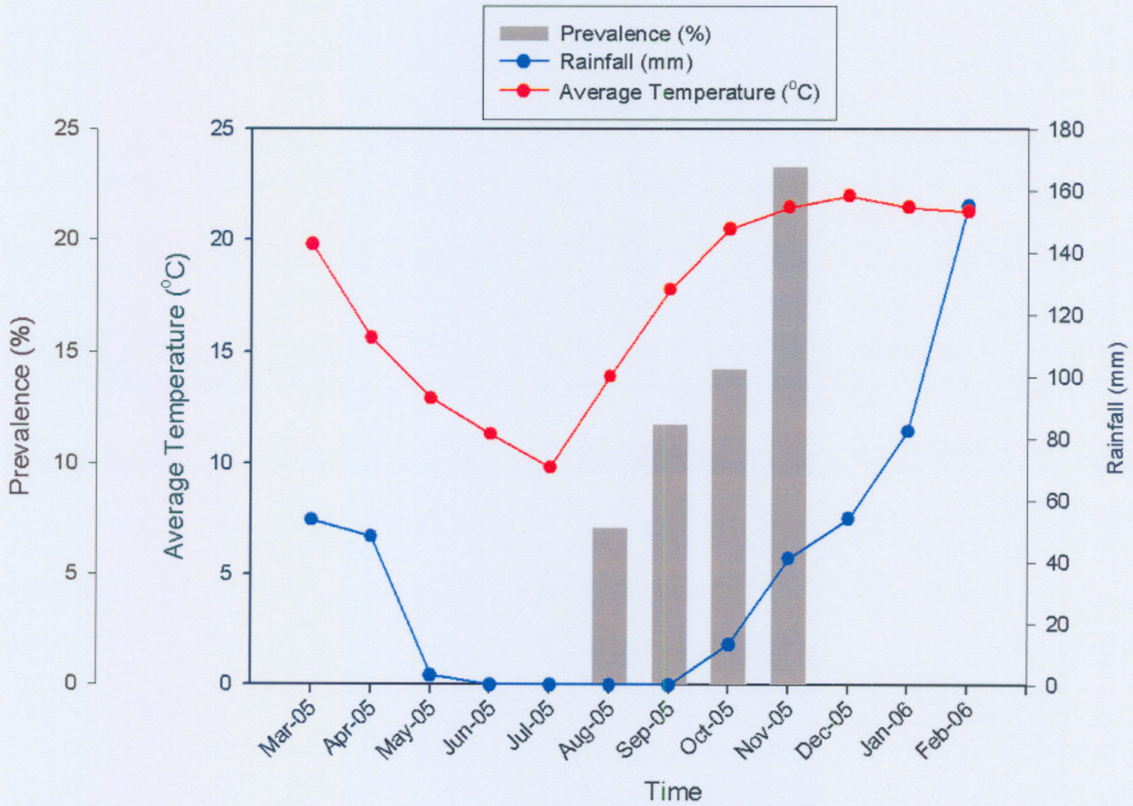


Figure 6-2 Graph showing the correlation between prevalence of the amphibian chytrid and rainfall and temperature during the study period.

6.3 Zoosporangium Density

Sporangia density ranged from 31.75 - 1939.76/mm^2 with a mean of 446.06/mm^2.

Tables 6-2 Summary of infection data for *Afrana angolensis*

	Gosner Stage	Body Length	Sporangia/field	Sporangia/mm^2
	26	37.0	11.9	421.7
	27	57.0	70.0	423.9
	33	60.0	122.7	738.0
	34	56.2	55.6	334.9
	35	63.5	5.3	31.8
	36	67.0	70.4	98.0
	37	79.7	68.5	412.4
	37	64.0	12.4	356.2
	38	71.7	59.1	71.1
	41	72.7	40.7	245.3
	41	87.6	322.0	1939.8
	41	79.9	166.6	1003.5
	41	71.4	86.9	523.6
	41	81.5	21.6	129.9
	41	58.6	100.5	605.4
	41	65.7	26.9	162.1
	41	65.0	14.2	85.5
Average	37.12	67.0	73.8	446.1

6.4 Developmental stage and size of *Afrana angolensis* versus infection

It seems that there is a correlation between infected tadpoles and growth. None of the screened tadpoles at stages 23 to 25 were infected, nor any of the tadpoles between stages 42 and 45. The average length of infected *A. angolensis* tadpoles was 67 mm and the average Gosner stage was 37 (Table 6-2).

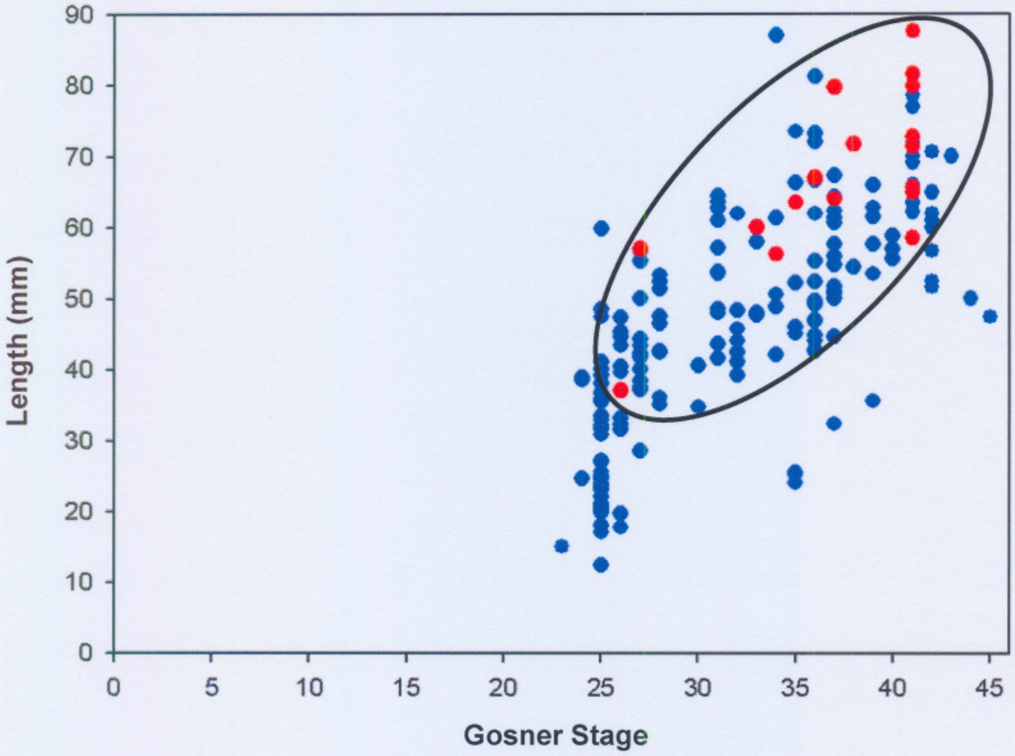


Figure 6-3 Scatter plot of developmental stage against size of *Afrana angolensis* tadpoles. *Batrachochytrium dendrobatidis* infected specimens are indicated in red.

