TITLE:
Threatened amphibians in the Succulent Karoo Hotspot: An integrated approach to their conservation

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BACKGROUND
The Succulent Karoo Hotspot covers nearly 120 000 km^2, stretching from north of Luderitz in Namibia to the southern Karoo. It has the world's highest diversity of succulents, and is the only plant hotspot in an arid area. The area is also rich in reptiles, and has a significant and interesting amphibian presence.
There are 25 species of amphibians in the area that form unique biogeographic assemblages (Alexander et al 2004). These are the Namaqualand Assemblage, and the Succulent Karoo Transitional Assemblage. The indicator species for these two groups include *Bufo robinsoni*, *Cacosternum namaquense*, *Strongylopus springbokensis* and *Tomopterna delalandii*. Of these, *S. springbokensis* and *B. macrops* are classified as Vulnerable (VU). The Namibian amphibians were not included in the analysis, but it is worth mentioning that *Breviceps macrops* has been recorded from near Luderitz, and that there are peripheral populations of amphibians to the north of Luderitz in the Naukluft Mountains, that may represent Vulnerable species, due to their restricted range.
In the widest sense, the following amphibians are either known to be threatened in South Africa, or have the potential to be threatened in Namibia:
Strongylopus springbokensis, known from the Gariep River south to the Olifants River
Breviceps macrops in the coastal dunes of Namaqualand and southern Nambia.
Bufo jordani, known only from the type locality in southern Namibia, may represent a threatened Namibian species.
As the amphibians of this hotspot are not well known, further work may yield other, undescribed, threatened species.

Threats to these three species include coastal diamond mining which has disturbed 65% of the coastal habitat (Pierce & Cowling 2004), where B. macrops occurs; overgrazing and modification of the spring habitats where *S. springbokensis* and *B. jordani* occur.

RESEARCH AIMS
This project aims to link to the following CEPF strategic directions approved for the Succulent Karoo Hotspot:

1. Engage the diamond mining sector in creating an awareness of the plight of *Breviceps macrops*.
2. Retain amphibian biodiversity in diamond mining areas. Old mined areas will be surveyed to determine if *B. macrops* has returned, and if so, how long this has taken. This evaluation will be compared to ongoing monitoring results of a population near Port Nolloth.
3. Retain amphibian biodiversity in springs and seeps, in particular populations of *Strongylopus springbokensis* that are threatened by agricultural activity.
4. Increase awareness of the amphibians in the Succulent Karoo Hotspot, emphasising the threatened species, by producing A2 sized posters in Afrikaans and English, for distribution to the schools, mine environmental offices, and conservation authorities.
5. Increase awareness of the amphibians in the Succulent Karoo Hotspot, by ongoing surveys, resulting in publication in scientific journals.

In addition, the following SKEP (Succulent Karoo Ecosystem Planning) conservation objectives will be targetted:
1. Both threatened species in the Red List will be highlighted in field studies and reports in order to encourage additional protection.
2. Sites that house these two (or more yet unrecognised) species will be identified and listed as candidate sites for protection.

The presence of chytrid has been confirmed in the area, and PCR methods will be used to rapidly survey for this disease.

Finally, this project will address one of the root causes of biodiversity loss identified in this region: lack of awareness of the existance, value, and market value of amphibians in the area.

METHODS

<u>Strongylopus springbokensis and other inland spp</u>

1. Survey springs and seeps to determine the micro-distribution patterns of these species. This is carried out during the breeding season using audio techniques, by collecting tadpoles, and by observing adults.
2. Determine the agricultural effects on these water sources by observation and by talking to the farmers.
3. Test all specimens for chytrid using a PCR-based method. Care will be taken not cross-contaminate water-bodies, and the necessary aseptic techniques will be applied.
4. Talk to environmental officers of mines that may affect local habitats, to increase awareness of these threatened amphibians
5. Search for unrecognised amphibian species that might be in need of protection, especially in Namibia.
5. Produce posters on amphibians of the hotspot, for distribution to local schools and other interested bodies.
6. Publish scientific papers on the results of the survey and the presence of threats such as chytrid, and make recommendations to the conservation authorities.

Breviceps macrops
1. Continue to monitor a population near Port Nolloth that will serve as a benchmark for comparisons with old mining areas. Animals are “marked” using photographs.
2. Endeavour to survey old mined areas, some of which have been backfilled, in order to determine if and how fast B. macrops recolonises such areas
3. Talk to the mine environmental officers to increase awareness of the threats to this species
4. Produce posters on Breviceps macrops, for distribution to local schools and other interested bodies.
5. Publish scientific papers on the results of the survey, and the recolonization experiment.

General methods
1. Participate in workshops to continue to keep amphibians on the conservation agenda, in an area best known for its plants
2. Add data to the SKEP website, to assist planners in protecting sites not yet destroyed.

WORKPLAN

TIME PERIOD	ACTIVITY
2006: August/Sept	Monitor Port Nolloth Breviceps population. Start chytrid PCR survey
2006: Oct/Nov	Chytrid PCR survey in dry season
2006: December	Initiate old mine surveys for Breviceps
2007: January	Survey Namibian region of hotspot for threatened amphibians
2007: July/Aug	Continue mine surveys for Breviceps
2007: Sept/Oct	Produce posters
2007: December	Write up results of fieldwork, upload web data

PROJECT EVALUATION
The project can be evaluated against the following planned outputs
1. Produce a poster on the amphibians of the Succulent Karoo Hotspot, emphasising the threatened species
2. Produce a poster on the desert rain frog, to highlight its importance
3. Produce a poster to suggest the value of amphibians in eco-tourism in the area
4. Publish two papers on the conservation of amphibians in the hotspot
5. Upload amphibian distribution data to the SKEP website

BUDGET

ITEM	EXPENSES	TOTAL USD
Travel: one trip to southern Namibia	3000 km @ $1.00	3000
Travel: 4 trips to Namaqualand	4 x 1200 km = 4800 km @ $1.00	4800
Subsistence: 30 days fieldwork	30 @ 100	3000

Laboratory: 1 PCR kit plus primers	750	750
Posters: printing	(depends on volume)	
Assistance: 60 days for labwork and posters and data upload	60 @ 50	3000
TOTAL (less posters)		14550

Results of a monitoring study of *Breviceps macrops*: Population size, density, home ranges, movement, and population age structure

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This is the third in a series of reports resulting from work under subproject 07-844 through Arizona State University, funded by the CEPF.

