Two unsuccessful reintroduction attempts of rock hyraxes (*Procavia capensis*) into a reserve in the KwaZulu-Natal Province, South Africa

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Rock hyraxes (*Procavia capensis*) are categorized as 'Least Concern' in the 2008 IUCN Red List of Threatened Species. In South Africa they were once listed as vermin in the old Cape Province due to their high population numbers and impact on grazing. However, about 10 years ago, populations in the KwaZulu-Natal province became locally extinct. This resulted in the recent reintroductions of rock hyraxes, purchased at annual wildlife auctions in the province. Success of these reintroductions was unknown as there had been no post-release monitoring. This study determined the success of reintroducing rock hyraxes, using two source populations, namely rock hyraxes that had been in captivity for 16 months (n = 17) and those from the wild (n = 9). Captive rock hyraxes did not have site fidelity after release and after three months could not be found. All wild rock hyraxes, except one whose fate is unknown, were found dead within 18 days of release. One had an accidental death while the rest were preyed upon. In conclusion, the reintroduction of captive and wild rock hyraxes likely failed due to predation. This may have been a consequence of group disintegration, probably as a result of incorrect group composition, captive stress, and type of release. Suggestions to improve the success of future rock hyrax reintroductions are provided.

Key words: KwaZulu-Natal, rock hyrax, *Procavia capensis,* re-introduction, post-release monitoring, translocations.

INTRODUCTION

Rock hyraxes (*Procavia capensis*) have a wide distributional range throughout Africa, being limited mainly by the presence of suitable rocky outcrops (Skinner & Chimimba 2005). They live in colonies of up to 36 individuals, largely consisting of a harem of females and a territorial male (Fourie & Perrin 1987a). Even though they have an eight-month gestation and usually give birth to one or two young (Miller 1971), their numbers have in the past increased to such an extent that they have officially been listed as vermin in some areas in South Africa (Hey 1964; Kolbe 1967; Lensing 1978). Explanations for the population growth include eradication of the natural predators (Kolbe 1967), but the problem was over-exaggerated due to conflicts with grazing for commercial farming (Lensing 1978). Rock hyraxes are categorized as 'Least Concern' in the 2008 IUCN Red List of Threatened Species (IUCN 2008). However, their numbers have declined due to disease, predation, territorial fighting and dispersal of males (Hoeck *et al.* 1982). They are killed by a variety of predators, including Verreaux's eagle (*Aquila verreauxii*) and are especially vulnerable to predation when they disperse, leading to a high male, especially juvenile, mortality (Hoeck 1982). Whole populations have become locally extinct due to drought (Barry & Mundy 1998), but mainly because of disease. Sarcoptic mange resulted in the extirpation of rock hyraxes in 1974 in Tanzania (Hoeck 1989) and in 1998 in Zimbabwe (Chiweshe 2005). This disease may have caused their localized extinctions in the KwaZulu-Natal Province (KZN), South Africa, 10 years ago, but speculations exist that the cause was viral (I. Rushworth & K. Gordon, Ezemvelo KZN Wildlife, pers. comm.)

Since 2004, rock hyraxes purchased from the local conservation authority's (Ezemvelo KZN Wildlife (EKZNW)) wildlife auctions have been reintroduced into various areas of KZN, *e.g.* Escourt and Weenen (R. Devduth, EKZNW, pers.

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comm.). However, no post-release monitoring was done to assess their success. In Gauteng Province, South Africa, rock hyraxes are removed from overpopulated urban nature reserves and released into areas where their numbers are thought to have declined, with the additional benefit of ensuring the survival of Roodekrans Verreaux's eagle populations ('Hyrax Operation Project': B. van der Lecq, Endangered Wildlife Trust, pers. comm.). Limited post-release observations suggest that only three out of six reintroductions resulted in self-sustaining populations (B. van der Lecq, pers. comm.). There have been three published accounts of rock hyrax translocations, but post-release monitoring was limited. In the Eastern Cape Province, South Africa, 22 rock hyraxes (18 females, four males) were captured and translocated to a holding site before being released (in four batches) at a site roughly 1 km away from the capture site (Crawford & Fairall 1984). Some were known to have survived for a few months after release, with two males returning to the vicinity of the capture site, but exact details were not given (Crawford & Fairall 1984). In the Serengeti, Tanzania, rock hyraxes have been reintroduced onto rocky outcrops using six individuals (four females, two males), which grew to 20 over five years (Hoeck 1982) and a pair (male, female), which grew to 15 over 10 years (Hoeck 1989), but further details were not documented. The present study was initiated to provide further insight into the fate of translocated/reintroduced rock hyraxes, through post-release monitoring. Success of release was assessed in terms of a reintroduction, such that the objective was to have a self-sustaining population of released animals (IUCN 1998) within one year.

