Demography of Brown Hyenas in Inland Areas of the Sperrgebiet, Namibia

Final Report

by

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Introduction

Brown hyenas are a carnivore species, which has been intensively studied in the Kalahari ecosystem during the 70s. In contrast to these areas, Namib brown hyenas are apex carnivores with hardly any competitive pressure from other carnivores. Therefore this study tried to broaden the knowledge about brown hyena ecology in an undisturbed, different and unique habitat.

The aim of this study was to survey home range size, habitat use and activity patterns, and to establish a first population size estimate of brown hyenas in inland areas of the Sperrgebiet. This project offered the unique opportunity to start conserving an ecologically unique carnivore population through providing information from scientific research and monitoring for species specific conservation planning for the proposed park's management plan.

Study Area

The focal areas of this study were the Klinghardt Mountains, approximately 90 km south-east of Luderitz, and their surrounding area (Figure 1).

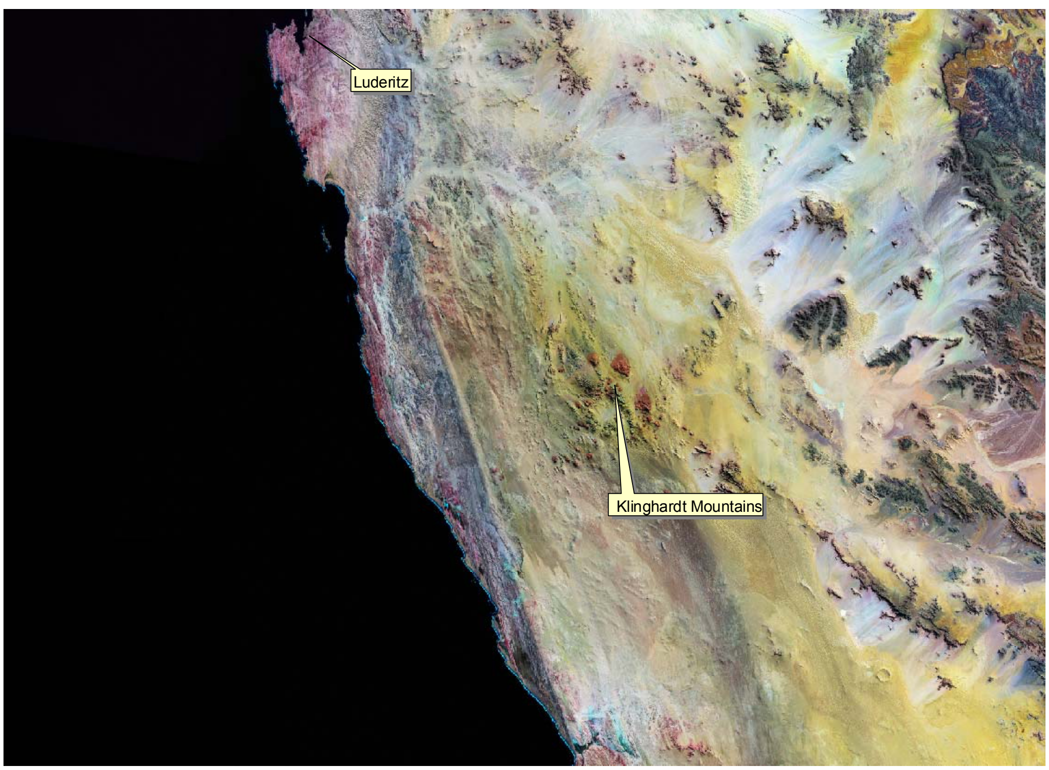


Figure 1: Study area

Methods

Brown hyenas were fitted with GPS collars (Televilt, Sweden). Three GPS collars were retrieved for data download and two were equipped with remote data download option and will remain fitted to the hyenas for another two years. The programming schedule per collar varied (Table 1).

Table 1: Daily number of GPS fixes

Hyena ID	Daily No Fixes
VRBHb1m	17
VRBHb2m	20
KHb1m	144
GHb1m	24
DHb1m	24

Information recorded by the GPS collars included date, time, time to fix, latitude, longitude, dilution of precision, number of satellite vehicles and in case of retrieved collars temperature and altitude readings were additionally downloaded.

Data sets were prepared for analysis by adding the Julian date, behaviour (walking, resting/not moving) and habitat type per fix and by calculating the distance between fixes, time between fixes, hourly distances and daily distances moved.

Results

Collar Performance

Collar performance was consistent during deployment, except for the GPS collar fitted to VRBHb1m. This hyena was severely injured during a fight and the collar was damaged (Figure 2) and therefore prematurely dropped off before its expiry date. However, on days when the collar functioned properly, performance was not different to the performance of all other collars. The percentage of recorded fixes differed per day and was dependent on the residual temperature between taken and missed fixes (Figure 3). High residual temperatures resulted in a lower percentage of fixes taken per day (Spearman Rank Correlation: VRBHb1m, $r = 0.46$, $p < 0.0001$; VRBHb2m, $r = 0.83$, $p < 0.001$; KHb1m, $r = 0.89$, $p < 0.0001$).

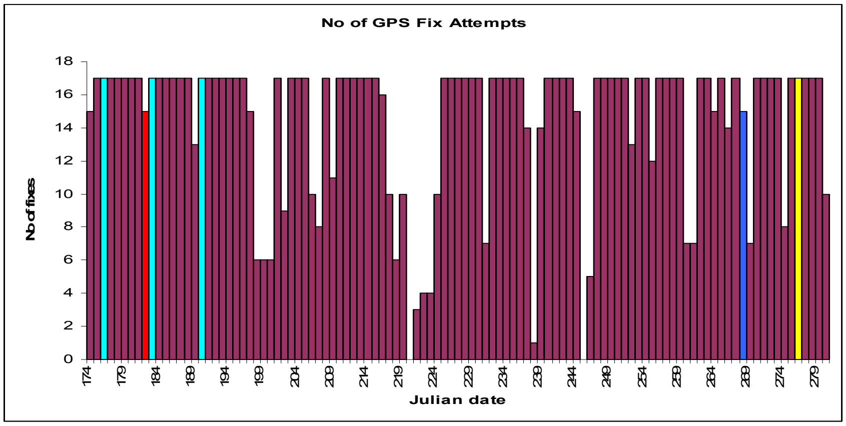
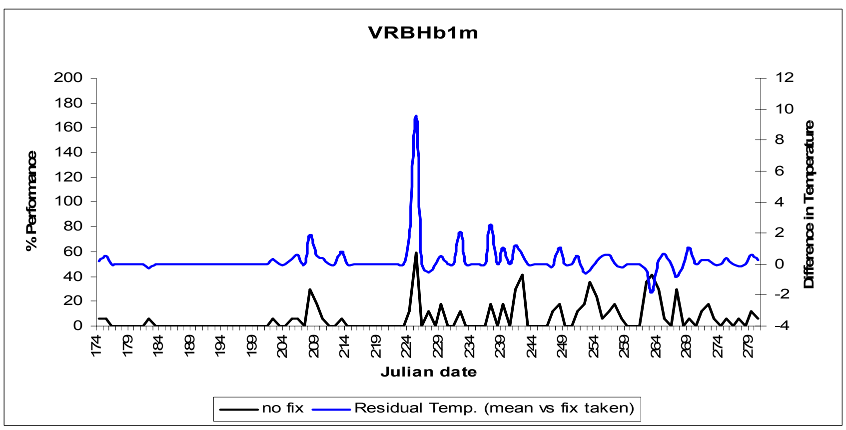
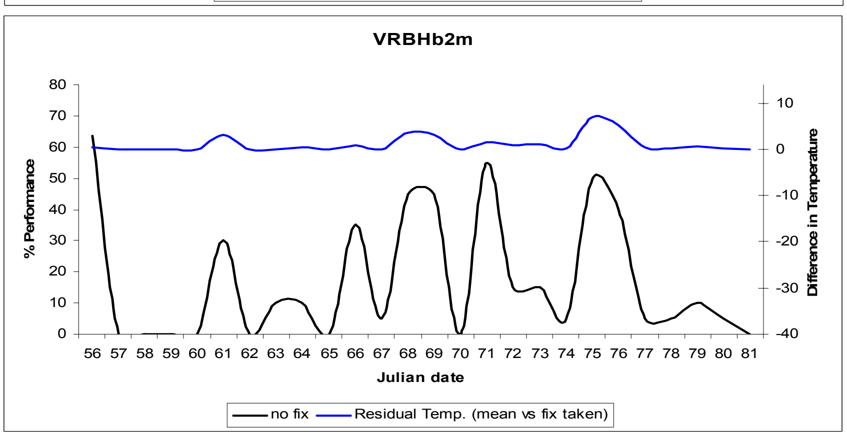


Figure 2: The following graph shows the number of fixes including attempts to record fixes according to the programmed schedule of VRBHb1m's collar (17 fixes per day). All bars should show 17 fixes, but as it can clearly be seen, the collar failed to take or attempt to take two positions on the 1 July (Julian date 182) and the performance decreased quite drastically afterwards (Red bar: collar failed for the first time (only 15 of 17 scheduled fixes attempted to be taken); turquoise bar: tracking flights with normal 40ppm VHF signal; blue bar: visual of brown hyena at colony and recovery signal (40 double ppm) was sent; yellow bar: last tracking flight to locate brown hyena with normal 40 ppm signal; 7 October 2005 (Julian date 274): drop off. Collar sent normal 40 ppm signal, changing to activity signal from time to time until drop off was triggered and the recovery signal was sent.





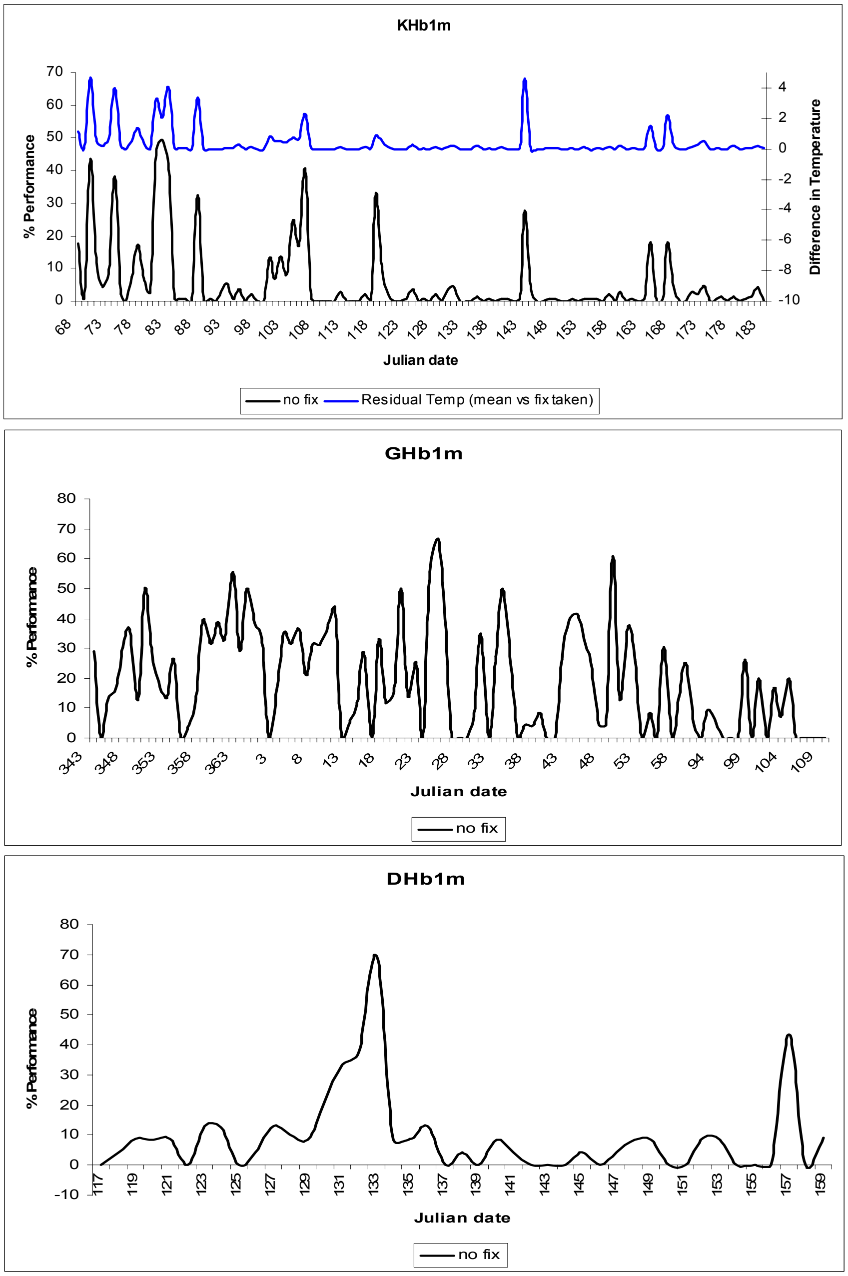


Figure 3: Percentage of daily fix collection and temperature residuals for three GPS collars.

Efficiency of Fix Collection

All collars were most efficient in fix collection at night (Figure 4). The difference between the proportion of fixes recorded during different times of the day was significant (ANOVA, $p = 0.003$).

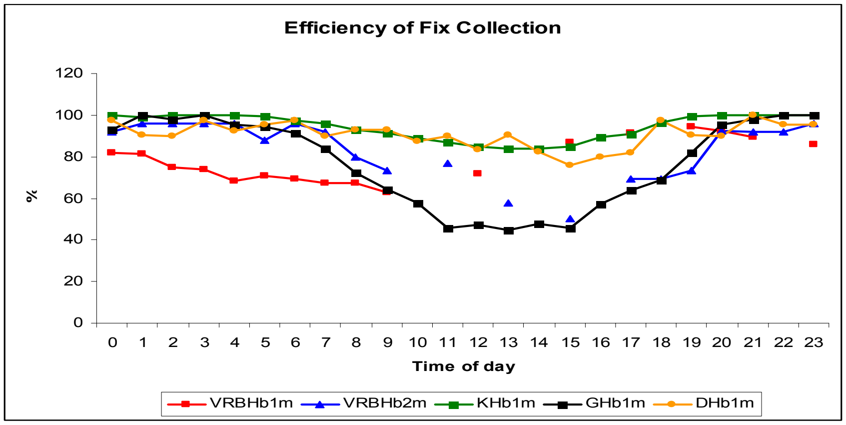


Figure 4: Percentage of fix collection during different times of the day.

Accuracy of Fixes

All GPS collars recorded fixes using predominately four, five or six satellites (ANOVA, $p < 0.001$) (Figure 5). Precision was poor with only three satellites, improving with four or five satellites and reaching an asymptote with six or more satellites (Figure 6).

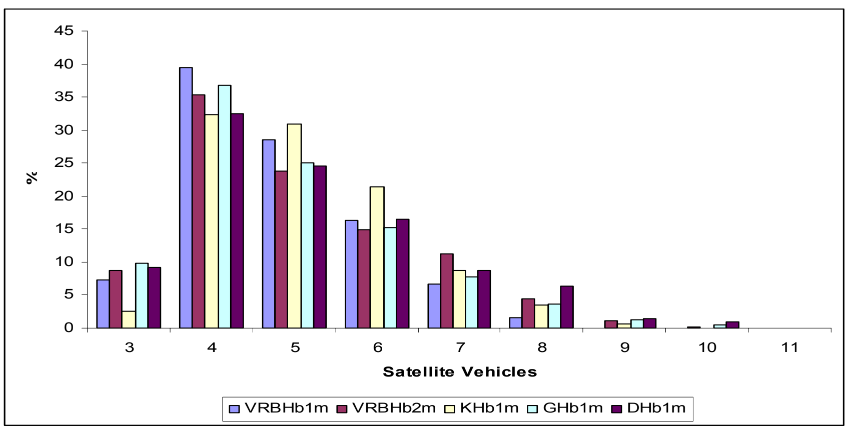


Figure 5: Percentage of the number of satellites used to record GPS position.

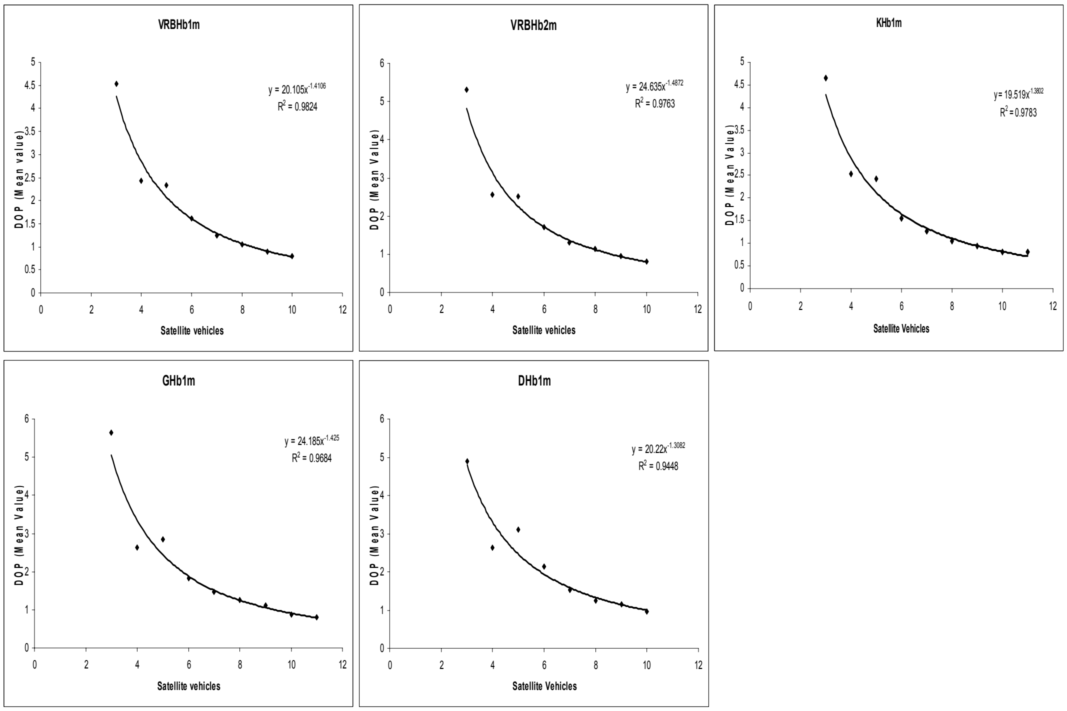


Figure 6: Dilution of precision (DOP) in relation to the number of satellite vehicles.

Variation of Accuracy

The time it took to obtain a GPS reading depended on the number of satellite vehicles (Figure 7) but not on the time of the day (Figure 8). It took significantly longer to obtain a GPS reading with three satellites (ANOVA, $p < 0.001$). Fix precision was dependent on the time of day (Figure 9) (ANOVA, $p = 0.001$).

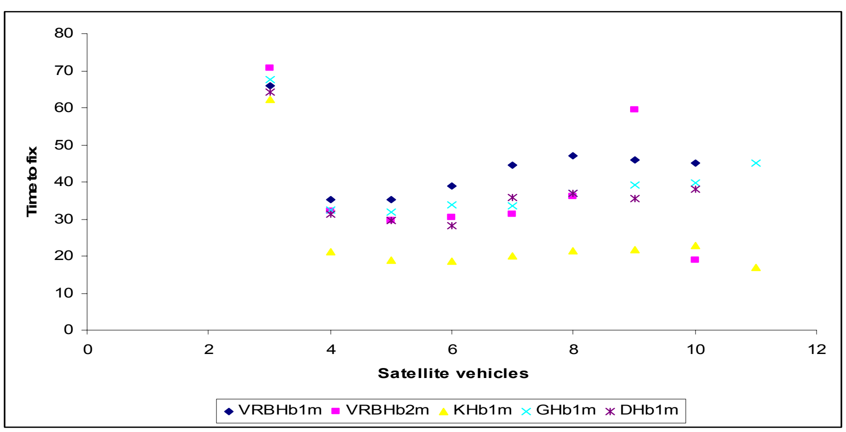


Figure 7: Time required to obtain GPS fix with differing numbers of satellite vehicles.