BACKGROUND

The Desert Rain Frog, *Breviceps macrops*, is known from the arid coastal dunes of south-western Africa, from Lüderitz in Namibia to near Koingnaas in South Africa (Minter 2004). It is found only in a narrow belt that largely coincides with strip mining activities, which has led to it being placed in the Vulnerable category of the IUCN. The biology, threats and conservation of this species were reviewed by Minter (2004). It is an important vertebrate component of the Succulent Karoo Hotspot.

This study was initiated to better understand the biology of the species, in particular the population density of the animals, their dispersal abilities, and reproductive rate, which are aspects that might throw light on the species' ability to recover from disturbances.

The study site is a strip of highly disturbed coastal dunes, situated north of the MacDougal Bay campsite near Port Nolloth, South Africa. The most southerly point of the strip is 29° 16' 35.10" S; 16° 52' 48.19" E, with the northern end 29° 16' 25.33" S; 16° 52' 42.67" E. The substrate is white calcitic sand, with vegetation classified as Richtersveld Coastal Duneveld (Mucina et al 2006). The area is essentially a desert, with an average precipitation, mostly as mist, of 58 mm (Mucina et al 2006). The study site is bordered to the south by the campsite, to the west by the beach, and to the east by a strip of housing. Monitoring was conducted in an area 200 m long, parallel to the beach, and 25-35 m wide, that covers 1.683 Ha. The area is centred on a disused recreation site, with the remains of fireplaces and a ruined ablution building (29° 16' 29.14" S; 16° 52' 45.45" E).

The specific questions addressed here are:
1. How many animals were present in the study site?
2. How far do the animals range?
3. What is the age structure of the population?

METHODS

The population has been monitored since October 2002, using mark-recapture. The dorsal patterns of each individual are unique, and digital photographs were used to "mark" the frogs. Frogs were photographed from October 2002, and each specimen was plotted using GPS from June 2004. During the monitoring sessions, a team of three or more people would walk slowly through the study area, line abreast, working from south to north, and then returning to the starting point, taking care to cover the full width of the habitat. The searching would commence after 21h00, as earlier work indicated that the frogs were active by that time. Each frog found was allocated a serial number, photographed, the SVL was measured, and a GPS position was noted. The animal, if disturbed, was replaced where it was found. *Breviceps macrops* is placid in the field, and many animals remained motionless while being photographed and measured. Animals were allocated a serial number each time they were found. Recaptures were determined by comparing photographs at the end of each night's session. A database allowed easy comparison of photographs.

The population size was determined using the Fisher-Ford estimation, based only on animals marked in September 2006, and recaptured in September 2007. Only adults, here defined as animals with snout-vent length >25 mm, were regarded as the sample captured in 2007. The subadults and juveniles found would have only been recruited since the 2006 survey, and their numbers were not used in the adult population estimation. The proportion of adults to juveniles was used to estimate the number of juveniles in the population, and the total population was estimated by summing the estimates for adults and juveniles.

The area of the study site was measured from a Google Earth image, using Google Planimeter (www.acme.com/google planimeter), and the number of frogs per Ha was calculated.

The positional data for each frog were used to determine home range and movement. The growth rate of these frogs can be calculated when a series of animals is recaptured. The size of each animal is assumed to be proportional to its age, so a frequency analysis of sizes serves as a surrogate for the age distribution of the population. The results can be used to evaluate the assumptions used in the population estimation in terms of a closed population.

RESULTS

<u>Photographic marking</u>

To date 259 animals have been marked, and each one has been found to have a unique dorsal pattern (Fig 1). The pattern may become more delicate as juveniles grow, due to the total dorsal area of the frog increasing while the markings cover the same area.

Figure 1. Examples of unique patterns used for marking individuals

Mark-recapture

The mark-recapture results are summarized for eight field sessions, from October 2002, through September 2007 (Table 1). The following standard notation is used:

i = mark-recapture event

n = number caught

r = number marked and released

Numbered columns refer to the field sessions when the recaptured animals were marked. For example, during session 7 (September 2006), 5 animals were recaptured, with the original marking having taken place in October 2002 (1 animal), June 2005 (2 animals), and July 2006 (2 animals).

Table 1. Summary of mark-recapture data

i	***n***	***r***	**1**	**2**	**3**	**4**	**5**	**6**	**7**
1	8	8	—						
2	3	3	1						
3	14	14	—						
4	10	10	1						
5	27	27	—	1					
6	6	6	—						
7	107	107				1	2	2	
8	68 (40 adults)	68						1	4

1. = October 2002
2. = November 2003
3. = June 2004
4. = September 2004
5. = June 2005

6. = July 2006
7. = September 2006
8. = September 2007

Home range and movement

The distances moved and/or days between captures were calculated, for all recaptures. No co-ordinates were taken for captures pre-2004. The data are summarized in Table 2, arranged from shortest to longest interval.