MATERIALS AND METHODS

There were two source populations for the reintroductions: rock hyraxes kept in captivity for 16 months (*i.e.* 'captive') and wild rock hyraxes. The IUCN's Guidelines for Re-introductions (1998) were partly followed, in that relevant biological information was gathered from the literature so that the reintroduction procedure considered the habitat and social and food requirements of this species. It was impossible to determine what caused the decline in the population, as it was reported to have occurred 10 years ago and no data were collected (I. Rushworth, EKZNW, pers. comm.). Ethical clearance was obtained from the University of KwaZulu-Natal (UKZN) ethics committee, and the relevant permits for capture, transport, holding in captivity and release of rock hyraxes were granted by the provincial government.

Release site

The release site was the 656 ha Umgeni Valley Nature Reserve (29°28′S, 30°16′E), near Howick, in KZN. Previously this reserve had naturally occurring rock hyraxes, but experienced a drastic population decline 10 years earlier (G. Boothway, Umgeni Valley Nature Reserve, pers. comm.). There were apparently two remnant groups of about four and five rock hyraxes in the reserve (G. Boothway, pers. comm.), but only four lone individuals were observed in the reserve during two years of the study (Wimberger, pers. obs). The vegetation is characterized as Midlands Mistbelt Grassland, with KZN Hinterland Thornveld nearby (Mucina & Rutherford 2006). The release site within the reserve was selected on it meeting the perceived criteria of shelter (rock crevices) and food requirements of rock hyraxes. Captive rock hyraxes were released within an extensive cliff range (indicated by a white star in Fig. 1), while the wild rock hyraxes were released on the slope of the valley, below the cliffs (indicated by a black star in Fig. 1). Signs of previous occupation by rock hyraxes were evident near both release sites but none were observed in the immediate vicinity on repeated visits to the area.

Capture site and general capture methods

Rock hyraxes were caught at Ladysmith, KZN (28°30′S, 29°45′E), about 150 km away from the release site, because the rock hyraxes there were abundant and viewed as pests. The capture site had a colony of rock hyraxes, which may have included several family groups, as documented to occur elsewhere (Gerlach & Hoek 2001). Mammal traps (900 × 310 × 320 mm), were baited with cabbage and set up at the chosen capture site at sunrise and monitored until about 10:00, then again at about 14:30 until sunset, as these are periods of peak rock hyrax activity (Hoeck 1975; Brown 2003). To minimize stress, a blanket was used to cover the cage of the rock hyrax once caught. The rock hyrax was then transferred into a securely closed basket (420 × 250 × 250 mm), with cabbage placed within, and was again covered with a blanket.

Captive rock hyraxes

Rock hyraxes were caught in winter (July 2005) when the scarcity of food made them easier to catch.