Linear regression was done to determine if there is a correlation between the development of tadpoles and the intensity of infection. The r-squared value for the correlation between Gosner stage and the sporangia density is 0.0585, indicating that there is a small correlation (Figure 6-4).

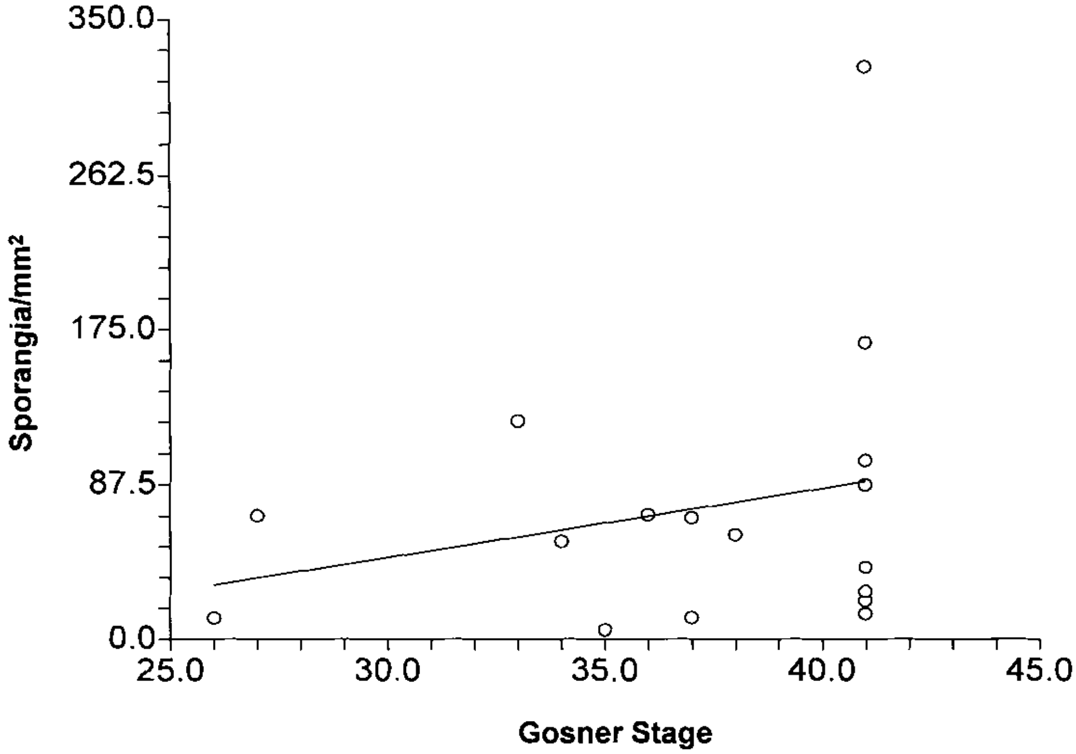


Figure 6-4 Linear regression plot of sporangia density per area against the Gosner Stage (R-Squared = 0.0585).

The correlation between sporangia density per area and Gosner stage is weak. T-test (0.3498 > 0.0500) indicates a no significant correlation between the variables.

The same was done for body length versus the sporangia density per area (Figure 6-5). The results indicate that there is a bigger correlation than for the Gosner stage.

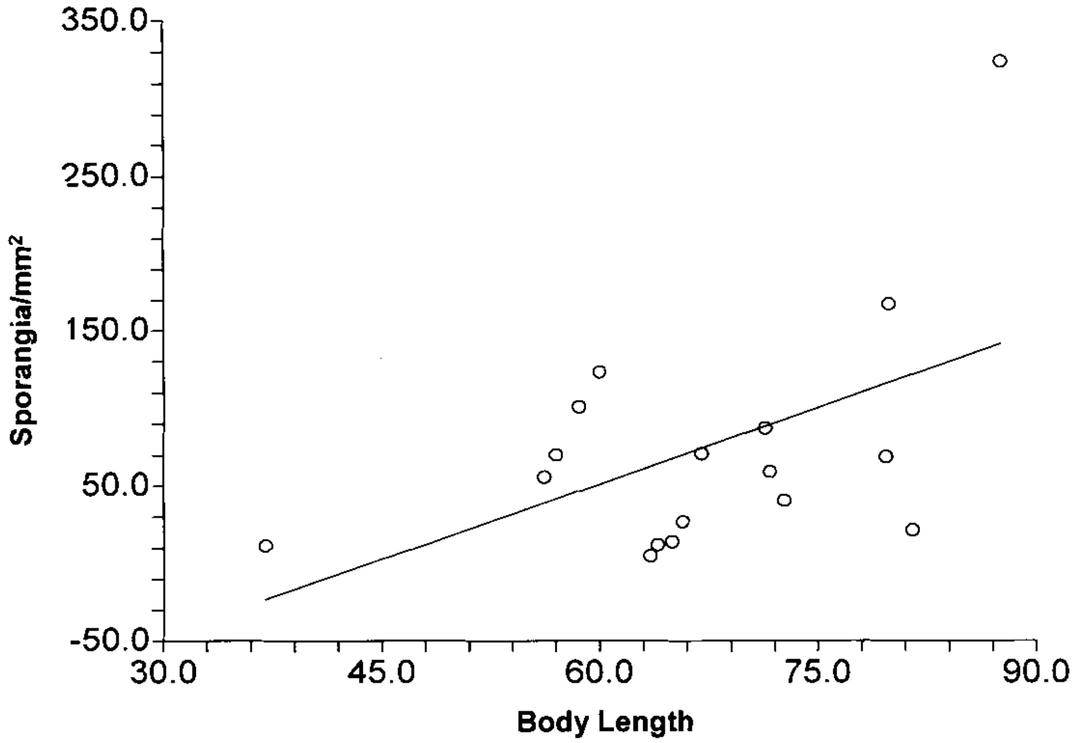


Figure 6-5 Linear regression plot of sporangia density per area against the body length (R-Squared ^{2} = 0.2492).

The t-test (0.0414 < 0.0500) for both of these variables is significant and shows there is some kind of correlation between them.

6.5 Histology Results

Thirty *X. laevis* were collected with the bucket traps. These were screened for chytridiomycosis through histological analysis of toe clippings. However, *B. dendrobatidis* was not detected in any of these frogs.

CHAPTER SEVEN

GENERAL DISCUSSION

7.1 Introduction

Studies of the distribution and abundance of species have led to a huge volume of evolutionary and ecological theory, which forms the underpinning of systematics, biogeography, ecology and conservation biology. In the past decade the loss of biodiversity stood out as one of the key issues of concern for biologists. This continued loss of biological diversity through anthropogenic activities will have a major impact on our ability to understand the scientific complexity of our surroundings and our ability to pursue science (Heyer *et al.*, 1994).

We cannot underestimate the role of amphibians in the ecosystem. In some areas their total biomass equals that of mammals and is more than twice that of resident birds in the peak of avian breeding activity (Burton & Linkens, 1975). The complex biphasic life cycles of amphibians and their permeable skin make them extremely vulnerable to changes in the environment and this makes them potentially excellent indicators of environmental health. However, in order to use amphibians as bio-indicators it is imperative that a full systematic account be available for the specific study area. Very few such studies have been undertaken in South Africa and the importance of biodiversity surveys cannot be overemphasised.