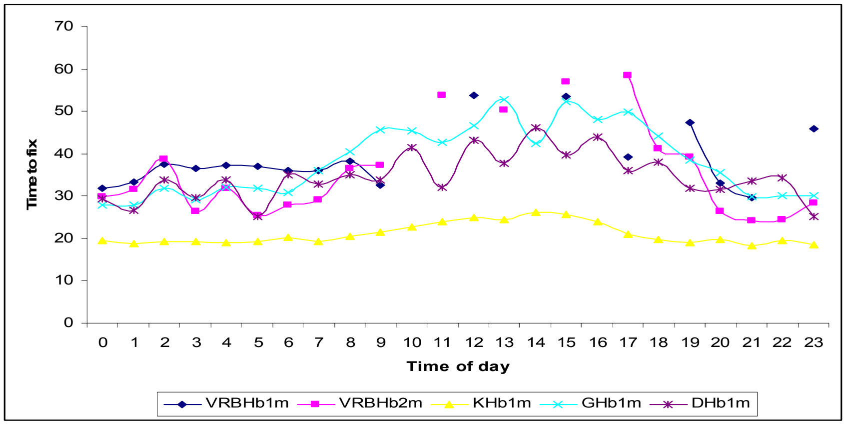


Figure 8: Time required to take GPS position during different times of the day.

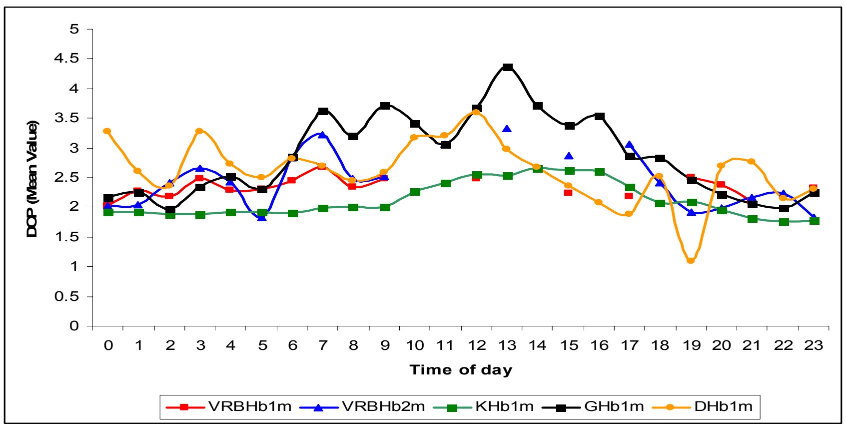


Figure 9: Dilution of precision during different times of the day.

The mean number of satellites per fix differed during different times of the day (ANOVA, $p < 0.001$). More satellites per fix were found at night than during the day (Figure 10).

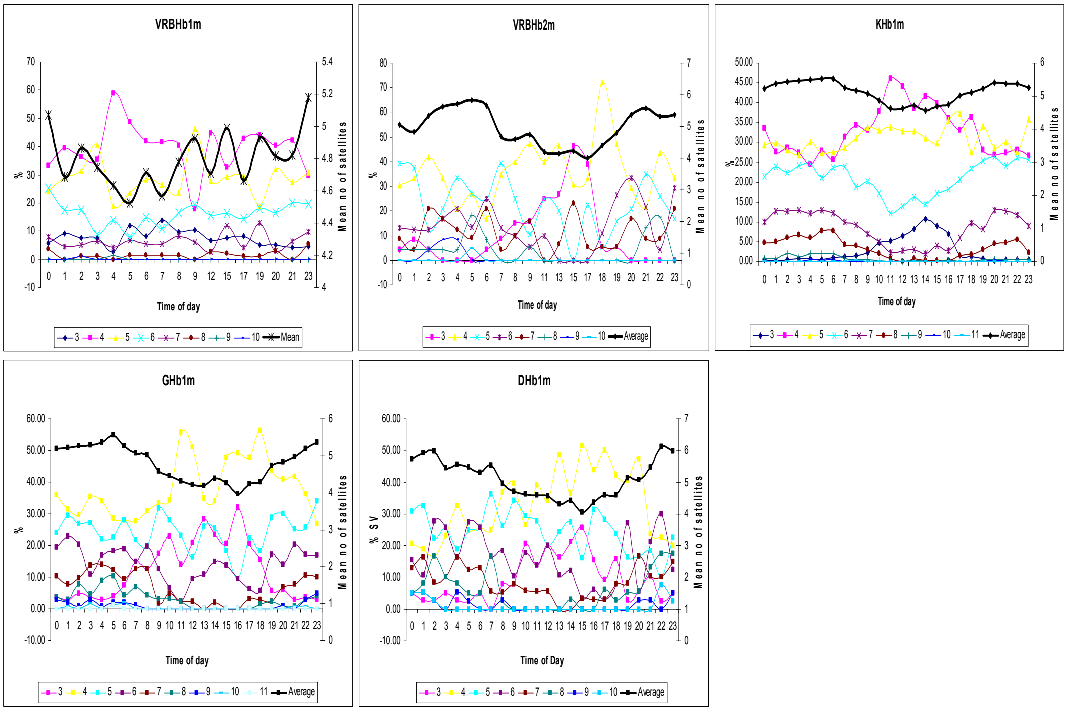


Figure 10: Mean number of satellites used to obtain GPS positions by different collars during different times of the day.

Individual Brown Hyenas

Although all home ranges of the five collared brown hyenas included the Klinghardt Mountain study area, two hyenas were of coastal clans (VRBHb1m & DHb1m), one hyena was a nomadic living male (VRBHb2m) and two were true inland hyenas (KHb1m & GHb1m).

Both, each individual hyena's and all hyenas' general activity, behaviour and ecology was described and analysed, and comparisons between hyenas were done.

VRBHb1m

- Male
- Age Class III (~10 years old)
- Excellent condition
- Collared: June 2005 to October 2005
- Number of GPS positions: 1615
- Status: resident

VRBHb1m's damaged collar was dropped off before its expiry date in October 2005.

Home Range Size

VRBHb1m's total home range was 1084 km^2. It included the area around the Van Reenen Bay seal colony and the eastern parts of the Klinghardt Mountains (Figure 11).

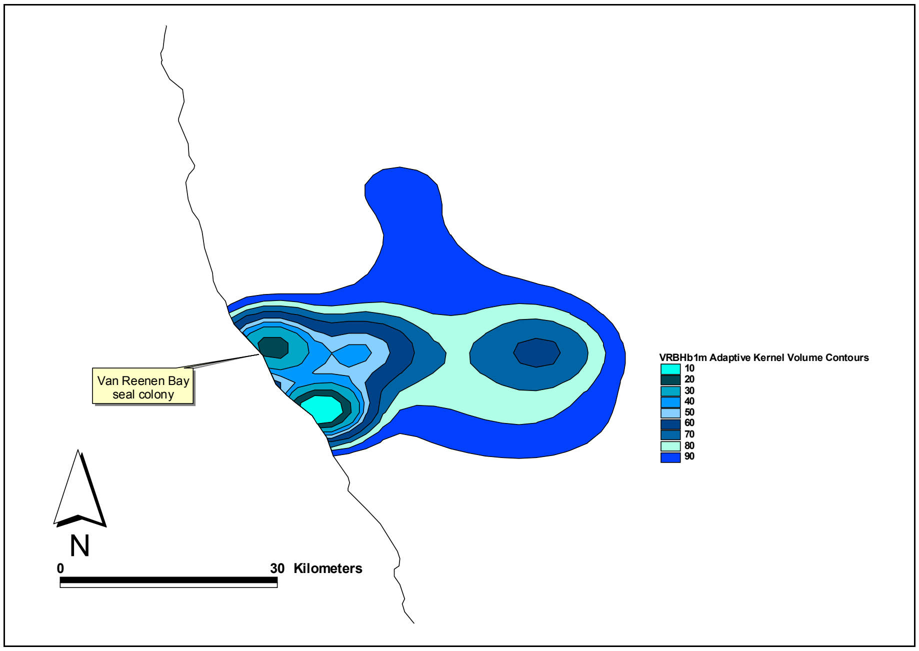


Figure 11: VRBHb1m's home range estimated by Adaptive Kernel Volume. Percentage volume contour lines represent the probability of finding the animal in this specific area (e.g. 90% contour line includes the 90% probability of finding the animal in this area).

VRBHb1m mostly used the coastal area of his home range, but the Klinghardt Mountains represented a core area too. The hyena's home range size and use changed over time. Its size was 875 km^2, 696 km^2, 779 km^2, 852 km^2 and 86 km^2 in June, July, August, September and October respectively (Figure 12). VRBHb1m was observed at the Van Reenen Bay seal colony in September. He was in a poor condition due to a fight that he must have had recently with another brown hyena. His movements became extremely restricted, possibly a result of a bacterial eye infection that was caused by the fight, hence his home range size in October was small and concentrated around the permanent food source at the Van Reenen Bay seal colony.

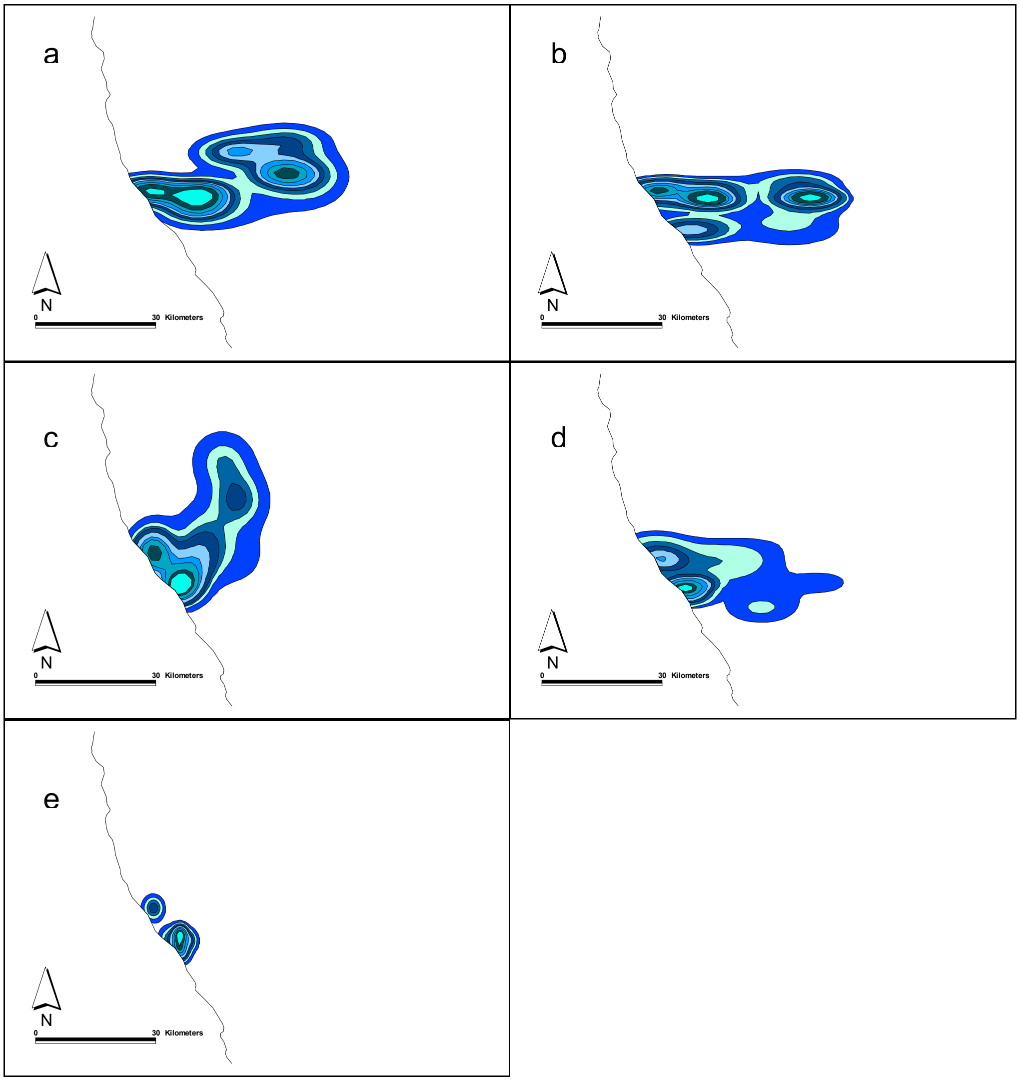


Figure 12: VRBHb1m's home ranges in (a) June, (b) July, (c) August, (d) September and (e) October (for legend see Figure 11).

Activity

VRBHb1m was mostly active between 19 and 23 h (Figure 13). Activity was significantly lower between 4 and 15 h (ANOVA, $p < 0.0001$). The difference between the movements during different times of the day between months was significant (Figure 14). VRBHb1m moved significantly shorter distances in September and October than between June and August (Repeated Measures ANOVA, $p < 0.0001$), possibly due to his injuries.

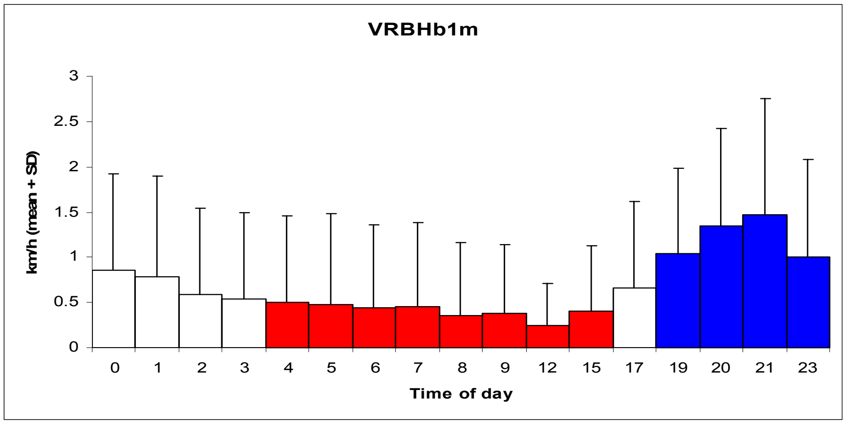


Figure 13: Mean distance (+SD) moved during different times of the day.

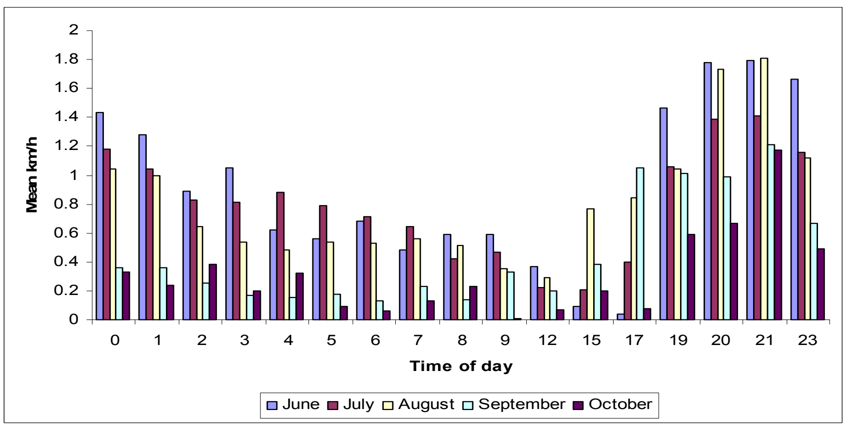


Figure 14: Mean distance moved per month during different times of the day.

VRBHb1m moved on average 15 km per day with a minimum movement of 400 m and a maximum movement of 41 km per day. Daily movement decreased significantly over the months (Figure 15), again possibly due to the hyena's injuries (ANOVA, $p < 0.01$).

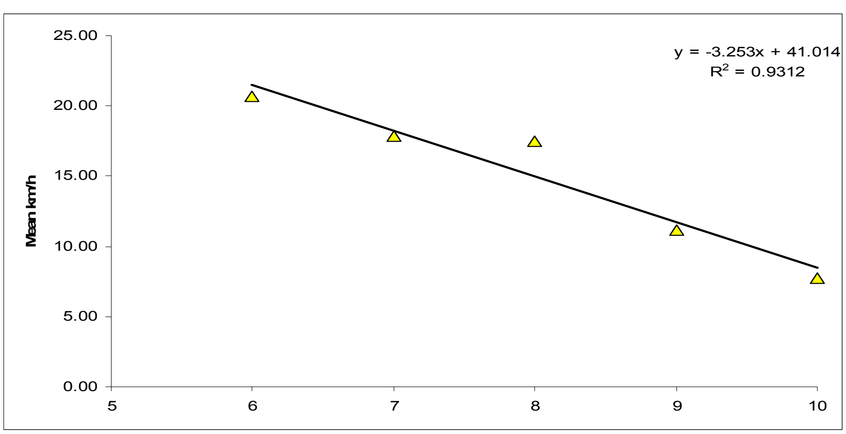


Figure 15: Mean daily distance moved between June and October (6 – 10).

Habitat Use

VRBHb1m made heterogeneous use of the available habitat (Chi^2 Test, $p < 0.0001$). Most time was spent in coastal hills and plains (Figure 16). where also the greatest distances were moved (Figure 17). There was no difference in habitat use while resting and walking.

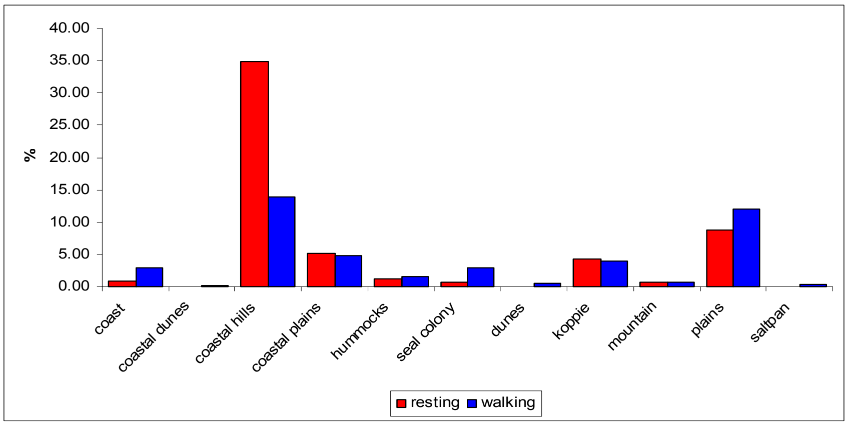


Figure 16: Percentage of GPS fixes recorded in different habitats while resting or walking.

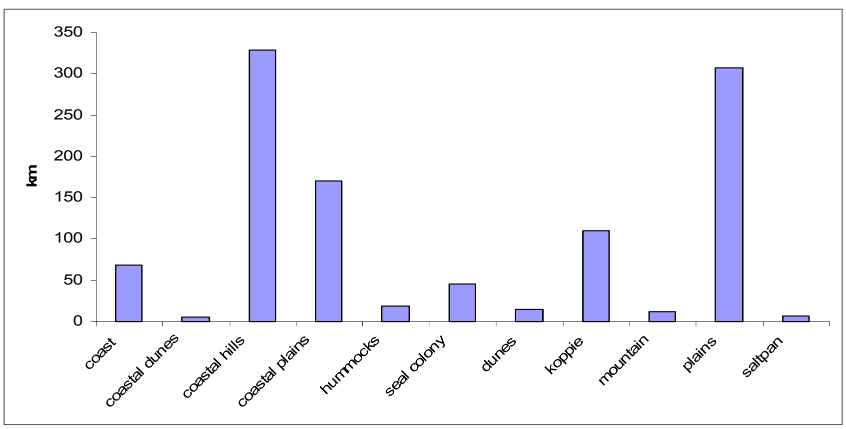
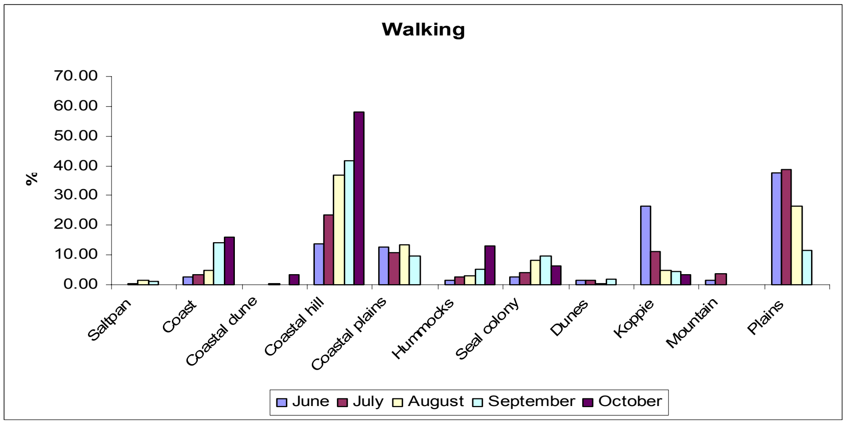


Figure 17: Distance walked in different habitats.

There was no difference in the use of different habitats while resting or walking between months. Coastal hills, plains and koppies (rocky outcrops) were the preferred habitat types for both behaviours (Figure 18).