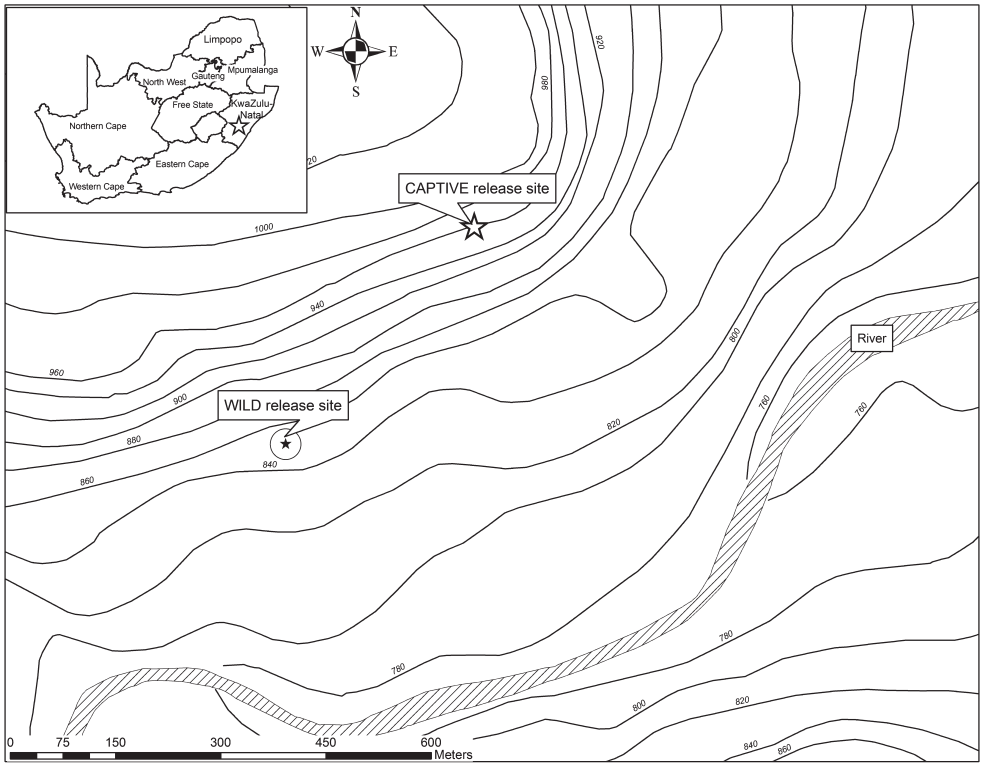

Fig. 1. Locations of release sites for captive and wild rock hyraxes in the Umgeni Valley Nature Reserve, KwaZulu-Natal, South Africa.

Ten rock hyraxes, six females and four males, were caught and housed at the UKZN Animal House Facility, Pietermaritzburg, where they remained in captivity for 16 months for an unrelated research study. For that study, they were housed in four small groups, namely: two females, two females and one male, two females and two males, and one female on her own. They were provided with wooden shelves to climb on and each cage had a hay-filled asbestos hutch (670 × 480 × 690 mm). Three months into captivity (in October), eight rock hyraxes (two females, six males) were born. Approximately one year after capture, of the original 10 rock hyraxes, after their first health check (see below), they were housed together in an outdoor cage (5.9 × 2.5 × 3.2 m), again with wooden shelves for them to climb on and four hay-filled asbestos hutches. They were fed daily with fresh cabbage, apples, carrots and rabbit pellets (Epol, Johannesburg) and water was provided *ad libitum.*

All rock hyraxes underwent three months of intensive disease and health monitoring prior to their release in November 2006. Monitoring included monthly group faecal collection for analyses of parasitic worms and eggs. Once a month the rock hyraxes were taken to a veterinary clinic and each anaesthetized with 15–20 mg Zoletil 100 (Virbac Animal Health, Johannesburg). During the first visit measurements of head and body length (distance from the tip of nose in a straight line to end of the tail (Fourie 1983)) and body mass were recorded for all. To allow for easy identification of the sexes, each hyrax was marked by attaching a coloured, plastic material (Sterkolite) onto both sides of the ear, while still anaethetized. Each tag was numbered to allow for individual identification. Each month, individual skin scrapings for determination of mite presence, specifically the sarcoptic mange mite (*Sarcoptes scabei*), were obtained. Monthly individual blood samples (2–5 ml of blood) were taken by a veterinarian and sent to the pathology laboratory (VetDiagnostix, Pietermaritzburg) for haematology and biochemistry analyses. The values were compared to the reference range provided by the International Species Information System (ISIS 2002). In addition, each rock hyrax was sprayed with anti-flea/tick medication

(Frontline, Fipronil, Merial, Halfway House). At the last health check, all individuals were vaccinated against rabies.

By the time of release, three adult females and one pup (juvenile less than two months old (Barry 1994)) had died in captivity, caused by old age, suffocation from being in the incorrect position for a pregnant female to recover from anaesthetic, illness (*Pasteurella pneumonia*: O. Tatham, Hilton Veterinary Clinic, pers. comm.) and accidental injury, respectively. In addition, two pups were born a few days before release. The decision to anaesthetize pregnant females for testing, and to include pups in the release were made in consultation with the veterinarian, and were based on preventing additional stress that would be caused by postponing the release, such as an increased time in captivity and having to repeat the health checks at a later stage. Consequently, 17 rock hyraxes were released (three adult females, four adult males, two juvenile females, six juvenile males, and two pups). Individuals were considered juveniles when younger than 12 months, subadults between 13 and 24 months old, and adults if older than 24 months (Fourie & Perrin 1987a), even though there is discrepancy over these age groups, as reproductive maturity is reached at about 16 months in females and 28 months in males (Fourie & Perrin 1987b).