7.2 Systematic accounts

Based on historical collections and observations, 16 species of frogs could be present in the study area. Of these, 13 were recorded during the present study. The three species that could be in the area but not recorded during the present study are *Phrynobatrachus natalensis* (Natal sand frog), *Pyxicephalus adspersus* (Giant Bullfrog) and *Semnodactylus wealii* (Rattling frog).

Passmore & Carruthers (1995) is the only source indicating on their distribution map that *P. natalensis* may be present in the study area. The survey done during the South African Frog Atlas (Minter *et al.*, 2004) project indicated that this species is found just east from the study area, although data prior to 1996 indicated that it was found west of the study area (Channing, 2004c). No records were found in the study area during the atlas project, that stretched from 1996 – 2003. *Phrynobatrachus natalensis* is typically found in a variety of vegetation types in Savanna and Grassland biomes where summer rainfall exceeds 500 mm annually (Channing, 2004c). Although the study area consists of suitable vegetation type and breeding habitat, the summer rainfall over the last 10 years for the months of November until February is 319.6 ± 52 mm indicating that for most years it is too dry for this species to occur in the study area.

Pyxicephalus adspersus is widely distributed in the greater Vredefort region (Passmore & Caruthers, 1995; Du Preez & Cook, 2004), but no records were found during the study period. The ideal breeding habitat for *P. adspersus* is seasonal, shallow, grassy pans in flat open areas. They also prefer sandy substrates (Du Preez & Cook, 2004). The north-western part of the dome is too rocky and does not have any typical breeding habitat for bullfrogs. The Free State side of the Vaal River consists of more sandy soil as well as ideal breeding sites that fill with water during the rainy season. Bullfrogs are explosive breeders and tadpoles will complete metamorphosis in as little as 26 days (Du Preez, 1996). Because of the rapid development and the fact that bullfrog tadpoles school it is quite possible that this species could have bred but was missed during the present study. A number of dedicated field trips to possible breeding sites were undertaken following heavy rains, but no evidence for the presence of *P. adspersus* was found.

Historic records (Du Preez, 2004) suggested that *S. wealii* was present in the study area, although this species was not found during the study period. Because the Vredefort Dome is situated on the western border of the range of *S. wealii*, this species most likely does not occur in the study area.

Based on the most recent biogeography of South African frogs (Minter *et al.*, 2004), three new records were made for the two quarter degree grid cells covering the study area. These are B*ufo poweri, Strongylopus fasciatus* and *Tomopterna natalensis*. In addition this is the first record for three more species *Bufo rangeri, Afrana fuscigula,* and *Kassina senegalensis* since before the frog atlas project commenced in 1996 (Minter *et al.*, 2004).

Most of the species documented during this study are widely distributed in the study area. Exceptions are *Breviceps adspersus, A. fuscigula* and *S. fasciatus* for which only a few records were found. Non-specialists should have little difficulty to distinguish between ten of the thirteen documented species. The *Bufo spp., Schismaderma carens* and *Tomopterna spp.* can normally be found on the roads and roadside pools and are easy to spot. *Afrana spp., Kassina senegalensis,* and *Cacosternum boetgerri* can easily be identified on their call during the breeding season. Water-bodies with good visibility can be ideal for the spotting of *Xenopus laevis*. They can be spotted the easiest with a flashlight at night, because they are often suspended just beneath the water surface.

No additional and special conservation measures are necessary for conserving the amphibian diversity of the study area. All the species are widely distributed elsewhere in South Africa and are conserved in numerous parks and other conservation areas (Minter *et al.*, 2004). If *P. adspersus* is discovered in the study area it may be worthwhile to draw up a plan to conserve this species. Most landowners in the Vredefort Dome World Heritage Site are well informed about and sympathetic towards eco-tourism and hence on conserving the fauna and flora of this unique region. *A Vredefort Dome Bergland Conservancy* has been established by private landowners in the North West Province and a *Vredefort Dome Conservancy* has also been established in the Free State Province by private landowners (IUCN, 2005). The only current threat to the amphibians in this area is road kills. The increase in eco-tourism can be expected to lead to increased traffic, which may increasingly contribute to mortalities due to traffic. The species most vulnerable to road mortality are members of Bufonidae that cross the roads that run through migration routes between breeding sites and they seem to spend a lot of time on roads probably looking for prey items. However, these species are widespread, abundant, and are highly fecund, and therefore road mortality is not expected to significantly affect populations of Bufonids in the dome.

A follow up on the present study will involve a field guide to the frogs and toads of the Vredefort Dome area. (Appendix C). The target market for this field guide will be tourist of the regions. The guide will give some overall information on amphibians and information on each species. The aim is to have this field guide ready for the 2006 Symposium of the Herpetological Association of Africa.

7.3 Seasonal variation anuran species composition

Most of the species documented in this study are active primarily in the summer wet seasons (December, January, and February). This is the breeding season for most frogs and also the months in which most of the rain occurs. The area is a summer rainfall area, and receives most of its rain during these months (Van der Walt, 1984). A few species are still active in the autumn months. The only species that remain active throughout the year are *A. angolensis* and *X. laevis.* The breeding season of *Afrana angolensis* spreads throughout the year, but peaks in spring and autumn (Channing, 2001). The other species start to occur after the first rains in spring. The first species to appear are the bufonids.

The diversity of amphibians increases as the rainfall increases. There is a strong statistical correlation between ecological factors (rainfall and temperature) and the variation in species richness. The r-square value (0.6617) indicates that there is a strong relationship between the temperature and the number of species encountered. This value indicates that 66 % of species encountered is determined by the temperature. If the temperature increases, there is a 66% chance that there will be an increase in the number of species found. The same can be said for rainfall. If the rainfall increases the number of species found will increase by 56%. This indicates that the most species will be found in the summer months, when rainfall and temperature are high.

Most of these frogs are active during the night. The only species regularly encountered during broad daylight are *Afrana angolensis* and *Schismaderma carens*. Amplecting pairs and calling males of *S. carens* were encountered in the afternoon following heavy rain showers that occurred the previous few days. This observation is not novel and has been documented previously (Balinsky, 1969; Theron & Minter, 2004; Channing, 2001). *Afrana angolensis* are present on the peripheries of ponds and rivers during the day, and escape to deeper water when approached.

All the permanent sites monitored over the study period have similar species richness, with an average of 6.44 ± 0.56 species per site, and a standard deviation of 1.67. The site with the highest richness of species was Thabela Thabeng (9 species) and the lowest Bluegumwoods – river (4 species).

The most effective technique to sample amphibians in the study area depends on the time of the year. Visual encounters seem to be the most productive method throughout the year. If only a quick survey is intended, (e.g. in December), call identification will be the best method. On the other hand, sampling for tadpoles is the best, easiest and quickest method to sample amphibians in the months of January and February. This is just after most of the species have bred and tadpoles are in abundance. However, identification of tadpoles requires more skill and aid from literature. The best time for tourists to go frogging is in the summer months and the best method of locating them will be through night driving and listening for calls, followed by searching with the aid of flashlights. Several species will be found on the roads after rain. This is the best time for night driving when it is most profitable to spot amphibians.