Table 2. Distances moved and intervals between captures

Frog ID	Dates	Coordinates First capture	Coordinates Second capture	Interval (days)	Distance (m)
20 (24)	11/6/04 11/6/04	29.0 S 43.2 E	30.2 S 43.0 E	0	37.83
39 (52)	25/6/05 25/6/05	32.7 S 44.9 E	32.8 S 45.0 E	0	4.40
45 (51)	25/6/05 25/6/05	30.5 S 44.2 E	30.3 S 44.1 E	0	6.95
46 (48)	25/6/05 25/6/05	29.1 S 42.9 E	29.0 S 43.0 E	0	4.40
71 (74)	5/7/06 5/7/06	31.9 S 44.4 E	32.2 S 44.4 E	0	9.33
97 (100)	4/9/06 4/9/06	31.1 S 44.4 E	30.9 S 44.2 E	0	8.80
16 (20)	10/6/04 11/6/04	30.1 S 42.7 E	29.0 S 43.2 E	1	37.58
211 (220)	18/9/07 19/9/07	33.4 S 45.3 E	33.4 S 45.1 E	1	6.22
52 (59)	25/6/05 26/6/05	32.8 S 45.0 E	32.9 S 44.9 E	1	4.40
84 (94)	3/9/06 4/9/06	31.8 S 44.6 E	32.1 S 44.5 E	1	9.83
103 (128)	5/9/06 7/9/06	33.9 S 45.5 E	33.8 S 45.9 E	2	12.82
122 (152)	6/9/06 8/9/06	31.3 S 43.7 E	31.3 S 43.7 E	2	0.00
135 (181)	7/9/06 9/9/06	31.1 S 44.2 E	31.8 S 44.2 E	2	21.77
106 (148)	5/9/06 8/9/06	32.9 S 45.2 E	32.9 S 44.7 E	3	15.55
83 (127)	3/9/06 7/9/06	32.8 S 44.9 E	33.8 S 45.1 E	4	31.72
95 (171)	4/9/06 9/9/06	32.1 S 44.3 E	32.0 S 44.4 E	5	4.40
74 (95)	5/7/06 4/9/06	32.2 S 44.4 E	32.1 S 44.3 E	60	4.40
73 (185)	5/7/06 9/9/06	29.9 S 42.6 E	31.1 S 42.5 E	64	37.45
10 (18)	18/11/03 11/6/04		32.5 S 44.0 E	205	
134 (201)	7/9/06 17/9/07	31.3 S 44.2 E	30.9 S 44.3 E	375	12.82
164 (222)	9/9/06 19/9/07	32.9 S 45.0 E	32.8 S 45.2 E	375	6.95
170 (228)	9/9/06 19/9/07	32.2 S 44.5 E	31.2 S 43.9 E	375	36.27

94 (212)	4/9/06 18/9/07	32.1 S 44.5 E	32.9 S 45.1 E	377	31.10
1 (10)	23/10/02 18/11/03			390	
60 (165)	26/6/05 9/9/06	32.8 S 45.2 E	32.3 S 45.0 E	440	16.75
67 (180)	26/6/05 9/9/06	31.7 S 44.3 E	31.5 S 44.2 E	440	6.95
70 (253)	4/7/06 20/9/07	20.2 S 42.3 E	32.2 S 44.6 E	441	379.99
9 (57)	13/11/03 26/6/05		33.4 S 44.9 E	531	
6 (36)	24/10/02 4/9/04		29.4 S 43.6 E	679	
33 (120)	4/9/04 6/9/06	30.7 S 43.1 E	30.8 S 42.6 E	732	15.86

The longest distance travelled was 379 m, between two captures about a year apart. This animal was initially found north of the study site, but it moved into the study area. Excluding this record, the mean distance covered (with minimum and maximum) is 15.4 m (0 - 37.8 m) n=25. One animal was recaptured in the same place, two days later. The longest distance travelled, 37.8 m, took a couple of hours between captures on the same night. Most of the animals moved very little, some being recaptured after a year just a few meters from where they were first found.

Population size and density

The most recent population estimate for the study site uses data collected in September 2006 and September 2007. Only adults in 2007 were considered, as the new juveniles could not have been present the previous year (Box 1). Assuming that the proportion of juveniles and adults captured is a fair reflection of the population structure, then the actual number of juveniles present in the second session (September 2007) can be estimated (Box 2).

Box 1. Estimation of adults in September 2007

Fisher-Ford estimation using sessions 7 and 8:
$(n8+1)/(r7+1) \times n7$
Using only adults in session 8: (40+1)/(4+1) x 107
total = 877

Box 2. Estimation of juveniles in September 2007

Number of adults captured in September 2007 = 40
Number of juveniles captured in September 2007 = 28
Estimated population size of adults = 877 (Box 1)
Estimated population size of juveniles = (877/40) x 28 = 613
Total population estimation in September 2007 = 877+613 = 1490

The area of the study site is 1.683 Ha, suggesting that the density of frogs in September 2007 was 885/Ha for all ages. The density of adults >25 mm SVL was 521/Ha.

Age structure of the population

Two sampling events, in September 2006 and September 2007, produced enough data that it was possible to compare the age cohorts identified by snout-vent length. Fig 2 illustrates the frequency of each size class, grouped to the nearest mm.

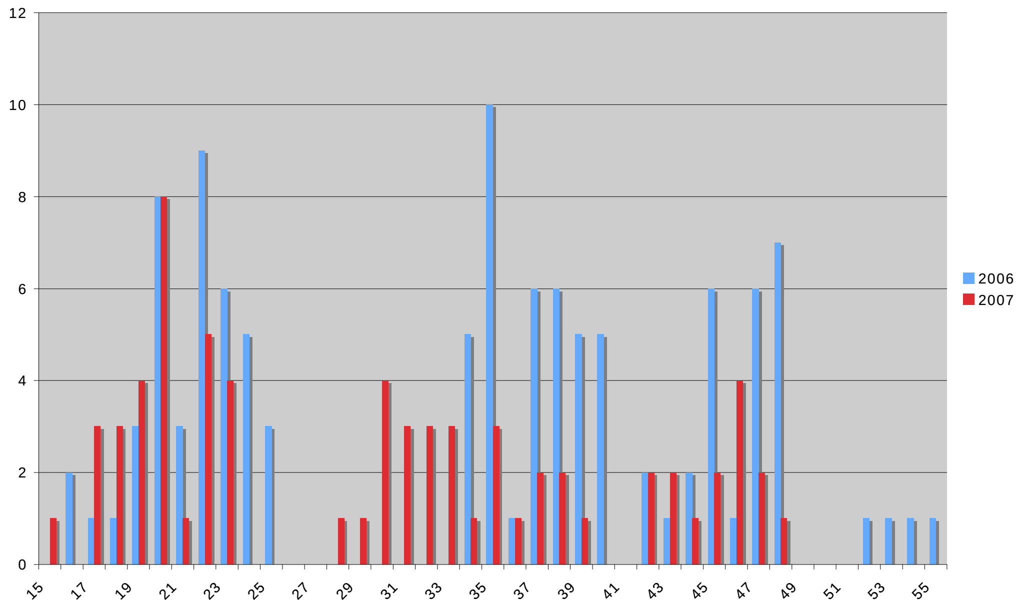

Figure 2. Frequency of the size classes of all frogs captured during September 2006 and September 2007. Size classes are based on snout-vent length, to the nearest mm.