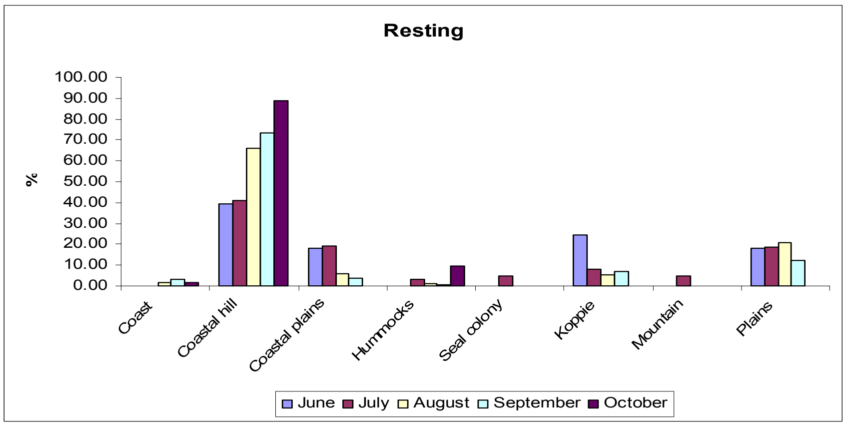


Figure 18: Percentage of fixes recorded in different habitats while walking and resting.

There was also no difference between the use of different habitats while resting during the day and at night (Figure 19). However coastal hills were proportionally more used at night. Since most food is found along the coast and VRBHb1m was mainly active at night, he might have carried food to protected feeding sites close the food sources, hence making more use of the coastal area.

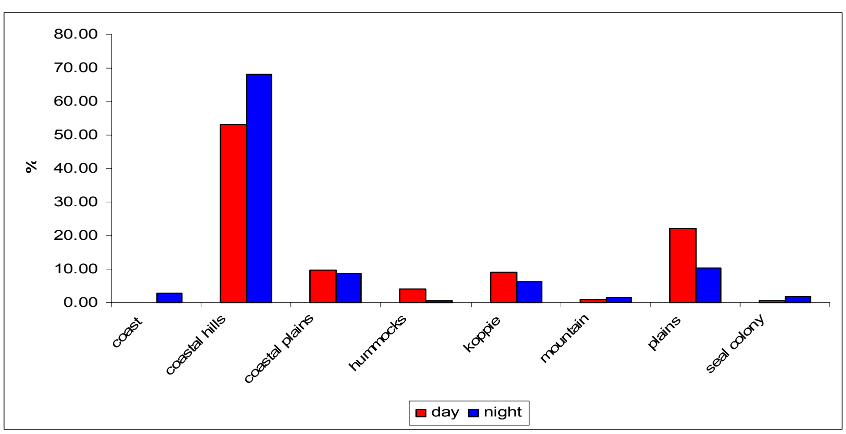


Figure 19: Habitat use while resting during the day and at night.

Behaviour

Three different types of behaviours were defined:

- Not moving (resting), when the hyena was presumably resting
- Moving in inland areas of the home range (walking)
- Moving in coastal areas of the home range (foraging)

The coastal area was defined as the area east of the main road from Luderitz to Oranjemund, which runs between 10 and 20 km west, parallel to the coast.

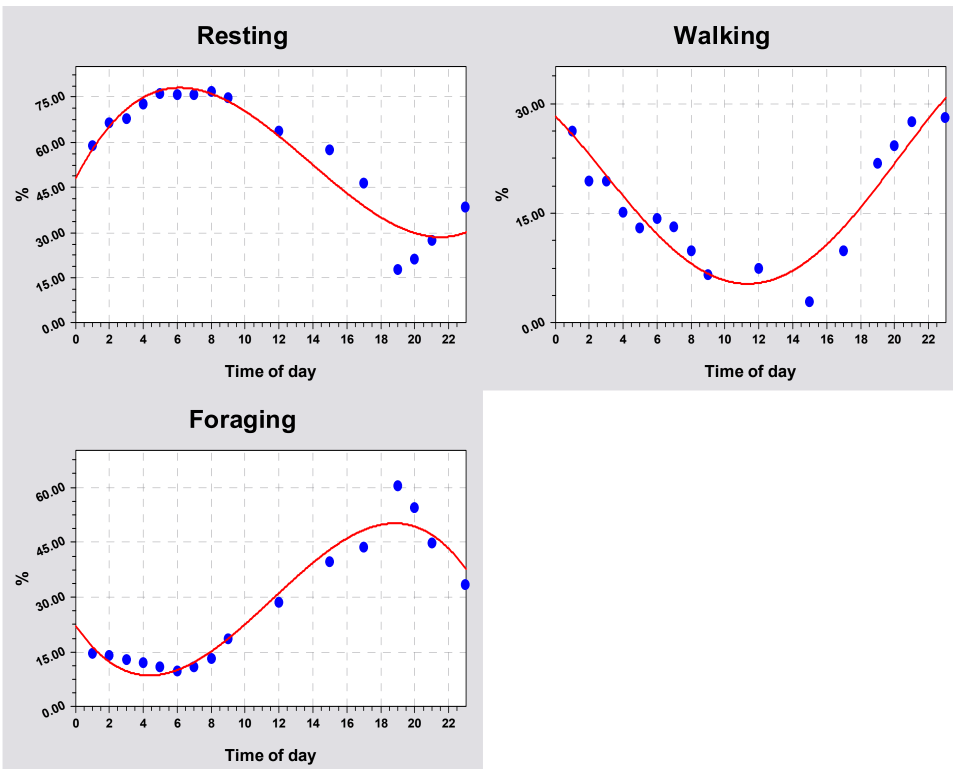


Figure 20: Pattern of the percentage of GPS fixes recorded while resting, walking and foraging during different times of the day.

The daily changes in behaviour of VRBHb1m showed significant patterns (resting r = 0.96, walking r = 0.94, foraging r = 0.97). Resting peaked at 8 h and was lowest at 21 h. Walking in inland areas of the home range peaked at midnight and was lowest at noon. Walking in coastal areas of the home range (foraging) peaked at 19 h and was lowest at 4 h (Figure 20).

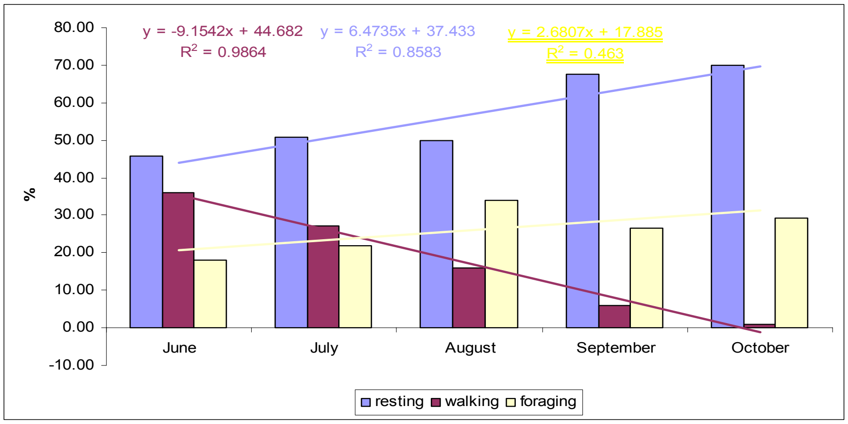


Figure 21: Changes in the percentage of GPS fixes recorded while resting, walking and foraging between months.

VRBHb1m's behaviour changed between months (Chi^2, $p < 0.0001$). He spent more time resting in September and October than during the other months, possibly due to his injuries (Figure 21).

Movement was significantly dependent on outside temperature (Mann-Whitney U-Test, $p < 0.0001$). The average outside temperature while resting was 29˚ C, ranging from 15 to 40˚ C, and the average outside temperature while moving was 18˚ C, ranging from 7 to 34˚ C.

VRBHb1m visited the fresh water source near Bogenfels on average every 6 ½ days, ranging from two to 17 days. He controlled his home range boundary every two to 10 days (average 3 ½ days). A typical home range boundary visit is shown as an example in Figure 22. He started visiting the home range boundary in the south-western parts of the Klinghardt Mountains, followed the boundary to the coast and walked to the Van Reenen Bay seal colony to forage.

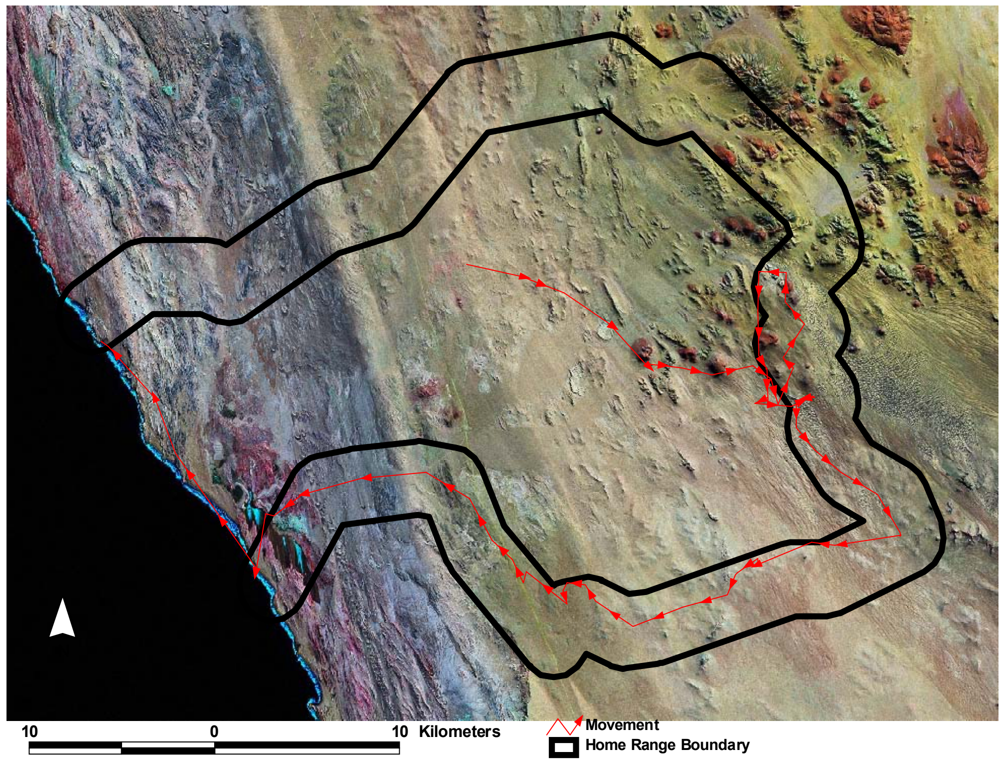


Figure 22: VRBHb1m's movement along home range boundary.

VRBHb2m

- Male
- Age Class III (~10 years old)
- Moderate condition
- Collared: February 2006 to March 2006
- Number of GPS positions: 508
- Status: nomad

VRBHb2m died of natural causes on 22 March 2006.

Home Range Size

VRBHb2m's total home range was 1702 km^2. It included the area around the Van Reenen Bay seal colony, the northern parts of the Klinghardt Mountains and the area around the Kaukasib fountain (Figure 23).

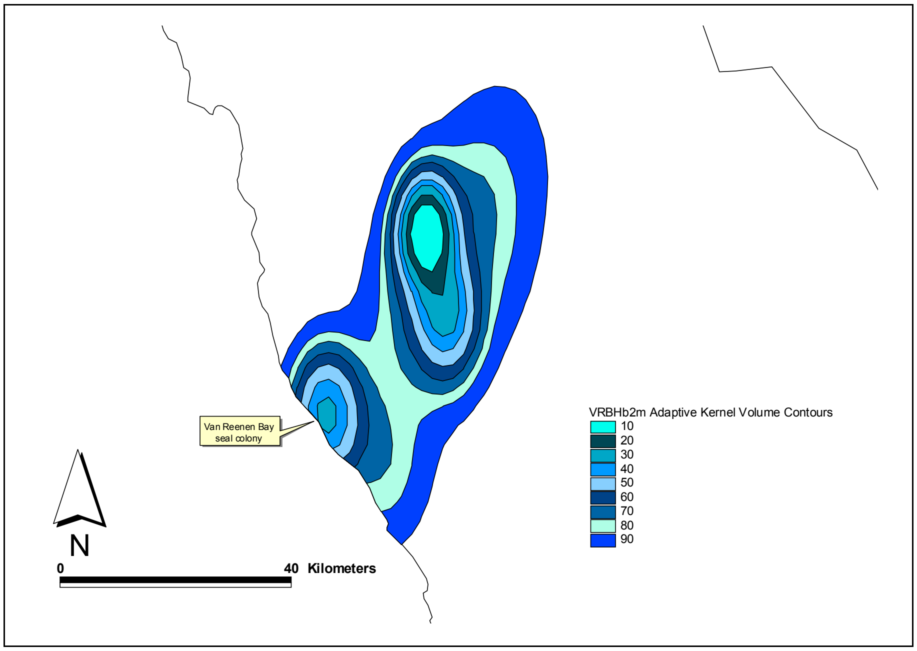


Figure 23: VRBHb2m's home range estimated by Adaptive Kernel Volume. Percentage volume contour lines represent the probability of finding the animal in this specific area (e.g. 90% contour line includes the 90% probability of finding the animal in this area).

VRBHb2m's core areas were the area around the Van Reenen Bay seal colony and the mountain range to the south-west of the Kaukasib fountain. VRBHb2m was located during an aerial tracking flight on 26 March 2006 to the east of the Kaukasib Fountain where he died on 22 March 2006. He seemed to have been on his way to the Wolf and Atlas Bay seal colonies, approximately 20 km south of Luderitz. This movement indicated that VRBHb2m was a nomadic living male.

Activity

VRBHb2m was mostly active between 21 and 5 h (Figure 24). Activity was significantly lower between 13 and 18 h (Kruskal Wallis Test, $p < 0.0001$).

VRBHb2m moved on average 19 km per day with a minimum movement of 700 m and a maximum movement of 43 km per day. His daily activity did not change significantly from the time of collar deployment until his death.

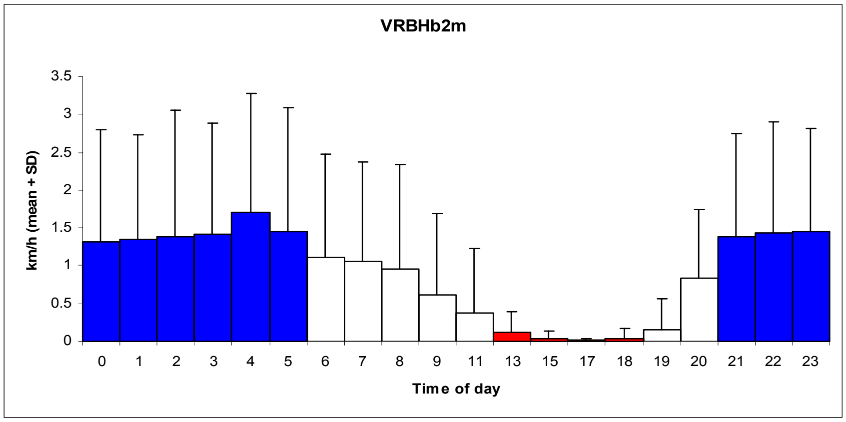


Figure 24: Mean distance (+SD) moved during different times of the day.

Habitat Use

VRBHb2m made heterogeneous use of the available habitat (Chi^2 Test, $p < 0.0001$). Most time was spent in coastal hills, koppies and plains (Figure 25), where also the greatest distances were moved (Figure 26). There was no difference in habitat use while resting and walking.

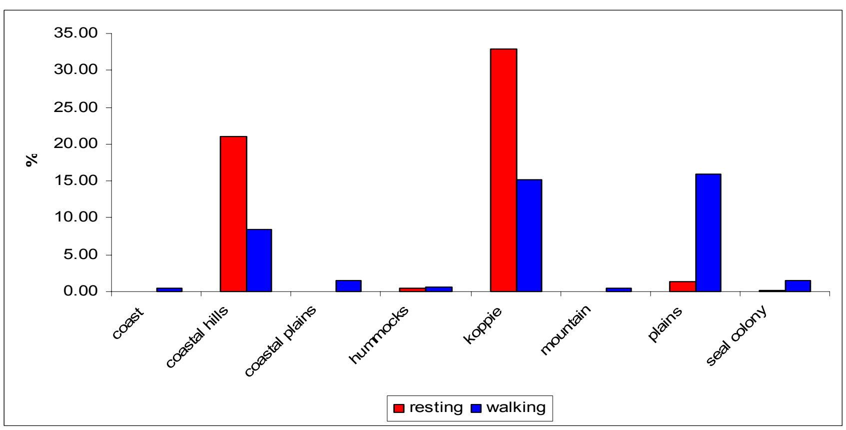


Figure 25: Percentage of GPS fixes recorded in different habitats while resting or walking.

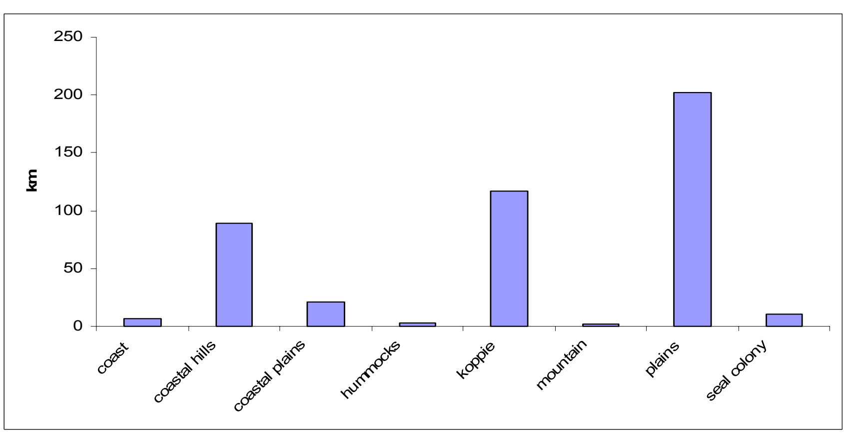


Figure 26: Distance walked in different habitats.

There was also no difference between the use of different habitats while resting during the day and at night (Figure 27). However koppies were proportionally more used during the day, indicating the importance of this habitat for finding protection against the heat. Night-time use of coastal hills indicates that they may be used as protected feeding areas.

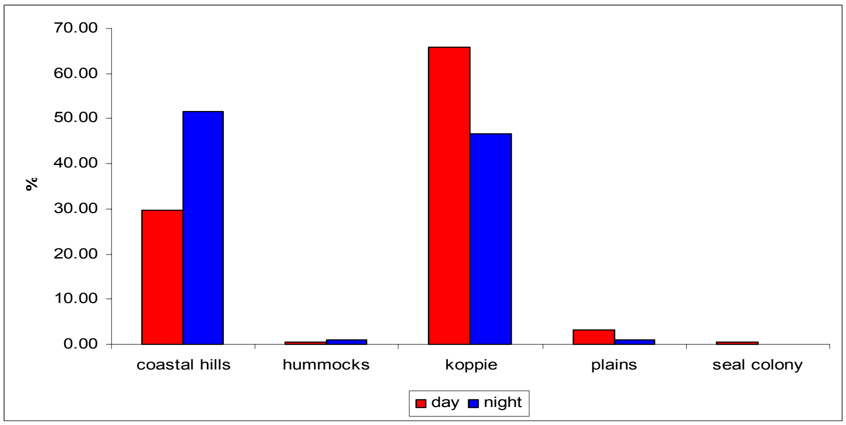


Figure 27: Habitat use while resting during the day and at night.

Behaviour

The daily changes in behaviour of VRBHb2m showed significant patterns (resting r = 0.93, walking r = 0.88, foraging r = 0.78). Resting peaked at 16 h and was lowest at midnight. Walking in inland areas of the home range peaked at 2 h and was lowest at 13 h. Walking in coastal areas of the home range (foraging) peaked at 5 h and was lowest at 17 h (Figure 28).

Movement was significantly dependent on outside temperature (Mann-Whitney U-Test, $p < 0.0001$). The average outside temperature while resting was 31˚ C, ranging from 15 to 47˚ C, and the average outside temperature while moving was 22˚ C, ranging from 14 to 47˚ C.

VRBHb2m visited the fresh water source near Bogenfels or the Kaukasib fountain on average every 5 days, ranging from three to 7 days.