7.4 Chytridiomycosis survey

The only species found infected with *Batrachochytrium dendrobatidis* in this study were *Afrana angolensis* and one metamorphic *Xenopus laevis*. These are semi-aquatic and totally-aquatic species, which makes them more susceptible to infections by this aquatic fungus. Only a few specimens of the other species were found and screened for *B. dendrobatidis*. They are known to be susceptible to *B. dendrobatidis* infections. A bigger sample size is needed for each of the other species encountered in the study area to determine the prevalence of amphibian chytrid infection.

Of all the permanent sites that were monitored over the study period only four (44.4%) were infected with *B. dendrobatidis*. This is relatively high, but more monitoring sites can give a more accurate representation of true prevalence. The highest prevalence occurred at site F (22.4% of examined individuals). It would be worthwhile to monitor this stream on a frequent basis to determine what the long-term effect of *B. dendrobatidis* is on the population dynamics of *A. angolensis*. All sites in which amphibian chytrid infections were detected had the same physical characteristics; infected sites are clear mountain streams, with a small volume and surface area. They are also found in the mountainous northwest side of the study area northwest of the Vaal River. This could be a biased impression, because most of the permanent monitoring sites were situated in this area. More sites in the Free State need to be screened to accurately conclude that *B. dendrobatidis* only occurs on the North West side of the study area.

Evidence from this study suggests that amphibian chytrid infections are seasonal in the Dome. The only infections found were during the drier period just preceding the wet summer months. Amphibian chytrid grows optimally at a low temperature range. In culture *B. dendrobatidis* develops most rapidly at 23°C and grows at 28°C, but does not grow significantly at 29°C (Longcore *et al.*, 1999). The elevated temperature experienced during the summer season does not seem to favour the fungus, which could explain the disappearance of the amphibian chytrid by December. A combination of seasonal factors, especially rainfall and temperature, may determine the presence of chytridiomycosis in the wild. During the rainy months of December, January and February no infections were found. Another possible reason for no infection is the dilution effect caused by more water during the rainy season. The tadpole density per volume water is less, thus lessening interaction and the possibility of becoming infected.

Sporangia density on tadpole mouthparts ranged from 31.75 - 1939.76/mm^2 with a mean of 446.06/mm^2. This is high in comparison with infection in sloughed skin of adult *Afrana fuscigula*, (mean of 55.2/mm^2) (Weldon, 2005). This could be because only the mouthparts of tadpoles are keratinised and therefore prone to infection. Thus the sporangia are concentrated on the mouthparts in comparison with the total area of skin that is vulnerable to infection in adults. Similarly, older and larger tadpoles are more prone to infection. The water volume decreases and the biomass of tadpoles increases in the months of August until November and thus more interaction between infected and non-infected tadpoles occur; at the same time the conditions start to favour *B. dendrobatidis* infections. A higher number of tadpoles at the beginning of the developmental spectrum was screened than at the end of the spectrum and is therefore a more reliable indication of an infection below the detection level given the prevalence in this sample or that tadpoles in early development do not readily become infected in the wild. An absence of infection in late developmental stages could be due to a small sample size.

The linear regression indicated that there was a small correlation between infection and the two-stage developmental factors (Gosner stage and body length). The r-square value indicated that there was a slightly higher correlation between infection and body length than the physiological stage of development. This correlation is, however, small, and indicates that infection is more reliable on other factors, such as temperature and rainfall, than on the stage of development. A bigger sample size is needed to do multi-regression variables or ANOVA, to determine which factors contribute most to infection. However, it is unlikely that any single factor alone influences the rate of infection. In reality, a combination of factors, such as dry conditions, cool weather and development of tadpoles, probably determines the prevalence of infection

No population declines were observed during the study period. Only one adult *A. angolensis* sampled at Site G (Waterfall) in October 2005 died with *B. dendrobatidis* infection. Upon approaching the stream for dip-net sampling the frog was encountered behaving abnormally. It did not jump into the water upon approaching like other individuals, but slowly advanced to the water, slid in and floated in the stream. It died upon transferring it to a container. Histological screening confirmed the presence of *B. dendrobatidis.* The next month the stream was flowing strongly and a lot of healthy *A. angolensis* were sampled and found to be clear of any amphibian chytrid infections; confirming that the dry period leading up to October and the concentration of frogs could have triggered the outbreak of *B. dendrobatidis* infections.

7.5 Future work and recommendations

The eco-tourism value of this area has only recently come to light with the announcement of World Heritage Site designation. The development of the Dome to a world-known tourism destination is only beginning, however. Thus this study is best used as a baseline for future work. The following recommendations are made for future studies on amphibians in this study area:

- Long-term monitoring of amphibians can lead to more reliable data to guide conservation actions in the Vredefort Dome World Heritage Site.

- Focused, extensive monitoring during the peak rainy season will help ensure that cryptic species that may have been overlooked in the present study can be accounted for.
- Additional trapping and monitoring techniques, such as the use of screen traps, can be used.
- Mark-and-recapture studies can be done to evaluate the migration between breeding sites and to monitor individual populations.
- The status of the amphibian chytrid, should be monitored frequently so that chytrid-associated die-offs can be quickly identified and action be taken to reduce the spread of the disease.
- The closeness of the study area to the North West University and the importance of the area from a conservation point make this an ideal monitoring area.

APPENDCIES

APPENDIX A

IUCN RED LIST CATEGORIES •
Prepared by the IUCN Species Survival Commission
As approved by the Meeting of the IUCN Council
Gland, Switzerland, February 2000

THE CATEGORIES

EXTINCT (EX)

A taxon is Extinct when there is no reasonable doubt that the last individual has died. A taxon is presumed Extinct when exhaustive surveys in known and/or expected habitat, at appropriate times (diurnal, seasonal, annual), throughout its historic range have failed to record an individual. Surveys should be over a time frame appropriate to the taxon's life cycle and life form.

EXTINCT IN THE WILD (EW)

A taxon is Extinct in the Wild when it is known only to survive in cultivation, in captivity or as a naturalised population (or populations) well outside the past range. A taxon is presumed extinct in the wild when exhaustive surveys in known and/or expected habitat, at appropriate times (diurnal, seasonal, annual), throughout its historic range have failed to record an individual. Surveys should be over a time frame appropriate to the taxon's life cycle and life form.

CRITICALLY ENDANGERED (CR)

A taxon is Critically Endangered when the best available evidence indicates that it meets any of the Criteria A to E (see below), and it is therefore considered to be facing an extremely high risk of extinction in the wild.

ENDANGERED (EN)

A taxon is Endangered when the best available evidence indicates that it meets any of the Criteria A to E (see below), and it is therefore considered to be facing a very high risk of extinction in the wild.

VULNERABLE (VU)

A taxon is Vulnerable when the best available evidence indicates that it meets any of the Criteria A to E (see below), and it is therefore considered to be facing a high risk of extinction in the wild.