The size of each animal is assumed to be related to its age, even if this is not a linear relationship.

The animals appear to breed in early spring, and the results in Fig 2 suggest that there were three age classes in 2006, and three in 2007. The 2006 results can be interpreted as a cohort born in 2006, one originating in 2005, one in 2004, and four very large individuals that might have originated in 2003, or merely be outliers of the 2004 population. The age of an animal can be estimated using bone growth rings (lines of arrested growth), but this part of the study is not yet complete. Another method is to take the maximum interval between captures of the same individual, which gives an absolute measure of the age since first capture.

<u>Age by recapture</u>

A total of 30 recaptures were made in 6 recapture sessions. Six recaptures were made on the same day as the original capture, 10 were made during the same field session as the original capture, from 1 to 5 days later. Two frogs were recaptured after 60 to 64 days, 1 was recaptured after 205 days, 5 were recaptured between 375 and 390 days later, 3 were recaptured after 440 to 441 days, 1 was recaptured after 531 days, 1 after 679 days, and 1 after 732 days.

This includes a frog that was recaptured twice (205 and 390 days), with a 595 day interval between the first and last capture. The 732 day interval, just over two years, is based on a frog that was an adult >30 mm SVL when first captured. This serves as corroboration for the maximum age of three years implied by the results in Fig 2.

DISCUSSION

Population size and density

The coastal dunes of northern Namaqualand represent one of the driest environments where amphibians are active throughout the year. They are present in all months except the very driest season, during February. Despite the harsh conditions, the density of amphibians is remarkably high, 885/Ha for all ages, and 521/Ha for adults. The frogs appear to live for three to four years.

Nothing is known of longevity in other species of *Breviceps*. The density of the Desert Rain Frog is the same order of magnitude as that of the Maud Island Frog, which reaches a density of 1187/Ha in a 16 Ha forest (Bell & Bell 1994).

Home range and movement

The habitat consists of small vegetated hummock dunes. The density of 512 adults/Ha suggests that each animal occupies a mean area of about 19.5 m^2 without overlap. Further studies are necessary to determine if frog density is related to habitat features such as vegetation cover, or dune topography. The mean distance of 15.4 m moved, suggests that the frogs are not territorial, but overlap substantially with other individuals. The largest movement recorded of 379 m indicates that some individuals can move appreciable distances, while others remain in one small area.

The Western Chorus Frog Pseudacris triseriata has reported home ranges of 641 to 6024 m2 (Kramer 1974). These home ranges have midpoint diameters that vary from 10 to 155 m (n=9). The distances moved by the Desert Rain Frog are slightly less than this, but in the same order of magnitude.

Age structure

During the September field sessions in 2006 and 2007, three distinct size classes were present, with about 60% of the animals being adults over 25 mm SVL. The maximum interval between captures is just over two years. The animal was an adult when first caught, which supports the results of the size class analysis, suggesting a life-span of three years.

The Ramsey Canon Leopard Frog *Lithobates subaquavocalis* has been shown to have a positive relationship between size and age, based on skeletalchronology (Platz et al 1997).

The threat of strip mining

A detailed study of the effects of diamond mining on this species are presented elsewhere (see Report 2). The genus *Breviceps* is widespread in southern Africa (Channing 2001). Breviceps macrops is able to survive in what might be the harshest environment for an amphibian, with some populations living on a narrow strip of coastal dunes, with salt pans less than 50 m from the beach. They are able to survive due to the high number of misty days, which allow the vegetation to grow, providing food for the ants and beetles on which the Desert Rain Frog feeds. They possess a thin, well vascularised belly patch which presumably allows them to take up moisture from the damp sand.

Strip mining for diamonds has damaged parts of the habitat in South Africa, but the relatively short life-cycle of three years should permit the populations to recover in these areas.

The diamond gravels are about worked out, and in the next decade or so the area may become more tourist-orientated, with the very real threat of strip development of housing and vacation units along the coast, in the prime habitat of this frog.

The results presented above, together with related studies, may help authorities to draw up appropriate management plans to ensure the future well-being of this important species.

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An evaluation of the threat of diamond mining to the Desert Rain Frog, *Breviceps macrops*

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This is the second in a series of reports resulting from work under subproject 07-844 through Arizona State University, funded by the CEPF.

INTRODUCTION

The Desert Rain Frog *Breviceps macrops* belongs to a genus of strange burrowing frogs (Fig 1). They are rotund with short legs and paddle-shaped feet, and able to survive in an arid coastal desert in the Succulent Karoo Biome. Precipitation here is mostly in the form of mist, and averages 45-114 mm per year in the areas where the frog is known (Mucina et al 2006, Jürgens 2006), with occasional rainfall increasing this to at least 146 mm (Channing & Van Wyk 1987). The biology of this species was reviewed by Minter (2004).

Figure 1. The Desert Rain Frog, *Breviceps macrops*

The species is found mostly on white coastal dunes (Fig 2), which run parallel to the coast in a narrow interrupted band sometimes only 50 m wide, with occasional larger dune fields. It occurs entirely within the coastal diamond mining areas of north-eastern South Africa and south-eastern Namibia.


Figure 2. Dune habitat of the Desert Rain Frog

Diamonds are found on the bedrock, below the sand overburden. They are mined by removing the sand, hand-collecting the diamonds or mechanically removing the diamondiferous gravel, and then replacing the sand. After the sand is replaced, the vegetation does not recover naturally in these disturbed areas (Carrick & Krüger 2007). The mines around Kleinzee have been attempting to keep the topsoil separate in this process, so that it can be spread over the deeper sands when the worked-out mine is backfilled. The disturbance to the soil structure is absolute, although work is progressing to determine the best ways to rehabilitate these old mines. South African legislation enacted in 1991 (The Minerals Act) requires that the land surface be restored (Carrick & Krüger 2007). As far as I can determine, there has been no study on rehabilitating the animals on old mine sites, although almost all the Namaqualand reptiles, mammals and amphibians are fossorial, and hence threatened by large-scale soil disturbance. A history of mining and plant restoration in Namaqualand is provided by Carrick & Krüger (2007).