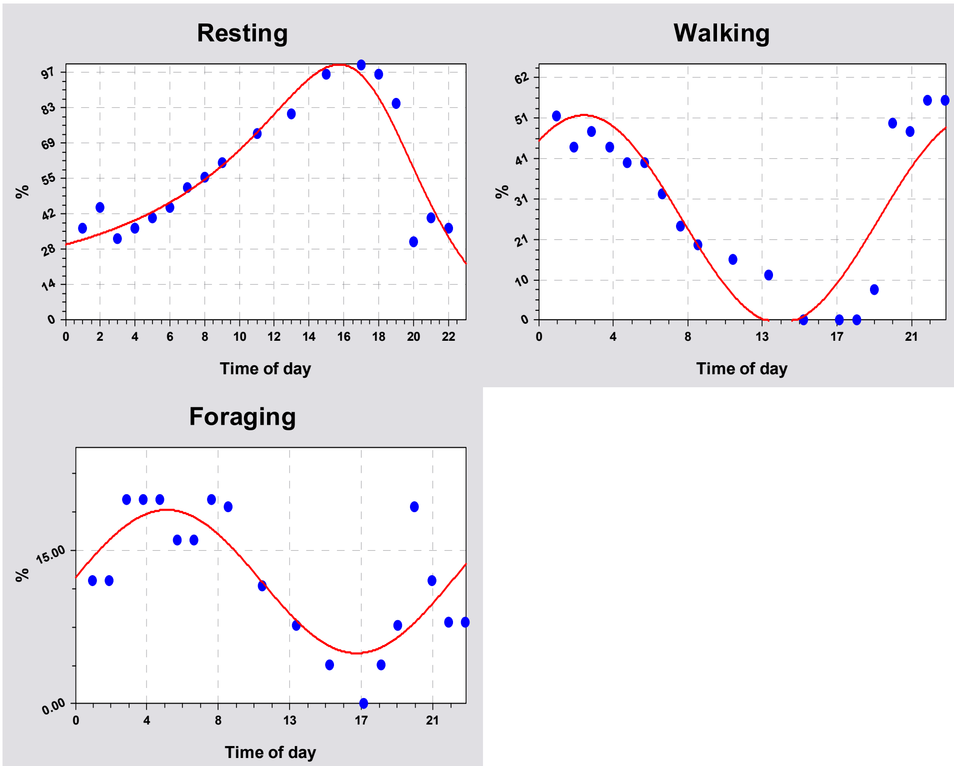


Figure 28: Pattern of the percentage of GPS fixes recorded while resting, walking and foraging during different times of the day.

KHb1m

- Male
- Age Class III (~14 years old)
- Moderate condition
- Collared: March 2005 to July 2005
- Number of GPS positions: 16604
- Status: resident

The collar was dropped off on 2 July 2005 about one month short of its expiry date. The GPS programming schedule was chosen at the maximum 144 fixes per day (every 10 minutes) to be able to compare this data to the quality of results of data retrieved from GPS collars with less intensive scheduling (e.g. 24 fixes per day), which enables us to make better decisions about programming schedules in future. Battery life therefore was short.

Home Range Size

KHb1m's total home range was 2335 km^2. It included the area around the Baker's Bay seal colony, the area east of the Klinghardt Mountains and the area around the Kaukasib fountain (Figure 29).

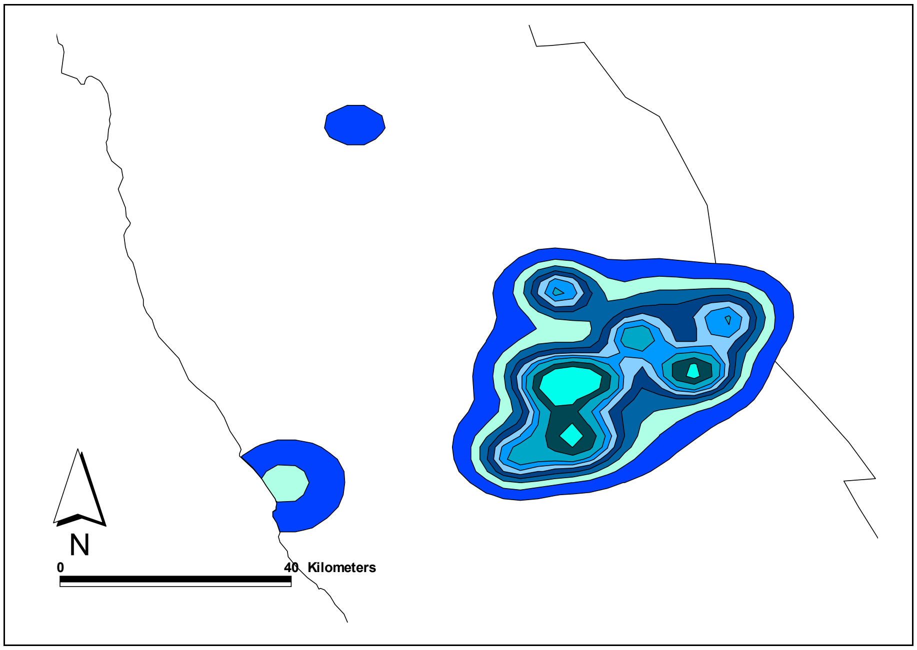


Figure 29: VRBHb2m's home range estimated by Adaptive Kernel Volume. Percentage volume contour lines represent the probability of finding the animal in this specific area (for legend see Figure 11).

The hyena's home range size and use changed over time. Its size decreased from 3435 km^2, to 2046 km^2, 1277 km^2 and 1196 km^2 in March, April, May and June respectively (Figure 30).

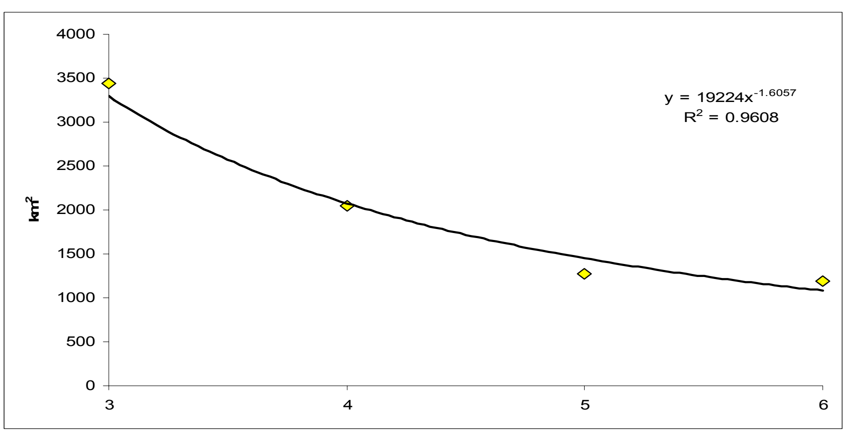


Figure 30: Change in home range size between March and June (3 – 6)

KHb1m visited the Kaukasib fountain only in March and stopped foraging at the Baker's Bay seal colony in May (Figure 31).

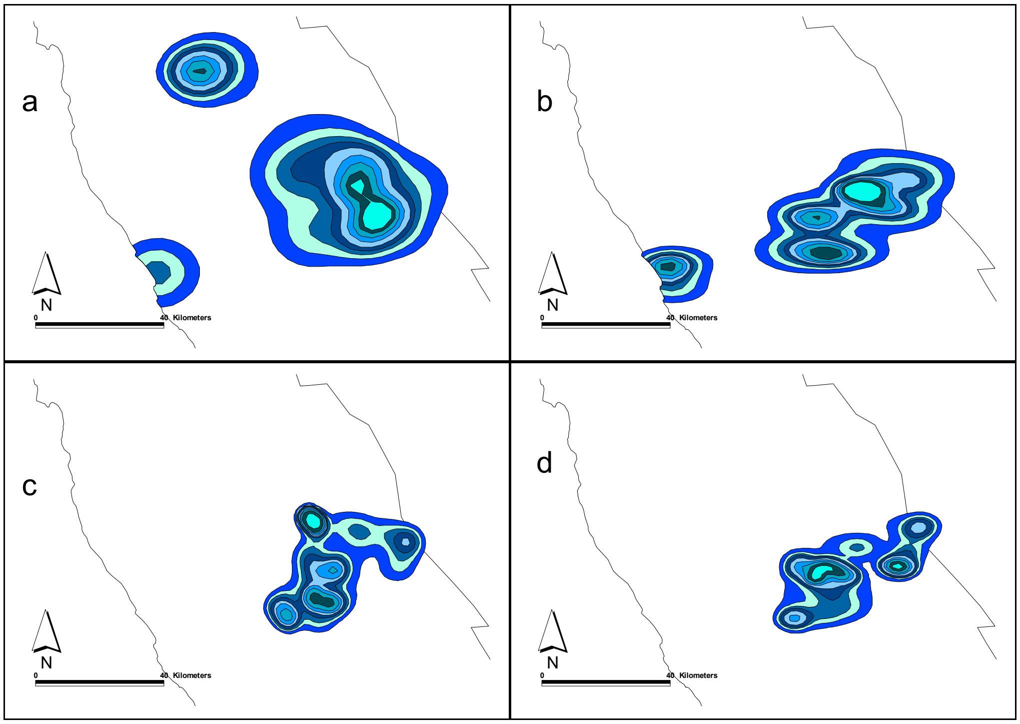


Figure 31: KHb1m's home ranges in (a) March, (b) April, (c) May and (d) June (for legend see Figure 11).

During times of low rainfall, KHb1m visited the Kaukasib fountain and the area around the Baker's Bay seal colony. There were three distinct core areas: the seal colony, the Kaukasib fountain and the area south of the active den site (Morgenberg area), where brackish water can be found periodically after rain (Figure 32 a).

Rainfall increased during the second quarter of 2005 and KHb1m's movements changed (Figure 32 b). He did not visit the Kaukasib fountain any more, which lies 70 km north of the centre of his home range. His movements showed concentrations around the Heioab mountain range, Pockenbank, the Morgenberg den site and again south of the den site. Periodic water can be found in all of these areas. Grassy plains are found particularly around the Pockenbank area after rains and it is assumed that game was found in the entire area between April and June, which lead to the changes in KHb1m's movements.

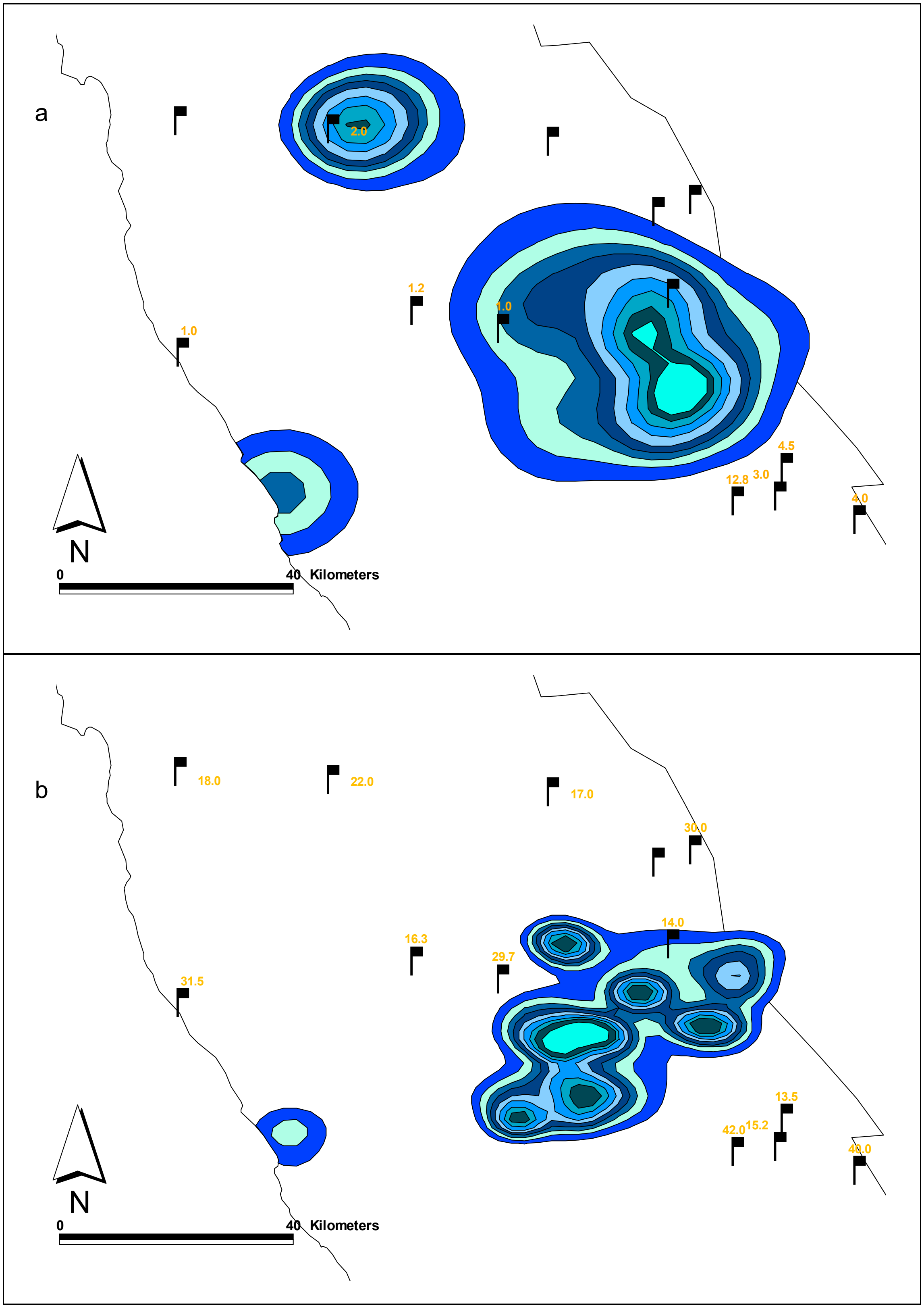


Figure 32: KHb1m's home ranges in relation to the quarterly rainfall. Flags represent rain gauges and their readings in mm for the periods (a) January to March 2005 and (b) April to June 2005 (for legend see Figure 11).

Activity

KHb1m was mostly active between 18 and 6 h (Figure 33). Activity was significantly lower between 8 and 17 h (ANOVA, $p < 0.0001$). There was no difference between the movements during different times of the day between months (Figure 34).

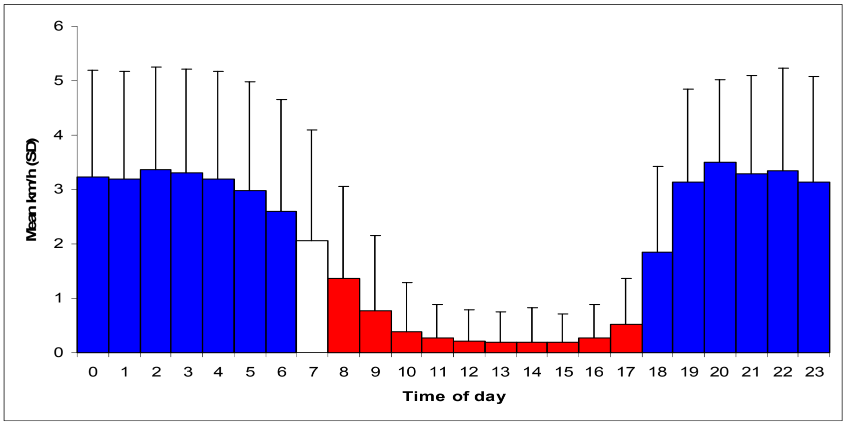


Figure 33: Mean distance (+SD) moved during different times of the day.

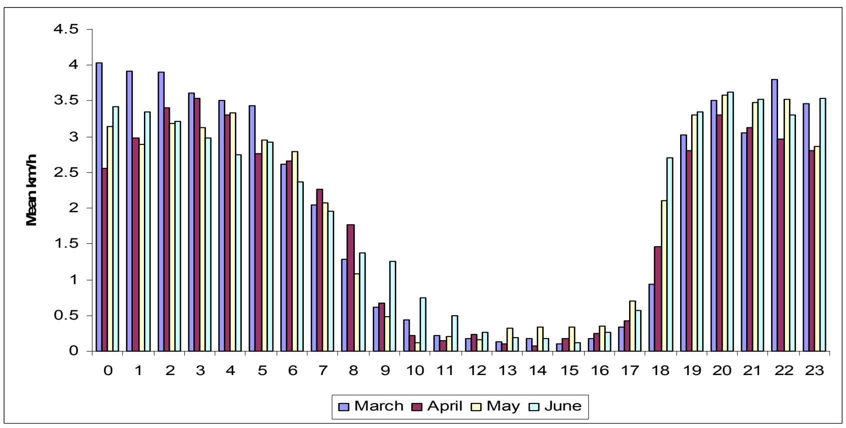


Figure 34: Mean distance moved per month during different times of the day.

KHb1m moved on average 47 km per day with a minimum movement of 8 km and a maximum movement of 82 km per day, without differences between months.

Habitat Use

KHb2m made heterogeneous use of the available habitat (Chi^2 Test, $p < 0.0001$). Most time was spent in plains, mountains and dunes (Figure 35), where also the greatest distances were moved (Figure 36). There was no difference in habitat use while resting and walking.

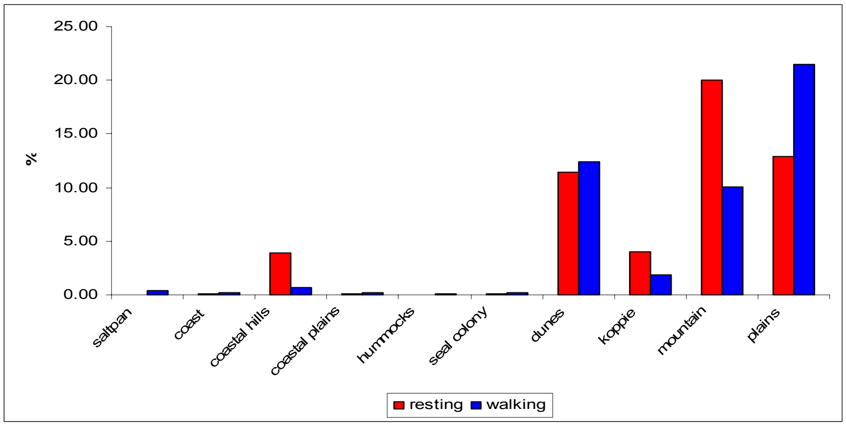


Figure 35: Percentage of GPS fixes recorded in different habitats while resting or walking.

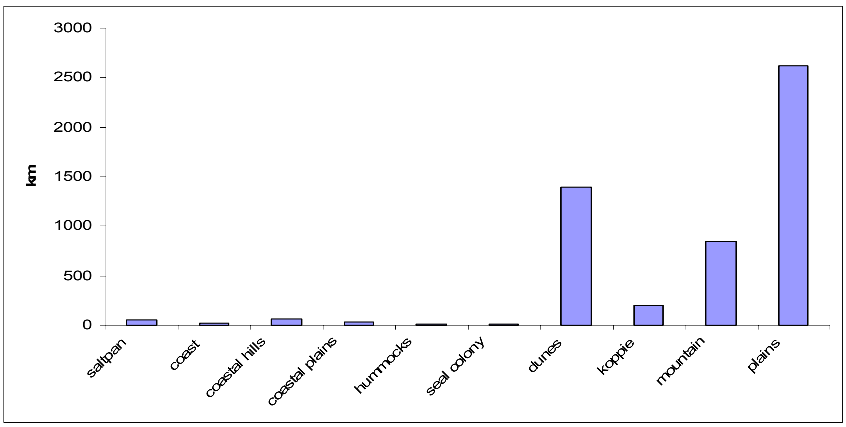
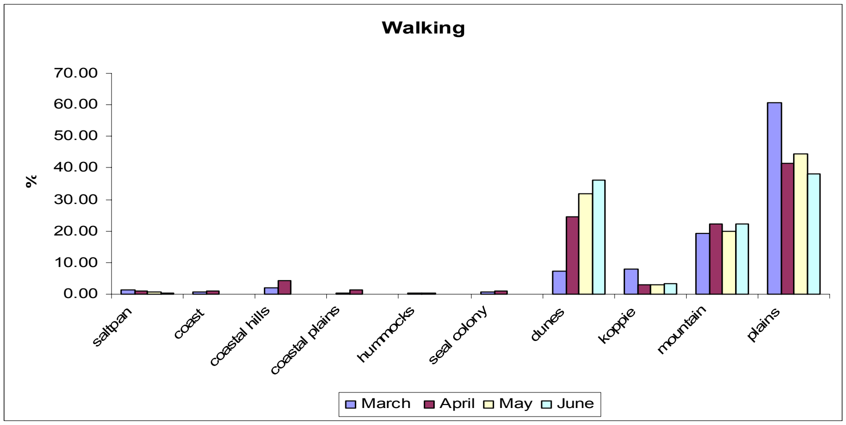


Figure 36: Distance walked in different habitats.