NEAR THREATENED (NT)

A taxon is Near Threatened when it has been evaluated against the criteria but does not qualify for Critically Endangered, Endangered or Vulnerable now, but is close to qualifying for or is likely to qualify for a threatened category in the near future.

LEAST CONCERN (LC)

A taxon is Least Concern when it has been evaluated against the criteria and does not qualify for Critically Endangered, Endangered, Vulnerable or Near Threatened. Widespread and abundant taxa are included in this category.

DATA DEFICIENT (DD)

A taxon is Data Deficient when there is inadequate information to make a direct, or indirect, assessment of its risk of extinction based on its distribution and/or population status. A taxon in this category may be well studied, and its biology well known, but appropriate data on abundance and/or distribution are lacking. Data Deficient is therefore not a category of threat. Listing of taxa in this category indicates that more information is required and acknowledges the possibility that future research will show that threatened classification is appropriate. It is important to make positive use of whatever data are available. In many cases great care should be exercised in choosing between DD and a threatened status. If the range of a taxon is suspected to be relatively circumscribed, and a considerable period of time has elapsed since the last record of the taxon, threatened status may well be justified.

NOT EVALUATED (NE)

A taxon is Not Evaluated when it is has not yet been evaluated against the criteria.

CRITERIA FOR CRITICALLY ENDANGERED, ENDANGERED AND VULNERABLE

CRITICALLY ENDANGERED (CR)

A taxon is Critically Endangered when the best available evidence indicates that it meets any of the following criteria (A to E), and it is therefore considered to be facing an extremely high risk of extinction in the wild:

A. Reduction in population size based on any of the following:

1. An observed, estimated, inferred or suspected population size reduction of 90% over the last 10 years or three generations, whichever is the longer, where the causes of the reduction are: clearly reversible AND understood AND ceased, based on (and specifying) any of the following:
    a. direct observation
    b. an index of abundance appropriate for the taxon

c. a decline in area of occupancy, extent of occurrence and/or quality of habitat
d. actual or potential levels of exploitation
e. the effects of introduced taxa, hybridisation, pathogens, pollutants, competitors or parasites.

2. An observed, estimated, inferred or suspected population size reduction of 80% over the last 10 years or three generations, whichever is the longer, where the decline or its causes have not ceased, based on (and specifying) any of (a) to (e) under A1.
3. A population size reduction of at least 80%, projected or suspected to be met within the next ten years or three generations, whichever is the longer (up to a maximum of 100 years), based on (and specifying) any of (b) to (e) under A1.
4. An observed, estimated, inferred, projected or suspected population size reduction of 80% over any 10 year or three generation period, whichever is longer (up to a maximum of 100 years), where the time period includes both the past and the future, and where the decline or its causes have not ceased, based on (and specifying) any of (a) to (e) under A1.

B. Geographic range in the form of either B1 (extent of occurrence) OR B2 (area of occupancy) OR both:

1. Extent of occurrence estimated to be less than 100 km^2, and estimates indicating any two of a-c:
   a. Severely fragmented or known to exist at only a single location.
   b. Continuing decline, observed, inferred or projected, in any of the following:
      i. extent of occurrence
      ii. area of occupancy
      iii. area, extent and/or quality of habitat
      iv. number of locations or subpopulations
      v. number of mature individuals.
   c. Extreme fluctuations in any of the following:
      i. extent of occurrence
      ii. area of occupancy
      iii. number of locations or subpopulations
      iv. number of mature individuals.
2. Area of occupancy estimated to be less than 10 km^2, and estimates indicating any two of a-c:
   a. Severely fragmented or known to exist at only a single location.
   b. Continuing decline, observed, inferred or projected, in any of the following:
      i. extent of occurrence
      ii. area of occupancy
      iii. area, extent and/or quality of habitat
      iv. number of locations or subpopulations
      v. number of mature individuals.
   c. Extreme fluctuations in any of the following:
      i. extent of occurrence
      ii. area of occupancy

iii. number of locations or subpopulations
iv. number of mature individuals.

C. Population size estimated to number less than 250 mature individuals and either:
1. An estimated continuing decline of at least 25% within three years or one generation, whichever is longer, OR
2. A continuing decline, observed, projected, or inferred, in numbers of mature individuals AND one of the following two (a or b):
   a. Population structure in the form of one of the following two:
      i. no subpopulation estimated to contain more than 50 mature individuals, OR
      ii. at least 90% of mature individuals are in one subpopulation.
   b. Extreme fluctuations in number of mature individuals.

D. Population size estimated to number less than 50 mature individuals.

E. Quantitative analysis showing the probability of extinction in the wild is at least 50% within 10 years or three generations, whichever is the longer (up to a maximum of 100 years).

ENDANGERED (EN)

A taxon is Endangered when best available evidence indicates that it meets any of the following criteria (A to E), and it is therefore considered to be facing a very high risk of extinction:

A. Reduction in population size based on any of the following:
1. An observed, estimated, inferred or suspected population size reduction of 70% over the last 10 years or three generations, whichever is the longer, where the causes of the reduction are: clearly reversible AND understood AND ceased, based on (and specifying) any of the following:
   a. direct observation
   b. an index of abundance appropriate for the taxon
   c. a decline in area of occupancy, extent of occurrence and/or quality of habitat
   d. actual or potential levels of exploitation
   e. the effects of introduced taxa, hybridisation, pathogens, pollutants, competitors or parasites.
2. An observed, estimated, inferred or suspected population size reduction of 50% over the last 10 years or three generations, whichever is the longer, where the decline or its causes have not ceased, based on (and specifying) any of (a) to (e) under A1.
3. A population size reduction of at least 50%, projected or suspected to be met within the next ten years or three generations, whichever is the longer (up to a maximum of 100 years), based on (and specifying) any of (b) to (e) under A1.

4. An observed, estimated, inferred, projected or suspected population size reduction of 50% over any 10 year or three generation period, whichever is longer (up to a maximum of 100 years), where the time period includes both the past and the future, AND where the decline or its causes have not ceased, based on (and specifying) any of the (a) to (e) under A1.

B. Geographic range in the form of either B 1 (extent of occurrence) OR B2 (area of occupancy) OR both:
1. Extent of occurrence estimated to be less than 5000 km^2, and estimates indicating any two of a-c:
   a. Severely fragmented or known to exist at no more than five locations.
   b. Continuing decline, observed, inferred or projected, in any of the following:
      i. extent of occurrence
      ii. area of occupancy
      iii. area, extent and/or quality of habitat
      iv. number of locations or subpopulations
      v. number of mature individuals.
   c. Extreme fluctuations in any of the following:
      i. extent of occurrence
      ii. area of occupancy
      iii. number of locations or subpopulations
      iv. number of mature individuals.
2. Area of occupancy estimated to be less than 500 km^2, and estimates indicating any two of a-c:
   a. Severely fragmented or known to exist at no more than five locations.
   b. Continuing decline, observed, inferred or projected, in any of the following:
      i. extent of occurrence
      ii. area of occupancy
      iii. area, extent and/or quality of habitat
      iv. number of locations or subpopulations
      v. number of mature individuals.
   c. Extreme fluctuations in any of the following:
      i. extent of occurrence
      ii. area of occupancy
      iii. number of locations or subpopulations
      iv. number of mature individuals.