Current opinion is that the frog habitat is threatened by “extensive loss to strip mining” (Minter 2004), leading to population fragmentation.

The aims of this study were:
1) To determine the habitat where the species occurs, and estimate habitat loss due to mining.
2) To evaluate the success of mine rehabilitation in terms of frog re-colonization of old mines.

METHODS

<u>Distribution</u>

The distribution of the Desert Rain Frog was determined from Namibian records held by M. Griffin (Namibian [illegible]), with published records, supplemented with my records based on recent fieldwork. The frog occurs almost entirely within restricted diamond mining areas, so the records in this area are opportunistic, and under-represent the expected distribution.

<u>Extent of suitable habitat</u>
Known records were mapped on to the vegetation units of Mucina et al (2006). The assumption was made that the frogs might occur throughout the habitat as defined by vegetation units. This is a testable hypothesis.

<u>Frogs in active mining areas</u>
Visits were made to the active diamond mines at Kleinzee and Koingnaas. Intensive searching was carried out during the day for frog tracks in suitable sandy habitat. This species leaves distinctive tracks (Fig 3), and small mounds where it has burrowed. At night searches were confined to the white coastal dunes.

Figure 3. Tracks of the Desert Rain Frog

<u>Frogs on rehabilitated mines</u>
Visits were made to rehabilitated areas, which varied in age from a few months to ten years. Five transects, each with a length of 100 m were placed to cover rehabilitated mines, with a sixth in an un-mined dune valley. Ten quadrats, each 5 x 5 m, were laid out on alternate sides of each transect. These were systematically searched for signs of frogs, reptiles and other animals.

<u>Extent of mining disturbance</u>

Detailed maps of past and present mining activities are not readily available due to commercial considerations. However, images from Google Earth (available at http://www.google.com) were sufficiently detailed to permit the currently active mines to be recognised, and scars from prospecting pits and other disturbances identified (Fig 4). The sizes of the following areas were determined using Google Planimeter (Available at www. acme.com).

1. Areas where *Breviceps macrops* might occur (area of occupancy). This includes the white sands along the coast, extending inland for a kilometre or two.
2. Prime areas where there is a high expectation of finding the frogs. This includes all the vegetated hummock dunes along the coast, just behind the high water mark. This is a subset of (1) above.

Figure 4. Coastal dunes (Photo: Google Earth)

3. Areas disturbed by mining. This includes all mining activities occurring within area (1) above.
The coastal distribution was only ground-truthed for areas close to Kleinzee.

RESULTS

<u>Distribution</u>

The localities where *Breviceps macrops* have been recorded are shown in fig 5.

<u>Extent of suitable habitat</u>

Breviceps macrops is effectively restricted to the Succulent Karoo Biome. In South Africa it occurs in the following vegetation units (descriptions after Mucina et al 2006):

SKs1 Richtersveld Coastal Duneveld.

This is described as a broad belt of 1-12 km, from a point between the Boegoe Twins and Alexander Bay, to about halfway between Port Nolloth and Kleinzee. Up to 200 m altitude. White sands of coastal origin.