Captive rock hyraxes were hard-released to mimic the methods used by the local conservation authority (R. Devduth, EKZNW, pers. comm.). They were released straight from the transport boxes into a hay-filled hutch. The hutch was left there for several months after the release. To help the hyraxes habituate, cabbage was provided on the release day and irregularly for one week after release.

The released hyraxes were monitored daily for the first week and then twice a week for the rest of the first month. This decreased to once a week for the second month, twice a month for the third month and once during the fourth and fifth months. Each monitoring day was from 15:30 to 18:30 and 06:00 to 09:00 the next day, during peak hyrax activity (Hoeck 1975; Brown 2003). Monitoring protocol changed from observing the released hyraxes at the release site, to additional observations at two new sites (after three and 13 days respectively). Eighteen days after release the monitoring protocol was again changed to walking two transects along the cliff edge and face (0.95 km and 0.61 km), where there was suitable hyrax habitat. Hyraxes have been recorded to disperse between 0.25 and 0.50 km (Fourie & Perrin 1987a). Both transects were walked twice in one monitoring session. The following observations were made: number of individuals seen; their sex and age class (based on relative size); any deaths; and their location relative to the release site, which was measured using a measuring wheel.

Differences in body mass between the three months of pre-release measurements were tested using repeated measured analysis of variance (RMANOVA), and if significant, the Scheffé post-hoc test (Statistica, Statsoft Inc. Tulsa, OK, U.S.A.), was used. Maximum number of hyraxes seen on each day was used to determine the minimum number of hyraxes alive in the group on each day.

Wild rock hyraxes

Rock hyraxes were caught over eight days in October (2007) and brought to the release site. To increase site fidelity after release (Bright & Morris 1994), they were kept for 14 days in a metal weld-mesh holding cage (1850 × 1850 × 1850 mm), including a roof and floor, at the release site. Most (75%) of the roof was also covered with canvas to provide protection from sun and rain. Two hay-filled hutches were placed inside the cage for cover. Branches were provided for climbing. Food and water were provided daily, as described before. Two days after the last group of hyraxes was released into the cage; all nine hyraxes (seven females, two males) were caught for pre-release health checks and measurements at the veterinary clinic.

As before, rock hyraxes were first anaesthetized and measured. Age was determined using Stevens' (1951) asymptotic growth equations for head and body length, hind foot length and body mass (Fourie 1983). Individual skin scrapings to determine mite presence were obtained, and each individual sprayed with anti-flea/tick medication. For identification, individuals were marked with differently coloured cable-ties (104 × 2.5 mm, Insulok®, Hellermann Tyton, Johannesburg, South Africa) in alternate ears. Individual radio-collars (C. Dearden, Pietermaritzburg) were fitted to the hyraxes, so that they could be located after release. Each collar had a radio-transmitter with a unique frequency (150 VHF range) and a 1/8 wavelength stainless-steel tracer wire antennae powered by a lithium 3.5V AA battery, sealed in flexible rubber coating (Loctite®, ColourGuard®,

Henkel, Düsseldorf, Germany). Each transmitter was attached with belting material, covered with heat-shrink tubing to prevent chaffing. Width of collars was 8 mm, but length depended on the individual hyrax's neck circumference, which averaged 181.1 ± 4.5 mm. Hyrax H1 was too small (neck circumference of 160 mm) to have a radio-collar attached. Collars weighed on average 23.0 ± 0.7 g (S.E.), less than 4% of body weight (Cochran 1980). For ethical reasons, collars were stitched together using cotton (2 mm thickness) to allow the collars to fall off after about a year. After recovery from the procedures, they were released seven days later. Supplementary food was provided for several days after release, until there was no evidence of use.