C. Population size estimated to number less than 2500 mature individuals and either:
1. An estimated continuing decline of at least 20% within five years or two generations, whichever is longer, OR
2. A continuing decline, observed, projected, or inferred, in numbers of mature individuals AND one of the following two (a or b):
   a. Population structure in the form of one of the following two:
      i. no subpopulation estimated To contain more than 250 mature individuals, OR

ii. at least 95% of mature individuals are in one subpopulation.

b. Extreme fluctuations in number of mature individuals. D. Population size estimated to number less than 250 mature individuals. E. Quantitative analysis showing the probability of extinction in the wild is at least 20% within 20 years or five generations, whichever is the longer (up to a maximum of 100 years).

VULNERABLE (VU)

A taxon is Vulnerable when best available evidence indicates that it meets any of the following criteria (A to E), and it is therefore considered to be facing a high risk of extinction in the wild:

A. Reduction in population size based on any of the following:

1. An observed, estimated, inferred or suspected population size reduction of 50% over the last 10 years or three generations, whichever is the longer, where the causes of the reduction are: clearly reversible AND understood AND ceased, based on (and specifying) any of the following:
   a. direct observation
   b. an index of abundance appropriate for the taxon
   c. a decline in area of occupancy, extent of occurrence and/or quality of habitat
   d. actual or potential levels of exploitation
   e. the effects of introduced taxa, hybridisation, pathogens, pollutants, competitors or parasites.
2. An observed, estimated, inferred or suspected population size reduction of 30% over the last 10 years or three generations, whichever is the longer, where the decline or its causes have not ceased, based on (and specifying) any of (a) to (e) under A1.
3. A population size reduction of at least 30%, projected or suspected to be met within the next ten years or three generations, whichever is the longer (up to a maximum of 100 years), based on (and specifying) any of (b) to (e) under A1.
4. An observed, estimated, inferred, projected or suspected population size reduction of 30% over any 10 year or three generation period, whichever is longer (up to a maximum of 100 years), where the time period includes both the past and, the future, AND where the decline or its causes have not ceased, based on (and specifying) any of the (a) to (e) under A1.

B. Geographic range in the form of either BI (extent of occurrence) OR B2 (area of occupancy) OR both:

1. Extent of occurrence estimated to be less than 20,000 km^2, and estimates indicating any two of a-c:
   a. Severely fragmented or known to exist at no more than ten locations.
   b. Continuing decline, observed, inferred or projected, in any of the following:
      i. extent of occurrence
      ii. area of occupancy
      iii. area, extent and/or quality of habitat

iv. number of locations or subpopulations
v. number of mature individuals.

c. Extreme fluctuations in any of the following:
i. extent of occurrence
ii. area of occupancy
iii. number of locations or subpopulations
iv. number of mature individuals.

2. Area of occupancy estimated to be less than 2000 km^2, and estimates indicating any two of a-c:
a. Severely fragmented or known to exist at no more than ten locations.
b. Continuing decline, observed, inferred or projected, in any of the following:
i. extent of occurrence
ii. area of occupancy
iii. area, extent and/or quality of habitat
iv. number of locations or subpopulations
v. number of mature individuals.
c. Extreme fluctuations in any of the following:
i. extent occurrence
ii area of occupancy
iii. number of locations or subpopulations
iv. number of mature individuals.

C. Population size estimated to number less than 10,000 mature individuals and either:
1. An estimated continuing decline of at least 10% within 10 years or three generations, whichever is longer, OR
2. A continuing decline, observed, projected, or inferred, in numbers of mature individuals AND one of the following two (a or b):
a. Population structure in the form of one of the following two:
i. no subpopulation estimated to contain more than 1000 mature individuals, OR
ii. all mature individuals are in one subpopulation.
b. Extreme fluctuations in number of mature individuals.

D. Population very small or restricted in the form of either of the following:
1. Population size estimated to number less than 1000 mature individuals.
2. Population with a very restricted area of occupancy (typically less than 20 km^2) or number of locations (typically 5 or less) such that it is prone to the effects of human activities or stochastic events within a very short time period in an uncertain future, and is thus capable of becoming Critically Endangered or even Extinct in a very short time period.

E. Quantitative analysis showing the probability of extinction in the wild is at least 10% within 100 years.

***Adapted from Minter *et al.*, 2004**

APPENDIX B

Vredefort Dome Anuran Monitoring Program

1. Collecting information

Observer's name...

Date (yy/mm/dd): ....

Time: ....

Grid cell: ....

Locality cords: ....

Locality name: ....

Locality description: ....

....

Weather conditions: ....

Rain (circle appropriate no.):

1.presently raining and/or defintely rained within last 24 hours

2.evidence of rain within last few days

3.no evidence of rain within last few days

4.don't know

2. Species identified Names of species	DENSITY	METHOD
1.		
2.		
3.		
4.		
5.		
6.		
7.		
8.		
9.		
10.		

Density: 1 Individuals (sporadic
2 Individuals (no overlapping
3 Some overlapping calls
4 Overlapping calls
5 Continuous chorus

Method: V - Visual encounter
C – Acoustic (call)
S – Reference specimen

Vredefort Dome Anuran Monitoring Program

1. Collecting information

Observer's name...

Date (yy/mm/dd):...

Time:...

Grid cell:...

Locality cords...

Locality name:...

Locality description:...

....

Weather conditions:...

Rain (circle appropriate no.):