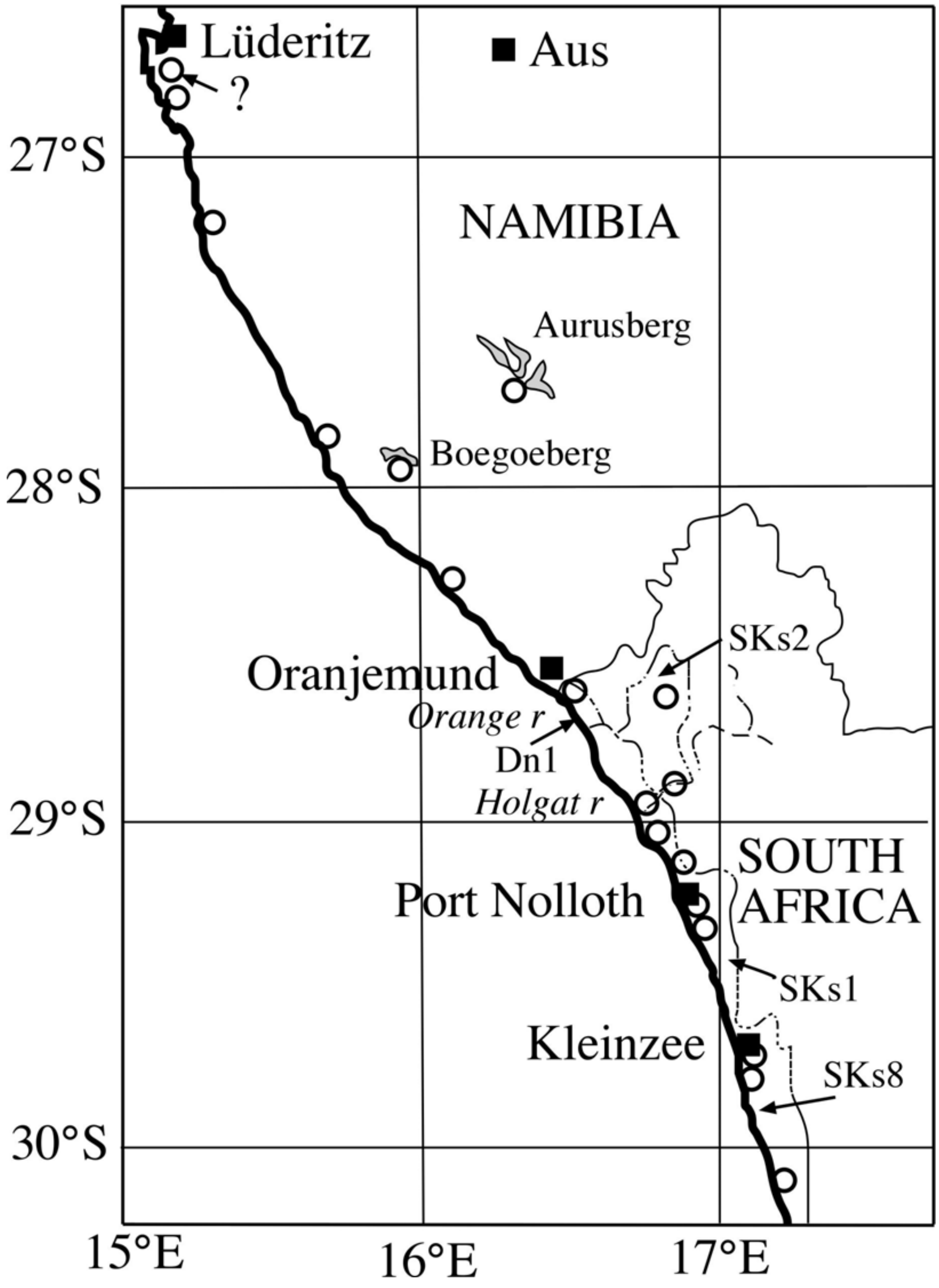

Figure 5. Localities where *Breviceps macrops* has been reported. Vegetation units (Dn1, SKs1, SKs2 and SKs8) after Mucina et al 2006. The question mark indicates the locality "Lüderitz area".

SKs2. Northern Richtersveld Yellow Duneveld.

5-25 km wide band from Holgat River to south of Brandkaros in the north.

SKs8 s). Namaqualand Coastal Duneveld.

From south of Groenriviermond to south of Port Nolloth. The rain frog is not yet recorded from the southern parts of this unit.

Dn1 Alexander Bay Coastal Duneveld.

Sandy coastal forelands from the mouth of the Orange and Cap Voltas south of Alex.

The extent of the vegetation units where Breviceps macrops occurs are shown in Fig 5 (from Mucina et al 2006). The southern extent of the Namaqualand Coastal Duneveld unit is not shown.

<u>Frogs in active mining areas</u>

No signs of frogs were found in the areas that I was able to visit, in both the BMC (Kleinzee) and the Koingnaas mine. Although it was not possible to survey the whole of the active mine, much of the mine is not situated on habitat suitable for Desert Rain Frogs (see below).

<u>Frogs on rehabilitated mines</u>

In the 60 quadrats surveyed, totalling 1500 m^2, no signs of frogs were observed. The rehabilitated mines developed some vegetation cover after a few years, but remained sterile of small mammals, reptiles and amphibians. The undisturbed dune valley where one transect was located, was much richer in animal life, with a number of reptiles, including a tortoise, puffadder, many species of sand lizards, and a burrowing adder. These results will be reported on as part of a Namaqualand Restoration Initiative project.

<u>Extent of mining disturbance</u>

For this report, the distribution of *Breviceps macrops* is partitioned into the South African population south of the Orange River, and the Namibian population to the north.

South African populations

<u>Areas where *B. macrops* is expected</u>

Starting from Koingnaas in the south, the distribution extends northward along the coast for 193 km. The total area where the species might occur is 512.0 km^2. This is effectively the “extent of occurrence” of the IUCN.

<u>Prime undisturbed areas</u>:

The total area of 184.6 km^2 includes all vegetated hummock dunes above the high water mark.

<u>Areas disturbed by mining</u>:

Areas of active and old mines, including rehabilitated mines occuring within the area where the species is expected cover 83.3 km^2. Mining has disturbed about 16% of the expected range of the species.

The IUCN “area of occupancy” is effectively the prime undisturbed areas (184.6 km^2), but might increase once the distribution away from the coast is determined. A study has already commenced to determine how far inland the species is found.

Namibian populations
The taxonomy of the *Breviceps* records in Namibia remains questionable. Some specimens attributed to *B. macrops* may be the widespread *B. adspersus*, or perhaps *B. namaquensis*, the inland relative of *B. macrops*. This is under investigation, but for the purposes of this report, the identification of Namibian records will stand.

<u>Areas where *B. macrops* is expected (extent of occurrence)</u>
The species is expected at Oranjemund, on the northern bank of the Orange River, extending northwards 250 km to Lüderitz. The area of occupancy is fragmented, with a total area of 221.1 km^2.

<u>Prime undisturbed areas (area of occupancy)</u>:
These areas are widely separated by tens of kilometers of bare rock, and total 19.8 km^2. Within the area of occupancy, areas disturbed by mining cover 41.9 km^2. This includes a continuous narrow strip just above the high water mark stretching 104 km northwards from Oranjemund.

DISCUSSION

<u>Quality of the distribution records</u>
The identity of the specimens reported from Namibia has not been confirmed, and this is an aspect of the problem that is presently under investigation. The distribution of the species is entirely within the restricted diamond mining areas, resulting in an under-reporting of localities.

<u>Extent of suitable habitat</u>
Port Nolloth receives about 200 mm of rainfall a year, but 148 days are foggy. The fog forms close to the coast, which may explain the distribution of the Desert Rain Frog in the white coastal dunes. A related species, *B. namaquensis*, appears to occur further inland in red dunes. It has been proposed that the two species may overlap, but this appears to be due to the reported type locality of B. namaquensis “Port Nolloth” (Power 1926) , which should probably be interpreted as the nearest large town.
The inland limits of *B. macrops* are presently under investigation, along with the potential overlap with *B. namaquensis*.

<u>Active mines and frogs</u>
Frogs are absent from the active mines near Kleinzee. This is partly due to the fact these mines follow old river-beds and fossil beach terraces, while the frogs are found on recent coastal dunes.

<u>Rehabilitated mines</u>
It appears that the vegetation on mines can be rehabilitated, at least as far as initial experiments show (Hälbich 2003). The results reported by Hälbich (2003) are based on work at the Namaqua Sands mine, situated just south of

the range of the Desert Rain Frog. A subsequent study (Blood 2008) pointed out that the functional diversity of the rehabilitated vegetation was a limiting factor, and there was a lack of plant species diversity. Natural recovery of vegetation does not occur on mines in Namaqualand, due to the poor rainfall and soils. The difficulties and successes of mine rehabilitation in Namaqualand are reviewed by Carrick & Krüger (2007). No fossorial reptiles or amphibians were found on rehabilited mines at Kleinzee.