Monitoring was conducted daily for the first week after release and then every few days until the end of the project. Monitoring sessions alternated between morning (start at 7:30) and afternoon (start at 16:30) and lasted until each radio-collared hyrax was located. A 3-tier Yagi aerial and a wide-range receiver (DJ-X10, Alinco Inc., Japan) were used to locate individuals. Positions of each rock hyrax were recorded using a Global Positioning System (GPS) (Garmin 12XL). The GPS positions were exported into the Geographical Information System (GIS) ArcMap 9.2 (Environmental Systems Research Institute, Redlands, CA, U.S.A.) for further analyses.

RESULTS

Captive rock hyraxes

Head and body length and body mass (in the first month) of rock hyraxes varied with age and sex: adult males (n = 4) were 481.3 ± 20.0 mm (mean ± S.E.) and 2975.0 ± 394.5 g, adult females (n = 5): 472.4 ± 15.1 mm and 2820.0 ± 287.1 g, juvenile males (n = 6): 403.5 ± 7.3 mm and 1550.0 ± 71.9 g, and juvenile females (n = 2): 412.5 ± 12.5 mm and 1550.0 ± 150.0 g. There was no significant difference in body mass between months (RMANOVA, $F_{(2, 32)} = 2.786$, $P = 0.077$) (first (2258.8 ± 204.4 g), second (2388.2 ± 178.8 g) and third month (2400.0 ± 171.9)).

Individuals' blood results (haemoglobin, red blood cell count, haematocrit, mean cell volume, mean cell haemoglobin, mean cell haemoglobin concentration, platelets, leucocyte count, neutrophils, lymphocytes, monocytes, eosinophils, basophils, sodium, potassium, chloride, urea, creatine, alkaline phosphotase, alanine aminotranferase, conjugate bilirubin and total protein) were generally within the reference range (ISIS 2000) (Wimberger unpubl. data), with no disease evident (J. Hill, Vetdiagnostix, pers. comm.).

A day after release, a maximum of 58% of the released rock hyraxes was seen (Fig. 2). There was a progressively greater disappearance of males than females, and near the end only females were located (Fig. 2). The unidentifiable hyraxes ('unknown') were those that moved too quickly to be identified, or no ear tags were seen. The pups were last seen alive 17 days after release and two days later, one of them was found dead due to starvation (R. Last, VetDiagnostix, pers. comm.), *i.e.* the mother abandoned it, or she had been killed.

Four days after release, captive rock hyraxes occupied various sites other than the release site (Table 1). These sites were along the cliff range. Only juvenile males were observed at Site 5. After 87 days after release, none of the captive hyraxes were located.

Wild rock hyraxes

Based on head and body length, hind foot length and body mass, the group consisted of the following age classes: one juvenile male (H1; 360 mm, 58 mm, 1000 g), one subadult male (H4; 405 mm, 65 mm, 1800 g), two subadult females (H2, H7; 400.0 ± 10.0 mm, 65.0 ± 1.0 mm, 1900.0 ± 200 g; H7 pregnant), and five adult females (H3, H5, H6, H8, H9; 468.0 ± 9.0 mm, 66.0 ± 0.4 mm, 3300.0 ± 126.5 g; all pregnant). Whilst in the holding cage the six pregnant females gave birth to four and three pups, four and six days apart, respectively, after the pre-release measurements were taken. The first pups were found dead inside the cage, still inside their birth sacks, while the second group of pups were alive for one day before being found dead with some of their body parts eaten. Both events were likely due to capture or captivity stress, as documented elsewhere (Calvete *et al.* 2005). Wild pregnant rock hyrax females taken into captivity have shown considerable stress, particularly a few days before and during parturition (Sale 1965a).

Once released, the hyraxes were very skittish and were not easily seen. Often they could be located only to the nearest rock crevice. Except for the initial and brief time H4 and H7 remained close to each other, the group had split up and were not seen together. Nearly all released hyraxes died within 18 days of release, with the first death two days following release (Table 2). The hyraxes were