There was no difference in the use of different habitats while resting, but habitat use changed while walking between months (Friedman Test, $p < 0.05$). Most walking fixes were recorded in plains, mountains and dunes. Significantly more movement took place in the dunes from April onwards, coinciding with an increase in rain. Koppies, mountains, plains and dunes were the preferred habitat while resting. However, coastal hills were also used as resting habitat in March and April, which were the times when KHb1m still foraged at the seal colony at Baker's Bay (Figure 37).



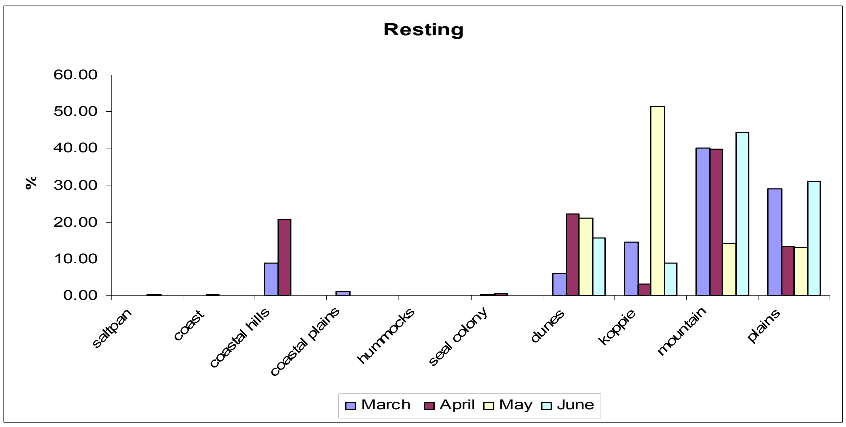


Figure 37: Percentage of fixes recorded in different habitats while walking and resting.

There was no difference between the use of different habitats while resting during the day and at night (Figure 38). However coastal hills were proportionally more used at night, indicating that KHb1m used protected feeding sites in the coastal hills after foraging at the seal colony and along the beaches.

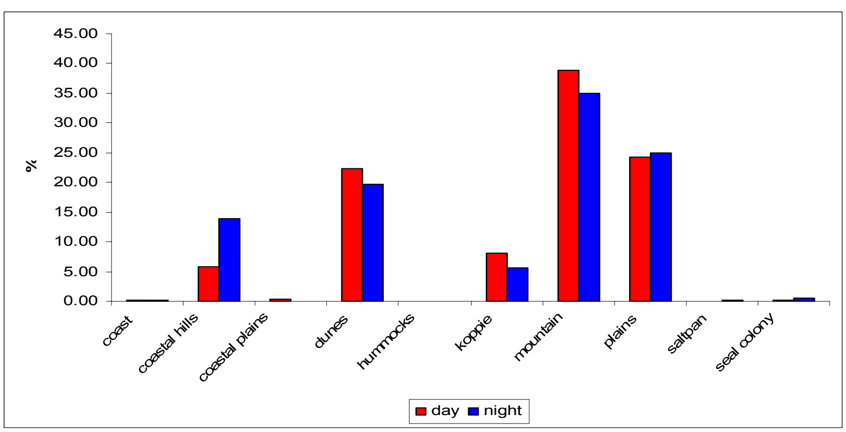


Figure 38: Habitat use while resting during the day and at night.

Behaviour

The daily changes in behaviour of KHb1m showed significant patterns for resting (r = 0.97) and walking (r = 0.97). Walking in coastal areas of his home range (foraging) did not show any pattern.

Resting peaked at 13 h and was lowest at 3 h. Walking in inland areas of the home range peaked at 22 and 3 h and was lowest at noon (Figure 39).

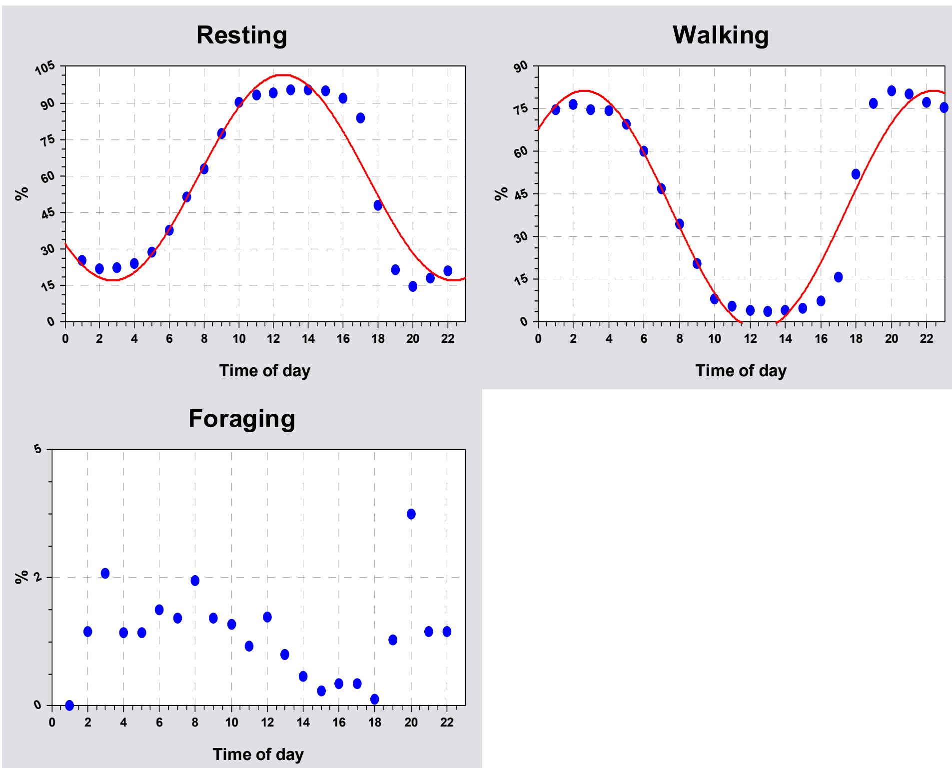


Figure 39: Pattern of the percentage of GPS fixes recorded while resting, walking and foraging during different times of the day.

KHb1m's behaviour changed between months (Chi^2, $p < 0.0001$). He spent more time resting in March and April than in May and July (Figure 40), indicating that he needed more time to search for food in winter than in autumn. Walking in coastal areas (foraging) only took place in March and April.

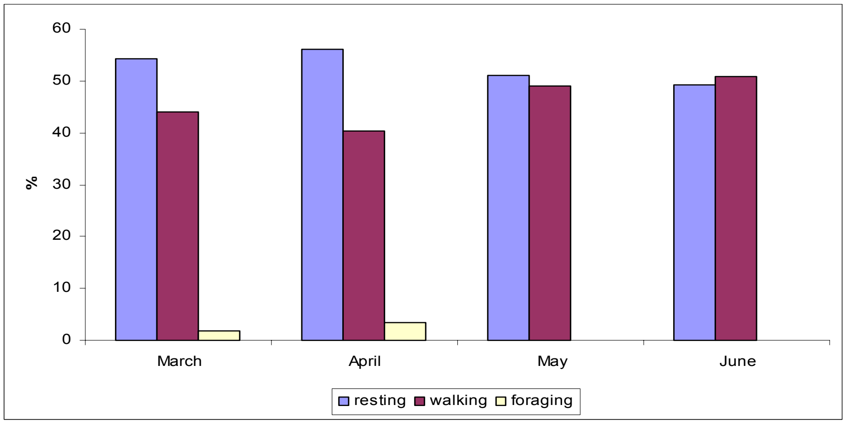


Figure 40: Changes in the percentage of GPS fixes recorded while resting, walking and foraging between months.

Movement was significantly dependent on outside temperature (Mann-Whitney U-Test, $p < 0.0001$). The average outside temperature while resting was 30˚ C, ranging from 8 to 47˚ C, and the average outside temperature while moving was 18˚ C, ranging from 4 to 46˚ C.

KHb1m visited the fresh water source near Kaukasib twice in March and possibly used other periodically available water sources from April onwards.

KHb1m visited the active den site to provide food for the cubs and to socialize with other clan members on average every four days. Intervals ranged from one to 16 days. He spent on average 4 hours resting near the den site, ranging from 10 minutes to 18 hours. Including other activities he spent on average five hours near the den, ranging from 15 minutes to 20 hours.

GHb1m

- Male
- Age Class III (~14 years old)
- Good condition
- Collared: December 2006 to present
- Number of GPS positions up to May 2007: 2736
- Status: resident

Home Range Size

GHb1m's total home range was 2296 km^2. It included the area around the Baker's Bay seal colony and the northern and eastern parts of the Klinghardt Mountains (Figure 41).

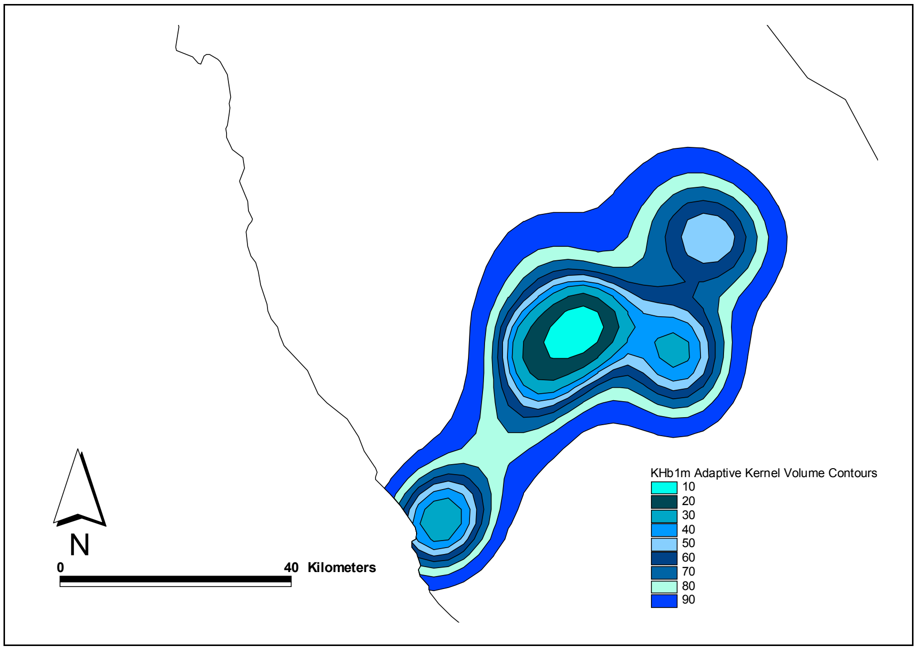


Figure 41: GHb2m's home range estimated by Adaptive Kernel Volume. Percentage volume contour lines represent the probability of finding the animal in this specific area (e.g. 90% contour line includes the 90% probability of finding the animal in this area).

The coastal area and the Klinghardt Mountains represented core areas. The hyena's home range size and use changed over time. Its size was 520 km^2, 709 km^2, 584 km^2, 718 km^2 and 208 km^2 in December, January, February, April and May (Figure 42). Similar to KHb1m, GHb1m stopped using the coastal area of his home range and hence foraging at the Baker's Bay seal colony in May.

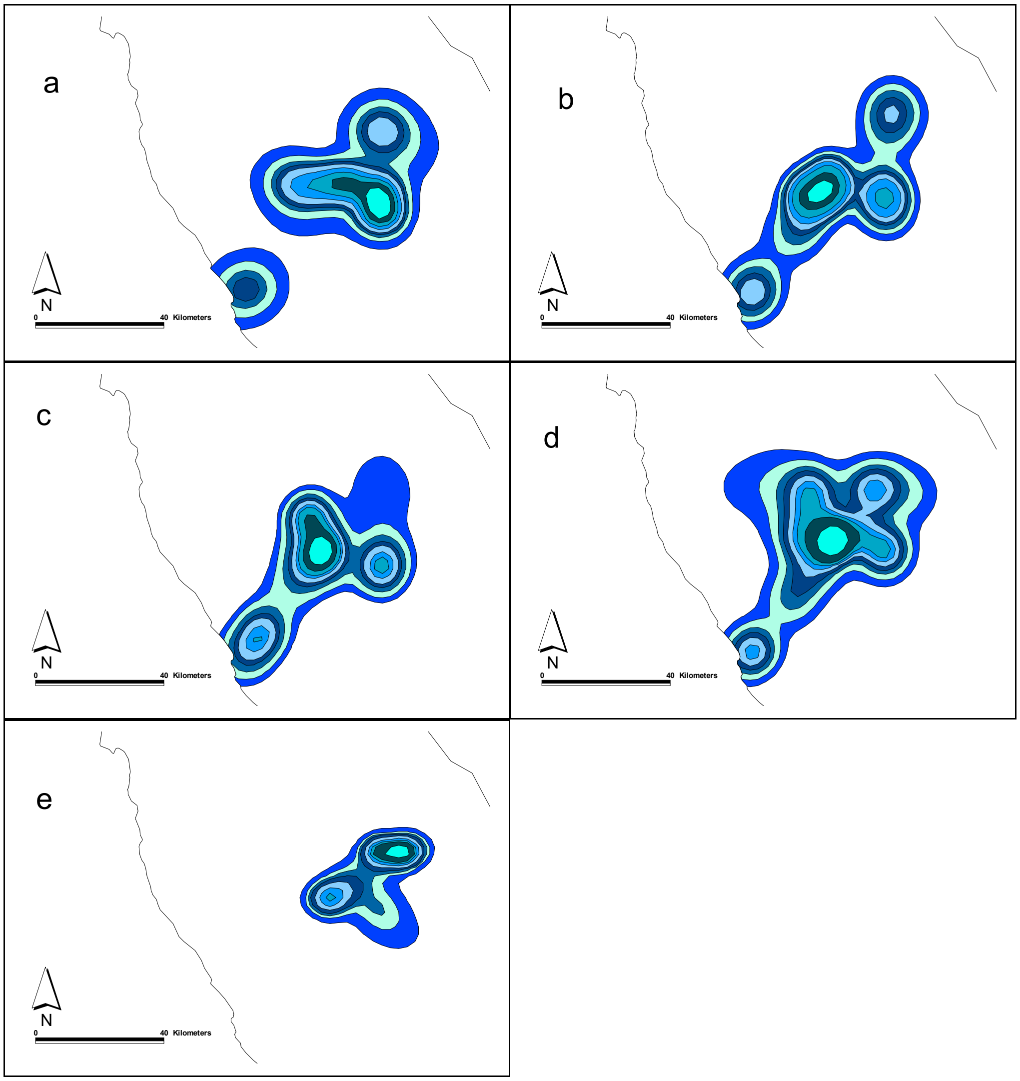


Figure 42: VRBHb1m's home ranges in (a) December, (b) January, (c) February, (d) April and (e) May (for legend see Figure 41).

During times of low rainfall, GHb1m's core areas were relatively widely distributed within the Klinghardt Mountains (Figure 43 a). Once rainfall was present GHb1m's movements changed. His movements showed two distinct concentrations in the Klinghardt Mountains (Figure 43 b and c). Grassy plains are found in this area after rains and it is assumed that game was found there from April and May onwards, which lead to the changes in GHb1m's movements.

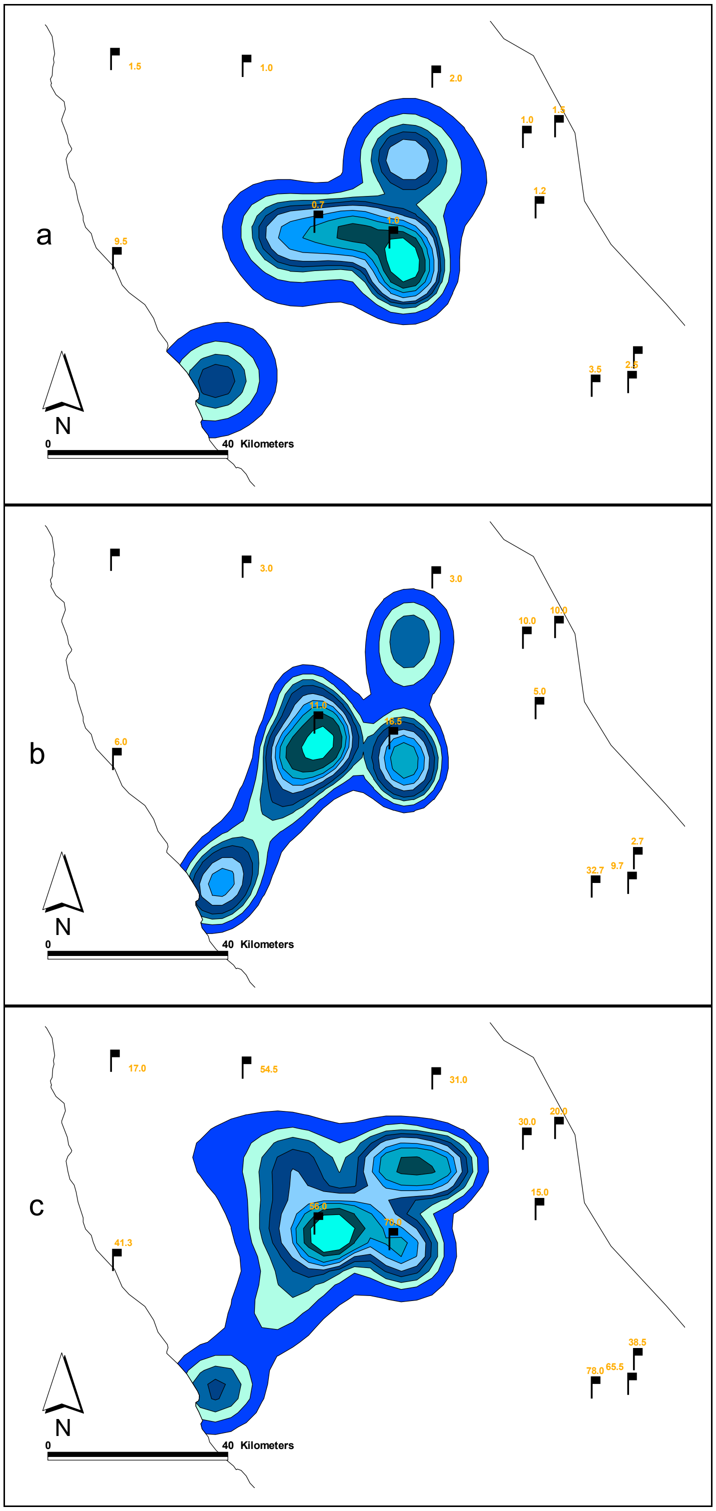


Figure 43: GHb1m's home ranges in relation to the quarterly rainfall. Flags represent rain gauges and their readings in mm for the periods (a) October to December 2006, (b) January to March 2007 and (c) April to June 2007 (for legend see Figure 41).

Activity

GHb1m was mostly active between 20 and 7 h (Figure 44). Activity was significantly lower between 8 and 19 h (ANOVA, $p < 0.0001$). The difference between the movements during different times of the day between months was significant (Figure 45). GHb1m moved significantly longer distances in December than in January, February and May (Friedman Test, $p = 0.0004$).

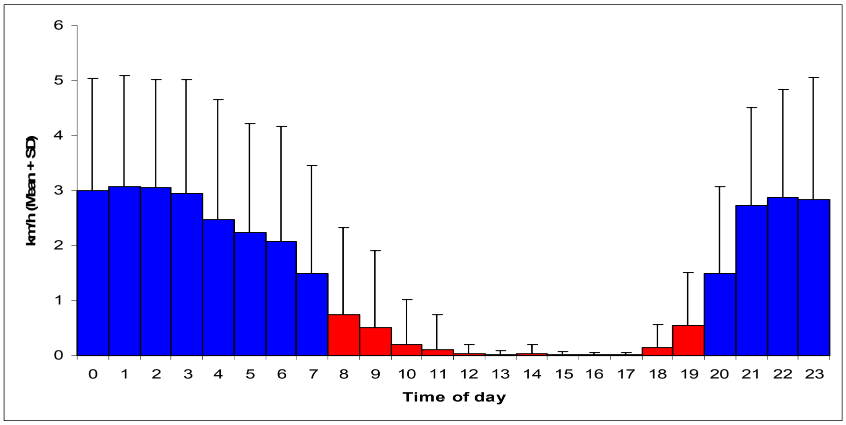


Figure 44: Mean distance (+SD) moved during different times of the day.