Extent of mining disturbance

Mining and frog distribution overlap, but economies of mining prevent complete habitat conversion. Mines prefer to follow ancient river-beds, as well as beach terraces.

The 104 km of coastal mining in Namibia has destroyed the hummock dune system where these frogs are found. The area has been stripped to bedrock, but not backfilled, allowing sea-water to seep through and produce a series of small impoundments just above the previous high water mark. It is doubtful whether the frogs could bypass or recolonize this section of the coast.

Mucina et al (2006) report that almost 10% of the SKs1 vegetation unit (Richtersveld Coastal Duneveld) has been transformed by diamond mining. The mines in both Namibia and South Africa are coming to the end of their productive lives, but although the threats of diamond mining to this species will cease in the near future, the threats of inappropriate uses of the habitat, such as strips of housing developments along the coastline, may pose even greater threats.

Conservation status

The species is currently assigned to the VU vulnerable status of the IUCN (Minter et al 2004). This study indicates that the extent of occurrence is 733.1 km^2, with the area of occupancy 204.4 $km^{2.}$ This meets the IUCN (2000) criteria of EN endangered (B1a,biii; B2a, biii).
The results of this study suggest that the Desert Rain Frog should be re-evaluated, and placed in the Endangered category.

Acknowledgements

This work was funded under subcontract 07-844 through Arizona State University, funded by the CEPF. The Critical Ecosystem Partnership Fund is a joint initiative of Conservation International, the Global Environment Facility, the Government of Japan, the MacArthur Foundation and the World Bank. A fundamental goal is to ensure civil society is engaged in biodiversity conservation.
De Beers mining (Paul Kruger and Nadia Williams) kindly permitted access into the mining areas at Kleinzee and Kooingnaas. Peter Carrick provided an opportunity to visit the active mines. Additional funding was provided by the University of the Western Cape, and the National Research Foundation. Mike Griffin of the Ministry for the Environment and Tourism in Namibia kindly shared locality records from Namibia.

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Threatened amphibians in the Succulent Karoo Hotspot of southern Namibia

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This is the fourth in a series of reports resulting from work under subproject 07-844 through Arizona State University, funded by the CEPF.

INTRODUCTION

The Succulent Karoo Hotspot extends into southern Namibia, including the Namib Desert and the Pro-Namib. For the purposes of this report, the isolated Naukluft Mountains are taken to form the northern margin of the Succulent Karoo.

The Namib Desert is one of the least hospitable places south of the Sahara for amphibians. The meagre rainfall, shifting sand dunes, and gravel plains are far from ideal habitats for frogs. Nevertheless, amphibians do manage to live under special conditions in this region.

Previous work on amphibians in this area (Channing 2001) lists the following species (taxonomy updated):

<u>Family Bufonidae</u>

Poyntonophrynus hoeschi

Widespread in central Namibia.

Vandijkophrynus robinsoni

Restricted to the Orange River Valley.

Vandijkophrynus gariepensis

Restricted to the Orange River valley

<u>Family Brevicipitidae</u>

Breviceps macrops

Known from the southern coastal Namib Desert.

<u>Family Microhylidae</u>

Phrynomantis annectens

Widespread in southern Namibia.

<u>Family Pipidae</u>

Xenopus laevis

Widespread in southern Africa.

<u>Family Pyxicephalidae</u>

Amietia angolensis

Restricted to the Orange River valley.

Amietia fuscigula

Restricted to the Orange River valley and the permanent springs in the Naukluft Mountains.

Cacosternum boettgeri

Peripheral, but may extend into the eastern margins of the area.
Cacosternum namaquense
Known from the Orange River valley and into southern Namibia.
Pyxicephalus adspersus
Peripheral, but may extend into the northern margins of the area.
Strongylopus grayii
Restricted to the Orange River valley.
Tomopterna tandyi
Widespread in Namibia.

The aims of this study were to identify and evaluate threatened amphibians in the northern extremes of the Succulent Karoo. Studies on the Desert Rain Frog, *Breviceps macrops*, are reported separately (see Channing 2008a,b).

METHODS

A field trip was made to the area in January, just after unusually heavy rain. Temporary pools had formed which served as breeding areas. Breeding males were located by their calls. Advertisement calls were recorded, as they are species-specific and may indicate cryptic or unrecognized taxa. Tadpoles were collected for later identification. Toe clips were taken for DNA analysis. Recordings were made with a Marantz PMD 660 digital recorder. Tissues for later DNA analysis were preserved in absolute ethanol.

RESULTS

Tandy's Sand Frog, *Tomopterna tandyi*, was widespread in riverbeds, as was the common platanna *Xenopus laevis*. The Cape River Frog, *Amietia fuscigula*, was found in the springs on both the eastern and western drainages of the Naukluft Mountains.

The common toad found at Naukluft (*Poyntonophrynus hoeschi*) was heard to have a long buzzing advertisement call, and was recorded. Males call from shallow water.

The recording shows that the call consists of a rapid buzz, with about 100 notes/second, at a dominant frequency of 2.0 kHz. The call may continue uninterrupted for 10 seconds (Fig 1).