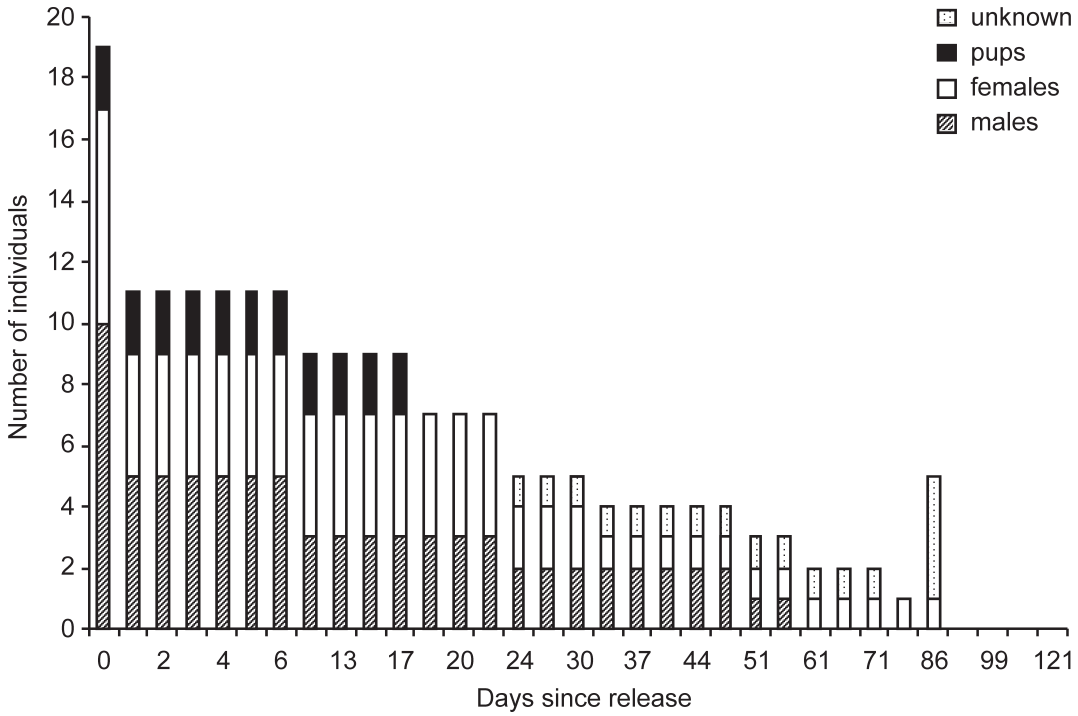

Fig. 2. Minimum number of captive rock hyraxes seen over 120 days after they were released.

found dead close to the release site, except H3. This hyrax dispersed a day after release and was found with no visible injuries, lying bloated in the river vegetation. Based on postmortem examinations on three hyraxes and the remains found for others, hyraxes H1, H2, H4, H5, H7 and H9 were probably predated by caracal (*Caracal caracal*) (O. Tatham, pers. comm; Grobler 1981). Because only one bone was found of H6, the predator could not be confirmed, and so may have been taken by a caracal or by the resident crowned eagle (*Stephanoaetus coronatus,* Boshoff *et al.* 1994) that nested near to the release site. The fates of H1 and H8 (Table 2) were unknown, but it is suspected that one was killed, as an unidentified rock hyrax spine was found with the remains of H4. In summary, after 18 days there were eight confirmed deaths out of the nine hyraxes, while the fate of one was unknown.

Table 1. Locations of sites used by captive rock hyraxes after release and the number of days they occupied the site.

Site occupied	No. of days at site (since release)	Distance and direction from release site
Site 1 (release site)	0–45	0
Site 2	4–6	173.6 m, west
Site 3	13–61	74.3 m, east
Site 4	18–87	164.4 m, east
Site 5	28–51	212.4 m, east

DISCUSSION

The reintroduction of rock hyraxes was unsuccessful, as none of the hyraxes was known to have survived. The failure of these releases was likely a result of predation and group disintegration, as documented in other studies (*e.g.* Banks *et al.* 2002 and Gusset *et al.* 2006, respectively). Lack of group cohesion was probably due to a combination of factors including incorrect group composition, capture and captive stress, and type of release. Only the type of release has been linked with group disintegration (Bright & Morris 1994; Gusset *et al.* 2006; Hunter *et al.* 2007), while the other two factors have been implicated in the failure of translocations (Sarrazin & Barbault 1996; Shier 2006; and Calvete *et al.* 2005; Teixeira *et al.* 2007, Dickens *et al.* 2009, respectively).