1.presently raining and/or defintely rained within last 24 hours

2.evidence of rain within last few days

3 no evidence of rain within last few days

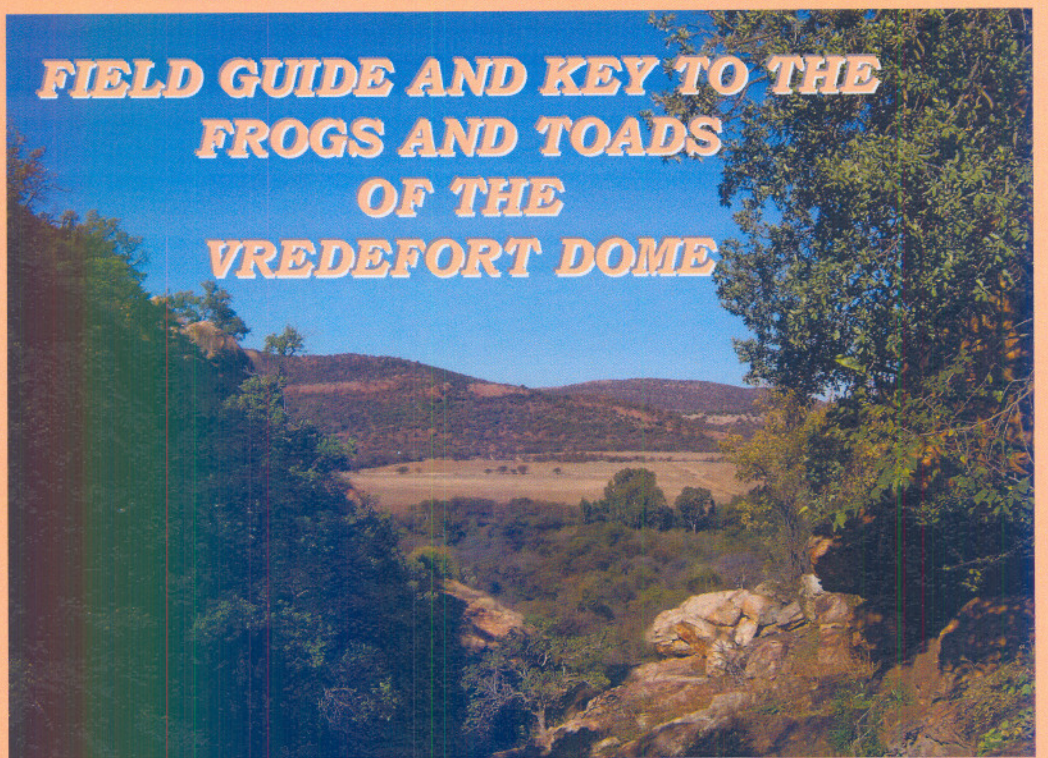
4.don't know

2. Tadpoles Names of species	N U M B E R
1.	
2.	
3.	
4	
5.	
6.	
7.	
8.	
9.	
10.	

APPENDIX C

Field guide and key to the frogs and toads of the Vredefort Dome area

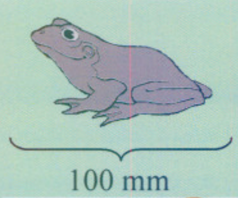
A user-friendly field guide is being developed for the Vredefort Dome area. The aim is that this field guide will be available before December 2006. Here we present the title page, contents page, the key to the field guide and a sample layout of one species namely *Bufo gutturalis.*



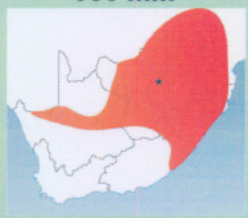
Werner Conradie
Louis du Preez
Ché Weldon
Kevin Smith

Contents

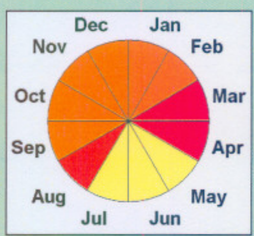
How to Interpret the Icons



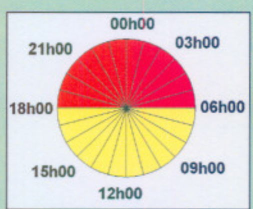
SIZE
This icon indicates the size of the frog. Body length is given in Snout-to-Vent length in millimeters. The four size classes indicate whether the frog is small, medium, large or extra large.



DISTRIBUTION
Distribution maps indicate the distribution in South Africa. The star indicates the locality of the Vredefort Dome.



ANNUAL ACTIVITY
This pie diagram indicates the annual activity of the frogs. Red represents the months when frogs are active, orange indicates when breeding takes place and yellow is the period of inactivity.



CIRCADIAN ACTIVITY
This pie diagram indicates the daily rhythm of frogs. Activity is indicated in red.

HABITAT
These icons indicates the habitat and breeding preferences of the species. Clockwise from top left: terrestrial, river/streams, ponds/temporary water holes and larger dams.

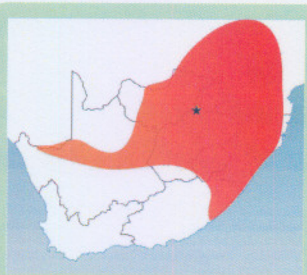
LOOK OUT FOR

- Cross shape on head
- Red infusion between thighs

KEY FEATURES
This icon lists the key features needed to identify a species.

Guttural Toad, Gorrelskurwepadda

Bufo gutturalis Power, 1927



Entomology

Bufo is Latin for "toad" and the specific name *gutturalis* is derived from the Latin word "guttur" which means throat. This refers to the deep guttural sound produced by the males.

Distribution

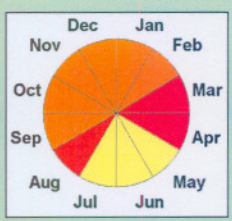
Its distribution is mainly in the northeast, particularly in the Kwazulu-Natal, Mpumalanga, Gauteng, central Limpopo, eastern North West and the northern and eastern Free State provinces, and Swaziland. They are absent from southern South Africa. This is one of the most distributed species in the area. It is found throughout the area.

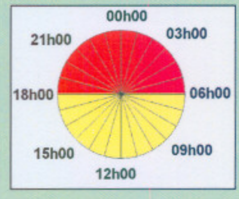
Habitat

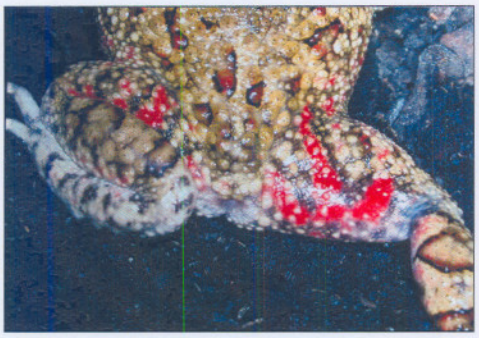
They are found in a variety of vegetation types in the Savanna, Grassland and thicket biomes. They are usually in the vicinity of dams, pools and wetlands. They are adapted to human habitats and are frequently found around garden ponds.

LOOK OUT FOR

- Cross shape on head
- Red infusion between thighs







Identification

Juveniles have a pale vertebral line across the back. Adults have a pair of dark patches on snout, combined with a second pair of blotches behind the eyes that leaves a pale ground colour cross-shape running from the nostril to back of the head and from eye to eye. The parotid gland is clearly visible. The thighs are infused with red spots and the abdomen is white/cream colour.

Breeding

Breeding usually takes place in early spring after the first rains. Males call from late Augusts until February. Breeding peeks in September and November. Males form large choruses and call from partly concealed positions. Up to 25 000 eggs are laid in double strings among vegetation. Tadpoles take 2-3 days to reach a free swimming stage and a further five to six weeks to reach metamorphosis.