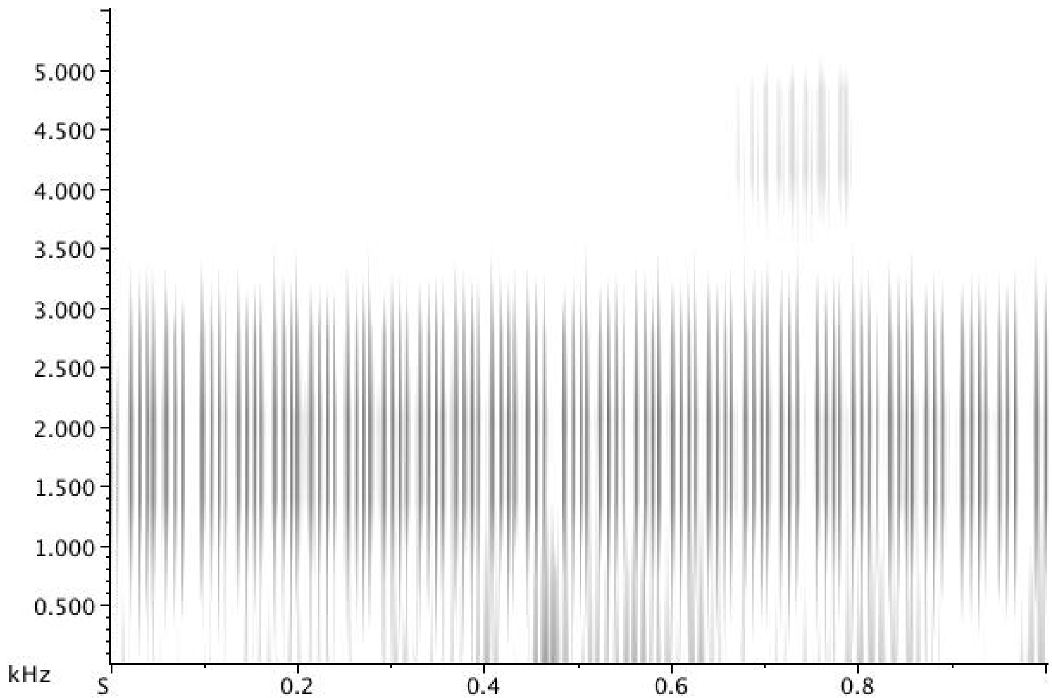

Figure 1. The advertisement call of *Poyntonophrynus jordan*i

The call of *P. hoeschi* from Windhoek consists of brief chirps, uttered at a rate of three per second. Each chirp consists of about 12 notes, with a duration of 0.1 seconds (Fig 2).

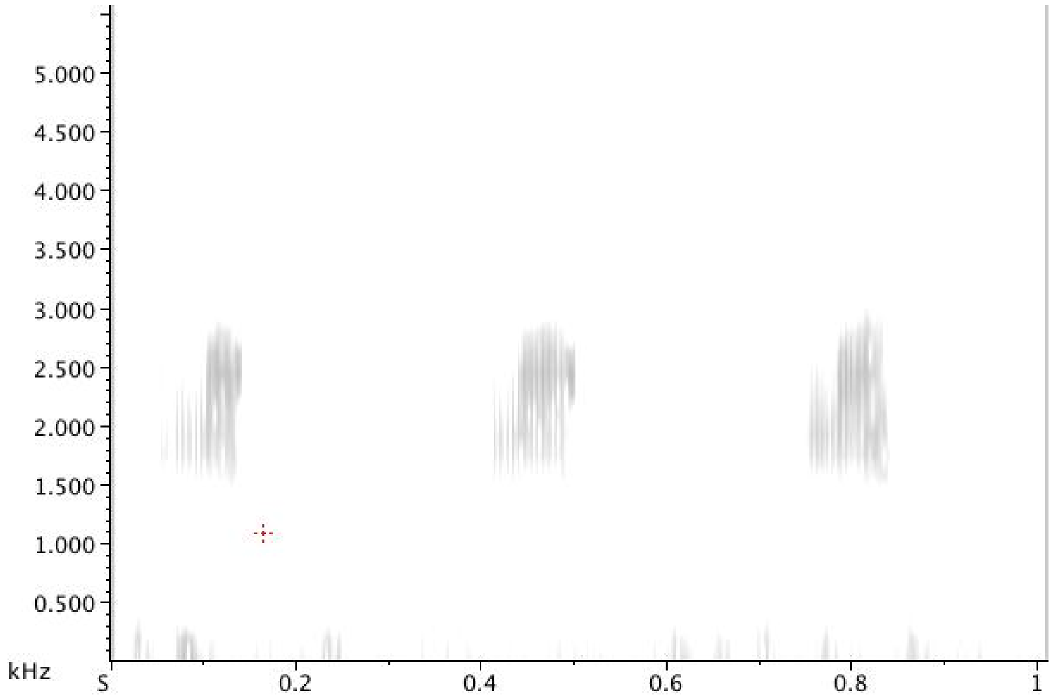

Figure 2. The advertisement call of *Poyntonophrynus hoeschi*

TAXONOMY

The advertisement call differences between the Windhoek and Naukluft toads indicate that two species are involved. The type locality of *P. hoeschi* is Okahandja, situated 45 km north of Windhoek. The name *jordani* was erected for then *Bufo jordani*, from Satansplatz, by Power in 1926. Satansplatz is only 15 km from the Naukluft Mountains. Detailed taxonomic studies by Poynton (1964) on this group recognised slight differences from typical *hoeschi* in a reduced auditory apparatus, and no marginal toe webbing. The dorsal colouration of preserved material was uniform (Poynton 1964), although in life the dorsum closely matches the colors of the local river gravel (Fig 3), with black, red and orange on a beige background.

Figure 3. Dorsal color pattern of the Naukluft toad.

DNA analysis is ongoing, to compare this form with other members of *Poyntonophrynus*. Provisionally, the Naukluft toad is assigned to *P. jordani*.

DISCUSSION

Two amphibians in the northern Succulent Karoo Biome are considered threatened: *Breviceps macrops* and *Poyntonophrynus jordani*. *Breviceps macrops* is threatened by diamond mining, discussed in Channing (2008a, b). *P. jordani* is presently only known from a very restricted range, within an extremely hostile environment for a small toad, considering the aridity of this area. It is considered Vulnerable as it is only known to occupy an extremely small area (IUCN 2000).

The discovery of an apparent new endemic species in the northern parts of the Succulent Karoo, increases the number of vertebrates restricted to this biome, and emphasizes the conservation importance of this hotspot.

Acknowledgements

This work was funded under subcontract 07-844 through Arizona State University, funded by the CEPF. The Critical Ecosystem Partnership Fund is a joint initiative of Conservation International, the Global Environment Facility, the Government of Japan, the MacArthur Foundation and the World Bank. A fundamental goal is to ensure civil society is engaged in biodiversity conservation. Additional funding was provided by the University of the Western Cape, and the National Research Foundation. Mike Griffin of the Ministry for the Environment and Tourism in Namibia kindly arranged permits and assisted in fieldwork in Nambia.

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