Populations of hyraxes are regulated by parasites, predation, intra-specific competition, reproduction, immigration and dispersal (Hoeck 1982). They are eaten by a variety of predators, including

Table 2. Fate of all wild rock hyraxes released, in the order of when their radio-collars were found, and how far this location is relative to the release site. Finding an unidentified rock hyrax spine together with H4, it was presumed that either H1 or H8 was killed.

Hyrax	Days after release	Distance from holding cage (m)	Fate and cause	Details of remains found
H1	N/a	N/a	Unknown	Did not have collar attached
H5	2	41	Dead (predation)	Intact stomach and intestine removed from body, the skin left intact (refer to text for more detail).
H9	4	18	Dead (predation)	Similar to H5
H8	5	109	Unknown	Collar was self-removed
H4	7	10	Dead (predation)	Similar to H5
H6	8	624	Dead (predation)	One bone
H7	8	74	Dead (predation)	Similar to H5
H3	11	1400	Dead (accident)	No injuries, in vegetation at river
H2	18	221	Dead (predation)	Similar to H5

black-backed jackal (*Canis mesomelas*), serval (*Leptailurus serval*) and puff-adder (*Bitis arietans*) (Hoeck 1982), but are the predominant prey of crowned eagle (25%–53%, Boschoff *et al.* 1994), caracal, (55%, Grobler 1981; 22%, Palmer & Fairall 1988), and Verreaux's eagle (98%, Gargett 1990). It has been estimated that 11% of the post-reproductive hyrax population ($n = 24\,553$) in an area were eaten by caracal in one year, and 4% by Verreaux's eagle over the same period (Fourie 1983). In our study, there were at least seven individuals (78% of the wild group, 27% of total) killed by caracal within 18 days, with the assumption of a similar fate for individuals in the 'captive' group, which were not radio-collared. Rock hyraxes are vulnerable to predation when foraging away from cover (Druce *et al.* 2006) and so are vulnerable when they are dispersing (Hoeck 1982). Similarly, they would also be vulnerable during the post-release period while finding suitable refuge (Biggins *et al.* 1999; Truett *et al.* 2001).

Failures of some other mammalian reintroductions have been caused by high predation within a few days (*e.g.* Banks *et al.* 2002; Calvete & Estrada 2004), or months (Ostermann *et al.* 2001; Short *et al.* 1992) after release. This was largely a consequence of high predator density, individuals unfamiliar with the terrain to successfully escape, or naivety of predators in the new area (Ostermann *et al.* 2001). These factors are all likely implicated in the failure of the hyrax reintroduction, while a high predator density is also considered a possible reason for the small rock hyrax population at the Umgeni Valley Nature Reserve (Fairall & Hanekom 1987). Furthermore, accumulation of waste (as well as increased smell and activity) inside the holding cage, used in the wild rock hyrax release, may have attracted predator/s, as reported elsewhere (Banks *et al.* 2002). Most of those hyraxes were found predated in close proximity to the holding cage and release site.

The rock hyraxes may have been vulnerable to predation as a consequence of small group size or group disintegration upon release, as this has consequences for group vigilance (Hoeck 1975). The group of 17 captive rock hyraxes and nine wild rock hyraxes were both similar in size to groups of wild rock hyraxes, which vary between nine (Fourie & Perrin 1987a) and 22 (Druce *et al.* 2006), up to 32 (Fourie & Perrin 1987a). Similar group sizes are known from rocky outcrops in the Serengeti (9 and 26), but may be as small as two individuals (Hoeck 1982). In addition, rock hyraxes have been previously reintroduced successfully onto rocky outcrops in the Serengeti, using only six individuals (Hoeck 1982) and a pair (Hoeck 1989). Therefore, group size (and their resulting composition and cohesion) may be less important than predation in the failure of the releases.

However, the importance of a socially intact group for a successful reintroduction of a social species has been raised in other studies (Kleiman 1989; May 1991; Jordon 2003; Gusset *et al.* 2006), but not previously considered important in transporting/reintroducing rock hyraxes, as hyraxes have been successfully reintroduced using individuals from two different colonies (Hoeck 1982).

Furthermore, hyraxes are generally not thought of as a true social species, because of a lack of social grooming and high intra-specific aggression (Sale 1970). It is suggested that hyraxes are only social as a result of their heat and water physiology (Sale 1970) and vulnerable to predators when feeding alone (Sale 1965b). While feeding, individuals in small groups position themselves so they face outwards in different directions to detect predators, while sentinels, especially the territorial male, warn them of danger (Hoeck 1975). Therefore, in the current hyrax reintroduction, the lack of a socially cohesive group (possibly because of an incorrect group composition and pre-release stress) may have led to increased vulnerability to predation.