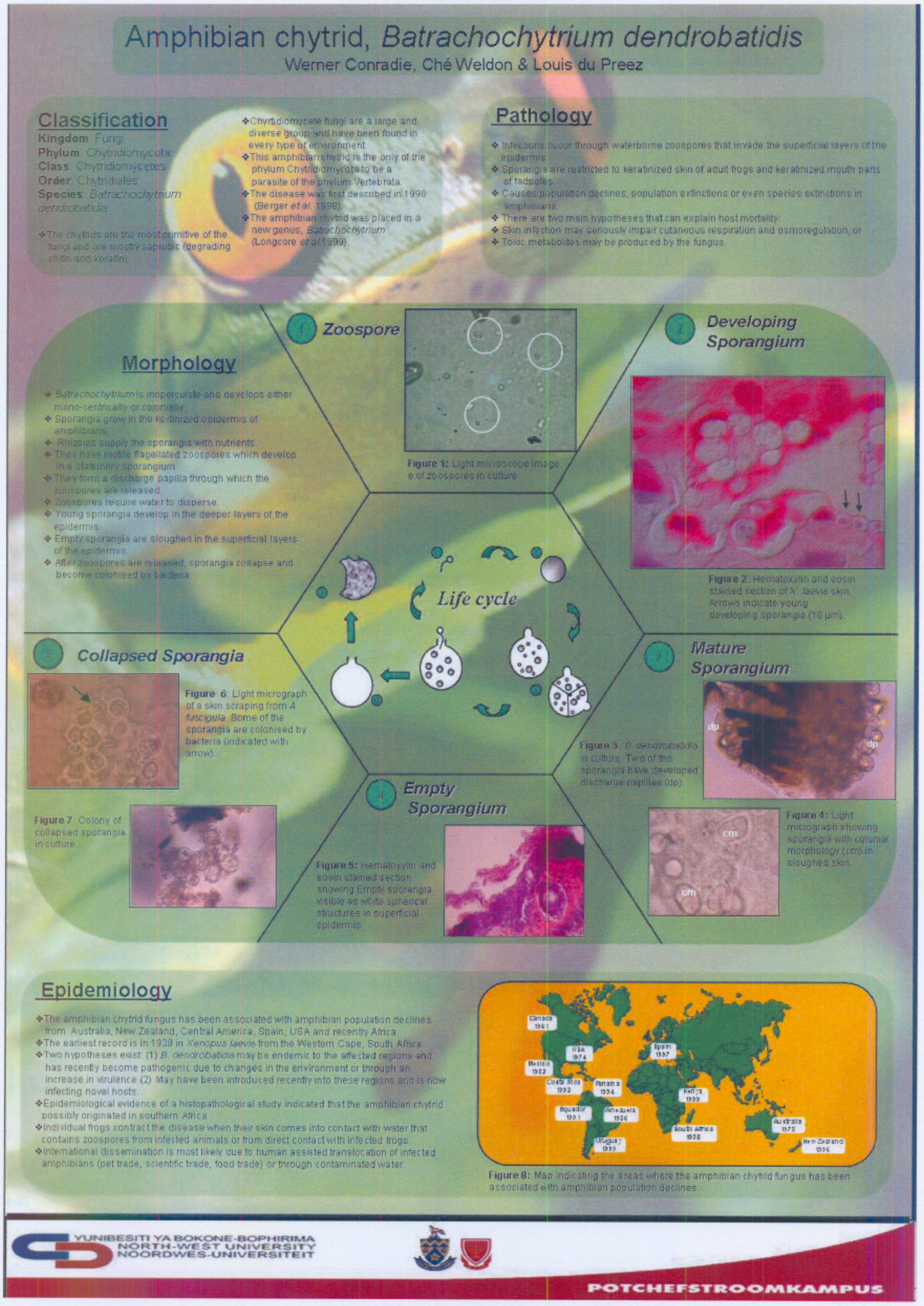
Tadpoles

The tadpole is small, up to 25 mm long. They are dark in colour with iridescent spots. There is no pigmentation across the anterior throat region, just under the mouth.

Call

The call is a deep guttural snoring 'qūirrrrâ – qūirrrrâ'.

APPENDIX D


Amphibian chytrid, *Batrachochytrium dendrobatidis*
Werner Conradie, Ché Weldon & Louis du Preez
Classification
Kingdom: Fungi
Phylum: Chytridiomycota
Class: Chytridiomycetes
Order: Chytridiales
Species: *Batrachochytrium dendrotobatidis*
❖ The chytrids are the most primitive of the fungi and are mostly saprobic (degrading chitin and keratin).
❖ Chyrtidiomycete fungi are a large and diverse group and have been found in every type of environment.
❖ This amphibian chytrid is the only of the phylum Chytridiomycota to be a parasite of the phylum Vertebrata.
❖ The disease was first described in 1998 (Berger *et al.* 1998).
❖ The amphibian chytrid was placed in a new genus, *Batrachochytrium* (Longcore *et al.* 1999).
Pathology
❖ Infections occur through waterborne zoospores that invade the superficial layers of the epidermis.
❖ Sporangia are restricted to keratinized skin of adult frogs and keratinized mouth parts of tadpoles.
❖ Causes population declines, population extinctions or even species extinctions in amphibians.
❖ There are two main hypotheses that can explain host mortality:
❖ Skin infection may seriously impair cutaneous respiration and osmoregulation, or
❖ Toxic metabolites may be produced by the fungus.
Morphology
❖ *Batrachochytrium* is inoperculate and develops either mono-centrically or colonially.
❖ Sporangia grow in the kertinized epidermis of amphibians.
❖ Rhizoids supply the sporangia with nutrients.
❖ They have motile flagellated zoospores which develop in a stationery sporangium.
❖ They form a discharge papilla through which the zoospores are released.
❖ Zoospores require water to disperse.
❖ Young sporangia develop in the deeper layers of the epidermis.
❖ Empty sporangia are sloughed in the superficial layers of the epidermis.
❖ After zoospores are released, sporangia collapse and become colonised by bacteria.
Zoospore
Figure 1: Light microscope image of zoospores in culture.
Developing Sporangium
Figure 2: Hematoxylin and eosin stained section of *X. laevis* skin. Arrows indicate young developing sporangia (10 µm).
Life cycle
Mature Sporangium
dp
dp
Figure 3: *B. dendrobatidis* in culture. Two of the sporangia have developed discharge papillae (dp).
cm
cm
Figure 4: Light micrograph showing sporangia with colonial morphology (cm) in sloughed skin.
Empty Sporangium
Figure 5: Hematoxylin and eosin stained section showing Empty sporangia visible as white spherical structures in superficial epidermis.
Collapsed Sporangia
Figure 6: Light micrograph of a skin scraping from *A. fuscigula*. Some of the sporangia are colonised by bacteria (indicated with arrow).
Figure 7: Colony of collapsed sporangia in culture.
Epidemiology
❖ The amphibian chytrid fungus has been associated with amphibian population declines from Australia, New Zealand, Central America, Spain, USA and recently Africa.
❖ The earliest record is in 1938 in *Xenopus laevis* from the Western Cape, South Africa.
❖ Two hypotheses exist: (1) *B. dendrobatidis* may be endemic to the affected regions and has recently become pathogenic due to changes in the environment or through an increase in virulence (2) May have been introduced recently into these regions and is now infecting novel hosts.
❖ Epidemiological evidence of a histopathological study indicated that the amphibian chytrid possibly originated in southern Africa.
❖ Individual frogs contract the disease when their skin comes into contact with water that contains zoospores from infected animals or from direct contact with infected frogs.
❖ International dissemination is most likely due to human assisted translocation of infected amphibians (pet trade, scientific trade, food trade) or through contaminated water.
Canada 1961
USA 1974
Mexico
Costa Rica
Panama
Equador
Venezuela
Uruguay
Spain 1997
Kenya
South Africa 1938
Australia 1978
New Zealand
Figure 8: Map indicating the areas where the amphibian chytrid fungus has been associated with amphibian population declines.
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NORTH-WEST UNIVERSITY
NOORDWES-UNIVERSITEIT
POTCHEFSTROOMKAMPUS

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