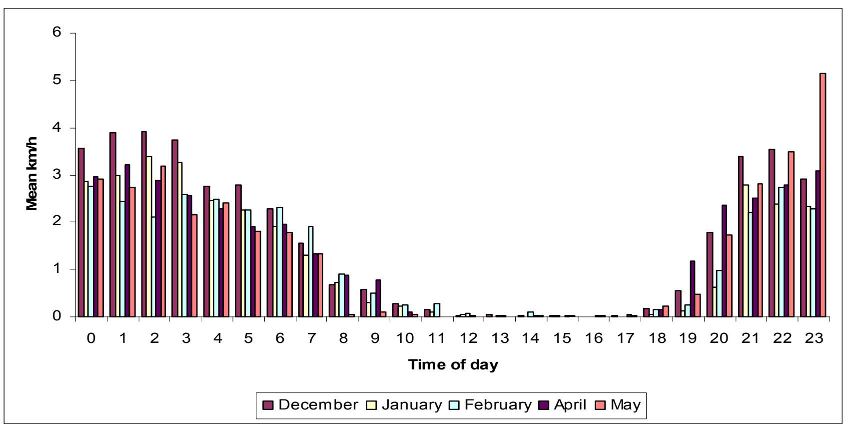


Figure 45: Mean distance moved per month during different times of the day.

GHb1m moved on average 31 km per day with a minimum movement of 2 km and a maximum movement of 77 km per day. Daily movement did not change between months.

Habitat Use

GHb1m made heterogeneous use of the available habitat (Chi^2 Test, $p < 0.0001$). Most time was spent in mountains, plains and koppies (Figure 46). The greatest distances were moved in the plains (Figure 47). There was no difference in habitat use while resting and walking.

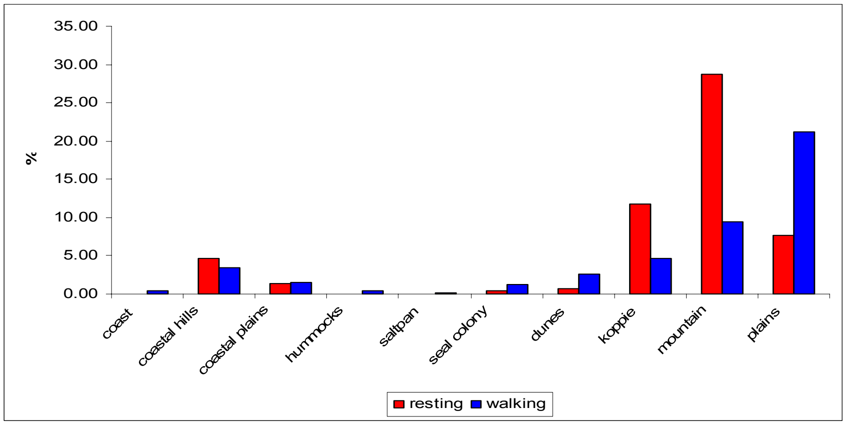


Figure 46: Percentage of GPS fixes recorded in different habitats while resting or walking.

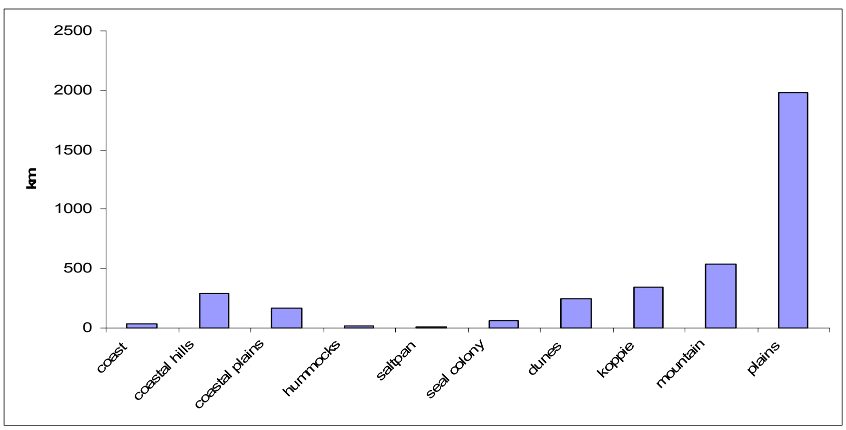
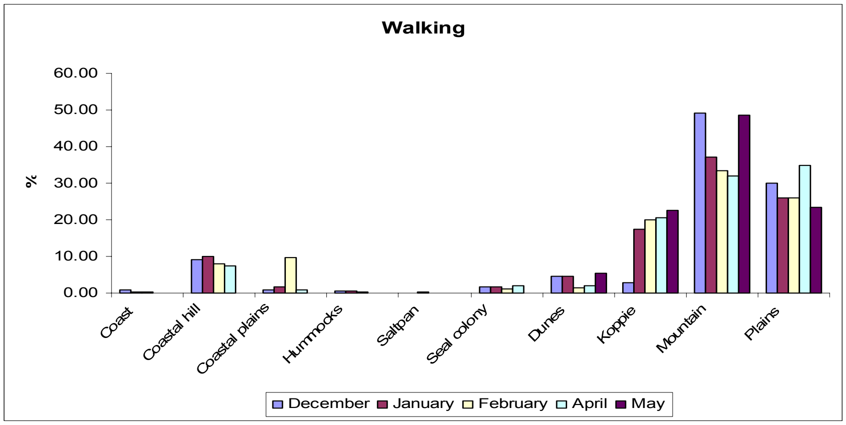


Figure 47: Distance walked in different habitats.

There was no difference in the use of different habitats while resting or walking between months. Coastal hills, plains and koppies were the preferred habitat types for both behaviours (Figure 48).



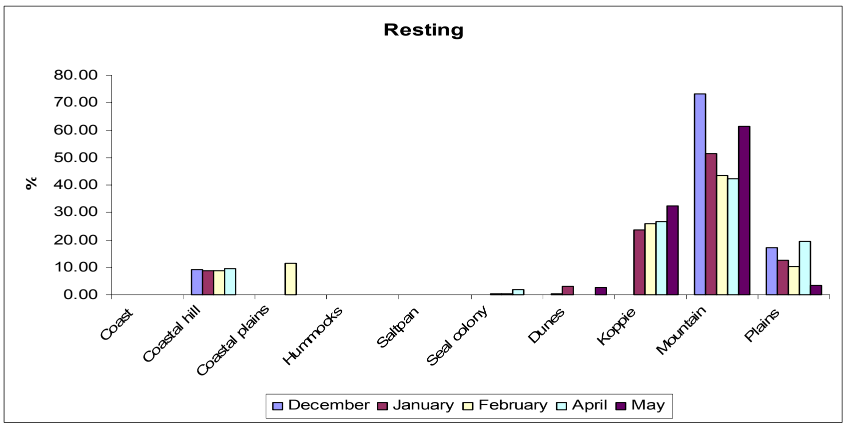


Figure 48: Percentage of fixes recorded in different habitats while walking and resting.

There was also no difference between the use of different habitats while resting during the day and at night (Figure 49). However, slightly more resting during the day took place in the mountains and koppies.

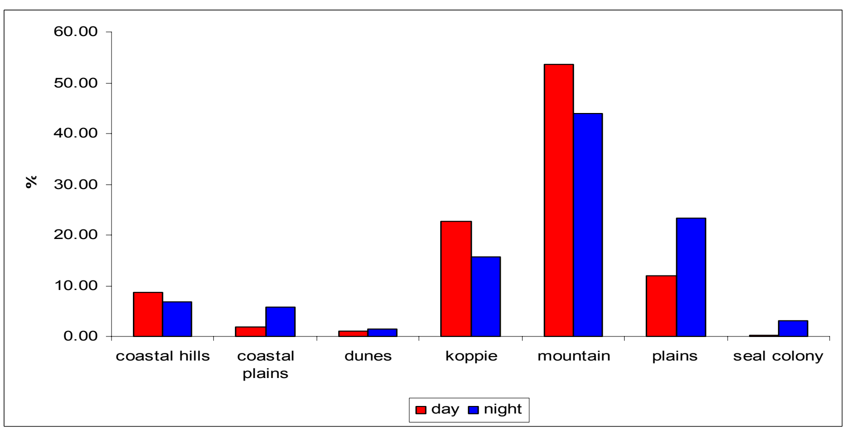


Figure 49: Habitat use while resting during the day and at night.

Behaviour

The daily changes in behaviour of GHb1m showed significant patterns for resting (r = 0.97), walking (r = 0.97) and foraging (r = 0.80). However, walking in coastal areas of his home range (foraging) showed a less distinct pattern.

Resting peaked at 13 h and was lowest at 2 h. Walking in inland areas of the home range peaked at 2 h and was lowest at 13 h. Walking in coastal areas of the home range (foraging) peaked at 3 h and was lowest at 14 h (Figure 50).

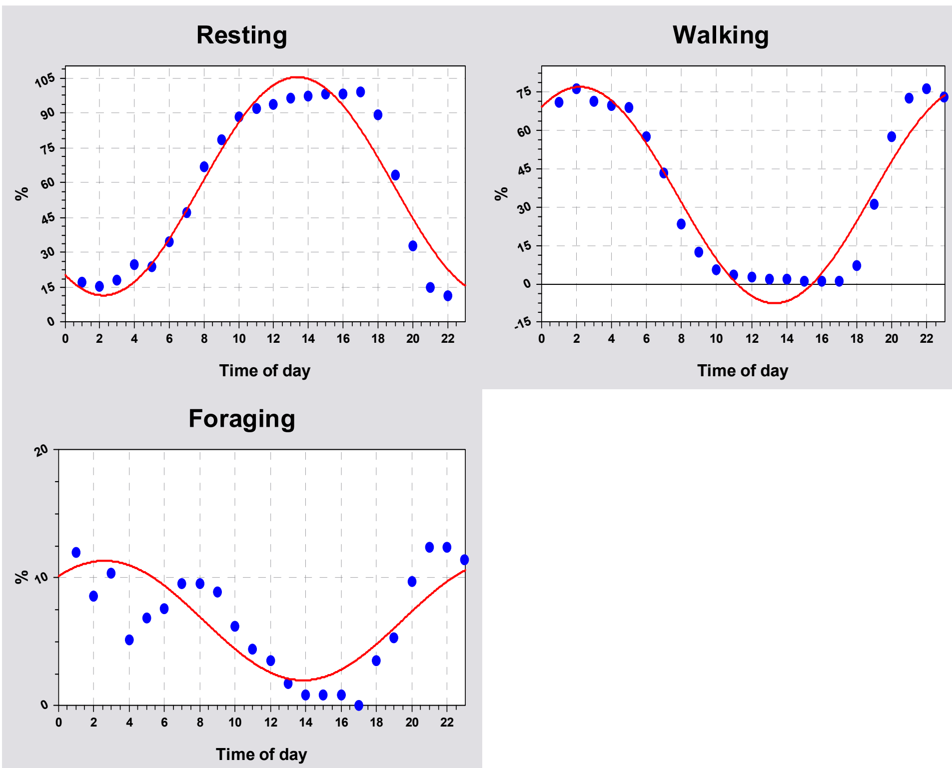


Figure 50: Pattern of the percentage of GPS fixes recorded while resting, walking and foraging during different times of the day.

GHb1m's behaviour did not change between months (Figure 51).

GHb1m visited the fresh water source near Baker's Bay on average every 8 ½ days, ranging from three to 14 days. He controlled his home range boundary every two to 4 days (average 2 ½ days).

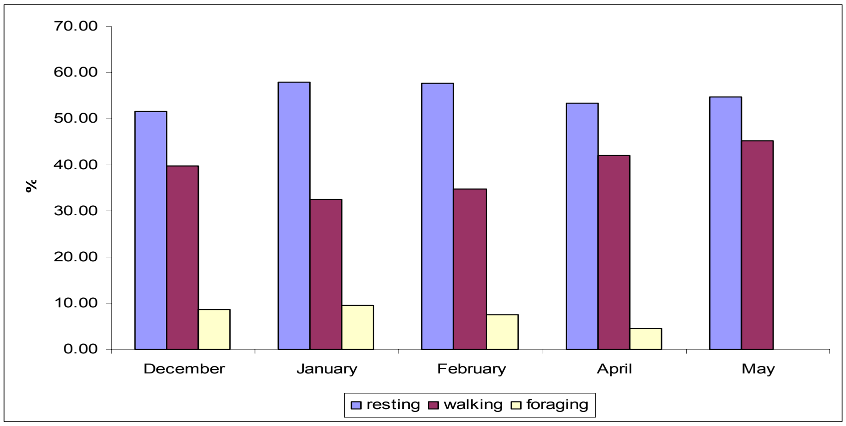


Figure 51: Changes in the percentage of GPS fixes recorded while resting, walking and foraging between months.

DHb1m

- Male
- Age Class III (~7 years old)
- Excellent condition
- Collared: March 2007 to present
- Number of GPS positions up to June 2007: 999
- Status: resident

Home Range Size

DHb1m's total home range was 780 km^2. It included the area around the Baker's Bay seal colony and the eastern parts of the Klinghardt Mountains (Figure 52).

The coastal area and the Klinghardt Mountains represented core areas. The hyena's home range size and use changed over time. Its size was 838 km^2, 667 km^2 and 611 km^2 in April, May and June respectively (Figure 53).

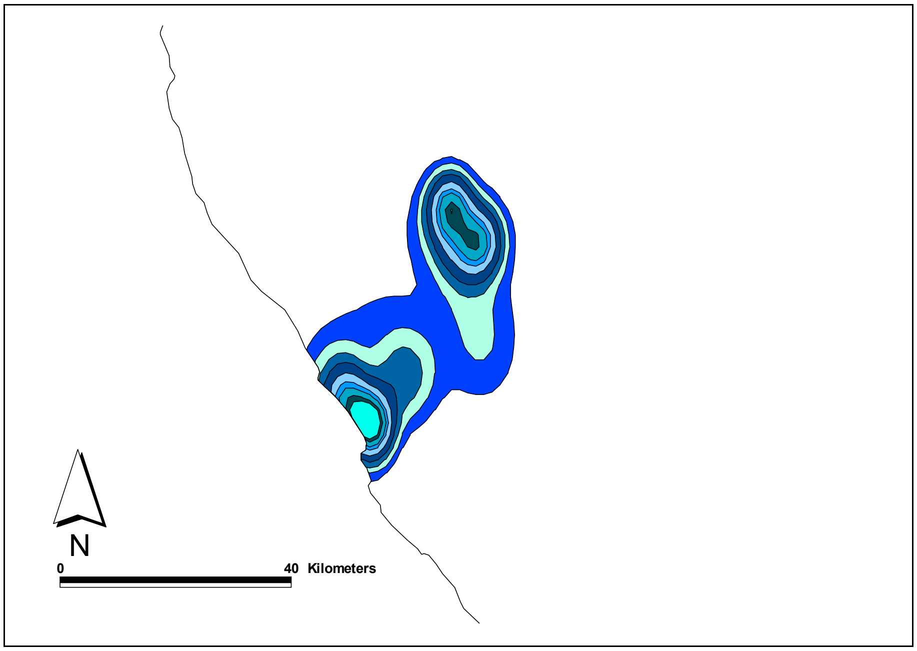


Figure 52: DHb1m's home range estimated by Adaptive Kernel Volume. Percentage volume contour lines represent the probability of finding the animal in this specific area (for legend see Figure 11).

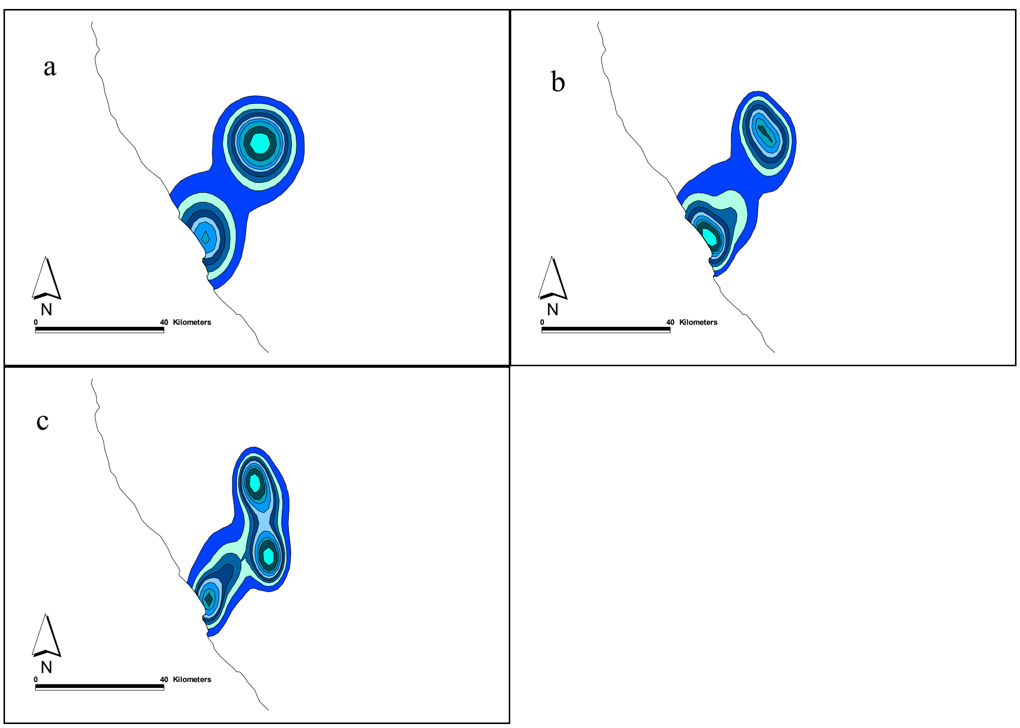


Figure 53: GHb1m's home ranges in (a) April, (b) May and (c) June (for legend see Figure 11).

Activity

DHb1m was mostly active between 20 and 6 h (Figure 54). Activity was significantly lower between 13 and 17 h (Kruskal Wallis Test, $p < 0.0001$). The difference between the movements during different times of the day between months was significant (Figure 55). DHb1m moved significantly longer distances in April than in May and June (Repeated Measures ANOVA, $p = 0.01$).

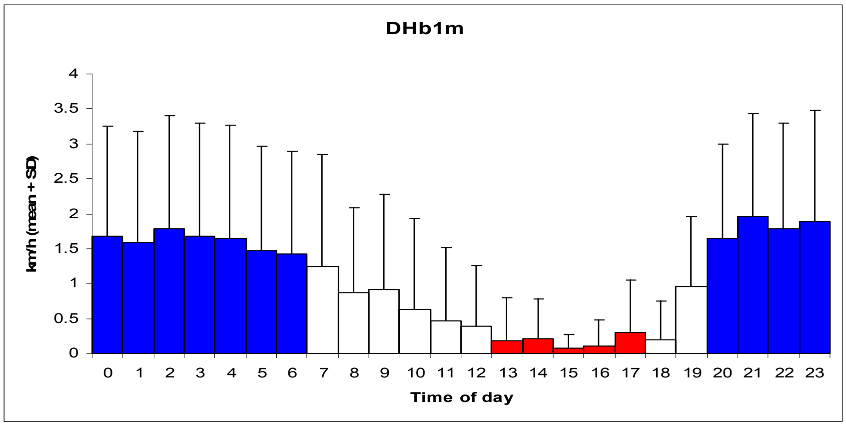


Figure 54: Mean distance (+SD) moved during different times of the day.

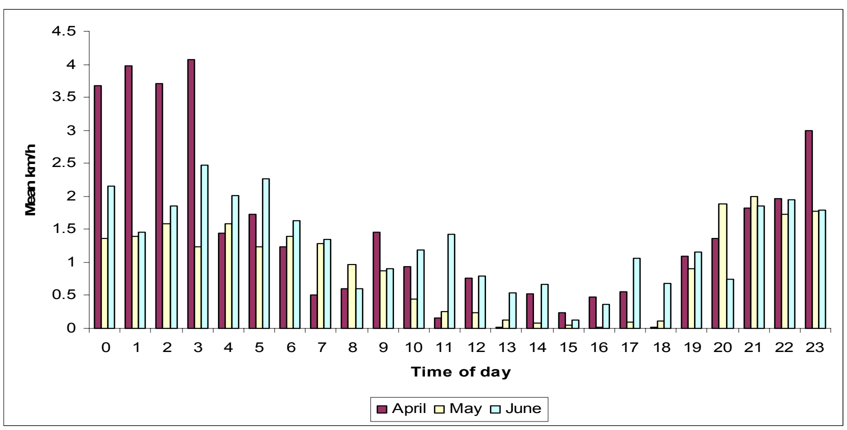


Figure 55: Mean distance moved per month during different times of the day.