In terms of group composition, a 'typical wild group' of rock hyraxes consists of one territorial adult male (older than four years), several adult females and several subadults and juveniles of both sexes, but sometimes peripheral males are found loosely associated (Fourie & Perrin 1987a). A female-bonded group is the basic hyrax group structure, and they are usually related to each other (Fourie & Perrin 1987a), but an adult male initiates the colonization of an area (Gerlach & Hoeck 2001). The 'captive' group in the present study was similarly structured, but had four adult males and may have had several unrelated females, as a consequence of capture bias. The time that this group had spent in captivity may have encouraged bonding (Woodford & Rossiter 1994; Hunter *et al.* 2007), as the successful reproduction a year after capture suggests this (Gusset *et al.* 2006). However, the time needed to establish hierarchies and relationships in rock hyraxes is unknown, and probably varies between mammal species. In African wild dogs (*Lycaon pictus*) it can take up to three months to establish a group, with no human disturbance during the bonding process (Gusset *et al.* 2006). The repeated health checks in this study may have caused additional stress to the hyraxes (Dickens *et al.* 2009), and together with pregnancy or lactation as physiological stressors (Fourie *et al.* 1987), bonding may have been affected. The hard release for the one group may have been a contributing factor to group disintegration and dispersal, as found in other studies (Bright & Morris 1994; Gusset *et al.* 2006; Hunter *et al.* 2007). However, the time the 'wild' group spent in the holding cage during the soft release may have been too stressful for this group to bond (Dickens *et al.* 2009), as indicated by cannibalism and mismothering of pups (Calvete *et al.* 2005). Disintegration of both groups in both releases may have increased the rock hyraxes' vulnerability to predation.

Although it is considered better to capture family groups (Shier 2006), the method of capturing all individuals in a colony, marking them for individual identification, then releasing them back to the colony so that family groups can be determined and then capturing these groups (Shier 2006), is impractical for use in rock hyraxes. Furthermore, since rock hyraxes show no sexual dimorphism (Hoeck 1982) and family groups are indistinguishable in a colony (authors, pers. obs.); the capture of family groups without individual marking is unlikely. Groups could thus be artificially constructed to resemble the wild group composition and should be allowed to bond for several months before release (Kleiman 1989; Jordon 2003), preferably long enough to breed and for the young to be several months old (Gusset *et al.* 2006). However, this could result in other problems such as disease and stress during captivity, as noted in our study, and seen in other captive situations (*e.g.* Sale 1965a; and in zoological garden exhibits in the U.S.A.: Anon. 2006).

To improve the success of future hyrax introductions, the following are suggested: a thorough search and estimation of predators in the release area should be conducted. If high, then one should consider actively deterring predators for a period after release (Calvete & Estrada 2004; Shier 2006), or consider another release site. Capture of hyraxes in KZN should be restricted to April to June, for ease of capture (low food availability in dry winter makes them easier to bait in traps), avoiding heavily pregnant females (they give birth between August and February (Taylor 1998)), and pups should be weaned (1 to 5 months after birth (Miller 1971)). However, It is difficult not to capture pregnant females, as they have an eight-month gestation (Miller 1971). Future studies should investigate the benefits of hard versus soft release. A suggestion for use in a soft release is to have a larger holding cage at the release site (at least three times larger than that used in this study), which includes a rocky habitat with crevices, that could be explored by the hyraxes before release. They would then have the opportunity to establish areas and paths needed to escape from predators (Jordon 2003). Post-release monitoring, especially with radio-telemetry, is essential to determine the fate of rock hyraxes after release.

In conclusion, the reintroduction of captive and wild rock hyraxes appeared to have failed because of predation. This may have been a consequence of group disintegration, resulting from incorrect group composition, captive stress, and type of release. Only with post-release monitoring using radio-collars was the fate of rock hyraxes released into a reserve in South Africa known. Therefore, based on the findings of this study, high mortality of rock hyraxes bought at wildlife auctions or removed in pest-control programmes and released into areas in South Africa is likely, unless methods are improved. Further research is needed.

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