DHb1m moved on average 25 km per day with a minimum movement of 900 m and a maximum movement of 55 km per day. Daily movement did not change between months.

Habitat Use

DHb1m made heterogeneous use of the available habitat (Chi^2 Test, $p < 0.0001$). Most time was spent in the coastal area, mountains and dunes (Figure 56). The greatest distances were moved in plains, coastal areas and koppies (Figure 57). There was no difference in habitat use while resting and walking.

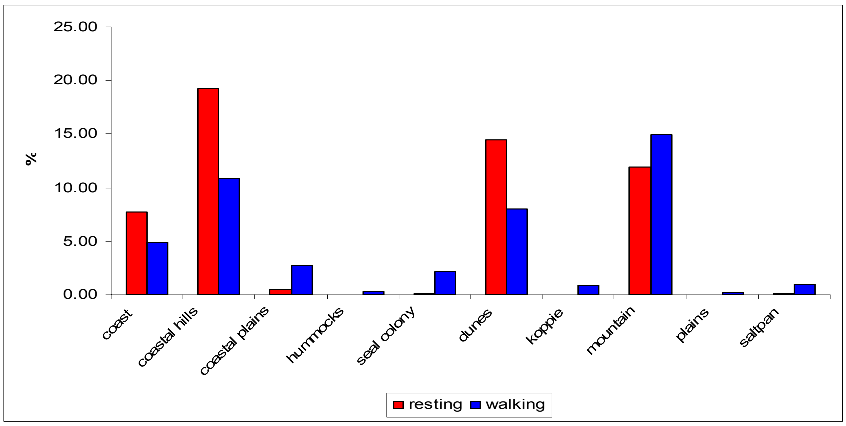


Figure 56: Percentage of GPS fixes recorded in different habitats while resting or walking.

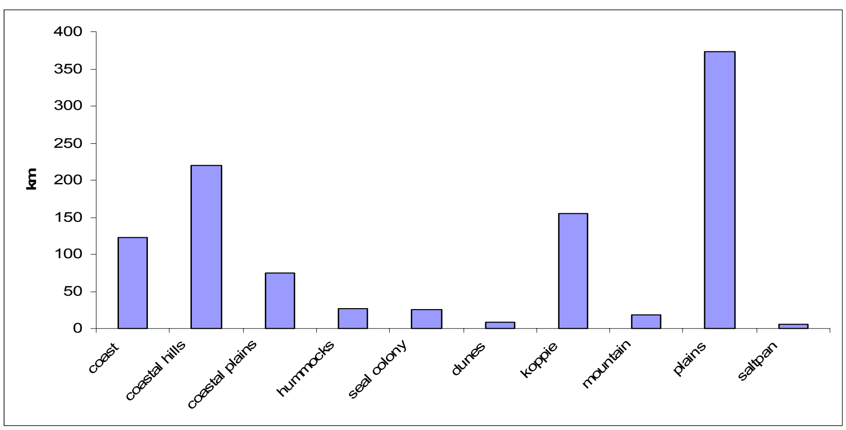


Figure 57: Distance walked in different habitats.

There was no difference in the use of different habitats while resting or walking between months. The coastal area, plains and koppies were the preferred habitat types for both behaviours (Figure 58).

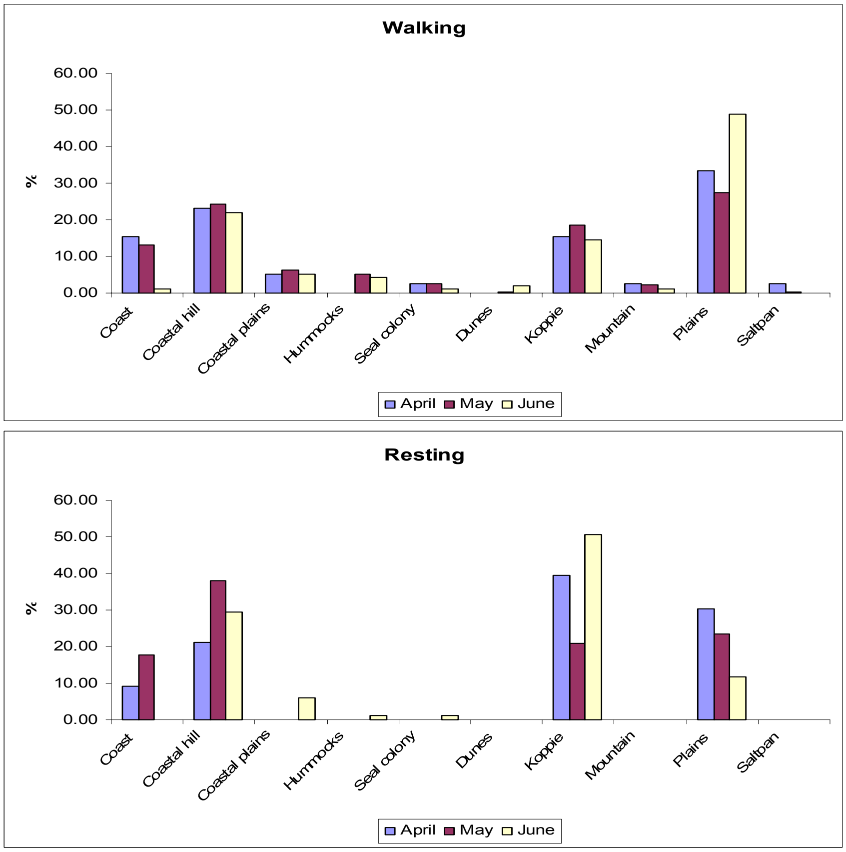


Figure 58: Percentage of fixes recorded in different habitats while walking and resting.

There was also no difference between the use of different habitats while resting during the day and at night (Figure 59). However koppies were proportionally more used as resting areas during the day.

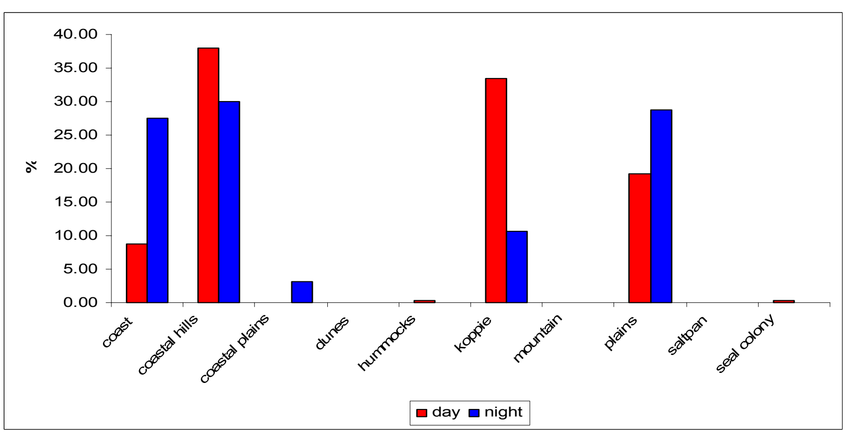


Figure 59: Habitat use while resting during the day and at night.

Behaviour

The daily changes in behaviour of DHb1m showed significant patterns for resting (r = 0.92), walking (r = 0.92) and foraging (r = 0.81).

Resting peaked at 13 h and was lowest between 3 and 4 h. Walking in inland areas of the home range peaked at 2 h and was lowest at 13 h. Walking in coastal areas of the home range (foraging) peaked at 5 h and was lowest at 13 h (Figure 60).

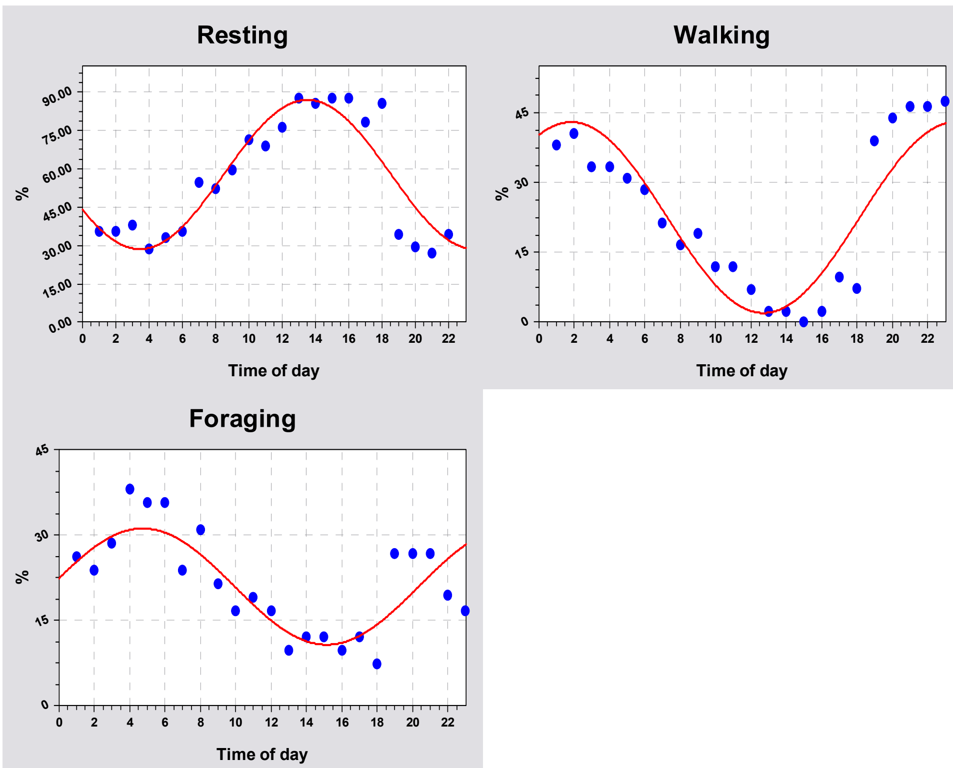


Figure 60: Pattern of the percentage of GPS fixes recorded while resting, walking and foraging during different times of the day.

DHb1m's behaviour did not change between months (Figure 61).

He visited the fresh water source near Baker's Bay on average every 4 days, ranging from one to 10 days.

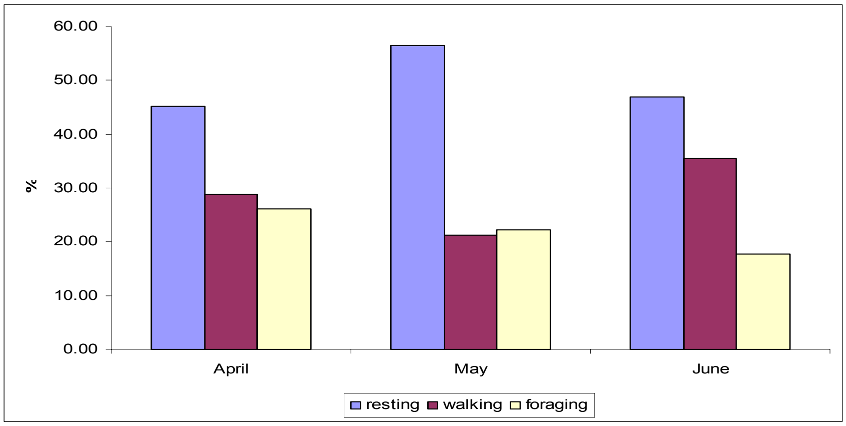


Figure 61: Changes in the percentage of GPS fixes recorded while resting, walking and foraging between months.

Comparisons between Brown Hyenas

Activity Patterns

The distance walked per hour during different times of the day differed significantly between hyenas (Friedman Test, $p < 0.0001$). The true inland hyenas' (KHb1m and GHb1m) activity was different to VRHb1m, DHb1m (true coastal hyenas), VRBHb1m (nomad) and VRBHb1m respectively (Figure 62). The true coastal hyenas' and the nomads' activities did not differ.

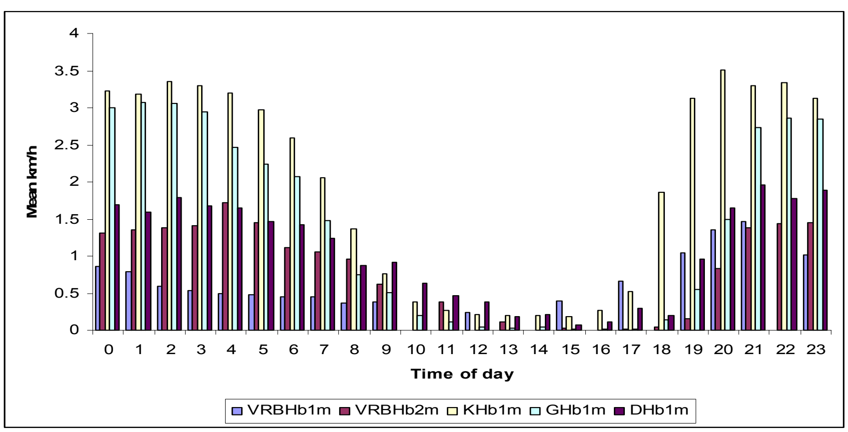


Figure 62: Mean distance walked during different times of the day of five collared brown hyenas.

The average daily distance and the minimum and maximum daily distance moved was different for each hyena (Table 2). KHb1m's movement for example ranged from 8.1 to 82.3 km, whereas VRBHb1m's movement only ranged from 400 m and 41.1 km.

Table 2: Mean, minimum and maximum daily distances moved by five collared brown hyenas.

	Distance	Minimum	Maximum
VRBHb1m	15.3	0.4	41.1
VRBHb2m	18.6	0.7	42.7
KHb1m	46.5	8.1	82.3
GHb1m	31.1	2.3	77.5
DHb1m	24.8	0.9	54.7

KHb1m's mean daily distance moved was significantly greater than of all other hyenas (ANOVA, $p < 0.0001$). Furthermore VRBHb1m's daily movement was less than those of GHb1m and DHb1m, and VRBHb2m's movement was less than that of GHb1m (Figure 63).

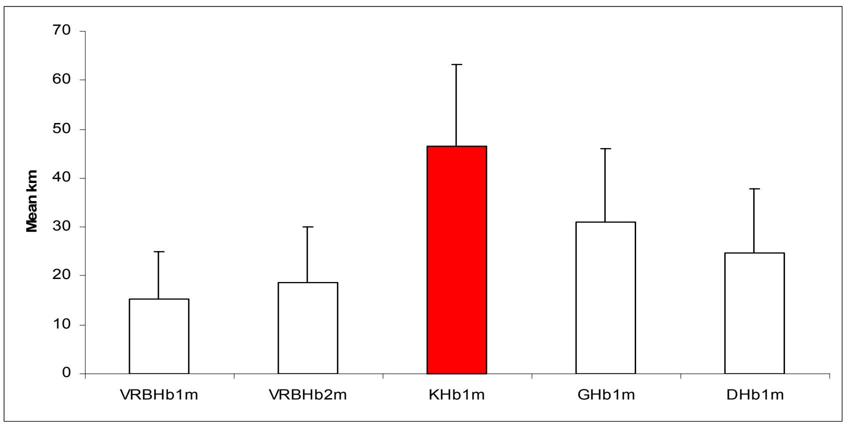


Figure 63: Mean (+SD) daily distance moved by five collared brown hyenas.

Home Range Size

Home ranges sizes varied and ranged from 707 to 4817 km^2 (Minimum Convex Polygon method – MCP) or 780 to 2335 km^2 (Adaptive Kernel Volume method) (Table 3).

Table 3: Home range sizes of five collared brown hyenas using Minimum Convex Polygon estimates (MCP) and Adaptive Kernel Volume estimates.

		Adaptive Kernel Volume		
Hyena	MCP (100%)	90%	80%	70%
VRBHb1m	1074	1084	633	403
VRBHb2m	1587	1702	1141	797
KHb1m	4817	2335	1573	1196
GHb1m	2814	2296	1616	1220
DHb1m	707	780	520	359

The number of fixes that were required to obtain reliable home range estimates varied between hyenas (Figure 64). A total of 176, 105, 174, 204 and 227 fixes were necessary for VRBHb1m, VRBHb2m, KHb1m, GHb1m and DHb1m respectively.

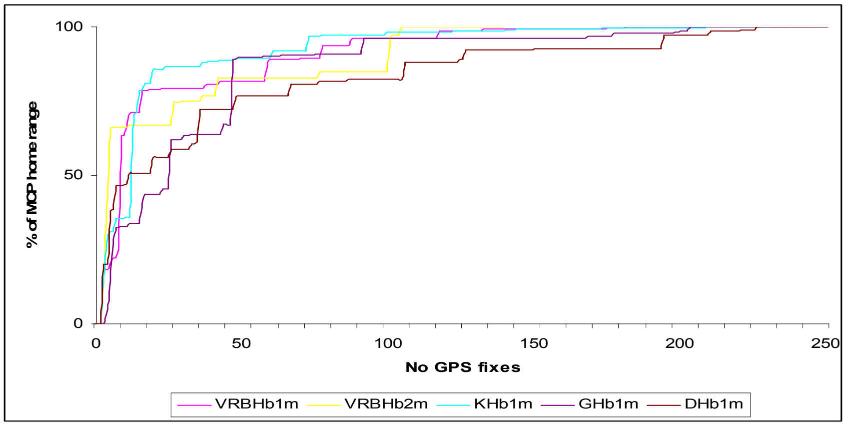


Figure 64: Percentage of 100% MCP home range depending on the number of recorded GPS fixes for five different collared brown hyenas.

Home ranges could overlap greatly depending on the estimator used (MCP or Adaptive Kernel Volume) and ranged from two to 91% and zero to 78% respectively (Table 4).

Table 4: Percentage of home range overlap (for example: VRBHb1m had an MCP overlap of his home range with VRBHb1m of 46.28%, whereas VRBHb2m had an MCP overlap of his home range with VRBHb1m of 31.32%).

		VRBHb1m	VRBHb2m	GHb1m	DHb1m	KHb1m
VRBHb1m	MCP		46.28	79.61	39.76	52.70
	90%		55.72	41.33	40.22	0.00
VRBHb2m	MCP	31.32		31.57	2.58	6.93
	90%	35.49		3.58	8.64	4.29
GHb1m	MCP	30.38	17.80		22.78	85.15
	90%	19.51	2.66		26.61	29.62
DHb1m	MCP	60.40	5.80	90.66		78.78
	90%	55.90	18.85	78.33		21.92
KHb1m	MCP	11.75	2.28	49.74	11.56	
	90%	0.00	3.13	29.12	7.32	

Habitat Use

All brown hyenas used different kind of habitats. While walking, all hyenas made use of plains. Coastal hyenas naturally spent more time walking in coastal hills than inland hyenas, where walking in and along mountains occurred the second most (Figure 65).

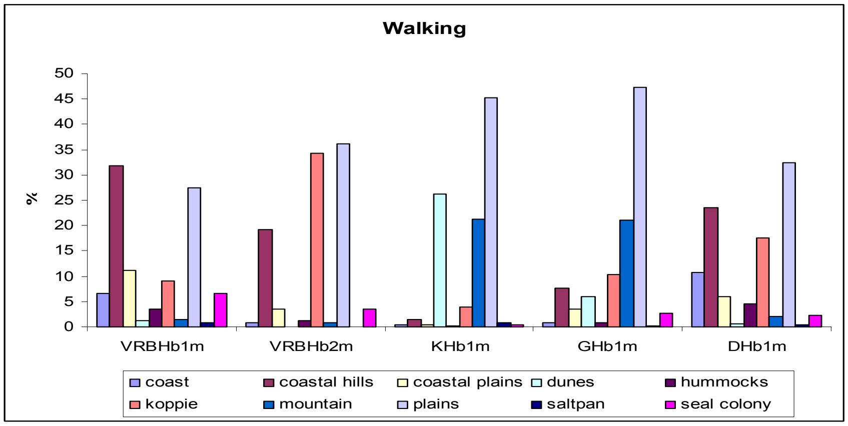


Figure 65: Habitats used by five brown hyenas while walking.

While resting, plains did not play an important role and coastal hyenas spent most time resting in coastal hills, whereas inland hyenas mainly rested in mountains. The nomadic living hyena took an intermediate position, obviously resting in coastal hills, when using the coastal area and resting in koppies, when being in inland areas of the Sperrgebiet (Figure 66).

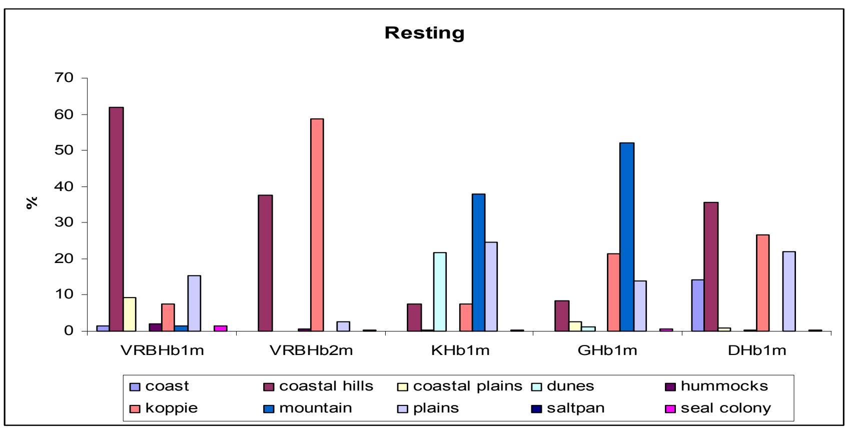


Figure 66: Habitats used by five brown hyenas while resting.

Mountains were not available in all of the hyenas' home ranges and were often replaced by resting or walking in and along koppies.

Therefore for further analysis a simplified map of the habitat types within the Sperrgebiet was created and the following habitat categories were defined (Figure 67):

- Coastal area (Coastal hills, coastal plains, coastal dunes, coast and seal colony)
- Dunes

- Mountains (mountains and koppies)
- Plains
- Saltpan

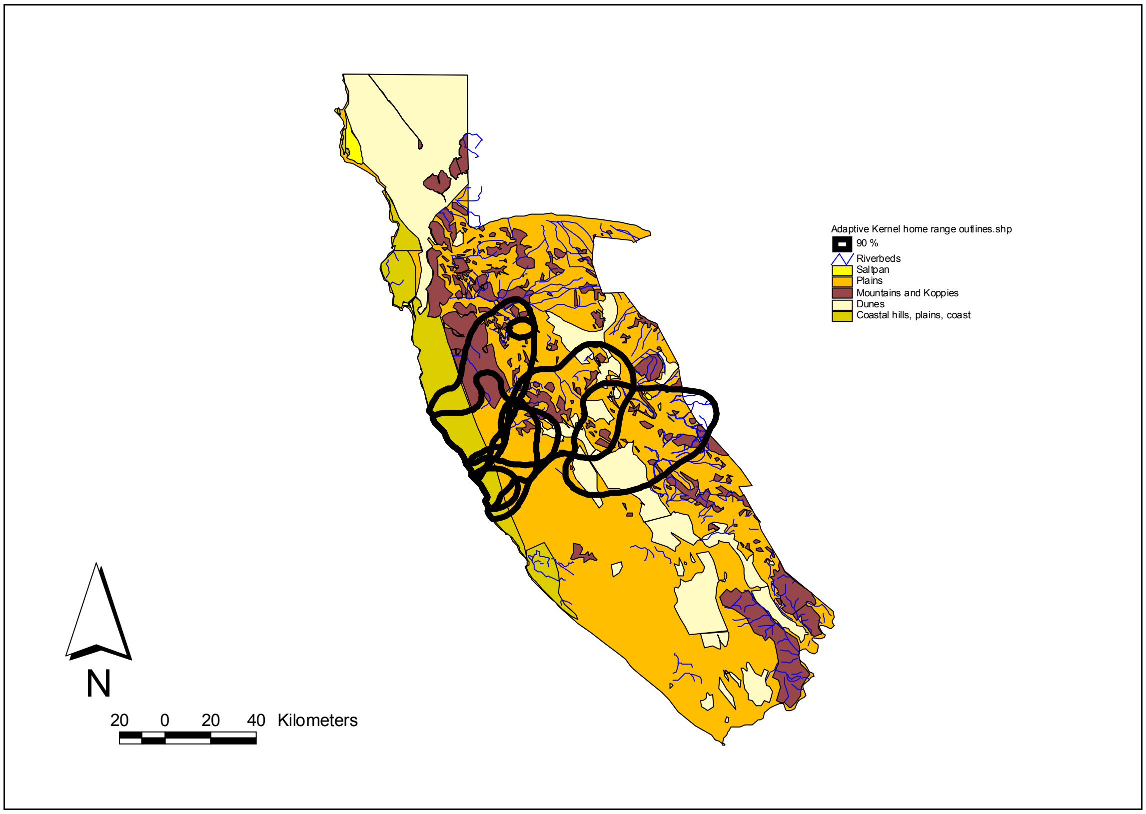


Figure 67: Map showing habitat categories and outlines of the 90% Kernel Volume contours of five collared brown hyenas.

Not all habitat categories were represented in the individual hyenas' home ranges, but overall, plains were the dominant habitat type in all home ranges (Figure 68).

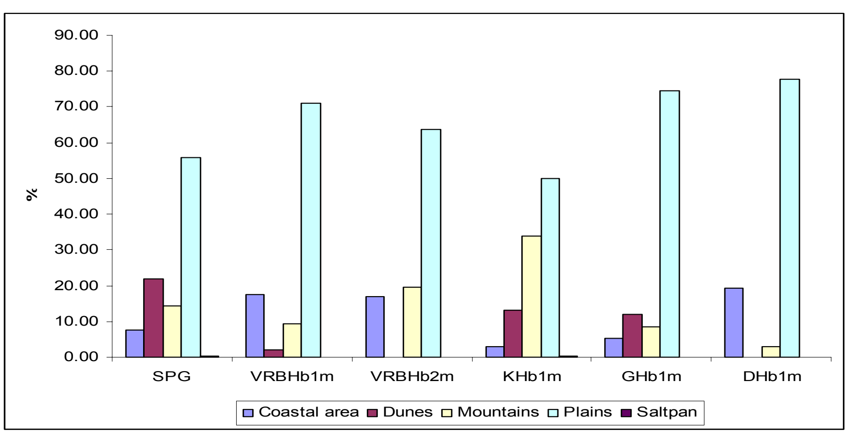
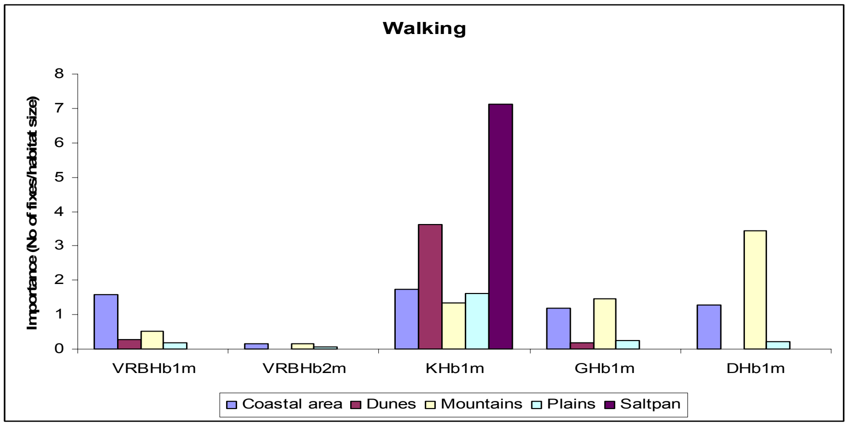


Figure 68: Percentage of habitat type availability in the Sperrgebiet (SPG) and within individual hyenas' home ranges.

Taking the available size (in km^2) into consideration, habitat use changed (Figure 69). While walking, the importance of plains decreased, while the coastal areas and mountains still represented important habitat types.



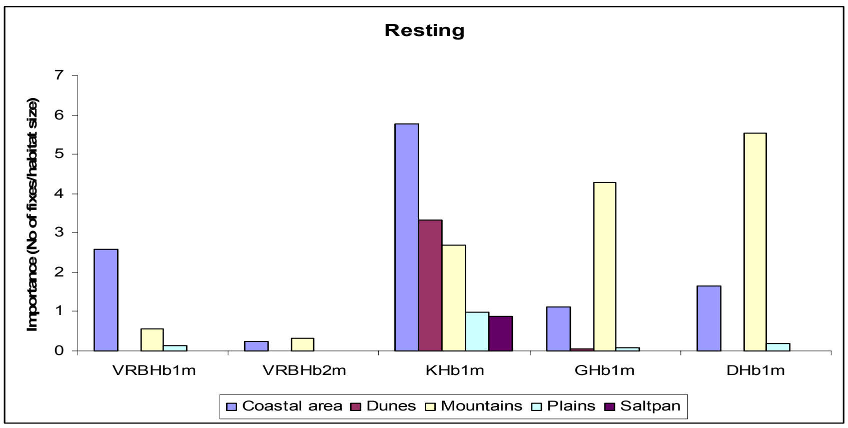


Figure 69: Importance (No of GPS fixes taken divided by size in km^2 of specific habitat type) of different habitat types for five brown hyenas.

Coastal hills and mountains remained the most important habitat types when the hyenas' were resting.

Genetics

Eight loci with varying degrees of heterozygosity were identified for brown hyenas. A total of 56 samples were analysed including samples from VRBHb1m, VRBHb2m and KHb1m.

The results showed that VRBHb1m was unrelated to VRBHb2m (relatedness = 0) and KHb1m (relatedness = 0.0027). VRBHb2m and KHb1m had the possible relation of half sib, full sib or parent-offspring (relatedness = 0.5).

No relationship between clan distance and relatedness could be found for any of the three hyenas (Figure 70).

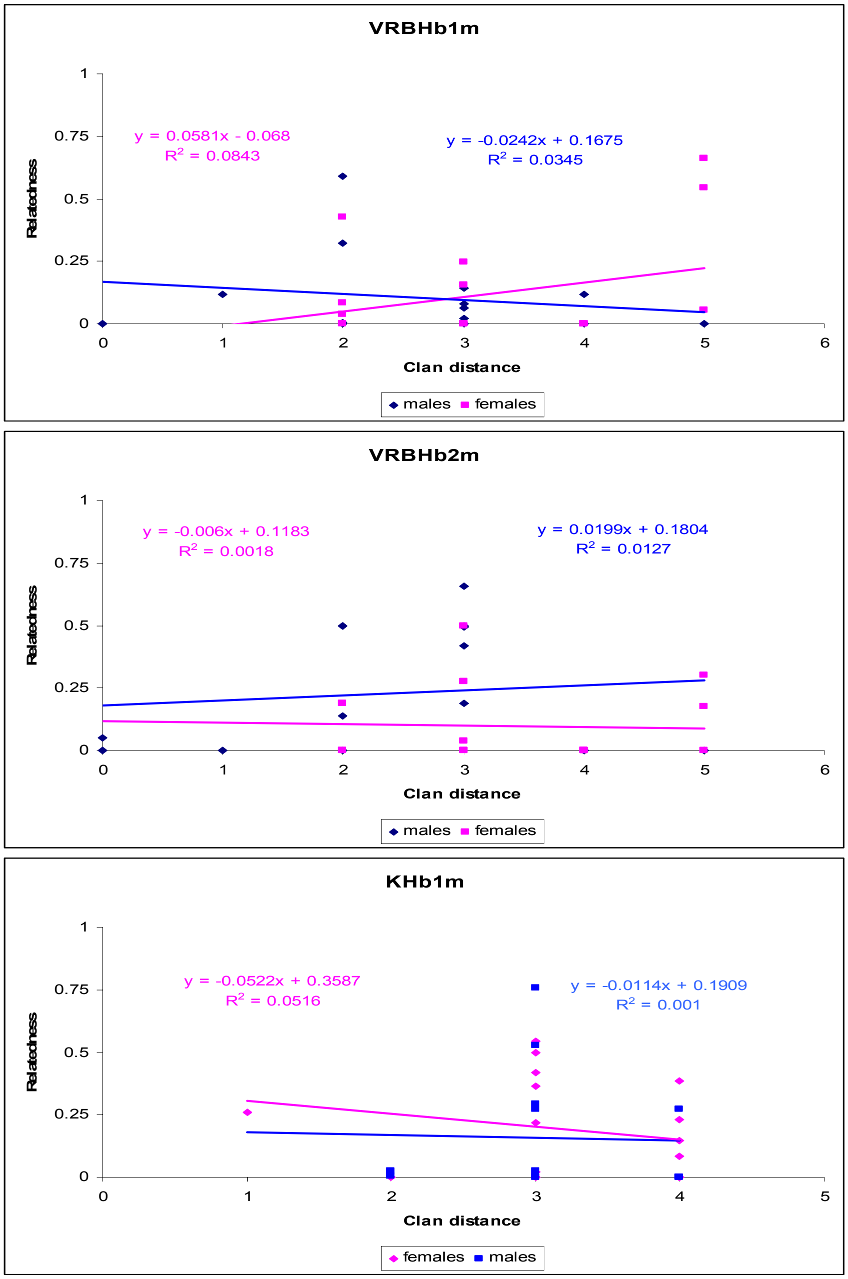


Figure 70: Relatedness of brown hyenas of different clans to VRHb1m, VRBHb2m and KHb1m.

Overall, the samples showed that the three brown hyenas were mostly unrelated to all other sampled individuals (Figure 71).

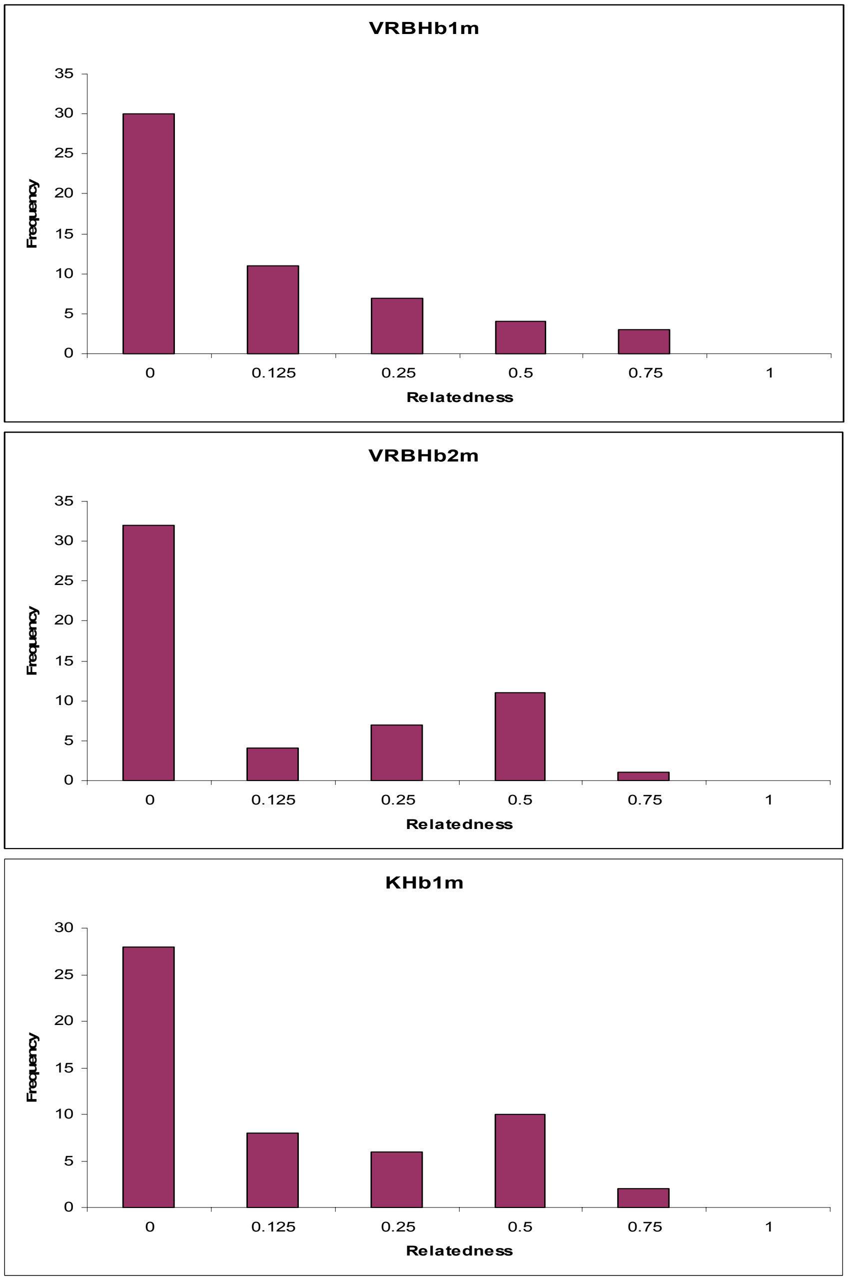


Figure 71: Frequency of relatedness of VRBHb1m, VRBHb2m and KHb1m to all other sampled hyenas.

Clan Distribution, Abundance and Relative Density

Inland home ranges overlapped on average 29%, coastal home ranges 48% and inland and coastal home ranges 35%. The total size of the Sperrgebiet is 22692 km^2 (length of coast is 350 km) and coastal hyenas' home ranges include on average 25 km of coastline. Considering the home range overlaps, a total of 14 coastal brown hyena clans and a total of 13 inland brown hyena clans are expected.

Abundance estimates for inland hyenas could not be done, but abundance of coastal hyenas was 1.1 to 1.3 brown hyenas per 100 km^2. However, brown hyena abundance of coastal hyenas is expected to be higher than abundance in inland areas of the Sperrgebiet due to the existence of localized, permanent food sources. Literature review revealed and estimate of 3.7 brown hyenas per clan (Table 5), giving a total estimate of 100 adult brown hyenas in the Sperrgebiet. Density was estimated at 1.8 hyenas per 100 km^2, ranging from 0.4 to 4.4.

Table 5: Estimates of mean, minimum and maximum number of brown hyenas inhabiting the Sperrgebiet per clan, for all clans and per size of the area.

	Coast		Inland		Sperrgebiet		Literature (Mills 1990)		
	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum	Mean	Minimum	Maximum
Clan	10	12	25	29	35	47	3.7	1	10
All Clans	144	170	157	183	301	471	100	27	270
Size	76	90	173	205	250	295	408	91	998

All these estimates highlight the difficulty of obtaining reliable abundance estimates. However, clan structure is important for brown hyenas and therefore the relationship between estimated clan size and number of clans in the Sperrgebiet is regarded to be the most reliable abundance indicator.

Diet

Only two den sites were discovered in inland areas of the Sperrgebiet (Morgenberg den and Munzenberg den – Figure 72).

Figure 72: Morgenberg and Munzenberg dens.

Most remains were of gemsbok, but springbok and ostrich remains were also found in large numbers. A proper inventory of the bones found in front of the dens still has to be carried out, once they are inactive, and faeces samples still have to be collected to obtain data about the inland hyenas' diet breadth.

Summary

Use of GPS Collars

The GPS collars used in this study proved to be a reliable tool to obtain data to reach the projects' aims. A scheduling of 24 fixes per day is sufficient, which provides battery life of up to four years, making long term studies possible. However, analysis of collar performance enables us to make suggestions to the supplier to prolong battery life by for example restricting the number of satellites for fix collection.

Activity Patterns

All hyenas were predominately active at night. However, movement in coastal areas showed a less distinct nocturnal pattern and foraging also took place during the day.

Home Range Size

Home ranges were large. The largest home ranges were of true inland hyenas, possibly related to the wider distribution of their food sources. Home ranges also overlapped greatly, but no data regarding sociality could be analysed, due to the different time frames of collar deployment.

Habitat Use and Diet

Coastal areas, mountains and koppies (rocky outcrops) were the most important habitat types for brown hyenas, although the habitat category of the plains was the one with the greatest availability. Also, habitat use may change with rainfall and further long term data has to be collected to analyse this relationship. However, first results show that hyena movement changes with changes in rainfall.

Open water also seems to be important, as permanent water holes were visited on a regular basis.

Mainland seal colonies are not only important for coastal hyenas. Both true inland hyenas foraged regularly at the seal colonies, but stopped visiting the seal colonies in May. This periodic use of the food source might be of major importance for inland hyenas and will be thoroughly observed and analysed in future.

Genetics and Abundance

The data indicates that emigration and immigration between Namibian brown hyena clans takes place on a regular basis. More genetic data has to be collected in future. However, indirect sampling is possible, since the baseline data is available now, so that samples of faeces, hair and paste marks can provide genetic information about Sperrgebiet brown hyenas of different clans. These samples can then also be used to draw conclusions about brown hyena population size in the Sperrgebiet.

Conclusions

For the proposed Sperrgebiet National Park's management plan, the following important topics can be raised:

- Protection of key areas, such as the coastal area and rocky outcrops (koppies)
- Protection of key resources, such as permanent and periodic water holes
- Protection of corridors to enable inland hyenas to reach coastal foraging sites
- Protection of den sites
- Development of a monitoring programme to detect changes in brown hyena abundance, activity and movement

This study is on-going and future results may provide information about

- Importance of rainfall
- Importance of mainland seal colonies for inland hyenas
- Abundance estimates through genetic sampling